INSTALLATION • OPERATION • MAINTENANCE

# INSTRUCTIONS

## TYPE SBF STATIC BREAKER FAILURE RELAY



CAUTION: Before putting relay into service, operate the relay to check the electrical connections. Close output switches last when placing relay in service. Open output switches first when removing relay from service.

### APPLICATION

This is a static breaker failure relay which monitors two phase currents, residual current, and a breaker trip circuit. The simultaneous presence of fault current plus a breaker tripping signal indicates that the breaker has failed to operate.

### CONSTRUCTION

Each current monitor contains an input transformer, a setting circuit, and a phase splitter circuit. Common to the three current monitors are a sensing circuit, an amplifier circuit, a voltage regulator, a feedback circuit and a transistor output.

An additional circuit monitors the breaker trip circuit. It contains a signal detector and amplifier, an oscillator, an isolating transformer, and an output amplifier.

Figure 1 shows the front and rear views of the relay.

Input Transformer - The input transformer is a two winding type with a non-tapped primary winding and a tapped secondary winding. The secondary is connected to the setting circuit and from a fixed tap to the phase splitter circuit as shown in Fig. 2.

Setting Circuit - The setting circuit is connected across the secondary winding of the input transformer and consists of two branches, a resistor and a rheostat connected in parallel with a resistor and Zener diode. This circuit loads the transformer and produces a secondary voltage proportional to the input current. The rheostat has a locking feature to minimize accidental change of current setting.

Phase Splitter Circuit - The phase splitter circuit consists of a capacitor, resistor, potentiometer and a three-phase rectifier bridge. This circuit converts the single phase a.c. voltage from the output of the transformer to a three-phase voltage and rectifies this voltage to d.c. as shown in Fig. 3.

Sensing Circuit - The sensing circuit consists of three resistors, a transistor and a Zener diode. This circuit is connected between the output of the phase splitter circuit and the amplifier circuit. In this circuit, a reference voltage is established which turns the transistor on. To turn the transistor off, the output voltage from the phase splitter must be greater than the reference voltage.

Amplifier Circuit - The amplifier circuit consists of a normally conducting transistor, Zener diode, three resistors and a diode. This is the final output stage of the current monitoring circuits.

Feedback Circuit - The feedback circuit consists of a resistor, potentiometer, and diode. This circuit controls the dropout current of the relay.

Voltage Regulator Circuit - The voltage regulator circuit consists of a silicon power regulator and a series resistor. The silicon power regulator is a 10 watt Zener diode mounted on an aluminum heat sink. The series resistor is a 3-1/2 inch resistor and is used to reduce the supply voltage to the Zener voltage.

Signal Detector - The signal detector and amplifier contains a Zener diode for level detection and two transistors with biasing resistors. The oscillator consists of a capacitor, a four layer diode and the primary of the isolation transformer. Output from the transformer is rectified and supplied to a two stage output amplifier. These components are all on the printed circuit board located at the top in the front view of Fig. 1.

## OPERATION

### Overcurrent Units

An overcurrent unit and the signal detector must both operate simultaneously before an output voltage will appear between terminals 1 and 2.

The components of the SBF relay are connected as shown in Fig. 3. With no input to the relay, transistors $Q_1$, $Q_2$ and $Q_{103}$ are conducting and less than 1.0 volt output is obtained from terminal 1 to terminal 2. Zener diode ($Z_4$) of the sensing circuit establishes the reference voltage from the emitter of $Q_1$ to negative and allows a base current to flow in $Q_1$ through $R_{11}$ to negative.

When a.c. current is applied to the primary of transformer (T1), a voltage is produced on the secondary side that is proportional to the amount of resistance in the rheostat (S1). This single phase voltage is applied to the phase splitter circuit where a three phase voltage is produced, rectified, and applied to resistor R11 of the sensing circuit through $R_{10}$. If the voltage from the rectifier is greater than the reference voltage across the sensing circuit, $Q_1$ turns off causing $Q_2$ to turn off and stop short circuiting the output. $Q_{103}$ must also stop conducting to obtain an output voltage.

If $Q_{103}$ is off when $Q_2$ turns off, voltage that develops across them is applied through a feedback circuit to the base of $Q_1$. By varying the magnitude of this voltage, the dropout of the relay can be regulated from approximately 98% to 0% of pickup.

When large currents are applied to the primary of the input transformer, the Zener clipper on the secondary prevents the voltage applied to the electronic components from becoming excessive.

Signal Detector

Transistor $Q_{103}$, in the Signal Detector circuit, can be turned off by applying a positive potential to the base circuit of $Q_{102}$. This voltage can be provided through relay terminal 13 from any source having a negative bus which is common to the output negative terminal 2.

An isolated voltage source may also be used to operate the Signal Detector. This is accomplished through the input amplifier, oscillator, and isolation transformer.

(Amplifier Circuit)

Current flow into the oscillator is controlled by a PNP type transistor $Q_{107}$. A standby potential of 125 volts d-c is required at terminal 11 with battery negative connected to terminal 20. Voltage across the amplifier circuit is regulated at 33 volts d-c by the Zener diode $Z_{102}$ and voltage dropping resistor R101.

The amplifier is turned on by a positive potential of 35V d.c. to 125V d.c. applied to terminal 12 with negative polarity connected to terminal 20. This causes current to flow into the base of the first stage transistor Q106 which is thereby driven into the conducting state. Base current for Q107 then flows through R106 and Q106 causing Q107 to conduct into the oscillator. When the positive signal is removed from terminal 12, Q106 reverts to a nonconducting state to block base current in Q107. Q107 then prevents the flow of current into the oscillator.

(Oscillator)

A capacitor C101 and four-layer diode Q101 produce voltage pulses across the transformer. When a voltage is allowed to develop across C101, it reaches the breakover level of the four-layer diode. At this time the diode Q101 quickly switches from a blocking state to a low resistance conducting state and thereby allows full capacitor voltage to be applied to the transformer primary. When C101 is discharged, Q101 switches back to the blocking state until its breakover voltage is reached again. This process continues as long as voltage is applied to the oscillator. A bridge rectifier converts the output of the transformer into a d.c. voltage which is applied to base circuit of Q102 to cause Q103 to turn off.

## CHARACTERISTICS

The SBF relay is available in the current ranges shown in Table I.

TABLE I

| Range | Scale Marking | | | | | |
|---|---|---|---|---|---|---|
| .25 - 1 ampere | .25 | .4 | .5 | .6 | .8 | 1.0 |
| .5 - 2 amperes | .5 | .75 | 1.0 | 1.25 | 1.5 | 2.0 |
| 1 - 4 amperes | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 4.0 |
| 2 - 8 amperes | 2 | 3 | 4 | 5 | 6 | 8 |
| 4 - 16 amperes | 4 | 6 | 8 | 10 | 12 | 16 |
| 10 - 40 amperes | 10 | 15 | 20 | 25 | 30 | 40 |

The setting of the relay is the minimum current required to produce an output. Settings between the scale markings can be obtained by applying the desired current to the relay and setting the rheostat at the desired point.

In the usual application, two inputs are the same range with a different range for the third input.

The operating time of the overcurrent units is shown in Fig. 4. As shown in the figure, there is a maximum and minimum operating time of the relay for each multiple of pickup. This difference in time is due to the point on the current wave that the fault current is applied. Figure 5 shows the operate times for different points on the fault wave for fault currents at twice pickup.

Current burden, current rating, and battery drain information is listed in Tables II, Table III, and Table IV respectively.

TABLE II

ENERGY REQUIREMENTS

| Ampere Range | Setting | VA at Setting | P.F. Angle | VA at 5 Amps. | P.F. Angle |
|---|---|---|---|---|---|
| .25 - 1 | .25 | 0.17 | 7.5 | 23 | 51° |
| | .4 | 0.31 | 15 | 22.8 | 50 |
| | .5 | 0.42 | 21 | 22.7 | 48 |
| | .6 | 0.54 | 25 | 22.6 | 48 |
| | .8 | 0.81 | 30 | 22.2 | 48 |
| | 1.0 | 1.20 | 35 | 21.8 | 48 |
| .5 - 2 | .5 | 0.17 | 7.5 | 8.80 | 32 |
| | .75 | 0.31 | 15 | 8.50 | 32 |
| | 1.0 | 0.42 | 21 | 8.10 | 33 |
| | 1.25 | 0.54 | 25 | 7.80 | 34 |
| | 1.5 | 0.81 | 30 | 7.60 | 36 |
| | 2.0 | 1.20 | 35 | 7.10 | 37 |
| 1 - 4 | 1 | 0.17 | 7.5 | 3.15 | 16 |
| | 1.5 | 0.31 | 15 | 2.95 | 19 |
| | 2 | 0.42 | 21 | 2.65 | 21 |
| | 2.5 | 0.54 | 25 | 2.35 | 25 |
| | 3 | 0.81 | 20 | 2.21 | 28 |
| | 4 | 1.20 | 35 | 2.0 | 30 |
| 2 - 8 | 2 | 0.22 | 7.5 | 1.4 | 13 |
| | 3 | 0.39 | 15 | 1.1 | 15 |
| | 4 | 0.60 | 21 | 0.95 | 21 |
| | 5 | 0.85 | 25 | 0.85 | 25 |
| | 6 | 1.17 | 30 | 0.80 | 30 |
| | 8 | 1.94 | 35 | 0.73 | 35 |
| 4 - 16 | 4 | 0.26 | 8.5 | 0.41 | 8.5 |
| | 6 | 0.49 | 13 | 0.34 | 13 |
| | 8 | 0.80 | 15 | 0.3 | 15 |
| | 10 | 1.15 | 16.5 | 0.29 | 16.5 |
| | 12 | 1.57 | 17.5 | 0.28 | 17.5 |
| | 16 | 2.56 | 19 | 0.25 | 19.0 |
| 10 - 40 | 10 | 1.0 | 3 | 0.25 | 3 |
| | 15 | 2.1 | 4 | 0.23 | 4 |
| | 20 | 3.6 | 5 | 0.21 | 5 |
| | 25 | 5.9 | 6 | 0.21 | 6 |
| | 30 | 8.1 | 6 | 0.20 | 6 |
| | 40 | 14.4 | 6 | 0.20 | 6 |

TABLE III

CURRENT RATINGS

Rating of the Overcurrent Units

| Range | Continuous Rating (Amperes) | One Second Rating (Amperes) |
|---|---|---|
| .25 - 1 | 6 | 185 |
| .5 - 2 | 8 | 350 |
| 1 - 4 | 10 | 400 |
| 2 - 8 | 12 | 400 |
| 4 - 16 | 15 | 400 |
| 10 - 40 | 20 | 460 |

TABLE IV

Battery Drain at 125 Volts D.C.

| | |
|---|---|
| Overcurrent Unit Terminal 10 Input | 100 MA |
| Signal Detector | |
| Terminal 11 Input | |
| Standby | 20 MA |
| Tripping | 25 MA |
| Terminal 12 Input | 3 MA |
| Terminal 13 Input | 26 MA |

SETTING

The pickup of the relay is selected by adjusting the rheostat, S, in the front of the relay. Setting in between the scale marking can be made by applying the desired current and adjusting the rheostat until an output is obtained.

INSTALLATION

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

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

## ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer.

### Acceptance Tests

The following check is recommended to insure that the relay is in proper working order. All checks can best be performed by connecting the relay per the test circuit of Fig. 6. Close SW. 1 and close SW. 2 to the "A" position.

1. Minimum Trip Current - Check pickup at the minimum and and maximum setting. This is accomplished by applying the specified current and checking that the voltmeter reads approximately 20 volts when the current is within 3% of the setting.

2. Dropout - After checking pickup, the dropout should be checked to be approximately 90% of the pickup when the a.c. current is gradually reduced.

### Routine Maintenance

All relays should be checked at least once every year or at such other time intervals as may be dicated by experience to be suitable to the particular application.

### Calibration

The signal detector requires no calibration.

Use the following procedure for calibrating the overcurrent units if the relay adjustments have been disturbed. This procedure should not be used until it is apparent that the relay is not in proper working order. A new scale plate may be necessary when parts are changed.

### Splitter Adjustments

1. Turn rheostat S, (S1, S2, or S3), to extreme counter-clockwise position.

2. Apply minimum S current to the proper relay terminals.

3. With a high resistance voltmeter (a.c.) adjust phase splitter potentiometer P, (P1, P2, or P3) Fig. 7, such that three voltages approximately equal to each other are obtained across TP1, Printed Circuit Board terminal 12 and Printed Circuit Board terminal 14. Use TP2 and PCB terminals 17 and 18 with S2 and P2. Use TP3 and PCB terminals 8 and 9 with S3 and P3.

Dial Calibration (S)

1. Apply 125 volts d.c. to relay terminals 10, 11, 12, and 2 as shown in Fig. 6. Close SW. 1 and close SW 2 to the "A" position.

2. Connect a high resistance d.c. voltmeter across terminals 1 and 2. Terminal 1 is positive.

3. Apply desired S current to terminal 8 and 9.

4. Turn S rheostat until the relay operates as indicated by a sudden reading of approximately 20 volts d.c. on meter.

5. Open SW 2A and close SW 2B. Output should go to 0.0 then back to 20V.

Dropout (P)

1. Set S on desired point and apply S amperes to relay to make it operate.

2. Lower S amperes to desired dropout value and adjust P potentiometer until voltmeter drops to approximately zero.

3. Verify dropout and pickup several times by raising a.c. current until relay operates and then lowering the a.c. current until relay drops out.

Trouble Shooting Procedure

Use the following procedure to locate the source of trouble if the SBF relay is not operating correctly.

1. Inspect all wires and connections, paying particular attention to printed circuit terminals.

2. Check resistances as listed on the internal schematic of the relays.

3. Check voltages as listed on the electrical checkpoints.

## ELECTRICAL CHECKPOINTS

Connect relay per test circuit of Fig. 6. All voltage readings should be made with a high resistance voltmeter. Refer to Fig. 3 for printed circuit board points. For some readings it is necessary to scrape varnish from the components to make a connection at the point.

### I. 125 Volts D.C., No A.C. Input

| Component | | Negative Terminal | Approximate D.C. Voltage |
|---|---|---|---|
| Z4 | to | 2 | 7 Volts |
| Z5 | to | 2 | less than .6 volts |
| Z8 | to | 2 | 45 Volts |

### II. Minimum Trip $I_1$ A.C. Current Applied

| Circuit | Terminals | Voltage |
|---|---|---|
| Phase Splitter | $TP_1$ to board 12 | 7.5 volts a.c. |
| | $TP_1$ to board 14 | 7.5 volts a.c. |
| | Board 12 to board 14 | 7.5 volts a.c. |
| Setting | Board 16 to board 12 | 15 volts a.c. |
| Output | Terminal 1 (+) and 2 | 18 to 22 volts D.C. |

Use similar test points and values for $I_3$ and $I_o$ inputs.

Fig. 8 shows the component location for the signal detector.

## ELECTRICAL PARTS LIST

| Circuit Symbol | Description |
|---|---|
| **CAPACITORS** | |
| C1-C2-C3 | 0.5 Mfd. |
| C101 | .25 Mfd. |
| C102 - C103 | .47 Mfd. |
| C104 | 150 PF |

## ELECTRICAL PARTS LIST

| Circuit Symbol | Description |
|---|---|
| **DIODES** | |
| D1 to D18 - 20 | 1N459A |
| D19 | 1N457A |
| D23-D109-D114 to D118 | CER-69 |
| D101-D104 to D108-D112-D113 | CER-68 |
| D110 - D111 | CER-71 |
| Q101 (4 Layer Diode) | 4E20-28 |
| **POTENTIOMETERS** | |
| P1-P2-P3 | 2.5K ohms - 1/4 W |
| P4 | 200K ohms - 1/4 W |
| **TRANSISTORS** | |
| Q1 | 2N652A |
| Q2 - Q102 to Q105 | 2N697 |
| Q106 | 2N699 |
| Q107 | 2N1132 |
| **RESISTORS** | |
| R1-R4-R7 | 2.7K ohms - 1/2 W |
| R2-R5-R8 | 50 ohms - 25 W |
| R3-R6-R9 | 300 ohms - 25 W |
| R10 | 15K ohms - 1/2 W |
| R11 | 39K ohms - 1/2 W |
| R14 | 2.25K ohms - 3 W |
| R15 | 3.9K ohms - 1 W |
| R16 | 33K ohms - 1/2 W |
| R17 | 1K ohms - 1/2 W |
| R18 | 10K ohms - 1/2 W |
| R24 | 1250 ohms - 40 W |
| R101 | 5.0K ohms - 25 W |
| R102-R107-R108-R114 | 22K ohms - 1/2 W |
| R104-R106 | 4.7K ohms - 1/2 W |
| R105 | 10K ohms - 1/2 W |
| R109 | 47K ohms - 1/2 W |
| R110-R112 | 100 ohms - 1/2 W |
| R111-R113 | 4.7K ohms - 1 W |
| R115 | 4.75K ohms - 25 W |

# ELECTRICAL PARTS LIST

| Circuit Symbol | Description |
|---|---|
| **RHEOSTAT** | |
| S1 - S2 - S3 | 1.5K ohms - 25 W |
| **TRANSFORMER** | |
| T1 - T2 | Style No. 410C278 XXX* |
| T3 | Style No. 410C268 XXX* |
| T101 | Style No. 629A372H01 |
| **ZENER DIODES** | |
| Z1 - Z2 - Z3 | 1N1832C |
| Z4 | 1N957B |
| Z5 | 1N3686B |
| Z8 | 1N1829A |
| Z101 | 1N752A |
| Z102 | 1N2990B |

*Last three digits depend upon the range of the overcurrent units.

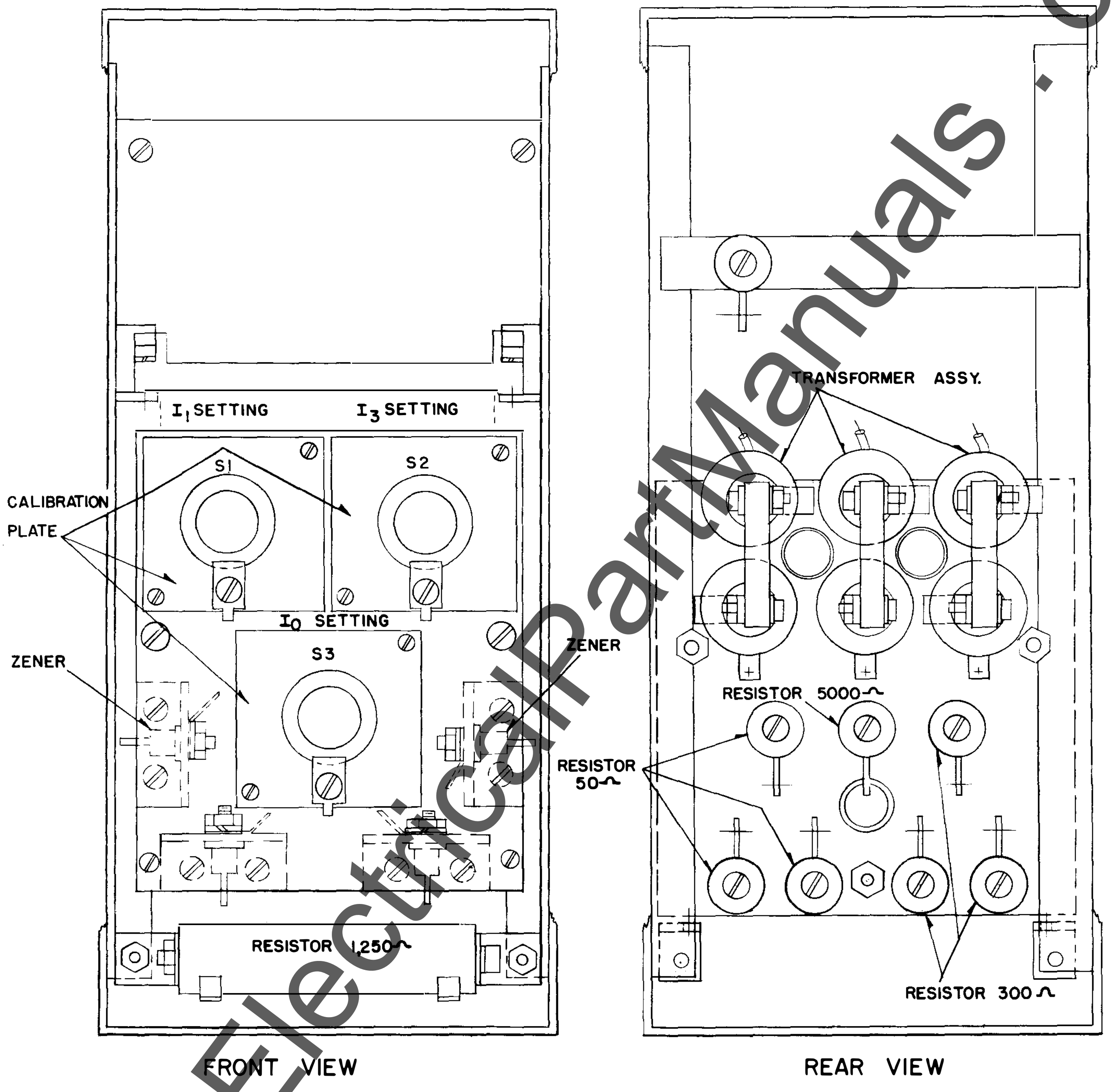



Fig. 1 Type SBF Relay in an FT32 Case.

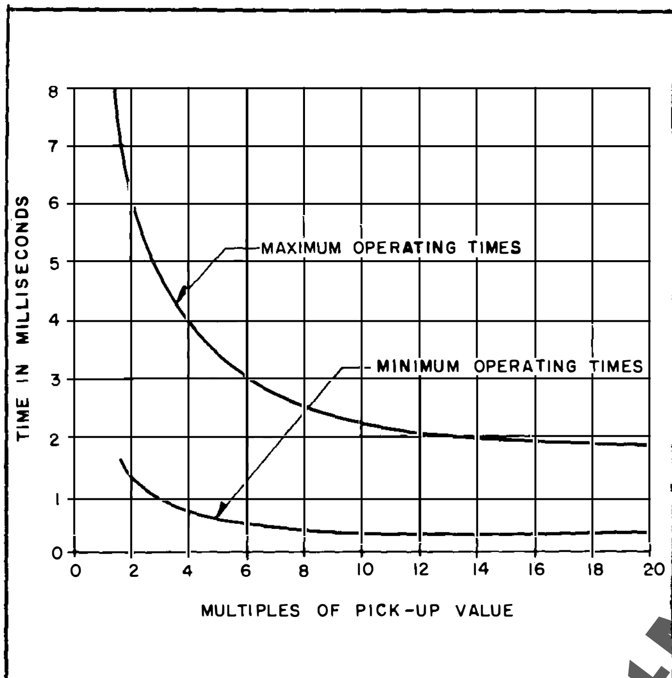


Fig. 4. Operating Time for the Overcurrent Units. (Dwg. 836A567).

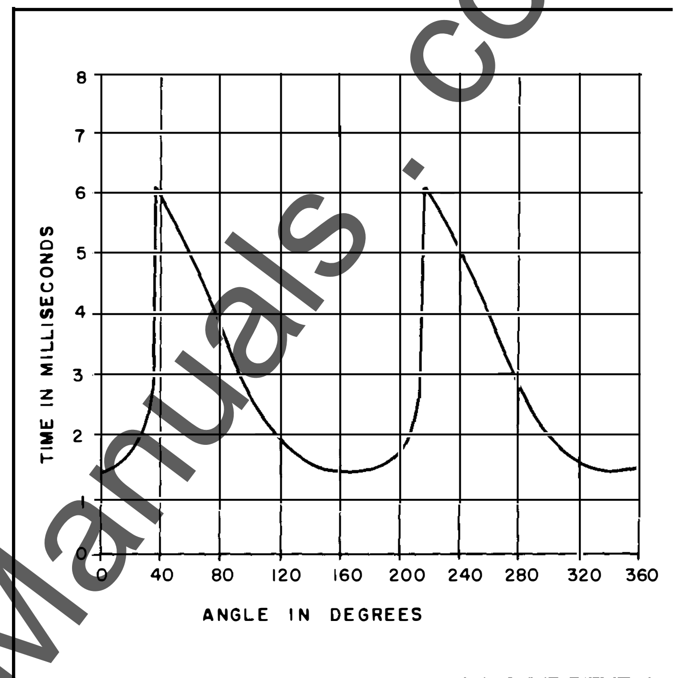


Fig. 5. Operating Time as a Function of Fault Incidence Angle at Twice Minimum Trip Current. (Dwg. 836A566).

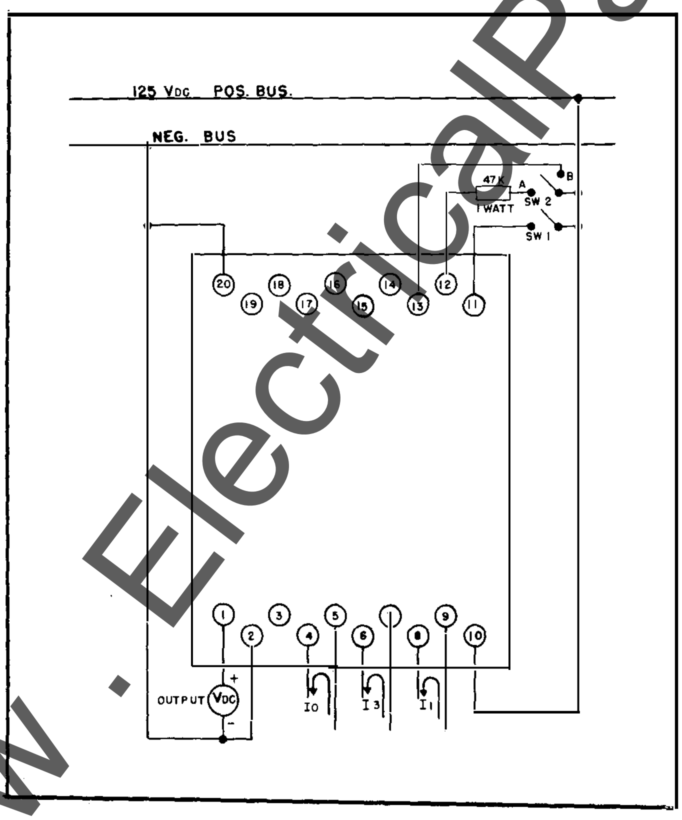


Fig. 6. Test Circuit for Type SBF Relay. (Dwg. 837A847)

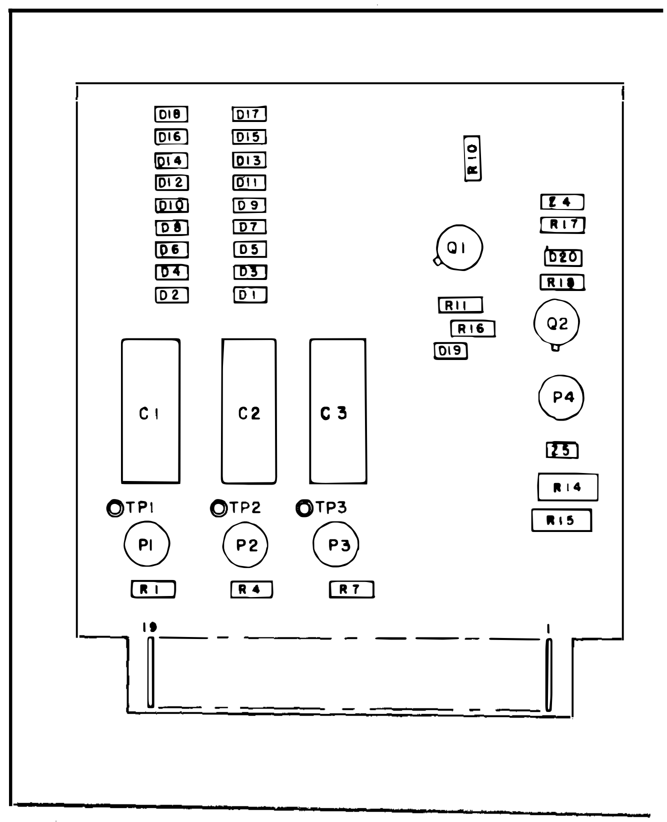


Fig. 7. Component Location for Overcurrent Logic in Type SBF Relay. (Dwg. 848A556).

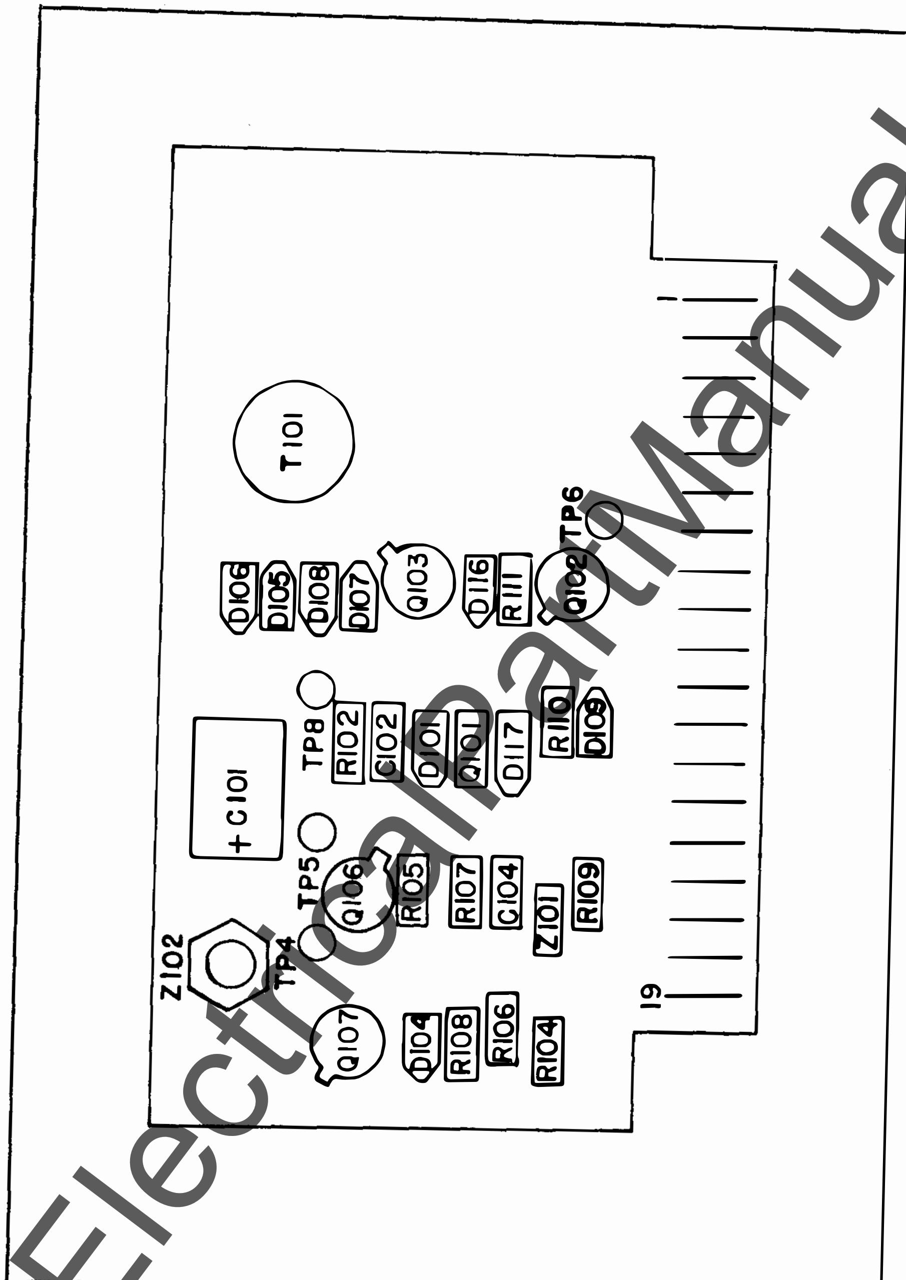


Fig. 8. Component Location for Signal Detection Logic in Type SBF Relay. (Dwg. 837A854).

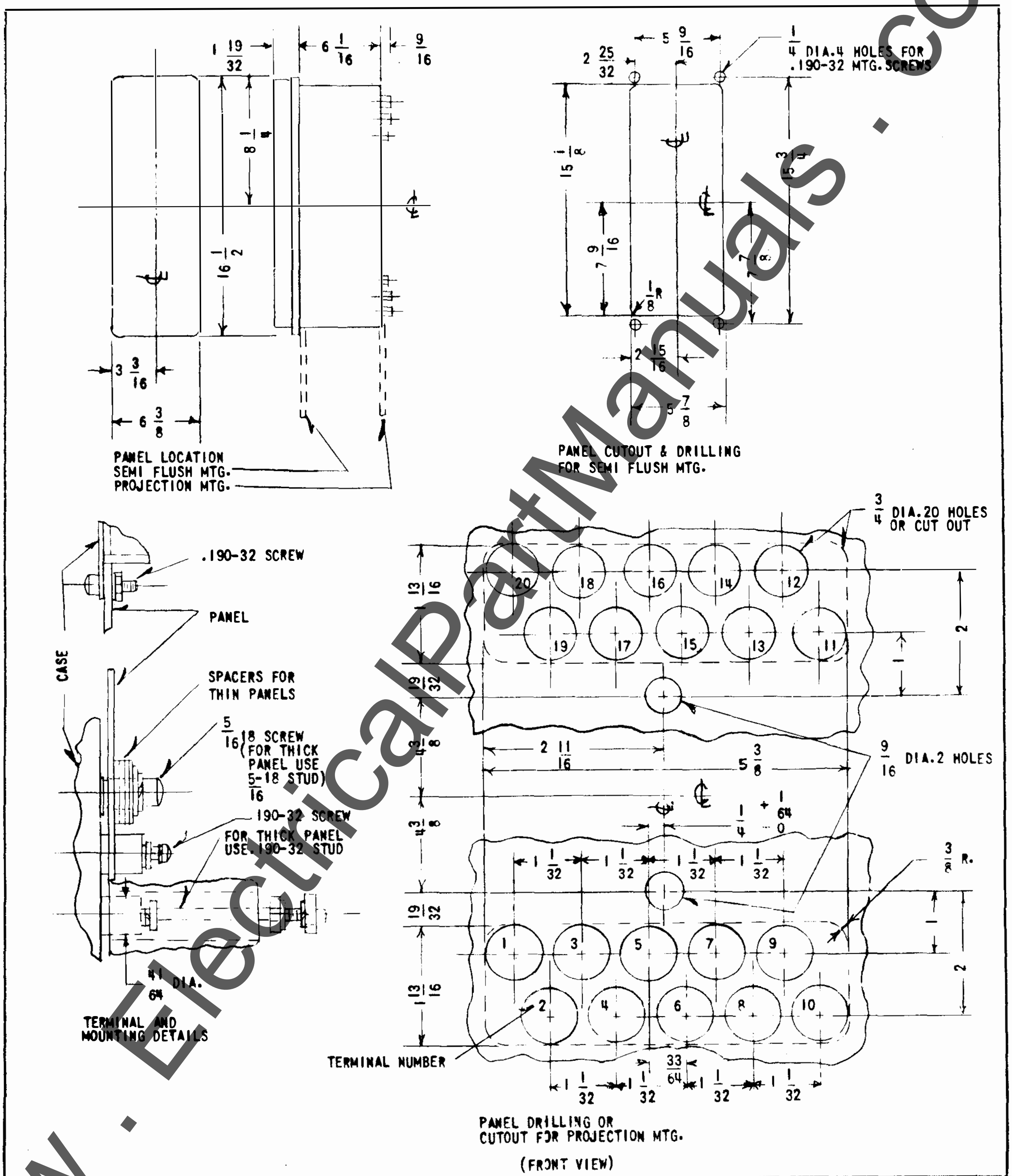


Fig. 9. Outline and Drilling Plan for Type SBF Relay in FT32 Case. (Dwg. 57-D-7903.

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