INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE SKBU PHASE COMPARISON RELAY FOR TYPE TC CARRIER CHANNEL

CAUTION: It is recommended that the user of this equipment become acquainted with the information in this instruction leaflet before energizing the carrier system. If the SKBU relay is mounted in a cabinet, the cabinet must be bolted down to the floor or otherwise secured before swinging out the equipment rack to prevent its tipping over.

APPLICATION

The type SKBU relay is a high speed carrier relay used in conjunction with a type TC power line carrier set to provide complete phase and ground fault protection of a two terminal or three terminal transmission line. Simultaneous tripping of the relays at each line terminal is obtained in less than twenty-five milliseconds 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 swing or out-of-step conditions. The carrier equipment operates directly from the station battery.

CONSTRUCTION

The type SKBU relay consists of a combination positive, negative and zero sequence current network, a saturating transformer, a 20-volt power supply, and printed circuit boards mounted on a standard 19-inch wide panel, 8-3/4 inches high (5 rack units). Edge slots are provided for mounting the rack on a standard relay rack. The location of these components is shown in Figures 1 and 2. The components are connected as shown in the internal schematics of Figures 3 and 4.

Sequence Network

The sequence filter consists of a three-legged iron core reactor and a set of resistors, R1 and RO. The reactor has three windings: two primary and a tapped secondary winding, wound on the center leg of a "F" type of lamination. The secondary taps are wired to the A, B, and C tap connections in the front of the relay (R1 taps). RO consists of three tube resistors with taps wired to F, G, and H tap connections in the front of the relay. The R1 resistor is a formed resistor associated with the tapped secondary of the reactor.

NEW INFORMATION

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Saturating Transformers

The voltage from the network is fed into the tapped primary of a small saturating transformer. This transformer and a Zener clipper (on a printed circuit board) connected across its secondary are used to limit the voltage impressed on the solid state circuits, 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.

Printed Circuit Boards

The number of boards varies with the application of the SKBU relay but in general consists of four printed circuit boards mounted in the order given (left to right-front view); a fault detector board, an amplifier and keying board, an output board, and a trip board. All of the circuitry that is suitable for mounting on printed circuit boards is contained in an enclosure that projects from the rear of the front panel and is accessible by opening a hinged door on the front of the panel. The printed circuit boards slide into position in slotted guides at the top and bottom of each compartment and the board terminals engage a terminal block at the rear of the compartment. Each board and terminal block is keyed so that if a board is placed in the wrong compartment it cannot be inserted into the terminal block. A handle on the front of each board is labeled to identify its function in the relay.

(1) Fault Detector Board

The fault detector board contains a resistor-Zener diode combination, a phase splitting network, and two solid state fault detectors (FD-1 and FD-2). The controls for setting pickup (S1 for FD-2, S3 for FD-1) and dropout (S2 for FD-2, S4 for FD-1) of the fault detectors are mounted on the plate in the front of the assembly.

(2) Amplifier and Keying Board

The amplifier and keying board contain a local squaring amplifier, a remote squaring amplifier, an "AND" circuit, and a transmitter keying circuit. A carrier squelch circuit is also located on the board.

(3) Output Board

The output board contains a 4 millisecond pickup and instantaneous dropout, timer circuit, flip-flop circuit, trip amplifier, transient blocking and unblocking circuit.

(4) Trip Board

The trip board contains the phase delay circuit for shifting the local signal with reference to the remote signal. This board also contains the final tripping output of the SKBU.

(5) Card Extender

A card extender (Style No. 644B315G02) is available for facilitating circuit voltage measurements or major adjustments. After withdrawing any one of the circuit boards, the extender is inserted in that compartment. The board then is inserted into the terminal block on the front of the extender. This restores all circuit connections, and all components and test points on the boards are readily accessible.

Test Points
Test points are located on each printed circuit board for the major components on the board. Complete circuit test points are wired to the front panel of the relay for convenience in adjusting and testing the relay.

OPERATION

A. System
The SKBU carrier relaying system compares the phase position of the currents at the ends of a line section over a carrier channel to determine whether an internal or external fault exists on the line section. The three-phase line currents energize a sequence network which produces a single-phase output voltage proportional to a combination of sequence components of the line current. During a fault, this single-phase voltage energizes the keying circuit to allow 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. 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 a internal fault to allow tripping during the half cycle 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 coordination, 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.

B. Relay
With reference to either Figs. 3 or 4, 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. This single phase output voltage is applied as inputs to two boards from the secondary of the saturating transformer.

1) Fault Detector Board (Phase Splitter Circuit)
2) Relay Board (Phase Delay Circuit)

1) Fault Detector

The a-c voltage is applied to a phase splitting network (C52, R54, R53) and a polyphase rectifier (diodes D51 to D56). The d-c voltage so obtained requires a minimum of filtering (C53) and responds rapidly to a change in magnitude of the a-c output. This d-c voltage is applied to two fault detector circuits which operate when the d-c input "signal" exceeds a predetermined value.

a. Fault Detector 1 (FD-1)

Under normal line conditions (no fault), current flows from positive 45 volts d-c through resistor R72 and Zener diode Z54 to negative, holding Q55 emitter at 6.8 volts positive. In transistor Q55, current flows from emitter to base, then through S3 and R71 to negative, thus turning on Q55. The collector current of Q55 provides base drive to transistors Q56 and Q57, turning them on also. The voltage drops across Q56 and Q57 are very low (about 0.5 volts), thus providing the equivalent of a closed contact. When a fault occurs, the d-c voltage from the polyphase rectifier is applied to S3 and R71. When this voltage exceeds the 6.8 volt drop across Zener diode Z54, transistor Q55 stops conducting. This removes the base current from Q56 and Q57, causing them to stop conducting, and providing the equivalent of an open circuit. With reference to Figure 7, this open circuit removes negative potential at point A and allows the potential at point C to become 20 volts. This increase in voltage at point C starts transmission of carrier.

When Q56 is cut off, its collector potential rises to about 20 volts. This also further raises the potential of Q55 base through feedback resistors R75 and S4, thus holding Q55 in a non-conducting state. When the input voltage (from the polyphase rectifier) is reduced, FD1 "resets" to allow transistors Q55, Q56 and Q57 to conduct. Resistor S3 is for setting the FD1 pickup current (calibration adjustment), and the setting of S4 determines the 80 percent dropout value.

b. Fault Detector 2 (FD-2)

Under normal conditions, transistor Q51 has no base "signal" and is turned off. The collector of Q51 is at a high enough positive potential to provide base drive for transistor Q52, driving it to full conduction. With Q52 fully conducting there is no base drive to transistor Q53. With no Q53 collector current, the base of PNP-type transistor Q54 is supplied from the 45 volt source through the drop of D58. Thus, the Q54 emitter is normally at a slightly lower potential than its base. This condition keeps transistor Q54 in a non-conducting state, equivalent to an open circuit. Zener diode Z3 is to protect transistor Q54 from external surge voltages.

When a fault causes the d-c input voltage from the polyphase rectifier to exceed the 6.8 volt rating of Zener diode Z52, (through R55, and S1) a positive bias is applied to Q51 base causing it to conduct. In turn, Q52 stops conducting, and capacitor C55 charges up, giving a few milliseconds time delay before Q53 and Q54 are switched to full conduction, thus "closing" FD2. The feedback resistors R60 and S2 provide a 90 percent FD2 dropout ratio with "toggle" action at the dropout point.

When FD-2 operates, positive 45 volts d-c is applied to the output board at terminal 18. This 45 volts is applied to the flip-flop circuit at terminal 19 and to the transient blocking circuit through Zener diode Z302. Thus, FD2 will "arm" the flip-flop and energize transient blocking of the SKBU relay.

2. Relay Board

The a-c voltage from the saturating transformer is also applied to the phase delay circuit through a low-pass filter of the relay board. The low-pass filter (C251, L251, C252) removes the harmonics from this voltage and applies a voltage that is essentially sinusoidal in waveform to R251 and R252 of the phase delay circuit. By menas of capacitor C253 and variable resistor S5, the voltage across terminals 4 and 9 can be made to lag the voltage across terminal 10 and 11 by a definite amount depending on the setting of S5. These two voltages are applied to the amplifier and keying board of the SKBU relay.

a) Undelayed Voltage to the Keying Circuit
b) Delayed Voltage to the Local Squaring Amplifier

a. Keying Circuit

Under normal conditons transistor Q102 is turned off. The collector of Q102 is at negative potential which allows base current to flow from positive 20 volts d-c through the base of transistor Q103, through R104 and R102 to negative. Transistor Q103 conducts and positive 20 volts is applied to the collector of Q103 to prevent base current from flowing in Q104. Since Q104 is not conducting, transistor Q105 does not conduct and the collector of Q105 is held at positive potential.

When a fault occurs, sinusoidal voltage is applied to transistor Q102 from terminals 4 and 10 of the relay board. On the positive half cycle, terminal 12 is more positive than terminal 4 of the amplifier and keying board, and Q102 does not conduct. However, on the negative half cycle of sine wave voltage, terminal 12 is more negative than terminal 4 and base current flows in Q102. This turns Q102 on and applies positive 20 volts to R102. This turns Q103 off which in turn puts negative potential on R106. Q104 then conducts to allow base current to flow into Q105. When Q105 conducts, its collector is connected to negative potential. Thus, the collector of Q105 is connected to negative on alternate half cycles of the 60-cycle voltage from the low pass filter. If FD-1 is not conducting, as seen from Fig. 7, turning Q105 on and off every half cycle, shorts the input to the TC carrier set every other half cycle so that carrier is transmitted on the half cycle when Q105 is not conducting.

b. Local Squaring Amplifier

The shifted voltage from the phase delay circuit is applied to the local squaring amplifier of the SKBU relay. Under non-fault conditions, Q108 is not conducting and R115 is at negative potential. As a result, the base of Q109 and Q111 is at a lower potential than the emitter of the transistors. Base current for both transistors flows from positive 20 volts through R116 and R115 to negative and both transistors conduct. With Q111 turned on, positive 20 volts is applied to R119 which is applied to R129 and R130 through D111 and D109 respectively. This voltage is the input to the AND circuit from the local signal and is the quantity to be compared with the signal from the remote terminal to determine if a fault is internal or external.

Under fault conditions, a sine wave of voltage is applied from emitter to base of transistor Q108. On the positive half cycle the base of transistor Q108 is more positive than the emitter and Q108 does not conduct. On the negative half cycle of sine wave voltage, the base is more negative than the emitter and Q108 conducts. Turning Q108 on applies positive 20 volts to R115 to cause Q109 to turn off. This causes Q111 to turn off such that negative potential is applied to R119. Hence, on alternate half cycles of sine wave voltage, negative voltage appears across R119 to apply negative voltage to R129 and R130 through D111 and D109 respectively. The voltage across the resistor is thus a square wave voltage varying from 20 volts d-c to 0 volt d-c dependent upon the polarity of the voltage from the phase delay circuit.

3. Remote Squaring Amplifier

Under non-fault conditions, carrier is not transmitted from the remote carrier set. As a result the base of Q113 is more negative than its emitter, and Q113 conducts. This applies positive 20 volts to the base of Q112 to prevent it from turning on. Hence, Q112 is not conducting and negative voltage appears across R123. This voltage is applied to R129 and R130 through D112 and D110 respectively, and allows the voltage across these resistors to remain at negative potential.

Under fault conditions, the remote TC carrier set is keyed on and off as described under the Keying Circuit. This signal is received at the local TC carrier receiver and is converted to a square wave voltage varying in magnitude from 45 volts to 0 volt. This voltage is applied to the base of Q113 through D108 and R128. Upon application of positive 45 volts d-c to the base of Q113, the potential of the base is greater than that of the emitter and Q113 stops conducting. This removes positive potential from R124 and allows the base of Q112 to become negative with respect to the emitter. Q112 turns on to apply positive voltage to R123. Hence, the voltage across R123 is a square wave voltage that is developed by the voltage received from the TC receiver. This voltage is applied to R129 and R130 through D112 and D110.

4. 4/0 Milliseconds Time Delay
The 4/0 time delay consists of R315, C305, R316, R317, R318, and R319. Under non-fault conditions, a continuous positive 20 volts is received from the local squaring amplifier at terminal 6 of the output board. This prevents capacitor C305 from charging and keeps the base of Q305 of the flip-flop at positive potential.

Under external fault conditions, the square wave voltage from the remote squaring amplifier and the square wave voltages from the local squaring amplifier are out of phase, such that a continuous 20 volts is received at terminal 6 of the Output board. C305 does not charge, and transistor Q305 cannot turn on.

Under internal fault conditions, the square wave voltages from the squaring amplifiers are in phase. Hence, for one-half cycle, negative voltage appears at terminal 6 of the Output board. This allows C305 to charge through resistors R315 and R129 to negative. After a calibrated time delay of 4 milliseconds, the voltage across C305, which is applied to the base-emitter circuit of transistor Q305 in the flip-flop circuit is sufficient to allow Q305 to conduct.

5. Flip-Flop
The flip-flop circuit consists of transistors Q305 and Q306 and associated components. Under normal conditions, transistor Q305 is in a non-conducting state, and transistor Q306 is fully conducting. The base of transistor Q306 is held well below its emitter potential by means of the voltage divider consisting of resistors R325, R326, D305, and R327. With this bias, transistor Q306 is held in saturation and the flip-flop is desensitized so that even if transistor Q305 turns on, transistor Q306 does not turn off. This desensitizing circuit is an arrangement to prevent inadvertent operation of the flip-flop in the presence of sur es on the d-c system. As long as Q306 is conducting, its collector is at a high enough positive potential such that transistor Q307 in the tripping amplifier cannot turn on.

Upon the occurrence of an internal fault, positive 45 volts d-c is applied from Q54 (FD-2) to terminal 18 of the Output board. This removes the desensitizing bias from transistor Q306 by making the potential of the junction of resistor R327 and diode D305 greater than the 20 volt supply for the flip-flop circuit. When this occurs, there is no current flow through resistor R326 and diode D305, and the flip-flop is now "armed" or in a ready condition for a tripping operation. Since the pulses from the "AND" circuit are in phase, after a 4 millisecond delay, the potential across capacitor C305 is sufficient to cause Q305 to conduct. This immediately causes operation of the flip-flop, turning off transistor Q306. When Q306 is no longer conducting, the potential of the junction of R329 and R328 drops to a relatively low value. When this occurs, there is sufficient voltage across the base-emitter circuit of transistor Q307 in the trip amplifier to cause it to turn on.

6. Trip Amplifier

When transistor Q307 is turned on by operation of the flip-flop, base current flows from positive 20 volts through Z305, the emitter-base junction of Q307, and the resistors R328 and R329 to negative. The collector current of transistor Q307 flows through R330 and the base-emitter junction of output transistor Q308. The collector of Q308 is connected to positive 45 volts d-c through R253 and the AR coil of the relay board. Collector current thus flows from positive 45 volts d-c through the AR coil, R253 to transistor Q308, hence, the AR operates to trip the breaker. In case of a voltage output from the SKBU relay, transistor Q252 turns on to provide 20 volts output to the next device.

7. Carrier Squelch

When the SKBU relay operates as a result of an internal fault, positive potential is applied to the squelch circuit of the amplifier and keying board. Ten milliseconds after positive potential is applied, capacitor C101 charges sufficiently to allow base current to flow to transistor Q106. Transistor Q106 turns on to short the carrier start lead to negative (ref. Fig. 7). Carrier is then turned off and will remain off for approximately 150 milliseconds after the SKBU resets to prevent delayed tripping of the remote breaker due to a short burst of carrier at the instant of the local breaker opening.

8. Transient Blocking

When Q54 (FD-2) turns on, positive 45 volts is applied to terminal 18 of the output board, and energizes the transient blocking circuit. Base current is supplied to transistor Q302 through resistor, R305, and Zener diode, Z302. Transistor, Q302, turns on to connect the base of transistor, Q303, to negative. Q303 stops conducting and capacitor C303 starts to charge. When the charge on capacitor C303 is sufficient to cause the breakdown of Zener diode Zener diode Z303, it turns on transistor Q304. This provides a conducting path from the base circuit of transistor Q306 in the flip-flop, diode D304, the resistor R324, and the collector emitter circuit of transistor Q304 to negative. This occurs after a time delay of 20 to 30 milliseconds and provides a path to apply a "desensitizing" bias to transistor Q306 in the flip-flop. Thus, the transient blocking circuit allows 20 to 30 milliseconds after the operation of FD-2 for the flip-flop to operate and energize the output of the relay. If tripping does not occur in this time, as during an external fault, the operation of the transient blocking circuit desensitizes the flip-flop to prevent undesirable operation during transients associated with power reversals on the protective line or at the clearing of an external fault.

The transient blocking circuit is cancelled either by FD-2 resetting or by the operation of the transient unblocking circuit.

9. Transient Unblocking

If an internal fault occurs before an external fault is cleared, high speed tripping is obtained. The square wave output from the local and remote squaring amplifier changes from an out-of-phase condition to an in-phase condition. As a result, negative potential is applied to the transient unblocking circuit at terminal 9 of the Output board. Zener diode Z301 breaks down and base current flows through Z301, emitter-base of Q301, resistor R303, Diode D302, and D301, resistor R130, and through the conducting transistor, Q304, to negative. Transistor Q301 turns on to apply positive potential to resistor, R309. Base current then flows through resistor R309, to turn on transistor Q303. Capacitor, C303, will be rapidly discharged to remove the potential from the base of transistor, Q304. Transistor Q304 turns off to interrupt the desensitizing circuit from the base of transistor Q306. When this happens, the flop-flop will then be able to operate to provide an input to the trip amplifier.

CHARACTERISTICS

The sequence network in the relay 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 T taps on the left-hand tap place indicate the balanced three phase amperes which will operate the carrier-start fault detector (FD-1). The taps available are 3, 4, 5, 6, 7, 8, and 10 and are on the primary of the saturating transformer. The second fault-detector unit (FD-2), which supervises operation of tripping, is adjusted to pick up at a current 25 percent above tap value.

For phase-to-phase faults AB and CA, enough negative sequence current has been introduced to allow the fault detector FD-1 to pick up at 86 percent of the tap setting. For BC faults, the fault detector will pick up at approximately 50 percent of the tap setting. This difference in pickup current for different phase-to-phase faults if 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 pickup under a minimum fault current, yet not operate under load. For these cases, a tap is available on the SKBU relay which cuts the three-phase sensitivity in half, while the phase-to-phase setting is substantially unchanged. The relay then trips at 90 percent 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 SKBU relay on negative-plus-zero sequence current. A tap is available to operate in this manner. The fault detector picks up at tap value for all phase-to-phase faults, but is unaffected by balanced load current or three-phase faults.

For ground faults, separate taps (Ro) are available for adjustment of the ground fault sensitivity to about 1/4 or 1/8 of the left-hand tap plate setting. See Table II. For example, if the SKBU relay is set at T, tap 4, the fault detector (FD-1) pickup current for ground faults can be either 1 or 1/2 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.

Operating Time	12 to 20 milliseconds
Transient Blocking Time	20 to 30 milliseconds
Transient Unblocking Time	20 to 30 milliseconds
Squelch Time	150 milliseconds
Ambient Temperature Range	-20°C to 55°C
Output Voltage (where used)	20 milliamperes at 20 volts d-c
Drain on 45 volt Power Supply of TC Set:	
Non-Trip Condition	60 MA
Trip Condition (with AR output)	100 MA
Trip Condition (with voltage output)	80 MA
Dimensions:	
Panel Height	8-3/4 inches or 5 rack unit
Panel Width	19 inches

ENERGY REQUIREMENTS

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

Relay Taps	Phase A VA	Phase A Angle	Phase B VA	Phase B Angle	Phase C VA	Phase C Angle
A-F-3	2.4	5°	0.6	0°	2.5	50°
A-H-10	3.25	0°	0.8	100°	1.28	55°
B-F-3	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 VA	Phase A Angle	Phase B VA	Phase B Angle	Phase C VA	Phase C 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.

SETTINGS

The SKBU 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 applications. 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 both terminals of a line section must be set to pickup at the same value of line current. This is necessary for correct blocking during faults external to the protected line section.

Sequence Combination Taps

The two halves of the right-hand tap plate are for connecting the sequence network to provide any of the combinations described in the previous section. The upper half of the tap plate or R1 taps 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 Right Hand Tap Block		Fault Detector FD-1 Pickup	
		R1	Ro	3Ø Fault	Ø-Ø Fault ~~0~~
1	Pos., Neg., Zero	C	G or H#	Tap Value	86% Tap Value (53% on BC Fault)
2	Pos., Neg., Zero	B /	G or H	2 x Tap Value	90% Tap Value (65% on BC Fault)
3	Neg., Zero	A /	G or H	--------	100% Tap Value

- Taps F, G, and H are zero-sequence taps for adjusting ground fault sensitivity.

See section on zero-sequence current tap.

~~O~~ - Fault detector FD-2 is set to pickup at 125% of FD-1 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 FD-1 and FD-2 will be 10 to 15 percent higher than the indicated values because of the variation in self-impedance of the sequence network and the saturating transformer.

Positive-Sequence Current Tap and FD-2 Tap

The left-hand tap plate, T, has taps of 3, 4, 5, 6, 7, 8, and 10 which represent the three-phase, fault detector FD-1 pickup currents, when the relay is connected for positive, negative and zero sequence output. The fault detector FD-2 closes its contact to allow tripping at current value 25 percent above the fault detector FD-1 setting. This 25 percent difference is necessary to insure that the carrier-start fault detectors (FD-1) at both ends of a 2-terminal transmission line section pickup to start carrier on an external fault before operating energy is applied through FD-2.

For a 3-terminal line, there is a provision on the printed circuit board for changing the temperature compensation when calibrating FD-2 to pickup at 250% of FD-1 setting. This is necessary to allow proper blocking on 3-terminal lines when approximately equal currents are fed in two terminals, and their sum flows out the third terminal of the line. The relay is shipped connected for 2-terminal line service. For a 3-terminal line, the jumper on the FD board must be changed to c-3, and FD-2 must be recalibrated for 250% of FD-1.

The T, Ro, and R1 taps 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 dropout current of the FD-1 fault detector is 80 percent of the pickup 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 pickup should be sufficient to allow the fault detector to dropout af er an external fault, when load current continues to flow.

Zero-Sequence Current Tap - Ro Taps

The lower half of the right-hand tap plate (Ro taps) 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.

TABLE II

Comb.	R1 Tap	Ground Fault Pickup Percent of T Tap Setting	
		Tap G	Tap H
1	C	25%	12%
2	B	20%	10%
3	A	20%	10%

Examples of SKBU 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:

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

Minimum Phase-to-Phase Fault Currents:

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

Fault detector FD-1 setting (three phase) must be at least:

$\frac{3.75}{0.80} = 4.7$ amperes (0.80 is dropout ratio of FD-1 fault so that the fault detector will reset on load current) (3)

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault detector FD-1 setting (three-Phase) must be not more than:

$$7.5 \times \frac{1}{0.866} \times \frac{1}{1.25} = 6.98 \text{ amperes}$$

$$1.25 = \frac{\text{FD-2 Pickup}}{\text{FD-1 Pickup}} \quad (4)$$

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 would be used (see Table I, 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 T, tap 6 and R1, tap C in use, the fault detector FD-1 pickup currents for ground faults are as follows:

Tap G $\quad 1/4 \times 6 = 1.5$ ampere
Minimum Trip = 1.25×1.5 ampere

Tap H $\quad 1/8 \times 6 = 0.75$ ampere
Minimum Trip = $1.25 \times 0.75 = 0.94$ ampere

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:

$$7.5 \times \frac{1}{1.25} \times \frac{1}{0.9} = 6.6 \text{ amperes} \qquad (5)$$

To be sure the fault detector FD-1 will reset after a fault, the minimum tap setting is determined as follows:

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

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

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.

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

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 ampere
Minimum Trip = 1.0 x 1.25 a. = 1.25 ampere

Tap H 1/10 x 5 = 0.5 ampere
Minimum Trip = 1.25 x 0.5 a. = 0.63 ampere

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

INSTALLATION

The SKBU relay is generally supplied in a cabinet or on a relay rack as part of a complete assembly. The location must be free from dust, excessive humidity, vibration, corrosive fumes, or heat. The maximum temperature around the chassis must not exceed 55°C.

ADJUSTMENTS AND MAINTENANCE

NOTE: The SKBU relay is normally supplied as part of a carrier relaying system, and its calibration should be checked after the system has been installed and interconnected. Details are given in the instructions of the assembly. The assembly instructions and not the following instruction should be followed when the relay is received as an integral part of the relaying system.

In those cases where the SKBU relay is not a part of a relaying system, the following procedure can be followed to verify that the circuits of the SKBU relay are functioning properly.

Test Equipment:

1. Oscilloscope
2. A.C. Current Source
3. Electronic Timer
4. A.C. Voltmeter
5. D.C. Voltmeter

Acceptance Test

Connect the relay to the test circuit of Fig. 8 which represents the TC carrier channel for test purposes.

Open all test switches of the test circuit and connect a 60 cycle test current between terminals 3 and 4 of the relay. Set relay taps on C and H and remove T tap screw.

1. Filter Output

a. Connect a high resistance a-c voltmeter across common of T tap block and the common of Ro tap block.

b. Pass with 3.44 amperes, 60 cycles into terminal 3 and out terminal 4 of relay. Voltmeter should read between 0.75 volts and 0.85 volts a-c.

2. FD-1 Pickup and Dropout

a. Set relay taps 5, C, and H. Close all switches of test circuit.

b. Connect a high resistance d-c voltmeter across X14 and X3 (Neg.)

c. Apply 60 cycle current to terminals 3 and 4 of the relay. Gradually increase the current until the voltmeter changes reading from approximately zero volts to approximately 20 volts. This is the operating current of FD-1 and should be 4.33 ± 5% amperes.

d. Gradually lower a-c test current until the d-c voltmeter drops to approximately zero volts. This is the dropout current of FD-1 and should occur at 80% of the pickup current.

3. FD-2 Pickup and Dropout

a. With the current test leads connected as in the FD-1 test, connect the voltmeter across X13 and X3 (Neg.)

b. Gradually raise a-c current until voltmeter reads approximately 45 volts. This should be 5.41 ± 5% amperes.

c. Gradually lower a-c test current until the d-c voltage reading drops to zero volts. This is dropout of FD-2 and should occur at 90% of pickup current.

4. Check of Local Squaring Amplifier

a. Open switches A, B, C, D, and E of test circuit.

b. Place scope across X10 and X3 (GRD). Apply 5 amperes a-c to terminals 3 and 4 of relay.

c. A square wave voltage should appear across X10 and X3 with the waveshape of Table III.

5. Check of Keying Circuit

a. Open all switches of test circuit and apply 5 amperes a-c to terminals 3 and 4 of the relay.

b. With scope check voltage across X11 and X3 (GRD). Waveform should be a square wave as shown in Table III.

c. Close switches A, B, C, and D. No change should be noted in waveform across X11 and X3 (GRD).

6. Check of Remote Squaring Amplifier

a. Close switches A, B, and C of the test circuit.

b. Apply 5 amperes a-c to terminals 3 and 4 of the SKBU relay.

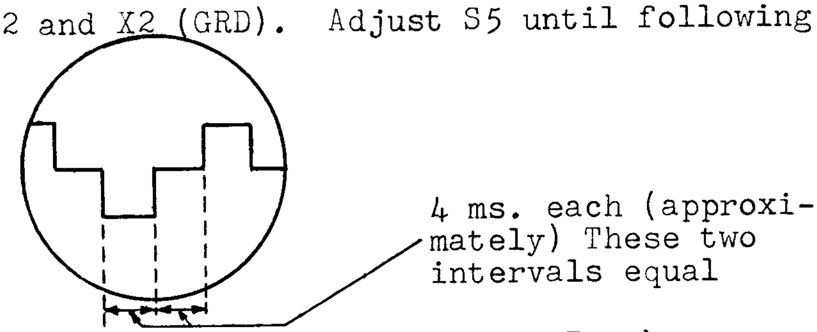
c. Put scope across X9 and X3 (GRD). A square wave of voltage should be obtained (see Table III).

7. Setting of S5 and S6

a. Set S5 to minimum resistance and S6 to maximum resistance (fully clockwise).

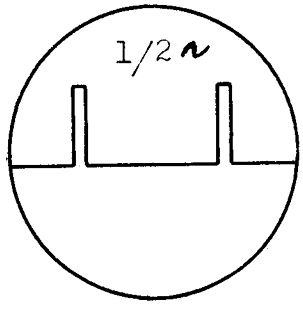
b. With switches A, B, and C of the test circuit closed, apply 6 amperes a-c to terminals 3 and 4 of the SKBU relay.

c. Place scope across X12 and X2 (GRD). Adjust S5 until following waveform is obtained.



d. Close switch D and adjust S6 until the AR trips. In the case of a voltage output SKBU relay, place d-c voltmeter across X16 and X3. Tripping is indicated by a change in voltage from 0 to 20 volts. This sets the triggering of the flip-flop after a 4 millisecond delay. Recheck pickup by moving 55 minimum, opening and closing switch D and then adjusting S5 until AR operates. It may be necessary to readjust S6 to obtain AR tripping on waveform of step c.

e. Slowly increase S5 to obtain the following waveform. Adjust for minimum area of the pips. This will be with S5 near minimum resistance.



8. Check of Transient Blocking

a. Connect electronic timer stop to X7 and X3 (GRD). Set timer stop on negative going pulse.

b. Connect timer start to timer start contacts of switch D. Set timer start to make.

c. With switches A, B, and C open, apply 6 amperes a-c to terminals 3 and 4 of the SKBU relay.

d. Close switch D and measure time for voltage to drop from 20 volts to approximately zero volts. This should be between 20 to 30 milliseconds. Take average of ten readings.

9. Check of Transient Unblocking Circuit

a. With electronic timer stop connected to X7 and X3 (GRD), set timer stop on positive going pulse. Also connect a-c voltmeter across X7 and X3 (NEG.)

b. Connect timer start to timer start contacts of switch A.

c. Apply 6 amperes a-c to terminal 4 and 3 of the SKBU relay, and close switches A, B, C, and D of test circuit. Closing switch D sets up transient blocking as can be seen by a change in voltage from 20 volts d-c to 0 volt d-c.

d. Open switch A and measure time for voltage to change from approximately zero volt to 20 volts. Time should be 20 to 30 milliseconds. Measure average of 10 trials. For each trial it will be necessary to close switch A and then open switch D. Switch D should then be closed and A opened to measure the unblocking time.

10. Check of Carrier Squelch Circuit

a. Connect timer stop across X11 and X3 GRD. Set timer stop on negative pulse.

b. Connect timer start. Set timer start to make.

c. Open switch C. Approximately 20 volts should appear across X11 and X3.

d. Close switch E and measure time for voltage to disappear. This should be 8 to 12 milliseconds.

e. Set timer stop on positive pulse and timer start on break.

f. Measure time for voltage to reappear by opening switch E. Time should be 120 to 180 milliseconds.

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.

CALIBRATION

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs. The relay should be connected to the test circuit of Fig. 8.

1. Sequence Filter

To calibrate the sequence filter, the top cover must be removed and the following procedure used: Remove the T tap screw and insert the tap screws in tap C and H of the R1 and Ro taps. Pass a single-phase current of 10 amperes, rated frequency through the reactor coils in series from phase B to phase C (relay terminals 4 and 5). Accurately measure the a-c voltage from terminal 3 to the common of the T tap plate. This voltage should be between 3.7 and 4.1 volts. Now pass 10 amperes from terminal 3 to terminal 4 with tap screw C removed, and connect voltmeter from terminal 3 to the right-hand (front Ro view) adjustable point of the formed resistor. Adjust this point to give a voltage equal to exactly one-third of the reactor drop. Note the above reading, and adjust the intermediate tap of formed resistor to give exactly 2/3 of the voltage obtained above for all of formed resistor. Measure this voltage from terminal 3 to the intermediate tap.

2. Phase Splitter

If replacement of the fault detector board or major component on the board necessitates a complete recalibration, proceed as follows:

a. Set relay taps 5-C-H.

b. Set S1 and S3 to full clockwise position.

c. Set S2 and S4 to mid-scale.

d. Pass 4.33 amperes through relay terminal 3 to terminal 4.

e. On fault detector board, check the a-c voltage from TP51 to TP52 and from TP52 to TP53 with a VTVM. Adjust the small pot. R53 on the fault detector board until these two voltages are equal.

f. Close all switches of test circuit and connect VTVM across X14 and X3 (Neg.)

g. Slowly turn S3 counterclockwise, with 4.33 amperes flowing, until FD-1 operates as indicated by a change in voltage reading from approximately zero volts to 20 volts d-c.

h. Reduce the a-c current to check FD-1 dropout. Adjust S4 to obtain 80 percent dropout (3.46 amperes). Dropout is indicated by a change in voltage reading from approximately 20 volts to 0 volt.

i. Recheck FD-1 pickup and dropout, and touch up S3 and S4 in that order for the correct calibration. Tighten the locking device.

j. Similarly recalibrate FD-2 using controls S1 (pickup) and S2 (dropout), repeating steps g, h, and i, except for FD-2 pickup of 5.41 amperes and dropout of 4.85 amperes. Pickup is measured using X13 and X3 (negative) and is indicated by a change in voltage reading from a low voltage to 45 volts.

3. 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 AR unit is not in proper working order, and then only if suitable tools are available for checking the adjustments.

a. 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.

b. 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.

c. Adjust each stationary contact screw to obtain a contact gap of 0.020 inch. This will give 15-30 grams contact pressure.

4. Check of Solid-State Circuits

Perform tests listed under "Acceptance" tests to verify that the SKBU relay is functioning correctly.

TROUBLE SHOOTING PROCEDURE

To trouble shoot the equipment, the logic diagram of either Fig. 5 or 6, voltages of Table III, should be used to isolate the circuit that is not performing correctly. The schematic of either Fig. 3 or 4, and the voltages of Table IV should then be used to isolate the faulty component.

TABLE IV

VOLTAGE MEASUREMENTS OF PRINTED CIRCUIT BOARD

1. Fault Detector Board

D-C Voltages - positive with respect to negative d-c (terminal 8 of board).

Test Point		I=O	I=2 x FD-2 p.u.
Terminal 14		45.0 VDC	45.0 VDC
TP 54		6.6	6.8
TP 55		6.6	less than 1
TP 56		14.5	less than 1
TP 57		less than 1	14.5
TP 58		45	less than 1
Terminal 13	FD-1	less than 1	20
Terminal 15	FD-2	less than 1	45
TP 52 - TP 51		less than 1	18 VAC Approximately
TP 52 - TP 53		less than 1	17.8 VAC Approximately

2. Amplifier and Keying

D-C Voltages - positive with respect to negative (terminal 8 of board).

Test Point	Normal	Fault
Terminal 4	20	20
TP 101	20	10
TP 102	20.3	19.8
TP 103	less than 1	10
Terminal 3	less than 1	9.8

3. Output Board

D-C Voltages - positive with respect to negative (terminal 8 of board):

Test Point	Normal	Fault
TP 302	19.5	19.0
TP 301	10	8.5
Terminal 14	20	19.0

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 the repair work. When ordering parts, always give the complete nameplate data. For components mounted on the printed circuit board, give the circuit symbol and the electrical value (ohms, mfd, etc.).

ELECTRICAL PARTS LIST

Fault Detector Board

Circuit Symbol	Description	Westinghouse Style Number
	Capacitor	
C51	0.10 MFD	15449220
C52-C55	0.5	187A624H11
C53	0.25	187A624H02
C54	1.0	187A624H04
	Diodes	
D51 to D56 - D61	1N459A	184A855H08
D57 to D60 - D62	1N457A	184A855H07
	Transistors	
Q51-Q52-Q56-Q57	2N697	184A638H18
Q53	2N699	184A638H19
Q54	2N2043	184A638H21
Q55	2N652A	184A638H16
	Resistors	
R51	50 Ohm, 5W	185A209H06
R52	9.1K Ohm, 1/2W	187A763H50
R53	2.5K Ohm, Pot.	629A430H03
R54	2.7K Ohm, 1/2W	629A530H42
R55-R73-R78	10K Ohm, 1/2W	629A530H56
R56-R58	15K Ohm, 1/2W	187A641H55
R57	18K Ohm, 1/2W	184A763H57
R59	Thermistor 1D05N	185A211H05
R60-R65	68K Ohm, 1/2W	187A641H71
R61	.22 Meg. Ohm, 1/2W	184A763H83
R62-R64-R68-R74	10K Ohm, 1/2W	187A641H51
R63	.1 Meg. Ohm, 1/2W	187A641H75
R66	470K Ohm, 1/2W	184A763H91
R67	39K Ohm, 1/2W	187A641H65
R69	1K Ohm, 1/2W	187A641H27
R70	6.8K Ohm, 1/2W	187A641H47
R71	20K Ohm, 1/2W	629A530H63
R72	3.9K Ohm, 1W	187A643H41
R75	33K Ohm, 1/2W	187A641H63
R76	10K Ohm, 1W	187A643H51
R77	1K Ohm, 1/2W	629A530H43
	Zener Diodes	
Z51	In1832C	184A617H06
Z52-Z54	1N957B	186A797H06
Z53	1N1789	584C434H08
Z55	1N3686B	185A212H06

ELECTRICAL PARTS LIST

Amplifier and Keying

Circuit Symbol	Description	Westinghouse Style Number
	Capacitor	
C101	39 MFD	187A508H04
	Diodes	
D101-D102-D104- D106 to D112	1N457A	184A855H07
D103	1N91	182A881H04
	Transistors	
Q101 to Q104 Q107 to Q113	2N652A	184A638H16
Q105-Q106	2N697	184A638H18
	Resistors	
R101-R103-R114-R127	100K Ohm, 1/2W	187A641H75
R102	150K Ohm, 1/2W	184A763H79
R104	33K Ohm, 1/2W	187A641H63
R105	68K Ohm, 1/2W	187A641H71
R106	27K Ohm, 1/2W	187A641H61
R107-R119-R123	4.7K Ohm, 1/2W	187A641H43
R108-R109-R126	10K Ohm, 1/2W	187A641H51
R110	3.3K Ohm, 1/2W	184A763H39
R111	5.6K Ohm, 1/2W	187A641H45
R112	1.2K Ohm, 1/2W	184A763H29
R113	330 Ohm, 2W	185A207H15
R115	180K Ohm, 1/2W	187A641H81
R116-R117-R130	22K Ohm, 1/2W	187A641H59
R118-R121-R129	47K Ohm, 1/2W	187A641H67
R120-R122	470K Ohm, 1/2W	187A641H91
R124-R125	15K Ohm, 1/2W	187A641H55
R128	39K Ohm, 1/2W	187A641H65
	Zener Diode	
Z101	1N748A	186A797H13

Output Board

Circuit Symbol	Description	Westinghouse Style Number
	Capacitors	
C301	1.0 MFD	187A624H04
C302	0.25 MFD	187A624H02
C303	3.0 MFD	188A293H06
C304-C306	0.05 MFD	187A624H08
C305	0.22 MFD	188A293H02
	Diodes	
D301-D304-D305-D306	1N457A	184A855H07
D302-D303	1N91	182A881H04

ELECTRICAL PARTS LIST

Output Board (continued)

Circuit Symbol	Description	Westinghouse Style Number
	Transistor	
Q301-Q305-Q306-Q307	2N652A	184A638H16
Q302-Q303-Q304	2N697	184A638H18
Q308	2N699	184A638H19
	Resistors	
R301-R303-R309-R310-R313-R324-R325	10K Ohm, 1/2W	187A641H51
R302	120K Ohm, 1/2W	187A641H77
R304	47 Ohm, 1/2W	187A640H17
R305	8.2K Ohm, 1/2W	187A641H49
R306-R315-R322	4.7K Ohm, 1/2W	187A641H43
R307-R331	2.2K Ohm, 1/2W	187A641H35
R308-R320	6.8K Ohm, 1/2W	187A641H47
R311	470 Ohm, 1/2W	187A641H19
R312	470K Ohm, 1/2W	187A641H91
R316-R321-R323	22K Ohm, 1/2W	187A641H59
R317-R328-R332	5.6K Ohm, 1/2W	184A763H45
R318	15K Ohm, 1/2W	187A641H55
R319	Thermistor 1D101	185A211H04
R326-R329	4.7K Ohm, 1/2W	184A763H43
R327	6.8K Ohm, 1/2W	184A763H47
R330	1.5K Ohm, 1/2W	187A641H31
	Zener Diodes	
Z301-Z303-Z305	1N957B	186A797H06
Z320	1N965B	186A797H08
Z304	1N960B	186A797H10
Z306	1N1789	584C434H08

Relay Board

Circuit Symbol	Description	Westinghouse Style Number
	Capacitors	
C251-C252-C253	0.25 MFD	187A624H02
	Resistors	
R251-R252	2.2K Ohm, 1/2W	187A641H35
R253	800 Ohm, 3W	184A859H06
	Filter Choke	
L251	8.5HY, 400 Ohm	188A460H01
	Trip	
AR		408C845G09

Where a voltage output is required, the AR relay is omitted and the following additional parts are located on the board.

ELECTRICAL PARTS LIST

Relay Board (continued)

Circuit Symbol	Description	Westinghouse Style Number
	Capacitors	
C254	0.25 MFD	187A624H02
	Diodes	
D251-D252	1N457A	184A855H07
D253	CER-69	188A342H06
	Transistors	
Q251-Q252	2N398A	184A638H12
	Resistors	
R253,R256	1K Ohm, 1/2W	184A763H27
R254	2.2K Ohm, 3W	184A859H15
R255	330 Ohm, 3W	184A859H14
R257	10K Ohm, 1/2W	184A763H51
R259	2.25K Ohm, 3W	184A636H03
	Zener Diode	
Z251	1N3686B	185A212H06

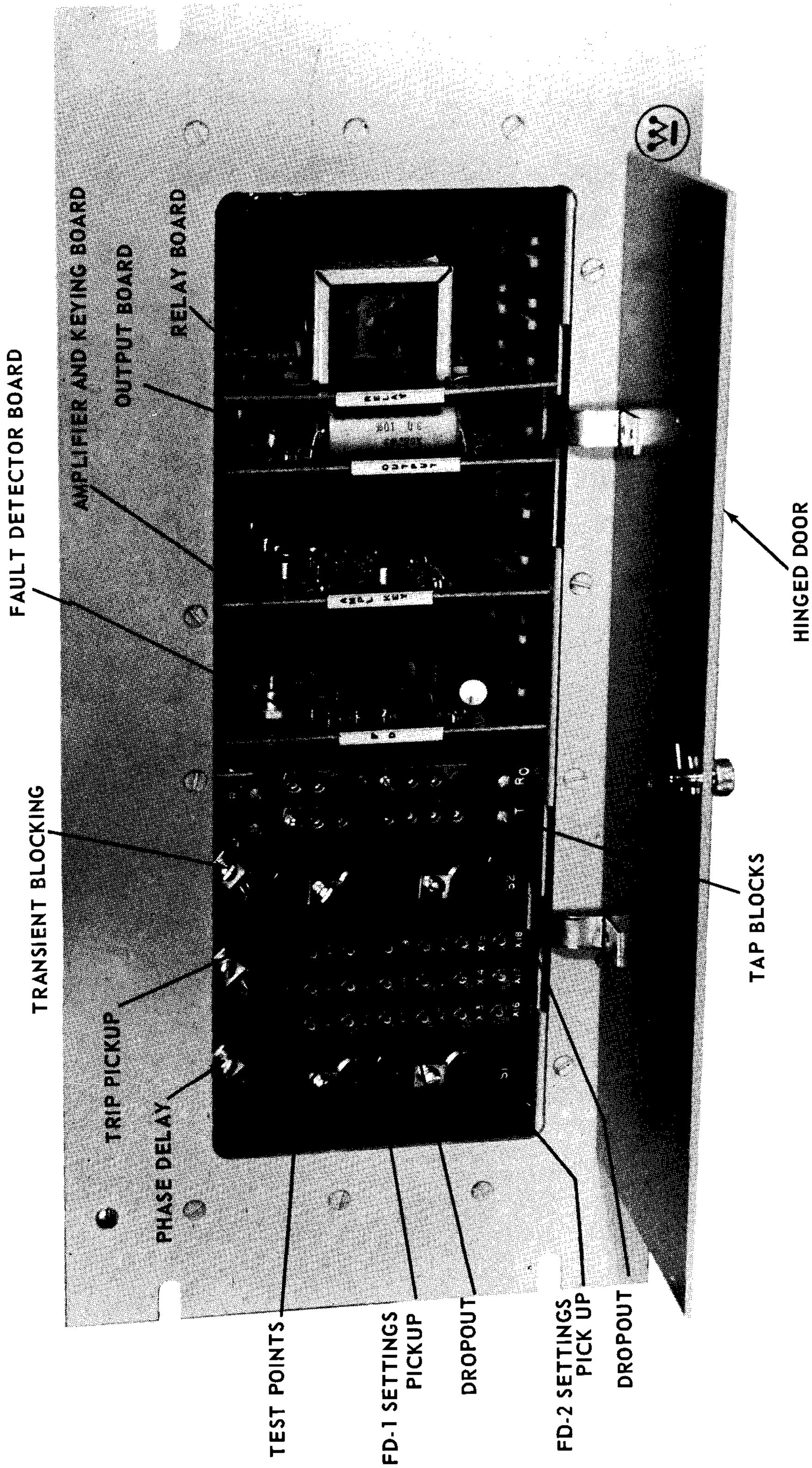


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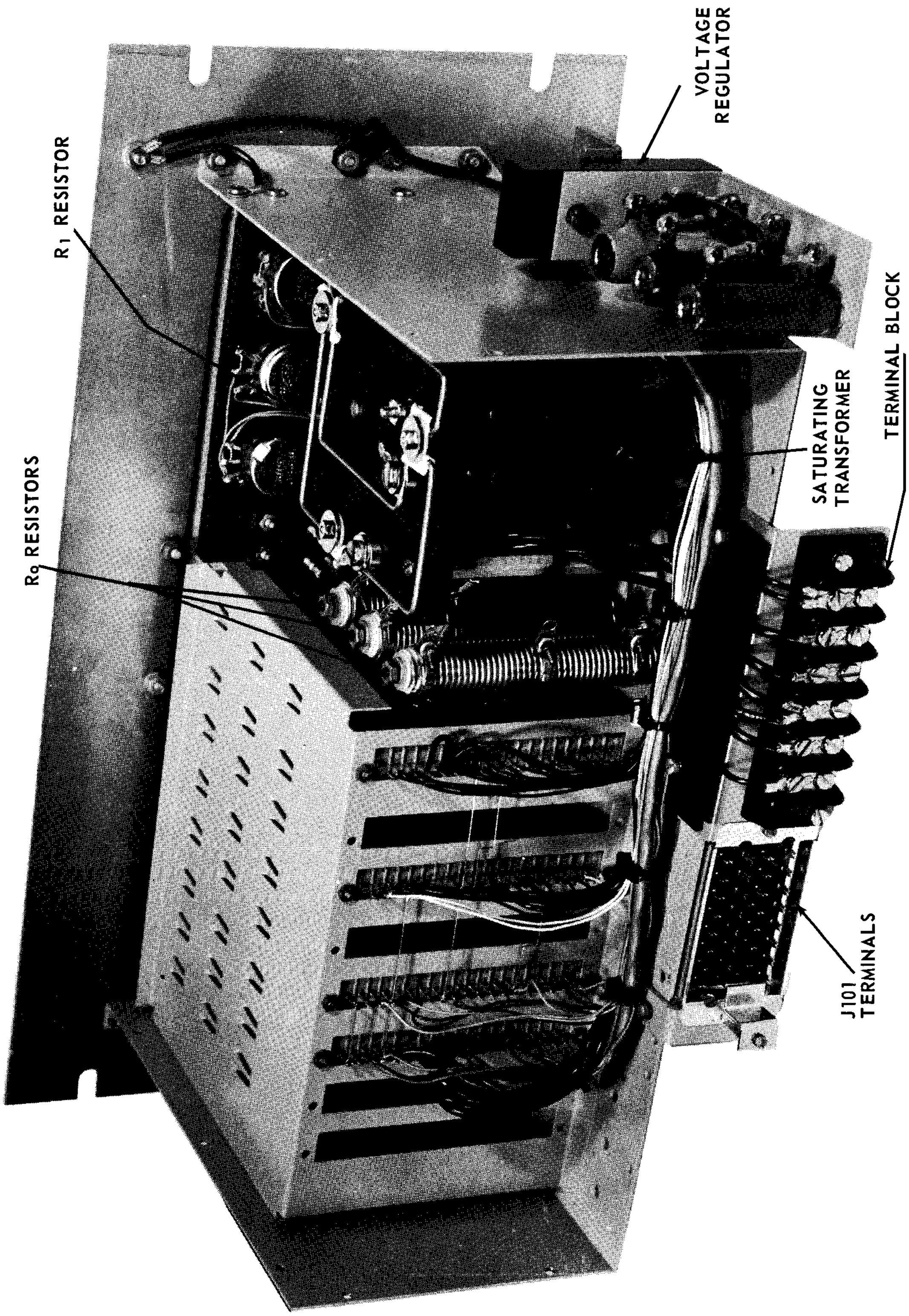
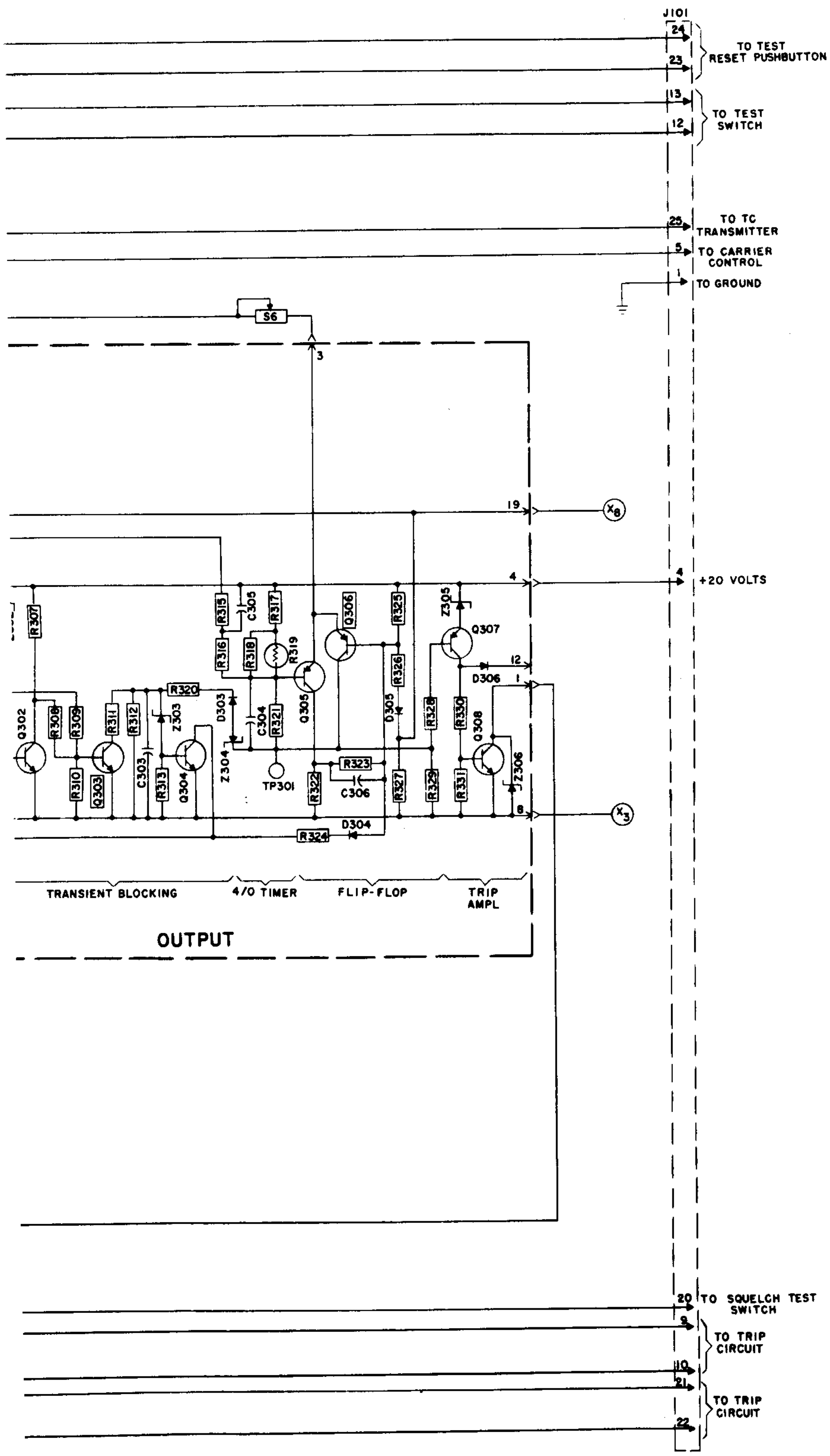
Fig. 1 Type SKBU Phase Comparison Relay (Front View)

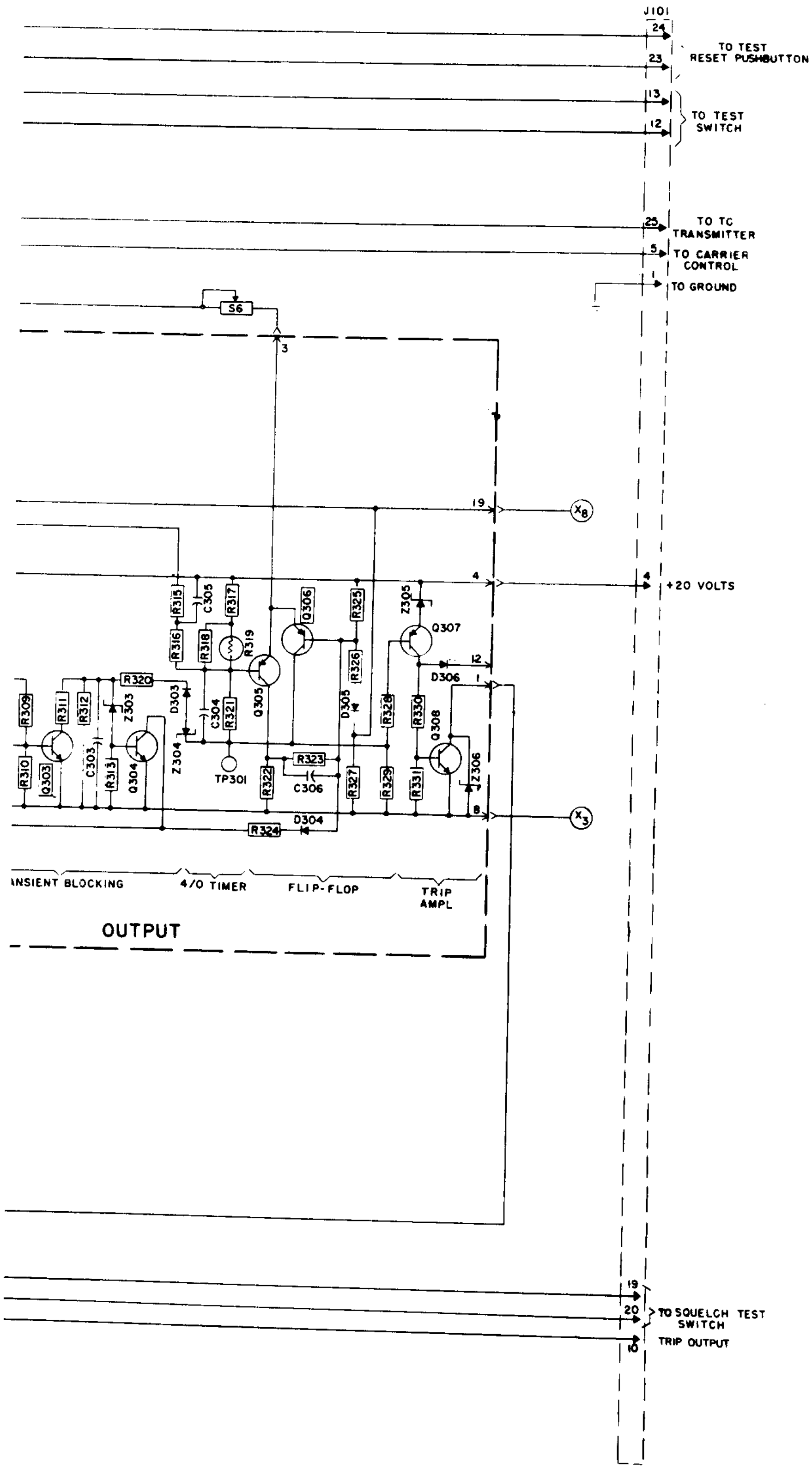


N365471

Fig. 2 Type SKBU Phase Comparison Relay (Rear View)


J101
TO TEST RESET PUSHBUTTON
TO TEST SWITCH
TO TC TRANSMITTER
TO CARRIER CONTROL
TO GROUND
S6
+20 VOLTS
TRANSIENT BLOCKING
4/0 TIMER
FLIP-FLOP
TRIP AMPL
OUTPUT
TO SQUELCH TEST SWITCH
TO TRIP CIRCUIT
TO TRIP CIRCUIT

756J654


J101
TO TEST
RESET PUSHBUTTON
TO TEST
SWITCH
TO TC
TRANSMITTER
TO CARRIER
CONTROL
TO GROUND
S6
+20 VOLTS
TP301
NSIENT BLOCKING
4/0 TIMER
FLIP-FLOP
TRIP
AMPL
OUTPUT
TO SQUELCH TEST
SWITCH
TRIP OUTPUT

756J704

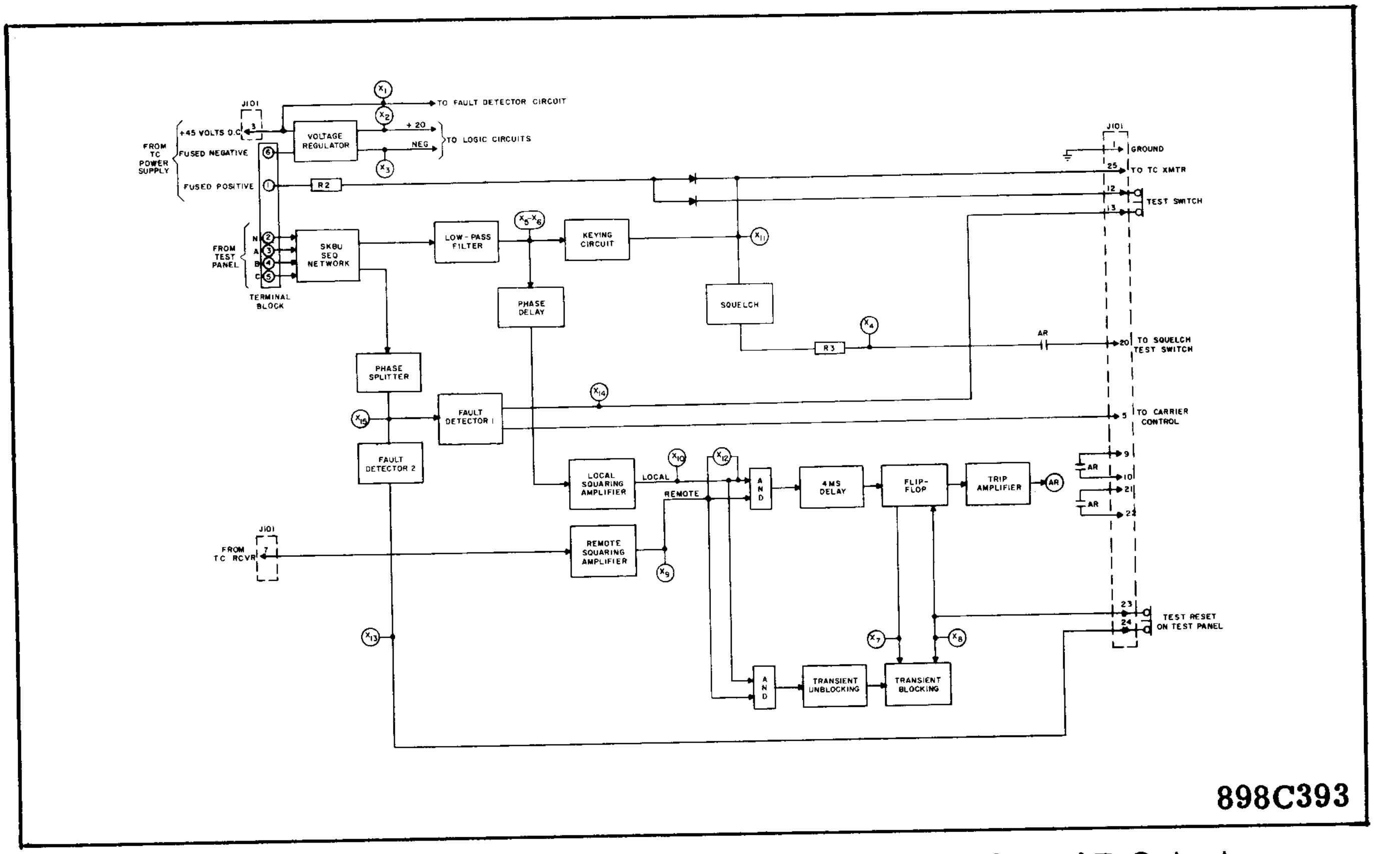


Fig. 5 Logic Diagram of the Type SKBU Relay with an AR Output

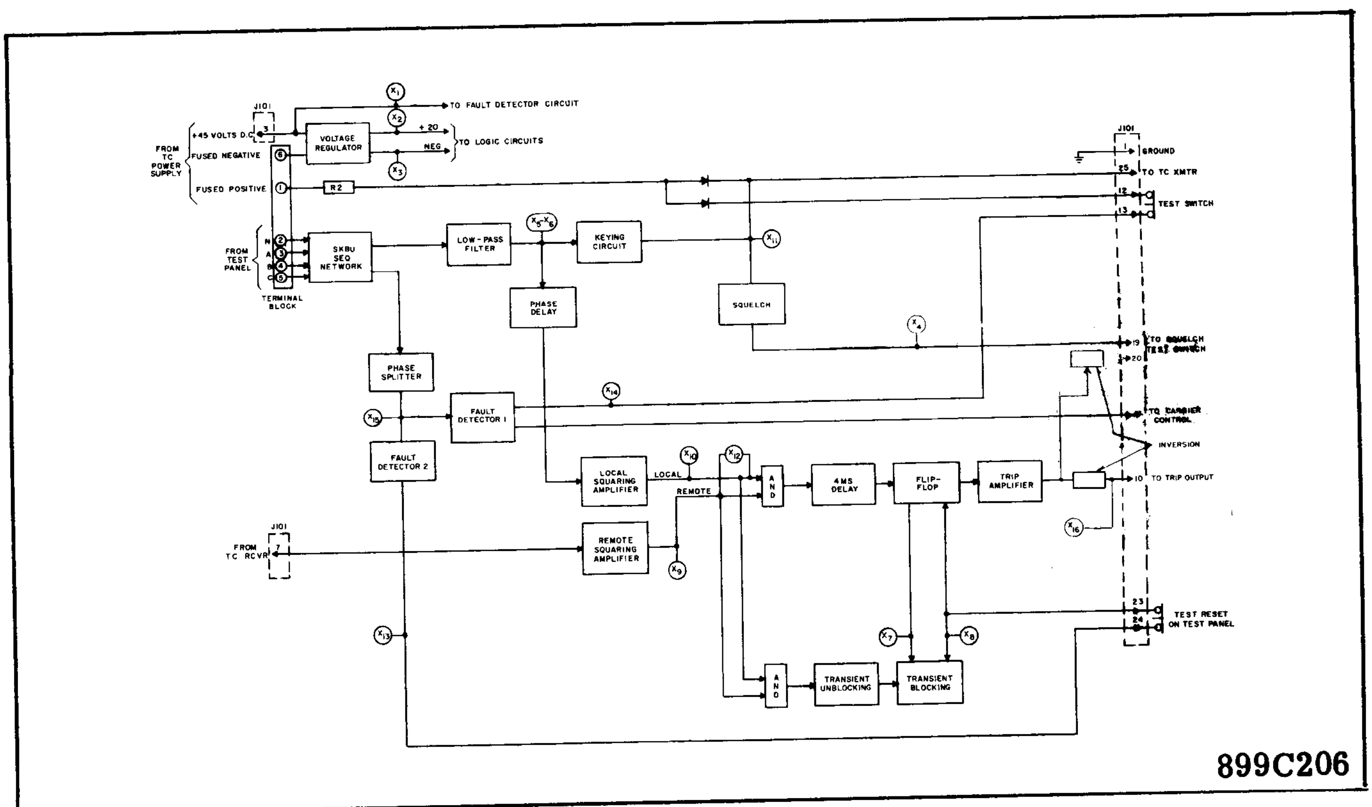


Fig. 6 Logic Diagram of the Type SKBU Relay with a Voltage Output

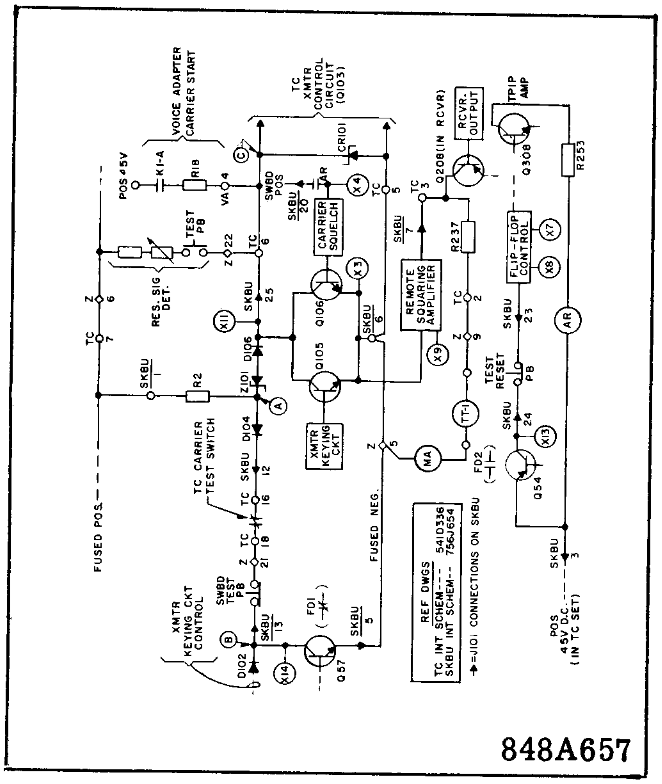


Fig. 7 Elementary Connections of TC SKBU Control Circuits

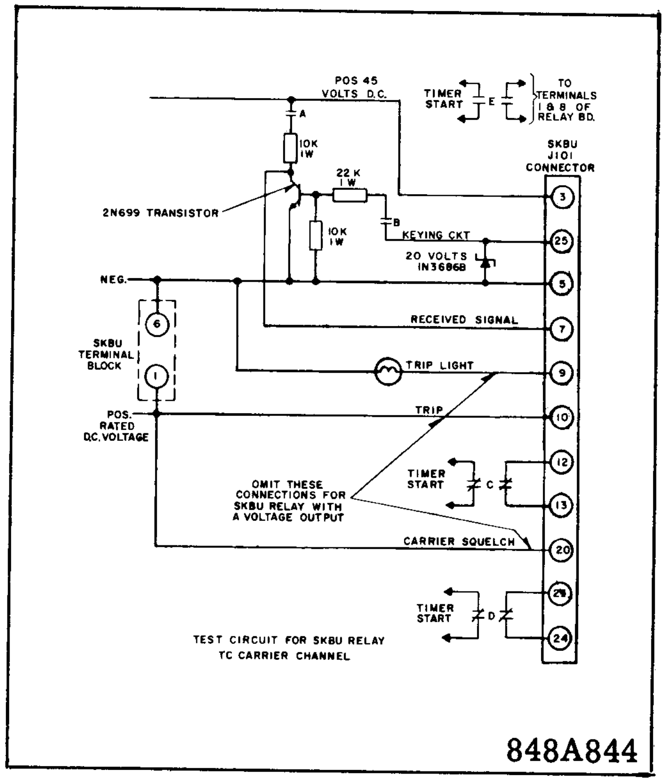


Fig. 8 Test Circuit of SKBU Relay

TEST POINT	CIRCUIT	VOLTAGES TO X3 (EXCEPT WHERE SPECIFIED) NORMAL **	EXTERNAL FAULT	INTERNAL FAULT
X1	POSITIVE 45 VOLTS FROM TC SET	+45	+45	+45
X2	REGULATED 20 VOLTS D.C.	+20	+20	+20
X3	NEGATIVE FROM TC SET	—	—	—
X4	CARRIER SQUELCH	0	0	RATED SUPPLY VOLTAGE
*X5 / *X6	LOW PASS FILTER VOLTAGE AT 2 TIMES PICKUP OF FD-1	0	4 TO 7 VOLTS RMS	4 TO 7 VOLTS RMS
X7	TRANSIENT BLOCKING	20	0	20
X8	ARMING	12	+20	+20
X9	REMOTE SQUARING AMPLIFIER	20	20 / 0	20 / 0
X10	LOCAL SQUARING AMPLIFIER	0	20 / 0	20 / 0
X11	KEYING	0	20 / 0	20 / 0
▲X12	LOCAL REMOTE COMPARER	—	0 / 2	0 / 2
X13	FD-2	0ø	+45	+45
X14	FD-1	0	+20	+20
X15	PHASE SPLITTER AT 2 TIMES PICKUP OF FD-1	0	16V D.C / 0	16V D.C. / 0
X16	TRIP OUTPUT-SKBU RELAY WITH VOLTAGE OUTPUT ONLY	0	0	20 VOLTS D.C.

* = VOLTS A.C. ACROSS X5 AND X6 ** NO LOAD CURRENT
▲ = VOLTS D.C. TO X2
ø = READING VARIES WITH VOLTMETER USED

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Fig. 9 Table III, Voltages of SKBU Relay

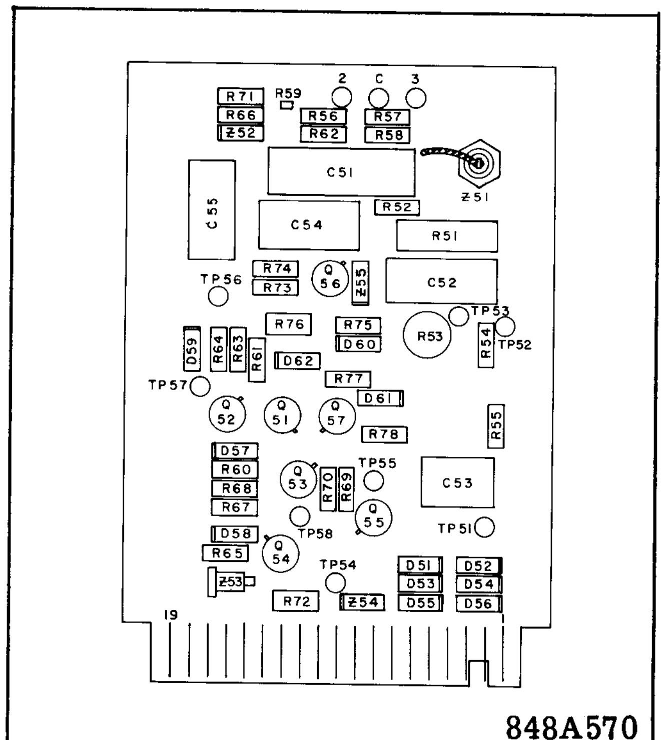


Fig. 10 Component Location on Fault Detector Printed Circuit Board for Type SKBU Relay

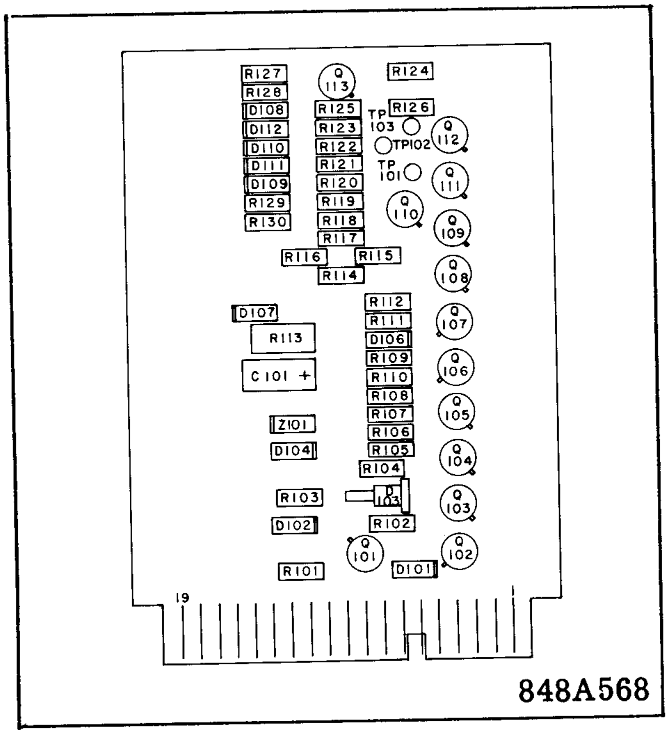


Fig. 11 Component Location on Amplifier and Keying Printed Circuit Board for Type SKBU Relay

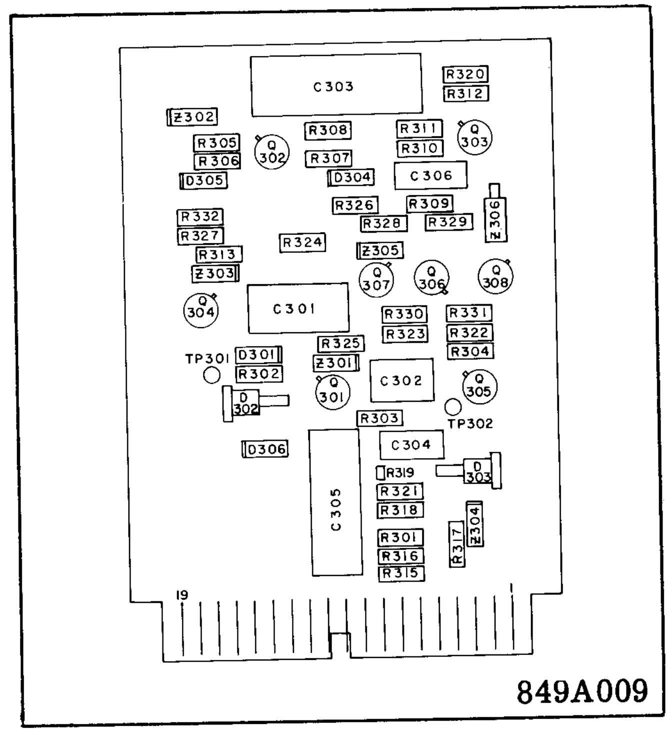


Fig. 12 Component Location on Output Printed Circuit Board for Type SKBU Relay

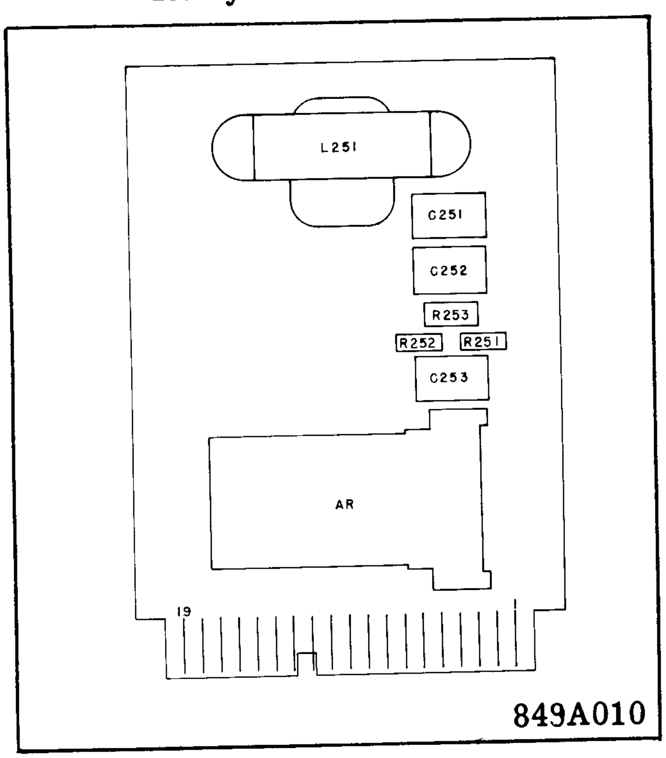


Fig. 13 Component Location on Relay Printed Circuit Board with an AR Output for Type SKBU Relay

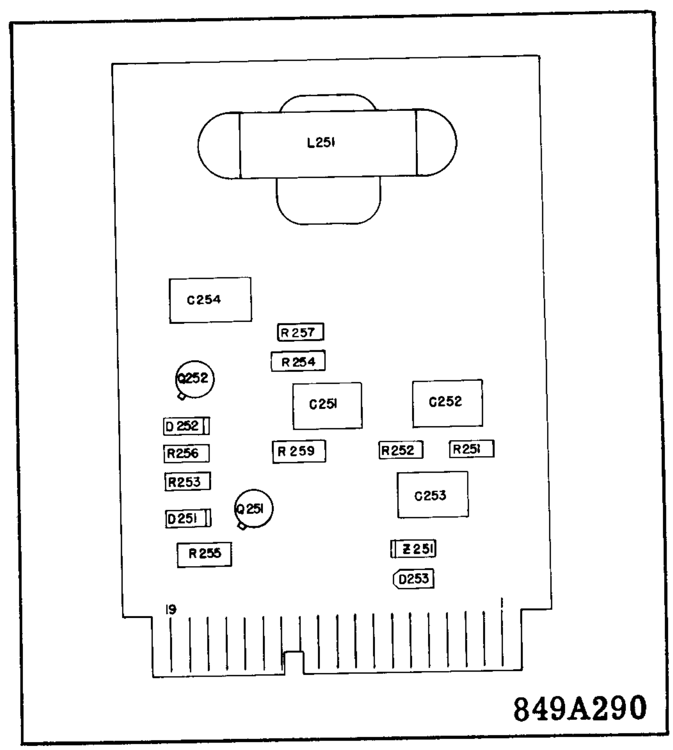


Fig. 14 Component Location on Relay Printed Circuit Board with a Voltage Output for Type SKBU Relay

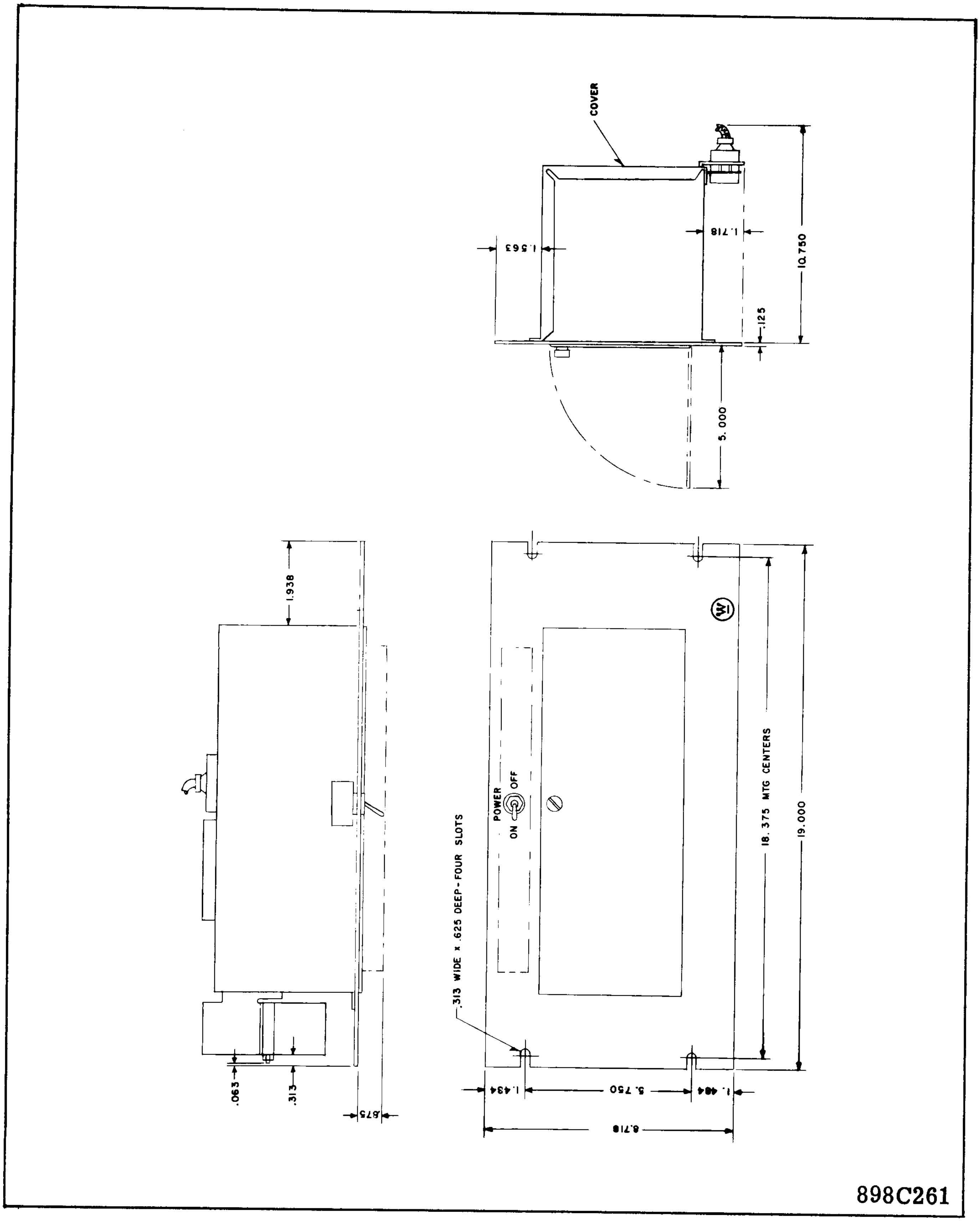


Fig. 15 Outline and Drilling Plan for Type SKBU Relay

WESTINGHOUSE ELECTRIC CORPORATION
RELAY-INSTRUMENT DIVISION

NEWARK, N. J.

Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE SKBU PHASE COMPARISON RELAY FOR TYPE TC CARRIER CHANNEL

CAUTION: It is recommended that the user of this equipment become acquainted with the information in this instruction leaflet before energizing the carrier system. If the SKBU relay is mounted in a cabinet, the cabinet must be bolted down to the floor or otherwise secured before swinging out the equipment rack to prevent its tipping over.

APPLICATION

The type SKBU relay is a high speed carrier relay used in conjunction with a type TC power line carrier set to provide complete phase and ground fault protection of a two terminal or three terminal transmission line. Simultaneous tripping of the relays at each line terminal is obtained in less than twenty-five milliseconds 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 swing or out-of-step conditions. The carrier equipment operates directly from the station battery.

CONSTRUCTION

The type SKBU relay consists of a combination positive, negative and zero sequence current network, a saturating transformer, a 20-volt power supply, and printed circuit boards mounted on a standard 19-inch wide panel, 8-3/4 inches high (5 rack units). Edge slots are provided for mounting the rack on a standard relay rack. The location of these components is shown in Figures 1 and 2. The components are connected as shown in the internal schematics of Figures 3 and 4.

Sequence Network

The sequence filter consists of a three-legged iron core reactor and a set of resistors, R1 and R0. The reactor has three windings: two primary and a tapped secondary winding, wound on the center leg of a "F" type of lamination. The secondary taps are wired to the A, B, and C tap connections in the front of the relay (R1 taps). R0 consists of three tube resistors with taps wired to F, G, and H tap connections in the front of the relay. The R1 resistor is a formed resistor associated with the tapped secondary of the reactor.

SUPERSEDES I. L. 41-954.1
*Denotes change from superseded issue.

EFFECTIVE AUGUST 1968

line current. This single phase output voltage is applied as inputs to two boards from the secondary of the saturating transformer.

1) Fault Detector Board (Phase Splitter Circuit)
2) Relay Board (Phase Delay Circuit)

1) Fault Detector

The a-c voltage is applied to a phase splitting network (C52, R54, R53) and a polyphase rectifier (diodes D51 to D56). The d-c voltage so obtained requires a minimum of filtering (C53) and responds rapidly to a change in magnitude of the a-c output. This d-c voltage is applied to two fault detector circuits which operate when the d-c input "signal" exceeds a predetermined value.

a. Fault Detector 1 (FD-1)

Under normal line conditions (no fault), current flows from positive 45 volts d-c through resistor R72 and Zener diode Z54 to negative, holding Q55 emitter at 6.8 volts positive. In transistor Q55, current flows from emitter to base, then through S3 and R71 to negative, thus turning on Q55. The collector current of Q55 provides base drive to transistors Q56 and Q57, turning them on also. The voltage drops across Q56 and Q57 are very low (about 0.5 volts), thus providing the equivalent of a closed contact. When a fault occurs, the d-c voltage from the polyphase rectifier is applied to S3 and R71. When this voltage exceeds the 6.8 volt drop across Zener diode Z54, transistor Q55 stops conducting. This removes the base current from Q56 and Q57, causing them to stop conducting, and providing the equivalent of an open circuit. With reference to Figure 7, this open circuit removes negative potential at point A and allows the potential at point C to become 20 volts. This increase in voltage at point C starts transmission of carrier.

When Q56 is cut off, its collector potential rises to about 20 volts. This also further raises the potential of Q55 base through feedback resistors R75 and S4, thus holding Q55 in a non-conducting state. When the input voltage (from the polyphase rectifier) is reduced, FD1 "resets" to allow transistors Q55, Q56 and Q57 to conduct. Resistor S3 is for setting the FD1 pickup current (calibration adjustment), and the setting of S4 determines the 80 percent dropout value.

b. Fault Detector 2 (FD-2)

Under normal conditions, transistor Q51 has no base "signal" and is turned off. The collector of Q51 is at a high enough positive potential to provide base drive for transistor Q52, driving it to full conduction. With Q52 fully conducting there is no base drive to transistor Q53. With no Q53 collector current, the base of PNP-type transistor Q54 is supplied from the 45 volt source through the drop of D58. Thus, the Q54 emitter is normally at a slightly lower potential than its base. This condition keeps transistor Q54 in a non-conducting state, equivalent to an open circuit. Zener diode Z3 is to protect transistor Q54 from external surge voltages.

When a fault causes the d-c input voltage from the polyphase rectifier to exceed the 6.8 volt rating of Zener diode Z52, (through R55, and S1) a positive bias is applied to Q51 base causing it to conduct. In turn, Q52 stops conducting, and capacitor C55 charges up, giving a few milliseconds time delay before Q53 and Q54 are switched to full conduction, thus "closing" FD2. The feedback resistors R60 and S2 provide a 90 percent FD2 dropout ratio with "toggle" action at the dropout point.

When FD-2 operates, positive 45 volts d-c is applied to the output board at terminal 18. This 45 volts is applied to the flip-flop circuit at terminal 19 and to the transient blocking circuit through Zener diode Z302. Thus, FD2 will "arm" the flip-flop and energize transient blocking of the SKBU relay.

2. Relay Board

The a-c voltage from the saturating transformer is also applied to the phase delay circuit through a low-pass filter of the relay board. The low-pass filter (C251, L251, C252) removes the harmonics from this voltage and applies a voltage that is essentially sinusoidal in waveform to R251 and R252 of the phase delay circuit. By menas of capacitor C253 and variable resistor S5, the voltage across terminals 4 and 9 can be made to lag the voltage across terminal 10 and 11 by a definite amount depending on the setting of S5. These two voltages are applied to the amplifier and keying board of the SKBU relay.

a) Undelayed Voltage to the Keying Circuit
b) Delayed Voltage to the Local Squaring Amplifier

a. Keying Circuit

Under normal conditons transistor Q102 is turned off. The collector of Q102 is at negative potential which allows base current to flow from positive 20 volts d-c through the base of transistor Q103, through R104 and R102 to negative. Transistor Q103 conducts and positive 20 volts is applied to the collector of Q103 to prevent base current from flowing in Q104. Since Q104 is not conducting, transistor Q105 does not conduct and the collector of Q105 is held at positive potential.

When a fault occurs, sinusoidal voltage is applied to transistor Q102 from terminals 4 and 10 of the relay board. On the positive half cycle, terminal 12 is more positive than terminal 4 of the amplifier and keying board, and Q102 does not conduct. However, on the negative half cycle of sine wave voltage, terminal 12 is more negative than terminal 4 and base current flows in Q102. This turns Q102 on and applies positive 20 volts to R102. This turns Q103 off which in turn puts negative potential on R106. Q104 then conducts to allow base current to flow into Q105. When Q105 conducts, its collector is connected to negative potential. Thus, the collector of Q105 is connected to negative on alternate half cycles of the 60-cycle voltage from the low pass filter. If FD-1 is not conducting, as seen from Fig. 7, turning Q105 on and off every half cycle, shorts the input to the TC carrier set every other half cycle so that carrier is transmitted on the half cycle when Q105 is not conducting.

b. Local Squaring Amplifier

The shifted voltage from the phase delay circuit is applied to the local squaring amplifier of the SKBU relay. Under non-fault conditions, Q108 is not conducting and R115 is at negative potential. As a result, the base of Q109 and Q111 is at a lower potential than the emitter of the transistors. Base current for both transistors flows from positive 20 volts through R116 and R115 to negative and both transistors conduct. With Q111 turned on, positive 20 volts is applied to R119 which is applied to R129 and R130 through D111 and D109 respectively. This voltage is the input to the AND circuit from the local signal and is the quantity to be compared with the signal from the remote terminal to determine if a fault is internal or external.

Under fault conditions, a sine wave of voltage is applied from emitter to base of transistor Q108. On the positive half cycle the base of transistor Q108 is more positive than the emitter and Q108 does not conduct. On the negative half cycle of sine wave voltage, the base is more negative than the emitter and Q108 conducts. Turning Q108 on applies positive 20 volts to R115 to cause Q109 to turn off. This causes Q111 to turn off such that negative potential is applied to R119. Hence, on alternate half cycles of sine wave voltage, negative voltage appears across R119 to apply negative voltage to R129 and R130 through D111 and D109 respectively. The voltage across the resistor is thus a square wave voltage varying from 20 volts d-c to 0 volt d-c dependent upon the polarity of the voltage from the phase delay circuit.

3. Remote Squaring Amplifier

Under non-fault conditions, carrier is not transmitted from the remote carrier set. As a result the base of Q113 is more negative than its emitter, and Q113 conducts. This applies positive 20 volts to the base of Q112 to prevent it from turning on. Hence, Q112 is not conducting and negative voltage appears across R123. This voltage is applied to R129 and R130 through D112 and D110 respectively, and allows the voltage across these resistors to remain at negative potential.

Under fault conditions, the remote TC carrier set is keyed on and off as described under the Keying Circuit. This signal is received at the local TC carrier receiver and is converted to a square wave voltage varying in magnitude from 45 volts to 0 volt. This voltage is applied to the base of Q113 through D108 and R128. Upon application of positive 45 volts d-c to the base of Q113, the potential of the base is greater than that of the emitter and Q113 stops conducting. This removes positive potential from R124 and allows the base of Q112 to become negative with respect to the emitter. Q112 turns on to apply positive voltage to R123. Hence, the voltage across R123 is a square wave voltage that is developed by the voltage received from the TC receiver. This voltage is applied to R129 and R130 through D112 and D110.

4. 4/0 Milliseconds Time Delay
The 4/0 time delay consists of R315, C305, R316, R317, R318, and R319. Under non-fault conditions, a continuous positive 20 volts is received from the local squaring amplifier at terminal 6 of the output board. This prevents capacitor C305 from charging and keeps the base of Q305 of the flip-flop at positive potential.

Under external fault conditions, the square wave voltage from the remote squaring amplifier and the square wave voltages from the local squaring amplifier are out of phase, such that a continuous 20 volts is received at terminal 6 of the Output board. C305 does not charge, and transistor Q305 cannot turn on.

Under internal fault conditions, the square wave voltages from the squaring amplifiers are in phase. Hence, for one-half cycle, negative voltage appears at terminal 6 of the Output board. This allows C305 to charge through resistors R315 and R129 to negative. After a calibrated time delay of 4 milliseconds, the voltage across C305, which is applied to the base-emitter circuit of transistor Q305 in the flip-flop circuit is sufficient to allow Q305 to conduct.

5. Flip-Flop
The flip-flop circuit consists of transistors Q305 and Q306 and associated components. Under normal conditions, transistor Q305 is in a non-conducting state, and transistor Q306 is fully conducting. The base of transistor Q306 is held well below its emitter potential by means of the voltage divider consisting of resistors R325, R326, D305, and R327. With this bias, transistor Q306 is held in saturation and the flip-flop is desensitized so that even if transistor Q305 turns on, transistor Q306 does not turn off. This desensitizing circuit is an arrangement to prevent inadvertent operation of the flip-flop in the presence of sur es on the d-c system. As long as Q306 is conducting, its collector is at a high enough positive potential such that transistor Q307 in the tripping amplifier cannot turn on.

Upon the occurrence of an internal fault, positive 45 volts d-c is applied from Q54 (FD-2) to terminal 18 of the Output board. This removes the desensitizing bias from transistor Q306 by making the potential of the junction of resistor R327 and diode D305 greater than the 20 volt supply for the flip-flop circuit. When this occurs, there is no current flow through resistor R326 and diode D305, and the flip-flop is now "armed" or in a ready condition for a tripping operation. Since the pulses from the "AND" circuit are in phase, after a 4 millisecond delay, the potential across capacitor C305 is sufficient to cause Q305 to conduct. This immediately causes operation of the flip-flop, turning off transistor Q306. When Q306 is no longer conducting, the potential of the junction of R329 and R328 drops to a relatively low value. When this occurs, there is sufficient voltage across the base-emitter circuit of transistor Q307 in the trip amplifier to cause it to turn on.

6. Trip Amplifier

When transistor Q307 is turned on by operation of the flip-flop, base current flows from positive 20 volts through Z305, the emitter-base junction of Q307, and the resistors R328 and R329 to negative. The collector current of transistor Q307 flows through R330 and the base-emitter junction of output transistor Q308. The collector of Q308 is connected to positive 45 volts d-c through R253 and the AR coil of the relay board. Collector current thus flows from positive 45 volts d-c through the AR coil, R253 to transistor Q308, hence, the AR operates to trip the breaker. In case of a voltage output from the SKBU relay, transistor Q252 turns on to provide 20 volts output to the next device.

7. Carrier Squelch

When the SKBU relay operates as a result of an internal fault, positive potential is applied to the squelch circuit of the amplifier and keying board. Ten milliseconds after positive potential is applied, capacitor C101 charges sufficiently to allow base current to flow to transistor Q106. Transistor Q106 turns on to short the carrier start lead to negative (ref. Fig. 7). Carrier is then turned off and will remain off for approximately 150 milliseconds after the SKBU resets to prevent delayed tripping of the remote breaker due to a short burst of carrier at the instant of the local breaker opening.

8. Transient Blocking

When Q54 (FD-2) turns on, positive 45 volts is applied to terminal 18 of the output board, and energizes the transient blocking circuit. Base current is supplied to transistor Q302 through resistor, R305, and Zener diode, Z302. Transistor, Q302, turns on to connect the base of transistor, Q303, to negative. Q303 stops conducting and capacitor C303 starts to charge. When the charge on capacitor C303 is sufficient to cause the breakdown of Zener diode Zener diode Z303, it turns on transistor Q304. This provides a conducting path from the base circuit of transistor Q306 in the flip-flop, diode D304, the resistor R324, and the collector emitter circuit of transistor Q304 to negative. This occurs after a time delay of 20 to 30 milliseconds and provides a path to apply a "desensitizing" bias to transistor Q306 in the flip-flop. Thus, the transient blocking circuit allows 20 to 30 milliseconds after the operation of FD-2 for the flip-flop to operate and energize the output of the relay. If tripping does not occur in this time, as during an external fault, the operation of the transient blocking circuit desensitizes the flip-flop to prevent undesirable operation during transients associated with power reversals on the protective line or at the clearing of an external fault.

The transient blocking circuit is cancelled either by FD-2 resetting or by the operation of the transient unblocking circuit.

9. Transient Unblocking

If an internal fault occurs before an external fault is cleared, high speed tripping is obtained. The square wave output from the local and remote squaring amplifier changes from an out-of-phase condition to an in-phase condition. As a result, negative potential is applied to the transient unblocking circuit at terminal 9 of the Output board. Zener diode Z301 breaks down and base current flows through Z301, emitter-base of Q301, resistor R303, Diode D302, and D301, resistor R130, and through the conducting transistor, Q304, to negative. Transistor Q301 turns on to apply positive potential to resistor, R309. Base current then flows through resistor R309, to turn on transistor Q303. Capacitor, C303, will be rapidly discharged to remove the potential from the base of transistor, Q304. Transistor Q304 turns off to interrupt the desensitizing circuit from the base of transistor Q306. When this happens, the flop-flop will then be able to operate to provide an input to the trip amplifier.

CHARACTERISTICS

The sequence network in the relay 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 T taps on the left-hand tap place indicate the balanced three phase amperes which will operate the carrier-start fault detector (FD-1). The taps available are 3, 4, 5, 6, 7, 8, and 10 and are on the primary of the saturating transformer. The second fault-detector unit (FD-2), which supervises operation of tripping, is adjusted to pick up at a current 25 percent above tap value.

For phase-to-phase faults AB and CA, enough negative sequence current has been introduced to allow the fault detector FD-1 to pick up at 86 percent of the tap setting. For BC faults, the fault detector will pick up at approximately 50 percent of the tap setting. This difference in pickup current for different phase-to-phase faults if 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 pickup under a minimum fault current, yet not operate under load. For these cases, a tap is available on the SKBU relay which cuts the three-phase sensitivity in half, while the phase-to-phase setting is substantially unchanged. The relay then trips at 90 percent 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 SKBU relay on negative-plus-zero sequence current. A tap is available to operate in this manner. The fault detector picks up at tap value for all phase-to-phase faults, but is unaffected by balanced load current or three-phase faults.

For ground faults, separate taps (Ro) are available for adjustment of the ground fault sensitivity to about 1/4 or 1/8 of the left-hand tap plate setting. See Table II. For example, if the SKBU relay is set at T, tap 4, the fault detector (FD-1) pickup current for ground faults can be either 1 or 1/2 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.

Operating Time	12 to 20 milliseconds
Transient Blocking Time	20 to 30 milliseconds
Transient Unblocking Time	20 to 30 milliseconds
Squelch Time	150 milliseconds
Ambient Temperature Range	-20°C to 55°C
Output Voltage (where used)	20 milliamperes at 20 volts d-c
Drain on 45 volt Power Supply of TC Set:	
Non-Trip Condition	60 MA
Trip Condition (with AR output)	100 MA
Trip Condition (with voltage output)	80 MA
Dimensions:	
Panel Height	8-3/4 inches or 5 rack unit
Panel Width	19 inches

ENERGY REQUIREMENTS

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

Relay	Phase A		Phase B		Phase C	
Taps	VA	Angle	VA	Angle	VA	Angle
A-F-3	2.4	5°	0.6	0°	2.5	50°
A-H-10	3.25	0°	0.8	100°	1.28	55°
B-F-3	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 VA	Phase A Angle	Phase B VA	Phase B Angle	Phase C VA	Phase C 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.

SETTINGS

The SKBU 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 applications. 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 both terminals of a line section must be set to pickup at the same value of line current. This is necessary for correct blocking during faults external to the protected line section.

Sequence Combination Taps

The two halves of the right-hand tap plate are for connecting the sequence network to provide any of the combinations described in the previous section. The upper half of the tap plate or R1 taps 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 Right Hand Tap Block		Fault Detector FD-1 Pickup	
		R1	Ro	3Ø Fault	Ø-Ø Fault ~~0~~
1	Pos., Neg., Zero	C	G or H#	Tap Value	86% Tap Value (53% on BC Fault)
2	Pos., Neg., Zero	B /	G or H	2 x Tap Value	90% Tap Value (65% on BC Fault)
3	Neg., Zero	A /	G or H	--------	100% Tap Value

\# - Taps F, G, and H are zero-sequence taps for adjusting ground fault sensitivity.

See section on zero-sequence current tap.

~~0~~ - Fault detector FD-2 is set to pickup at 125% of FD-1 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 FD-1 and FD-2 will be 10 to 15 percent higher than the indicated values because of the variation in self-impedance of the sequence network and the saturating transformer.

Positive-Sequence Current Tap and FD-2 Tap

The left-hand tap plate, T, has taps of 3, 4, 5, 6, 7, 8, and 10 which represent the three-phase, fault detector FD-1 pickup currents, when the relay is connected for positive, negative and zero sequence output. The fault detector FD-2 closes its contact to allow tripping at current value 25 percent above the fault detector FD-1 setting. This 25 percent difference is necessary to insure that the carrier-start fault detectors (FD-1) at both ends of a 2-terminal transmission line section pickup to start carrier on an external fault before operating energy is applied through FD-2.

For a 3-terminal line, there is a provision on the printed circuit board for changing the temperature compensation when calibrating FD-2 to pickup at 250% of FD-1 setting. This is necessary to allow proper blocking on 3-terminal lines when approximately equal currents are fed in two terminals, and their sum flows out the third terminal of the line. The relay is shipped connected for 2-terminal line service. For a 3-terminal line, the jumper on the FD board must be changed to c-3, and FD-2 must be recalibrated for 250% of FD-1.

The T, Ro, and R1 taps 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 dropout current of the FD-1 fault detector is 80 percent of the pickup 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 pickup should be sufficient to allow the fault detector to dropout after an external fault, when load current continues to flow.

Zero-Sequence Current Tap - Ro Taps

The lower half of the right-hand tap plate (Ro taps) 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.

TABLE II

Comb.	R1 Tap	Ground Fault Pickup Percent of T Tap Setting	
		Tap G	Tap H
1	C	25%	12%
2	B	20%	10%
3	A	20%	10%

Examples of SKBU 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:

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

Minimum Phase-to-Phase Fault Currents:

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

Fault detector FD-1 setting (three phase) must be at least:

$\frac{3.75}{0.80} = 4.7$ amperes (0.80 is dropout ratio of FD-1 fault so that the fault detector will reset on load current) (3)

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault detector FD-1 setting (three-Phase) must be not more than:

$$7.5 \times \frac{1}{0.866} \times \frac{1}{1.25} = 6.98 \text{ amperes}$$

$$1.25 = \frac{\text{FD-2 Pickup}}{\text{FD-1 Pickup}} \quad (4)$$

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 would be used (see Table I, 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 T, tap 6 and R1, tap C in use, the fault detector FD-1 pickup currents for ground faults are as follows:

Tap G $\quad 1/4 \times 6 = 1.5$ ampere
Minimum Trip $= 1.25 \times 1.5$ ampere

Tap H $\quad 1/8 \times 6 = 0.75$ ampere
Minimum Trip $= 1.25 \times 0.75 = 0.94$ ampere

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:

$$7.5 \times \frac{1}{1.25} \times \frac{1}{0.9} = 6.6 \text{ amperes} \qquad (5)$$

To be sure the fault detector FD-1 will reset after a fault, the minimum tap setting is determined as follows:

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

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

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.

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

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 ampere
Minimum Trip = 1.0 x 1.25 a. = 1.25 ampere

Tap H 1/10 x 5 = 0.5 ampere
Minimum Trip = 1.25 x 0.5 a. = 0.63 ampere

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

INSTALLATION

The SKBU relay is generally supplied in a cabinet or on a relay rack as part of a complete assembly. The location must be free from dust, excessive humidity, vibration, corrosive fumes, or heat. The maximum temperature around the chassis must not exceed 55°C.

ADJUSTMENTS AND MAINTENANCE

NOTE: The SKBU relay is normally supplied as part of a carrier relaying system, and its calibration should be checked after the system has been installed and interconnected. Details are given in the instructions of the assembly. The assembly instructions and not the following instruction should be followed when the relay is received as an integral part of the relaying system.

In those cases where the SKBU relay is not a part of a relaying system, the following procedure can be followed to verify that the circuits of the SKBU relay are functioning properly.

Test Equipment:

1. Oscilloscope
2. A.C. Current Source
3. Electronic Timer
4. A.C. Voltmeter
5. D.C. Voltmeter

Acceptance Test

Connect the relay to the test circuit of Fig. 8 which represents the TC carrier channel for test purposes.

Open all test switches of the test circuit and connect a 60 cycle test current between terminals 3 and 4 of the relay. Set relay taps on C and H and remove T tap screw.

1. Filter Output

a. Connect a high resistance a-c voltmeter across common of T tap block and the common of Ro tap block.

b. Pass with 3.44 amperes, 60 cycles into terminal 3 and out terminal 4 of relay. Voltmeter should read between 0.75 volts and 0.85 volts a-c.

2. FD-1 Pickup and Dropout

a. Set relay taps 5, C, and H. Close all switches of test circuit.

b. Connect a high resistance d-c voltmeter across X14 and X3 (Neg.)

c. Apply 60 cycle current to terminals 3 and 4 of the relay. Gradually increase the current until the voltmeter changes reading from approximately zero volts to approximately 20 volts. This is the operating current of FD-1 and should be 4.33 ± 5% amperes.

d. Gradually lower a-c test current until the d-c voltmeter drops to approximately zero volts. This is the dropout current of FD-1 and should occur at 80% of the pickup current.

3. FD-2 Pickup and Dropout

a. With the current test leads connected as in the FD-1 test, connect the voltmeter across X13 and X3 (Neg.)

b. Gradually raise a-c current until voltmeter reads approximately 45 volts. This should be 5.41 ± 5% amperes.

c. Gradually lower a-c test current until the d-c voltage reading drops to zero volts. This is dropout of FD-2 and should occur at 90% of pickup current.

4. Check of Local Squaring Amplifier

a. Open switches A, B, C, D, and E of test circuit.

b. Place scope across X10 and X3 (GRD). Apply 5 amperes a-c to terminals 3 and 4 of relay.

c. A square wave voltage should appear across X10 and X3 with the waveshape of Table III.

5. Check of Keying Circuit

a. Open all switches of test circuit and apply 5 amperes a-c to terminals 3 and 4 of the relay.

b. With scope check voltage across X11 and X3 (GRD). Waveform should be a square wave as shown in Table III.

c. Close switches A, B, C, and D. No change should be noted in waveform across X11 and X3 (GRD).

6. Check of Remote Squaring Amplifier

a. Close switches A, B, and C of the test circuit.

b. Apply 5 amperes a-c to terminals 3 and 4 of the SKBU relay.

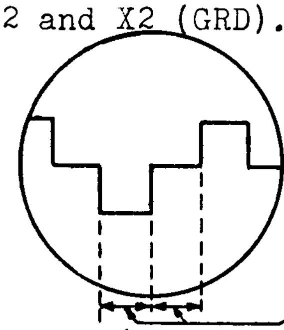
c. Put scope across X9 and X3 (GRD). A square wave of voltage should be obtained (see Table III).

7. Setting of S5 and S6

a. Set S5 to minimum resistance and S6 to maximum resistance (fully clockwise).

b. With switches A, B, and C of the test circuit closed, apply 6 amperes a-c to terminals 3 and 4 of the SKBU relay.

c. Place scope across X12 and X2 (GRD). Adjust S5 until following waveform is obtained.

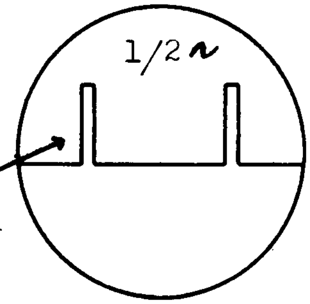


4 ms. each (approximately) These two intervals equal

d. Close switch D and adjust S6 until the AR trips. In the case of a voltage output SKBU relay, place d-c voltmeter across X16 and X3. Tripping is indicated by a change in voltage from 0 to 20 volts. This sets the triggering of the flip-flop after a 4 millisecond delay. Recheck pickup by moving 55 minimum, opening and closing switch D and then adjusting S5 until AR operates. It may be necessary to readjust S6 to obtain AR tripping on waveform of step c.

e. Slowly increase S5 to obtain the following waveform. Adjust for minimum area of the pips. This will be with S5 near minimum resistance.

*** Minimum Pips may point up as shown or down**



8. Check of Transient Blocking

a. Connect electronic timer stop to X7 and X3 (GRD). Set timer stop on negative going pulse.

b. Connect timer start to timer start contacts of switch D. Set timer start to make.

c. With switches A, B, and C open, apply 6 amperes a-c to terminals 3 and 4 of the SKBU relay.

d. Close switch D and measure time for voltage to drop from 20 volts to approximately zero volts. This should be between 20 to 30 milliseconds. Take average of ten readings.

9. Check of Transient Unblocking Circuit

a. With electronic timer stop connected to X7 and X3 (GRD), set timer stop on positive going pulse. Also connect a-c voltmeter across X7 and X3 (NEG.)

b. Connect timer start to timer start contacts of switch A.

c. Apply 6 amperes a-c to terminal 4 and 3 of the SKBU relay, and close switches A, B, C, and D of test circuit. Closing switch D sets up transient blocking as can be seen by a change in voltage from 20 volts d-c to 0 volt d-c.

d. Open switch A and measure time for voltage to change from approximately zero volt to 20 volts. Time should be 20 to 30 milliseconds. Measure average of 10 trials. For each trial it will be necessary to close switch A and then open switch D. Switch D should then be closed and A opened to measure the unblocking time.

10. Check of Carrier Squelch Circuit

a. Connect timer stop across X11 and X3 GRD. Set timer stop on negative pulse.

b. Connect timer start. Set timer start to make.

c. Open switch C. Approximately 20 volts should appear across X11 and X3.

d. Close switch E and measure time for voltage to disappear. This should be 8 to 12 milliseconds.

e. Set timer stop on positive pulse and timer start on break.

f. Measure time for voltage to reappear by opening switch E. Time should be 120 to 180 milliseconds.

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.

CALIBRATION

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs. The relay should be connected to the test circuit of Fig. 8.

1. Sequence Filter

To calibrate the sequence filter, the top cover must be removed and the following procedure used: Remove the T tap screw and insert the tap screws in tap C and H of the R1 and Ro taps. Pass a single-phase current of 10 amperes, rated frequency through the reactor coils in series from phase B to phase C (relay terminals 4 and 5). Accurately measure the a-c voltage from terminal 3 to the common of the T tap plate. This voltage should be between 3.7 and 4.1 volts. Now pass 10 amperes from terminal 3 to terminal 4 with tap screw C removed, and connect voltmeter from terminal 3 to the right-hand (front Ro view) adjustable point of the formed resistor. Adjust this point to give a voltage equal to exactly one-third of the reactor drop. Note the above reading, and adjust the intermediate tap of formed resistor to give exactly 2/3 of the voltage obtained above for all of formed resistor. Measure this voltage from terminal 3 to the intermediate tap.

2. Phase Splitter

If replacement of the fault detector board or major component on the board necessitates a complete recalibration, proceed as follows:

a. Set relay taps 5-C-H.

b. Set S1 and S3 to full clockwise position.

c. Set S2 and S4 to mid-scale.

d. Pass 4.33 amperes through relay terminal 3 to terminal 4.

e. On fault detector board, check the a-c voltage from TP51 to TP52 and from TP52 to TP53 with a VTVM. Adjust the small pot. R53 on the fault detector board until these two voltages are equal.

f. Close all switches of test circuit and connect VTVM across X14 and X3 (Neg.)

g. Slowly turn S3 counterclockwise, with 4.33 amperes flowing, until FD-1 operates as indicated by a change in voltage reading from approximately zero volts to 20 volts d-c.

h. Reduce the a-c current to check FD-1 dropout. Adjust S4 to obtain 80 percent dropout (3.46 amperes). Dropout is indicated by a change in voltage reading from approximately 20 volts to 0 volt.

i. Recheck FD-1 pickup and dropout, and touch up S3 and S4 in that order for the correct calibration. Tighten the locking device.

j. Similarly recalibrate FD-2 using controls S1 (pickup) and S2 (dropout), repeating steps g, h, and i, except for FD-2 pickup of 5.41 amperes and dropout of 4.85 amperes. Pickup is measured using X13 and X3 (negative) and is indicated by a change in voltage reading from a low voltage to 45 volts.

3. 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 AR unit is not in proper working order, and then only if suitable tools are available for checking the adjustments.

a. 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.

b. 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.

c. Adjust each stationary contact screw to obtain a contact gap of 0.020 inch. This will give 15-30 grams contact pressure.

4. Check of Solid-State Circuits

Perform tests listed under "Acceptance" tests to verify that the SKBU relay is functioning correctly.

TROUBLE SHOOTING PROCEDURE

To trouble shoot the equipment, the logic diagram of either Fig. 5 or 6, voltages of Table III, should be used to isolate the circuit that is not performing correctly. The schematic of either Fig. 3 or 4, and the voltages of Table IV should then be used to isolate the faulty component.

TABLE IV

VOLTAGE MEASUREMENTS OF PRINTED CIRCUIT BOARD

1. Fault Detector Board

D-C Voltages - positive with respect to negative d-c (terminal 8 of board).

Test Point	I=0	I=2 x FD-2 p.u.
Terminal 14	45.0 VDC	45.0 VDC
TP 54	6.6	6.8
TP 55	6.6	less than 1
TP 56	14.5	less than 1
TP 57	less than 1	14.5
TP 58	45	less than 1
Terminal 13 FD-1	less than 1	20
Terminal 15 FD-2	less than 1	45
TP 52 - TP 51	less than 1	18 VAC Approximately
TP 52 - TP 53	less than 1	17.8 VAC Approximately

2. Amplifier and Keying

D-C Voltages - positive with respect to negative (terminal 8 of board).

Test Point	Normal	Fault
Terminal 4	20	20
TP 101	20	10
TP 102	20.3	19.8
TP 103	less than 1	10
Terminal 3	less than 1	9.8

3. Output Board

D-C Voltages - positive with respect to negative (terminal 8 of board):

Test Point	Normal	Fault
TP 302	19.5	19.0
TP 301	10	8.5
Terminal 14	20	19.0

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 the repair work. When ordering parts, always give the complete nameplate data. For components mounted on the printed circuit board, give the circuit symbol and the electrical value (ohms, mfd, etc.).

ELECTRICAL PARTS LIST

Fault Detector Board

Circuit Symbol	Description	Westinghouse Style Number
	Capacitor	
C51	0.10 MFD	15449220
C52-C55	0.5	187A624H11
C53	0.25	187A624H02
C54	1.0	187A624H04
	Diodes	
D51 to D56 - D61	1N459A	184A855H08
D57 to D60 - D62	1N457A	184A855H07
	Transistors	
Q51-Q52-Q56-Q57	2N697	184A638H18
Q53	2N699	184A638H19
Q54	2N2043	184A638H21
Q55	2N652A	184A638H16
	Resistors	
R51	50 Ohm, 5W	185A209H06
R52	9.1K Ohm, 1/2W	187A763H50
R53	2.5K Ohm, Pot.	629A430H03
R54	2.7K Ohm, 1/2W	629A530H42
R55-R73-R78	10K Ohm, 1/2W	629A530H56
R56-R58	15K Ohm, 1/2W	187A641H55
R57	18K Ohm, 1/2W	184A763H57
R59	Thermistor 1D05N	185A211H05
R60-R65	68K Ohm, 1/2W	187A641H71
R61	.22 Meg. Ohm, 1/2W	184A763H83
R62-R64-R68-R74	10K Ohm, 1/2W	187A641H51
R63	.1 Meg. Ohm, 1/2W	187A641H75
R66	470K Ohm, 1/2W	184A763H91
R67	39K Ohm, 1/2W	187A641H65
R69	1K Ohm, 1/2W	187A641H27
R70	6.8K Ohm, 1/2W	187A641H47
R71	20K Ohm, 1/2W	629A530H63
R72	3.9K Ohm, 1W	187A643H41
R75	33K Ohm, 1/2W	187A641H63
R76	10K Ohm, 1W	187A643H51
R77	1K Ohm, 1/2W	629A530H43
	Zener Diodes	
Z51	In1832C	184A617H06
Z52-Z54	1N957B	186A797H06
Z53	1N1789	584C434H08
Z55	1N3686B	185A212H06

ELECTRICAL PARTS LIST

Amplifier and Keying

Circuit Symbol	Description	Westinghouse Style Number
	Capacitor	
C101	39 MFD	187A508H04
	Diodes	
D101-D102-D104-D106 to D112	1N457A	184A855H07
D103	1N91	182A881H04
	Transistors	
Q101 to Q104 Q107 to Q113	2N652A	184A638H16
Q105-Q106	2N697	184A638H18
	Resistors	
R101-R103-R114-R127	100K Ohm, 1/2W	187A641H75
R102	150K Ohm, 1/2W	184A763H79
R104	33K Ohm, 1/2W	187A641H63
R105	68K Ohm, 1/2W	187A641H71
R106	27K Ohm, 1/2W	187A641H61
R107-R119-R123	4.7K Ohm, 1/2W	187A641H43
R108-R109-R126	10K Ohm, 1/2W	187A641H51
R110	3.3K Ohm, 1/2W	184A763H39
R111	5.6K Ohm, 1/2W	187A641H45
R112	1.2K Ohm, 1/2W	184A763H29
R113	330 Ohm, 2W	185A207H15
R115	180K Ohm, 1/2W	187A641H81
R116-R117-R130	22K Ohm, 1/2W	187A641H59
R118-R121-R129	47K Ohm, 1/2W	187A641H67
R120-R122	470K Ohm, 1/2W	187A641H91
R124-R125	15K Ohm, 1/2W	187A641H55
R128	39K Ohm, 1/2W	187A641H65
	Zener Diode	
Z101	1N748A	186A797H13

Output Board

Circuit Symbol	Description	Westinghouse Style Number
	Capacitors	
C301	1.0 MFD	187A624H04
C302	0.25 MFD	187A624H02
C303	3.0 MFD	188A293H06
C304-C306	0.05 MFD	187A624H08
C305	0.22 MFD	188A293H02
	Diodes	
D301-D304-D305-D306	1N457A	184A855H07
D302-D303	1N91	182A881H04

ELECTRICAL PARTS LIST

Output Board (continued)

Circuit Symbol	Description	Westinghouse Style Number
	Transistor	
Q301-Q305-Q306-Q307	2N652A	184A638H16
Q302-Q303-Q304	2N697	184A638H18
Q308	2N699	184A638H19
	Resistors	
R301-R303-R309-R310-R313-R324-R325	10K Ohm, 1/2W	187A641H51
R302	120K Ohm, 1/2W	187A641H77
R304	47 Ohm, 1/2W	187A640H17
R305	8.2K Ohm, 1/2W	187A641H49
R306-R315-R322	4.7K Ohm, 1/2W	187A641H43
R307-R331	2.2K Ohm, 1/2W	187A641H35
R308-R320	6.8K Ohm, 1/2W	187A641H47
R311	470 Ohm, 1/2W	187A641H19
R312	470K Ohm, 1/2W	187A641H91
R316-R321-R323	22K Ohm, 1/2W	187A641H59
R317-R328-R332	5.6K Ohm, 1/2W	184A763H45
R318	15K Ohm, 1/2W	187A641H55
R319	Thermistor 1D101	185A211H04
R326-R329	4.7K Ohm, 1/2W	184A763H43
R327	6.8K Ohm, 1/2W	184A763H47
R330	1.5K Ohm, 1/2W	187A641H31
	Zener Diodes	
Z301-Z303-Z305	1N957B	186A797H06
Z320	1N965B	186A797H08
Z304	1N960B	186A797H10
Z306	1N1789	584C434H08

Relay Board

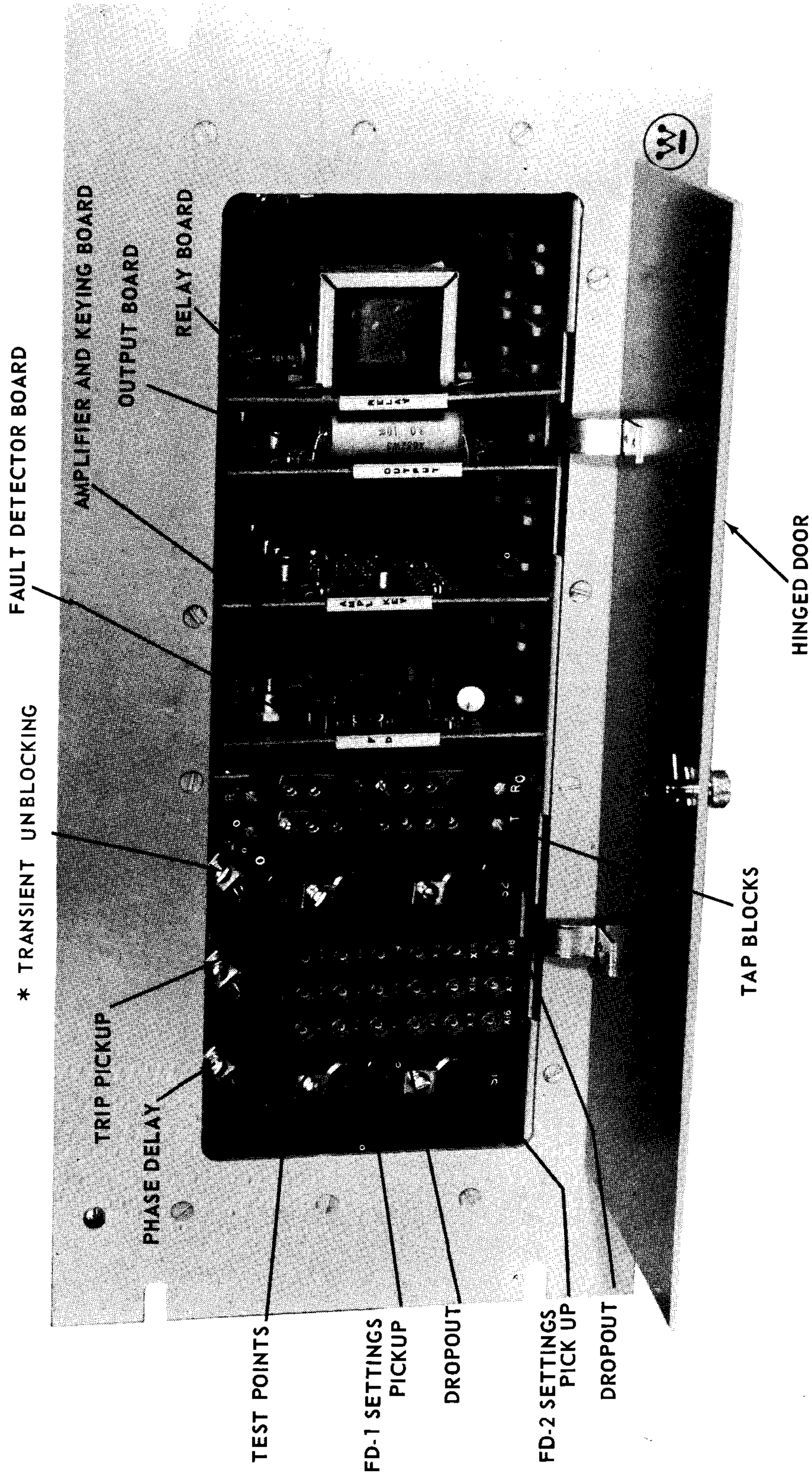
Circuit Symbol	Description	Westinghouse Style Number
	Capacitors	
C251-C252-C253	0.25 MFD	187A624H02
	Resistors	
R251-R252	2.2K Ohm, 1/2W	187A641H35
R253	800 Ohm, 3W	184A859H06
	Filter Choke	
L251	8.5HY, 400 Ohm	188A460H01
	Trip	
AR		408C845G09

Where a voltage output is required, the AR relay is omitted and the following additional parts are located on the board.

ELECTRICAL PARTS LIST

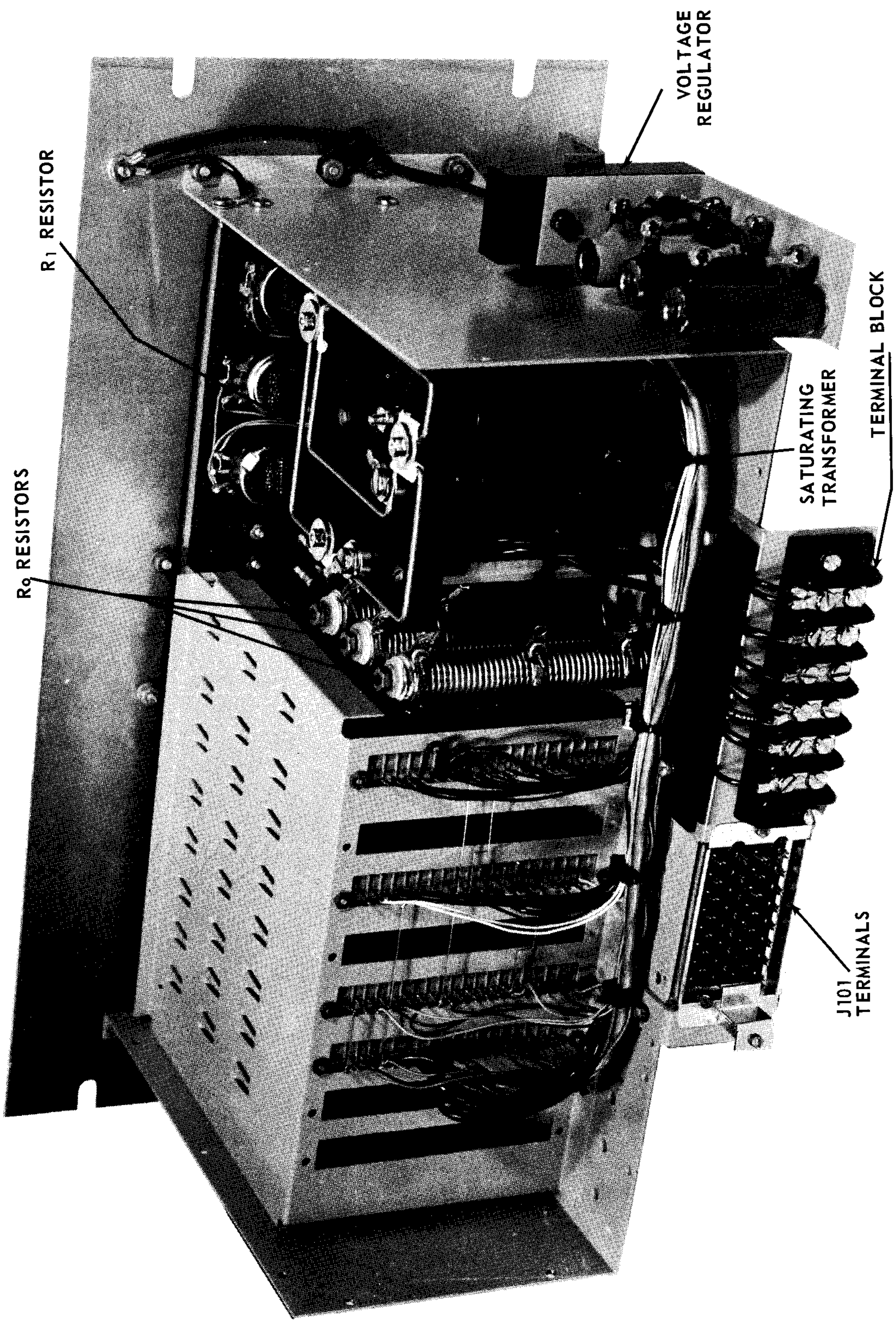
Relay Board (continued)

Circuit Symbol	Description	Westinghouse Style Number
	Capacitors	
C254	0.25 MFD	187A624H02
	Diodes	
D251-D252	IN457A	184A855H07
D253	CER-69	188A342H06
	Transistors	
Q251-Q252	2N398A	184A638H12
	Resistors	
R253,R256	IK Ohm, I/2W	184A763H27
R254	2.2K Ohm, 3W	184A859H15
R255	330 Ohm, 3W	184A859H14
R257	10K Ohm, 1/2W	184A763H51
R259	2.25K Ohm, 3W	184A636H03
	Zener Diode	
Z251	IN3686B	185A212H06



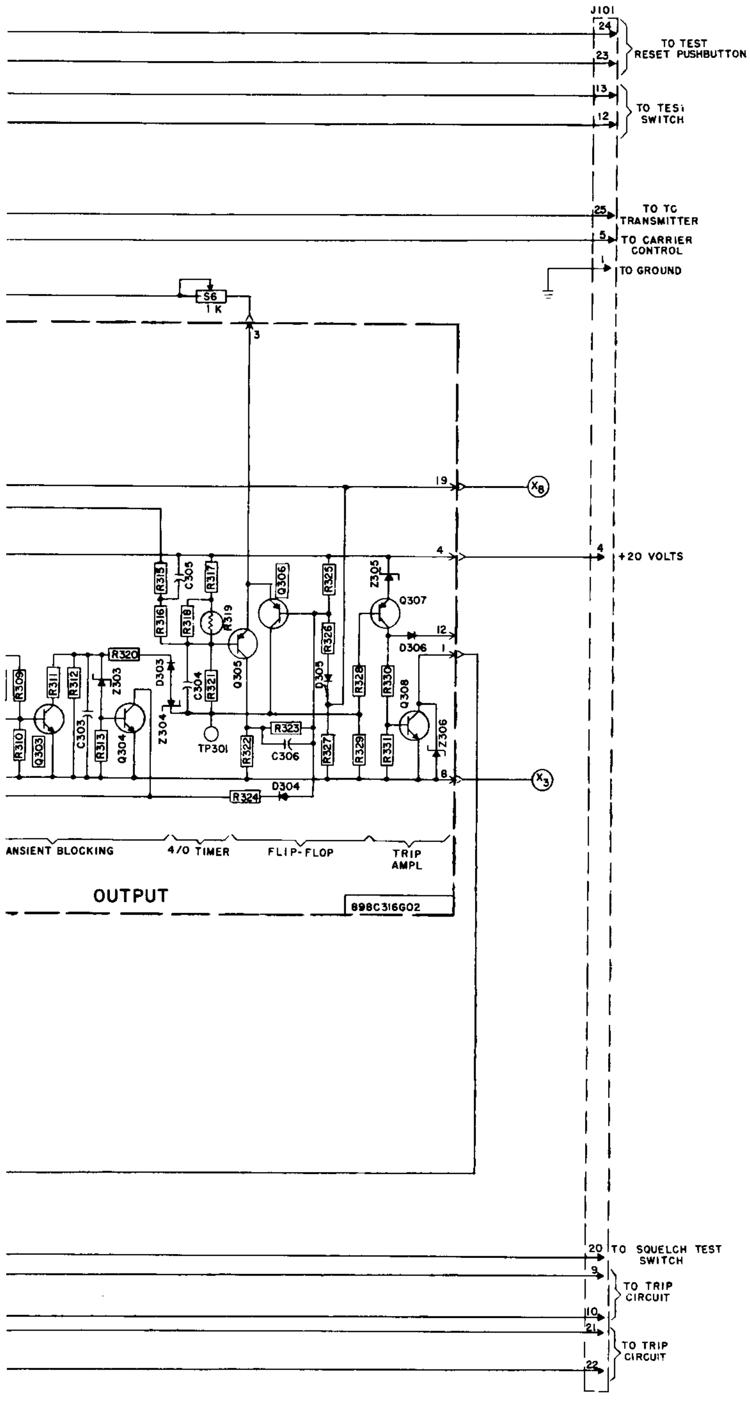
N365472

Fig. 1 Type SKBU Phase Comparison Relay (Front View)

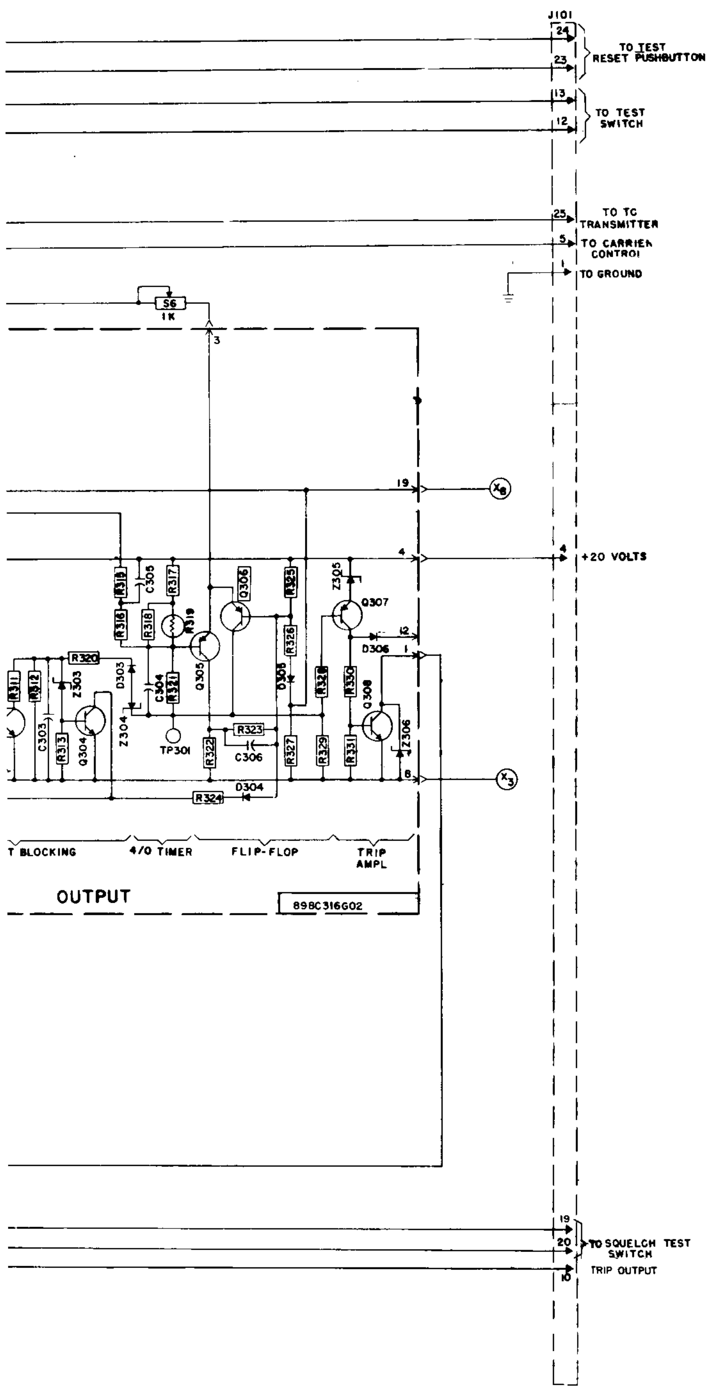


N365471

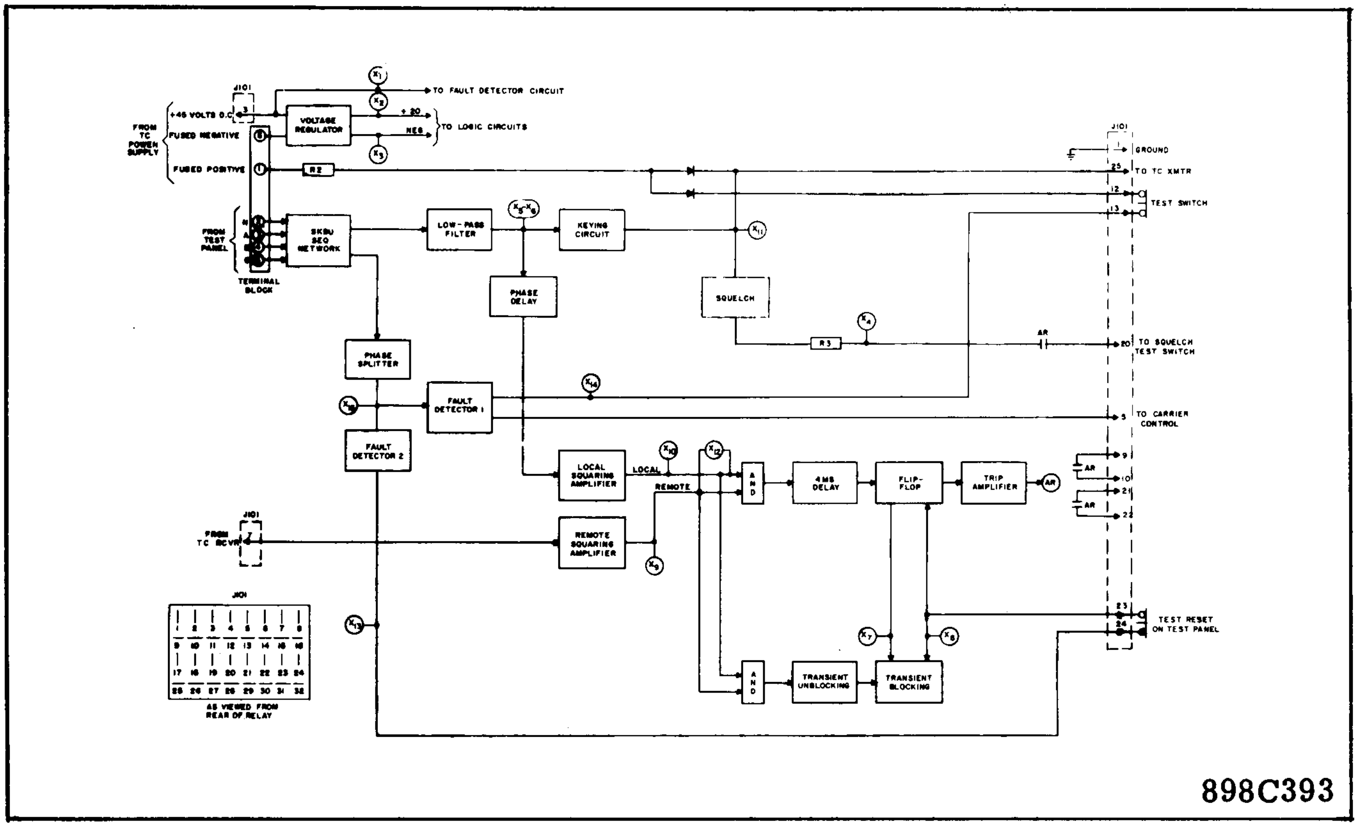
Fig. 2 Type SKBU Phase Comparison Relay (Rear View)


J101
TO TEST
RESET PUSHBUTTON
TO TEST
SWITCH
TO TC
TRANSMITTER
TO CARRIER
CONTROL
TO GROUND
S6
1 K
+20 VOLTS
R315
C305
R317
Q306
R325
Z305
Q307
R316
R318
R319
Q305
R326
D306
R320
D303
R309
R311
R312
Z303
C304
R321
D305
R328
R330
Q308
Z304
Q303
Q304
R313
C303
TP301
R322
R323
C306
R327
R329
R331
Z306
R310
R324
D304
ANSIENT BLOCKING
4/0 TIMER
FLIP-FLOP
TRIP
AMPL
OUTPUT
898C316G02
TO SQUELCH TEST
SWITCH
TO TRIP
CIRCUIT
TO TRIP
CIRCUIT

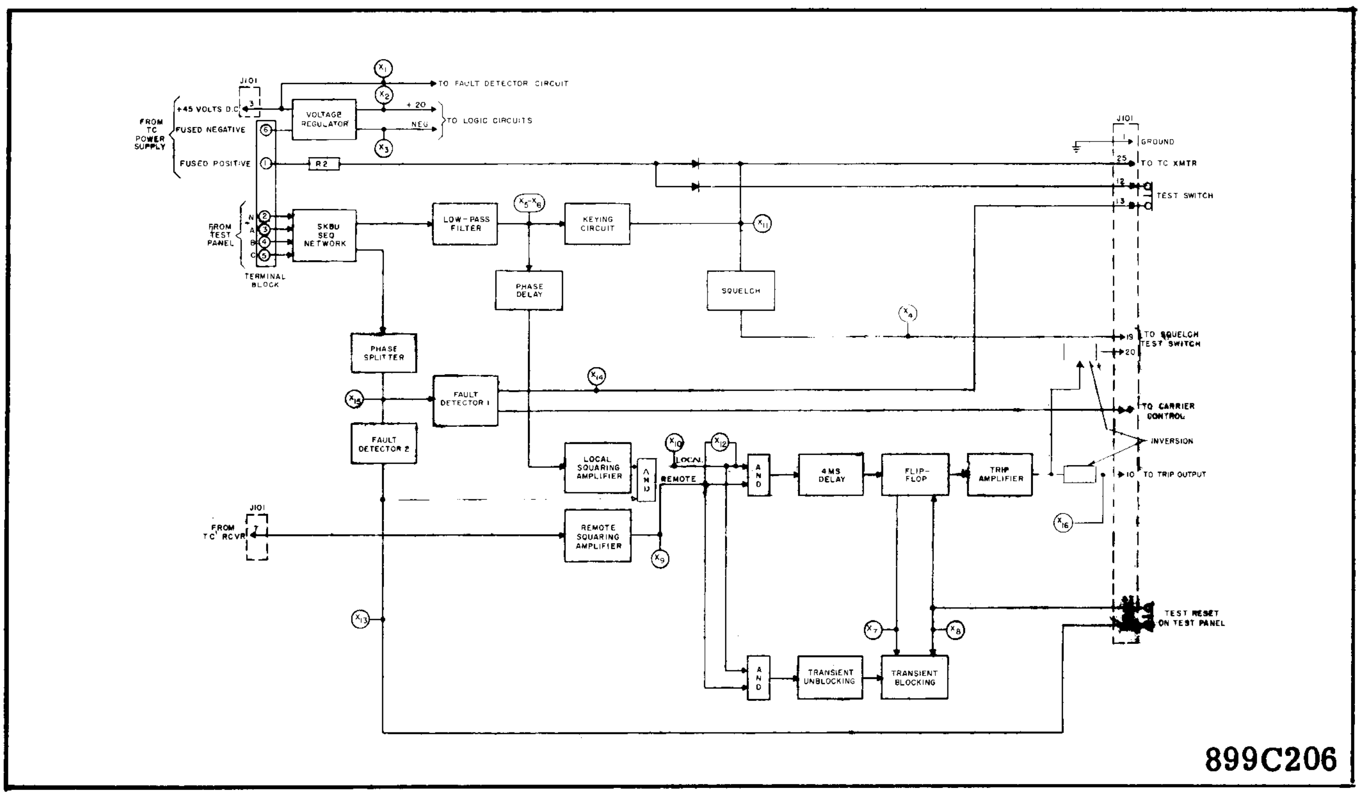
756J654


J101
TO TEST RESET PUSHBUTTON
TO TEST SWITCH
TO TC TRANSMITTER
TO CARRIER CONTROL
TO GROUND
+20 VOLTS
TO SQUELCH TEST SWITCH
TRIP OUTPUT
T BLOCKING
4/0 TIMER
FLIP-FLOP
TRIP AMPL
OUTPUT
898C316G02
TP301

756J704



* **Fig. 5 Logic Diagram of the Type SKBU Relay with an AR Output**



* **Fig. 6 Logic Diagram of the Type SKBU Relay with a Voltage Output**

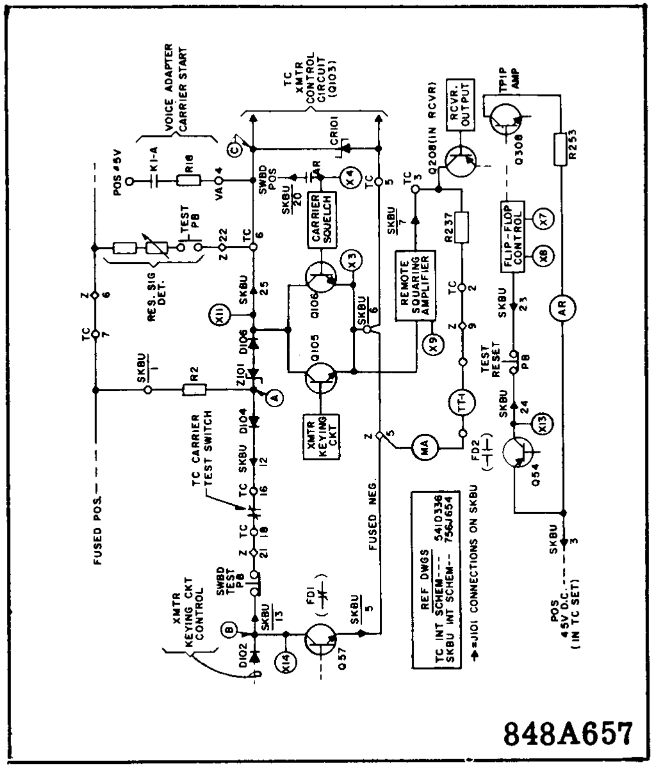
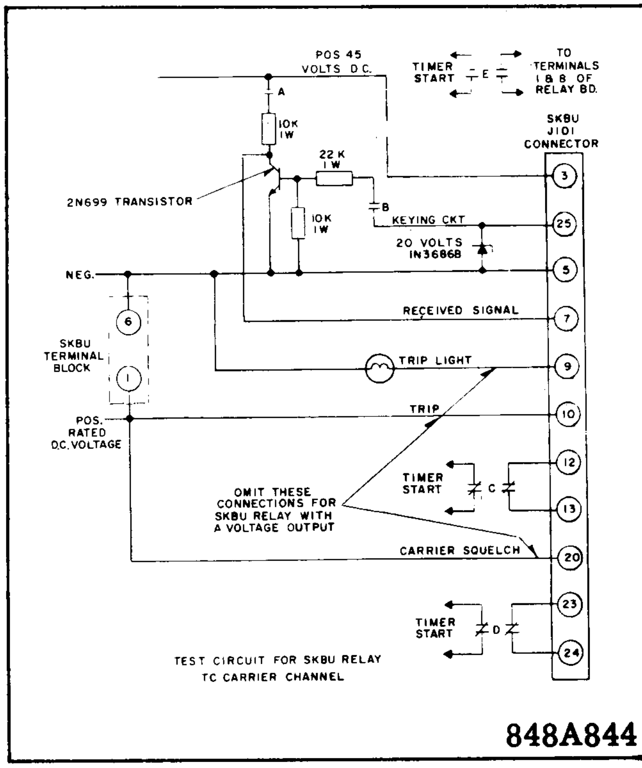


Fig. 7 Elementary Connections of TC SKBU Control Circuits



* Fig. 8 Test Circuit of SKBU Relay

TEST POINT	CIRCUIT	VOLTAGES TO X3 (EXCEPT WHERE SPECIFIED)		
		NORMAL **	EXTERNAL FAULT	INTERNAL FAULT
X1	POSITIVE 45 VOLTS FROM TC SET	+45	+45	+45
X2	REGULATED 20 VOLTS D.C.	+20	+20	+20
X3	NEGATIVE FROM TC SET	—	—	—
X4	CARRIER SQUELCH	0	0	RATED SUPPLY VOLTAGE
*X5 / *X6	LOW PASS FILTER VOLTAGE AT 2 TIMES PICKUP OF FD-1	0	4 TO 7 VOLTS RMS	4 TO 7 VOLTS RMS
X7	TRANSIENT BLOCKING	20	0	20
X8	ARMING	12	+20	+20
X9	REMOTE SQUARING AMPLIFIER	0	20 / 0	20 / 0
X10	LOCAL SQUARING AMPLIFIER	20	20 / 0	20 / 0
X11	KEYING	0	20 / 0	20 / 0
^X12	LOCAL REMOTE COMPARER	—	0 / 2	0 / 2
X13	FD-2	0 ø	+45	+45
X14	FD-1	0	+20	+20
X15	PHASE SPLITTER AT 2 TIMES PICKUP OF FD-1	0	16V D.C / 0	16V D.C. / 0
X16	TRIP OUTPUT-SKBU RELAY WITH VOLTAGE OUTPUT ONLY	0	0	20 VOLTS D.C.

* = VOLTS A.C. ACROSS X5 AND X6   ** NO LOAD CURRENT
^ = VOLTS D.C. TO X2
ø = READING VARIES WITH VOLTMETER USED

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* Fig. 9 Table III, Voltages of SKBU Relay

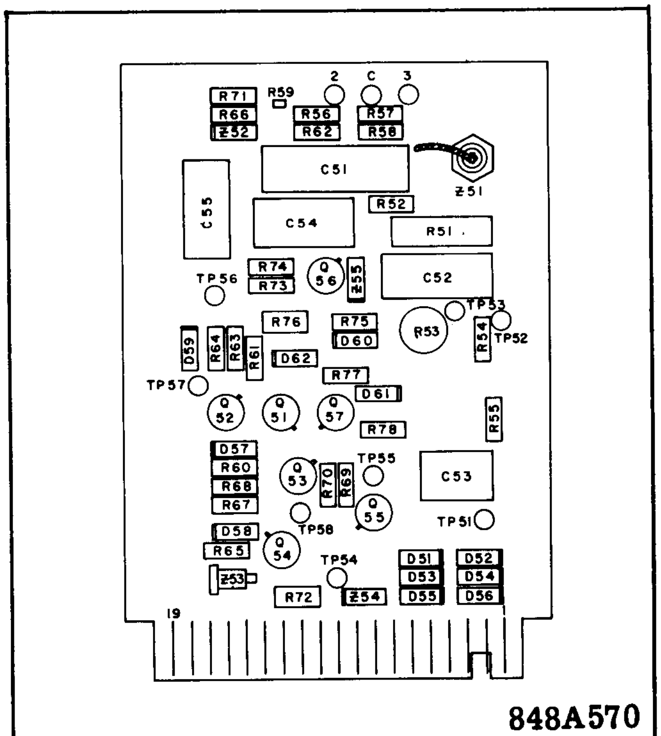


Fig. 10 Component Location on Fault Detector Printed Circuit Board for Type SKBU Relay

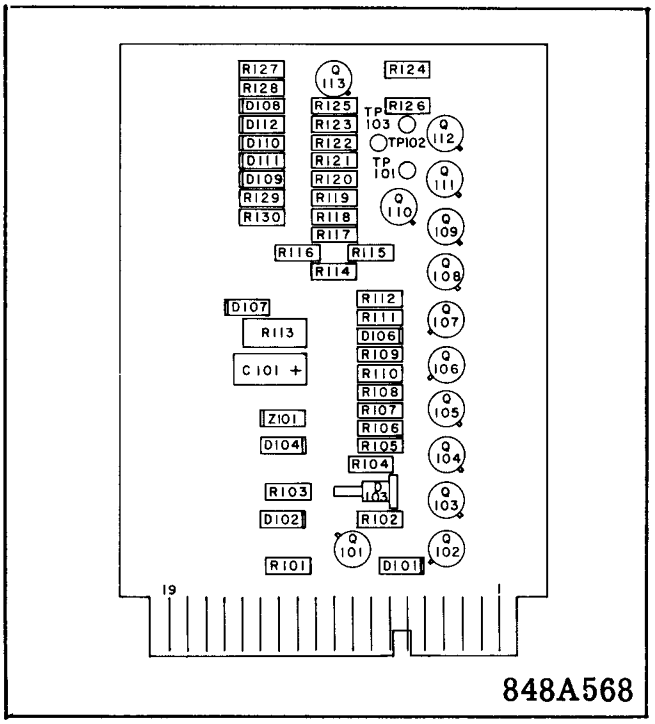


Fig. 11 Component Location on Amplifier and Keying Printed Circuit Board for Type SKBU Relay

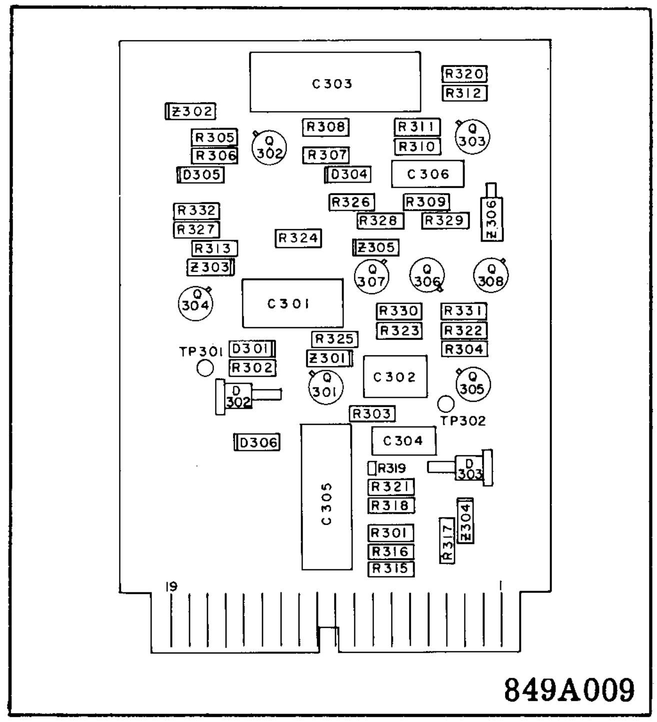


Fig. 12 Component Location on Output Printed Circuit Board for Type SKBU Relay

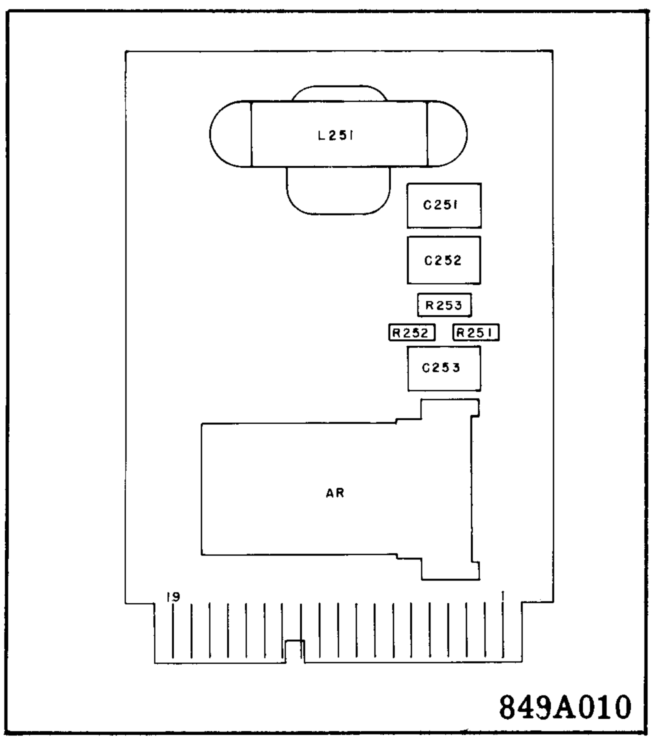


Fig. 13 Component Location on Relay Printed Circuit Board with an AR Output for Type SKBU Relay

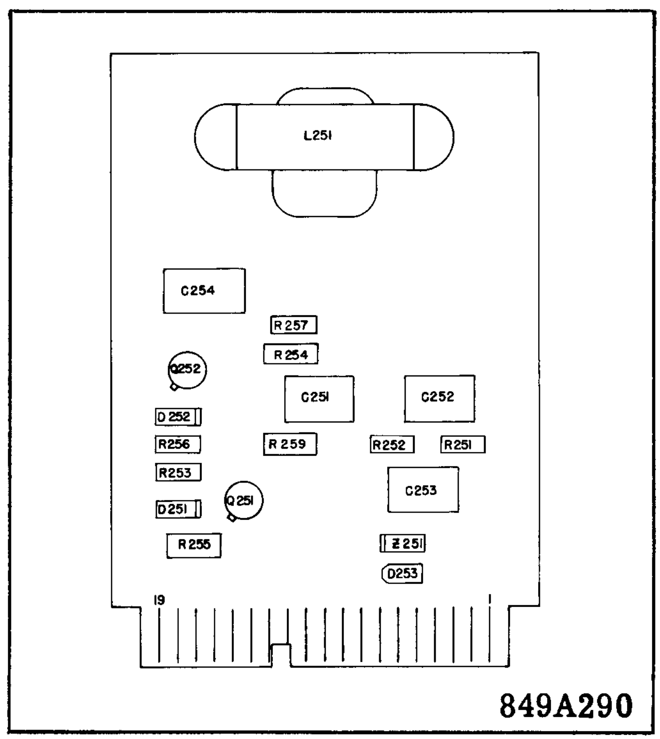
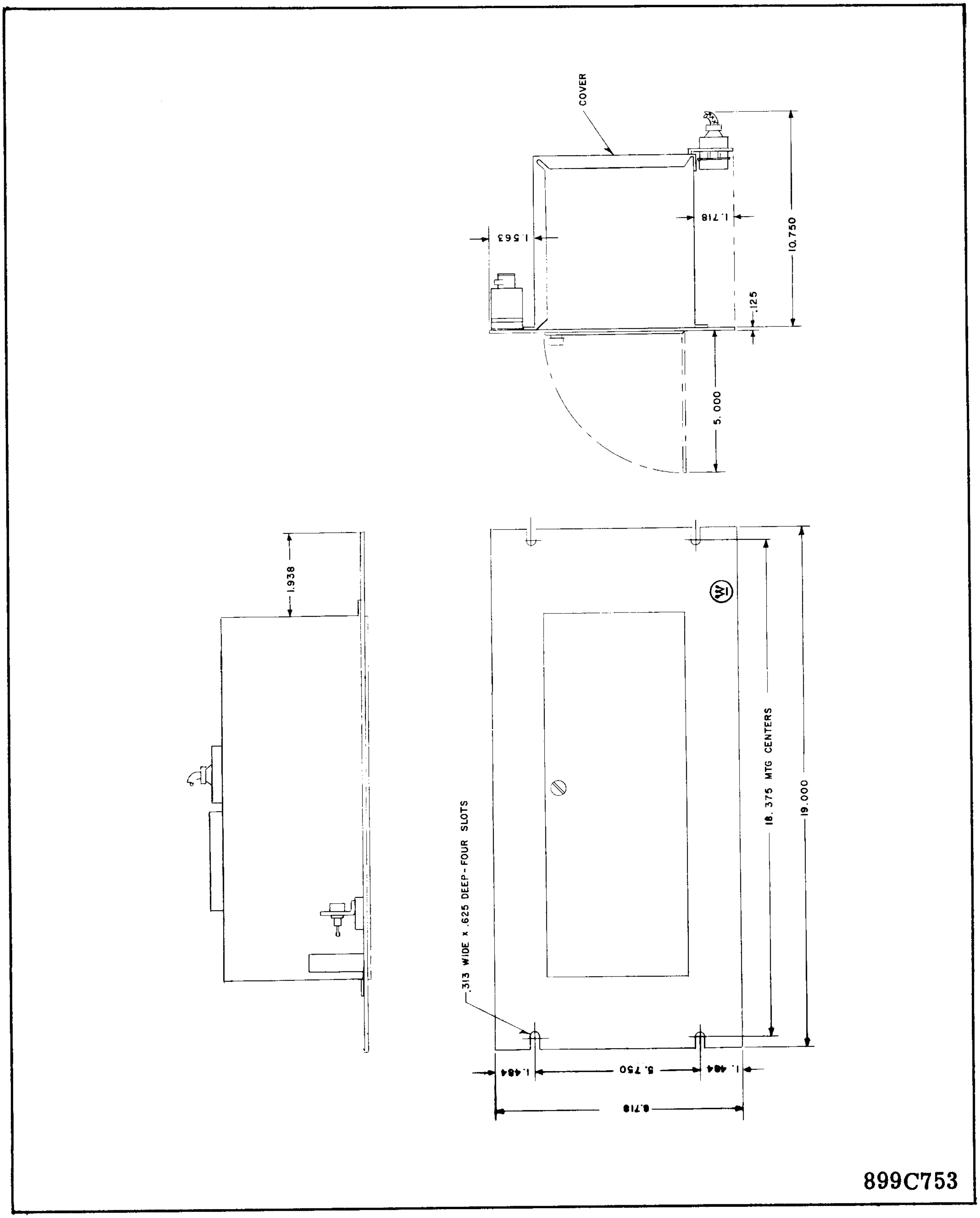


Fig. 14 Component Location on Relay Printed Circuit Board with a Voltage Output for Type SKBU Relay



* Fig. 15 Outline and Drilling Plan for Type SKBU Relay

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