**ABB Automation Inc.**
Substation Automation and Protection Division
Coral Springs, FL 33065

Instruction Leaflet

**41-973.5R**

Effective: November 1999
Supersedes I.L. 41-973.5Q Dated February 1996

( | ) Denotes change since previous issue

# Type PM Line of Relays For Pilot-Wire Monitoring and Transferred Tripping

**CAUTION**

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

## 1.0 APPLICATION

Type PM Monitoring Relays provide continuous monitoring of a pilot-wire circuit to detect open circuits, short circuits, grounds, and wire reversal. In addition, transferred tripping can be effected where the PM-3, PM-13, PMG-13 or PM-23 relays are used. Table 1 illustrates the functions available with each relay. A 10 mfd. Capacitor is supplied with each PM relay. This capacitor provides an ac path between the two halves of the insulating transformer secondary windings as shown in figures 25 through 31.

Any relay which has a ground detection unit (5 unit), may have a momentary contact closure when a ground occurs on the station battery. If the momentary contact closure causes a problem, relays are available with an auxiliary telephone relay which has a pickup delay to eliminate this problem

Each circuit requires the following:

| At one end to introduce monitoring current<br>One of the following: | |
|---|---|
| For ac supply | For dc Supply |
| PMA | PMD |
| PMA-1 | PMD-1 |
| PM-13 or PMG-13 (ac) | PM-13 or PMG-13 (dc) |
| <u>At the other end to receive monitoring current (two terminal line):</u> | |
| One PM-23 or PM-2 or PM-4 | |
| <u>At the other ends to receive monitoring current (three terminal line):</u> | |
| One PM-23 or one PM-4 or one PM-2 for each remote terminal. | |

## 2.0 CONSTRUCTION

PM relays consist of the following:

| **PMA** | **PMA-1** |
|---|---|
| 1 Polar Alarm Unit (1)<br>1 Polar Ground Unit (5)<br>1 Tapped Transformer<br>1 Full-Wave Rectifier<br>3-4 mfd Capacitors<br>1 set of Potential Divider Resistors | 1 Polar Alarm Unit<br>1 Tapped Transformer<br>1 Full-Wave Rectifier<br>1-4 mfd Capacitor<br>1 Set of Potential Divider Resistors |
| **PMD** | **PMD-1** |
| 1 Polar Alarm Unit (1)<br>1 Polar Ground Unit (5)<br>2-4 mfd Capacitors<br>1 Set of Potential Divider Resistors | 1 Polar Alarm Unit<br>1 Set of Potential Divider Resistors |

*All possible contingencies which may arise during installation, operation or maintenance, and all details and variations of this equipment do not purport to be covered by these instructions. If further information is desired by purchaser regarding this particular installation, operation or maintenance of this equipment, the local ABB Power T&D Company Inc. representative should be contacted.*

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| PMG-13 | PM-13 |
|---|---|
| 1 Polar Alarm Unit (1)<br>1 Polar Ground Unit (5)<br>1 Polar Trip Unit (3)<br>1 Indicating Contactor Switch<br>1 Set of Potential Divider Resistors<br>1 Tapped Transformer (ac Relay Only)<br>1 Blocking Rectifier<br>2 Remote Trip Resistors<br>3-4 mfd Capacitors (ac Relay)<br>2-4 mfd Capacitors (dc Relay) | 1 Polar Alarm Unit (1)<br>1 Polar Trip Unit (3)<br>1 Indicating Contactor Switch<br>1 Set of Potential Divider Resistors<br>1 Tapped Transformer (ac Relay only)<br>1 Full-Wave Rectifier (ac Relay only)<br>1 Blocking Rectifier<br>2 Remote Trip Resistors<br>1-4 mfd Capacitor |

**PM-23**

1 Polar Alarm Unit (2)
1 Polar Trip Unit (3)
1 Indicating Contactor Switch (ICS)
1 Milliammeter, 5.0 mA
1 Set of Adjustable and Fixed Resistors
2 Blocking Rectifiers

**PM-2**

1 Polar Alarm Unit (2)
1 Milliammeter, 5.0 mA
1 Set of Adjustable Resistors
1 Blocking Rectifier

**PM-3**

1 Polar Trip Unit (3)
1 Resistor
1 Blocking Rectifier
1 Indicating Contactor Switch (ICS)

**PM-4**

1 Blocking Rectifier
1 Set of Adjustable and Fixed Resistors

**PM-5**

1 Polar Ground Unit (5)
2-4 mfd Capacitors
1 Fixed Resistor

**Table 1:**

| Function | PMA & PMD | PMA-1 & PMD-1 | PM-13 | PMG-13 | PM-23 | PM-2 | PM-3 | PM-4 | PM-5 |
|---|---|---|---|---|---|---|---|---|---|
| Monitoring Current Source | X | X | X | X | | | | | |
| Receives Monitoring Current | | | | | X | X | | X | |
| Trouble Alarm | X | X | X | X | X | X | | | X |
| Transmits Trip Signal | X† | X† | X | X | X† | X† | X† | X† | |
| Receives Trip Signal | | | X | X | X | | X | | |
| Sensitive Ground Detection | X | | | X | | | | | X |
| Measures Monitoring Current | | | | | X | X | | | |

† *With external Resistors*

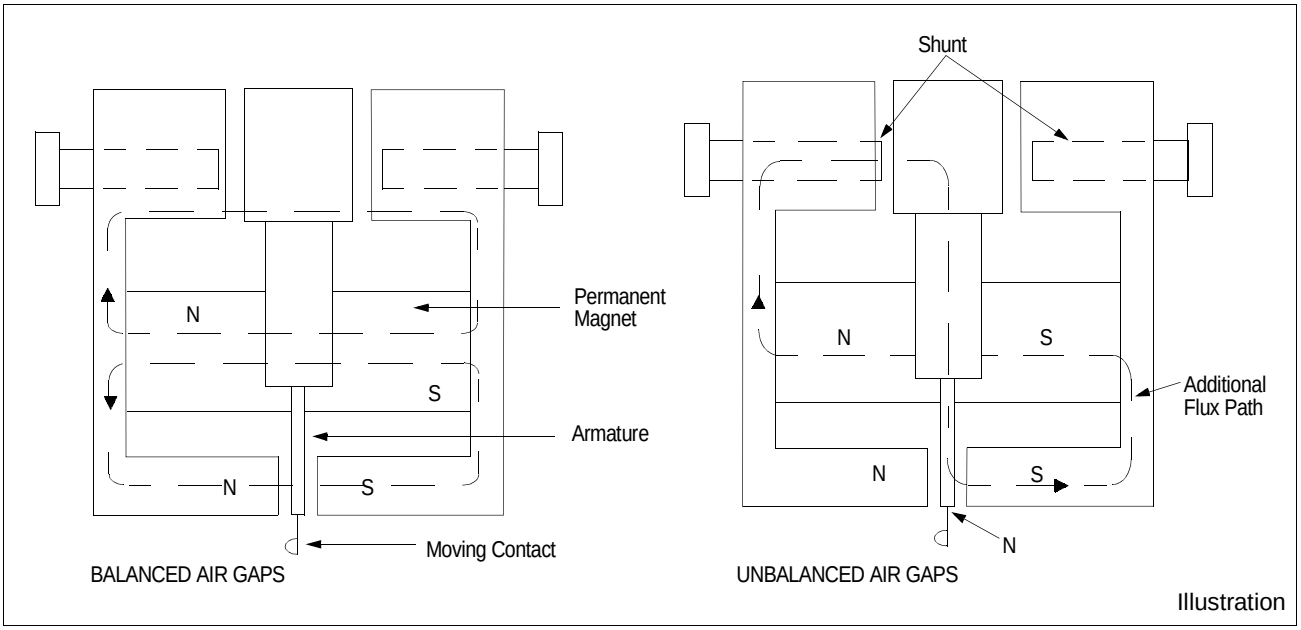


*Figure 1: Polar Unit Permanent Magnet Flux Paths.*

### 2.1 POLAR UNIT

The polar unit consists of a rectangular shaped magnetic frame, an electromagnet, a permanent magnet, and an armature. The poles of the crescent shaped permanent magnet bridge the magnet frame. The magnetic frame consists of three pieces joined in the rear with two brass rods and silver solder. These nonmagnetic joints represent air gaps, which are bridged by two adjustable magnetic shunts. The winding or windings are wound around a magnetic core. The armature is fastened to this core and is free to move in the front air gap. The moving contact is connected to the free end of a leaf spring, which, in turn, is fastened to the armature.

### 2.2 INDICATING CONTACTOR SWITCH

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

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

PMD & MDG-13 with Tel. Relay: In the relays type PMD and PMG-13 where they are energized with dc power supply, the ground polar unit (#5) could momentarily close its contact (for about 10 ms) if either positive or negative supply is grounded. To eliminate this momentary operation, a telephone relay with a nominal operating time of 25 ms was connected in series with contact of the “5” unit, and the contact of the telephone relay is used as an overall contact of the “5” unit. This type of relay should be used where the dc power supply is subjected to short-to-the-ground.

## 3.0 OPERATION

### 3.1 PILOT WIRE MONITORING

Monitoring current is introduced into the pilot-wire as sown in the external schematics, figures 25 to 31, by the monitoring current source. External schematics showing other combinations are available upon request. A nominal 20 volts is impressed across the 10 mfd capacitor at the left-hand line terminal in figures 25 to 31. This voltage produces a current circulating through one winding of the HCB insulating transformer, one pilot-wire, the PM-23, PM-2 or PM-4, and back through the other pilot-wire and the other winding of HCB insulating transformer.

Adjustment of the resistors of the PM-23, PM-2 or PM-4 relay at the other end of the pilot-wire provides a normal one-milliampere dc circulating current. In

the case of three-terminal lines, the monitoring source relay output current is 2 mA in order to provide each receiving end relay with 1 mA. The alarm unit of the monitoring current source relay is adjusted to float between the high and low current contacts with normal monitoring current. The PM-23, receiving end alarm relay, is adjusted to float between the low-current alarm contact and a contact stop with 1 mA flowing.

### 3.2 SHORT CIRCUITS

A complete or partial short circuit on the pilot-wires increases the current in the current-source relay, causing the high-current alarm contacts to close. The resulting current decrease in the PM-23 relay closes the alarm contact. Short circuits of 5000 ohms or less will be detected.

### 3.3 OPEN CIRCUITS

Current decreases to zero in all relays. Low current alarm contact of the current source relay closes. Alarm contact of PM-23 relay closes.

### 3.4 REVERSE WIRES

On applications using the PM-23 relay, current increases in the sending end relay to close the high current alarm contacts. Current drops to zero in the PM-23 relay monitoring coil to close the low-current alarm contacts.

If the pilot-wire should be opened, the low-current contacts of the (2) unit will close. If the pilot-wire is then reconnected with reversed connections, the (2) unit low-current contacts will remain closed. The capacitor at the sending end discharges through the pilot-wire and the trip unit (3) circuit when the pilot-wire is connected reversed. This would momentarily operate the trip unit (3) contact which would cause an incorrect trip; however, this is prevented by the (2) unit low-current contacts which connect a 2.25K resistor across the trip unit (3) coil. The 2.2K resistor remains connected across the trip-unit (3) coil until the pilot-wire is connected properly.

The current decreases in both sending and receiving end relays when the PM-2, or PM-4 relays are used. Low-current alarm contacts close.

### 3.5 GROUNDS

The voltage-divider circuit of the PMA, PMD, and PMG-13 source relays has its midpoint grounded through a current-limiting resistor. Thus, a pilot-wire ground will cause an increase in current in one coil circuit, and a decrease in the other one. This unbalance in the current flowing through the two windings (5) of the ground alarm relay unit will cause it to close one of its contacts (depending on which point wire is grounded) to give an alarm. Grounds of 10,000 ohms or less will be detected.

For adding the sensitive ground detection where PMA-1, PMD-1, or PM-13 relays have been installed, the PM-5 relay can be added to the circuitry, as shown in figure 30. This relay also has a 10,000 ohm ground sensitivity.

### 3.6 TRANSFERRED TRIPPING

Breakers located at the PMG-13 or PM-13 and PM-3 or PM-23 stations can be tripped by the application of a dc voltage to the pilot-wires at remote locations, as shown in figures 25 to 31. Transferred tripping can be effected from any location by applying 48 volts dc (through dropping resistors when required) to the pilot-wire with polarity opposite to that of the monitoring voltage. When tripping the PM-23, the current is increased above 2.0 mA, in reverse direction, to close the trip contact. When tripping the PMG-13 or PM-13, the reversed dc voltage operates the trip unit (3).

See Tables 2 and 3 for tripping resistor values. Nominal tripping currents is 5 mA at all rated voltages.

### 3.7 POLAR UNIT

Polar unit flux paths are shown in figure 1. With balanced air gaps, permanent magnet flux flows in two paths, one through the front, and one through the rear gaps. This flux produces north and south poles, as shown. By turning the left shunt in, some of the flux is forced through the armature, making it a north pole. Thus, reducing the left-hand rear gap will produce a force tending to pull the armature to the right. Similarly reducing the right-hand gap will make the armature a south pole and produce a force tending to pull the armature to the left.

The alarm unit contacts of the sending and receiving end relays are biased to move to the left when the relay is deenergized. The PMG-13 or PM-13 and PM-23 trip unit contact is biased to move to the left when the relay is deenergized. The PM-5 is adjusted so that the moving contact floats when the relay is deenergized.

# 4.0 CHARACTERISTICS

## 4.1 NOMINAL CALIBRATION VALUES

Nominal current values to close contacts are listed in Tables 4 and 5.

## 4.2 VOLTAGE RATINGS

Supply voltage ratings of the monitoring source relays to obtain continuous current as follows:

| | |
|---|---|
| dc | 48, 125, and 250 volts |
| ac | 120 volts, 60 hertz (Primary taps 100, 110, 120 and 130) |

voltage impressed on the pilot-wire is a nominal 20 volts for monitoring, and 48 volts for tripping. Supply voltage ratings to obtain remote tripping are: 48, 125, and 250 volts dc.

## 4.3 COIL RESISTANCE (EACH WINDING)

| | |
|---|---|
| Alarm coil (1)<br>two terminal line<br>three terminal line | <br>1050-1250 ohms<br>700-900 ohms |
| Alarm coil (2) | 2200-2600 ohms |
| Trip coil (3) | 1800-2200 ohms |
| Ground Alarm coil | 5200-5800 ohms |

## 4.4 PM-4 AND PM-23 RESISTANCE

Nominal PM-4 and PM-23 total resistance when adjusted for service is 20,000 ohms less pilot-wire loop resistance at 1 mA.

## 4.5 PMA, PMA-1 AND AC PMG-13, PM-13 BURDEN

| | |
|---|---|
| 0.5 VA at tap voltage | 2-terminal line relay |
| 1.0 VA at tap voltage | 3-terminal line relay |

## 4.6 RECTIFIERS

| | |
|---|---|
| Approximate forward resistance | 560 ohms at 1 mA<br>300 ohms at 2 mA |
| Rating<br>Continuous forward current amperes | <br>1 |
| Continuous back voltage-rms volts | 200 |

## 4.7 REMOTE TRIPPING

Remote trip resistors are listed in Table 2 and 3 for 48, 125, and 250 volts dc.

The relays have sufficient thermal capacity to withstand 20 mA dc continuously when remote tripping. Nominal trip currents in the tripping relays are 5.0 mA dc with 48, 125, and 250 volts dc supply and a 2000 ohm pilot wire.

## 4.8 TRIP CIRCUIT

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

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

## 4.9 TRIP CIRCUIT CONSTANT

Indicating Contactor Switch (ICS)

| Tap | Resistance |
|---|---|
| 0.2 ampere | 6.5 ohms dc |
| 2.0 ampere | 0.15 ohms dc |

# 5.0 SETTINGS

Operating units of all relays are adjusted in the factory to the values listed in Tables 4 and 5 to a tolerance of ±8%. No settings are required on these units.

For all 48/125 volt dc relays, connect jumpers across resistors as shown on the internal schematics.

## 5.1 PM-4, PM-2, AND PM-23 RELAYS

Adjust the resistors in the PM-4, PM-2, or PM-23 relay or relays to a value of 1 mA dc with the monitoring circuits connected for service. Use the milliammeter in the PM-23 for this purpose or use a portable milliammeter with a resistance of less than 200 ohms. Where it is not practical no three-terminal lines to adjust both receiving relays simultaneously, set one receiving relay for 18,000 ohms total resistance (including relay coil and resistors) by measurement prior to final adjustment of the other receiving relay. This procedure will minimize the change in monitoring current in the first relay to be adjusted when making the final adjustment of the second relay.

**Table 2:**
**PMA, PMA-1, AND PMD-1 APPLICATIONS**
**EXTERNAL RESISTORS FOR DC REMOTE TRIPPING**
**(2 REQUIRED PER STATION)**

| # Line Terminals | dc Voltage | Station A PMA or PMA-1 | Station A PMD or PMD-1 | Station B PM-2 & PM-3 or PM-23 or PMA-4 | Station C PM-2 & PM-3 or PM-23 or PM-4 | To Operate |
|---|---|---|---|---|---|---|
| 2 | 48 | 200 | 200 | - | - | PM-23 or PM-3 |
| | 125 | 3550 | 3550 | - | - | " |
| | 250 | 9300 | 9300 | - | - | " |
| 3 | 48 | 200 | 200 | - | - | " |
| | 125 | 2000 | 2000 | - | - | " |
| | 250 | 5600 | 5600 | - | - | " |

**Table 3A:**
**PMG-13 AND PM-13 (DC SUPPLY) APPLICATIONS**
**RESISTORS FOR DC REMOTE TRIPPING**
**(2 REQUIRED PER STATION)**

| # Line Terminals | dc Voltage | Station A PMG-13 or PM-13 | Station B PM-2 & PM-3 or PM-23 or PM-4 | Station C PM-2 & PM-3 or PM-23 or PM-4 | To Operate |
|---|---|---|---|---|---|
| 2 | 48 | 200† | 200 | - | PMG-13 or PM-13 |
| | 125 | 2120† | 2120 | - | and PM-23 or PM-3 |
| | 250 | 5600† | 5600 | - | " |
| 3 | 48 | 200† | 200 | 200 | " |
| | 125 | 1500† | 1500 | 1500 | " |
| | 250 | 4000† | 4000 | 4000 | " |

**Table 3B:**
**PMG-13 AND PM-13 (AC SUPPLY) APPLICATIONS**
**RESISTORS FOR DC REMOTE TRIPPING**
**(2 REQUIRED PER STATION)**

| # Line Terminals | dc Voltage | Station A PMG-13 or PM-13 | Station B PM-2 & PM-3 or PM-23 or PM-4 | Station C PM-2 & PM-3 or PM-23 or PM-4 | To Operate |
|---|---|---|---|---|---|
| 2 | 48 | 200† | 200 | - | PMG-13 or PM-13 |
| | 125 | 2120† | 2120 | - | and PM-23 or PM-3 |
| | 250 | 5600† | 5600 | - | " |
| 3 | 48 | 200† | 200 | 200 | " |
| | 125 | 1500† | 1500 | 1500 | " |
| | 250 | 4000† | 4000 | 4000 | " |

† *Mounted in Relay*

**Table 4:**
**NOMINAL CALIBRATION VALUES - TWO TERMINAL LINE**

| RELAY | LOW CURRENT ALARM[1] | HIGH CURRENT ALARM[2] | TRIP |
|---|---|---|---|
| PMA OR PMA-1 | 0.65 mA | 1.3mA | - |
| PMD OR PMD-1 | 0.65 | 1.3 | - |
| PM-5† | - | ±0.3 | - |
| PMG-13 OR PM-13 | 0.65‡ | 1.3‡ | 14 V |
| PM-23 OR PM-2 & PM-3† | 0.65 | - | 14 V |

† *Same relay as for three-terminal lines*

‡ *These are pilot-wire current values*

[1] *Left-Hand Contact*

[2] *Right-hand Contact*

**Table 5:**
**NOMINAL CALIBRATION VALUES - THREE TERMINAL LINE**

| RELAY | LOW CURRENT ALARM | HIGH CURRENT ALARM | TRIP |
|---|---|---|---|
| PMA OR PMA-1 | 0.7 mA | 2.3mA | - |
| PMD OR PMD-1 | 0.7 | 2.3 | - |
| PM-5† | - | ±0.3 | - |
| PMG-13 OR PM-13 | 0.7‡ | 2.3‡ | 14 V |
| PM-23 OR PM-2 & PM-3† | 0.65 | - | 14 V |

† *Same relay as for two-terminal lines*

‡ *These are pilot-wire current values*

### 5.2 PMA, PMA-1, PMG-13 AND PM-13 RELAYS

Select the transformer tap nearest to expected normal ac supply voltage. The full wave rectifier is connected to a secondary transformer tap. Where desired, the output voltage can be raised about 5% by reconnecting across the full secondary winding.

### 5.3 INDICATING CONTACTOR SWITCH

No setting is required on the ICS unit except the selection of the 0.2 or 2.0 ampere tap setting. This selection is made by connecting the lead located in front of the tap block to the desired setting by means of the connecting screw. When the relay energizes a type WL relay switch, or equivalent, use the 0.2 ampere tap.

## 6.0 INSTALLATION

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

For detailed FT case information, refer to Instruction Leaflet 41-076.

Where the potential to ground impressed on the relays can exceed 700 volts, a drainage reactor in conjunction with its surge protectors, or the reactor in conjunction with 700 volt carbon-block arresters, is recommended. For details, see Protection of Pilot-Wire Circuits, AIEE Committee Report, paper 58-1190, AIEE Transactions, 1959, Volume 78, Part III B pp. 205-212. Also, see AIEE Special Publication S-117, Applications and Protection of Pilot-Wire Circuits for Protective Relaying, July 1960.

## 7.0 ADJUSTMENTS AND MAINTENANCE

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

adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions in the succeeding sections should be followed.

### 7.1 ACCEPTANCE TESTS

The following tests are recommended when the relay is received from the factory. If the relay does not perform as specified below, the relay either is not properly calibrated or it contains a defect. ***(Relays must be tested in the case.)***

#### 7.1.1 Indicating Contactor Switch (ICS)

Close the contact of the tripping unit and pass sufficient direct current through the trip circuit to close the contacts of the ICS unit. This value of current should not be greater than the particular ICS tap setting being used (0.2 or 2.0). The indicator target should drop freely.

#### 7.1.2 PMA and PMA-1 Relays

**Alarm Unit (1)**

Set the primary tap on 120 volts. Connect a variable resistor of approximately 20,000 ohms in series with a low-range dc milliammeter across terminals 6 and 7 with the instrument positive connected to terminal 7. Apply 120 volts at rated frequency to terminals 4 and 5. Adjust the 20,000 ohm resistor to obtain a current of one mA dc. For a three-terminal line relay, use a 10,000 ohm resistor and set the current to 2 mA dc. At this value, the moving contact of the alarm or monitoring relay unit (1) should float between the two sets of stationary contacts. In the PMA relay, the ground alarm unit (5) contact should also float. (This contact will also float when the relay is deenergized.) Increase and decrease the one or two milliampere monitoring current to check the calibration values listed in Tables 4 and 5.

**Ground Unit (5)**

Reconnect the 20,000 ohm resistor. For the PMA relay only, short terminals 7 and 3. The contact of the ground alarm unit (5) should close to the right when the relay is energized. Remove the short, and connect it between terminals 6 and 3. The ground alarm unit (5) should close to the left. The action of the monitoring unit (1) contact is of no significance in this simulated pilot-wire ground test. To check the pickup current of the ground detector, first remove to the 20,000 ohm resistor from terminals 6 and 7. Connect a 0-1 dc milliammeter in series with a variable resistor of about 50,000 ohms between terminals 3 and 6. The ground unit should close its left-hand contact at approximately 0.3 mA dc. With the milliammeter and resistor connected between terminals 3 and 7, the right-hand contact should close at 0.3 mA dc.

#### 7.1.3 PMD and PMD-1 Relays

**Alarm and Ground Units**

Connect an adjustable 20,000 ohm resistor (or 10,000 ohms for a 3-terminal relay) in series with a dc milliammeter across terminals 6 and 7 with the instrument positive connected to terminal 7. Apply rated dc voltage to terminals 8 and 9 with positive on terminal 9. Now check the PMD and PMD-1 relays, following the procedure given in the previous section for the PMA and PMA-1 relays, respectively. Note, however, that terminal 5 of the PMD relay corresponds to terminal 3 of the PMA relay.

#### 7.1.4 PM-2, PM-3, and PM-23 Relays

**Alarm Unit (2)**

Apply a variable dc voltage of approximately 20 volts to relay terminals 8 and 9 (terminal 9 positive) of the PM-2 or PM-23 relay. Adjust the voltage to obtain a reading of one mA on the relay milliammeter. The monitoring polar unit (2) contacts should float. Reduce the current gradually. The monitoring alarm contacts should close at 0.65 mA dc. The tripping unit (3) of the PM-23 relay should not move during this test. The milliammeter has been adjusted to read 1 mA $\pm$ 5%. As a result the pointer may not read zero for a zero current condition.

**Tripping Unit (3)**

to check the PM-3 relay or the tripping unit of the PM-23 relay, apply the variable dc voltage in series with an external milliammeter to relay terminals 8 and 9 with terminal 8 positive for the PM-23 relay, or terminal 9 positive for the PM-3 relay. When checking the pickup of the PM-23 trip unit block open the alarm unit contacts (2) so as to remove the shunt resistor from around the trip coil (3).

The tripping relay unit (3) should pickup with positive action at 14 volts dc and should drop out at approximately 10 volts. The alarm unit of the PM-23 relay will not operate during this test.

#### 7.1.5 PM-4 Relay

This device is simply a set of resistors and a diode to connect into the pilot-wire circuit to provide a path for

the monitoring current. The resistors can be checked with an ohmmeter, and the diode can be checked either with an ohmmeter, or as explained in the section entitled “Rectifier Check” under “Routine Maintenance”. If an ohmmeter is used, the difference in forward and reverse resistance readings obtained will be dependent on the current flowing through the diode.

#### 7.1.6 PM-5 Relay

Apply 5 volts dc in series with a 0-1 dc milliammeter and a 20,000 ohm variable resistor to terminals 6 and 7 with positive on terminal 6. The left-hand contact should close at approximately 0.3 mA. Now apply the same circuit to terminals 8 and 9 with positive on terminal 9. The right-hand contact should close at approximately 0.3 mA.

#### 7.1.7 PM-13 Relays – ac and dc

**Alarm Unit (1)**

Connect a variable 20,000 ohm resistor (10,000 ohms for a 3-terminal line relay) in series with a dc milliammeter across terminals 8 and 9 with the instrument positive on terminal 9. For the ac relay, set the primary tap on 120 volts. Now apply the rated supply voltage to terminals 4 and 5. This will be 48, 125, or 250 volts dc, or 120 volts ac as indicated on the relay nameplate. Adjust the variable resistor to obtain a current of one mA for a 2-terminal line relay, or 2 mA for a 3-terminal relay. At this value, the moving contacts of the alarm or monitoring (1) relay unit (the upper polar unit) should float between the two sets of stationary contacts. Increase and decrease the one or 2 mA monitoring current to check the calibration values listed in Tables 4 and 5.

**Tripping Unit (3)**

To check the operation of the tripping unit 3 (the lower polar unit), apply a dc potential across terminals 16 (positive) and 20 (negative). The tripping polar unit should pick up at 14 volts. The resistance of the series dropping resistors for transferred tripping (listed in Table 3A and Table 3B) can be checked with an ohmmeter. The circuit location of these resistors can readily be seen from the external schematic, figure 27.

#### 7.1.8 PMG-13 Relays – ac and dc

**Alarm and Tripping Units**

Follow the procedure given in the previous section for the ac and dc PM-13 relays.

**Ground Unit (5)**

Connect the 20,000 ohm (or 10,000 ohm) resistor and milliammeter across terminals 8 and 9. With rated voltage applied and one mA (or 2 mA) flowing, successively short circuit terminals 3 and 8, then 3 and 9. The ground alarm unit 5 (lower polar unit) should move first to the left, then to the right. To check the pickup current of the ground detector, first remove the 20,000 ohm resistor from terminals 8 and 9. Connect a 0-1 dc milliammeter in series with a variable resistor of about 50,000 ohms between terminals 3 and 8. The left-hand contact should close at approximately 0.3 mA dc. With the milliammeter resistor connected between terminals 3 and 9, the right-hand contact should close at 0.3 mA dc. The external schematic diagrams for these relays are shown in figures 27 and 29.

## 8.0 ROUTINE MAINTENANCE


**DO NOT make any performance check, calibration tests, or adjustments while the PM relays are energized or connected to the pilot-wires, to prevent the possibility of inadvertently causing a break operation. The PM relays may be removed from service for testing, without jeopardizing HCB relay protection, providing that the connections between the 10 mfd capacitor and the HCB insulating transformer are not disturbed.**

### 8.1 CONTACTS

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

### 8.2 OPERATIONAL CHECK

In addition to cleaning contacts, it is recommended that an operational check be performed periodically by opening and short circuited the pilot-wires, as well as grounding term at the relay terminals.

**NOTE: These pilot-wire faults should not be applied directly to the pilot-wires when the HCB relays are in service. It is recommended that the trip circuits of the PM relays be opened (where trip-**

**ping is used), to prevent the possibility of inadvertently tripping the associated circuit breaker during testing. If the relays do not perform as expected, and diode failure is suspected, the diode tests described in the following section may be performed.**

### 8.3 RECTIFIER (DIODE) CHECK (AC RELAYS ONLY)

If there is suspicion of a rectifier (diode) failure, apply 30 volts dc reverse voltage (positive on cathode) through a 300 ohm resistance to the diode. Measure the voltage across the diode. If this voltage is not essentially 30 volts, the diode is short circulated. Now apply 30 volts dc in the forward direction through the 300 ohm resistor, and measure the voltage across the resistor. If the voltage is not essentially 30 volts, the diode may have a high forward resistance. If voltage is zero, the diode is open-circuited.

## 9.0 CALIBRATION

If the relay has been dismantled or the calibration has been disturbed, use the following procedure for calibration. ***(Relays must be tested in the case.)***

With the permanent magnet removed, see that the moving armature floats in the central area of the air-gap between the poles of the polar unit frame. If necessary, loosen the core screw in the center rear of the unit and shift the core and contact assembly until the armature floats. (This can best be done with the polar unit removed from the relay.) Then retighten the core screw and replace he permanent magnet with the dimple (north pole) on the magnet to the left when viewed from the front.

### 9.1 POLAR UNITS – GENERAL

The following mechanical adjustments are given as a guide, and some deviation from them may be necessary to obtain proper electrical calibration.

#### 9.1.1 Magnetic Shunt Adjustment

The sensitivity of the polar unit is adjusted by means of two magnetic, screw-type shunts at the rear of the unit, as shown in figure 1. These shunt screws are held in proper adjustment by a flat strip spring across the back of the polar unit frame, so no locking screws are required. Looking at the relay, front view, turning out the right-hand shunt to open the right-hand air gap decreases the amount of current required to close the right-hand contact. Conversely, drawing out the left-hand shunt increases the amount of current required to close the right-hand contact, or decreases the amount of current required to close the left-hand contact (with the proper direction of current flow). Also, if a relay trips to the right at the proper current, the dropout current can be raised by turning in the right-hand shunt. The two shunt-screw adjustments are not independent, however, and a certain amount of trimming adjustment of both shunt screws is generally necessary to obtain the desired pickup and dropout calibration.

In general, the farther out the two shunt screws are turned, the greater the toggle action will be, and as a result, the lower the dropout current. For the tripping units (3) of the PM-3, PM-13, and PM-23 relays, toggle action is desirable, with a dropout current around 75 percent of the pickup current. For the monitoring alarm relay units, toggle action is not desired. Instead, the armature is adjusted to float between the pole faces at a given current (1 or 2 mA), and to move gradually toward the high or low current alarm as the coil current is increased or decreased. Similarly, the floating adjustment of the armature of the ground alarm unit (5) requires that both shunt screws be turned in relatively far. Then the armature will move gradually to the left or right as the current through the two #5 coils is unbalanced.

The electrical calibration of the polar unit is also affected by the contact adjustment as this changes the position of the polar unit armature. Do not change the contact adjustment without rechecking the electrical calibration.

The chart on page 11 indicates the units present in each relay.

#### 9.1.2 Contact Adjustment – all relays

For all monitoring alarm units, designed (1) or (2), turn in all the stationary contact and contact stop screws until they just touch the moving contact. Advance the screws to hold the armature in the central portion of the magnetic air gap between the two-pole faces. (The stationary contact screws have a round silver contact face; the stop screws do not have this silver facing.) Now back off all the contact and contact stop screws one full turn. This will give a total contact travel of 0.050 inch. When the relay is properly calibrated, some touch-up adjustment may be necessary so that double contacts will both close at the same current value. The contact gap between the floating moving contact and the right-hand or left-hand stationary contacts or contact stops will be approximately 0.025 inch when the relay is in operation.

For the tripping (3) units of the PM-3, PM-13, PMG-

| Function and unit | PMA PMD | PMA-1 PMD-1 | PM-2 | PM-3 | PM-4 | PM-5 | PM-13 | PMG-13 | PM-23 |
|---|---|---|---|---|---|---|---|---|---|
| Alarm for p.w. open, short or reversal (1) (2) | X | X | X | | | | X | X | X |
| Transfer Trip Unit (3) | | | | X | | | X | X | X |
| Alarm for p.w. ground (5) | X | | | | | X | | X | |
| dc Path for Monitoring Current | | | | | X | | | | |

13, and PM-23 relays, adjust the contacts as described in the previous paragraph, except back off the contact and stop screws one-half turn each to give a total moving contact travel of approximately 0.025 inch.

In operation of the tripping unit, the moving contact will normally rest against the contact stop screws, and will pickup only for a transferred tripping operation.

For the pilot-wire ground alarm unit (5) of the PMA, PMD, PM-5, and PMG-13 relays, follow the same general procedure except back off both stationary contact screws two turns each. This will give a contact tap of 0.050 on each side of the moving contact when it is in its normal central position.

### 9.1.3 Contact Gap

The contact gap between the floating moving contact and the right-hand or left-hand stationary contacts of contact stops must not be less than 25% of the overall stationary-to-stationary contact gap, i.e., with an overall contact gap of .100 excluding dimension of moving contact, the gap of the floating contact to either stationary contact can be .025 to 0.75.

### 9.1.4 Electrical Calibration – all relays

In the following sections, the calibration instructions are given for the polar unit which performs a certain function, such as alarm (1) or (2), ground (5), or trip (3), rather than giving calibration instructions for each complete relay. In this way, considerable duplication of instructions has been eliminated.

### 9.1.5 Alarm Unit (1)

Connect the relay as described under the “Acceptance Tests” section, for the particular relay involved. Screw the two magnetic shunts all the way in, then back them out five turns each. With the relay energized at rated voltage, set the monitoring current at 1.3 or 2.3 mA dc for 2 or 3 terminal relay respectively, by adjusting the external resistor. If the relay does not close its right-hand contact, turn in the left shunt screw until the right-hand contact just closes. If the right-hand contact is closed at 1.3 mA, turn in the right shunt until a point is reached when the right-hand contact is just closed at 1.3 mA.

Now drop the current to 0.65 mA and adjust the opposite shunt until the left-hand contact just closes at 0.65 mA dc. At 1.0 mA dc the moving contact should float half way between the two sets of stationary contacts with a 0.025 inch gap on each side. Recheck the high and low current calibration several times, touching up the shunt adjustments as required to obtain the desired calibration.

### 9.1.6 Polarization Check

For all source relays, which are listed below, make the following additional calibration check:

| | |
|---|---|
| PMA | PM-13 (ac and dc) |
| PMA-1 | PMG-13 (ac and dc) |
| PMD | |
| PMD-1 | |

After calibration as described in the previous sections, connect a 20,000 ohm resistor (or 10,000 ohms for 3-terminal applications) across the output terminals, and energize the relay at its rated supply voltage. With these connections, approximately one (or two) milliamperes dc will flow through the monitor relay coils and external resistor, thus representing normal operating conditions.

Now momentarily (one second or so) apply 125 volts dc directly to the pilot-wire terminals of the relay, as indicated in the following table.

| Relay | Terminals for Momentary Application of 125 V dc | |
|---|---|---|
| | POS. | NEG. |
| PMA, PMA-1<br>PMD, PMD-1 | 6 | 7 |
| PM-13 (ac or dc)<br>PMG-13 (ac or dc) | 8 | 9 |

After momentary application of the transfer-trip voltages as just explained, recheck the calibration of the monitoring alarm unit (1). If it has changed, make necessary trimming adjustments of the shunt screws until there is no change in calibrating of the alarm unit (1) after the transfer-trip voltage has been applied. The purpose of this test is to compensate for the small residual magnetism in the relay unit. The ground alarm unit (5) will not be affected by this test as the ampere turns of the two windings cancel each other.

### 9.1.7 Alarm Unit (2)

For the alarm unit of the PM-2 or PM-23 relays, adjust the shunts so that the relay moving contact floats at one mA dc and closes the left-hand contact at 0.65 mA dc. The moving contact should float midway between the contact and contact stop at 1.0 mA dc. There is no high current calibration for this relay unit.

Now apply 125 volts dc momentarily (one second or so) across the alarm unit coil-circuit terminals in a direction to operate the alarm relay. Then recheck the alarm unit calibration. If there is any change, touch up the shunt adjustments until there is no change in calibration after 125 Vdc has been applied.

### 9.1.8 Tripping Unit (3)

To calibrate the tripping unit of the PM-3, PM-13, PMG-13, or PM-23 relays, apply a dc voltage as explained below, to the following relay terminals:

| Relays | dc Voltage | |
|---|---|---|
| | Pos. | Neg. |
| PM-3 | 9 | 8 |
| PM-13 (ac or dc) | 16 | 20 |
| PMG-13 (ac or dc) | 8 | 9 |
| PM-23 | 8 | 9 |

Momentarily (one second or so) apply 125 Vdc to the terminals shown in the chart. Starting with both shunts all the way in, turn out the right-hand shunt screw until the relay closes its right-hand trip contact at 14 volts dc.

**NOTE: In the calibration of a PM-23, the alarm unit (2) contact must be blocked open so as not to affect the tripping unit pickup. (This will give approximately 2 mA through the relay coil.) Now draw out the left-hand shunt until the relay resets with toggle action (not gradually) at not less than 10 volts dc. When the calibration is approximately correct, again apply 125 volts dc to the indicated terminals, then recheck the pickup and dropout voltage, making any necessary trimming adjustments of the shunts. When the relay is properly adjusted, the application of 125 volts dc will not change the pickup or dropout voltage points. The relay should trip and reset with toggle action in this application. This will require both shunt screws to be withdrawn farther than for floating action.**

### 9.1.9 Ground Alarm Unit (5)

For the PM-5 relay, turn both shunt screws all the way in, then back them out five turns each. Pass a current of 0.3 mA dc in terminal 6 and out terminal 7. Following the same general procedure as described previously in the section entitled “Alarm Unit (1),” adjust the shunt screws so that the left-hand contact closes at 0.3 mA. Now pass 0.3 mA dc in terminal 9 and out terminal 8, and adjust for closing of the right-hand contact at 0.3 mA. Recheck both pickup points several times, and make trimming adjustments of both shunts as required to obtain contact closing at 0.3 mA dc in each direction.

For the ground unit (5) of the PMA, PMD, and PMG-13 relays, connect a variable resistance of about 50,000 ohms in series with a 0-1 dc milliammeter between the terminals indicated in the following table:

| Relay | Relay Terminals | |
|---|---|---|
| | L.H. Contact Check | R.H. Contact Check |
| PMA<br>PMD<br>PMG-13 | 3† and 6<br>5† and 6<br>3† and 8 | 3 and 7†<br>5 and 7†<br>3 and 9† |

† *Milliammeter positive to this terminal*

Turn the shunts all the way in, then back them out five turns each. With the relay connected as shown in the left-hand column of the table, apply rated voltage to the relay and adjust the 50,000 ohm resistor for 0.3 mA dc. Now following the procedure in the previous paragraph for the PM-5 relay, adjust the shunts until the left-hand contact closes at 0.3 mA dc. Change the connections as indicated in the right-hand column, and adjust the opposite shunt until the right-hand contact closes. Recheck back and forth several times and make necessary trimming adjustments to obtain pickup at 0.3 mA in each direction. The armature will move gradually as the current is changed for this relay unit.

#### 9.1.10 ICS Unit

Close the main relay tripping contact circuit with a jumper connected directly across the contact terminals of the polar unit. Pass sufficient direct current through the relay trip circuit to close the contacts of the ICS unit. This value of current should not be greater than the ICS tap setting being used (0.2 or 2.0). The indicator target should drop freely. The contact gap should be approximately 0.047 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

## 10.0 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 repair work. When ordering parts, always give the complete nameplate data.

## INDEX TO FIGURES
## INTERNAL SCHEMATICS

**Figure No.**



## EXTERNAL SCHEMATICS



## OUTLINE AND DRILLING PLANS

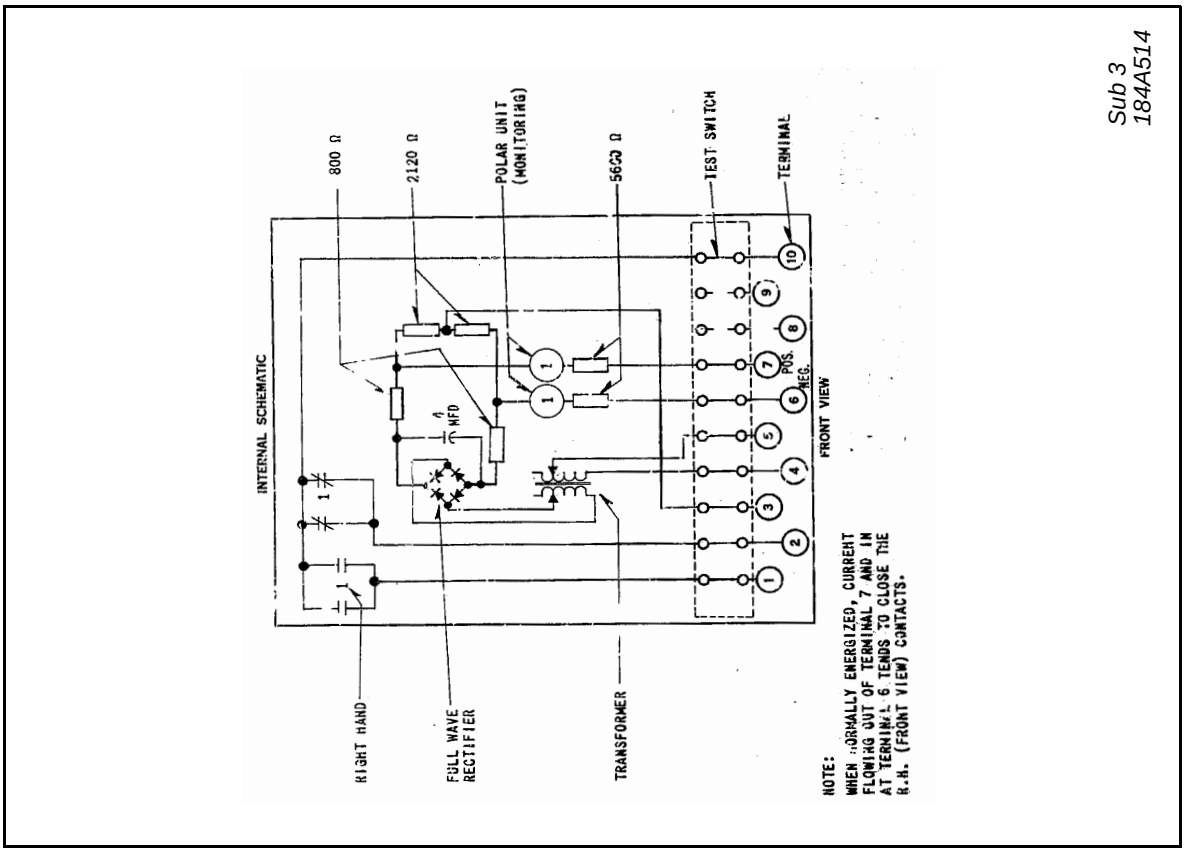


*Figure 3: Internal Schematic of Type PMA-1 Relay in the FT-21 case - 120 volts, 60 hertz supply – for two-terminal lines.*

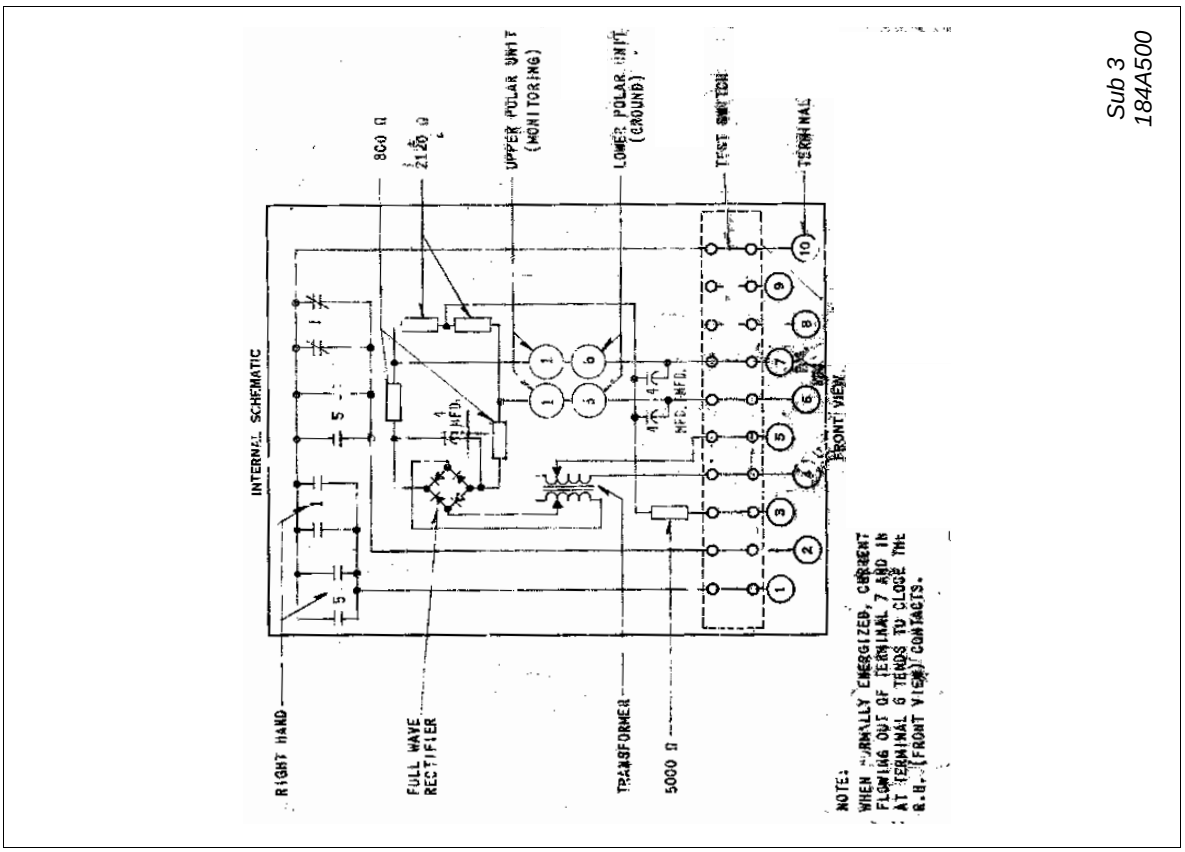


*Figure 2: Internal Schematic of the Type PMA Relay in FT-31 case - 120 volt, 60 hertz supply – for two-terminal lines.*

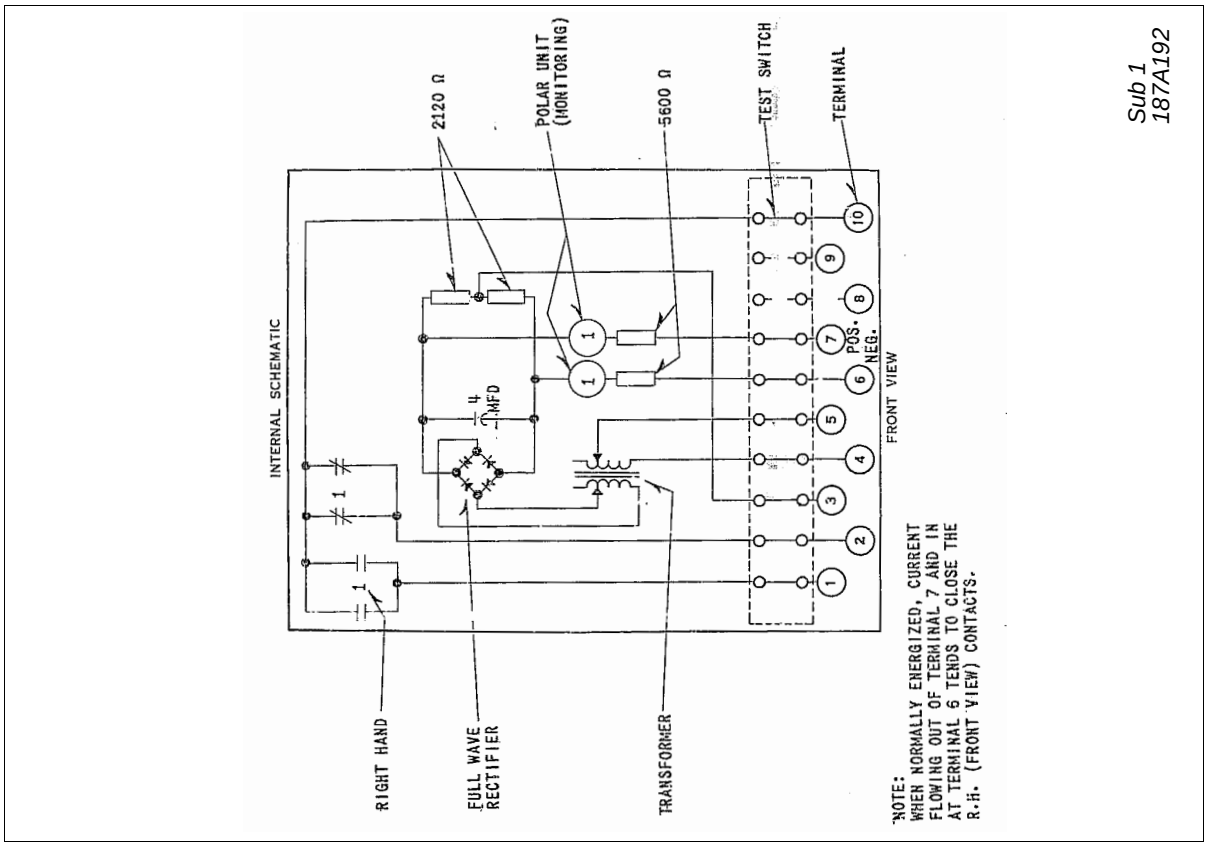


*Figure 5: Internal Schematic of Type PMA-1 Relay in FT-21 case - 120 volt, 60 hertz supply – for three-terminal lines.*

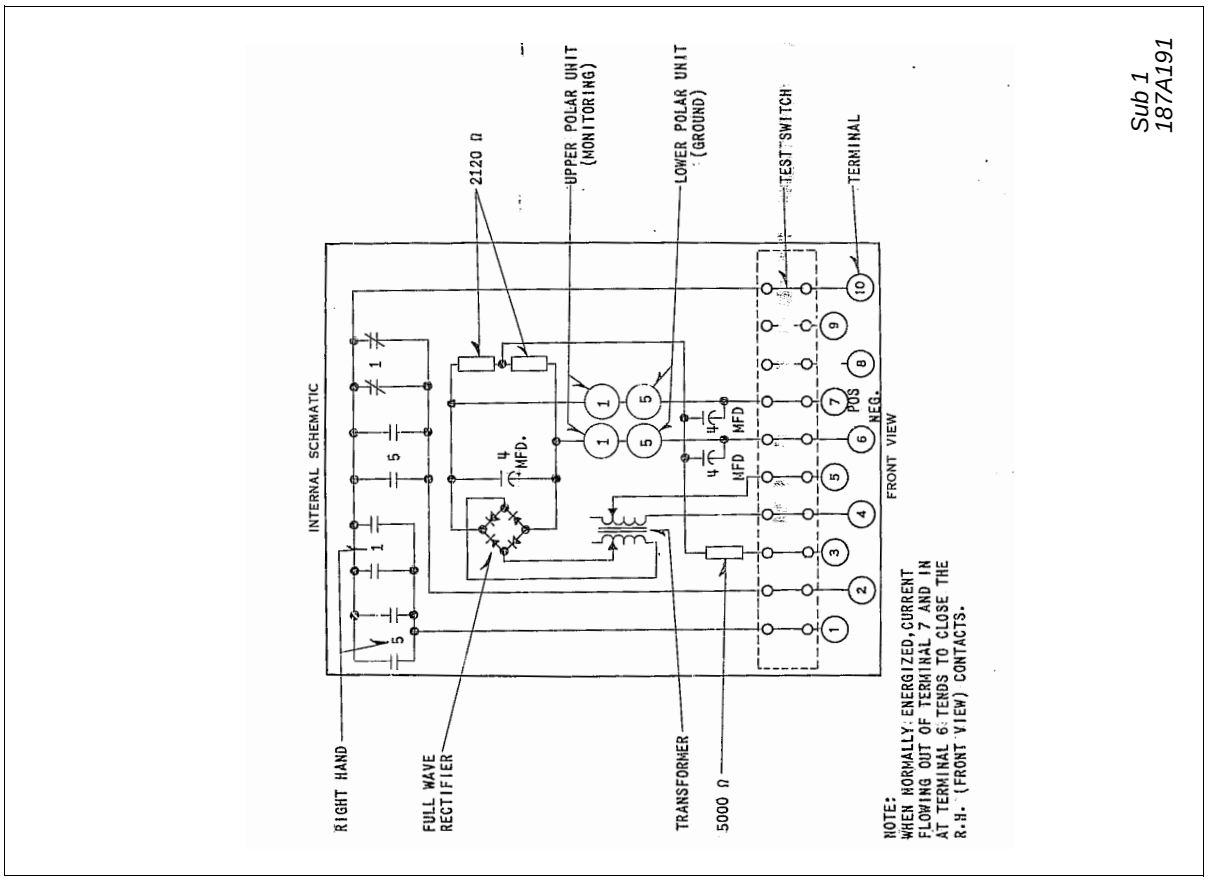


*Figure 4: Internal Schematic of Type PMA Relay in FT-31 case - 120 volt, 60 hertz supply – for three-terminal lines.*

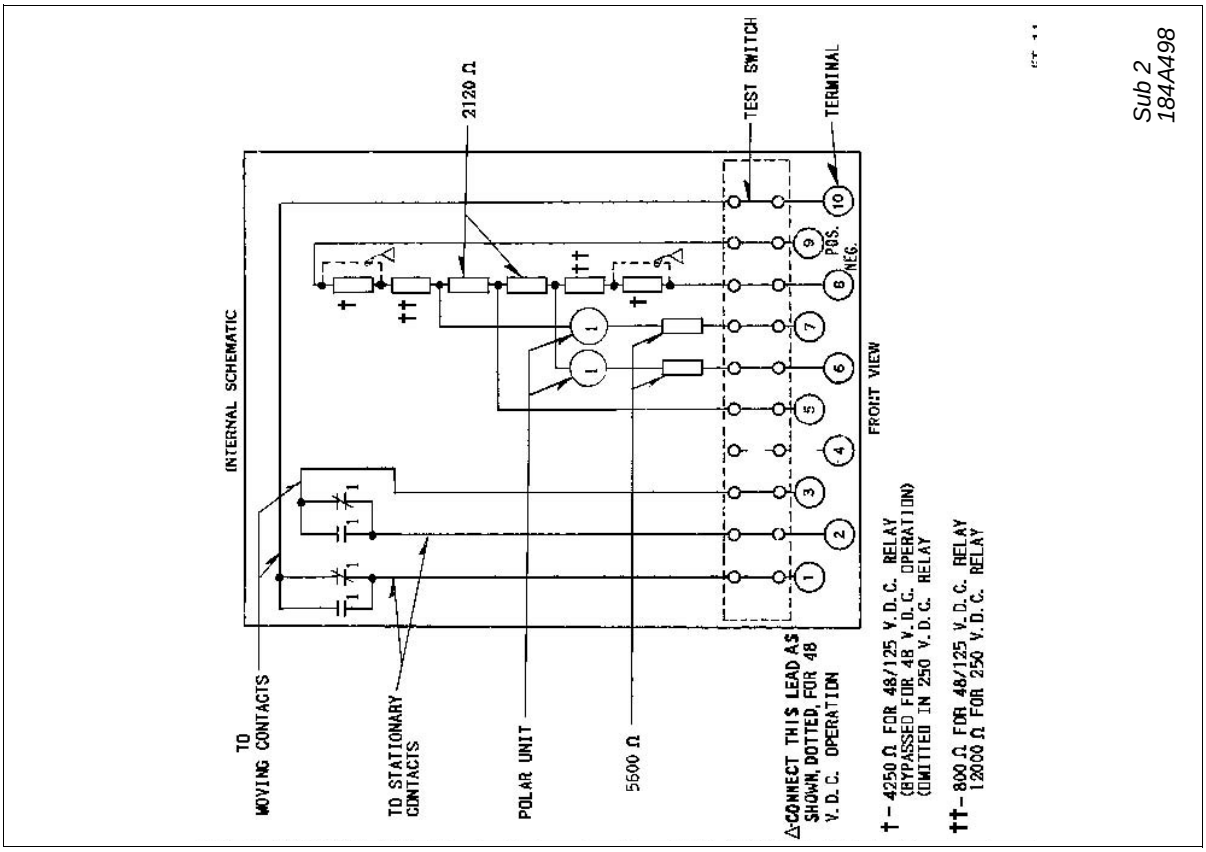


*Figure 7: Internal Schematic of the Type PMD-1 Relay in the FT-11 case - dc supply – for two-terminal lines.*

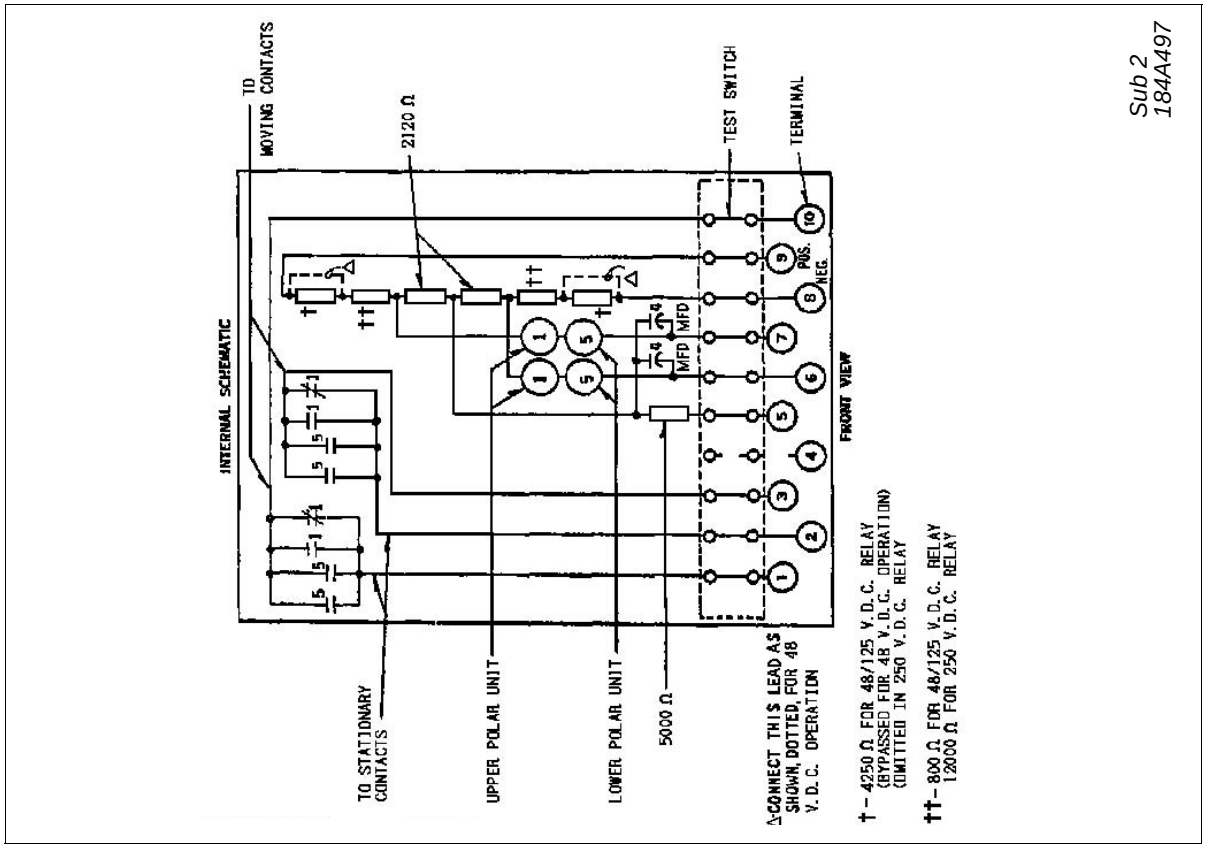


*Figure 6: Internal Schematic of the Type PMD Relay in FT-21 case - dc supply – for two-terminal lines.*

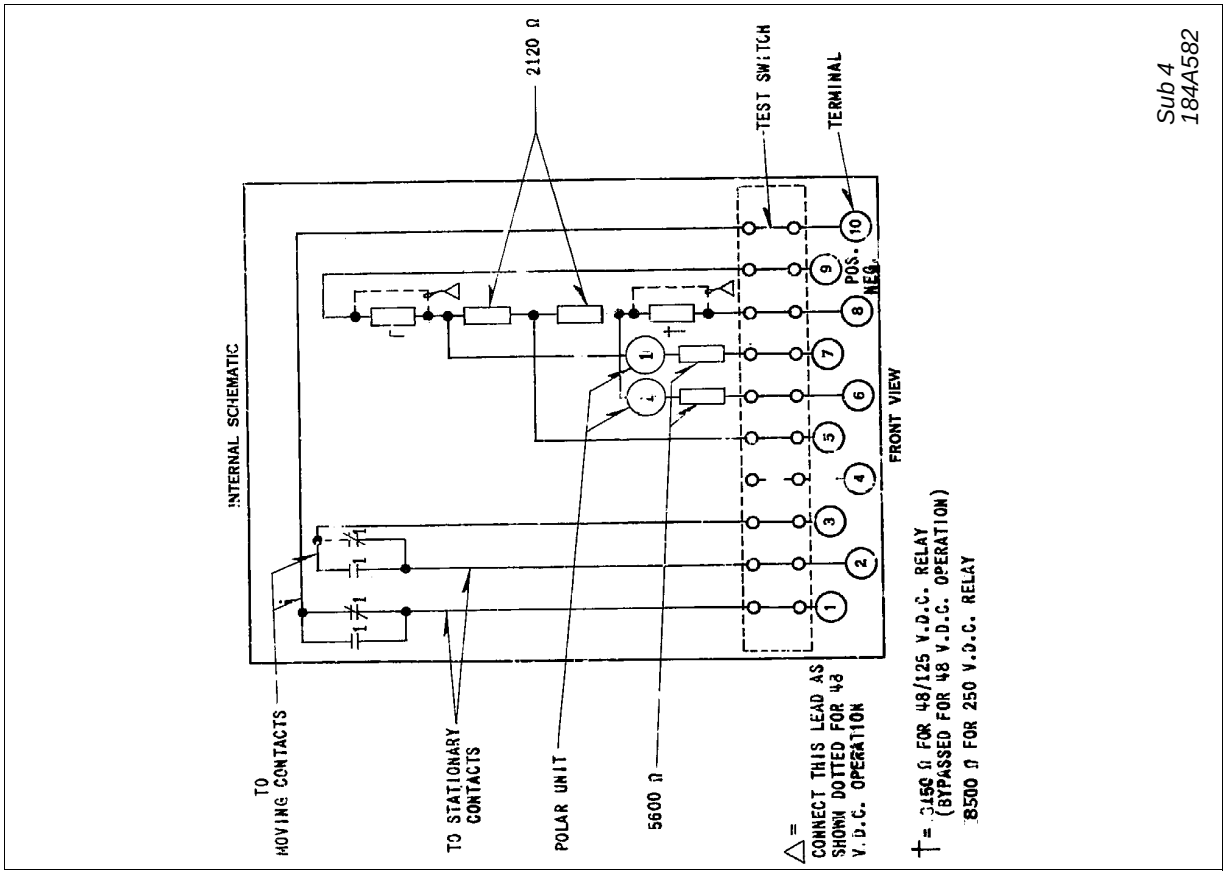


*Figure 9: Internal Schematic of the Type PMD-1 Relay in the FT-11 case - dc supply – for three-terminal lines.*

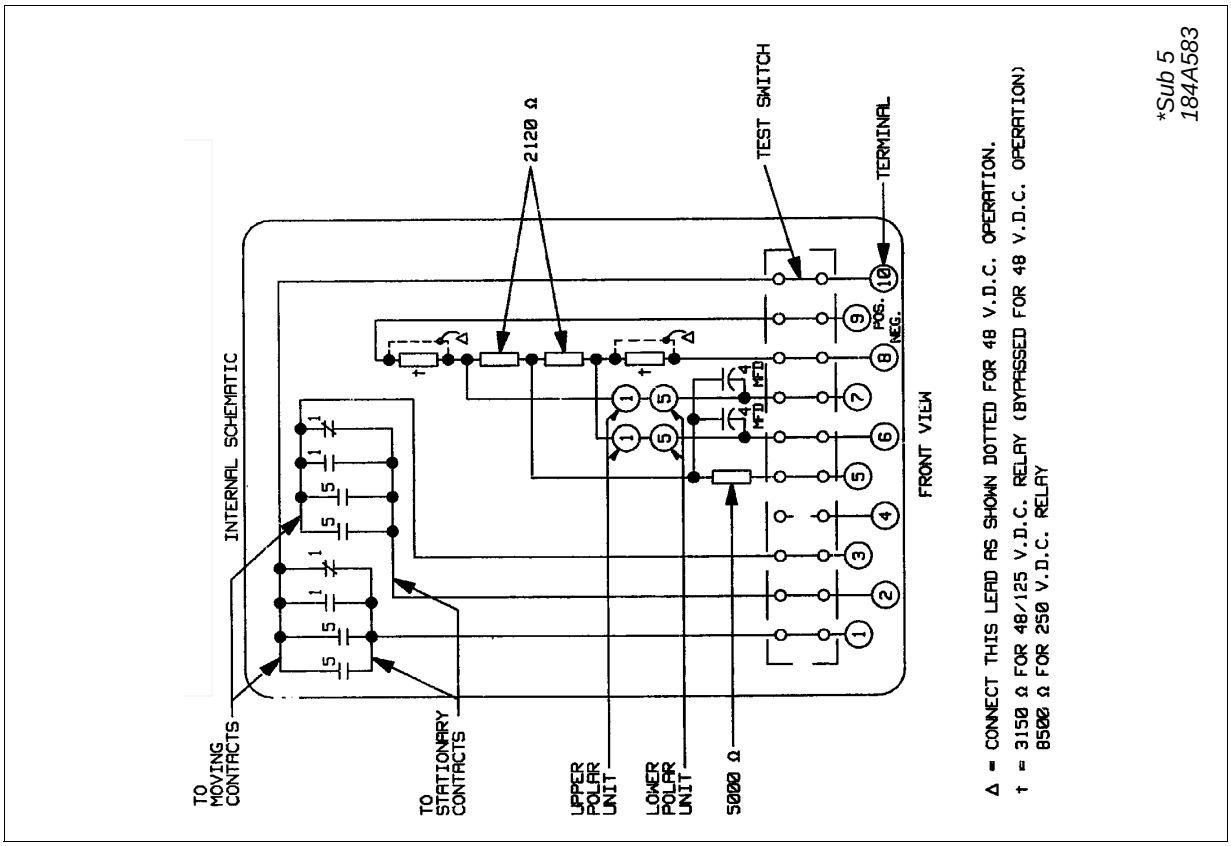


*Figure 8: Internal Schematic of the Type PMD Relay in the FT-21 case - dc supply – for three-terminal lines.*

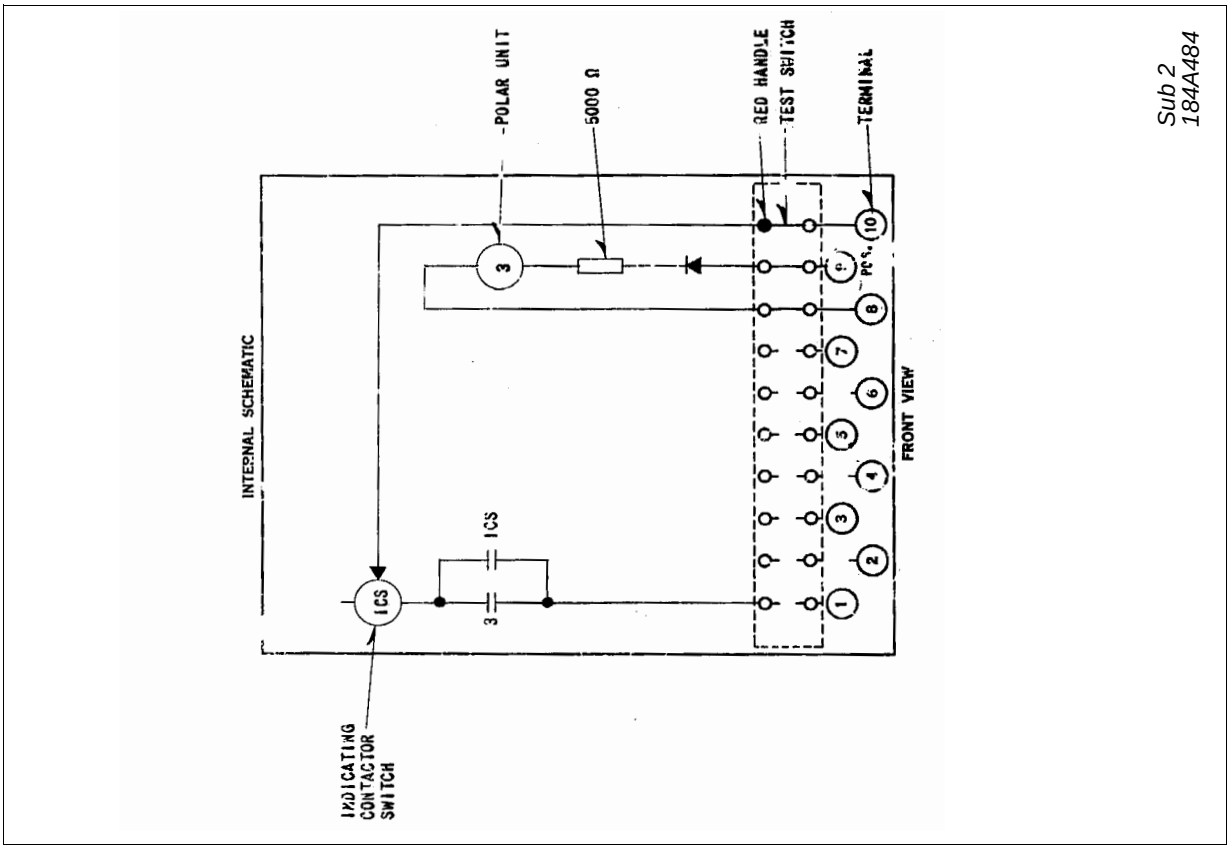


*Figure 11: Internal Schematic of the Type PM-3 Relay in the FT-11 case.*

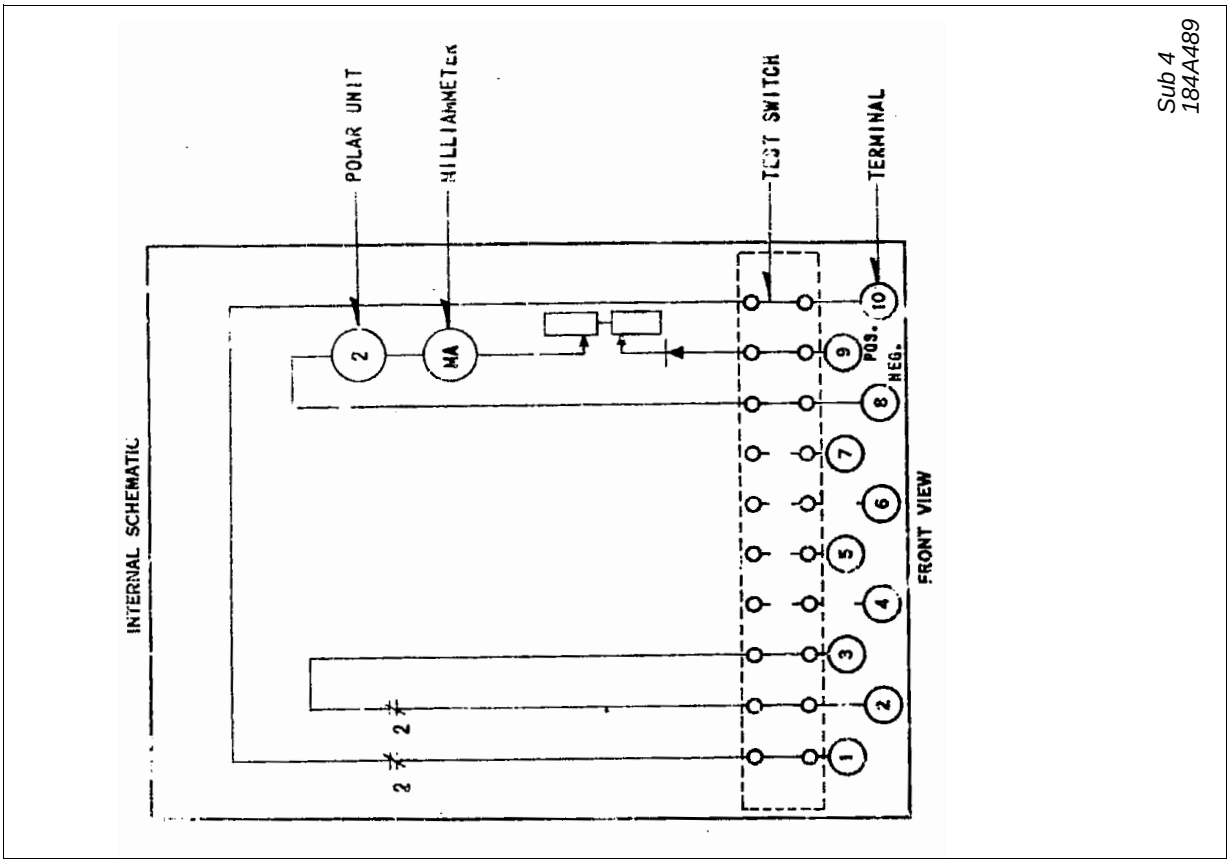


*Figure 10: Internal Schematic of the Type PM-2 Relay in the FT-21 case.*

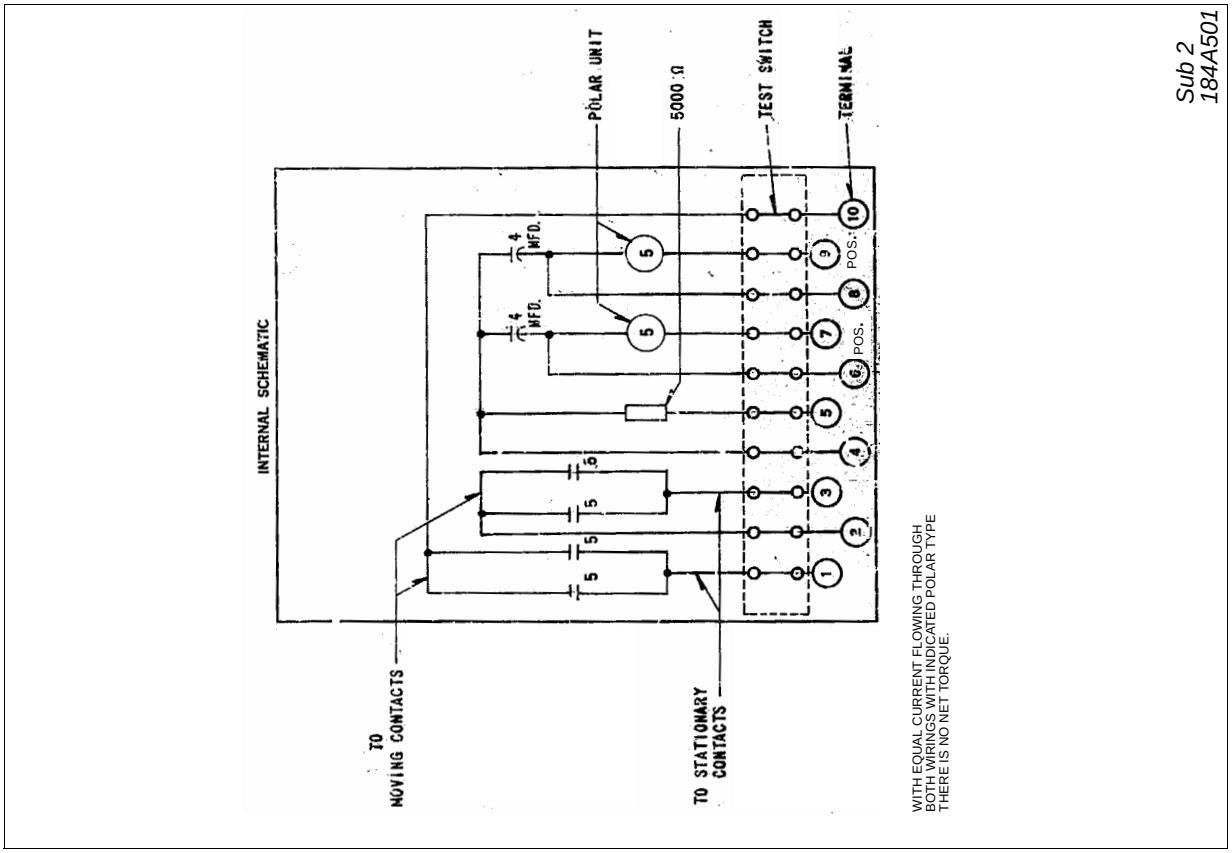


*Figure 13: Internal Schematic of the Type PM-5 Ground Detector Relay in the FT-11 case.*

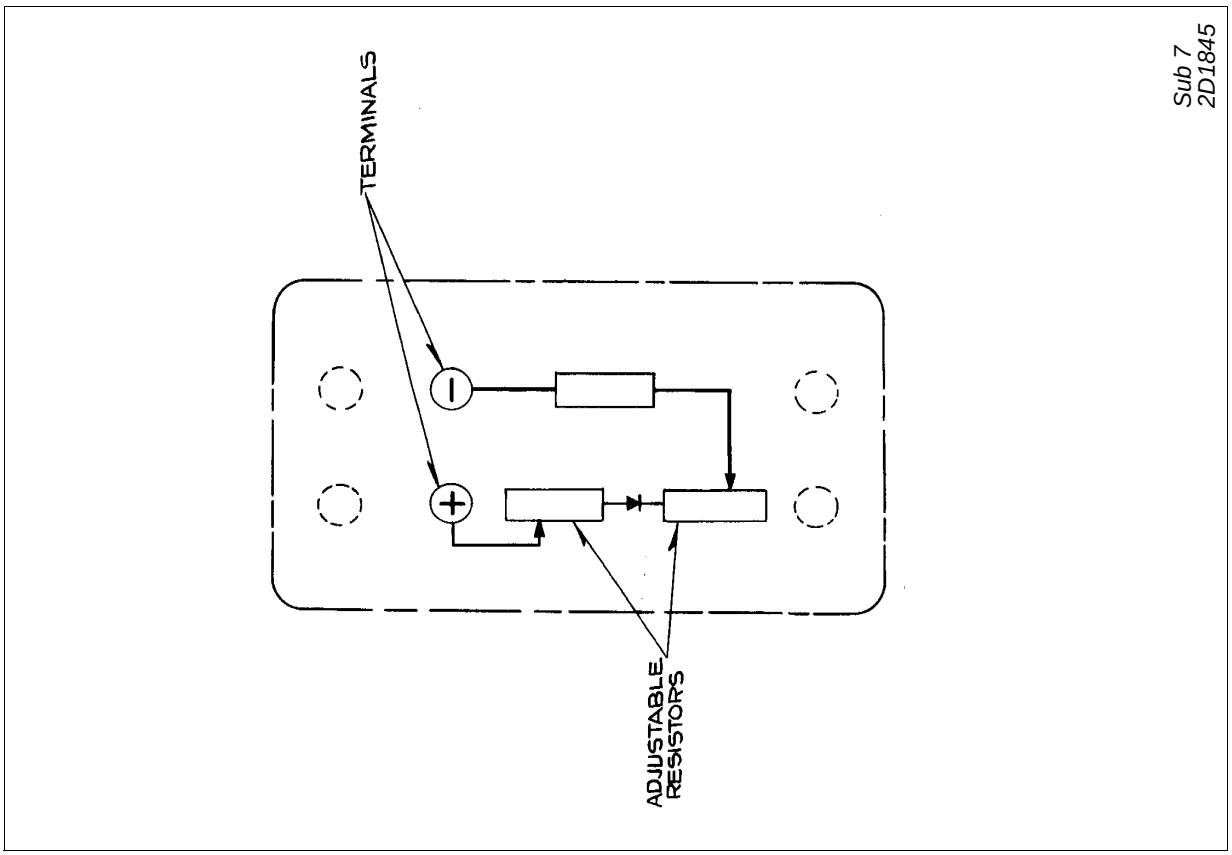


*Figure 12: Internal Schematic of the Type PM-4 Auxiliary Unit in the small molded case.*

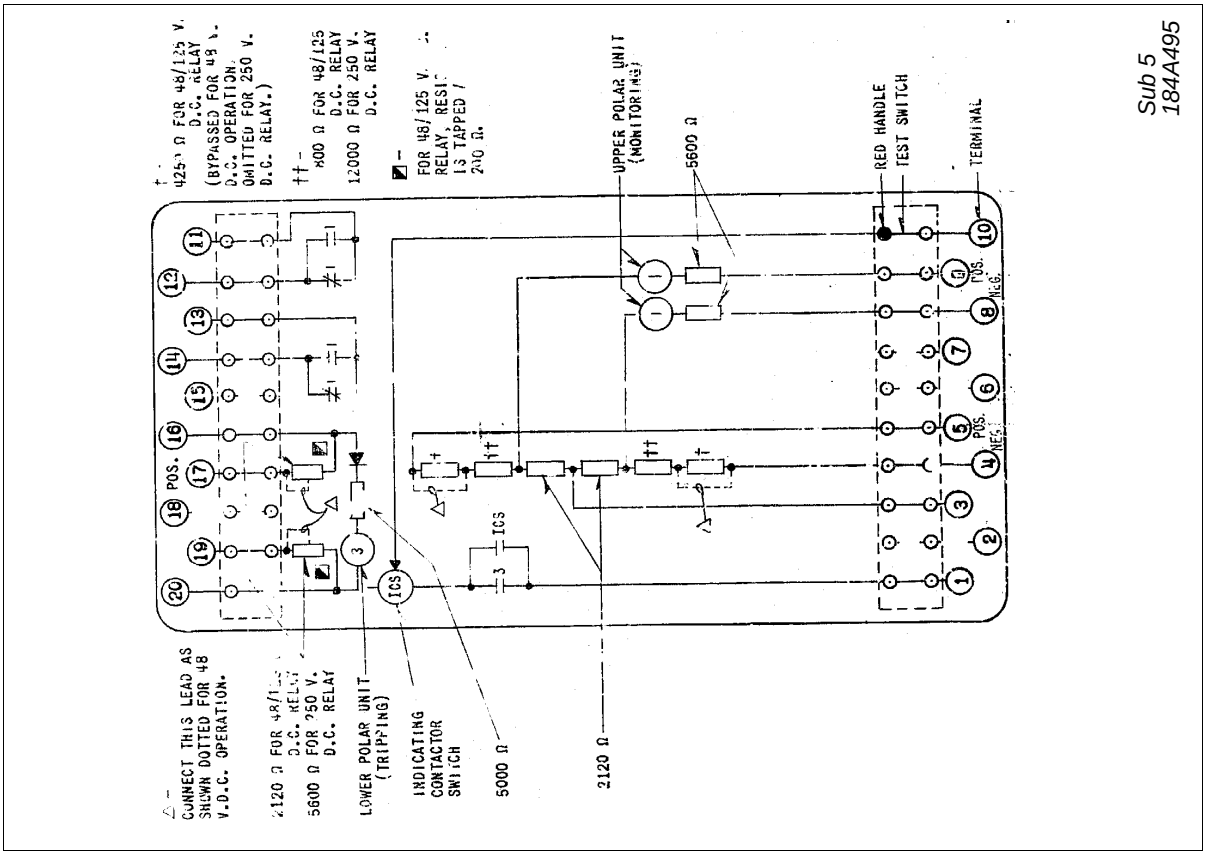


*Figure 15: Internal Schematic of the Type PM-13 Relay in the FT-32 case - dc supply – for two-terminal lines.*

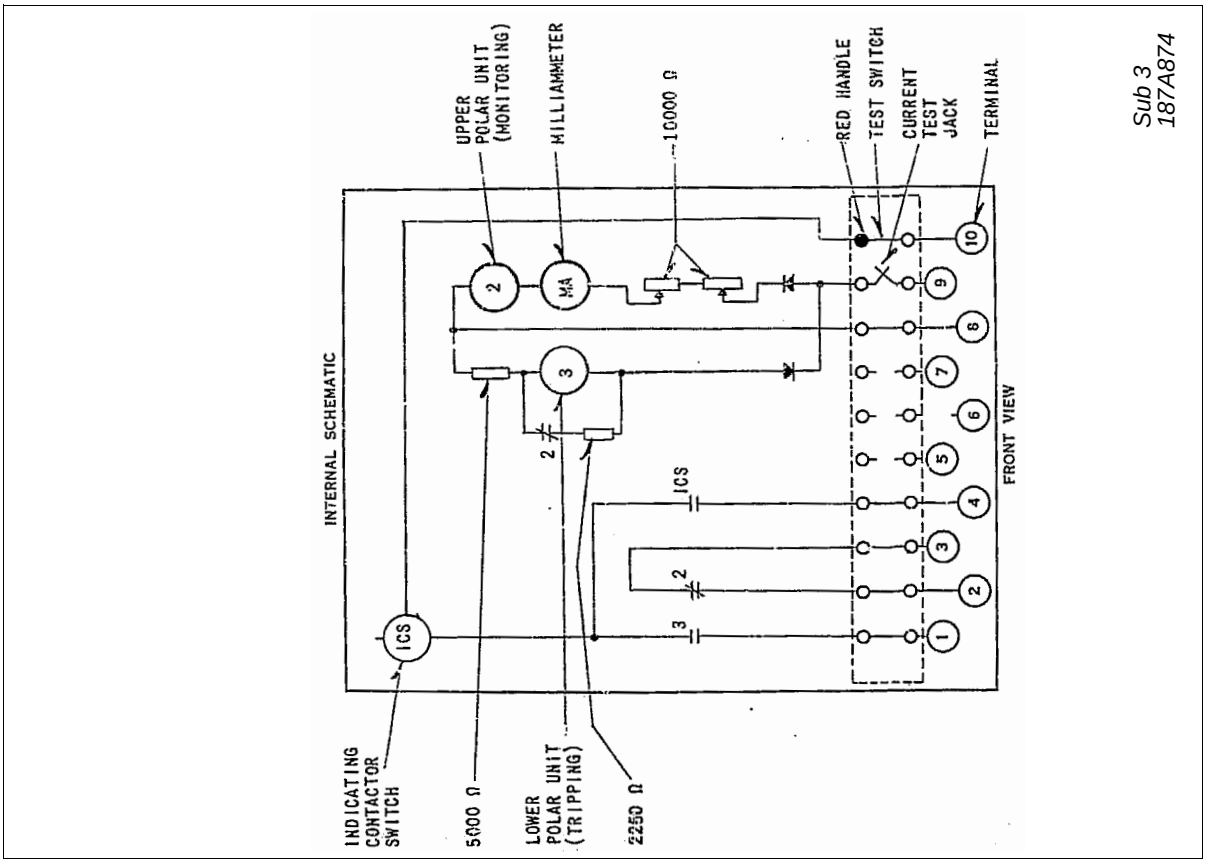


*Figure 14: Internal Schematic of the Type PM-23 Relay in the FT-21 case.*

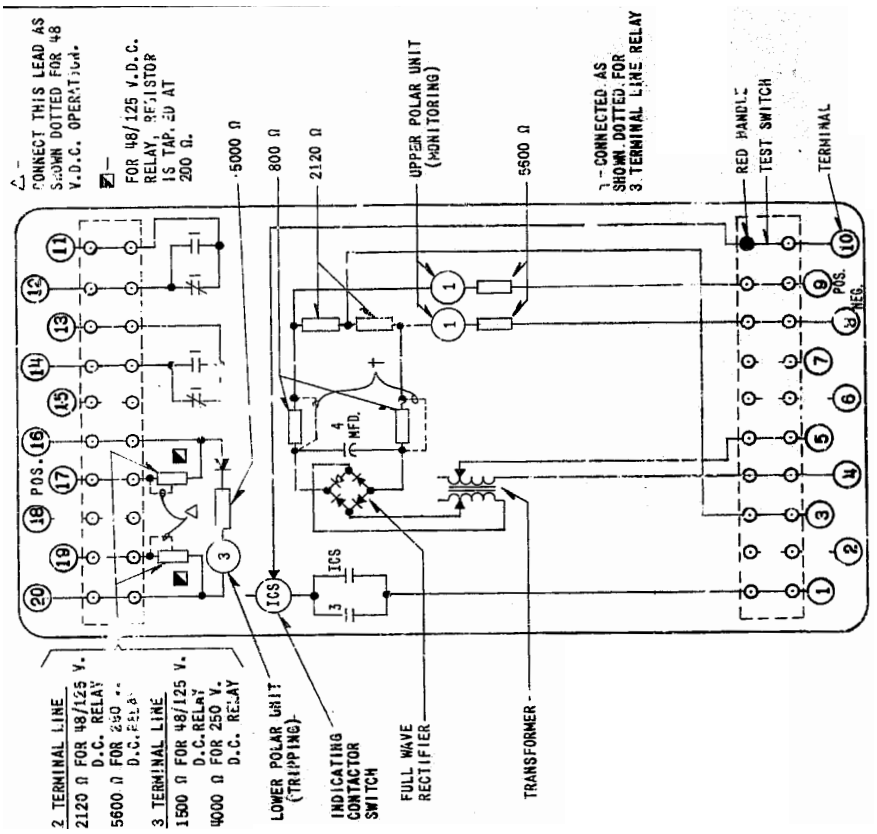


*Figure 17: Internal Schematic of the Type PM-13 Relay in the FT-32 case - 120 volt, 60 hertz supply – for two or three-terminal lines.*

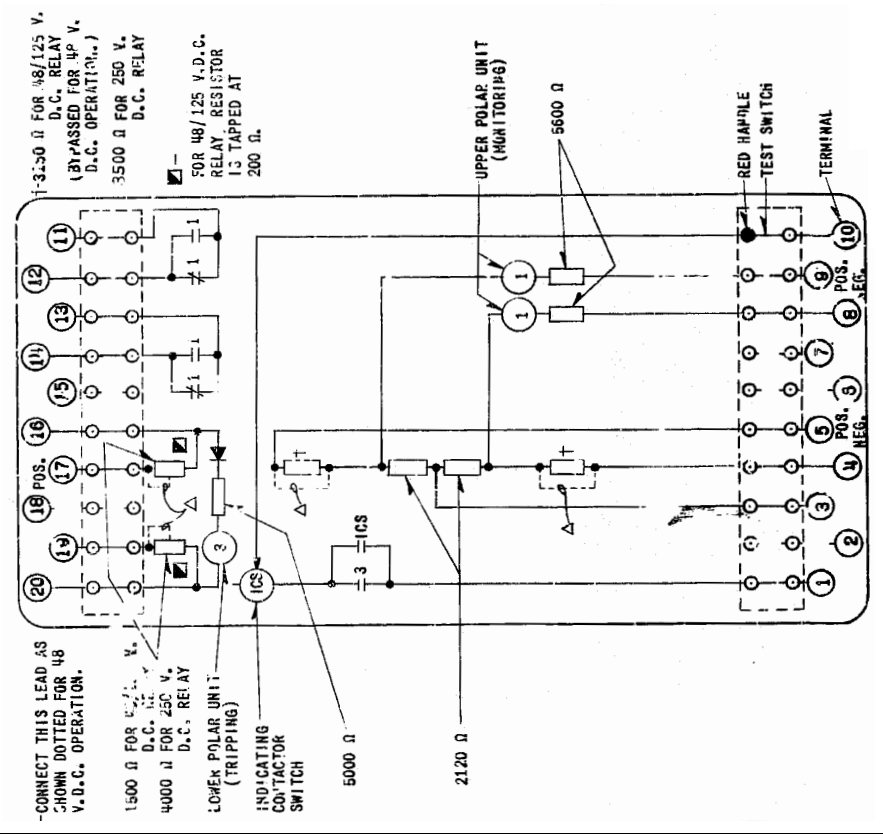


*Figure 16: Internal Schematic of the type PM-13 Relay in the FT-32 case - dc supply – for three-terminal lines.*

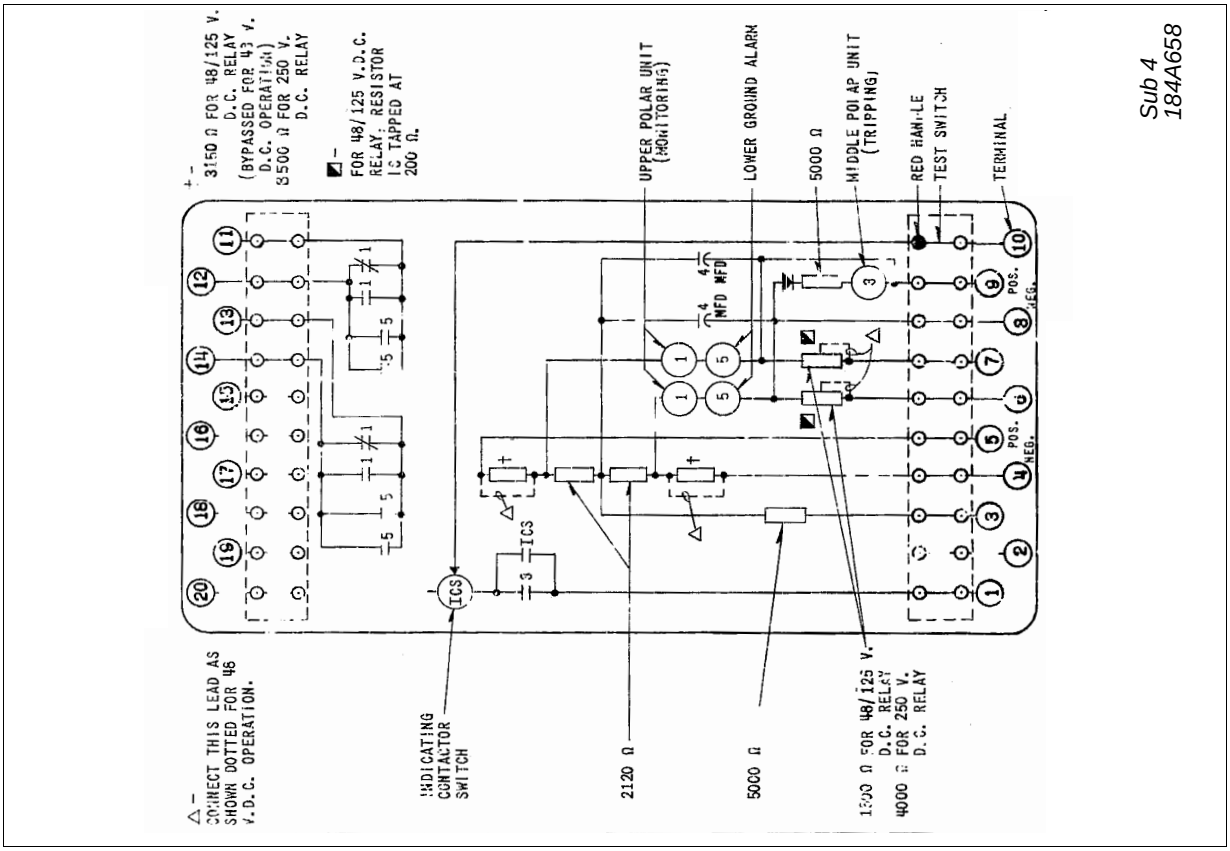


*Figure 19: Internal Schematic of the type PMG-13 Relay in the FT-32 case - dc supply – for three-terminal lines.*

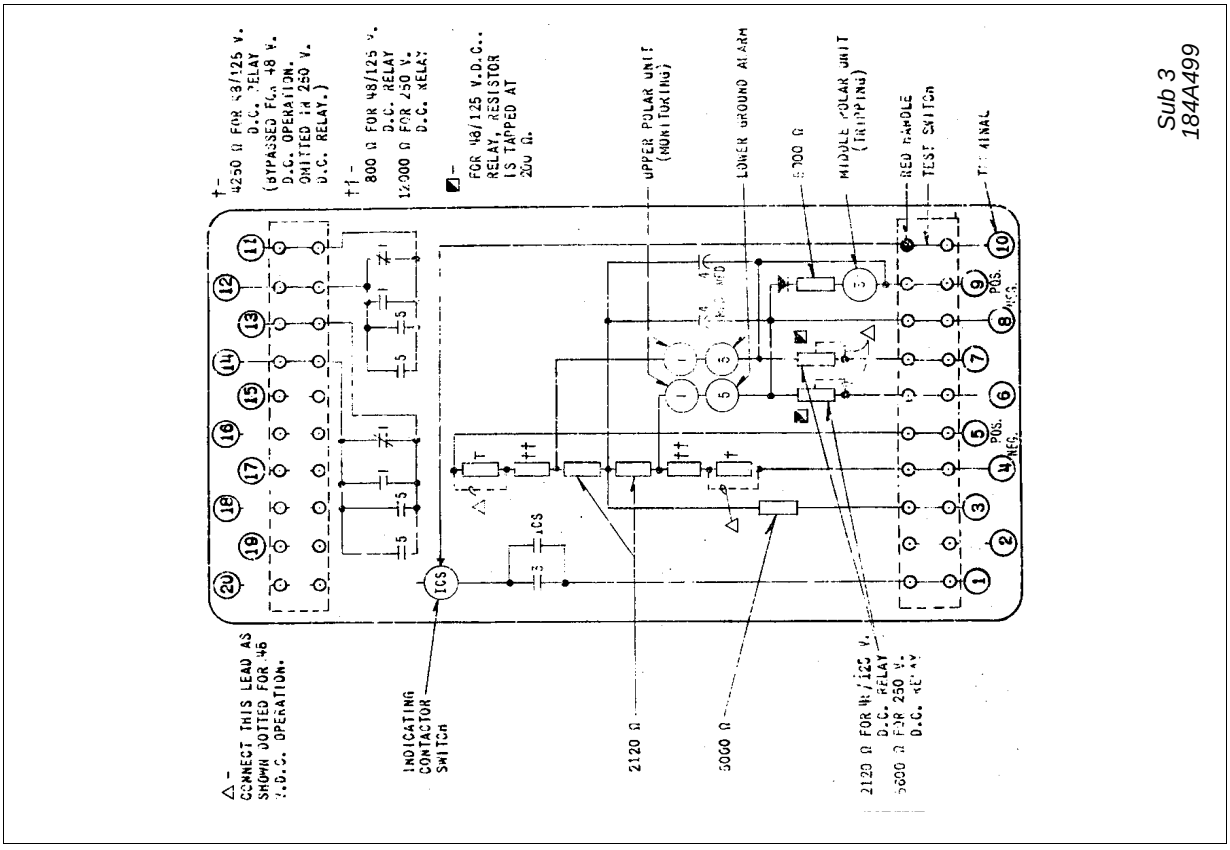


*Figure 18: Internal Schematic of the Type PMG-13 Relay in the FT-32 case - dc supply – for two-terminal lines.*

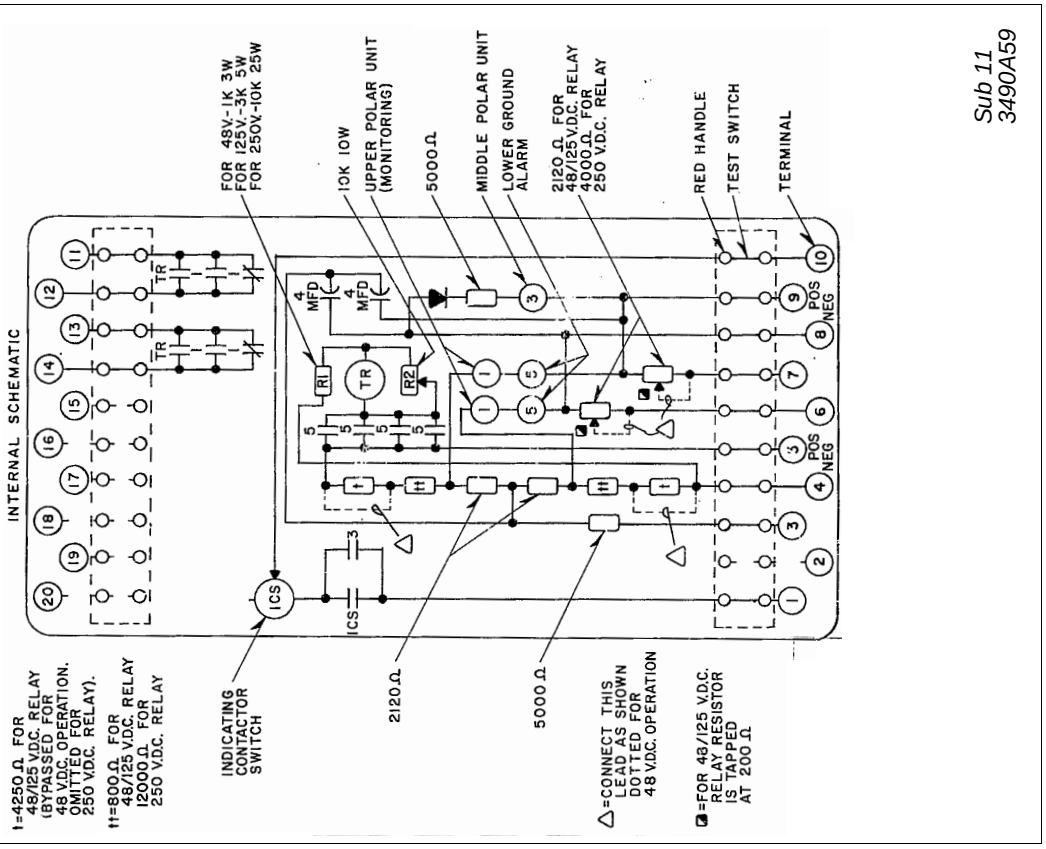


*Figure 21: PMG-13 Relay with Ground Alarm and Remote Trip - two-terminal lines with Telephone Relay Output. FT-32 case*

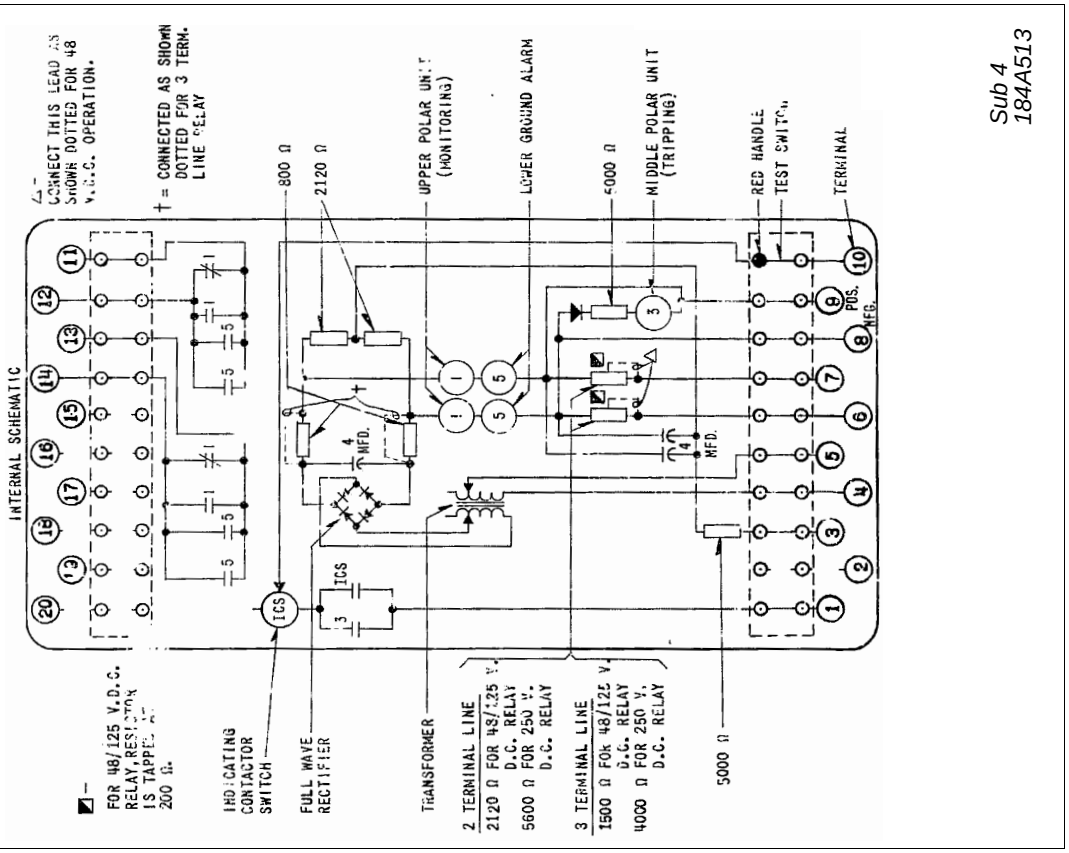


*Figure 20: Internal Schematic of the Type PMG-13 Relay in the FT-32 case - 120 volts, 60 hertz supply – for two or three-terminal lines.*

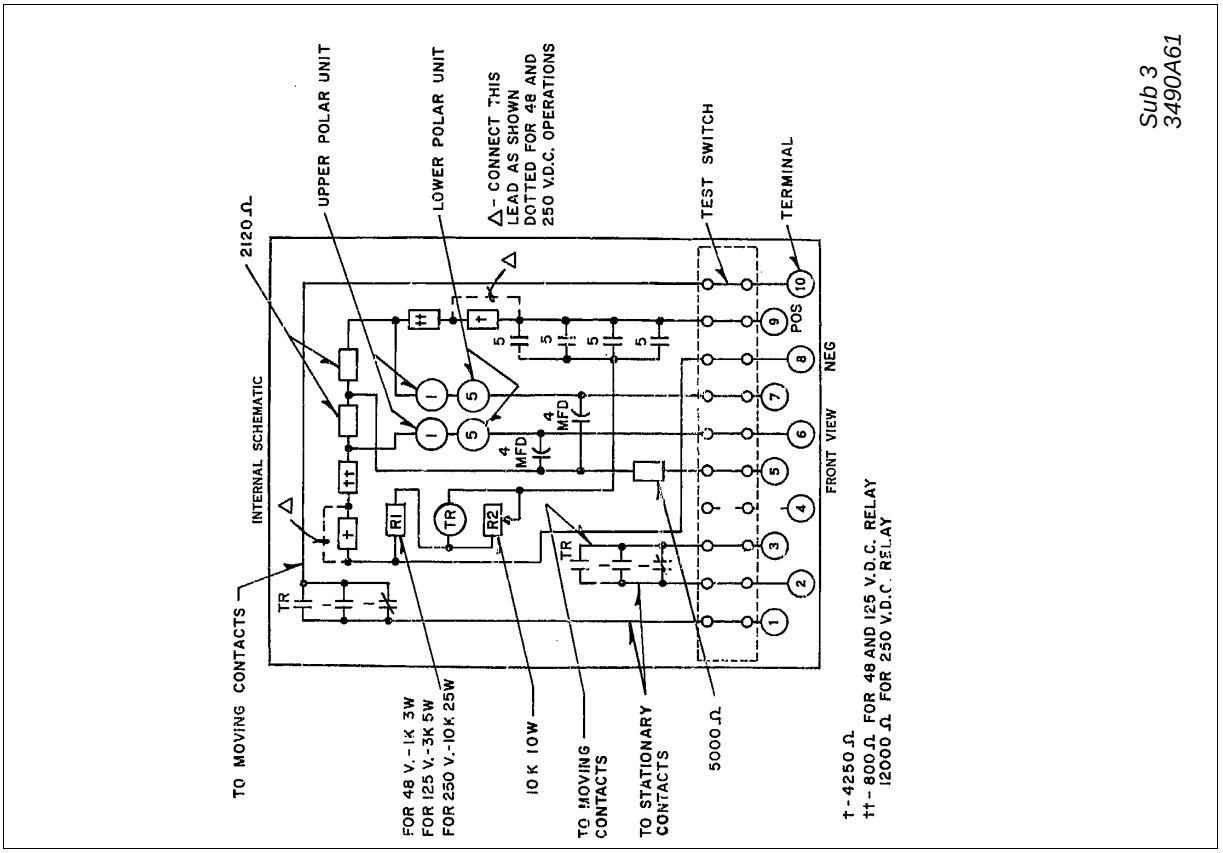


*Figure 23: PMD Relay - Ground Alarm, D.P.D.T. Contacts, two-terminal lines with Telephone Relay Output. FT-21 case.*

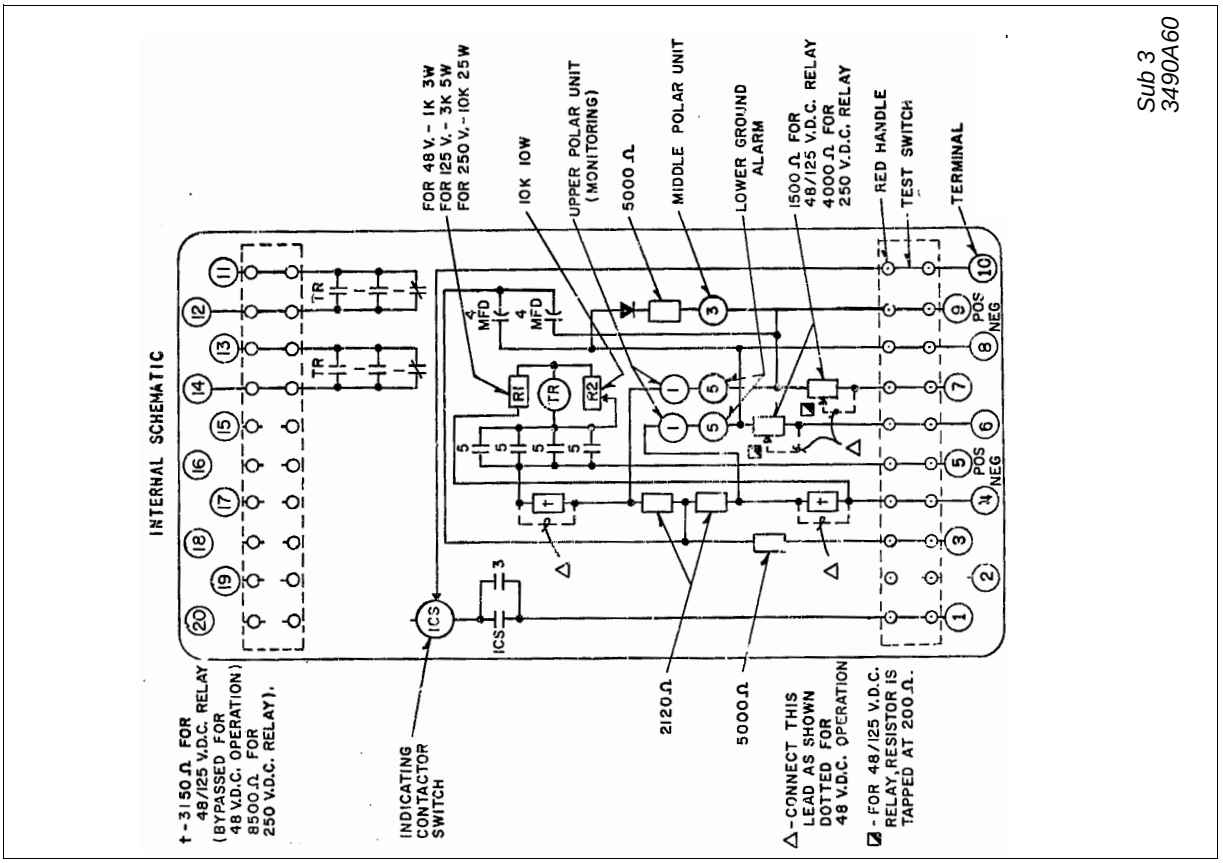


*Figure 22: PMG-13 Relay with Ground Alarm and Remote Trip - three-terminal lines with Telephone Relay output. FT-32 case.*

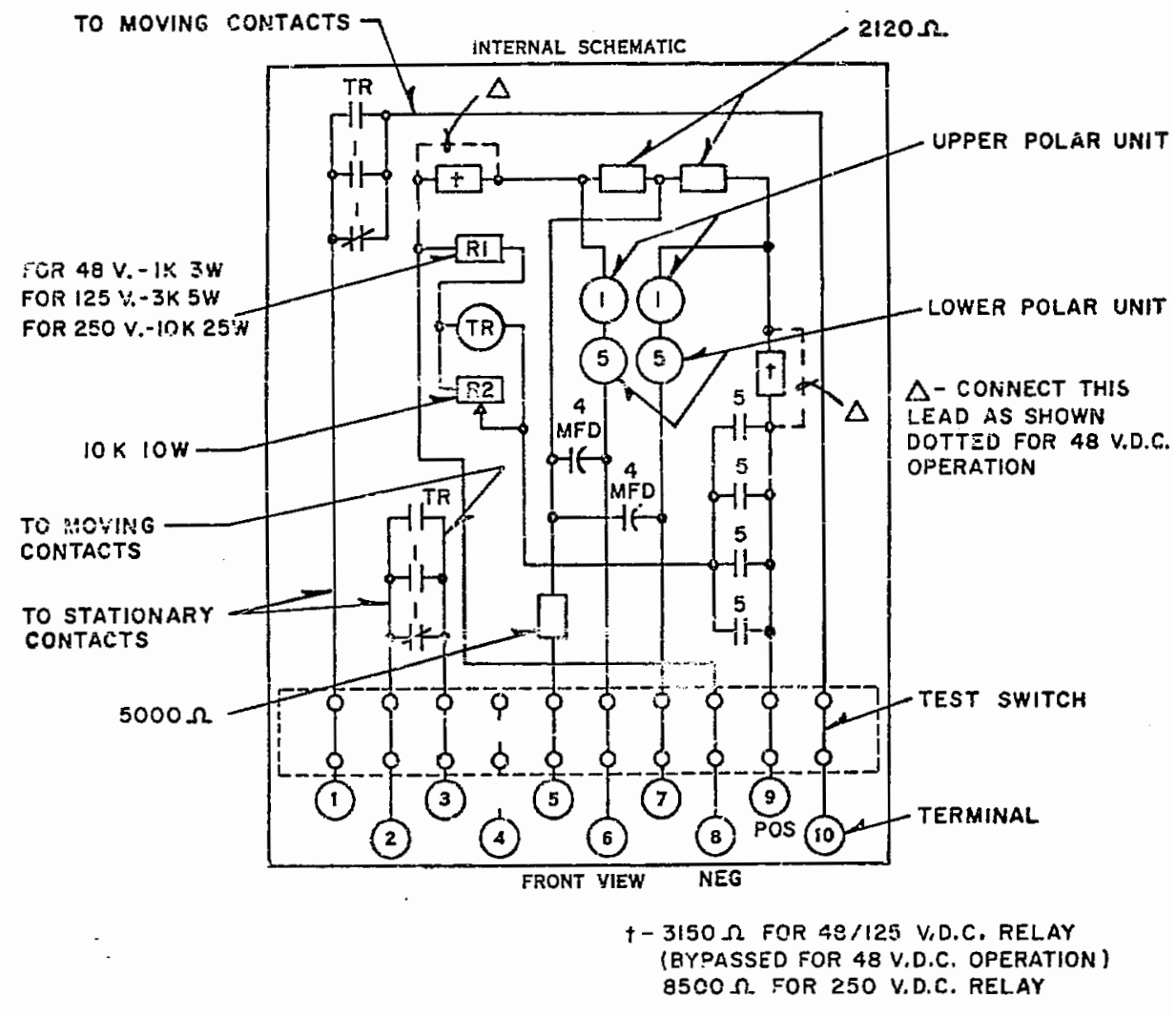


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*Figure 24: PMD Relay - Ground Alarm, D.P.D.T, Contacts, three-terminal lines with Telephone Relay Output. FT-21 case.*

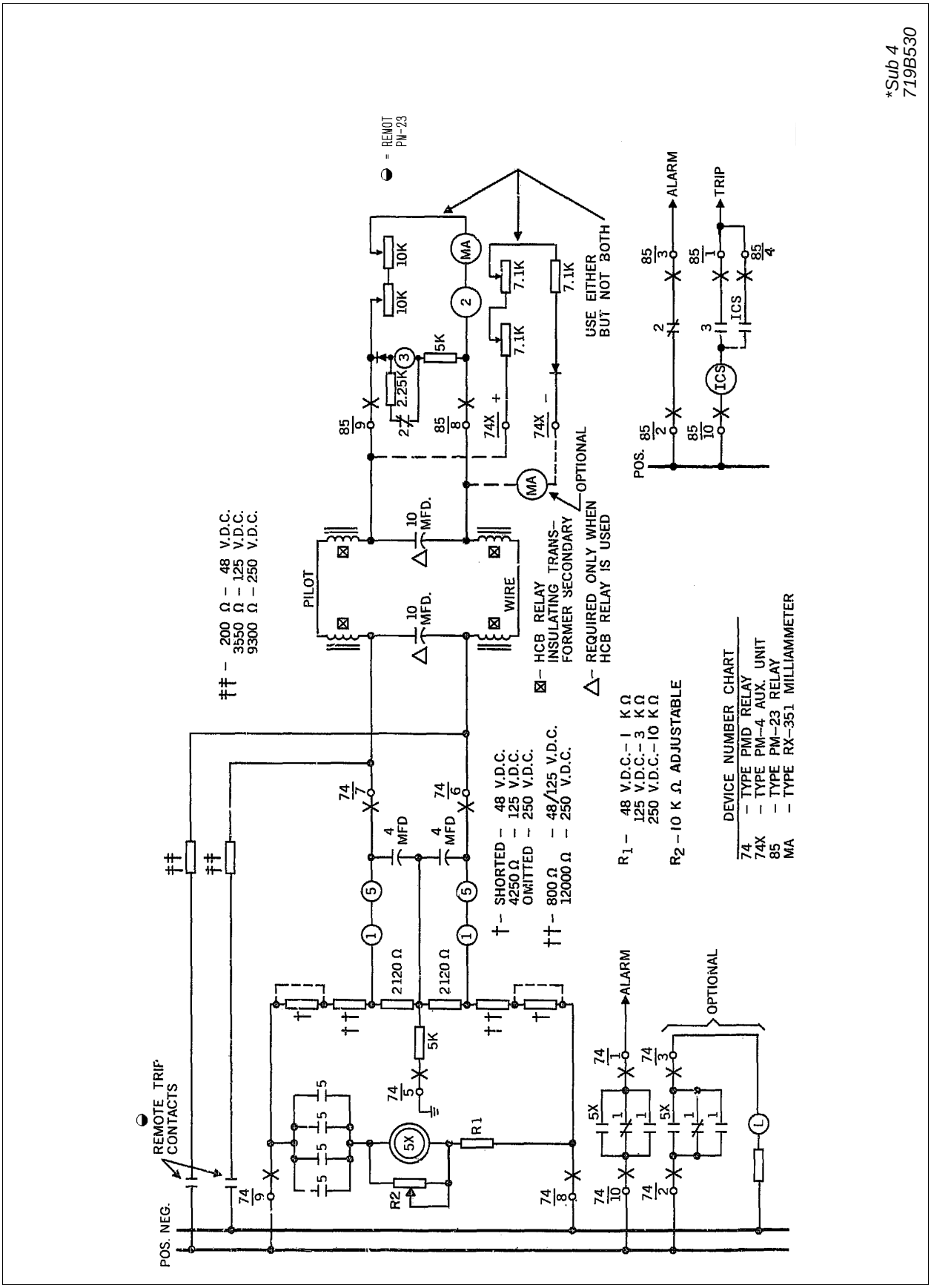


*Figure 25: External Schematic of the type PMD Relay with Type PM-23 or PM-4 Relay – two-terminal lines.*

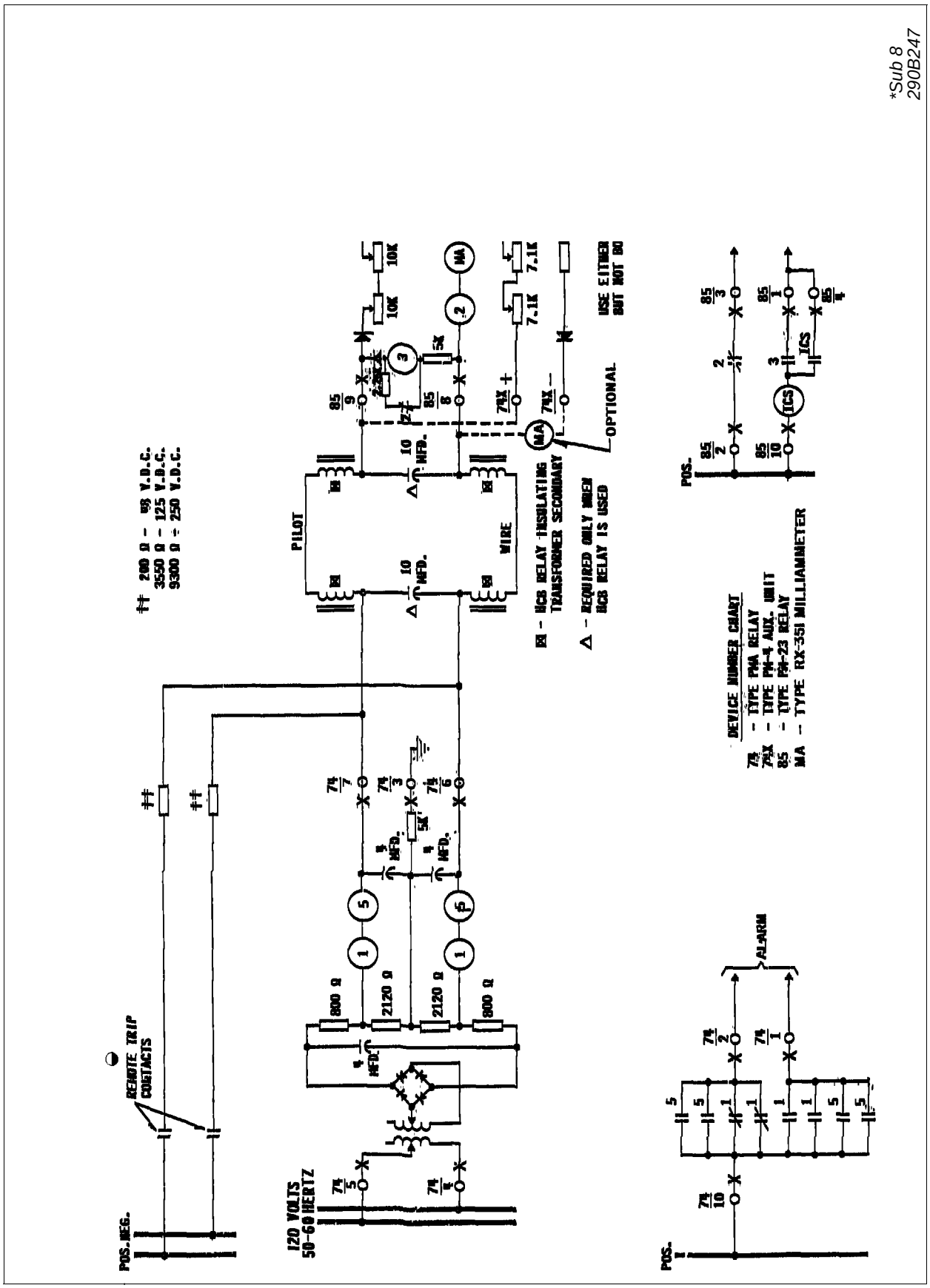


*Figure 26: External Schematic of the Type PMA Relay with Type PM-23 or PM-4 Relay – two-terminal lines.*

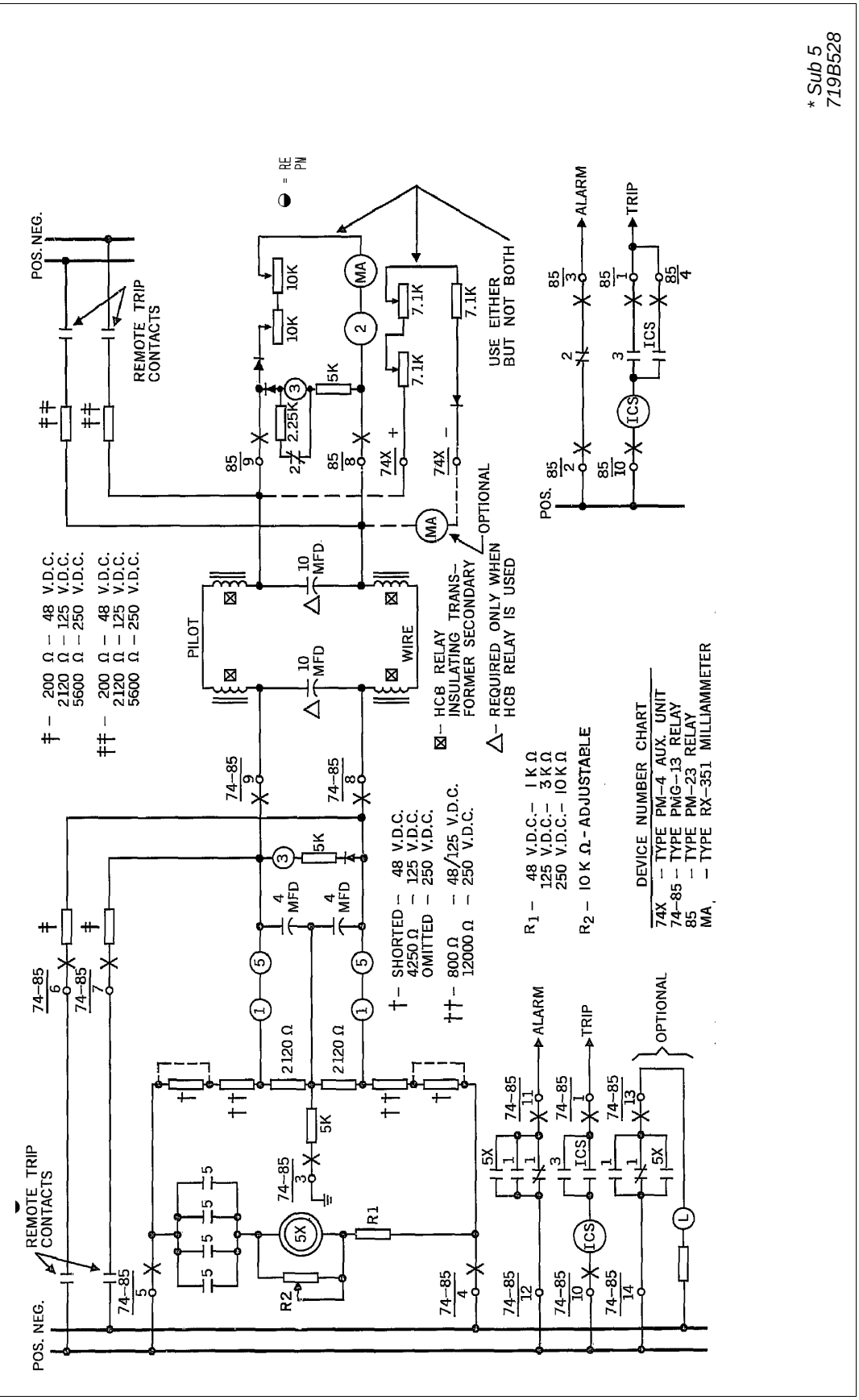


*Figure 27: External Schematic of the dc Type PMG-13 Relay with Type PM-23 or PM-4 Relay – two-terminal lines.*

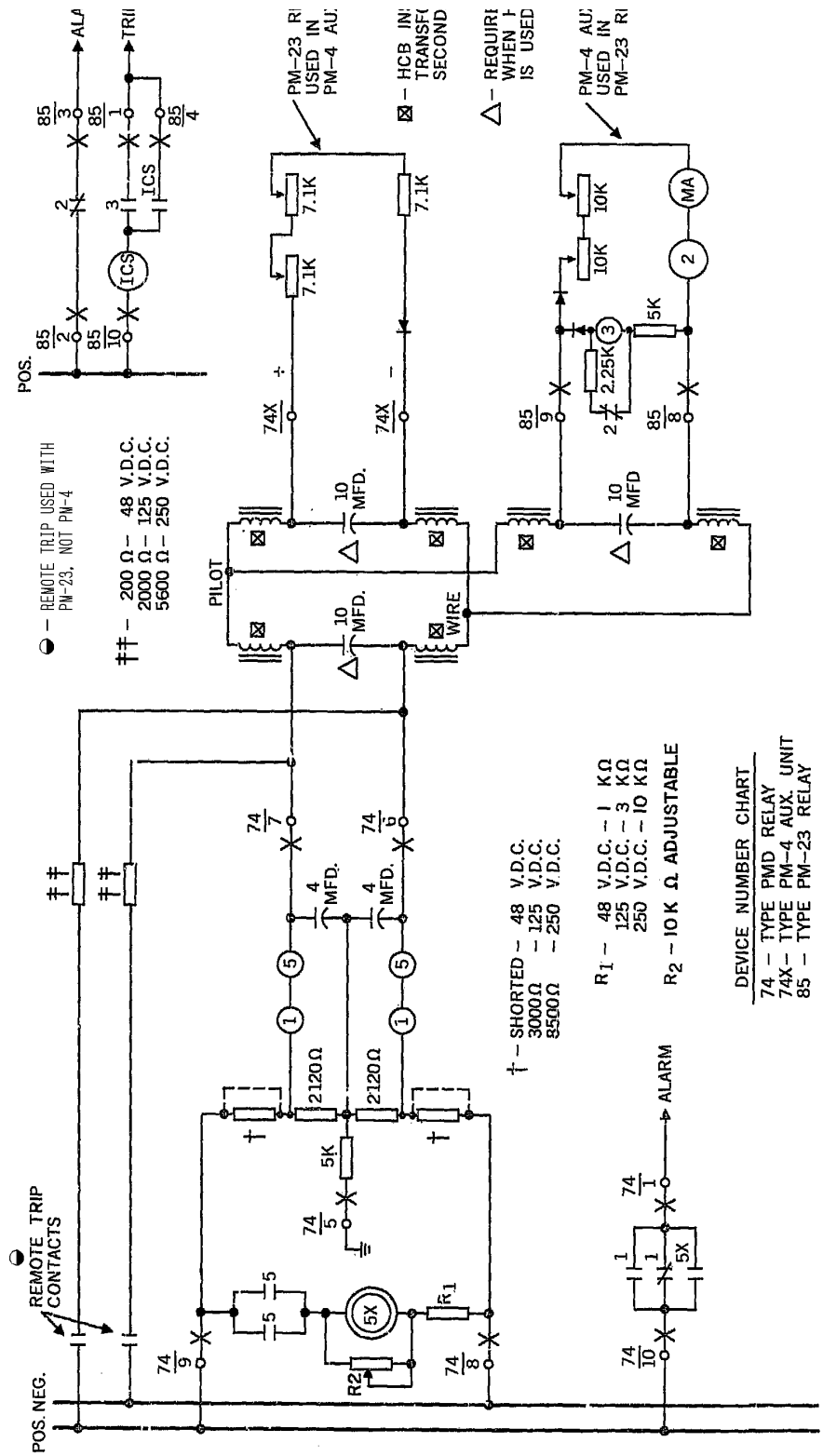


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*Figure 28: External Schematic of the Type PMD Relay with Type PM-23 and PM-4 Relays – three-terminal lines.*

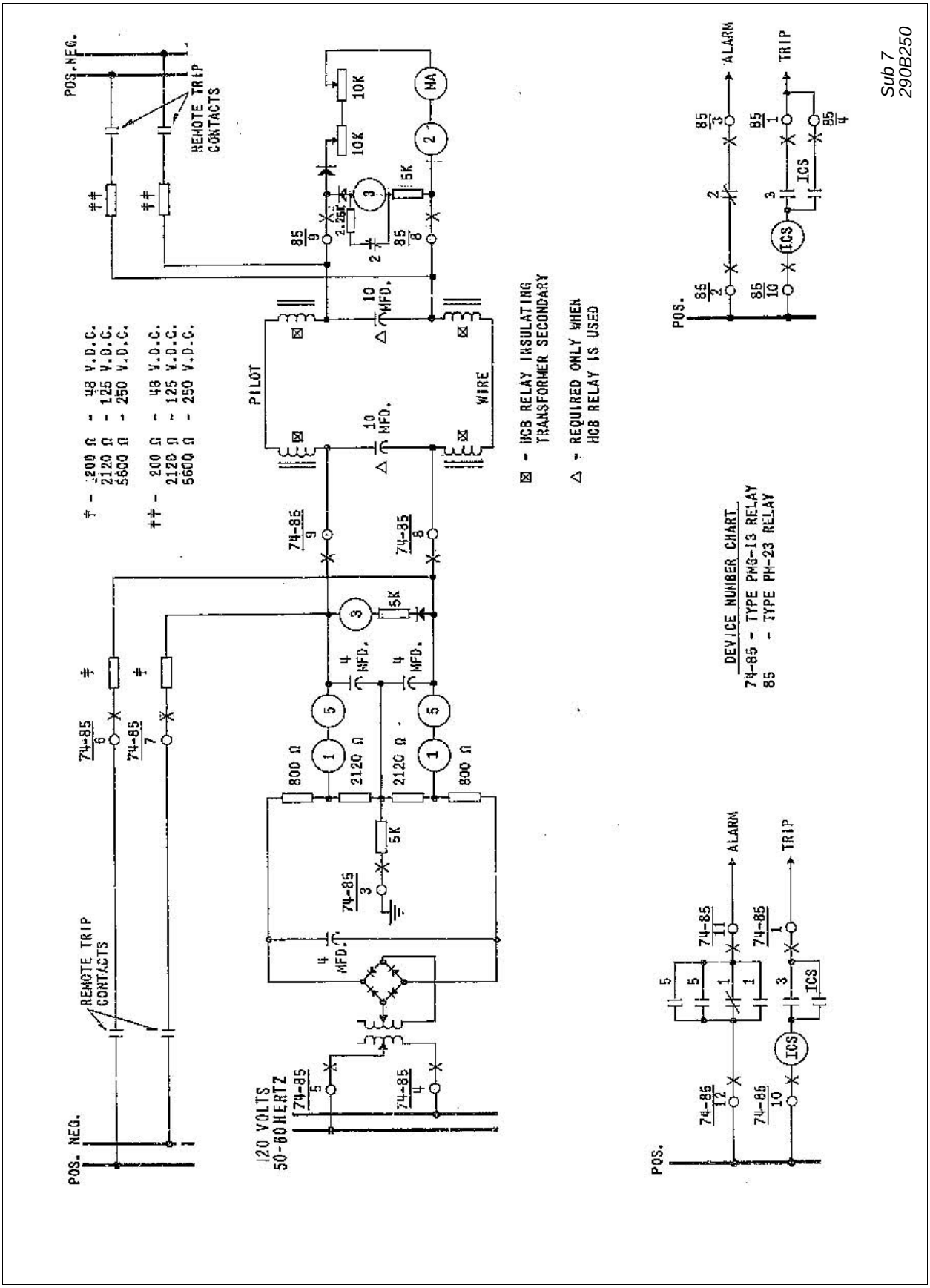



*Figure 29: External Schematic of the ac Type PMG-13 with Type PM-23 Relay – two-terminal lines.*

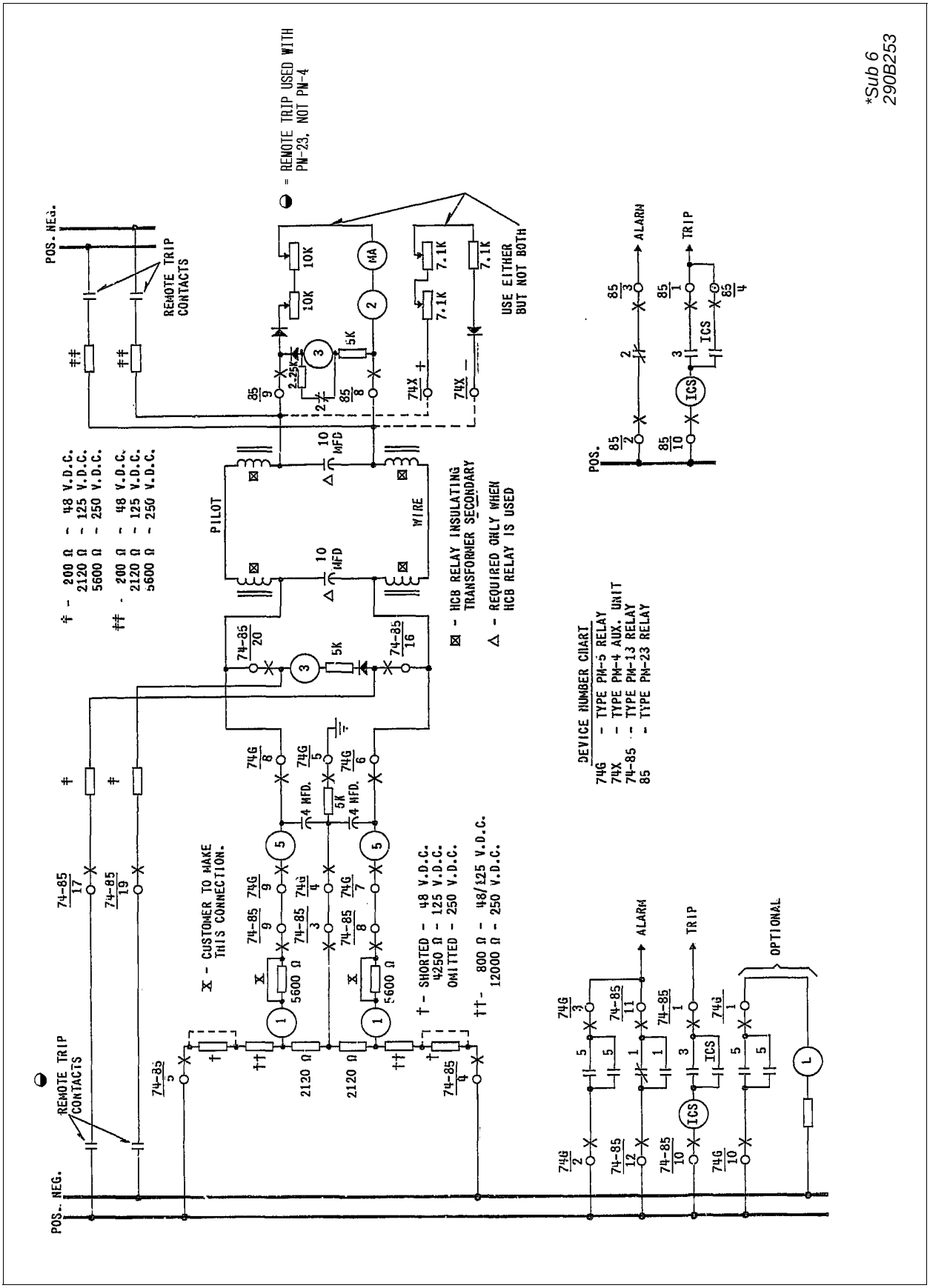



*Figure 30: External Schematic of the dc Type PM-13 and PM-5 Relay with Type PM-23 or PM-4 Relay – two-terminal lines.*

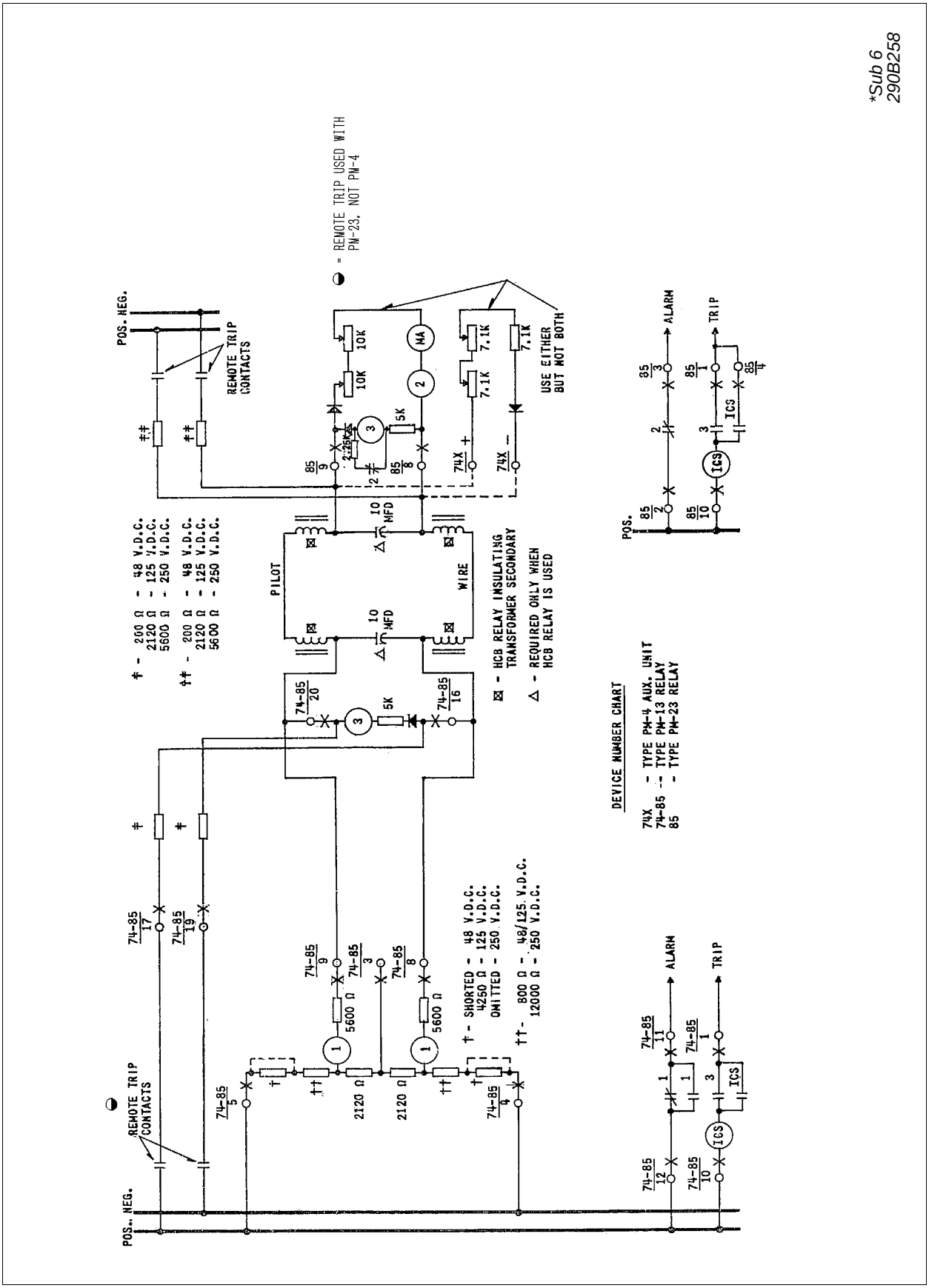



*Figure 31: External Schematic of the dc Type PM-13 Relay with Type PM-23 or PM-4 Relay – two-terminal lines.*

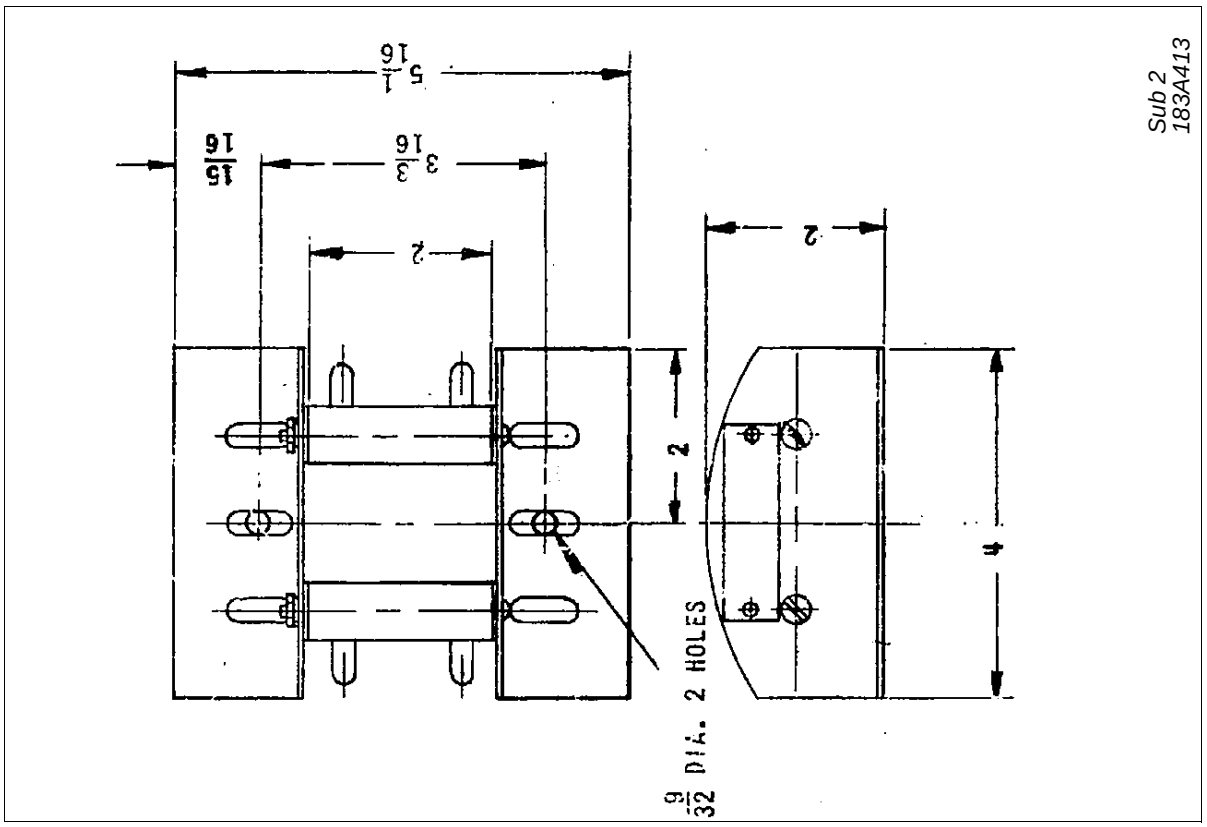
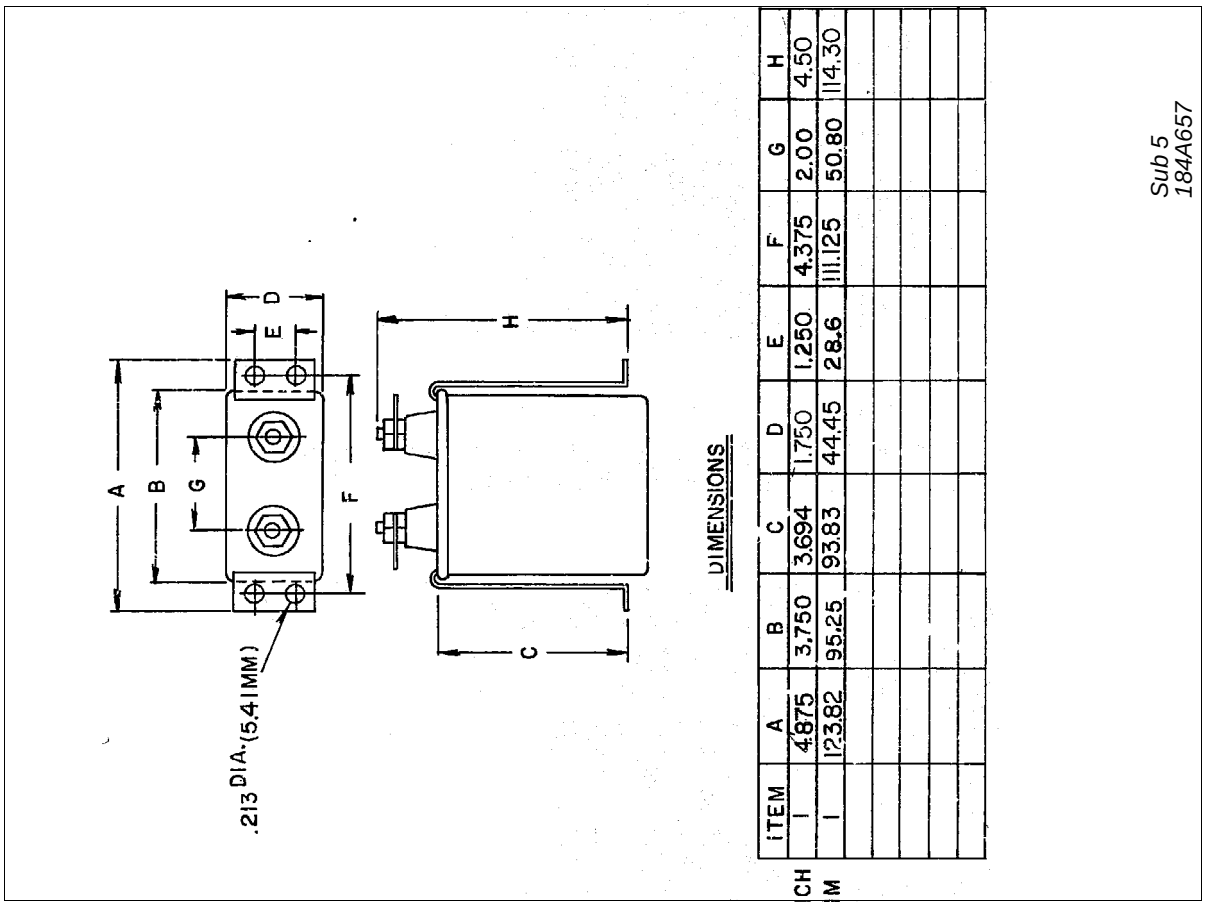



*Figure 33: Outline and Drilling Plan for External Remote Trip Resistor Assembly.*




| CH ITEM | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | 4.875 | 3.750 | 3.694 | 1.750 | 1.250 | 4.375 | 2.00 | 4.50 |
| M 1 | 123.82 | 95.25 | 93.83 | 44.45 | 28.6 | 111.125 | 50.80 | 114.30 |

*Figure 32: Outline and Drilling Plan for 10 mfd capacitor – for references only.*

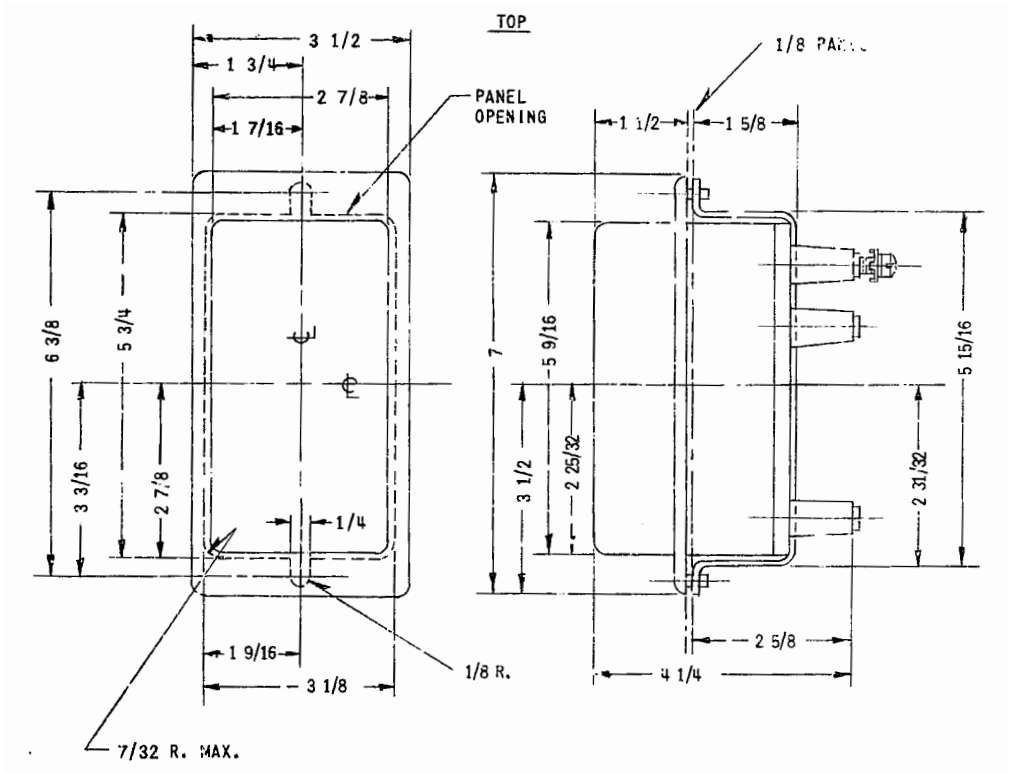



*Figure 34: Outline and Drilling Plan for the Type PM-4 auxiliary Unit in the projection molded case.*

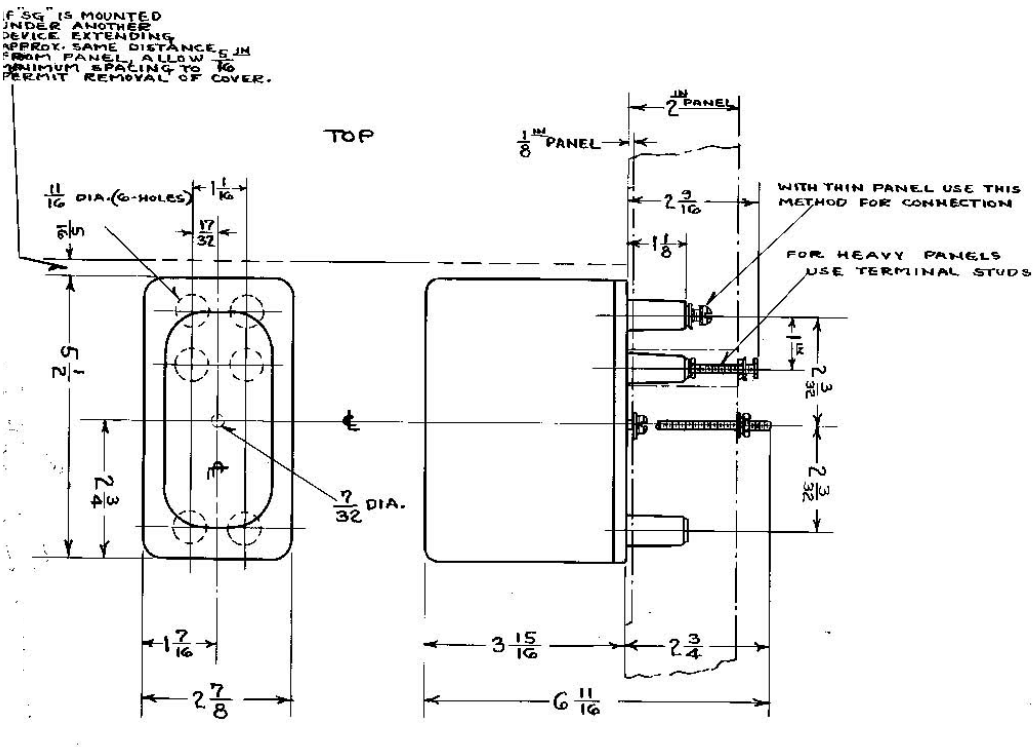
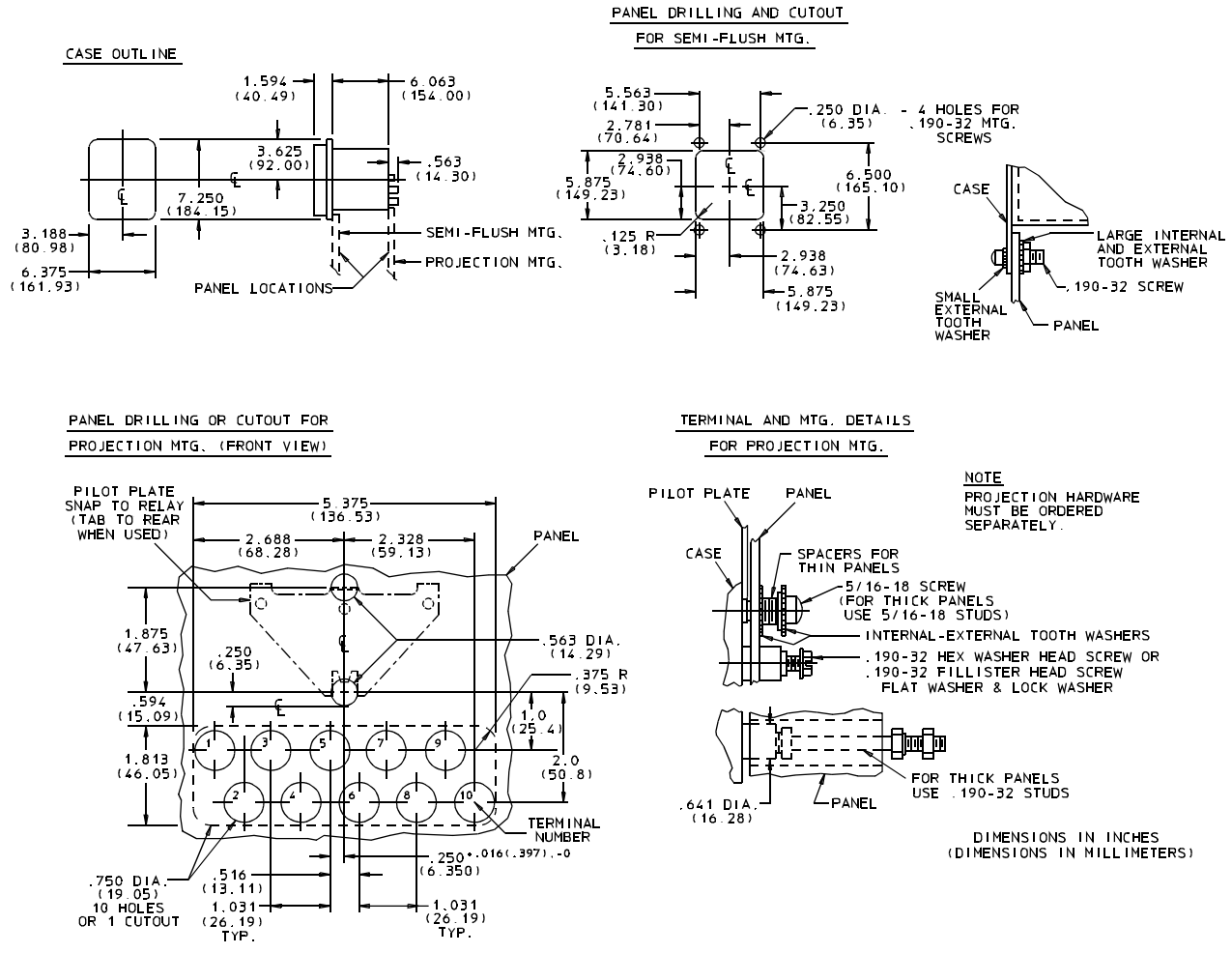
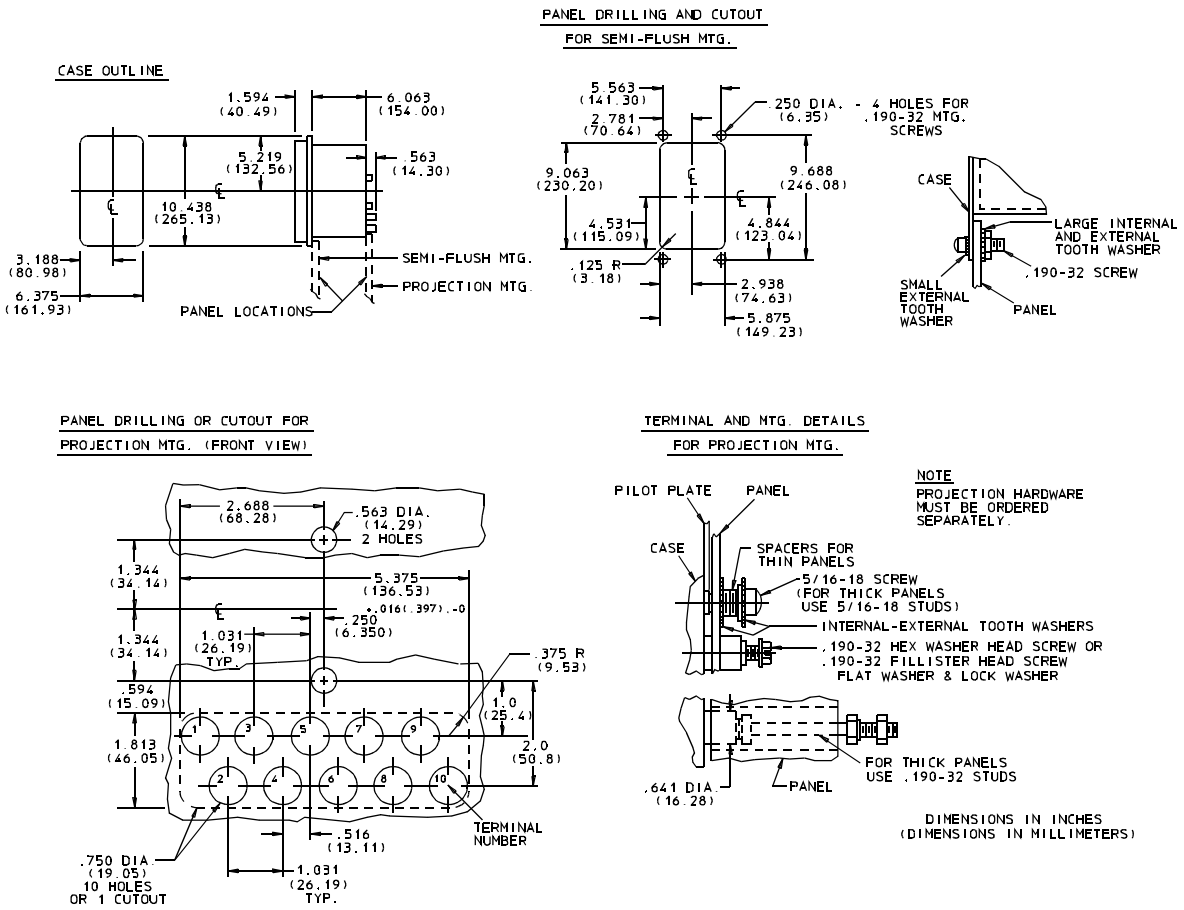



*Figure 35: Outline and Drilling Plan for the Type PM-4 Auxiliary Unit in the Semi-Flush molded case.*



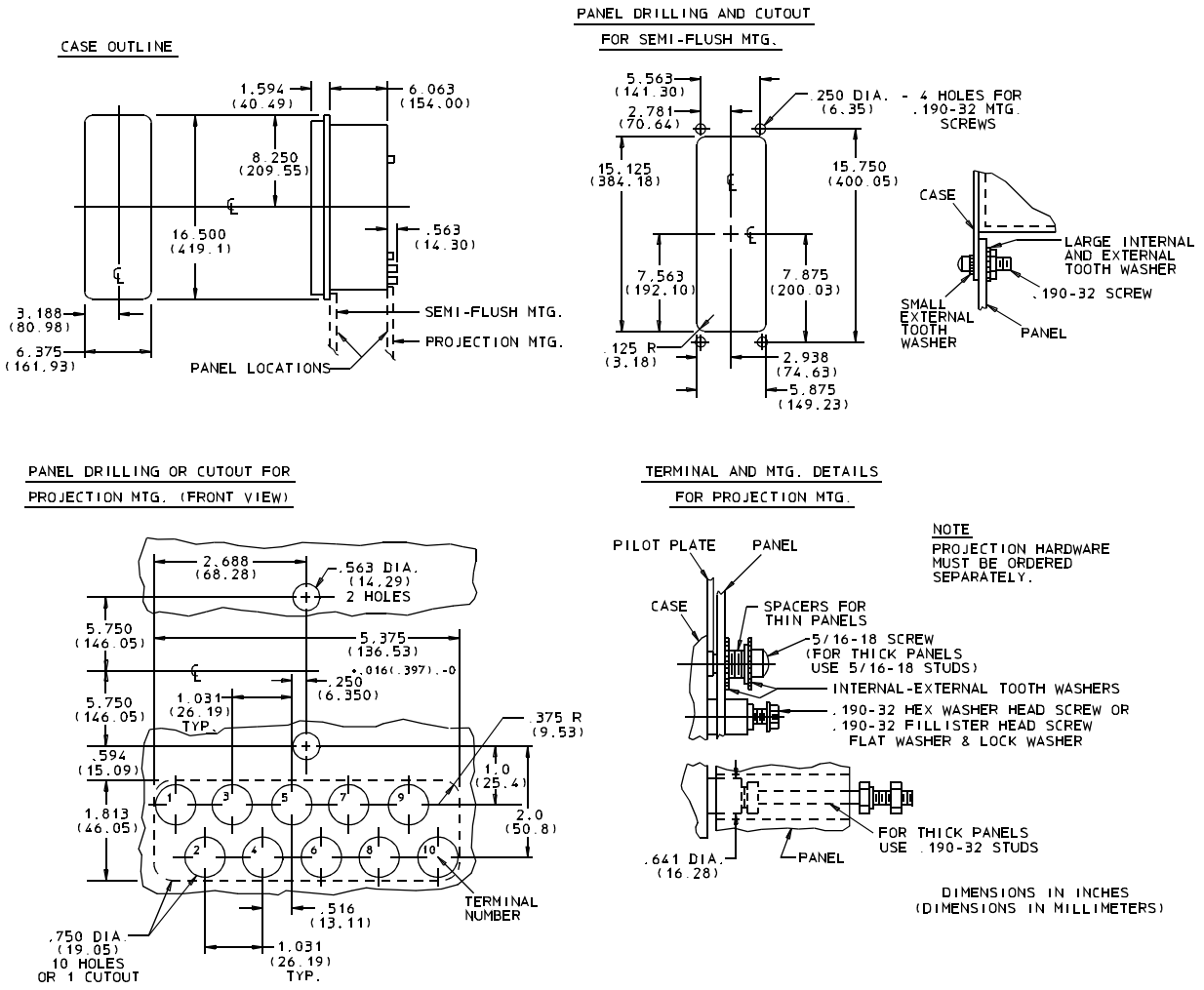

*Sub 20
57D7900

*Figure 36: Outline and Drilling Plan for the Type PM-3, PM-5, & PMD-1 Relays in the Type FT-11 case.*




*Sub 17
57D7901

*Figure 37: Outline and Drilling Plan for the Type PM-2, PM-23, PMA-1 and PMD Relays in the Type FT-21 case*




*Sub 17
57D7902

*Figure 38: Outline and Drilling Plan for the Type PMA Relay in the Type FT-31 case.*

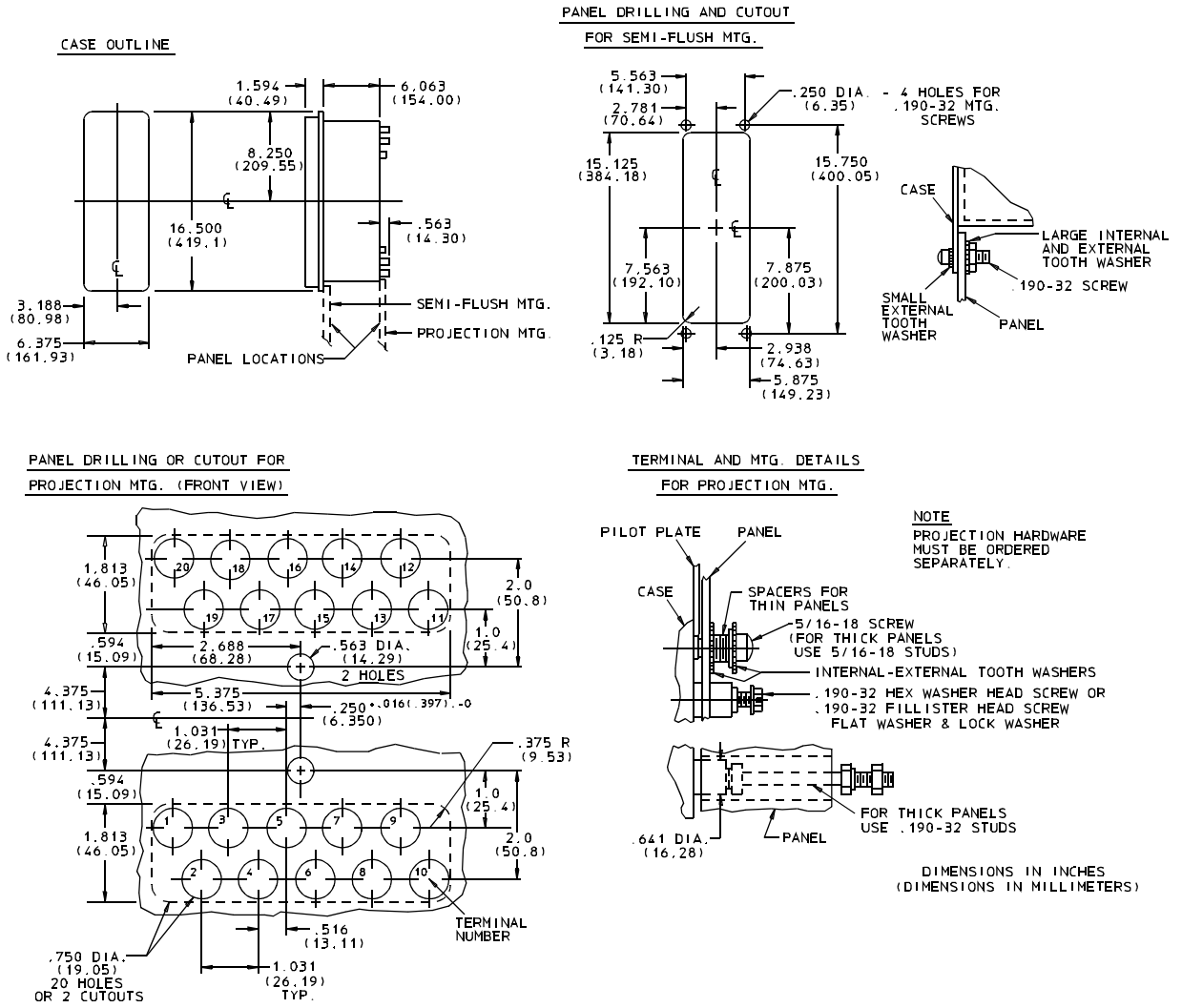



*Figure 39: Outline and Drilling Plan for the Type PM-13 and PMG-13 Relays in the Type FT-32 case.*

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