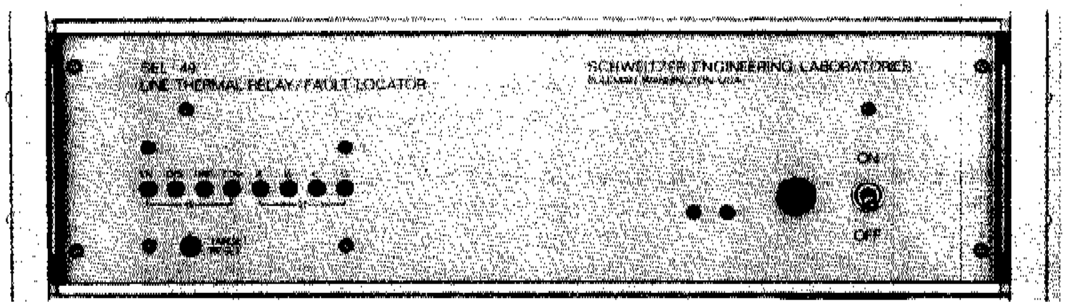
SCHWEITZER ENGINEERING LABORATORIES, INC.

Making Electric Power Safer, More Reliable, and More Economical



SEL-49

LINE THERMAL RELAY WITH DISTANCE RELAY AND FAULT LOCATOR

DATA SHEET

- ESTIMATES CONDUCTOR TEMPERATURE FROM CURRENT AND AMBIENT TEMPERATURE
- FAULT LOCATOR INCLUDES ZERO-SEQUENCE MUTUAL COUPLING COMPENSATION
- PROVIDES SEPARATE OUTPUTS FOR TRIPPING AND ALARMING
- INTERNAL CLOCK MAY BE SYNCHRONIZED TO TIME CODE INPUT
- AUTOMATICALLY ISSUES TIME-TO-TRIP MESSAGES DURING OVERLOADS
- ONE-ZONE DISTANCE RELAY PROVIDES PROTECTION FOR ALL FAULTS
- TARGETS INDICATE THERMAL AND DISTANCE RELAY OPERATIONS
- INCLUDES EVENT RECORDING, AUTOMATIC SELF TESTING, AND OTHER ADVANCED FEATURES

Home Office: **2350 NE Hopkins Court • Pullman, WA 99163-5603** **Tel: (509) 332-1890 Fax: (509) 332-7990**

Field Offices:
71 E Rambler • Holland, PA 18966-2034 Tel & Fax: (215) 322-5226
140 Iowa Ave, Suite 201 • Belleville, IL 62220-3940 Tel: (618) 233-1010 Fax: (618) 233-1042
454 S Anderson Rd, BTC 531 • Rock Hill, SC 29730-3390 Tel: (803) 329-6300 Fax: (803) 329-6320
15738 W National Ave • New Berlin, WI 53151-5119 Tel: (414) 789-8260 Fax: (414) 789-8470

GENERAL DESCRIPTION

The SEL-49 relay is a digital protective relay which provides transmission line protection from overloads and short circuits.

Overload protection is provided with the help of a thermal model which estimates the conductor temperature from measurements of the ambient temperature and conductor currents. The estimated conductor temperature is compared against low and high thresholds to signal alarm or tripping via separate output contacts.

A thermal predictor determines if the conductor will reach a critical temperature and provides the time remaining until that temperature will be reached should the overload continue. The SEL-49 relay automatically issues reports including time-to-trip, measured ambient temperature, estimated conductor temperature, and a heating and cooling budget. As the temperature nears the trip setpoint, the SEL-49 relay generates the reports more frequently. A report is also issued when conditions return to normal.

Figure 1 shows an electrical equivalent of the thermal model used by the SEL-49 relay. The heat power input P is determined from the electrical losses, plus the solar heating (solar heating is estimated from the time of day and relay location, and assumes a clear sky). Computation of the resistive heating component includes the effect of the resistance temperature coefficient. The ambient temperature (TA) may be entered as a constant or taken from a temperature transducer.

Thus, the heat input drives the thermal model, and the variable TC is the conductor temperature estimated by the model. The relay estimates the conductor temperature from the model differential equations which are solved recursively as time progresses.

The temperature predictor estimates the expected steady-state temperature, assuming the present rate of heating continues. If the predicted temperature exceeds the relay setting, the time remaining to reach the trip temperature is computed and reported.

Short-circuit protection is provided by single-zone mho relays for all fault types. The SEL-49 relay includes logic and timing features so that the mho relays can be used for backup protection or indirect, underreaching, and overreaching transfer-trip schemes.

The SEL-49 relay locates transmission line faults from its voltage and current measurements using the field-proven techniques of the SEL-21 relay. An enhancement is an input for the residual current from parallel circuits, allowing compensation for zero-sequence mutual coupling from parallel lines.

The SEL-49 relay also provides event reporting, control, remote setting, and metering capabilities.

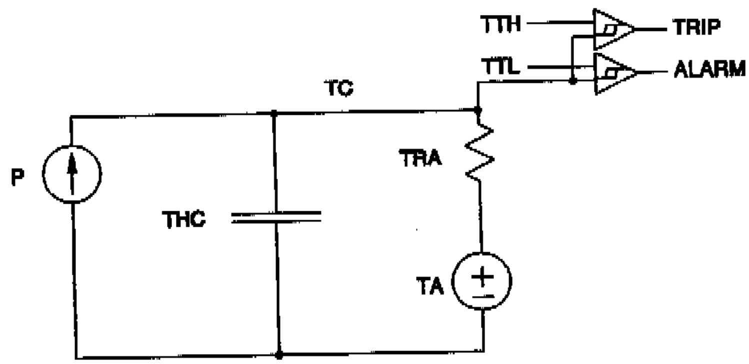


Figure 1: Thermal Model

Thermal Variables

P	- Heat power input	(watts/Kft)
THC	- Thermal heat capacity	(J/°C Kft)
TRA	- Thermal resistance to ambient	(watts/°C Kft)
TC	- Estimated conductor temperature	(°C)
TA	- Ambient temperature	(°C)
TI	- Initial conductor temperature	(°C)
TTH	- High temperature threshold	(°C)
TTL	- Low temperature threshold	(°C)
I	- Conductor current	(Amperes)
rac	- ac resistance	(ohms/Kft)
rdelt	- Temperature coefficient of ac resistance	(ohms/°C Kft)

Thermal Model Equation

$$\frac{d\ TC}{dt} * THC = P - \frac{(TC - TA)}{TRA}$$

Heating Equation

$$P = I^2 * (rac + (TC - 25) * rdelt) + Qsun + Qsky$$

Cooling Equation

$$\frac{(TC - TA)}{TRA} = Qradiated + Qconvected$$

Thermal Equation Solved for TC

$$TC = \int_0^t (P/THC - (TC - TA)/(TRA * THC))dt + TI$$

THERMAL MESSAGE EXAMPLES

Short Report Under "Normal" Line Conditions

```
=>>TEMP

Example 230 kV Line, Drake Conductor   Date:  6/29/90   Time:  12:45:36
Line cond.    :    Normal
Load          :    372.11 MVA
Limit         :    424.83 MVA
Margin        :    51.63 MVA
```

Long Report Under "Normal" Line Conditions

```
=>>TEMP L

Example 230 kV Line, Drake Conductor   Date:  6/29/90   Time:  12:45:29
Line Cond.    :    Normal          IsqdR heating  :    21.5 W/ft
Time to trip  :       .min         Solar heating  :     8.5 W/ft
Line Temp.    :    76.5°C          Atms. cooling  :    30.3 W/ft
Amb. Temp.    :    20.0°C          Net heating    :    -0.2 W/ft
Load          :372.61 MVA           902.9 amps
Limit         :424.90 MVA          1027.0 amps
Margin        : 51.34 MVA           124.1 amps
```

Short Report During Abnormal Line Conditions

```
=>>TEMP

Example 230 kV Line, Drake Conductor    Date:  1/1/90    Time:  23:45:14
Line cond.    :    OVERLOAD
Time to trip  :   16.9  min
Line Temp.    :      25.8°C
Load          :  565.26 MVA
Limit         :  469.70 MVA
Margin        :  -95.56 MVA
```

Long Report During Abnormal Line Conditions

```
=>>TEMP L

Example 230 kV Line, Drake Conductor    Date:  1/1/90   Time:  23:45:35
Line cond.    :    OVERLOAD        IsqdR heating  :    44.2 W/ft
Time to trip :    16.4 min        Solar heating  :     0.0 W/ft
Line Temp.    :      27.9°C        Atms. cooling  :     4.3 W/ft
Amb. Temp.    :      20.0°C        Net heating    :    39.9 W/ft
Load          :   564.7 MVA        1405.1 amps
Limit         :  469.51 MVA        1168.2 amps
Margin        :  -95.19 MVA        -236.8 amps
```

APPLICATIONS

Match the loading of transmission lines to the environmental conditions. The SEL-49 relay provides a TEMP (temperature) command which shows the heating budget for the modeled transmission line under its present operating conditions. One particularly important quantity shown is the maximum steady-state current which can be handled given the ambient temperature, the amount of solar heating calculated at that point in time, and the thermal model settings.

Protect against overloads that result in overtemperature conditions without tripping on temporary overloads that do not last long enough for the conductor temperature to exceed a specified value. During overloads, the SEL-49 relay automatically generates messages indicating the time remaining before the temperature setpoint is exceeded if the overload continues.

Apply the SEL-49 relay as a fault locator and compensate for residual current in parallel circuits.

SPECIFICATIONS

Relay Functions	Thermal protection for overhead lines Estimation of time to overheat Automatic report generation Mho characteristics for all fault types Mho units are sound-phase polarized Negative-sequence directional supervision Separate timers for line and ground faults Instantaneous positive-sequence overcurrent unit Instantaneous positive-sequence overvoltage unit Instantaneous negative-sequence overcurrent unit Instantaneous negative-sequence overvoltage unit Ground switch detection Blown potential fuse detection Automatic phase-sequence checking of voltages and currents upon power-up Separate outputs for high and low set thermal relays
Mho Unit Operating Time	10 - 32 ms; 20 ms typical, including output relay delay
Steady-State Error (distance relays)	Less than 3% of set reach
Transient Overreach	Less than 5% of set reach
Thermal Status Reporting	Report includes: estimated time to trip, line condition, summary of heating and cooling inputs, estimated line temperature, and ambient temperature.
Fault Location	Algorithm compensates for prefault load flow and fault resistance for improved accuracy over a wide range of system conditions. Demonstrated accuracy is about one percent of line length. Fault location is reported in miles or kilometers and secondary ohms. Residual current input provides compensation for zero-sequence mutual coupling.
Fault Reporting	A data record including fault date, time, type, location, duration, current, relay settings, and units which operated is generated after each fault. Phasor information on currents and voltages indicates prefault, fault, and postfault conditions. This report may also be generated upon command or triggered by a contact closure. The state of all contact inputs and outputs is also reported.
Self Testing	Analog ac channels checked for offset. Stall timer monitors processor and five-volt supply. Power supply voltage level checking. Settings, RAM, ROM and A/D converter checking. These self tests are designed to detect virtually any hardware or firmware failure. Failure of any test generates alarm message and closes ALARM contacts. Critical failures disable protection and control to prevent misoperation.

Thermal Model Range Models conductors with time constants from 5 to 40 minutes

Reach Setting .5 to 32 ohms; other ranges available

Signal Inputs Three voltage channels (67 V L - N nominal)
Four current channels (5 A nominal; 500 A for 1 second)
One temperature input (0 - 5 V corresponds to -23.3 to 65.6°C)
IRIG-B isolated input: 10 - 20 mA

Setting Means Digital, via serial communications ports. Parameters are entered in response to prompting messages. Parameters of line are entered in primary ohms. Line length and CT, PT ratios are entered, and displayed quantities are scaled into primary units (e.g. miles, kV, A). Nonvolatile memory retains settings in two identical arrays. Self tests compare these arrays. Should any difference ever be detected, an alarm is generated and relay and control functions are disabled to prevent misoperation.

System Outputs and Inputs Eight relay outputs rated for breaker tripping. Six optically-isolated contact inputs. Two serial communications ports (RS-232-C) for use with CRT, printing terminal, printer, modem, computer, etc. One clock port for demodulated IRIG-B clock signal. Ports are EMI protected.

Power Supply 48 Volt: Vdc, 160 watts
125 Volt: Vdc; 200 watts

Surge Filtering Power supply line filter
All control inputs and outputs bypassed to ground
Contact inputs filtered by RC networks
Relay outputs protected by MOVs
SWC tested

Dimensions 5¼" x 19" x 13." Mounts in standard 19" relay rack.

Weight 20 pounds

OUTPUT EQUATIONS

This section summarizes how the thermal unit, mho units, control inputs, and commands via communications link affect relay outputs.

The SEL-49 output relay states depend on the states of the following:

Relay elements
Control inputs
Setting parameters
Commands received over communications link
Self test status

Since so many binary variables are involved, we define functioning using Boolean logic equations. First, all the logic variables are defined as either primary logic variables, intermediate logic variables, or output logic variables. Next, the values of the intermediate logic variables are derived from the primary logic variables. Finally, output variables are defined using the primary and intermediate logic variables.

DEFINITION OF VARIABLES

Primary Logic Variables

Relay Elements

Thermal relay low set	49L
Thermal relay high set	49H
Single-phase overcurrent relays	50A, 50B, 50C (50FD setting determines pickup)
Ground distance relays	21A, 21B, 21C
Phase distance relays	21AB, 21BC, 21CA
Positive-sequence overcurrent relay	46P **(pickup at 0.14 to 0.7 a sec)
High-set pos-seq overcurrent relay	46PH (pickup settable)
Positive-sequence overvoltage relay	47P **(pickup at 0.14 to 0.7 v sec)
Negative-sequence overcurrent relay	46Q **(pickup at 0.14 to 0.7 a sec)
Negative-sequence overvoltage relay	47Q (pickup at 0.75 v sec)
High-set neg-seq overvoltage relay	47QH (pickup at 16.8 v sec)
Negative-sequence directional relay	*32Q

* This logic variable is also asserted if a three-phase fault is indicated by operation of all ground mho units or all phase mho units.

** Depends on relay reach. For all reaches above two ohms secondary, the lower limit applies.

Control Inputs

Direct trip	DT
Transfer trip	TT
Block trip	BT
Direct close	DC
Circuit breaker monitor	52A
External trigger	EXT

Commands via Communication Channels

Close command received	CC
Open command received	OC

Mho Timers

Ground fault timer timeout	21GT
Line fault timer timeout	21LT

Relay Enables Logic Switches

Thermal trip enabled	THE
Mho trip enabled	ZE
Transfer trip output enabled	TTE
Neg-seq directional supervision enabled	32QE
Blown potential fuse detect enabled	BPFE

Intermediate Logic Variables

Composite distance relay	21
Composite distance relay timeout	21D
Forward direction fault	GD
Blown potential fuse detected	BPF
Ground switch detect	GS

Output Logic Variables

Circuit breaker trip	TRIP	
Circuit breaker close	CLOSE	
Transfer trip initiate	TTI	(A1 on rear panel)
Over high temp. threshold	TH	(A2 on rear panel)
Over low temp. threshold	TL	(A3 on rear panel)
System alarm	ALARM	

DEFINITION OF INTERMEDIATE VARIABLES

```
21  = (                                              composite distance relay fault

      21A*50A      + 21B*50B     + 21C*50C               ground fault

 + 21AB*50A*50B   + 21BC*50B*50C           + 21CA*50C*50Aphase fault

      )

21D   =   (                                              composite distance relay fault

        (21A*50A        + 21B*50B  + 21C*50C)*21GT  ground fault and timer

      + (21AB*50A*50B + 21BC*50B*50C                 phase fault and timer

         + 21CA*50C*50A)*21LT
      )

GD  = (                                              forward direction fault

        32Q                                               neg-seq directional pickup

      + NOT(46Q*47Q)                                      not enough neg-seq for 32Q

      + NOT(32QE)                                         32 sup. not enabled

      )
```

```
BPF   =   (                                          blown potential fuse detected

      47QH*NOT(46Q)*BPFE                             large neg-seq voltage
                                                     small neg-seq current
      )                                              blown fuse detect enabled


GS  = (                                          ground switch detect

      46PH * NOT (47P)                               large pos-seq current
                                                     no pos-seq voltage
      )
```

DEFINITION OF OUTPUT VARIABLES

```
Close TRIP contact =                             energize the trip coil circuit
      (

      NOT(BT)*                                       no block trip input
       (
        DT                                           direct trip input

       + OC                                          open command received

       + 49H*THE                                     high temp. and thermal trip
enable

       + ((21D*GD*46P*47P+GS)NOT(BPF))*ZE            valid mho fault and enable

       + ((21*GD*46P*47P+GS)NOT(BPF))*TT             mho fault and trans. trip input
       )
      )
```

```
Open TRIP contact =                                   open the trip relay
    (

    NOT(52A)*                                              circuit breaker open
     (

       NOT(49H*THE)                                        no thermal trip condition

     + NOT(((21D*GD*46P*47P+GS)NOT(BPF))*ZE)               no valid enabled mho fault

     + NOT(((21*GD*46P*47P+GS)NOT(BPF))*TT)                no valid transfer trip

     )
    )


Assert CLOSE contact                                  close the breaker
    (

    NOT(52A)*                                              circuit breaker open
     (
        DC                                                 direct close input asserted

      + CC                                                 close command issued
     )
    )


Assert TTI output                                     initiate transfer tripping
    (

    21*GD*46P*47P*NOT(BPF)*TTE                             valid mho fault and transfer
                                                           trip enabled
    )


Assert TH output                                      signal that over high temp. threshold

    (
    49H                                                    49 high set pickup
    )


Assert TL output                                      signal that over low temp. threshold

    (
    49L                                                    49 low set pickup
    )
```

Assert ALARM output — system alarm

(

+ BPF — blown pot. fuse detected

+ relay or control disabled — result of failed self test or disable during setting

+ loss of power

+ processor stall

)

Pulse ALARM output — pulse alarm for one second

(

failed Level 1 access on third try

+ attempt Level 2 access

+ fail Level 2 access

+ offset, master offset self test failure

)

SETTING PROCEDURE

The setting procedure consists of answering prompting messages with new data or typing **<ENTER>** to indicate no change. Once all data are provided, the new settings are displayed and a prompt issued requesting approval to enable the relay with the new settings. Error messages are included to indicate when entered data result in out-of-range settings.

SET COMMAND EXAMPLE

```
=>>SET
Enter data or <ENTER> for no change

Relay ID =
Example 230 kV Line, Drake Conductor
?

R1 (ohms pri).................... = 13.90  ?
X1 (ohms pri).................... = 79.96  ?
R0 (ohms pri).................... = 41.50  ?
X0 (ohms pri).................... = 248.57 ?
RM0 (ohms pri)................... = 37.35  ?
XM0 (ohms pri)................... = 223.90 ?
MCT Ratio........................ = 200.00 ?
CT Ratio......................... = 200.00 ?
PT Ratio......................... = 2000.0 ?

Line Length (miles).............. = 100.00 ?
Max Torque Ang(deg).............. = 80.80  ?
Z Reach    (% line).............. = 120.00 ?
Z Delay-Ground(cyc).............. = 0.00   ?
Z Delay-Line  (cyc).............. = 0.00   ?
50FD Pickup (A pri).............. = 200.00 ?
+Seq OCThrsh(A pri).............. = 6000.0 ?

Default Sol. ht.(watts/Kft)...... = 4000.0 ?
Solar abs. coeff. (no unit)...... = 0.97   ?
Conductor Diameter (inches)...... = 1.11   ?
Long. of T.Std  (deg. w.l.)...... = 125.00 ?
Long. of cond.  (deg. w.l.)...... = 117.00 ?
Lat. of cond. (deg. n.lat.)...... = 47.00  ?
AC resistance       (mohms/Kft).. = 22.16  ?
T.C. of res  (uohms/°C Kft)...... = 83.33  ?
Ther. heat cap  (KJ/°C Kft)...... = 392.10 ?
Ther. res to amb (°C Kft/Kw)..... = 1.86   ?
Est. ambient temp.  (°C)......... = 20.00  ?
Est. offset temp.   (°C)......... = 0.00   ?
High temp. thresh.  (°C)......... = 90.00  ?
Low temp. thresh.   (°C)......... = 80.00  ?
PORT 1 timeout (minutes)......... = 5      ?
PORT 2 timeout (minutes)......... = 0      ?
Automatic port (1,2,3,4)......... = 2      ?
Modem answer rings............... = 3      ?
Trans Trip Init (Y or N)......... = Y      ?
Mho zone trip   (Y or N)......... = Y      ?
Neg-Seq Dir Sup (Y or N)......... = Y      ?
Blown Pot Fuse  (Y or N)......... = Y      ?
Thermal trip en (Y or N)......... = Y      ?
Temp. sensor    (Y or N)......... = Y      ?
Solar model en  (Y or N)......... = Y      ?

New settings for:
Example 230 kV Line, Drake Conductor
R1  = 13.90   X1   = 79.96   R0  = 41.50   X0  = 248.57  RM0 = 37.35
XM0 = 223.90  MCTR= 200.00   CTR = 200.00  PTR = 2000.0  LL  = 100.00
MTA = 80.80   Z%   = 120.00  ZDG = 0.00    ZDL = 0.00    50FD= 200.00
46PH= 6000.0  DSH  = 4000.0  SAC = 0.97    DIA = 1.11    LSTD= 125.00
LON = 117.00  LAT  = 47.00   RAC = 22.16   RTC = 83.33   THC = 392.10
TRA = 1.86    EAT  = 20.00   EOT = 0.00    TH  = 90.00   TL  = 80.00
TIM1= 5       TIM2= 0        AUTO= 2       RING= 3
TTI = Y       ZE   = Y       32QE= Y       BPFE= Y
THE = Y       TSE  = Y       SGE = Y

OK (Y/N) ? y
Working...
Enabled
=>>
```

SAMPLE EVENT REPORT FOR AN A-G FAULT

```
Example 230 kV Line, Drake Conductor            Date:  1/1/90      Time:  00:09:53

            Currents                           Voltages          Mho  +Seq -Seq Outs   Ins
             (amps)                              (kV)
                                                               ABCABC iIv ivV3 TCTTTA DTBD5E
/K*Reff      A         B         C       A        B       C    GGGBCA        2 PLTHLL TTTC2T

    -16     -17        0        -2   -95.9    86.4    76.9   ...... *.* **.. ...... ....*.
   -171    -176        0         0    -4.4  -112.7   118.9   ...... *.* **.. ...... ....*.
     25      17        0         0    95.8   -86.3   -76.9   ...... *.* **.. ...... ....*.
    171     176        0         2     4.4   112.8  -118.9   ...... *.* **.. ...... ....*.

    -25     -20        0         0   -95.8    86.2    76.9   ...... *.* **.. ...... ....*.
   -171    -173        0        -2    -4.4  -112.8   118.9   ...... *.* **.. ...... ....*.
     29      20        0         2    95.8   -86.2   -77.0   ...... *.* **.. ...... ....*.
    171     176        0         0     4.3   112.9  -118.9   ...... *.* **.. ...... ....*.

    -29     -23        0        -2   -95.7    86.1    77.1   ...... *.* **.. ...... ....*.
   -171    -176        0         2    -4.3  -113.0   118.9   ...... *.* **.. ...... ....*.
     25      26        0         0    95.8   -86.0   -77.3   ...... *.* **.. ...... ....*.
    176     170        0         0     4.2   113.0  -118.8   ...... *.* **.. ...... ....*.

    -16     -32        0         0   -95.8    86.0    77.4   ...... *.* **.. ...... ....*.
   -239    -211        2         0    -4.5  -113.3   118.6   ...... *.* **.. ...... ....*.
    -62     -47        0         2    96.1   -85.7   -77.3   ...... *.* **.. ...... ....*.
    679     647        0         0     4.5   113.4  -118.6   *..... *.* **.* *.*... ....*.

    -12      -5        0         0   -96.2    85.6    77.3   *..... *.* **.* *.*... ....*.
  -1195   -1177        0         0    -4.1  -113.1   118.7   *..... *.* **.* *.*... ....*.
    184     167        0         0    95.8   -85.7   -77.5   *..... *.* **.* *.*... ....*.
   1350    1333        0         0     4.1   113.1  -118.6   *..... *.* **.* *.*... ....*.

   -201    -185        0         0   -95.8    85.7    77.6   *..... *.* **.* *.*... ....*.
  -1371   -1356        0         0    -4.1  -113.2   118.5   *..... *.* **.* *.*... ....*.
    205     185        0         0    95.9   -85.7   -77.6   *..... *.* **.* *.*... ......
   1375    1359        0         0     3.9   113.3  -118.5   *..... *.* **.* *.*... ......

   -205    -188        0         0   -95.8    85.6    77.7   *..... *.* **.* *.*... ......
  -1367   -1359        0         2    -3.9  -113.4   118.4   *..... *.* **.* *.*... ......
    201     188        0         0    95.8   -85.5   -77.8   *..... *.* **.* *.*... ......
   1367    1362        0         0     3.9   113.4  -118.3   *..... *.* **.* *.*... ......

   -197    -182        2         0   -95.9    85.5    77.8   *..... *.* **.* *.*... ......
  -1329   -1318        0         0    -3.7  -113.4   118.3   *..... *.* **.* *.*... ......
    272     258        0         0    95.8   -85.5   -77.9   *..... *.* **.* *.*... ......
    901     894        0         0     3.7   113.5  -118.2   *..... *.* **.* *.*... ......

   -209    -203        0         0   -95.8    85.4    77.9   *..... *.* **.* *.*... ......
   -369    -364        0         0    -3.7  -113.5   118.3   *..... *.* **.* *.*... ......
     50      47        0         0    95.9   -85.3   -78.0   ...... *.* **.* ...... ......
    197     197        0         0     3.5   113.6  -118.3   ...... *.* **.. ...... ......

    -29     -26        0         0   -95.8    85.2    78.1   ...... *.* **.. ...... ......
   -171    -176        0         0    -3.5  -113.6   118.1   ...... *.* **.. ...... ......
     25      23        0         0    95.8   -85.2   -78.1   ...... *.* **.. ...... ......
    171     176        0         0     3.5   113.6  -118.0   ...... *.* **.. ...... ......

    -25     -23        0         0   -95.8    85.2    78.2   ...... *.* **.. ...... ......
   -171    -176        0         0    -3.4  -113.7   118.0   ...... *.* **.. ...... ......
     25      26        0         0    95.7   -85.1   -78.3   ...... *.* **.. ...... ......
    167     173        0         0     3.3   113.8  -118.1   ...... *.* **.. ...... ......

Event    : AG      Location    : 50.28  mi   4.08   ohms sec
Duration: 5.00     Flt Current: 1372
R1   = 13.90    X1   = 79.96    R0   = 41.50    X0   = 248.57  RM0 = 37.35
XM0  = 223.90   MCTR= 200.00    CTR  = 200.00   PTR  = 2000.0  LL   = 100.00
MTA  = 80.8     Z%   = 120.00   ZDG  = 0.00     ZDL  = 0.00    50FD= 200.00
46PH= 6000.0    DSH  = 4000.0   SAC  = 0.97     DIA  = 1.11    LSTD= 125.00
LON  = 117.00   LAT  = 47.00    RAC  = 22.16    RTC  = 83.33   THC  = 392.10
TRA  = 1.86     EAT  = 20.00    EDT  = 0.00     TH   = 90.00   TL   = 80.00
```

The settings shown at the bottom of the event report are briefly explained below.

Example 230 kV Line, Drake Conductor	Relay identification string.
R1 = 13.90	Positive-sequence resistance of 13.90 ohms primary.
X1 = 79.96	Positive-sequence reactance of 79.96 ohms primary.
RO = 41.50	Zero-sequence resistance of 41.50 ohms primary.
XO = 248.57	Zero-sequence reactance of 248.57 ohms primary.
RMO = 37.35	Zero-sequence mutual resistance of 37.35 ohms primary.
XMO = 223.70	Zero-sequence mutual reactance of 223.70 ohms primary.
MCTR = 200	Current transformer ratio for mutual circuit of 200:1.
CTR = 300	Current transformer ratio for line of 300:1.
PTR = 2000	Voltage transformer ratio for line of 2000:1.
LL = 100.00	Line length of 100 miles or kilometers.
MTA = 80.8	Mho maximum torque angle of 80.8°.
Z % = 120.0	Mho reach of 120% of line.
Z DG = 0.0	Mho delay of 0 cycles for ground faults.
Z DL = 0.0	Mho delay of 0 cycles for line-to-line faults.
50FD = 200.00	Phase overcurrent fault locator setting 200 amps.
46PH = 6000	High-set positive-sequence overcurrent relay pickup of 6000 A.
DSH = 4000	Default solar heating rate of 4000 W/Kft.
SAC = 0.97	Solar absorption coefficient of 0.97.
DIA = 1.11	Conductor diameter of 1.11 inches.
LSTD = 125.00	Standard longitude of 125° west.
LON = 117.00	Longitude of relay location of 117° west.
LAT = 47.00	Latitude of relay location of 47° north.
RAC = 22.16	AC resistance of 25°C of 22.16 milliohm/Kft.
RTC = 83.33	Resistance tempco of 83.33 microohms/Kft-°C.
THC = 392.10	Thermal capacity of conductor of 392.10 KJ/°C-Kft.
TRA = 1.86	Thermal resistance to ambient of 1.86°C/KW-Kft.
EAT = 20.00	Estimated ambient temperature of 20.00°C.
EOT = 0.00	Estimated offset temperature of 0.00°C.
TH = 90.00	High temperature threshold of 90.00°C.
TL = 80.00	Low temperature threshold of 80.00°C.
TIM1 = 5	Communications PORT 1 timeout (minutes).
TIM2 = 0	Communications PORT 2 timeout (minutes).
AUTO = 4	Automatic Fault Locator and Self Test reports to go to both ports.
RING = 3	Modem on PORT 1 to answer after three rings.
TTI = Y	Transfer Trip Initiate relay is enabled.
ZE = Y	Mho relay is enabled for direct tripping.
32QE = Y	Negative-sequence directional supervision is enabled.
BPFE = Y	Blown-potential fuse condition blocks tripping.
THE = Y	Thermal tripping is enabled.
TSE = Y	Ambient temperature sensor reading is used.
SGE = Y	Solar heat generator is enabled.

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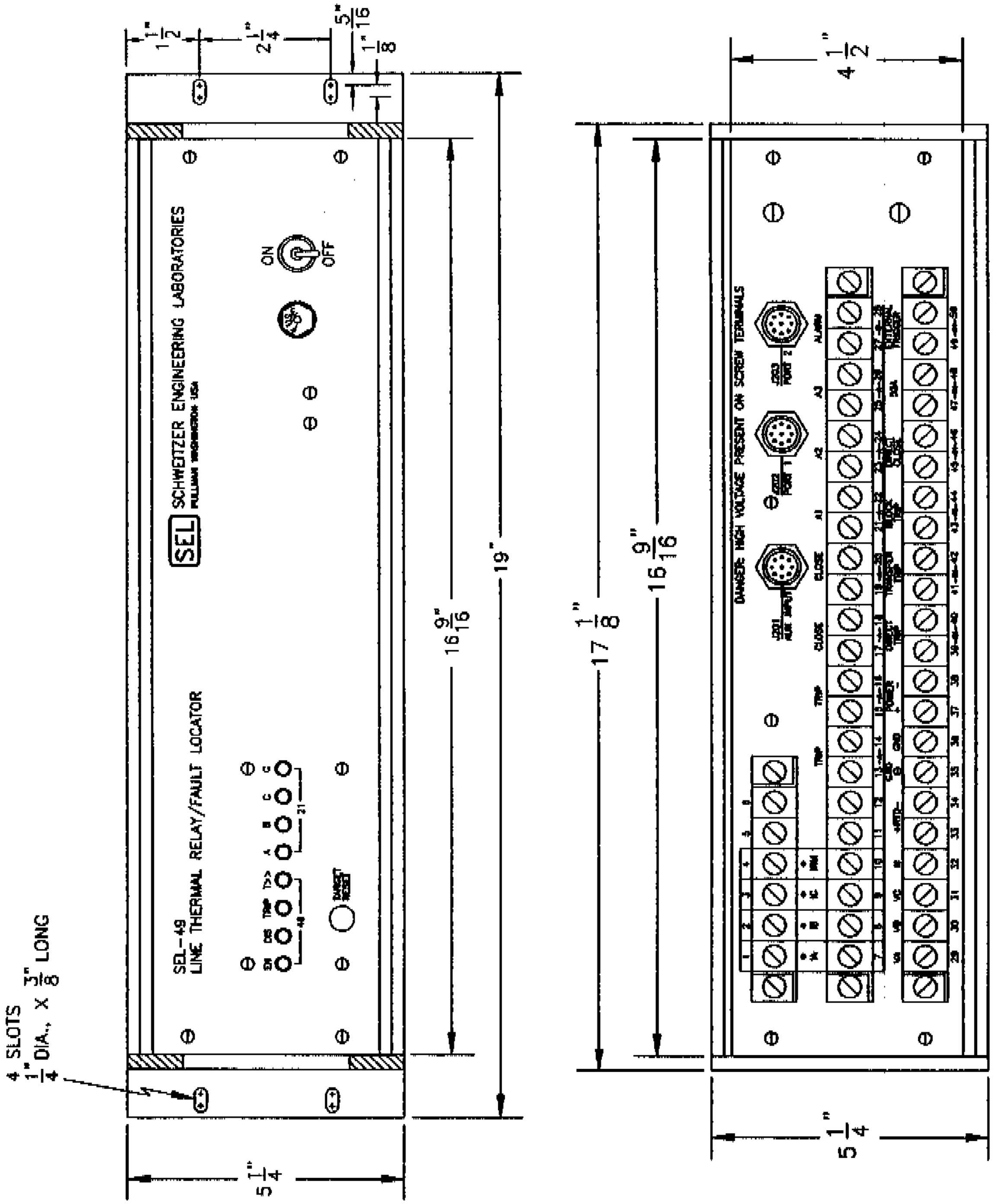
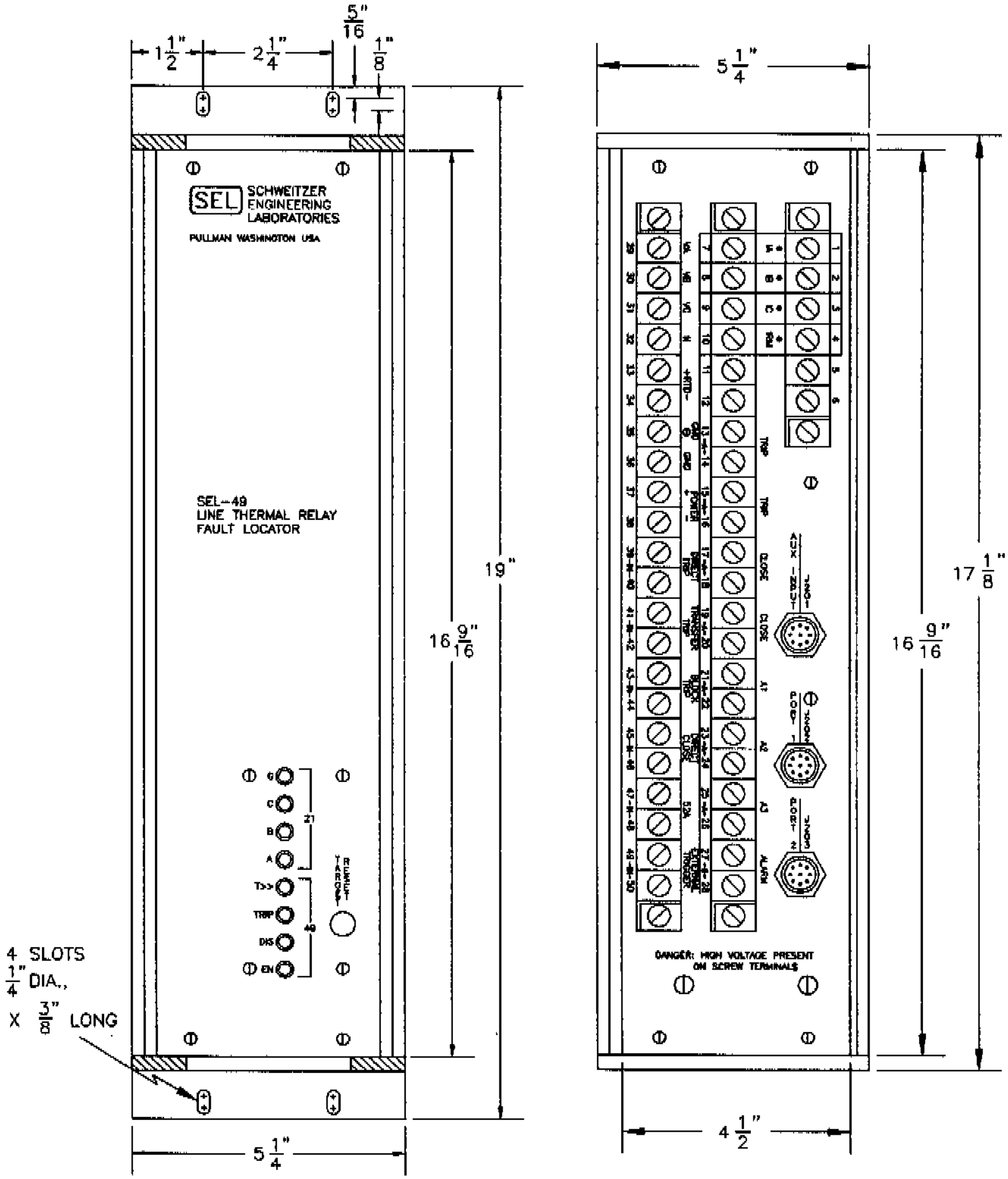
Revised 10/88

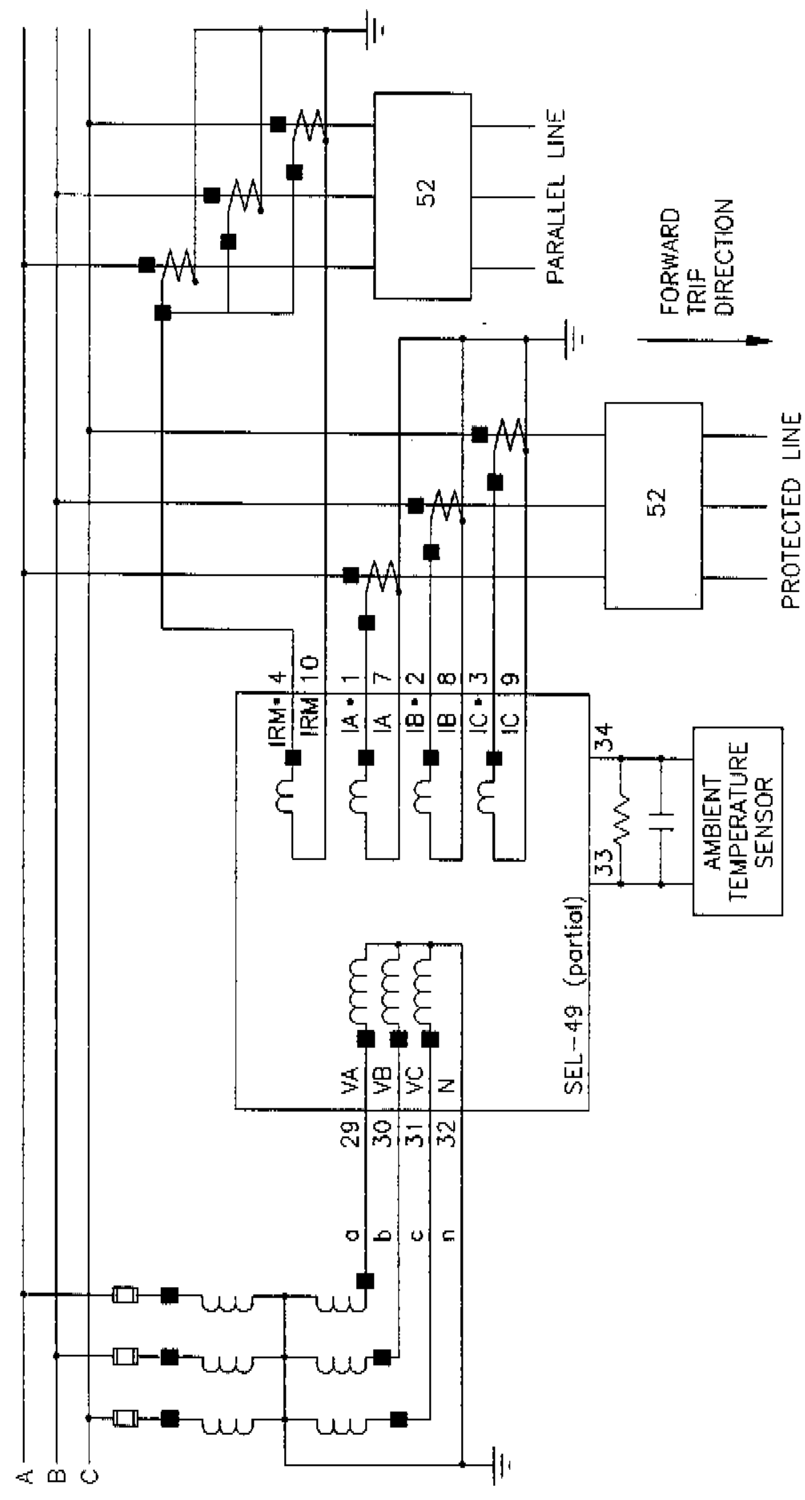


SEL-49 Horizontal Front and Rear Panel Drawing DWG. NO. A7-0810A

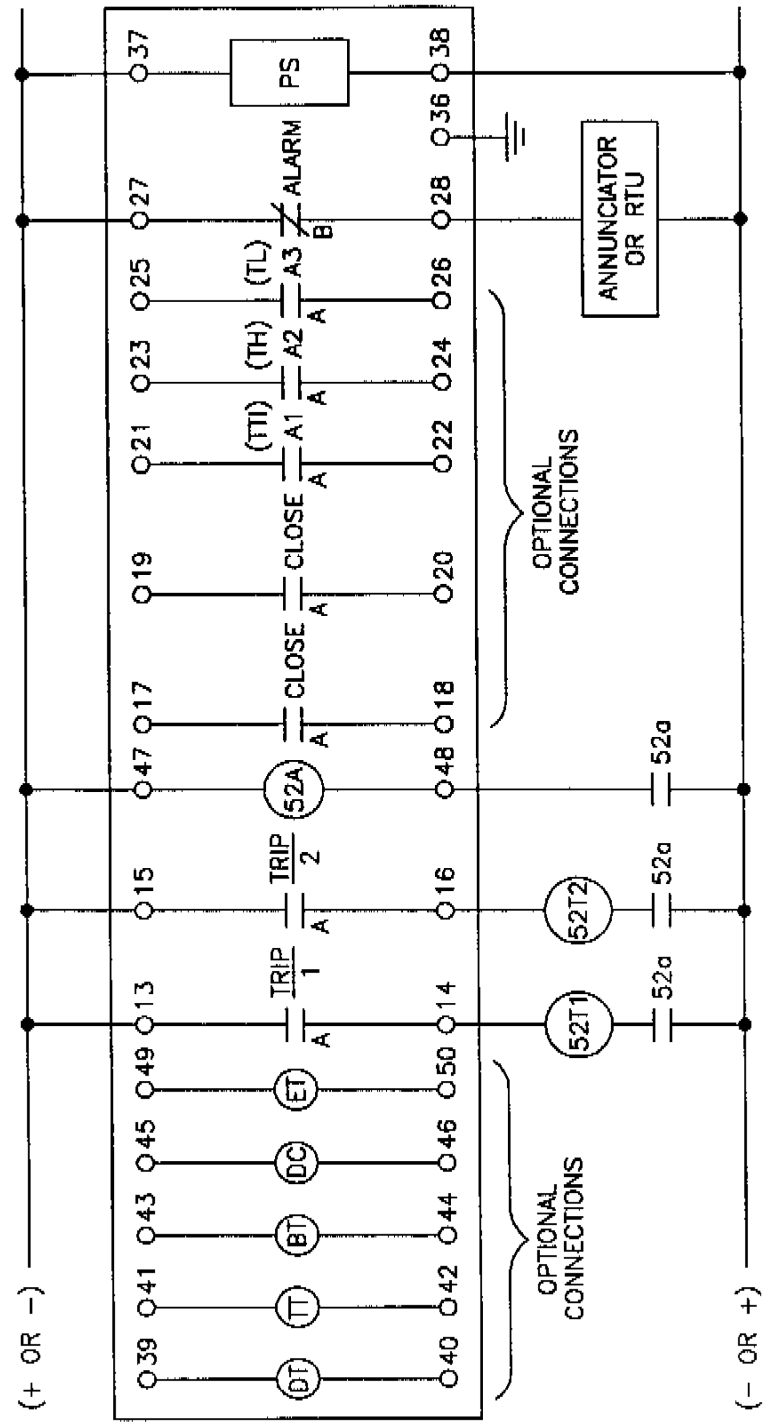


SEL-49 Vertical Front and Rear Panel Drawing

DWG. NO. A7-0805A



SEL-49 External Current, Voltage, and Temperature Connections



SEL-49 External Connection Diagram