INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE SKB AND SKB-1 RELAYS AND TEST EQUIPMENT FOR TYPE TC CARRIER

INSTRUCTIONS

CAUTION: Before putting relays into service, 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 SKB relay is a high-speed carrier relay with static fault detectors used in conjunction with power-line carrier equipment to provide complete phase and ground fault protection of a transmission line section. Simultaneous tripping of the relays at each line terminal is obtained in less than two cycles for all internal faults within the limits of the relay settings. The relay operates on line current only, and no source of a-c line potential is required. Consequently, the relays will not trip during a system swing or out-of-step conditions. The carrier equipment operates directly from the station battery.

The type SKB-1 relay is used in distance phase-comparison carrier relaying where separate distance-type fault detectors supplement the overcurrent fault detectors of the SKB-1 relay to give improved phase-fault sensitivity. Unless otherwise stated, the following sections of this instruction leaflet apply to both the types SKB and SKB-1 relays.

The SKB relay is available with indicating contactor switches with either a 1-ampere or a 0.2/2.0-ampere rating. The 0.2/2.0-ampere rating is recommended where a lockout relay is energized or where a high resistance auxiliary tripping relay is utilized. The SKB-1 relay has a low-current operation indicator, and the trip circuit energizes an external static tripping device.

PART I

TYPE SKB AND SKB-1 RELAYS

CONSTRUCTION

The relay consists of a combination positive, negative, and zero sequence current network, a saturating auxiliary transformer, Zener clipper, high-speed type AR tripping relay unit, indicating contactor switch plus the static fault-detector circuitry which is mounted on a printed-circuit board. These components are all mounted in an FT42 Flexitest relay case.

Sequence Network

The currents from the current-transformer secondaries are passed through a network consisting of a three-winding iron-core reactor and two resistors. The zero-sequence resistor, R_0, consists of three resistor tubes tapped to obtain settings for various ground fault conditions. The other resistor R_1 is a formed single wire mounted on the rear of the relay sub-base. The output of this network provides a voltage across the primary of the saturating transformer.

The lower tap block provides for adjustment of the relative amounts of the positive, negative, and zero sequence components of current in the network output. Thus, a single relay unit energized from the network can be used as a fault detector for all types of faults.

Saturating Auxiliary Transformer

The voltage from the network is fed into the tapped primary (upper tap plate) of a small saturating transformer. This transformer and a Zener clipper connected across its secondary are used to limit the voltage impressed on the static fault detectors and the carrier control unit, thus providing a small range of voltage for a large variation of maximum to minimum fault currents. This provides high operating energy for light faults, and limits the operating energy for heavy faults to a reasonable value.

The upper tap plate changes the output of the saturating transformer, and is marked in amperes required to pick up the lower fault detector unit. For further discussion, see section entitled, SETTINGS.

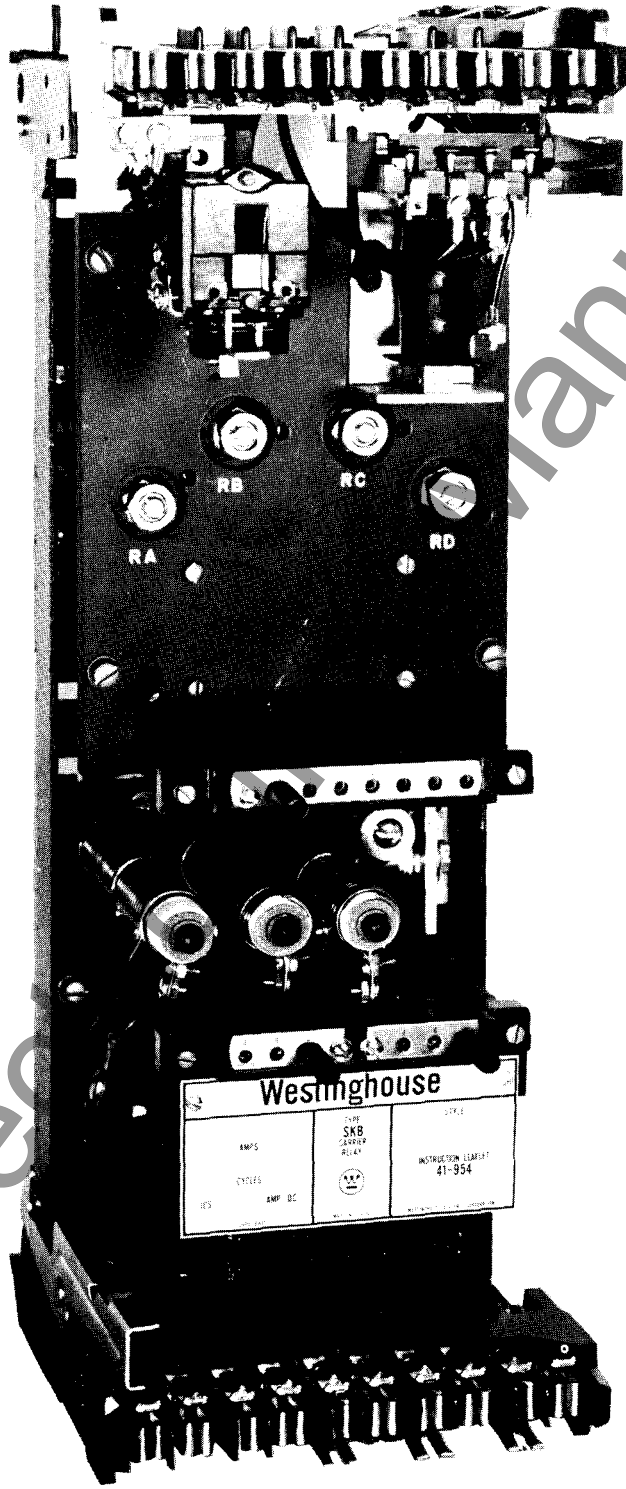

Fig. 1 Type SKB Relay – Front View

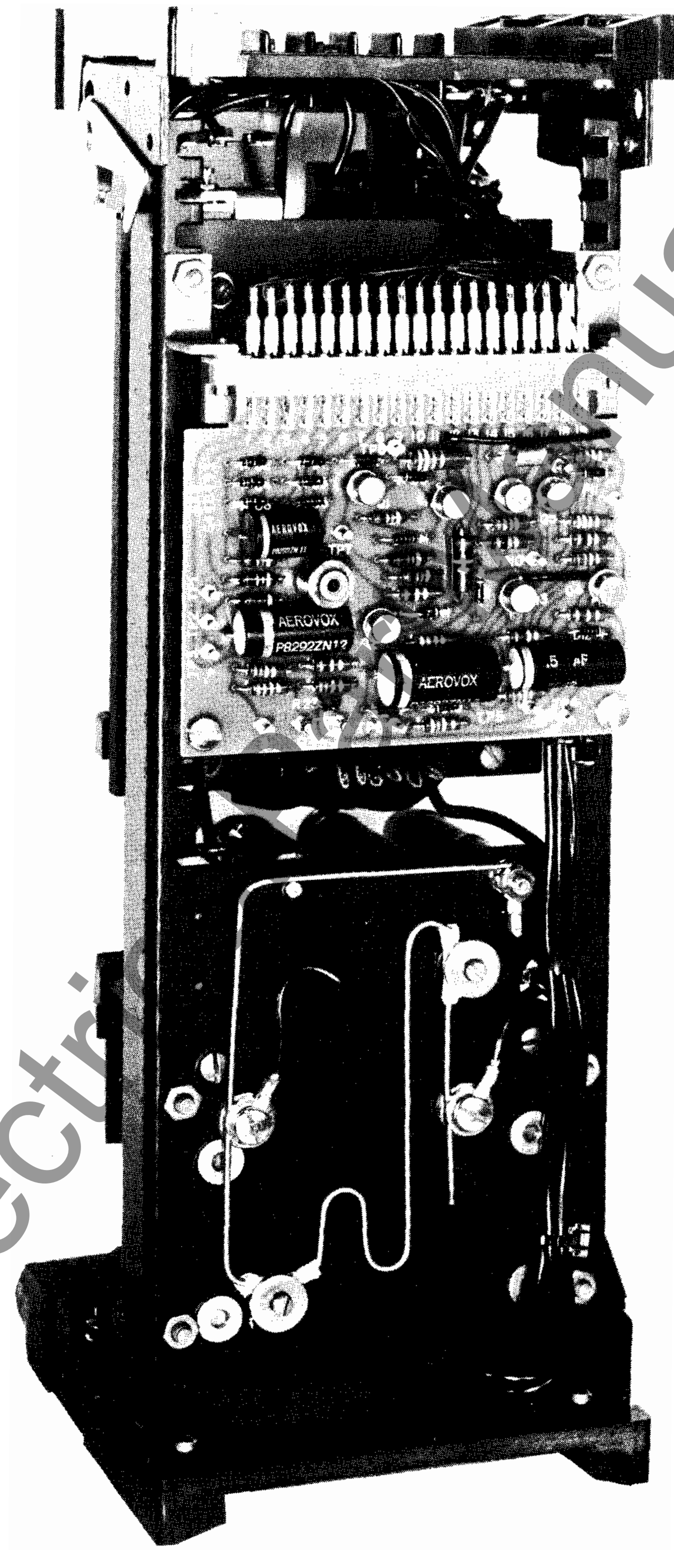

Fig. 2 Type SKB Relay — Rear View

Static Fault Detectors

The static circuitry for the two fault detectors FD1 and FD2 is mounted on a single printed circuit board on the rear of the relay chassis. Four controls for separately setting the pickup and dropout of FD1 and FD2 are mounted on a sub-panel in the chassis. The controls, with locking shafts, are adjustable from the front of the relay.

Tripping Reloy

The AR tripping relay is a small high-speed attracted-armature type of unit. An insulated member, fastened to the free end of the armature, draws down four moving-contact springs to close the trip-circuit contacts when the relay coil is energized.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch in the SKB relay 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 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. In the SKB-1 relay, the device has no contacts, and is used only as an operation indicator (OI).

OPERATION

The SKB or SKB-1 carrier relaying system compares the phase positions of the currents at the ends of a line-section over a carrier channel to determine whether an internal or external fault exists. The three-phase line currents energize a sequence network which gives a single-phase output voltage proportional to a combination of sequence components of the line current. During a fault, this single-phase voltage energizes a static control unit (TCU) which allows the transmission of carrier on alternate half-cycles of the power-frequency current. Carrier is transmitted from both line terminals in this manner, and is received at the opposite ends where it is compared with the phase position of the local sequence network output. If the local and remote half-cycle pulses are of the correct phase position for an internal fault, after a 4-millisecond delay during the half cycle in which carrier is not transmitted, tripping will be initiated through operation of the flip-flop and trip amplifier circuits in the TCU control unit. Current transformer connections to the sequence networks at the two terminals are such that carrier is transmitted on the same half cycles from both terminals during an internal fault, thus allowing tripping during the half cycles that carrier is not transmitted. However, if the fault is external to the protected line section, carrier is transmitted on alternate half cycles from opposite terminals. Thus each terminal blocks the opposite terminal during the half cycle when it is attempting to trip.

The four-millisecond delay previously mentioned is added to allow for differences in current transformer performance at opposite line terminals, relay co-ordination, and momentary interruptions in carrier caused by arcing over of protective gaps in the tuning equipment.

Since this relaying system operates only during a fault, the carrier channel is available at all other times for the transmission of other functions.

OPERATION

STATIC FAULT DETECTORS

The functional elements of the static fault detectors are shown in Fig. 3. The single-phase output of the sequence network (not shown) connects to the INPUT terminal shown at the left side of the drawing. This a-c voltage is applied to a phase-splitting network and polyphase rectifier. The resulting d-c voltage has relatively little ripple without much filtering which would slow down the fault detector operation. The d-c voltage is fed to two level detectors which determine the operating currents of FD1 and FD2. The output of FD1 level detector is amplified and provides a ''normally-closed'' FD1 static contact to start carrier.

The operation of FD2 is delayed about 5 milliseconds to insure coordination in setting up blocking for external faults where FD1 must operate to start carrier blocking a few milliseconds before FD2 energizes the comparison and flip-flop circuits. The output of FD2 fault detector circuit is equivalent to a ''normally-open'' contact.

The complete circuitry of the SKB relay is shown in Fig. 4. The sequence network, saturating transformer, phase-splitting network, and polyphase rectifier occupy the lower third of the diagram. The FD2 circuitry is in the middle portion, and the FD1 portion is in the upper part of the diagram. The type AR tripping relay is shown at the top. Fig. 5 is a simplified schematic of the SKB relay with the static fault detector circuitry omitted.

Figures 6 and 7 are the complete and simplified schematic diagrams, respectively, of the type SKB-1 relay. This relay differs from the SKB relay in the trip circuit wiring to terminals 1, 10, and 20, and in the connections from the saturating transformer tapped secondary to the input terminals 5 and 7 of the printed circuit board. The sequence network (R1, R0, and the mutual reactor) and the printed circuit board assembly for the static fault detectors for the SKB and SKB-1 relays are identical. Figure 8 shows the location of components on the printed circuit board for the static fault detectors for both the SKB and SKB-1 relays.

With reference to Fig. 4, the output voltage of the sequence network and saturating transformer is applied to a phase-splitting network (C1, R1, R2) and a polyphase rectifier (diodes D1 to D6). The d-c voltage so obtained requires a minimum of filtering (C2), and responds rapidly to a change in magnitude of the a-c output. This d-c voltage is applied to the FD1 and FD2 circuits which operate when the d-c input "signal" exceeds a predetermined value.

FD1 - Under normal line conditions (no fault), current flows from relay terminal 19 (pos. 45 v) through resistor R4 and Zener diode Z1 to negative, holding Q1 emitter at 6.8 volts positive. In transistor Q1, current flows from emitter to base, then through RA and R3 to negative, thus turning on Q1. The collector current of Q1 provides base drive to transistors Q2 and Q7, turning them on also. The voltage drop across Q7 is very low (less than 0.5 volt), thus providing the equivalent of a closed contact. When a fault occurs and the d-c input voltage to Q1 base (from the polyphase rectifier) exceeds the 6.8-volt drop across Zener diode Z1, transistor Q1 stops conducting. This removes the base current from Q2 and Q7, causing them to stop conducting, and providing the equivalent of an open contact at Q7 collector-emitter circuit.

When Q2 is cut off as just explained, its collector potential rises to about 20 volts. This further raises the potential of Q1 base through feedback resistors R6 and RB, thus holding Q1 in a non-conducting state. When the input voltage is sufficiently reduced to allow FD1 to "reset," transistors Q1, Q2, and Q7 again conduct. Resistor RA is for setting the FD1 pickup current (calibration adjustment), and the setting of RB determines the 80 per cent dropout value.

FD-2 - Under normal conditions, transistor Q3 has no base "signal" and thus is turned off (not conducting). Thus Q3 collector is at a high enough positive potential to provide base drive for transistor Q4, driving it to full conduction. With Q4 fully conducting, there is no base drive to transistor Q5. With no Q5 collector current, the base of PNP-type transistor Q6 is supplied from the 45-volt source through the drop of diode D11. Thus the Q6 emitter is normally at a slightly lower potential than its base. This condition keeps transistor Q6 in a non-conducting state, equivalent to an open contact. Zener diode Z3 is to protect transistor Q6 from external surge voltages.

When a fault causes the d-c input voltage from the adjustable resistor RC to exceed the 6.8-volt rating of Zener diode Z2, a positive bias is applied to Q3 base, causing it to conduct. In turn, Q4 stops conducting, and capacitor C5 charges up, giving a few milliseconds' time delay before Q5 and Q6 are switched to full conduction, thus "closing" FD2. The feedback resistors R13 and RD provide a 90-percent FD2 dropout ratio with "toggle" action at the dropout point.

CHARACTERISTICS

The sequence network in the relays is arranged for several possible combinations of sequence components. For most applications, the output of the network will contain the positive, negative, and zero sequence components of the line current. In this case, the taps on the upper tap plate indicate the balanced three-phase amperes which will operate the carrier-start fault detector FD1. The second fault-detector unit FD2, which supervises operation of the AR tripping relay, is adjusted to pick up at a current 25 percent above tap value. The taps available are 3, 4, 5, 6, 7, 8, and 10, for the SKB relay, and 6, 8, 10, 12, 14, 16, and 20 for the SKB-1 relay. These taps are on the primary of the saturating transformer.

For phase-to-phase faults AB and CA, enough negative sequence current has been introduced to allow the fault detector FD1 to pick up at 86% of the tap setting. For BC faults, the fault detector will pick up at approximately 50% of the tap setting.

This difference in pick-up current for different phase-to-phase faults is fundamental, and occurs because of the angles at which the positive and negative sequence components of current add together.

With the sequence network arranged for positive, negative, and zero sequence output, there are some applications where the maximum load current and minimum fault current are too close together to set the relay to pick up under minimum fault current, yet not operate under load. For these cases, a tap is available on both the SKB and SKB-1 relays which cuts the three-phase sensitivity in half, while the phase-to-phase setting is substantially unchanged. The relay then trips at 90% of tap value for AB and CA faults, and at twice tap value for three-phase faults. The setting for BC faults is 65 percent of tap value. In some cases, it may be desirable to eliminate response to positive-sequence current entirely, and operate the SKB relay on negative-plus-zero sequence current. A tap is available to operate in this manner. The fault detector FD1 picks up at about 95% of tap value for all phase-to-phase faults, but is unaffected by balanced load current or three-phase faults when using this tap.

For ground faults, separate taps are available for adjustment of the ground fault sensitivity to about 1/4 or 1/8 of the upper tap plate setting. See Table II. For example, if the upper tap plate of the SKB relay is set at tap 4, the fault detector (FD1) pick-up current for ground faults can be either 1 or ½ ampere. In special applications, it may be desirable to eliminate response to zero-sequence current. The relay is provided with a tap to allow such operation.

Trip Circuit

The main contacts of the SKB relay 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 trip contacts of the SKB-1 relay have no seal-in device since they energize the low-current input of a static tripping relay.

Trip Circuit Constants – SKB Relay

Indicating Contactor Switch (ICS)

0.2-ampere tap, 6.5 ohms d-c resistance
2.0-ampere tap, 0.15 ohms d-c resistance
1.0-ampere tap, 0.1 ohms d-c resistance

SETTINGS – SKB RELAY

The SKB relay has separate tap plates for adjustment of the phase and ground fault sensitivities and the sequence components included in the network output. The range of the available taps is sufficient to cover a wide range of application. The method of determining the correct taps for a given installation is discussed in the following paragraphs.

In all cases, the similar fault detectors on the relays at all terminals of a line section must be set to pick up at the same value of line current. This is necessary for correct blocking during faults external to the protected line section.

Positive-Sequence Current Tap and FD2 Tap

The upper tap plate has taps of 3, 4, 5, 6, 7, 8, and 10 for the SKB relay, or 6 to 20 for the SKB-1 relay. As mentioned before, these numbers represent the three-phase, fault detector FD1 pickup currents, when the relay is connected for positive, negative and zero sequence output. The fault detector FD2 operates to allow tripping at a current value 25 percent above the fault detector FD1 setting. This 25 percent difference is necessary to insure that the carrier-start fault detectors (FD1) at both ends of a 2-terminal transmission line section pick up to start carrier on an external fault before operating energy is applied through FD2.

For a 3-terminal line, FD2 settings must be readjusted for pickup at 250 percent of FD1 setting. This is necessary to allow proper blocking when approximately equal currents flow in two terminals, and their sum flows out the third line terminal. The relay is normally shipped calibrated for 2-terminal line operation.

When the SKB is to be used on a 3-terminal line, FD2 must be recalibrated as explained in the previous paragraph, and the FD2 temperature-compensating circuit must also be changed to accomodate the new Rc (FD2 pickup) setting. This is accomplished by changing the jumper near the lower left corner of the printed circuit board (see Fig. 8) from C-2 to C-3, as shown.

The taps on the upper and lower tap plates should be selected to assure operation on minimum internal line-to-line faults, and yet not operate on normal load current, particularly if the carrier channel is to be used for auxiliary functions. The drop-out current of the FD-1 fault detector is 80 percent of the pick up current, and this factor must also be considered in selecting the positive-sequence current tap and sequence component combination. The margin between load current and fault detector pick up should be sufficient to allow the fault detector to drop out after an external fault, when load current continues to flow.

Sequence Combination Taps

The two halves of the lower tap plate are for connecting the sequence network to provide any of the combinations described in the previous section. The left half of the tap plate changes the tap on the third winding of the mutual reactor and thus changes the relative amounts of positive and negative sequence sensitivity. Operation of the relay with the various taps is given in the table below.

TABLE I

COMB.	SEQUENCE COMPONENTS IN NETWORK OUTPUT	TAPS ON LOWER TAP BLOCK		FAULT DETECTOR FD1 PICK-UP △	
		LEFT HALF	RIGHT HALF	3 ϕ FAULT	ϕ - ϕ FAULT
1	Positive, Negative, Zero	C	G or H *	Tap Value	86% Tap Value (53% on BC Fault)
2	Positive, Negative, Zero	B +	G or H	2 x Tap Value	90% Tap Value (65% on BC Fault)
3	Negative, Zero	A +	G or H	——	95% Tap Value

* Taps F, G, and H are zero-sequence taps for adjusting ground fault sensitivity. See section on zero-sequence current tap.

△ Fault detector FD2 is set to pick up at 125% of FD1 for a two-terminal line, or 250% for a three-terminal line.

+ When taps A and 3, or B and 3 are used, the relay pickup currents for FD1 and FD2 will be 10 or 15 percent higher than the indicated values because of the variation in self-impedance of the sequence network and the saturating transformer.

Zero-Sequence Current Tap

The right half of the lower tap plate is for adjusting the ground fault response of the relay. Taps G and H give the approximate ground fault sensitivities as listed in Table II. Tap F is used in applications where increased sensitivity to ground faults is not required. When this tap is used, the voltage output of the network caused by zero-sequence current is eliminated.

NOTE: Because of inherent characteristics of the sequence network, there will be small variations (from the values listed in Tables I and II) in the pickup current for various phase or ground fault combinations. However, these variations will be the same from one relay to another.

TABLE II

COMB.	LOWER LEFT TAP	GROUND FAULT PICKUP	
		TAP G	TAP H
1	C	25%	12%
2	B	20%	10%
3	A	20%	10%

Examples of SKB Relay Settings

Case I

Assume a two-terminal line with current transformers rated 400/5 at both terminals. Also assume that full load current is 300 amperes, and that on minimum internal phase-to-phase faults 2000 amperes is fed in from one end and 600 amperes from the other end. Further assume that on minimum internal ground faults, 400 amperes is fed in from one end, and 100 amperes from the other end.

Positive-Sequence Current Tap

Secondary Values:

$$\text{Load Current} = 300 \times \frac{5}{400} = 3.75 \text{ amperes} \quad (1)$$

Minimum Phase-to-Phase Fault Currents:

$$600 \times \frac{5}{400} = 7.5 \text{ amperes} \quad (2)$$

Fault detector FD1 setting (three-phase) must be at least:

$$\frac{3.75}{0.80} = 4.7 \text{ amperes (0.80 is dropout ratio of FD-1 fault detector)} \quad (3)$$

so that the fault detector will reset on load current.

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault detector FD1 setting(three-phase) must be not more than:

$$7.5 \times \frac{1}{0.866} \times \frac{1}{1.25} = 6.98 \text{ amperes} \quad (4)$$

$$1.25 = \frac{\text{FD2 pickup}}{\text{FD1 pickup}}$$

Sequence Combination Tap

From a comparison of (3) and (4) above, it is evident that the fault detector can be set to trip under minimum phase fault condition yet not operate under maximum load. In this case, tap C on the lower left tap block would be used (see Table 1, Comb. 1) as there is sufficient difference between maximum load and minimum fault to use the full three-phase sensitivity. Current tap 6 would be used in preference to tap 5 to allow for occurrence of higher load current.

Zero Sequence Tap

Secondary Value:

$$100 \times \frac{5}{400} = 1.25 \text{ amperes minimum ground fault current.}$$

With the upper tap 6 and sequence tap C in use, the fault detector FD1 pickup currents for ground faults are as follows:

Lower right tap G–1/4 x 6 = 1.5 amp.
Minimum trip = 1.25 x 1.5 = 1.88 amp.
Lower right tap H–1/8 x 6 = 0.75 amp.
Minimum trip = 1.25 x 0.75 = 0.94 amp.

From the above, tap H would be used to trip the minimum ground fault of 1.25 amperes.

Case II

Assume the same fault currents as in Case I, but a maximum load current of 550 amperes. In this example, with the same sequence combination as in Case I, the fault detectors cannot be set to trip on the minimum internal three-phase fault, yet remain inoperative on load current. Compare equations(5) and (6). However, by connecting the network per Combination 2 on Table I, the relay can be set to trip on minimum phase-to-phase fault, although it will have only half the sensitivity to three-phase faults. This will allow operation at maximum load without picking up the fault detector, and provide high speed relaying of all except light three-phase faults.

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault detector tap must now be not more than:

$$7.5 \times \frac{1}{1.25} \times \frac{1}{0.9} = 6.6 \quad (5)$$

To be sure the fault detector FD1 will reset after a fault, the minimum tap setting is determined as follows:

$$\text{Load Current} = 550 \times \frac{5}{400} = 6.9 \text{ amps} \quad (6)$$

$$\frac{6.9}{0.80} = 8.6 \quad (7)$$

Since the fault detector pickup current for three-phase faults is twice tap value, half the above value (Eq. 7) should be used in determining the minimum three-phase tap.

$$\frac{8.6}{2} = 4.3 \quad (8)$$

From a comparison of (5) and (8) above, tap 5 or 6 could be used. (Continuous load current rating of relay is 10 amperes.)

With the three-phase tap 5 in use, the fault detector pickup current for ground faults will be as follows:

Tap G–1/5 x 5 = 1.0 a.
Minimum trip = 1.0 x 1.25 a. = 1.25 amp.

Tap H–1/10 x 5 = 0.5 a.
Minimum trip = 1.25 x 0.5 a. = 0.63 amp.

Therefore, tap H would be used to trip the minimum ground fault of 1.25 ampere with a margin of safety.

Indicating Contactor Switch (ICS) – SKB Relay

No setting is required for relays with a 1.0 ampere unit. For relays with a 0.2/2.0 ampere unit, connect the lead located in front of the tap block to the desired setting by means of the connecting screw. When the relay energizes a 125 or 250-volt d-c type WL relay switch, or equivalent, use the 0.2 ampere tap; for 48-volt d-c applications set the unit in tap 2 and use a type WL relay with a S# 304C209-G01 coil, or equivalent.

SETTINGS – SKB-1 RELAY

The SKB-1 relay tap settings are made from a consideration of just maximum load current and the resetting of FD1 fault detector. The SKB-1 current taps are 6, 8, 10, 12, 14, 16, and 20. On taps 6 and C, FD1 will operate at 6 amperes, 3-phase, and reset at 80% of pickup, or 4.8 amperes. This will be adequate in most cases where maximum load current is in the order of 3 to 4 amperes, secondary values. If maximum load current is 5 amperes or slightly higher, tap 8 should be used, which will give a dropout current for FD1 or 6.4 amperes.

For most SKB-1 relay applications, where static phase-distance relays are used as phase fault detectors, taps 6-C-H are recommended. This will give a minimum trip sensitivity for phase-to-ground faults of 6 x 1/8 x 1.25 or 0.94 ampere. Taps A or B are not recommended for SKB-1 relay application.

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 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.

ADJUSTMENT AND MAINTENANCE

CAUTION: When changing taps under load, the spare tap screw should be inserted in the new tap before removing the other tap screw.

Acceptance Tests

Since the static fault detector circuits obtain their d-c supply voltage from the associated type TC carrier set, the fault detector calibration can must easily be checked after the SKB relay and TC-TCU carrier assembly have been installed and interconnected.

NOTE: The relay current tap numbers and the FD1 and FD2 pickup and dropout current values in the Acceptance Tests and Calibration sections apply to the SKB relay. For the equivalent tap number and current value for the SKB-1 relay, double the figures given for the SKB relay.

The carrier trip circuit should be open for the following check: Set the SKB relay on taps 5, C, and H. Connect a 60-cycle test current circuit between phases A and B of the relay (terminals 5 and 7). Connect a high-resistance d-c voltmeter between relay terminal (or test switch) 15 (pos.) and 18 (neg.). This will read approximately 20 volts when FD1 operates. Gradually increase the current. At 4.33 amperes, FD1 should operate, starting the transmission of half-cycle pulses of carrier, and the d-c voltmeter will read 20 volts.

Continue to increase the test current. At 5.41 amperes, FD2 should operate. If the R101 controls in the type TCU control unit have been set, the AR tripping unit in the SKB relay will operate. The operation of FD1 and FD2 can also be noted by observing the change in d-c voltage at the printed circuit board terminals 14 (FD1) and 15 (FD2) relative to TP4 (negative). See Table I for typical values for these voltages under standby and operating conditions.

Now back off the test current to check the dropout values. Fault detector FD2 should drop out at 90 per cent of pickup, or 4.85 amperes. The FD1 dropout is 80 per cent of pickup, or 3.46 amperes.

The fault detectors have been properly calibrated at the factory and normally will require no further adjustment. If it is found desirable to touch up the calibration, this can be done by loosening the locking nut and changing the adjustment of the appropriate control as listed at the beginning of this section. Turning RA or RC in a clockwise direction will increase the FD1 or FD2 pickup. Similarly, turning RB or RD in a clockwise direction will increase the dropout current.

The pickup and dropout calibration settings of FD1 and FD2 are made with the four controls on the SKB or SKB-1 relay subpanel, as follows:

Relay Unit	Pickup	Dropout
FD1	RA	RB
FD2	RC	RD

These four controls have slotted shafts (for screwdriver adjustment) and locking nuts which are tightened after proper adjustment.

Typical test point voltage values listed in Table I will be useful when checking the apparatus. The readings will remain fairly constant over an indefinite period unless a failure occurs. Voltages should be measured with a vacuum-tube voltmeter. To facilitate taking these voltages, a test cable is available. See Fig. 9. To use this cable, remove the SKB or SKB-1 chassis from its case. Remove the printed circuit board from the back of the relay, and insert the board end of the test cable in its place. Now plug the removed board into the receptacle at the other end of the cable. Replace the relay chassis in its case on the switchboard and close the test switches. The relay can now be energized and operated to obtain the readings in Table I. The test cable can also be used, if desired, with the printed circuit boards of the type TCU Control Unit. However, do not use these test cables in the TC transmitter where r.f. voltages are involved.

TABLE I

Note: All d-c voltages are positive with respect to negative d-c(TP4). All voltages are read with a vtvm, and in general will be within ± 10% of the values listed.

TEST POINT	$I_{SKB} = 0$	$I_{SKB} = 2 \times$ FD2 p.u. ¢
TP5	45.0 vdc	45.0 vdc
TP6	6.5	6.8
TP7	6.5	< 0.5
TP8	14.0	< 0.5
TP9	< 0.5	14.0
TP10	45.0	< 0.5
TP11	44.5	44.5
* Term. 14	< 0.5	20.0
* Term. 15	—	44.5
* Term. 19	< 0.5	20.0
A-C TEST POINT VOLTAGES		
TP2 to TP1	18.0 vac approx.	
TP2 to TP3	17.5 vac approx.	

* On Printed Circuit Board

¢ - Test current of twice FD2 pickup for the taps used.

< 0.5 - means less than 0.5

After the SKB or SKB-1 and associated relays and the carrier equipment have been installed and adjusted, the system can be checked following the procedure in Part II of this I.L. under the heading "OVERALL TEST OF COMPLETE INSTALLATION."

Routine Maintenance

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

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.

The performance of the phase comparison carrier relaying can be checked periodically as explained in Part III of this I.L. under the heading "TYPE SKB or SKB-1 TEST FACILITIES APPLICATION."

Calibration

Normally, there are no adjustments to be made in the sequence network. The taps on the three tubular R_O resistors are brazed in place and cannot get out of adjustment. The two taps on the formed R1 resistor are factory settings, and should not require readjustment. However, if there is reason to suspect that the tap position has changed, the following procedure can be used to check the R1 tap settings for either the SKB or SKB-1 relay:

Remove the current tap screw (upper tap plate), and insert the tap screws in taps C and H on the lower tap plate.

Pass a single-phase current of ten amperes (SKB or SKB-1), rated frequency, through the reactor coils in series from phase B to phase C (relay terminals 7 and 9). Accurately measure the a-c voltage from phase A terminal to the upper tap plate. This voltage should be between 3.8 and 4.0 volts a-c. Now pass 10 amperes from phase A to phase B with the lower tap screw C removed. Adjust the R1 tap further from the R1 mounting screw to give a voltage drop across R1 equal to exactly one-third of the reactor drop. This voltage can be measured directly across the terminals of the resistor R1 from the mounting screw to the last tap on R1.

Note the above reading, and adjust the intermediate tap on R1 to give exactly 1/3 of the voltage obtained above for all of R1. Measure the voltage from the R1 mounting screw to the intermediate tap.

If replacement of the printed circuit board or major components necessitates a complete recalibration, proceed as follows:

1. Set relay taps on 5-C-H. (10-C-H for SKB-1)
2. Use a phase A-B test current. (double the following current values for SKB-1 relay).
3. Set RA and RC to full clockwise position.
4. Set RB and RD to mid-scale.
5. Pass 4.33 amperes through the relay (phase A to B).
6. Check the a-c voltage from TP2 to TP1 and from TP2 to TP3 with a vtvm. Adjust the small pot. R2 on the printed circuit board until these two voltages are equal.
7. Now slowly turn RA counterclockwise, with 4.33 amperes flowing, until FD1 operates.
8. Reduce the phase A-B current to check FD1 dropout. Adjust RB to get 80 percent dropout (3.46 Amperes).
9. Recheck FD1 pickup and dropout, and touch up RA and RB in that order for the correct calibration. Tighten the locknuts.
10. Similarly recalibrate FD2 using controls RC (pickup) and RD (dropout), repeating steps 7, 8, and 9 except for FD2 pickup of 5.41 amp. and dropout of 4.85 amp. Do not readjust R2.
11. For 3-terminal lines, change the printed circuit board link from C2 to C3, then calibrate FD2 for 10.82 amp. pickup and 9.7 amp. dropout.

Tripping Relay (AR)

The type AR tripping relay unit has been properly adjusted at the factory to insure correct operation, and should not be disturbed after receipt by the customer. If, however, the adjustments are disturbed in error, or it becomes necessary to replace some part in the field, use the following adjustment procedure. This procedure should not be used until it is apparent that the relay is not in proper working order, and then only if suitable tools are available for checking the adjustments.

1. Adjust the set screw at the rear of the top of the frame to obtain a 0.009-inch gap at the rear end of the armature air gap.
2. Adjust each contact spring to obtain 4 grams pressure at the very end of the spring. This pressure is measured when the spring moves away from the edge of the slot in the insulated crosspiece.
3. Adjust each stationary contact screw to obtain a contact gap of 0.020 inch. This will give 15-30 grams contact pressure.

This completes the adjustment procedure for the AR relay unit. The resistance of the AR relay coil is 100 ohms.

Indicating Contactor Switch (ICS in SKB Relay)

Close the main relay contacts and pass sufficient direct 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.

Operation Indicator (OI in SKB-1 Relay)

Apply 80 percent of rated voltage across relay terminals or test switches 1 and 10. When the AR relay is operated, the orange target should drop.

There are no seal-in contacts on the operation indicator, which is a voltage-operated device.

Replacement of Printed-Circuit Board Components

If a defective resistor, capacitor, or diode is found, cut it out of the circuit by first clipping off its leads on the component side of the printed circuit board. Then turn the board over, melt the solder holding the remaining lead to the printed pad, and remove the lead with tweezers.

NOTE: For such work, a 60-watt iron with a small, clean, well-tinned tip is recommended. Use a 60-40 (tin-lead) rosin-core solder. Do not hold the iron against the printed-circuit board any longer than necessary to remove and replace the component. If the terminal hole in the board closes up with solder, use the iron to melt it, then open up the hole with a fine awl or similar tool.

Where transistors are mounted on small plastic pads, the leads cannot be clipped off. In such a case, melt the solder on one connection at a time, while gently tilting back that section of the transistor. Because of the small flexible leads, the transistor will gradually separate from the board.

Wherever possible, use a heat-sink (such as an alligator clip) on any transistor or diode being soldered. As an alternate, use a long-nosed pliers to hold the lead (being soldered) between the device and the point of soldering.

ELECTRICAL PARTS LIST

Symbol	Description	Style
C1	0.5 mfd. 200V ± 10%	187A624H11
C2	0.25 mfd, 200V ± 20%	187A624H02
C4	1.0 mfd, 200V ± 20%	187A624H04
C5	0.5 mfd, 200V ± 10%	187A624H11
CT	0.1 mfd, 400V.D.C.	1544920
D1-D7	IN459A Diode	184A855H08
D8-D12	IN457A Diode	184A855H07
Q1	2N652A	184A638H16
Q2-Q3	2N697	184A638H18
Q4	2N697	184A638H18
Q5	2N699	184A638H19
Q6	2N2043	184A638H21
Q7	2N697	184A638H18
R1	2.7K 1/2W ± 5%	629A530H42
R2	2.5K ± 20% 1/4W Pot	629A430H03
R3	20K 1/2W ± 5%	629A530H63
R4	3.9K 1W ± 5%	187A643H41
R6	33K 1/2W ± 10%	187A641H63
R7	10K 1/2W ± 5%	629A530H56
R8	10K 1/2W ± 10%	187A641H51
R9	10K 1/2W ± 5%	629A530H56
R10	0.22 MEG, 1/2W ± 5%	184A763H83
R11	10K 1/2W ± 10%	187A641H51
R12	15K 1/2W ± 10%	187A641H55
R13	68K 1/2W ± 10%	187A641H71
R14	0.1 MEG, 1/2W ± 10%	187A641H75
R15	10K 1/2W ± 10%	187A641H51
R16	68K 1/2W ± 10%	187A641H71
R17	39K 1/2W ± 10%	187A641H65
R18	10K 1/2W ± 10%	187A641H51
R19	6.8K 1/2W ± 10%	187A641H47
R21	18K 1/2W ± 5%	184A763H57
R22	15K 1/2W ± 10%	187A641H55
R23	Type 1DO51 Thermistor, 20K at 25 °C.	185A211H05
R24	470K 1/2W ± 5%	184A763H91
R25	10K 1W ± 5%	187A643H51
R26	1K 1/2W ± 5%	629A530H32
R27	10K 1/2W ± 5%	629A530H56
RA	30K pot.	185A067H15
RB	200K pot.	185A067H14
RC	40K pot.	185A067H16
RD	200K pot.	185A067H14
RT	50 ohms, 2" tube	1340388
RL	9.1K, ½ watt, ±5%-SKB-1 only	
Z1	IN957B (6.8v, 0.4w) Zener Diode	186A797H06
Z2	IN957B (6.8v, 0.4w) Zener Diode	186A797H06
Z3	IN1789 (56v, 1.0w) Zener Diode	584C434H08
Z4	IN3686B (20v, 0.75w) Zener Diode	185A212H06
ZT	IN1832C (62v, 10w) Zener Clipper	184A617H06

Test Equipment

1. A-C ammeter and load box (for fault-detector calibration).
2. Vacuum-tube voltmeter for a-c and d-c measurements.
3. Cathode-ray oscilloscope (to check carrier keying and 60-cycle square-wave voltages in TCU Control Unit).
4. Test Cable

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. For components mounted on the printed circuit board, give the circuit symbol, electrical value, and style number.

ENERGY REQUIREMENTS SKB OR SKB-1 RELAY

Burdens measured at a balanced three-phase current of five amperes:

Relay Taps	Phase A		Phase B		Phase C	
	VA	Angle	VA	Angle	VA	Angle
A-F- 3	2.47	5°	0.6	0°	2.5	20°
A-H-10	3.25	0°	0.8	100°	1.28	55°
B-F-33	2.3	0°	0.63	0°	2.45	55°
B-H-10	4.95	0°	2.35	90°	0.3	60°
C-F- 3	2.32	0°	0.78	0°	2.36	50°
C-H-10	6.35	342°	3.83	80°	1.98	185°

Burdens measured at a single-phase-to-neutral current of five amperes:

Relay Taps	Phase A		Phase B		Phase C	
	VA	Angle	VA	Angle	VA	Angle
A-F- 3	2.47	0°	2.1	10°	1.97	20°
A-H-10	7.3	60°	12.5	53°	6.7	26°
B-F- 3	2.45	0°	2.09	15°	2.07	10°
B-H-10	16.8	55°	22.0	50°	12.3	38°
C-F- 3	2.49	0°	1.99	15°	2.11	15°
C-H-10	31.2	41°	36.0	38°	23.6	35°

The angles above are the degrees by which the current lags its respective voltage.

PART II – TYPE TCU CONTROL UNIT

The construction, operation, and adjustment of the type TCU Control Unit used with the SKB or SKB-1 relays are covered in separate instructions identified as I.L. 41-944.5 plus supplements, when required. The Control Unit is a part of the Type TC carrier assembly.

OVERALL TEST OF COMPLETE INSTALLATION

After the complete equipment has been installed and adjusted, the following tests can be made which will provide an overall check on the relay and carrier equipment. The phase rotation of the three-phase currents can be checked by measuring the a-c voltage across relay terminals 2 and 3 with a high resistance a-c voltmeter of at least 1000 ohms per volt. The reading obtained should be approximately 0.9 volts per ampere of balanced three-phase load current (secondary value) with relay taps 4, C and H, or taps 8-C-H for the SKB-1 relay.

The following test requires that a balanced three-phase load current of at least 1.0 ampere (secondary) be flowing through the line-section protected by the SKB relays. At both terminals of the protected line section, remove the SKB or SKB-1 relay cover and open the trip circuit by pulling the test switch blade with the red handle. Put the tap screw on the upper tap plate in the 4 tap, and on the lower ones in the C and H taps. Be sure to insert the spare tap screw before removing the connected one. Now open test switches 4 and 5 on the relay at one end of the line section (station A) and insert a current test plug or strip of insulating material into the test jack on switch 5 to open the circuit through that switch. The above operation shorts the phase A to neutral circuit ahead of the sequence filter and disconnects the phase A lead from the filter. This causes the phase B and C currents to return to the current tramsformers through the zero-sequence resistor in the filter, thus simulating a reversed phase A-to-ground fault fed from one end of the line only, As a result, both the fault detectors and tripping relay at Station A should operate. Completion of the trip circuit can be checked by connecting a small lamp (not over 10 watts) across the terminals of test switch 10. (SKB only.)

Now perform the above operations at the opposite end of the line section (station B) and momentarily open and reclose test switch 11 or momentarily depress the Test Reset push-button, if more convenient. This simulates a phase-to-ground fault external to the protected line section. The fault detectors, but not the operating unit should operate. Test switch 11 operation is required to make sure that "flip-flop" stage in the control unit is in reset position. Now open and reclose switch 11 at station A in order to reset "flip-flop" stage from previous "trip" condition. The operating unit at station A should stay open now. Restore test switches 4 and 5 at Station A to normal (closed). The line conditions now represent a phase-to-ground fault fed from Station B. only. The fault detectors at A should reset and the operating unit at B should pick up. Restore test switches 4 and 5 at Station B to normal, and all elements of the relay at Station B should reset.

The above tests have checked phase rotation, the polarity of the sequence filter output, the interconnections between the relay and the carrier set and the Phase A current connections to the relay at both stations. Phase B and C should be similarly checked by opening test switches 6 and 7 for phase B, and switches 8 and 9 for phase C. The same procedure described for Phase A is then followed.

If all the tests have been completed with satisfactory results, the test switches at both line terminals should be closed (close the trip-circuit test switch last) and the relay cover replaced. The equipment is now ready to protect the line-section to which it is connected.

PART III – TYPE SKB OR SKB-1 TEST FACILITIES APPLICATION

The test facilities provide a simple manually operated test procedure that will check the combined relay and carrier equipment. The test can be performed without the aid of instruments. The results give assurance that all equipment is in normal operating condition without resorting to more elaborate test procedures.

CONSTRUCTION

Test Switch

The type W-2 test switch is a four-position, multi-stage switch. The contact arrangement is shown in Fig. 10, and the outline and drilling plan in Fig. 11. The "on" contacts are used to complete the SKB trip circuit and the alarm circuit. These contacts are indicated in Fig. 10 by contacts C5-D5 and A1-B1. In the "Off" position, the SKB trip circuit is opened through contact C5-D5, but the alarm circuit remains closed through contact A1Z-B1Z. Two test positions to the left of the "Off" position are provided. When the switch is moved to either of these positions, the relay trip and alarm circuits are interrupted and a red alarm light is turned on by switch contacts A6-B6 and A7-B7. Moving the switch to the "Test 1" position will connect the output of the auxiliary test transformer directly to the SKB terminals number 8 and 9. Moving the switch to the "Test 2" position will connect the test transformer with a reversed polarity to the SKB relay.

For the SKB-1 relay, refer to the overall diagram which applies to the particular order for actual connections.

Auxiliary Test Transformer

The auxiliary test transformer is designed to operate from a 120-volt, 60-cycle power source. Four secondary taps numbered 1, 2, 3, and 4 are provided to vary the magnitude of the phase-C-to-ground test current approximately as follows:

TRANS TAP	RELAY TAP	
	G	H
1	3 amp.	2 amp.
2	5 amp.	4 amp.
3	7.5 amp.	5.5 amp.
4	9.5 amp.	7 amp.

The outline and drilling plan of the transformer is shown in Fig. 12.

Indicating Lamps

The red and blue indicating lamps are standard rectangular Minalites. Outline and drilling dimensions are given in Fig. 11.

ADJUSTMENT

Choose a transformer tap that will provide approximately two times the phase-to-ground current setting of the FD-2 fault detector as previously determined.

OPERATION

A multi-contact switch is provided at each line terminal which serves the dual functions of a carrier on-off switch and a test switch. This switch is arranged to apply a single-phase current to the SKB or SKB-1 relay to simulate internal and through fault conditions. Relay operation is noted by observing a blue indicating lamp connected in the SKB relay trip circuit. During the test the SKB trip circuit to the line breaker is opened and a red warning light is energized through auxiliary contacts on the test switch.

Use of the auxiliary test equipment is to be limited to provide a simplified test after the initial installation tests have been performed as described in Part II of this instruction leaflet.

The test apparatus is to be connected as shown in Fig. 10 with the auxiliary test transformers energized from 120-volt, 60-cycle power sources, at each line terminal, that are in phase with each other. The following operation procedure assumes that the same polarity is used in connecting the test transformer at each line terminal.

1. Turn the carrier test switch at both line terminals to OFF.

2. Turn the carrier test switch to TEST 1 at station A. The "A" relay should operate to transmit half cycle impulses of carrier, and trip. Tripping will be indicated by the blue light.

3. Turn the SKB test switch at Station B to TEST 1. This will simulate an internal fault fed from both line terminals. The relay at Station B will trip, and the relay at Station A will remain tripped. Tripping will be indicated by the blue lights at each line terminal. Carrier will be transmitted in half cycle impulses simultaneously from each end of the line.

4. Reset the SKB test switch at Station A. The relay at Station A will reset and turn off the blue light. The relay at Station B will hold its trip contact closed, lighting the blue light.

5. Turn the SKB test switch at Station A to TEST 2. Depress Test Reset pushbutton momentarily to reset Flip-Flop stage that may have operated during switching the test switch to position 2. Operate Test Reset pushbutton at Station B to reset Flip-Flop stage from previous tripped position. Both blue lights should be off at this point, which represents an external fault.

6. Reset the test switches at both line terminals to OFF before returning to ON for normal service. Push in handle to turn in ON position.

This completes the test procedure.

Component Style Numbers

Test Transformer	S# 1338284
Type W-2 Test Switch	S# 505A742G01 for 1/8" panel mounting.
Type W-2 Test Switch	S# 505A742G02 for 1-½" panel mounting.

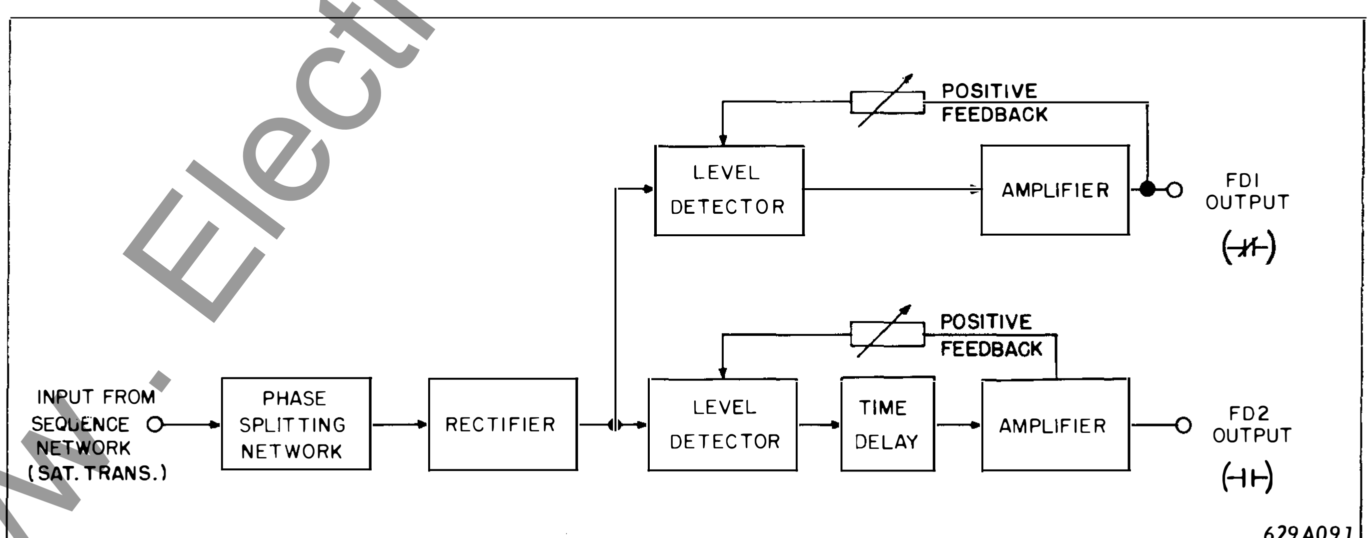

Fig. 3 Static Fault Detector Block Diagram

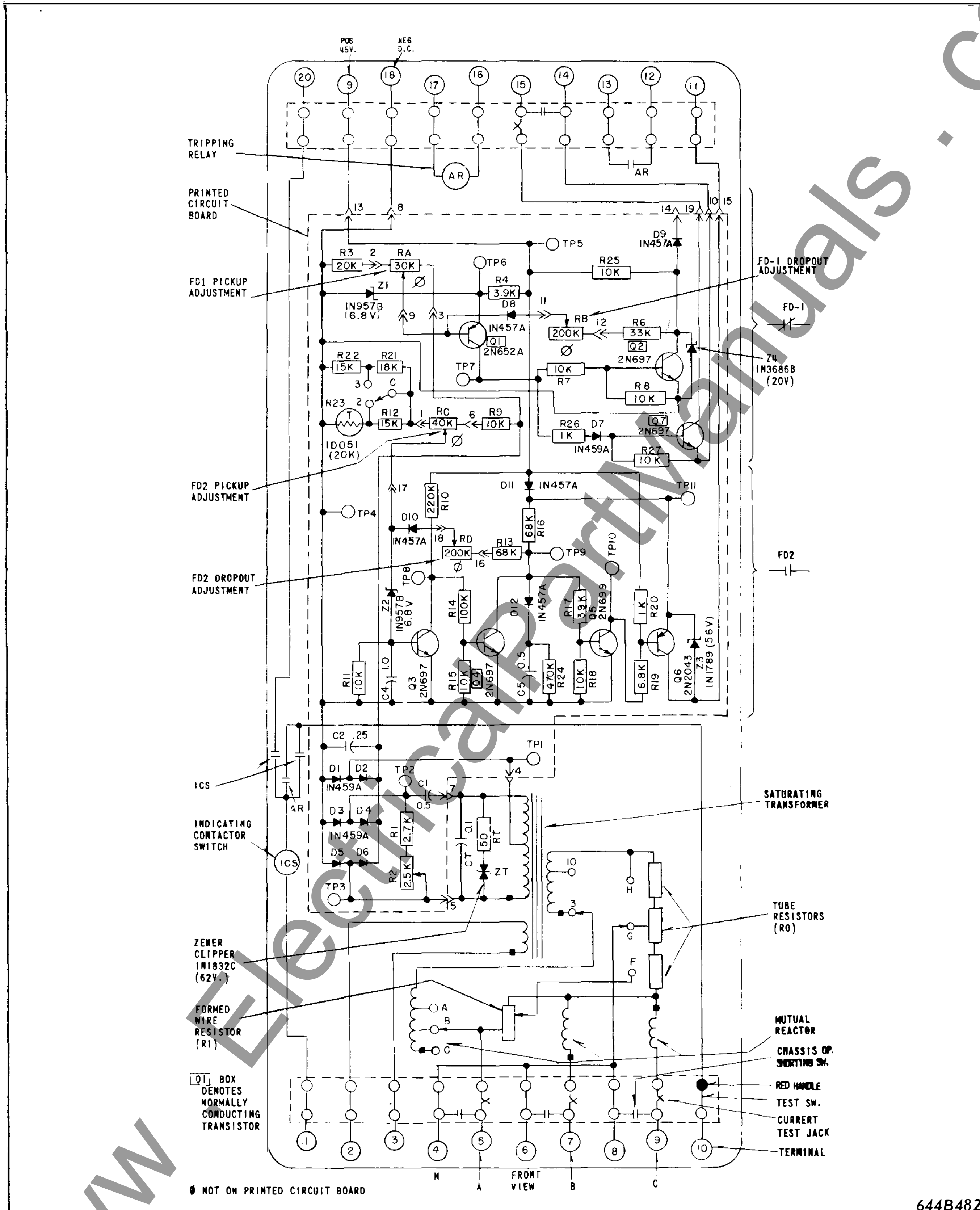

Fig. 4 Complete Internal Schematic of SKB Relay

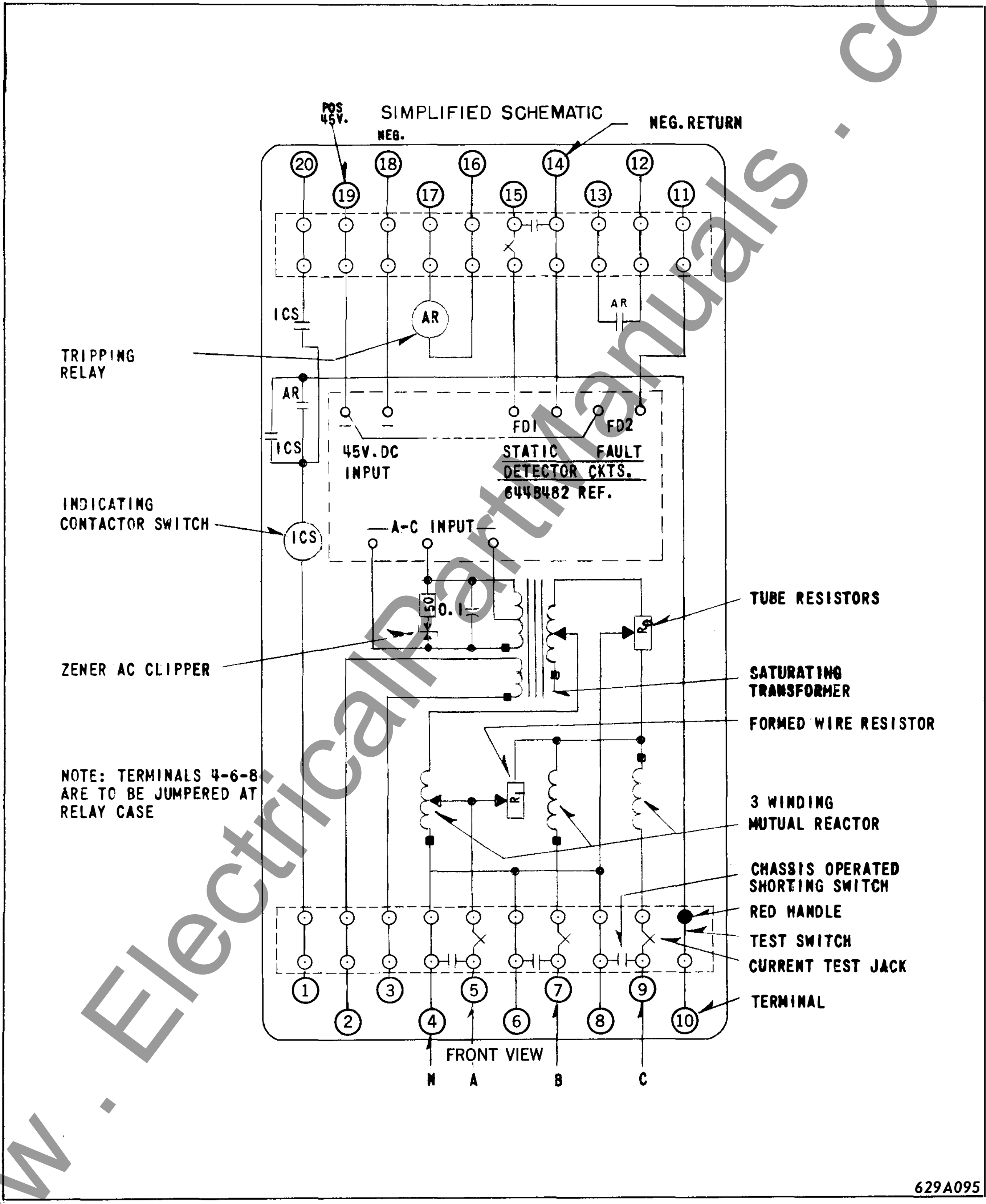

Fig. 5 Simplified Schematic – Type SKB Relay

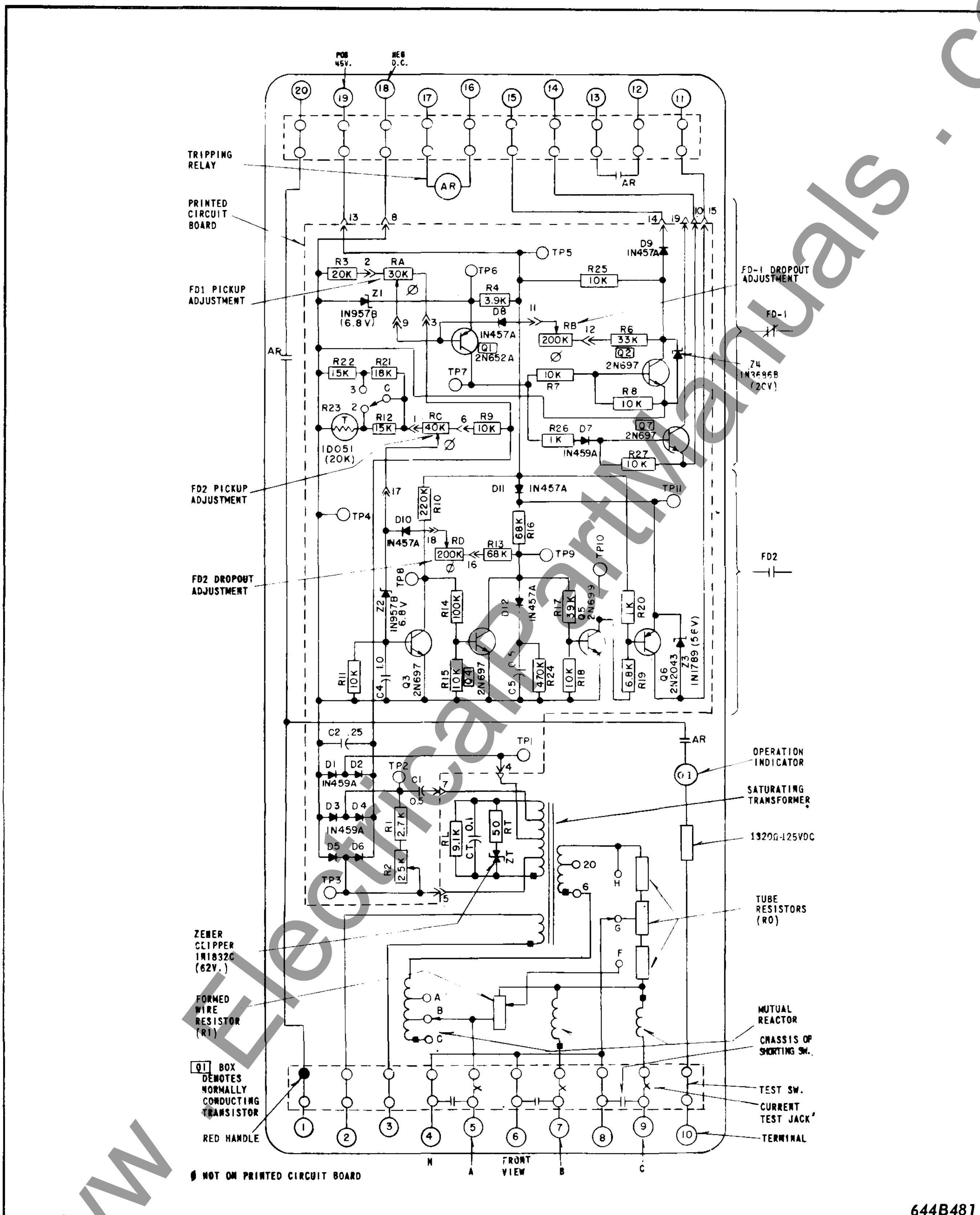

Fig. 6 Complete Internal Schematic of SKB-1 Relay

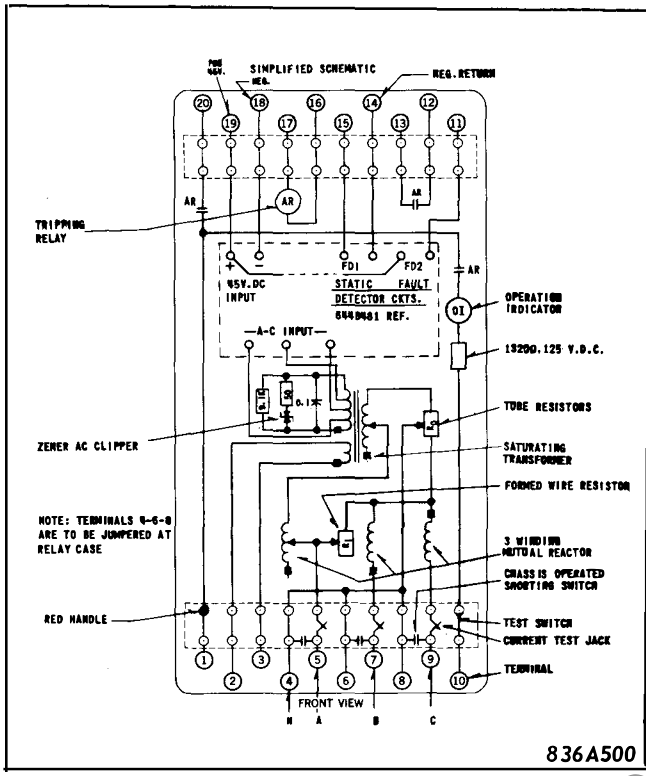

Fig. 7 Simplified Schematic – Type SKB-1 Relay

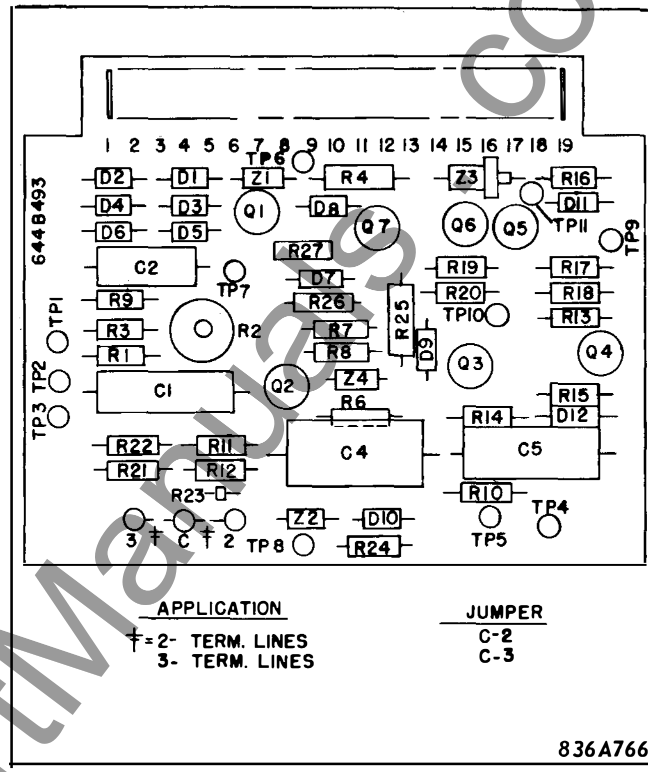

Fig. 8 Printed Circuit Board Component Location, SKB or SKB-1 Relay

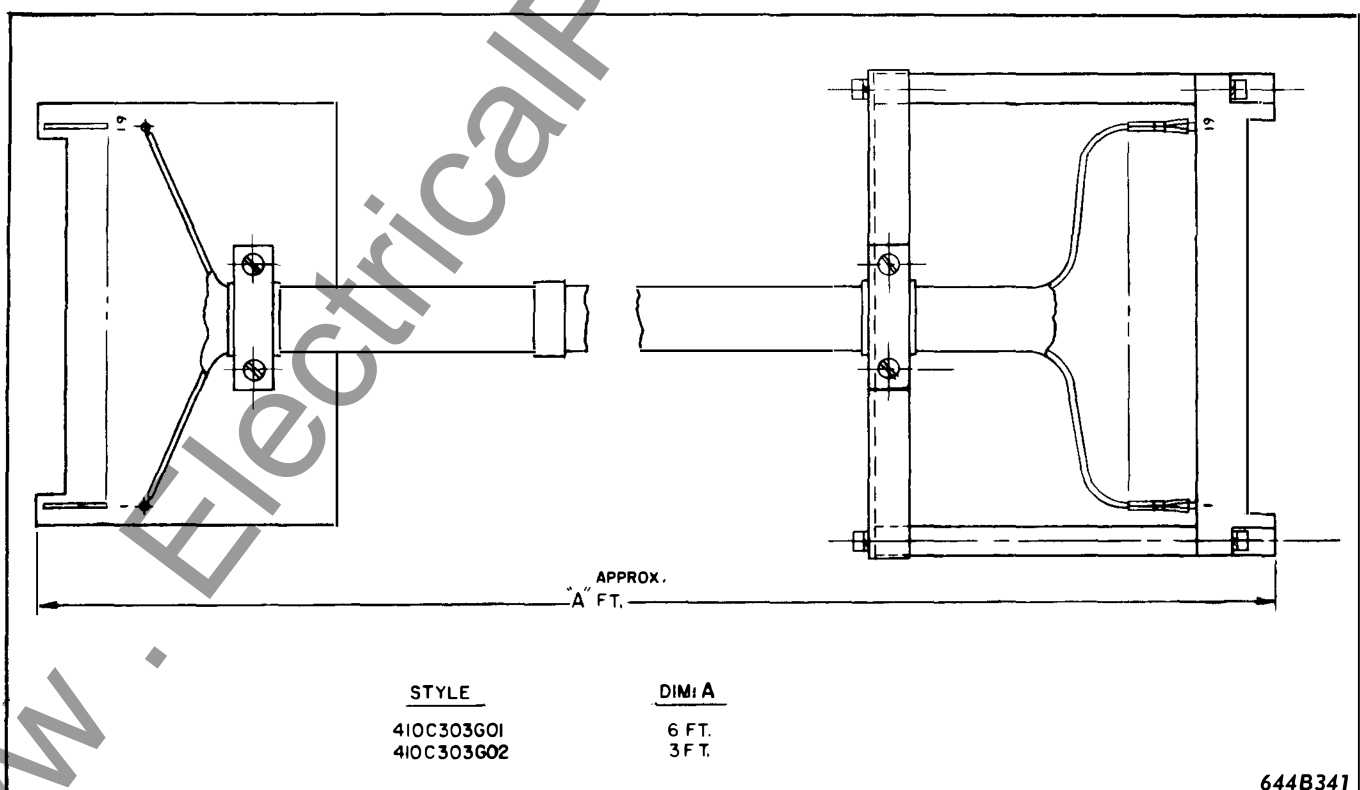

Fig. 9 Test Cable Assembly

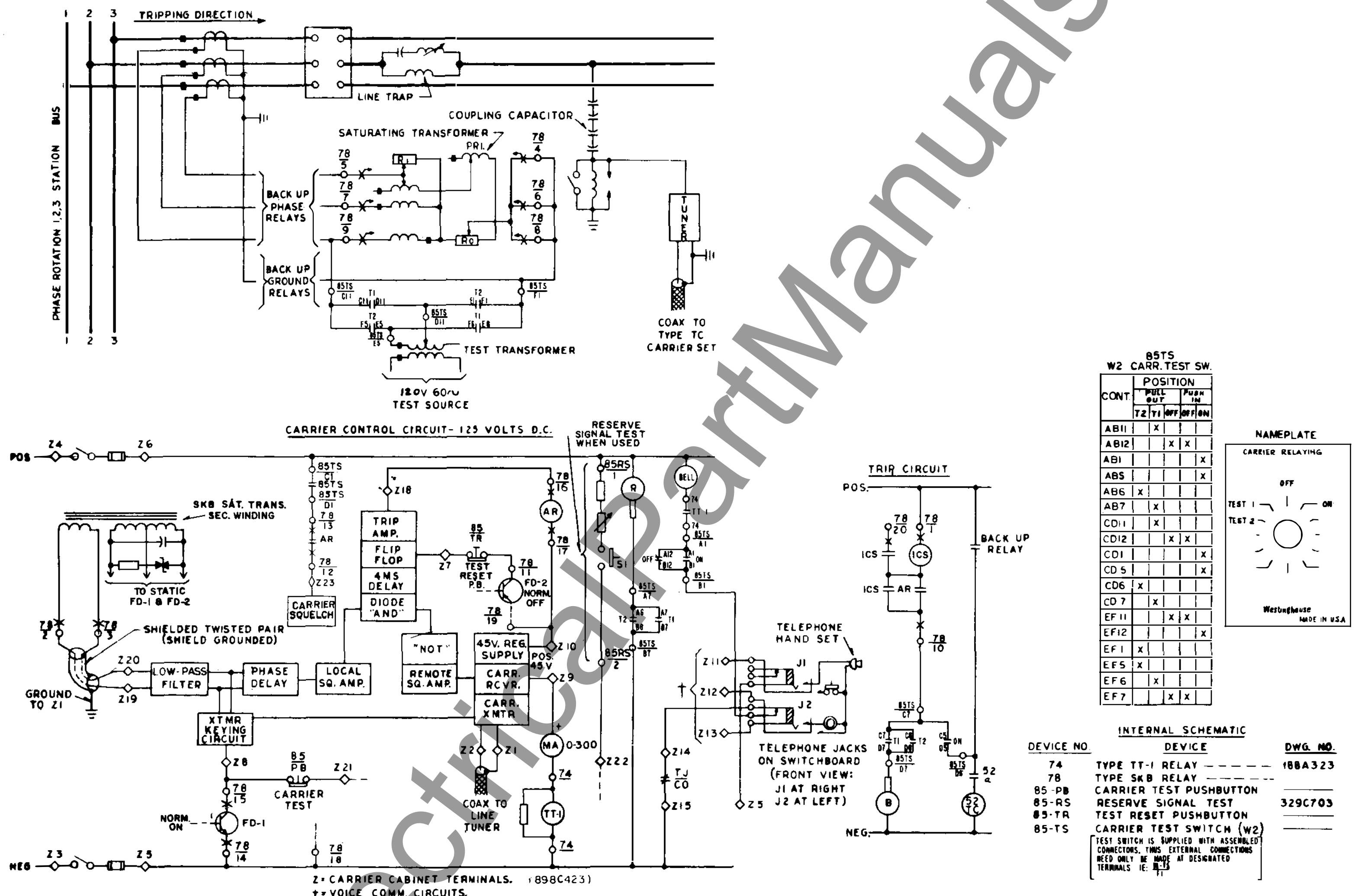

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Fig. 10 External Schematic of the SKB Relay and Test Facilities, with TT-1 Alarm Relay

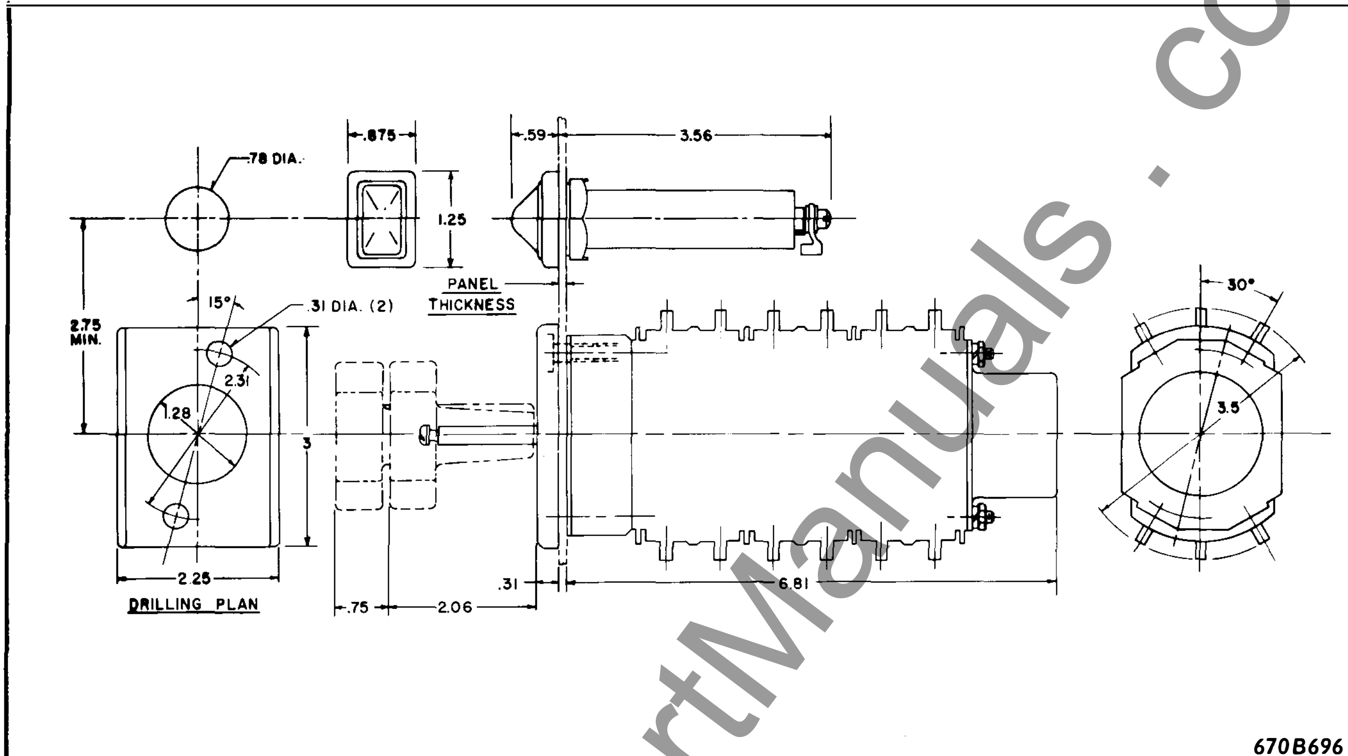

Fig. 11 Outline and Drilling Plan of the Type W-2 Test Switch and Indicating Lamps Used for SKB or SKB-1 Testing

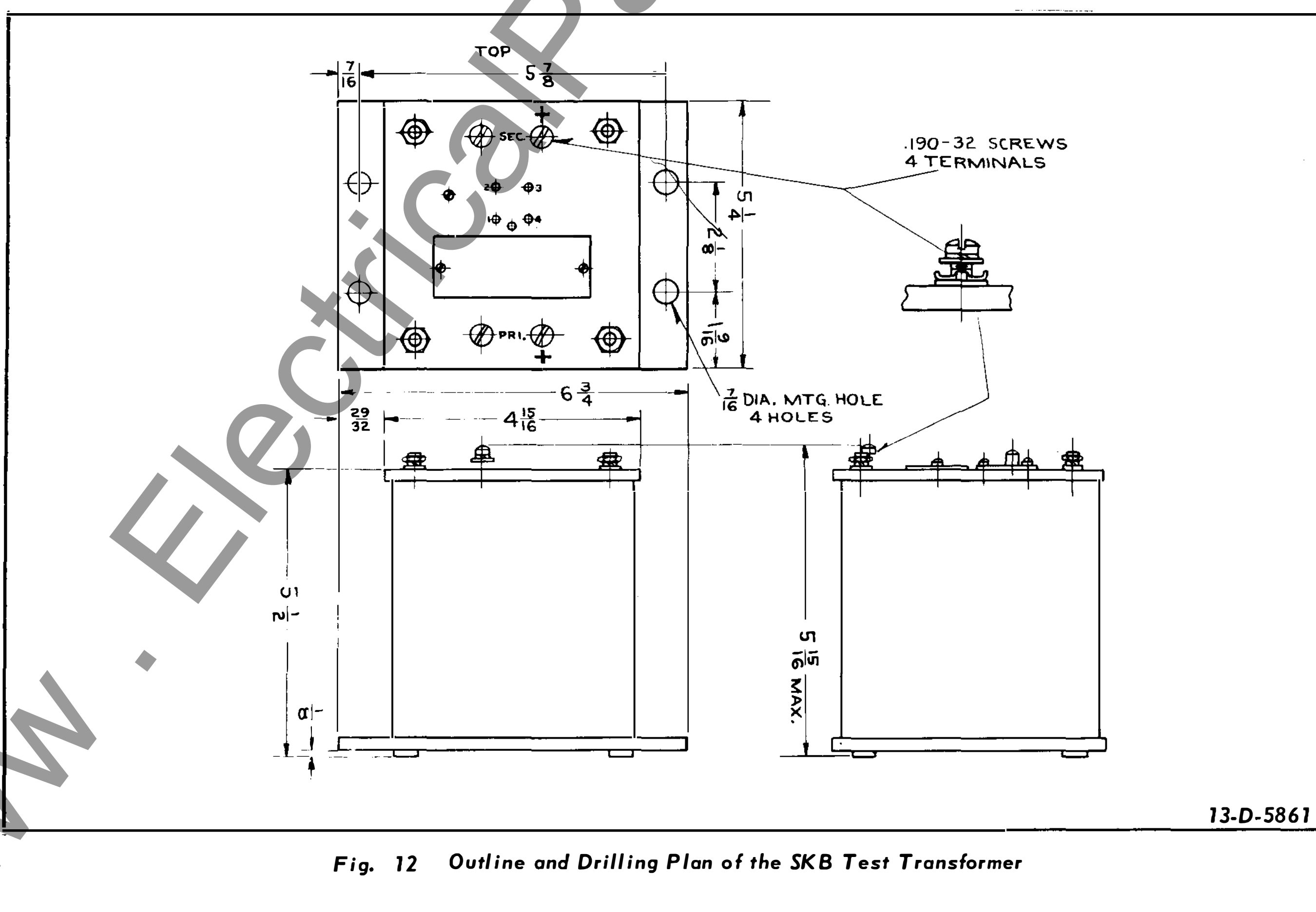

Fig. 12 Outline and Drilling Plan of the SKB Test Transformer

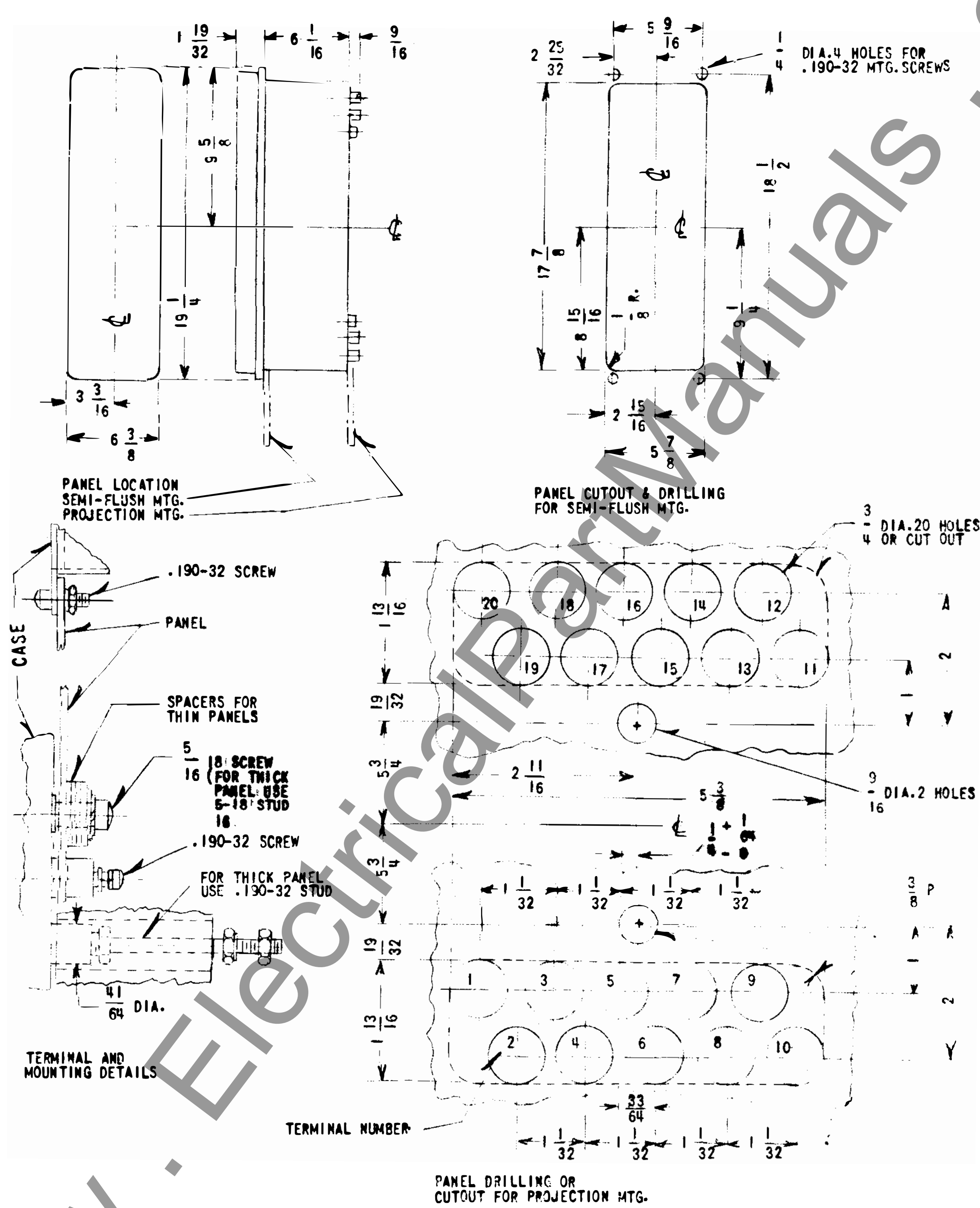

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Fig. 13 Outline and Drilling Plan of the SKB or SKB-1 Relay in the FT-42 Case

WESTINGHOUSE ELECTRIC CORPORATION

RELAY-INSTRUMENT DIVISION **NEWARK, N. J.**

Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE SKB AND SKB-1 RELAYS AND TEST EQUIPMENT FOR TYPE TC CARRIER

INSTRUCTIONS

CAUTION: Before putting relays into service, 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 SKB relay is a high-speed carrier relay with static fault detectors used in conjunction with power-line carrier equipment to provide complete phase and ground fault protection of a transmission line section. Simultaneous tripping of the relays at each line terminal is obtained in less than two cycles for all internal faults within the limits of the relay settings. The relay operates on line current only, and no source of a-c line potential is required. Consequently, the relays will not trip during a system swing or out-of-step conditions. The carrier equipment operates directly from the station battery.

The type SKB-1 relay is used in distance phase-comparison carrier relaying where separate distance-type fault detectors supplement the overcurrent fault detectors of the SKB-1 relay to give improved phase-fault sensitivity. Unless otherwise stated, the following sections of this instruction leaflet apply to both the types SKB and SKB-1 relays.

The SKB relay is available with indicating contactor switches with either a 1-ampere or a 0.2/2.0-ampere rating. The 0.2/2.0-ampere rating is recommended where a lockout relay is energized or where a high resistance auxiliary tripping relay is utilized. The SKB-1 relay has a low-current operation indicator, and the trip circuit energizes an external static tripping device.

PART I

TYPE SKB AND SKB-1 RELAYS

CONSTRUCTION

The relay consists of a combination positive, negative, and zero sequence current network, a saturating auxiliary transformer, Zener clipper, high-speed type AR tripping relay unit, indicating contactor switch plus the static fault-detector circuitry which is mounted on a printed-circuit board. These components are all mounted in an FT42 Flexitest relay case.

Sequence Network

The currents from the current-transformer secondaries are passed through a network consisting of a three-winding iron-core reactor and two resistors. The zero-sequence resistor, R_0, consists of three resistor tubes tapped to obtain settings for various ground fault conditions. The other resistor R_1 is a formed single wire mounted on the rear of the relay sub-base. The output of this network provides a voltage across the primary of the saturating transformer.

The lower tap block provides for adjustment of the relative amounts of the positive, negative, and zero sequence components of current in the network output. Thus, a single relay unit energized from the network can be used as a fault detector for all types of faults.

Saturating Auxiliary Transformer

The voltage from the network is fed into the tapped primary (upper tap plate) of a small saturating transformer. This transformer and a Zener clipper connected across its secondary are used to limit the voltage impressed on the static fault detectors and the carrier control unit, thus providing a small range of voltage for a large variation of maximum to minimum fault currents. This provides high operating energy for light faults, and limits the operating energy for heavy faults to a reasonable value.

The upper tap plate changes the output of the saturating transformer, and is marked in amperes required to pick up the lower fault detector unit. For further discussion, see section entitled, SETTINGS.

SUPERSEEDES I.L. 41-954B
*Denotes changed from superseded issue.

EFFECTIVE DECEMBER 1968

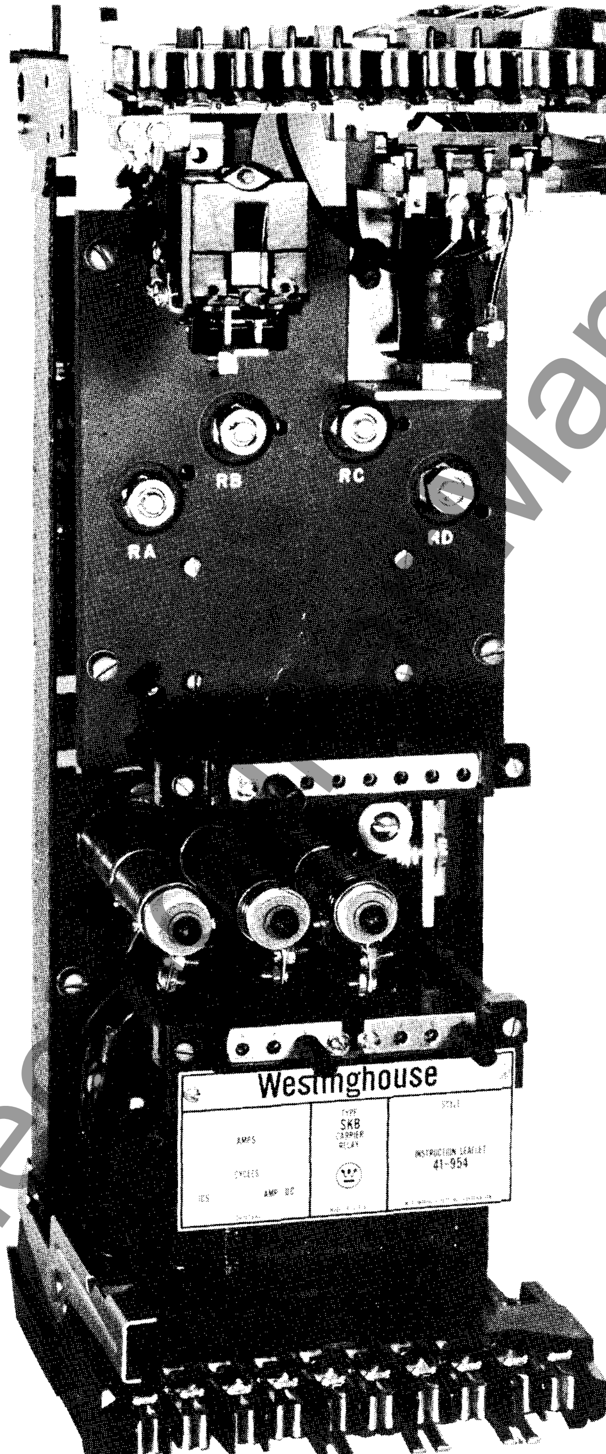


Fig. 1 Type SKB Relay — Front View

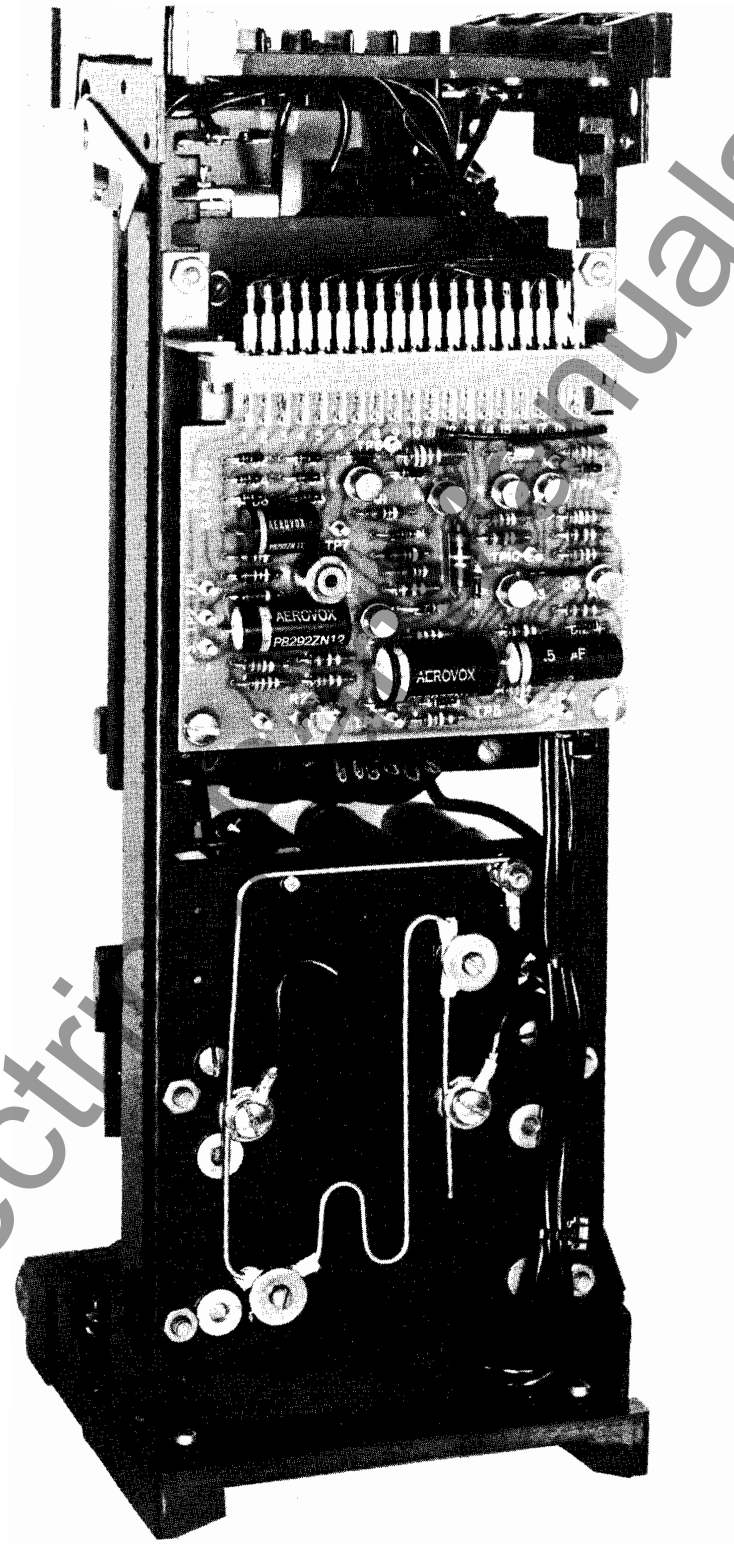


Fig. 2 Type SKB Relay – Rear View

Static Fault Detectors

The static circuitry for the two fault detectors FD1 and FD2 is mounted on a single printed circuit board on the rear of the relay chassis. Four controls for separately setting the pickup and dropout of FD1 and FD2 are mounted on a sub-panel in the chassis. The controls, with locking shafts, are adjustable from the front of the relay.

Tripping Relay

The AR tripping relay is a small high-speed attracted-armature type of unit. An insulated member, fastened to the free end of the armature, draws down four moving-contact springs to close the trip-circuit contacts when the relay coil is energized.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch in the SKB relay 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 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. In the SKB-1 relay, the device has no contacts, and is used only as an operation indicator (OI).

OPERATION

The SKB or SKB-1 carrier relaying system compares the phase positions of the currents at the ends of a line-section over a carrier channel to determine whether an internal or external fault exists. The three-phase line currents energize a sequence network which gives a single-phase output voltage proportional to a combination of sequence components of the line current. During a fault, this single-phase voltage energizes a static control unit (TCU) which allows the transmission of carrier on alternate half-cycles of the power-frequency current. Carrier is transmitted from both line terminals in this manner, and is received at the opposite ends where it is compared with the phase position of the local sequence network output. If the local and remote half-cycle pulses are of the correct phase position for an internal fault, after a 4-millisecond delay during the half cycle in which carrier is not transmitted, tripping will be initiated through operation of the flip-flop and trip amplifier circuits in the TCU control unit. Current transformer connections to the sequence networks at the two terminals are such that carrier is transmitted on the same half cycles from both terminals during an internal fault, thus allowing tripping during the half cycles that carrier is not transmitted. However, if the fault is external to the protected line section, carrier is transmitted on alternate half cycles from opposite terminals. Thus each terminal blocks the opposite terminal during the half cycle when it is attempting to trip.

The four-millisecond delay previously mentioned is added to allow for differences in current transformer performance at opposite line terminals, relay co-ordination, and momentary interruptions in carrier caused by arcing over of protective gaps in the tuning equipment.

Since this relaying system operates only during a fault, the carrier channel is available at all other times for the transmission of other functions.

OPERATION

STATIC FAULT DETECTORS

The functional elements of the static fault detectors are shown in Fig. 3. The single-phase output of the sequence network (not shown) connects to the INPUT terminal shown at the left side of the drawing. This a-c voltage is applied to a phase-splitting network and polyphase rectifier. The resulting d-c voltage has relatively little ripple without much filtering which would slow down the fault detector operation. The d-c voltage is fed to two level detectors which determine the operating currents of FD1 and FD2. The output of FD1 level detector is amplified and provides a "normally-closed" FD1 static contact to start carrier.

The operation of FD2 is delayed about 5 milliseconds to insure coordination in setting up blocking for external faults where FD1 must operate to start carrier blocking a few milliseconds before FD2 energizes the comparison and flip-flop circuits. The output of FD2 fault detector circuit is equivalent to a "normally-open" contact.

The complete circuitry of the SKB relay is shown in Fig. 4. The sequence network, saturating transformer, phase-splitting network, and polyphase rectifier occupy the lower third of the diagram. The FD2 circuitry is in the middle portion, and the FD1 portion is in the upper part of the diagram. The type AR tripping relay is shown at the top. Fig. 5 is a simplified schematic of the SKB relay with the static fault detector circuitry omitted.

Figures 6 and 7 are the complete and simplified schematic diagrams, respectively, of the type SKB-1 relay. This relay differs from the SKB relay in the trip circuit wiring to terminals 1, 10, and 20, and in the connections from the saturating transformer tapped secondary to the input terminals 5 and 7 of the printed circuit board. The sequence network (R1, R0, and the mutual reactor) and the printed circuit board assembly for the static fault detectors for the SKB and SKB-1 relays are identical. Figure 8 shows the location of components on the printed circuit board for the static fault detectors for both the SKB and SKB-1 relays.

With reference to Fig. 4, the output voltage of the sequence network and saturating transformer is applied to a phase-splitting network (C1, R1, R2) and a polyphase rectifier (diodes D1 to D6). The d-c voltage so obtained requires a minimum of filtering (C2), and responds rapidly to a change in magnitude of the a-c output. This d-c voltage is applied to the FD1 and FD2 circuits which operate when the d-c input "signal" exceeds a predetermined value.

FD1 - Under normal line conditions (no fault), current flows from relay terminal 19 (pos. 45 v) through resistor R4 and Zener diode Z1 to negative, holding Q1 emitter at 6.8 volts positive. In transistor Q1, current flows from emitter to base, then through RA and R3 to negative, thus turning on Q1. The collector current of Q1 provides base drive to transistors Q2 and Q7, turning them on also. The voltage drop across Q7 is very low (less than 0.5 volt), thus providing the equivalent of a closed contact. When a fault occurs and the d-c input voltage to Q1 base (from the polyphase rectifier) exceeds the 6.8-volt drop across Zener diode Z1, transistor Q1 stops conducting. This removes the base current from Q2 and Q7, causing them to stop conducting, and providing the equivalent of an open contact at Q7 collector-emitter circuit.

When Q2 is cut off as just explained, its collector potential rises to about 20 volts. This further raises the potential of Q1 base through feedback resistors R6 and RB, thus holding Q1 in a non-conducting state. When the input voltage is sufficiently reduced to allow FD1 to "reset," transistors Q1, Q2, and Q7 again conduct. Resistor RA is for setting the FD1 pickup current (calibration adjustment), and the setting of RB determines the 80 per cent dropout value.

FD-2 - Under normal conditions, transistor Q3 has no base "signal" and thus is turned off (not conducting). Thus Q3 collector is at a high enough positive potential to provide base drive for transistor Q4, driving it to full conduction. With Q4 fully conducting, there is no base drive to transistor Q5. With no Q5 collector current, the base of PNP-type transistor Q6 is supplied from the 45-volt source through the drop of diode D11. Thus the Q6 emitter is normally at a slightly lower potential than its base. This condition keeps transistor Q6 in a non-conducting state, equivalent to an open contact. Zener diode Z3 is to protect transistor Q6 from external surge voltages.

When a fault causes the d-c input voltage from the adjustable resistor RC to exceed the 6.8-volt rating of Zener diode Z2, a positive bias is applied to Q3 base, causing it to conduct. In turn, Q4 stops conducting, and capacitor C5 charges up, giving a few milliseconds' time delay before Q5 and Q6 are switched to full conduction, thus "closing" FD2. The feedback resistors R13 and RD provide a 90-percent FD2 dropout ratio with "toggle" action at the dropout point.

CHARACTERISTICS

The sequence network in the relays is arranged for several possible combinations of sequence components. For most applications, the output of the network will contain the positive, negative, and zero sequence components of the line current. In this case, the taps on the upper tap plate indicate the balanced three-phase amperes which will operate the carrier-start fault detector FD1. The second fault-detector unit FD2, which supervises operation of the AR tripping relay, is adjusted to pick up at a current 25 percent above tap value. The taps available are 3, 4, 5, 6, 7, 8, and 10, for the SKB relay, and 6, 8, 10, 12, 14, 16, and 20 for the SKB-1 relay. These taps are on the primary of the saturating transformer.

For phase-to-phase faults AB and CA, enough negative sequence current has been introduced to allow the fault detector FD1 to pick up at 86% of the tap setting. For BC faults, the fault detector will pick up at approximately 50% of the tap setting.

This difference in pick-up current for different phase-to-phase faults is fundamental, and occurs because of the angles at which the positive and negative sequence components of current add together.

With the sequence network arranged for positive, negative, and zero sequence output, there are some applications where the maximum load current and minimum fault current are too close together to set the relay to pick up under minimum fault current, yet not operate under load. For these cases, a tap is available on both the SKB and SKB-1 relays which cuts the three-phase sensitivity in half, while the phase-to-phase setting is substantially unchanged. The relay then trips at 90% of tap value for AB and CA faults, and at twice tap value for three-phase faults. The setting for BC faults is 65 percent of tap value. In some cases, it may be desirable to eliminate response to positive-sequence current entirely, and operate the SKB relay on negative-plus-zero sequence current. A tap is available to operate in this manner. The fault detector FD1 picks up at about 95% of tap value for all phase-to-phase faults, but is unaffected by balanced load current or three-phase faults when using this tap.

For ground faults, separate taps are available for adjustment of the ground fault sensitivity to about 1/4 or 1/8 of the upper tap plate setting. See Table II. For example, if the upper tap plate of the SKB relay is set at tap 4, the fault detector (FD1) pick-up current for ground faults can be either 1 or ½ ampere. In special applications, it may be desirable to eliminate response to zero-sequence current. The relay is provided with a tap to allow such operation.

Trip Circuit

The main contacts of the SKB relay 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 trip contacts of the SKB-1 relay have no seal-in device since they energize the low-current input of a static tripping relay.

Trip Circuit Constants – SKB Relay

Indicating Contactor Switch (ICS)

0.2-ampere tap, 6.5 ohms d-c resistance
2.0-ampere tap, 0.15 ohms d-c resistance
1.0-ampere tap, 0.1 ohms d-c resistance

SETTINGS – SKB RELAY

The SKB relay has separate tap plates for adjustment of the phase and ground fault sensitivities and the sequence components included in the network output. The range of the available taps is sufficient to cover a wide range of application. The method of determining the correct taps for a given installation is discussed in the following paragraphs.

In all cases, the similar fault detectors on the relays at all terminals of a line section must be set to pick up at the same value of line current. This is necessary for correct blocking during faults external to the protected line section.

Positive-Sequence Current Tap and FD2 Tap

The upper tap plate has taps of 3, 4, 5, 6, 7, 8, and 10 for the SKB relay, or 6 to 20 for the SKB-1 relay. As mentioned before, these numbers represent the three-phase, fault detector FD1 pickup currents, when the relay is connected for positive, negative and zero sequence output. The fault detector FD2 operates to allow tripping at a current value 25 percent above the fault detector FD1 setting. This 25 percent difference is necessary to insure that the carrier-start fault detectors (FD1) at both ends of a 2-terminal transmission line section pick up to start carrier on an external fault before operating energy is applied through FD2.

For a 3-terminal line, FD2 settings must be readjusted for pickup at 250 percent of FD1 setting. This is necessary to allow proper blocking when approximately equal currents flow in two terminals, and their sum flows out the third line terminal. The relay is normally shipped calibrated for 2-terminal line operation.

When the SKB is to be used on a 3-terminal line, FD2 must be recalibrated as explained in the previous paragraph, and the FD2 temperature-compensating circuit must also be changed to accomodate the new Rc (FD2 pickup) setting. This is accomplished by changing the jumper near the lower left corner of the printed circuit board (see Fig. 8) from C-2 to C-3, as shown.

The taps on the upper and lower tap plates should be selected to assure operation on minimum internal line-to-line faults, and yet not operate on normal load current, particularly if the carrier channel is to be used for auxiliary functions. The drop-out current of the FD-1 fault detector is 80 percent of the pick up current, and this factor must also be considered in selecting the positive-sequence current tap and sequence component combination. The margin between load current and fault detector pick up should be sufficient to allow the fault detector to drop out after an external fault, when load current continues to flow.

Sequence Combination Taps

The two halves of the lower tap plate are for connecting the sequence network to provide any of the combinations described in the previous section. The left half of the tap plate changes the tap on the third winding of the mutual reactor and thus changes the relative amounts of positive and negative sequence sensitivity. Operation of the relay with the various taps is given in the table below.

TABLE I

COMB.	SEQUENCE COMPONENTS IN NETWORK OUTPUT	TAPS ON LOWER TAP BLOCK		FAULT DETECTOR FD1 PICK-UP △	
		LEFT HALF	RIGHT HALF	3 ϕ FAULT	ϕ - ϕ FAULT
1	Positive, Negative, Zero	C	G or H *	Tap Value	86% Tap Value (53% on BC Fault)
2	Positive, Negative, Zero	B +	G or H	2 x Tap Value	90% Tap Value (65% on BC Fault)
3	Negative, Zero	A +	G or H	——	95% Tap Value

* Taps F, G, and H are zero-sequence taps for adjusting ground fault sensitivity. See section on zero-sequence current tap.

△ Fault detector FD2 is set to pick up at 125% of FD1 for a two-terminal line, or 250% for a three-terminal line.

\+ When taps A and 3, or B and 3 are used, the relay pickup currents for FD1 and FD2 will be 10 or 15 percent higher than the indicated values because of the variation in self-impedance of the sequence network and the saturating transformer.

Zero-Sequence Current Tap

The right half of the lower tap plate is for adjusting the ground fault response of the relay. Taps G and H give the approximate ground fault sensitivities as listed in Table II. Tap F is used in applications where increased sensitivity to ground faults is not required. When this tap is used, the voltage output of the network caused by zero-sequence current is eliminated.

NOTE: Because of inherent characteristics of the sequence network, there will be small variations (from the values listed in Tables I and II) in the pickup current for various phase or ground fault combinations. However, these variations will be the same from one relay to another.

TABLE II

COMB.	LOWER LEFT TAP	GROUND FAULT PICKUP	
		TAP G	TAP H
1	C	25%	12%
2	B	20%	10%
3	A	20%	10%

Examples of SKB Relay Settings

Case I

Assume a two-terminal line with current transformers rated 400/5 at both terminals. Also assume that full load current is 300 amperes, and that on minimum internal phase-to-phase faults 2000 amperes is fed in from one end and 600 amperes from the other end. Further assume that on minimum internal ground faults, 400 amperes is fed in from one end, and 100 amperes from the other end.

Positive-Sequence Current Tap

Secondary Values:

$$\text{Load Current} = 300 \times \frac{5}{400} = 3.75 \text{ amperes} \quad (1)$$

Minimum Phase-to-Phase Fault Currents:

$$600 \times \frac{5}{400} = 7.5 \text{ amperes} \quad (2)$$

Fault detector FD1 setting (three-phase) must be at least:

$$\frac{3.75}{0.80} = 4.7 \text{ amperes (0.80 is dropout ratio of FD-1 fault detector)} \quad (3)$$

so that the fault detector will reset on load current.

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault detector FD1 setting(three-phase) must be not more than:

$$7.5 \times \frac{1}{0.866} \times \frac{1}{1.25} = 6.98 \text{ amperes} \quad (4)$$

$$1.25 = \frac{\text{FD2 pickup}}{\text{FD1 pickup}}$$

Sequence Combination Tap

From a comparison of (3) and (4) above, it is evident that the fault detector can be set to trip under minimum phase fault condition yet not operate under maximum load. In this case, tap C on the lower left tap block would be used (see Table 1, Comb. 1) as there is sufficient difference between maximum load and minimum fault to use the full three-phase sensitivity. Current tap 6 would be used in preference to tap 5 to allow for occurrence of higher load current.

Zero Sequence Tap

Secondary Value:

$$100 \times \frac{5}{400} = 1.25 \text{ amperes minimum ground fault current.}$$

With the upper tap 6 and sequence tap C in use, the fault detector FD1 pickup currents for ground faults are as follows:

Lower right tap G–1/4 x 6 = 1.5 amp.
Minimum trip = 1.25 x 1.5 = 1.88 amp.
Lower right tap H–1/8 x 6 = 0.75 amp.
Minimum trip = 1.25 x 0.75 = 0.94 amp.

From the above, tap H would be used to trip the minimum ground fault of 1.25 amperes.

Case II

Assume the same fault currents as in Case I, but a maximum load current of 550 amperes. In this example, with the same sequence combination as in Case I, the fault detectors cannot be set to trip on the minimum internal three-phase fault, yet remain inoperative on load current. Compare equations (5) and (6). However, by connecting the network per Combination 2 on Table I, the relay can be set to trip on minimum phase-to-phase fault, although it will have only half the sensitivity to three-phase faults. This will allow operation at maximum load without picking up the fault detector, and provide high speed relaying of all except light three-phase faults.

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault detector tap must now be not more than:

$$7.5 \times \frac{1}{1.25} \times \frac{1}{0.9} = 6.6 \quad (5)$$

To be sure the fault detector FD1 will reset after a fault, the minimum tap setting is determined as follows:

$$\text{Load Current} = 550 \times \frac{5}{400} = 6.9 \text{ amps} \quad (6)$$

$$\frac{6.9}{0.80} = 8.6 \quad (7)$$

Since the fault detector pickup current for three-phase faults is twice tap value, half the above value (Eq. 7) should be used in determining the minimum three-phase tap.

$$\frac{8.6}{2} = 4.3 \quad (8)$$

From a comparison of (5) and (8) above, tap 5 or 6 could be used. (Continuous load current rating of relay is 10 amperes.)

With the three-phase tap 5 in use, the fault detector pickup current for ground faults will be as follows:

Tap G–1/5 x 5 = 1.0 a.
Minimum trip = 1.0 x 1.25 a. = 1.25 amp.

Tap H–1/10 x 5 = 0.5 a.
Minimum trip = 1.25 x 0.5 a. = 0.63 amp.

Therefore, tap H would be used to trip the minimum ground fault of 1.25 ampere with a margin of safety.

Indicating Contactor Switch (ICS) – SKB Relay

No setting is required for relays with a 1.0 ampere unit. For relays with a 0.2/2.0 ampere unit, connect the lead located in front of the tap block to the desired setting by means of the connecting screw. When the relay energizes a 125 or 250-volt d-c type WL relay switch, or equivalent, use the 0.2 ampere tap; for 48-volt d-c applications set the unit in tap 2 and use a type WL relay with a S# 304C209-G01 coil, or equivalent.

SETTINGS – SKB-1 RELAY

The SKB-1 relay tap settings are made from a consideration of just maximum load current and the resetting of FD1 fault detector. The SKB-1 current taps are 6, 8, 10, 12, 14, 16, and 20. On taps 6 and C, FD1 will operate at 6 amperes, 3-phase, and reset at 80% of pickup, or 4.8 amperes. This will be adequate in most cases where maximum load current is in the order of 3 to 4 amperes, secondary values. If maximum load current is 5 amperes or slightly higher, tap 8 should be used, which will give a dropout current for FD1 or 6.4 amperes.

For most SKB-1 relay applications, where static phase-distance relays are used as phase fault detectors, taps 6-C-H are recommended. This will give a minimum trip sensitivity for phase-to-ground faults of 6 x 1/8 x 1.25 or 0.94 ampere. Taps A or B are not recommended for SKB-1 relay application.

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 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.

ADJUSTMENT AND MAINTENANCE

CAUTION: When changing taps under load, the spare tap screw should be inserted in the new tap before removing the other tap screw.

Acceptance Tests

Since the static fault detector circuits obtain their d-c supply voltage from the associated type TC carrier set, the fault detector calibration can must easily be checked after the SKB relay and TC-TCU carrier assembly have been installed and interconnected.

NOTE: The relay current tap numbers and the FD1 and FD2 pickup and dropout current values in the Acceptance Tests and Calibration sections apply to the SKB relay. For the equivalent tap number and current value for the SKB-1 relay, double the figures given for the SKB relay.

The carrier trip circuit should be open for the following check: Set the SKB relay on taps 5, C, and H. Connect a 60-cycle test current circuit between phases A and B of the relay (terminals 5 and 7.). Connect a high-resistance d-c voltmeter between relay terminal (or test switch) 15 (pos.) and 18 (neg.). This will read approximately 20 volts when FD1 operates. Gradually increase the current. At 4.33 amperes, FD1 should operate, starting the transmission of half-cycle pulses of carrier, and the d-c voltmeter will read 20 volts.

Continue to increase the test current. At 5.41 amperes, FD2 should operate. If the R101 controls in the type TCU control unit have been set, the AR tripping unit in the SKB relay will operate. The operation of FD1 and FD2 can also be noted by observing the change in d-c voltage at the printed circuit board terminals 14 (FD1) and 15 (FD2) relative to TP4 (negative). See Table I for typical values for these voltages under standby and operating conditions.

Now back off the test current to check the dropout values. Fault detector FD2 should drop out at 90 per cent of pickup, or 4.85 amperes. The FD1 dropout is 80 per cent of pickup, or 3.46 amperes.

The fault detectors have been properly calibrated at the factory and normally will require no further adjustment. If it is found desirable to touch up the calibration, this can be done by loosening the locking nut and changing the adjustment of the appropriate control as listed at the beginning of this section. Turning RA or RC in a clockwise direction will increase the FD1 or FD2 pickup. Similarly, turning RB or RD in a clockwise direction will increase the dropout current.

The pickup and dropout calibration settings of FD1 and FD2 are made with the four controls on the SKB or SKB-1 relay subpanel, as follows:

Relay Unit	Pickup	Dropout
FD1	RA	RB
FD2	RC	RD

These four controls have slotted shafts (for screwdriver adjustment) and locking nuts which are tightened after proper adjustment.

Typical test point voltage values listed in Table I will be useful when checking the apparatus. The readings will remain fairly constant over an indefinite period unless a failure occurs. Voltages should be measured with a vacuum-tube voltmeter. To facilitate taking these voltages, a test cable is available. See Fig. 9. To use this cable, remove the SKB or SKB-1 chassis from its case. Remove the printed circuit board from the back of the relay, and insert the board end of the test cable in its place. Now plug the removed board into the receptacle at the other end of the cable. Replace the relay chassis in its case on the switchboard and close the test switches. The relay can now be energized and operated to obtain the readings in Table I. The test cable can also be used, if desired, with the printed circuit boards of the type TCU Control Unit. However, do not use these test cables in the TC transmitter where r.f. voltages are involved.

TABLE I

Note: All d-c voltages are positive with respect to negative d-c (TP4). All voltages are read with a vtvm, and in general will be within ± 10% of the values listed.

TEST POINT	$I_{SKB} = 0$	$I_{SKB} = 2 \times FD2$ p.u. ϕ
TP5	45.0 vdc	45.0 vdc
TP6	6.5	6.8
TP7	6.5	< 0.5
TP8	14.0	< 0.5
TP9	< 0.5	14.0
TP10	45.0	< 0.5
TP11	45	45
*Term. 14	< 0.5	20.0
*Term. 15	—	44.5
*Term. 19	< 0.5	20.0

A-C TEST POINT VOLTAGES	
TP2 to TP1	18.0 vac approx.
TP2 to TP3	17.5 vac approx.

* On Printed Circuit Board

ϕ - Test current of twice FD2 pickup for the taps used.

< 0.5 - means less than 0.5

After the SKB or SKB-1 and associated relays and the carrier equipment have been installed and adjusted, the system can be checked following the procedure in Part II of this I.L. under the heading "OVERALL TEST OF COMPLETE INSTALLATION."

Routine Maintenance

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

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.

The performance of the phase comparison carrier relaying can be checked periodically as explained in Part III of this I.L. under the heading "TYPE SKB or SKB-1 TEST FACILITIES APPLICATION."

Calibration

Normally, there are no adjustments to be made in the sequence network. The taps on the three tubular R_0 resistors are brazed in place and cannot get out of adjustment. The two taps on the formed R1 resistor are factory settings, and should not require readjustment. However, if there is reason to suspect that the tap position has changed, the following procedure can be used to check the R1 tap settings for either the SKB or SKB-1 relay:

Remove the current tap screw (upper tap plate), and insert the tap screws in taps C and H on the lower tap plate.

Pass a single-phase current of ten amperes (SKB or SKB-1), rated frequency, through the reactor coils in series from phase B to phase C (relay terminals 7 and 9). Accurately measure the a-c voltage from phase A terminal to the upper tap plate. This voltage should be between 3.8 and 4.0 volts a-c. Now pass 10 amperes from phase A to phase B with the lower tap screw C removed. Adjust the R1 tap further from the R1 mounting screw to give a voltage drop across R1 equal to exactly one-third of the reactor drop. This voltage can be measured directly across the terminals of the resistor R1 from the mounting screw to the last tap on R1.

Note the above reading, and adjust the intermediate tap on R1 to give exactly 1/3 of the voltage obtained above for all of R1. Measure the voltage from the R1 mounting screw to the intermediate tap.

If replacement of the printed circuit board or major components necessitates a complete recalibration, proceed as follows:

1. Set relay taps on 5-C-H. (10-C-H for SKB-1)
2. Use a phase A-B test current. (double the following current values for SKB-1 relay).
3. Set RA and RC to full clockwise position.
4. Set RB and RD to mid-scale.
5. Pass 4.33 amperes through the relay (phase A to B).
6. Check the a-c voltage from TP2 to TP1 and from TP2 to TP3 with a vtvm. Adjust the small pot. R2 on the printed circuit board until these two voltages are equal.
7. Now slowly turn RA counterclockwise, with 4.33 amperes flowing, until FD1 operates.
8. Reduce the phase A-B current to check FD1 dropout. Adjust RB to get 80 percent dropout (3.46 Amperes).
9. Recheck FD1 pickup and dropout, and touch up RA and RB in that order for the correct calibration. Tighten the locknuts.
10. Similarly recalibrate FD2 using controls RC (pickup) and RD (dropout), repeating steps 7, 8, and 9 except for FD2 pickup of 5.41 amp. and dropout of 4.85 amp. Do not readjust R2.
11. For 3-terminal lines, change the printed circuit board link from C2 to C3, then calibrate FD2 for 10.82 amp. pickup and 9.7 amp. dropout.

Tripping Relay (AR)

The type AR tripping relay unit has been properly adjusted at the factory to insure correct operation, and should not be disturbed after receipt by the customer. If, however, the adjustments are disturbed in error, or it becomes necessary to replace some part in the field, use the following adjustment procedure. This procedure should not be used until it is apparent that the relay is not in proper working order, and then only if suitable tools are available for checking the adjustments.

1. Adjust the set screw at the rear of the top of the frame to obtain a 0.009-inch gap at the rear end of the armature air gap.
2. Adjust each contact spring to obtain 4 grams pressure at the very end of the spring. This pressure is measured when the spring moves away from the edge of the slot in the insulated crosspiece.
3. Adjust each stationary contact screw to obtain a contact gap of 0.020 inch. This will give 15-30 grams contact pressure.

This completes the adjustment procedure for the AR relay unit. The resistance of the AR relay coil is 100 ohms.

Indicating Contactor Switch (ICS in SKB Relay)

Close the main relay contacts and pass sufficient direct 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.

Operation Indicator (OI in SKB-1 Relay)

Apply 80 percent of rated voltage across relay terminals or test switches 1 and 10. When the AR relay is operated, the orange target should drop.

There are no seal-in contacts on the operation indicator, which is a voltage-operated device.

Replacement of Printed-Circuit Board Components

If a defective resistor, capacitor, or diode is found, cut it out of the circuit by first clipping off its leads on the component side of the printed circuit board. Then turn the board over, melt the solder holding the remaining lead to the printed pad, and remove the lead with tweezers.

NOTE: For such work, a 60-watt iron with a small, clean, well-tinned tip is recommended. Use a 60-40 (tin-lead) rosin-core solder. Do not hold the iron against the printed-circuit board any longer than necessary to remove and replace the component. If the terminal hole in the board closes up with solder, use the iron to melt it, then open up the hole with a fine awl or similar tool.

Where transistors are mounted on small plastic pads, the leads cannot be clipped off. In such a case, melt the solder on one connection at a time, while gently tilting back that section of the transistor. Because of the small flexible leads, the transistor will gradually separate from the board.

Wherever possible, use a heat-sink (such as an alligator clip) on any transistor or diode being soldered. As an alternate, use a long-nosed pliers to hold the lead (being soldered) between the device and the point of soldering.

* ELECTRICAL PARTS LIST

Symbol	Description	Style
C1	0.5 mfd. 200V ± 10%	187A624H11
C2	0.25 mfd, 200V ± 20%	187A624H02
C4	1.0 mfd, 200V ± 20%	187A624H04
C5	0.5 mfd, 200V ± 10%	187A624H11
CT	0.1 mfd, 400V.D.C.	1544920
D1-D7	IN459A Diode	184A855H08
D8-D9 D10-D12	IN457A Diode	184A855H07
Q1	2N652A	184A638H16
Q2-Q3	2N697	184A638H18
Q4	2N697	184A638H18
Q5	2N699	184A638H19
Q6	2N4356	849A441H02
Q7	2N697	184A638H18
R1	2.7K 1/2W ± 5%	629A530H42
R2	2.5K ± 20% 1/4W Pot	629A430H03
R3,R28	20K 1/2W ± 5%	629A530H63
R4	3.9K 1W ± 5%	187A643H41
R6	33K 1/2W ± 10%	187A641H63
R7	10K 1/2W ± 5%	629A530H56
R8	10K 1/2W ± 10%	187A641H51
R9	10K 1/2W ± 5%	629A530H56
R10	0.22 MEG, 1/2W ± 5%	184A763H83
R11	10K 1/2W ± 10%	187A641H51
R12	15K 1/2W ± 10%	187A641H55
R13	33K 1/2W ± 10%	187A641H71
R14	0.1 MEG, 1/2W ± 10%	187A641H75
R15	10K 1/2W ± 10%	187A641H51

Symbol	Description	Style
R16	68K 1/2W ± 10%	187A641H71
R17	39K 1/2W ± 10%	187A641H65
R18	10K 1/2W ± 10%	187A641H51
R19	6.8K 1/2W ± 10%	187A641H47
R21	18K 1/2W ± 5%	184A763H57
R22	15K 1/2W ± 10%	187A641H55
R23	Type 1DO51 Thermistor, 20K at 25°C.	185A211H05
R25	10K 1W ± 5%	187A643H51
R26	1K 1/2W ± 5%	629A530H32
R27, R29	10K 1/2W ± 5%	629A530H56
RA	30K pot.	185A067H15
RB	200K pot.	185A067H14
RC	40K pot.	185A067H16
RD	200K pot.	185A067H14
RT	50 ohms, 2" tube	1340388
RL	9.1K, ½ watt, ±5%-SKB-1 only	
Z1	IN957B (6.8v, 0.4w) Zener Diode	186A797H06
Z2	IN957B (6.8v, 0.4w) Zener Diode	186A797H06
Z3	IN1789 (56v, 1.0w) Zener Diode	584C434H08
Z4	IN3686B (20v, 0.75w) Zener Diode	185A212H06
ZT	IN1832C (62v, 10w) Zener Clipper	184A617H06

Test Equipment

1. A-C ammeter and load box (for fault-detector calibration).
2. Vacuum-tube voltmeter for a-c and d-c measurements.
3. Cathode-ray oscilloscope (to check carrier keying and 60-cycle square-wave voltages in TCU Control Unit).
4. Test Cable

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. For components mounted on the printed circuit board, give the circuit symbol, electrical value, and style number.

ENERGY REQUIREMENTS SKB OR SKB-1 RELAY

Burdens measured at a balanced three-phase current of five amperes:

Relay Taps	Phase A		Phase B		Phase C	
	VA	Angle	VA	Angle	VA	Angle
A-F- 3	2.47	5°	0.6	0°	2.5	20°
A-H-10	3.25	0°	0.8	100°	1.28	55°
B-F-33	2.3	0°	0.63	0°	2.45	55°
B-H-10	4.95	0°	2.35	90°	0.3	60°
C-F- 3	2.32	0°	0.78	0°	2.36	50°
C-H-10	6.35	342°	3.83	80°	1.98	185°

Burdens measured at a single-phase-to-neutral current of five amperes:

Relay Taps	Phase A		Phase B		Phase C	
	VA	Angle	VA	Angle	VA	Angle
A-F- 3	2.47	0°	2.1	10°	1.97	20°
A-H-10	7.3	60°	12.5	53°	6.7	26°
B-F- 3	2.45	0°	2.09	15°	2.07	10°
B-H-10	16.8	55°	22.0	50°	12.3	38°
C-F- 3	2.49	0°	1.99	15°	2.11	15°
C-H-10	31.2	41°	36.0	38°	23.6	35°

The angles above are the degrees by which the current lags its respective voltage.

PART II – TYPE TCU CONTROL UNIT

The construction, operation, and adjustment of the type TCU Control Unit used with the SKB or SKB-1 relays are covered in separate instructions identified as I.L. 41-944.5 plus supplements, when required. The Control Unit is a part of the Type TC carrier assembly.

OVERALL TEST OF COMPLETE INSTALLATION

After the complete equipment has been installed and adjusted, the following tests can be made which will provide an overall check on the relay and carrier equipment. The phase rotation of the three-phase currents can be checked by measuring the a-c voltage across relay terminals 2 and 3 with a high resistance a-c voltmeter of at least 1000 ohms per volt. The reading obtained should be approximately 0.9 volts per ampere of balanced three-phase load current (secondary value) with relay taps 4, C and H, or taps 8-C-H for the SKB-1 relay.

The following test requires that a balanced three-phase load current of at least 1.0 ampere (secondary) be flowing through the line-section protected by the SKB relays. At both terminals of the protected line section, remove the SKB or SKB-1 relay cover and open the trip circuit by pulling the test switch blade with the red handle. Put the tap screw on the upper tap plate in the 4 tap, and on the lower ones in the C and H taps. Be sure to insert the spare tap screw before removing the connected one. Now open test switches 4 and 5 on the relay at one end of the line section (station A) and insert a current test plug or strip of insulating material into the test jack on switch 5 to open the circuit through that switch. The above operation shorts the phase A to neutral circuit ahead of the sequence filter and disconnects the phase A lead from the filter. This causes the phase B and C currents to return to the current tramsformers through the zero-sequence resistor in the filter, thus simulating a reversed phase A-to-ground fault fed from one end of the line only, As a result, both the fault detectors and tripping relay at Station A should operate. Completion of the trip circuit can be checked by connecting a small lamp (not over 10 watts) across the terminals of test switch 10. (SKB only.)

Now perform the above operations at the opposite end of the line section (station B) and momentarily open and reclose test switch 11 or momentarily depress the Test Reset push-button, if more convenient. This simulates a phase-to-ground fault external to the protected line section. The fault detectors, but not the operating unit should operate. Test switch 11 operation is required to make sure that "flip-flop" stage in the control unit is in reset position. Now open and reclose switch 11 at station A in order to reset "flip-flop" stage from previous "trip" condition. The operating unit at station A should stay open now. Restore test switches 4 and 5 at Station A to normal (closed). The line conditions now represent a phase-to-ground fault fed from Station B. only. The fault detectors at A should reset and the operating unit at B should pick up. Restore test switches 4 and 5 at Station B to normal, and all elements of the relay at Station B should reset.

The above tests have checked phase rotation, the polarity of the sequence filter output, the interconnections between the relay and the carrier set and the Phase A current connections to the relay at both stations. Phase B and C should be similarly checked by opening test switches 6 and 7 for phase B, and switches 8 and 9 for phase C. The same procedure described for Phase A is then followed.

If all the tests have been completed with satisfactory results, the test switches at both line terminals should be closed (close the trip-circuit test switch last) and the relay cover replaced. The equipment is now ready to protect the line-section to which it is connected.

PART III – TYPE SKB OR SKB-1 TEST FACILITIES APPLICATION

The test facilities provide a simple manually operated test procedure that will check the combined relay and carrier equipment. The test can be performed without the aid of instruments. The results give assurance that all equipment is in normal operating condition without resorting to more elaborate test procedures.

CONSTRUCTION

Test Switch

The type W-2 test switch is a four-position, multi-stage switch. The contact arrangement is shown in Fig. 10, and the outline and drilling plan in Fig. 11. The "on" contacts are used to complete the SKB trip circuit and the alarm circuit. These contacts are indicated in Fig. 10 by contacts C5-D5 and A1-B1. In the "Off" position, the SKB trip circuit is opened through contact C5-D5, but the alarm circuit remains closed through contact A1Z-B1Z. Two test positions to the left of the "Off" position are provided. When the switch is moved to either of these positions, the relay trip and alarm circuits are interrupted and a red alarm light is turned on by switch contacts A6-B6 and A7-B7. Moving the switch to the "Test 1" position will connect the output of the auxiliary test transformer directly to the SKB terminals number 8 and 9. Moving the switch to the "Test 2" position will connect the test transformer with a reversed polarity to the SKB relay.

For the SKB-1 relay, refer to the overall diagram which applies to the particular order for actual connections.

Auxiliary Test Transformer

The auxiliary test transformer is designed to operate from a 120-volt, 60-cycle power source. Four secondary taps numbered 1, 2, 3, and 4 are provided to vary the magnitude of the phase-C-to-ground test current approximately as follows:

TRANS TAP	RELAY TAP	
	G	H
1	3 amp.	2 amp.
2	5 amp.	4 amp.
3	7.5 amp.	5.5 amp.
4	9.5 amp.	7 amp.

The outline and drilling plan of the transformer is shown in Fig. 12.

Indicating Lamps

The red and blue indicating lamps are standard rectangular Minalites. Outline and drilling dimensions are given in Fig. 11.

ADJUSTMENT

Choose a transformer tap that will provide approximately two times the phase-to-ground current setting of the FD-2 fault detector as previously determined.

OPERATION

A multi-contact switch is provided at each line terminal which serves the dual functions of a carrier on-off switch and a test switch. This switch is arranged to apply a single-phase current to the SKB or SKB-1 relay to simulate internal and through fault conditions. Relay operation is noted by observing a blue indicating lamp connected in the SKB relay trip circuit. During the test the SKB trip circuit to the line breaker is opened and a red warning light is energized through auxiliary contacts on the test switch.

Use of the auxiliary test equipment is to be limited to provide a simplified test after the initial installation tests have been performed as described in Part II of this instruction leaflet.

The test apparatus is to be connected as shown in Fig. 10 with the auxiliary test transformers energized from 120-volt, 60-cycle power sources, at each line terminal, that are in phase with each other. The following operation procedure assumes that the same polarity is used in connecting the test transformer at each line terminal.

1. Turn the carrier test switch at both line terminals to OFF.
2. Turn the carrier test switch to TEST 1 at station A. The "A" relay should operate to transmit half cycle impulses of carrier, and trip. Tripping will be indicated by the blue light.
3. Turn the SKB test switch at Station B to TEST 1. This will simulate an internal fault fed from both line terminals. The relay at Station B will trip, and the relay at Station A will remain tripped. Tripping will be indicated by the blue lights at each line terminal Carrier will be transmitted in half cycle impulses simultaneously from each end of the line.
4. Reset the SKB test switch at Station A. The relay at Station A will reset and turn off the blue light. The relay at Station B will hold its trip contact closed, lighting the blue light.
5. Turn the SKB test switch at Station A to TEST 2. Depress Test Reset pushbutton momentarily to reset Flip-Flop stage that may have operated during switching the test switch to position 2. Operate Test Reset pushbutton at Station B to reset Flip-Flop stage from previous tripped position. Both blue lights should be off at this point, which represents an external fault.
6. Reset the test switches at both line terminals to OFF before returning to ON for normal service. Push in handle to turn in ON position.

This completes the test procedure.

Component Style Numbers

Test Transformer	S# 1338284
Type W-2 Test Switch	S# 505A742G01 for 1/8" panel mounting.
Type W-2 Test Switch	S# 505A742G02 for 1-½" panel mounting.

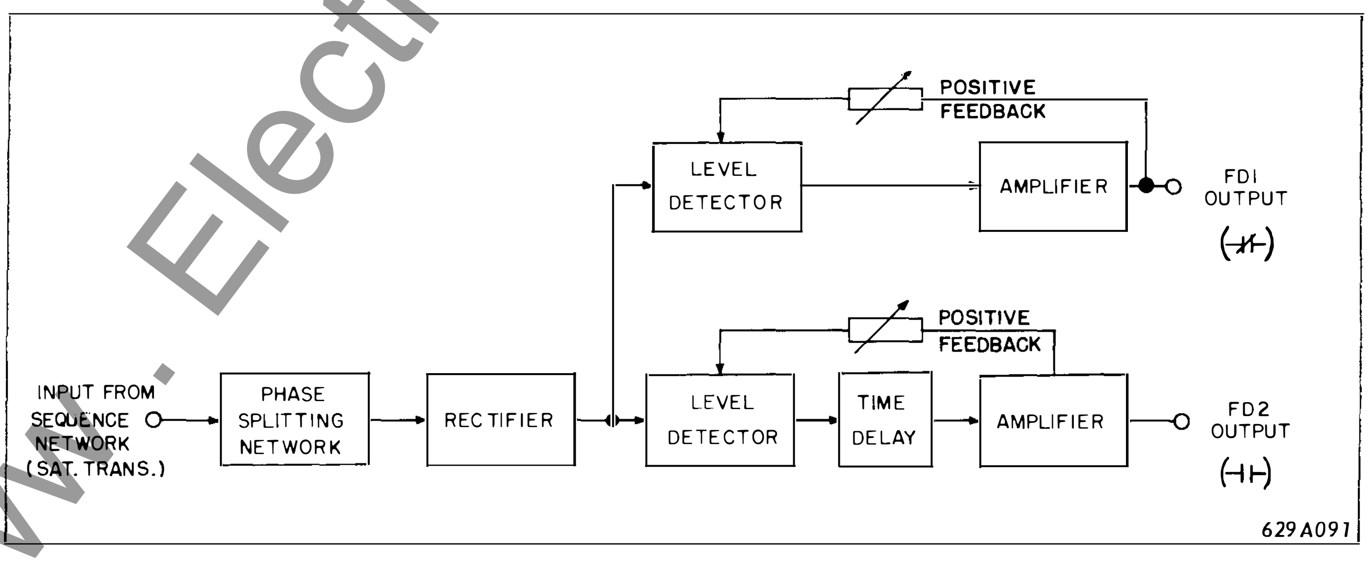
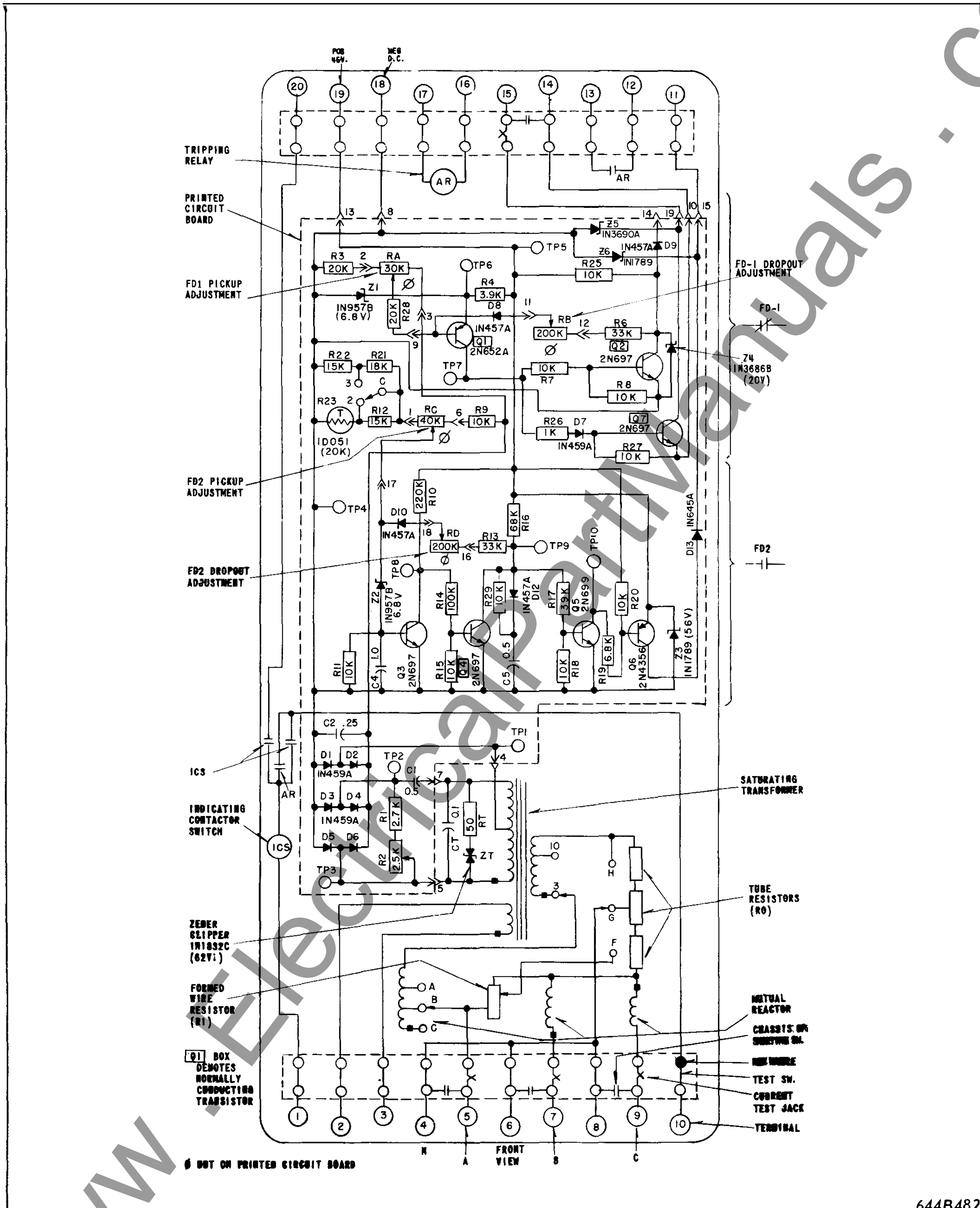


Fig. 3 Static Fault Detector Block Diagram



∗ *Fig. 4 Complete Internal Schematic of SKB Relay*

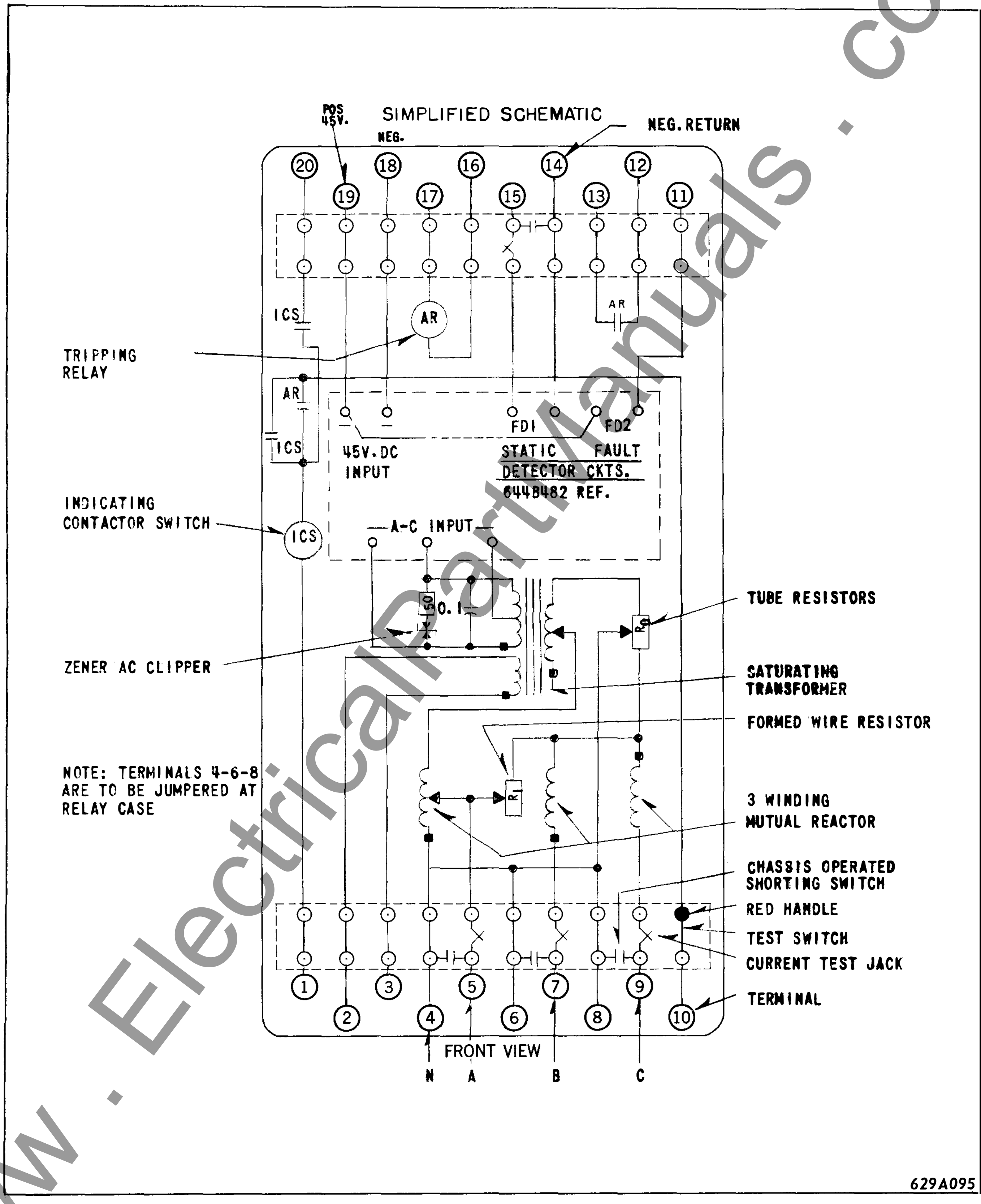
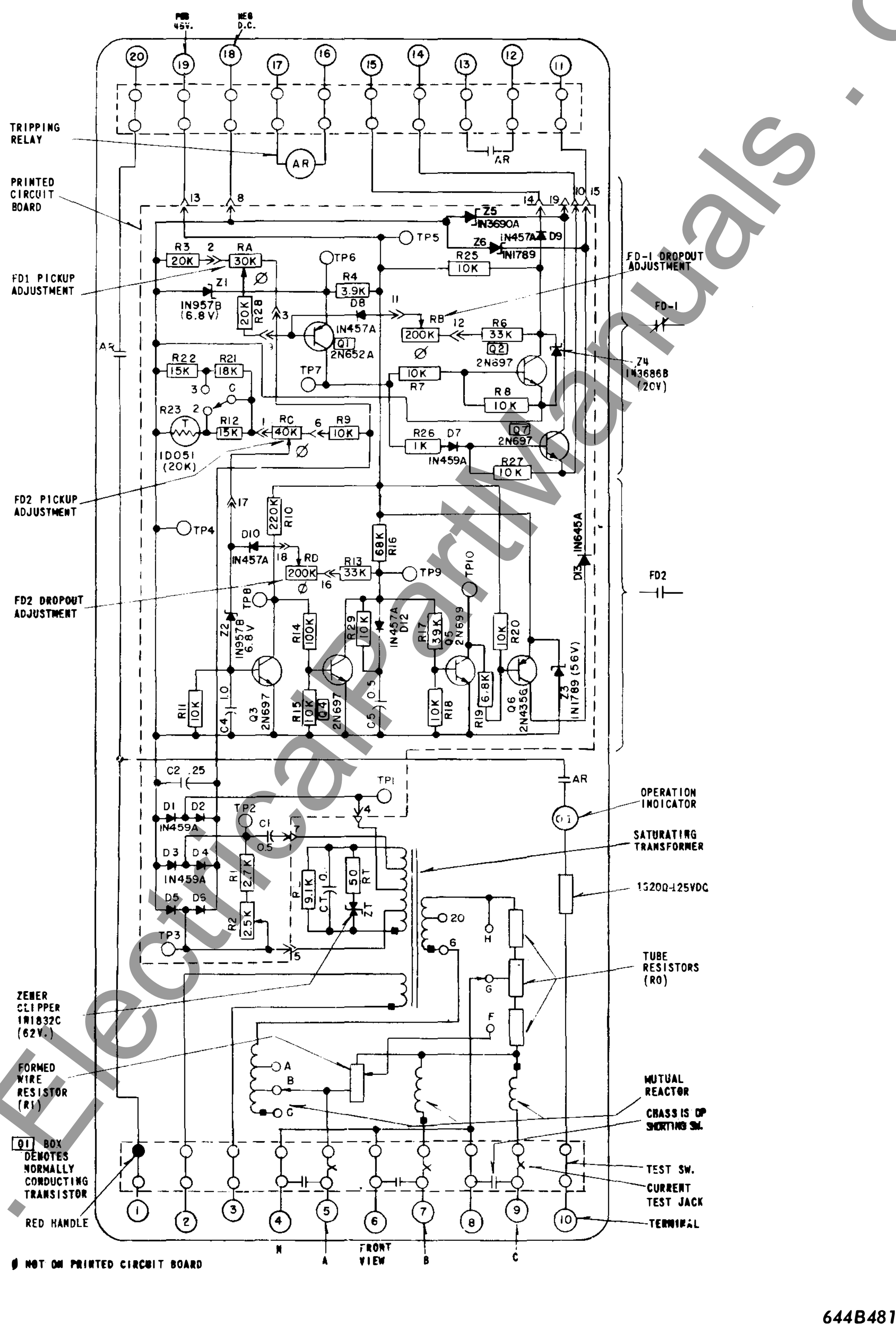
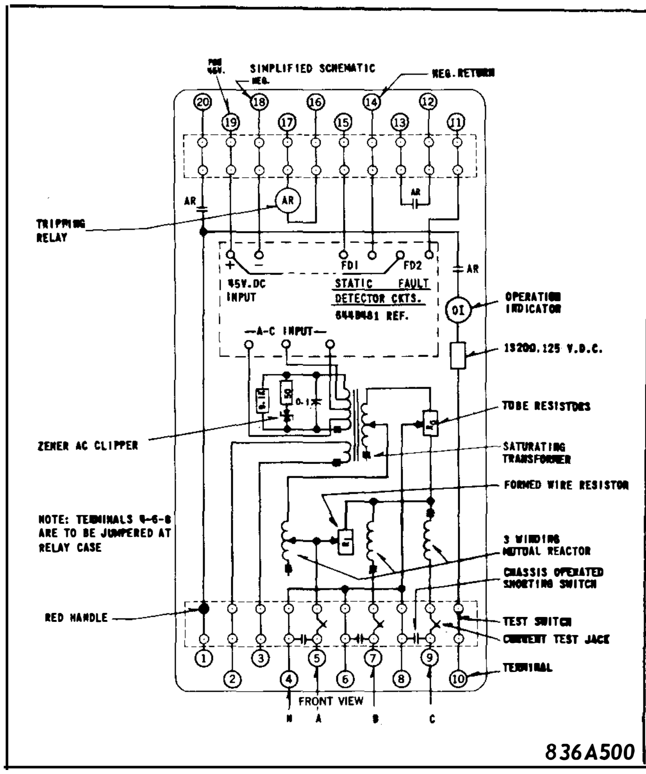


Fig. 5 Simplified Schematic — Type SKB Relay



✱ Fig. 6 Complete Internal Schematic of SKB-1 Relay



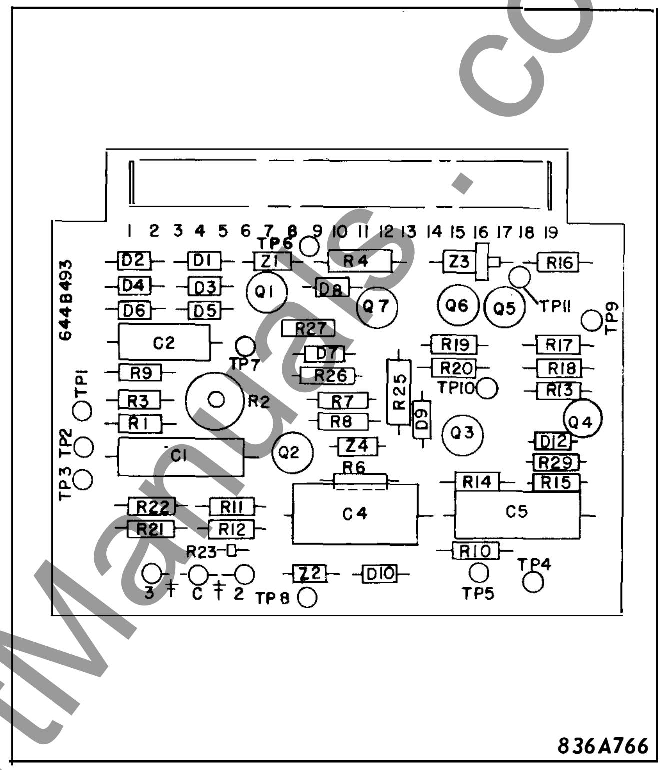


Fig. 7 Simplified Schematic – Type SKB-1 Relay

** Fig. 8 Printed Circuit Board Component Location, SKB or SKB-1 Relay*

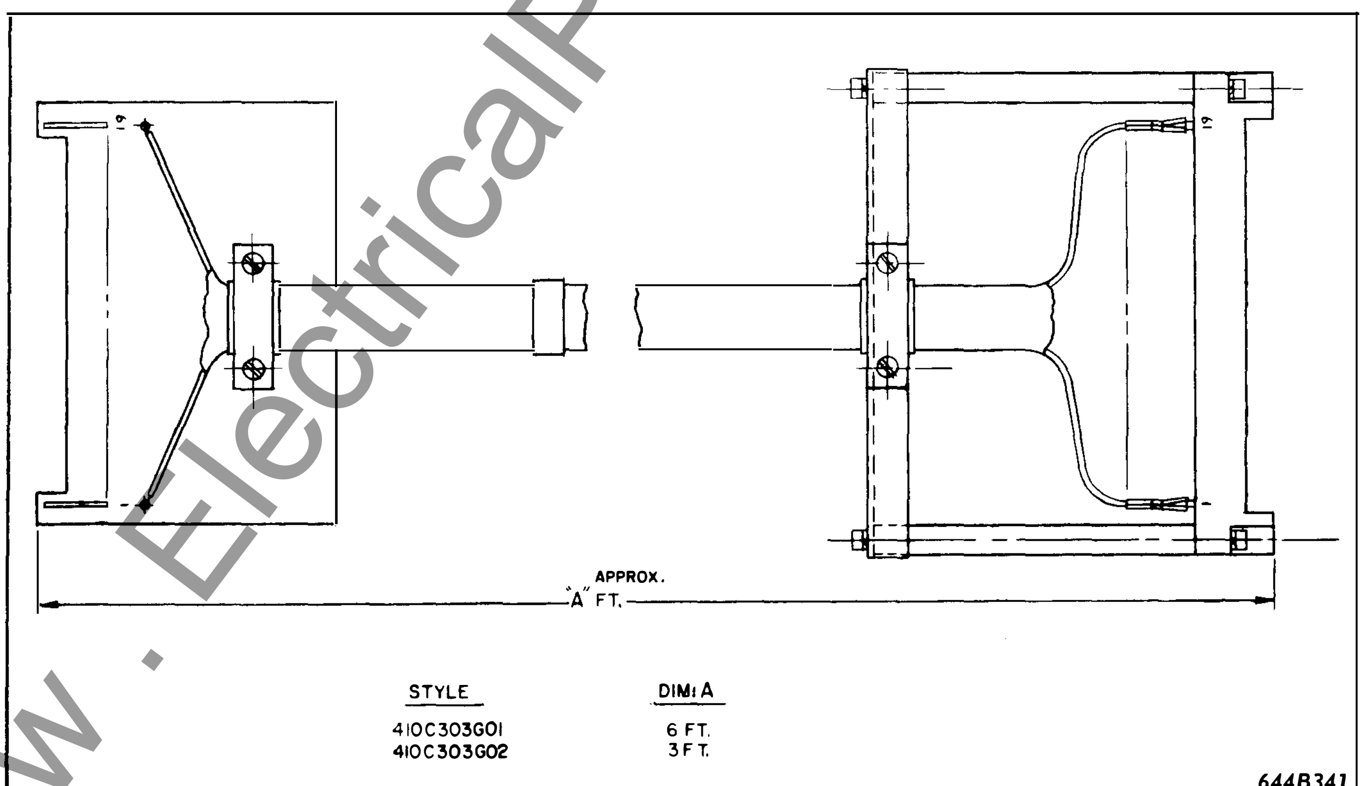
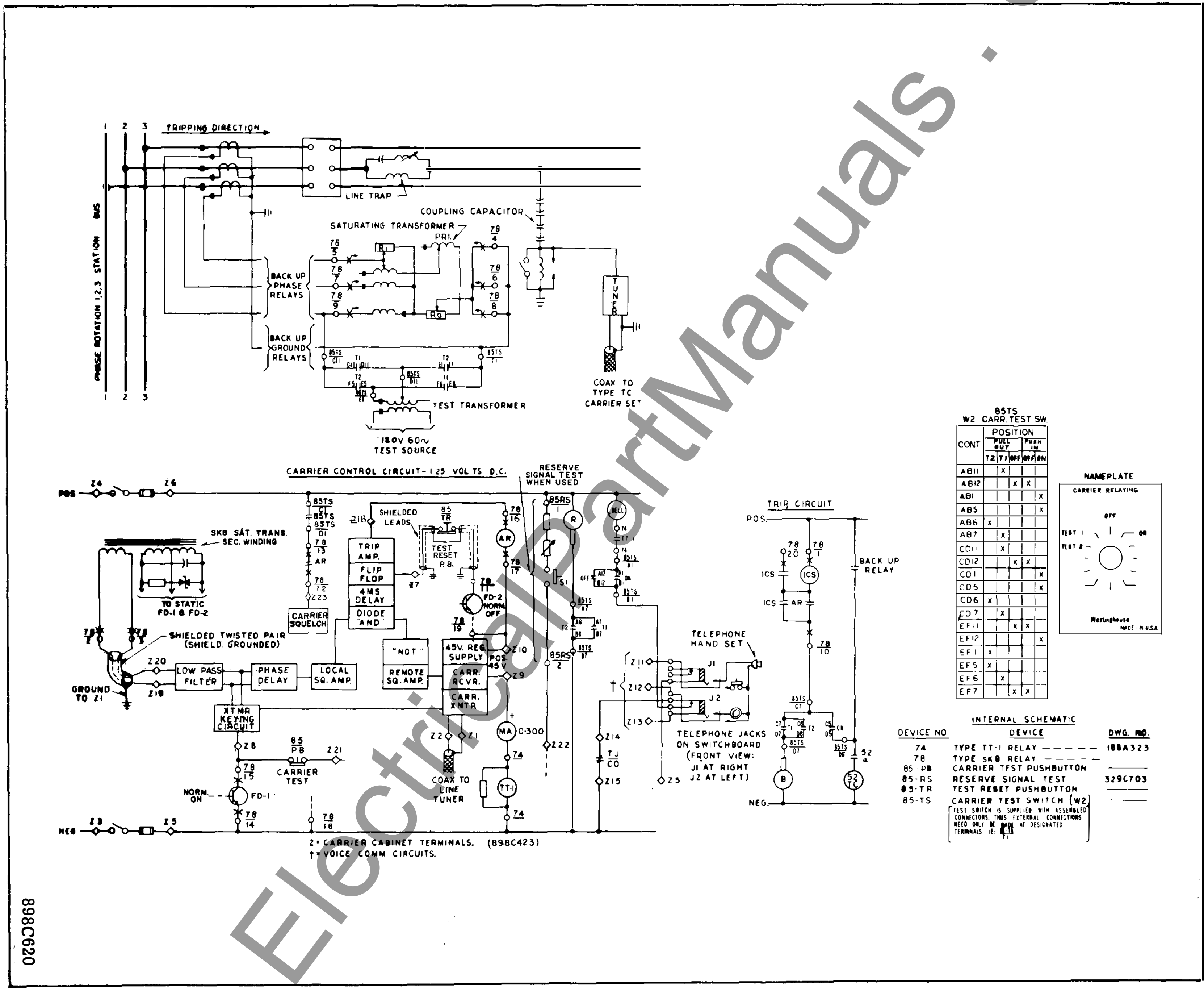


Fig. 9 Test Cable Assembly



85TS W2 CARR. TEST SW.

CONT	POSITION PULL OUT T2	T1	OFF	PUSH IN OFF	ON
AB11		x			
AB12			x	x	
AB1					x
AB5					x
AB6	x				
AB7		x			
CD11		x			
CD12			x	x	
CD1					x
CD5					x
CD6	x				
CD7		x			
EF11			x	x	
EF12					x
EF1	x				
EF5	x				
EF6		x			
EF7			x	x	

INTERNAL SCHEMATIC

DEVICE NO	DEVICE	DWG. NO.
74	TYPE TT-1 RELAY	188A323
78	TYPE SKB RELAY	
85-PB	CARRIER TEST PUSHBUTTON	
85-RS	RESERVE SIGNAL TEST	329C703
85-TR	TEST RESET PUSHBUTTON	
85-TS	CARRIER TEST SWITCH (W2)	

TEST SWITCH IS SUPPLIED WITH ASSEMBLED CONNECTORS. THUS EXTERNAL CONNECTIONS NEED ONLY BE MADE AT DESIGNATED TERMINALS IE: T1

* *Fig. 10 External Schematic of the SKB Relay and Test Facilities, with TT-1 Alarm Relay*

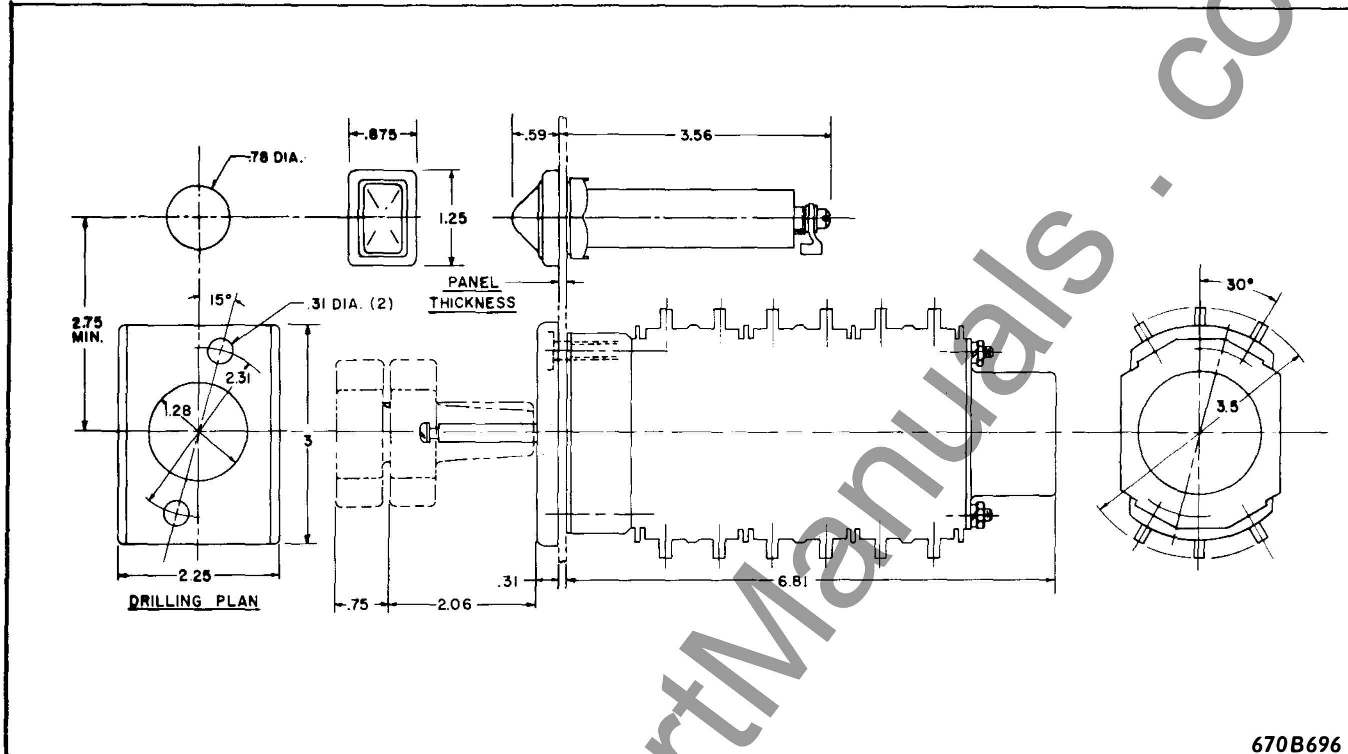


Fig. 11 Outline and Drilling Plan of the Type W-2 Test Switch and Indicating Lamps Used for SKB or SKB-1 Testing

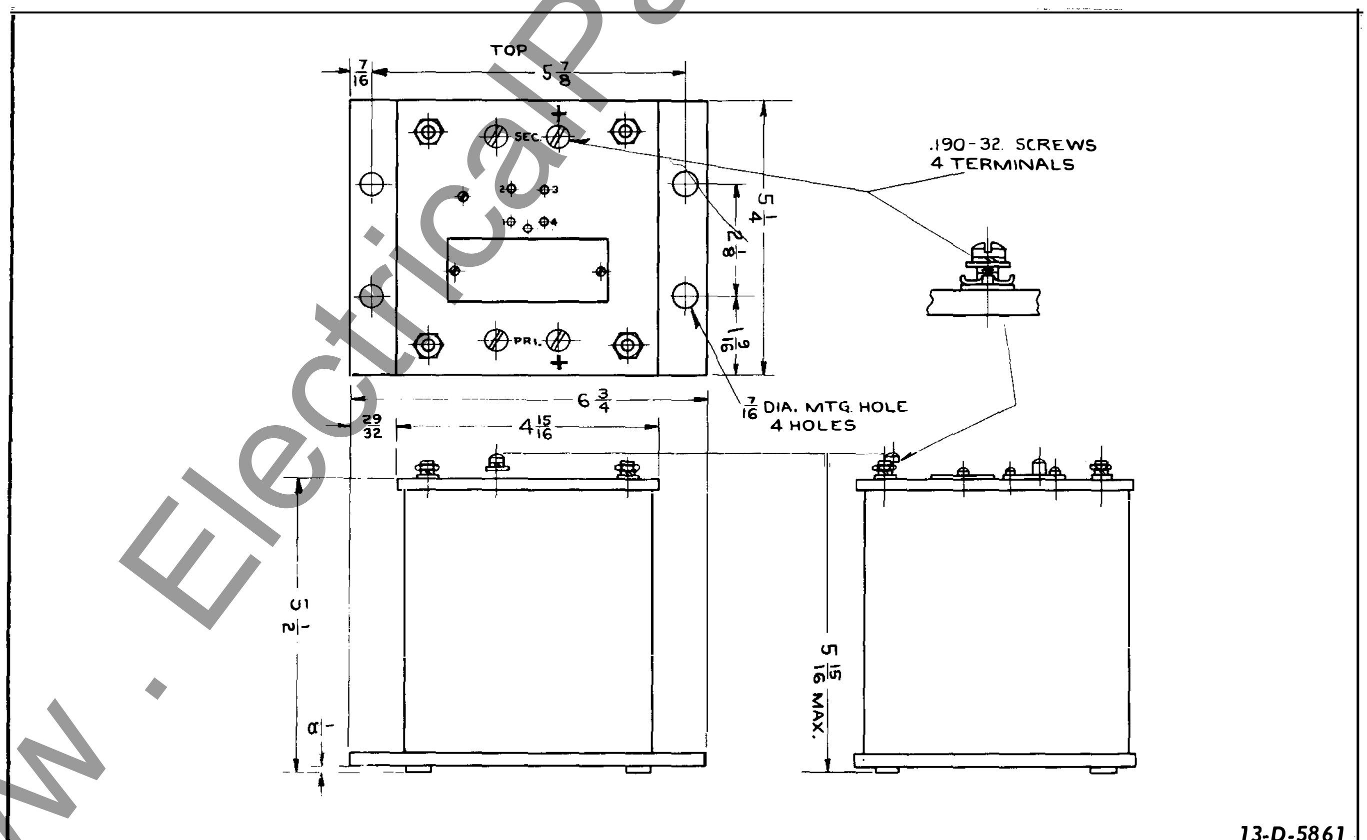


Fig. 12 Outline and Drilling Plan of the SKB Test Transformer

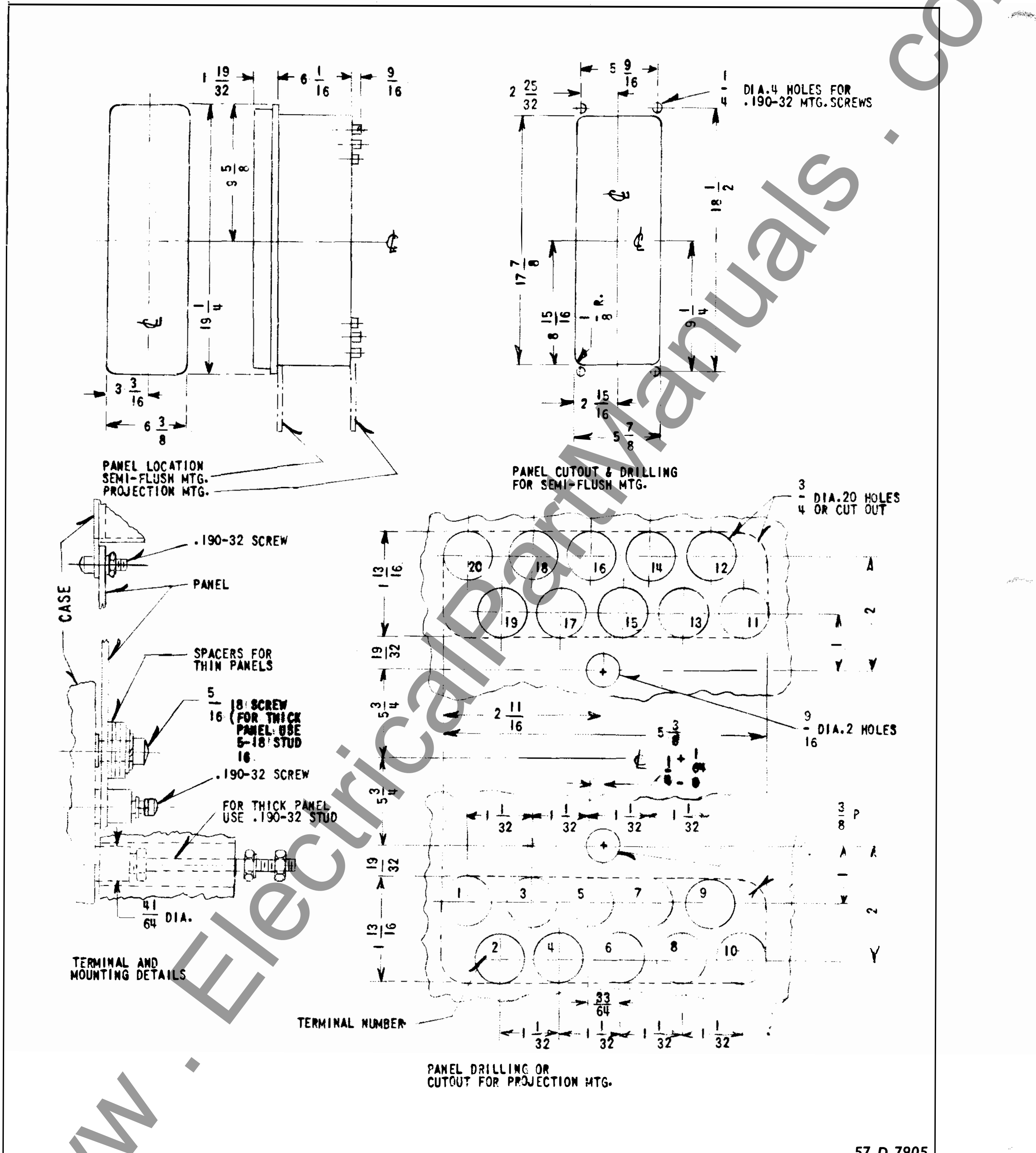


Fig. 13 Outline and Drilling Plan of the SKB or SKB-1 Relay in the FT-42 Case

WESTINGHOUSE ELECTRIC CORPORATION

RELAY-INSTRUMENT DIVISION **NEWARK, N. J.**

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