SCHWEITZER ENGINEERING LABORATORIES, INC.

Making Electric Power Safer, More Reliable, and More Economical

DWG 11001

SEL-221-16

PHASE AND GROUND DISTANCE RELAY
DIRECTIONAL GROUND RELAY
RECLOSING RELAY
FAULT LOCATOR

- Three zones of instantaneous/definite-time phase and ground distance protection
- Residual time-overcurrent element with selectable curves
- Instantaneous residual overcurrent element
- Negative-sequence polarization of ground directional elements
- Versatile user-programmable logic for outputs and tripping
- Programmable switch-onto-fault logic
- Loss-of-Potential detection logic
- Programmable single-shot reclosing
- Fault locating
- Metering
- EIA-232 Communication ports for local and remote access
- Automatic self-testing
- Demodulated IRIG-B time-code input
- Target indicators for faults and testing
- Compact and economical

Home Office:	**2350 NE Hopkins Court · Pullman, WA USA 99163-5603**	**Tel: (509) 332-1890 Fax: (509) 332-7990**
Field Offices:	71 E Rambler · Holland, PA 18966-2034	Tel (215) 322-5226 Fax: (215) 322-5783
	140 Iowa Ave, Suite 201 · Belleville, IL 62220-3940	Tel: (618) 233-1010 Fax: (618) 233-1042
	2250 Shamrock Court · Rock Hill, SC 29730-3349	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
	1362 Haverhill Dr · New Port Richey, FL 34655-4232	Tel: (813) 376-7754 Fax: (813) 376-7654

PRODUCT OVERVIEW

SEL-221-16 Description

The SEL-221-16 Distance Relay with Fault Locator simultaneously provides high-speed and time-delayed protection for transmission, subtransmission, and distribution lines. An 18-bit Relay Word combines mho distance elements, overcurrent elements, directional elements, timers, and data and control bits. You can program the tripping, output, and reclosing logic through Relay Word bit combinations to control the relay outputs.

Because of its many relay elements, large setting ranges, programmability, and low cost, this relay meets the requirements of a broad spectrum of applications. Flexible yet simple programmability provides access to relay elements (before and after time delays) and logic results. The relay features include three zones of phase-to-phase distance and phase-to-ground distance elements, time delayed backup for Zones 2 and 3 phase and ground elements, residual instantaneous and time-overcurrent elements, single-shot reclosing with programmable initiate and reclose conditions, and Loss-of-Potential logic.

Analog inputs from current and voltage transformers are delivered to the protective relaying elements and saved for additional features such as metering and fault locating.

The relay generates an eleven-cycle event report starting with information captured four cycles before fault detection through seven cycles afterward. Each event report resembles a sequence-of-events report; each includes the following information every quarter-cycle for eleven cycles:

- Voltages (VA, VB, and VC)
- Currents (IA, IB, IC, and IR)
- Fault type and involved phases
- Fault location
- Secondary ohms to the fault location
- Maximum phase current measured near the middle of the fault
- Date and time of the event
- Relay element status
- External inputs (breaker status, etc.)
- Relay contact output status

The information in each event report simplifies analysis of the most complex system operations.

The relay stores the latest twelve event reports, allowing retrieval and examination after the event. You may retrieve any or all records remotely or locally through either of the two serial communications ports.

The metering function permits interrogation of the relay to obtain power system voltage, current, real power, and reactive power readings. The function also includes per-phase measurements of voltage and current. Metering is very valuable for unmanned or remote substations.

The CLOSE, A1, A2, A3, A4, and ALARM outputs may be specified as "a" or "b" type contacts. TRIP outputs are always an "a" type contact.

The relay is compatible with the SEL-2020 Communications Processor, the SEL-PRTU Protective Relay Terminal Unit, the SEL-DTA2 Display/Transducer Adapter, the SEL-RD Relay Display, and the SEL-PROFILE Transmission Line Fault Analysis Program.

Obsolete Relay Replacement

The SEL-221-16 Relay is an ideal relay to use as a replacement for obsolete or aging electromechanical relays that are used in a step-distance scheme. The relay has three forward-looking zones of phase and ground distance protection as well as a directional ground overcurrent relay. A single-shot recloser is also included. It occupies less space on a panel than the electromechanical relays that it can replace. It also adds valuable features such as fault locating, metering functions, and remote communications.

Operating Principles

Mho Distance Elements

The SEL-221-16 Relay uses mho characteristics for phase and ground distance protection. Figure 1 shows the impedance characteristics of the phase and ground distance elements.

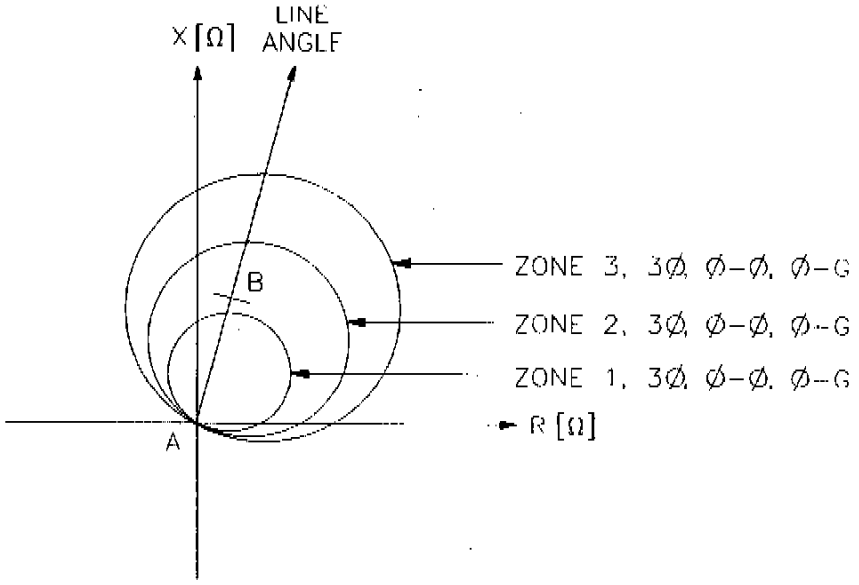

Figure 1: Phase and Ground Mho Distance Elements

The mho elements use positive-sequence memory polarization that expand in proportion to the source impedance to provide positive, secure operation for close-in faults. Independent timers are settable for Zone 2 phase, Zone 2 ground, and Zone 3 elements. Fault detectors and negative-sequence directional elements supervise the distance elements. Loss-of-Potential logic, if enabled, also supervises the distance elements.

Overcurrent Elements

Residual Overcurrent Elements

Residual overcurrent elements provide backup protection for ground faults. A time-overcurrent element detects highly-resistive ground faults. It is available with either US curves (moderately inverse, inverse, very inverse, and extremely inverse) or IEC curves (standard inverse, very inverse, extremely inverse, and long time delay). This element may be nondirectional or forward-reaching, as enabled in relay settings.

An instantaneous residual overcurrent element may be nondirectional or forward-reaching, as enabled in the settings. Negative-sequence directional polarization is used for the residual overcurrent elements.

Phase Overcurrent Elements

Low-set phase overcurrent elements supervise phase distance elements and release the TRIP output contacts in conjunction with the low-set residual overcurrent element. Low-set phase overcurrent elements are used in the Loss-of-Potential logic to detect blown voltage transformer fuses. Low-set phase overcurrent elements may be used in the Remote-End-Just-Opened (REJO) logic to detect remote breaker clearance of in-section faults.

High-set nondirectional phase overcurrent elements provide switch-onto-fault protection for close-in faults.

Negative-Sequence Directional Element

Directional polarization is based upon negative-sequence voltage and current. The negative-sequence directional element may be used to polarize the ground directional overcurrent protection.

Loss-of-Potential (LOP) Detection

The Loss-of-Potential logic detects one, two, or three blown secondary voltage transformer fuses. This protection may be enabled or disabled with a simple setting. When enabled, an LOP condition blocks all mho distance elements. LOP detection may be selected to close a programmable output relay or the ALARM contact for indication purposes.

Remote-End-Just-Opened (REJO) Protection

User-selected elements are enabled to trip if the remote breaker clears. The REJO logic can provide pilotless accelerated tripping in many applications.

Switch-Onto-Fault Protection

User-selected elements are enabled to trip for 52BT time after the line breaker closes. The switch-onto-fault logic requires no communications channel equipment.

Reclosing Relay

The reclosing relay consists of a single reclosing shot with a settable open interval timer and a settable reset timer. Reclose initiate and reclose cancel conditions are selected in settable logic masks.

IRIG-B Input

The relay accepts demodulated IRIG-B from an external source such as the SEL-2020 Communications Processor or other clock source to set its internal clock.

Relay Word

The Relay Word consists of three rows of eight-bit groups which represent the state of the relay elements (both instantaneous and timed), timer and logic outputs, and relay inputs. Each bit in the Relay Word has two states: logical 1 when the element is asserted, logical 0 when the element is deasserted.

Each quarter-cycle, the relay samples voltage and current data, performs intermediate logic to determine if elements are asserted, and sets appropriate bits in the Relay Word.

Each TRIP, programmable output relay, and reclose initiate and cancel condition has a corresponding logic mask. These masks determine the state of the output relay and reclosing sequence, depending on which elements are asserted in the Relay Word.

Table 1 shows the SEL-221-16 Relay Word.

Table 1: Relay Word

Z1P	Z1G	Z2PT	Z2GT	Z3	Z3T	3P21	32Q
67N	51NP	51NT	50NG	50P	50H	IN1	REJO
LOP	TRIP						

Event Reporting

The relay retains eleven-cycle data records for each of the last twelve events. The long form of each event record includes the following:

1. Date and time of disturbance
2. Terminal identifier
3. Input voltages and currents every quarter-cycle
4. Relay element status every quarter-cycle
5. Input and output contact status every quarter-cycle

6. Fault location
7. Event type
8. Maximum phase current magnitude near the middle of the fault
9. Fault duration in cycles
10. Relay and logic settings

An event report is triggered when certain relay elements pick up, the TRIP output contacts close, External Trigger input contacts are asserted, or by execution of the TRIGGER or OPEN commands. If tripping occurs after the end of the event report, the trip triggers a second report.

Fault Location

The relay computes fault location using event report data stored for each fault or disturbance. The primary fault locating algorithm compensates for prefault current to improve fault locating accuracy for high-resistance faults. The relay uses two fault locating methods: the Takagi method where sound prefault data are available, or a simple reactance method when sound prefault data are not available.

Metering

The meter function shows the line-neutral and line-line ac voltage and current values, megawatts (P to represent real power), and megavars (Q to represent reactive power) in primary values. You can display these values locally or remotely with the METER command.

Targeting

Under normal operating conditions, the enable (EN) LED is illuminated. If the relay trips, it illuminates the LED(s) for the highest priority zone and fault type at the time of trip. Target LEDs are latching, so the targets remain illuminated until you press the Target Reset button, execute the TARGET R command, or a trip with a different zone and fault type occurs. When a new trip occurs, targets clear and display the new tripping target.

The TARGET command and front panel LED display allow assignment of front panel LEDs to show the state of relay inputs, outputs, and Relay Word elements.

Self-Testing

The relay runs exhaustive self-tests which ensure reliable operation. If a test fails, the relay enters a warning or failure state, closes the ALARM output relay, and issues a status report to the port designated automatic. The duration of ALARM output contact closure depends on which self-test warns or fails.

Self-tests check the following items:

- Analog Channel Offset (IR, IA, IB, IC, VA, VB, and VC)
- +5 V Power Supply
- ±15 V Power Supplies

- Random-Access Memory (RAM)
- Read-Only Memory (ROM)
- Analog-to-Digital Conversion Time
- Master Offset
- Settings

Contact Inputs and Outputs

The relay has six opto-isolator inputs to sense external conditions: a programmable input, received permissive trip and block trip signals, breaker status, direct close, and external event report trigger. Assert these logic inputs by applying control voltage to the corresponding rear-panel input terminals. The programmable input, permissive trip, block trip, and direct close inputs are monitor points and are displayed in the event report only. They control no relay functions.

The relay has seven output contacts: TRIP, CLOSE, ALARM, and four programmable outputs (A1, A2, A3, and A4). Any output contact except TRIP may be configured as either "a" or "b."

Communications Ports

Relay rear-panel connectors labeled Port 1 and Port 2 are EIA-232 serial data interfaces. Port 2 has both front (2F) and rear (2R) panel connectors. Generally, Port 1 is used for remote communications via a modem, while Port 2R is used for communicating with an SEL-2020 Communications Processor or SEL-PRTU Protective Relay Terminal Unit. Port 2R may also be connected to the SEL-DTA or SEL-RD, which serves as a local operator interface. Port 2F on the front panel is used for local communications. Communicating through Port 2F disables communications through Port 2R.

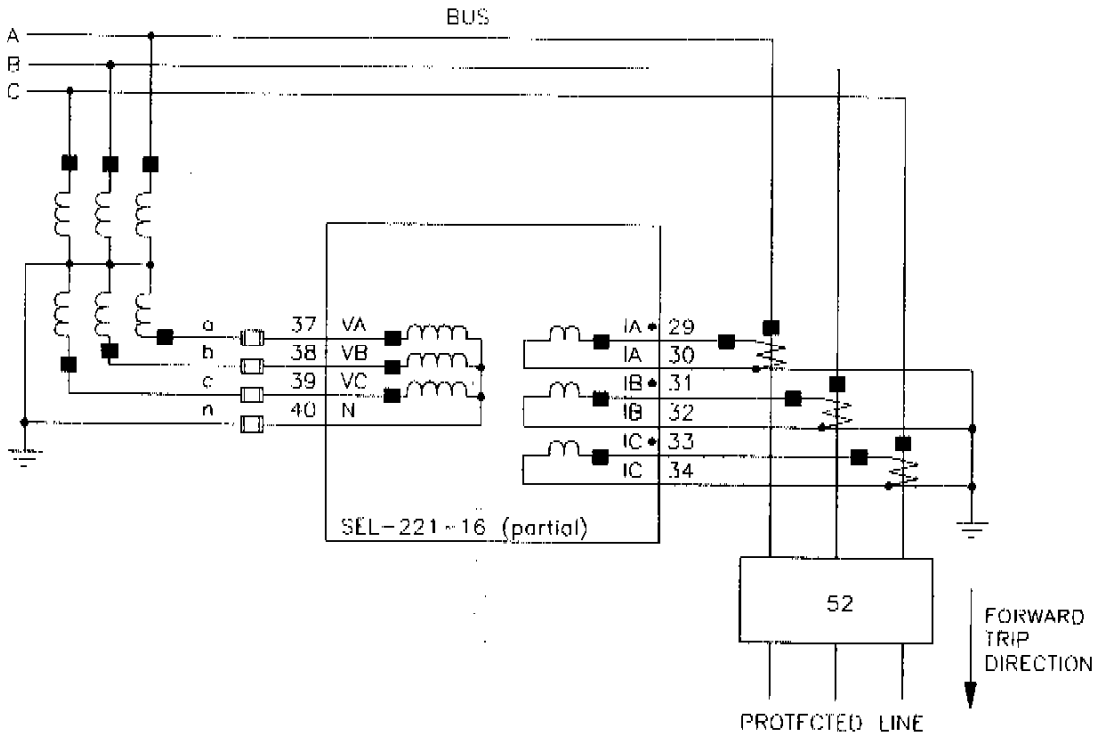

Figure 2: SEL-221-16 Relay External AC Current and Voltage Connections

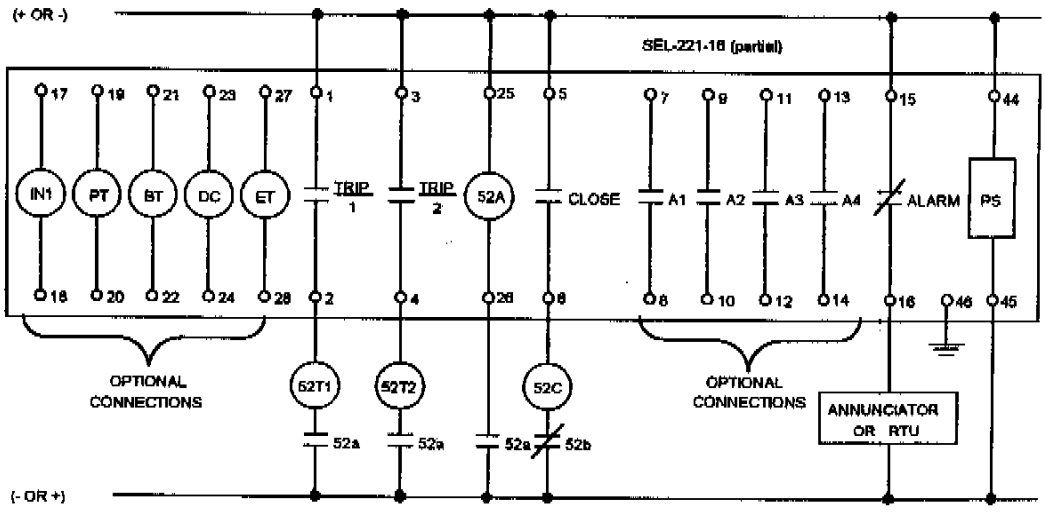

Figure 3: SEL-221-16 Relay External DC Connection Diagram (Typical)

TECHNICAL SPECIFICATIONS

General Specifications

AC Input Voltage	115 volt nominal phase-to-phase, three-phase four-wire connection
AC Input Current	5 amps per phase nominal 15 amps per phase continuous 500 amps for one second thermal rating
Output Contacts	*IEEE C37.90 Tripping Output Performance Requirements.* 30 A make. 6 A carry; MOV protected.
Logic Input Ratings	24 Vdc: 15 - 30 Vdc 48 Vdc: 30 - 60 Vdc 125 Vdc: 80 - 150 Vdc 250 Vdc: 150 - 300 Vdc Current = 4 mA at nominal voltage
Power Supply Ratings	24/48 Volt: 20 - 60 Vdc. 125/250 Volt: 85 - 350 Vdc or 85 - 264 Vac. 10 watts nominal, 14 watts max. (all output relays energized)
Time Code Input	Relay accepts demodulated IRIG-B time code
Serial Communications	Two EIA-232 serial communications ports. Port 2 has front and rear connectors.
Dielectric Strength	Voltage and current inputs: 2500 Vac for 10 seconds Power supply, logic inputs, and contact outputs: 3000 Vdc for 10 seconds
Burn-in Temperature	60°C (140°F) for 96 hours or equivalent
Dimensions	8.81 cm x 48.26 cm x 22.86 cm (3.47" x 19.00" x 9.00") (H x W x D)
Unit Weight	5.5 kg (12 pounds)
Shipping Weight	7.7 kg (17 pounds), including one instruction manual.
Mounting	Available in horizontal or vertical mounting configurations.
Operating Temperature	-40°C to 70°C (-40°F to 158°F)
Type Tests and Standards	*IEEE C37.90 IEEE Standard for Relays and Relay Systems Associated with Electrical Power Apparatus.* Dielectric Tests.

IEEE C37.90.1 IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems.

IEEE C37.90.2 IEEE Trial-Use Standard, Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers.

Exceptions:

5.5.2 (2)	Performed with 200 frequency steps per octave
5.5.3	*Digital Equipment Modulation Test* not performed
5.5.4	Test Signal turned off between frequency steps to simulate keying.

IEC 68-2-30 Basic environmental testing procedures, Part 2: Tests, Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle).
Humidity, 95% between 25°C and 55°C.

IEC 255-5 Electrical relays, Part 5: Insulation tests for electrical relays.
Impulse voltage test, 0.5 Joule, 5000 volt.
Dielectric test, Series C.

IEC255-21-1 Electrical relays, Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment, Section One - Vibration test (sinusoidal).

IEC 255-21-2 Electrical relays, Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment, Section Two - Shock and bump tests.

IEC 255-22-1 Electrical disturbance tests for measuring relays and protection equipment, Part 1: 1 MHz burst disturbance tests.

IEC 529 Degrees of protection provided by enclosures (IP30).

IEC 801-2 Electromagnetic compatibility for industrial-process measurement and control equipment, Part 2: Electrostatic discharge requirements.

IEC 801-3 Electromagnetic compatibility for industrial process measurement and control equipment, Part 3: Radiated electromagnetic field requirements.

Exceptions:

9.1	Frequency sweep approximated with 200 frequency steps per octave.

IEC 801-4 Electromagnetic comptibility for industrial-process measurements and control equipment. Part 4: Electrical fast transient/burst requirements.

Relay Element Ranges

Distance Elements	Secondary Reach Setting Range:	0.125 - 64.0 ohms
Minimum Sensitivity	Secondary, defined by the fault detector minimum setting	0.5 Amps
Maximum Torque Angle (MTA)		47° - 90°
Residual Current Compensation (K) Factor Range	Magnitude limits: Range limits: Where: $K = \frac{Z0 - Z1}{3 X Z1}$ $Z0 = R0 + jX0$ $Z1 = R1 + jX1$ R0, X0, R1, X1 Relay Impedance Settings	$0.0833 < \lvert K \rvert < 2.0$ $47° < MTA + \angle K < 113°$
Accuracy	Steady-state Error:	±5% of set reach ±0.01 ohm at MTA for V > 5 V and I > 2 A.
	Transient Overreach:	±5% of set reach, plus steady-state error
Zone 2 and 3 Distance Element Timers	Range in quarter-cycle steps:	3 - 2000 cycles
Nondirectional Phase Overcurrent Elements	**Low-set ground fault detectors** Pickup in secondary Amps:	0.5A to 25 times 51NP, but less than 40 A, ±0.1 A ±2% of setting
	Transient overreach:	±5% of set pickup
	Phase fault detectors Pickup in secondary Amps:	0.5 to 40 A, ±0.1 A ±2% of setting
	Transient overreach:	±5% of set pickup

	High-set phase overcurrent elements	
	Pickup in secondary Amps:	0.5 to 80 A, ±0.1 A ±2% of setting
	Transient overreach:	±5% of set pickup
Ground Overcurrent Elements	**Residual instantaneous overcurrent** Supervises ground distance elements	
	Pickup in secondary Amps:	0.5 A to 25 times 51N pickup, but less than 40 A
	Transient overreach:	±5% of set pickup
	Residual time-overcurrent element (available with either US curves or IEC curves)	
US Curves	Moderately Inverse, Inverse, Very Inverse, Extremely Inverse	
	Time dial in 0.01 steps:	0.50 to 15.00
	Pickup in secondary Amps:	0.5 to 8.0 A, ±0.05 A ±3% of setting
	Timing:	±4% and ±1 cycle for residual current magnitude between 2 and 20 multiples of pickup
	May be directionally controlled	
IEC Curves	Standard Inverse, Very Inverse, Extremely Inverse, Long Time Delay	
	Time dial in 0.01 steps:	0.05 to 1.00
	Pickup in secondary Amps:	0.5 to 8.0 A, ±0.05 A ±3% of setting
	Timing:	±4% and ±1 cycle for residual current magnitude between 2 and 20 multiples of pickup
	May be directionally controlled	

	High-set Instantaneous Residual overcurrent element	
	Pickup in secondary Amps:	0.5 A to 50 times 51N pickup
	Transient overreach:	±5% of set pickup
	May be directionally controlled	
Negative-Sequence Directional Elements	Sensitivity:	0.32 VA (V2 x I2) at MTA
Sequence-Component Elements	Used in Loss-of-Potential logic	
	Negative-sequence overvoltage element	
	Pickup of V2 (fixed):	14 V
	Negative-sequence overcurrent element	
	Pickup of I2 (fixed):	0.083 A
Miscellaneous Timers	Set in cycles with quarter-cycle resolution	
	79OI: Reclose Relay Open Interval:	0.0 - 8,000 cycles
	79RS: Reclose Relay Reset Time:	60.0 - 8,000 cycles
	A1TP: A1 Output Contact TDPU Timer:	0.0 - 8,000 cycles
	52BT: Switch-Onto-Fault Timer:	0.5 - 10,000 cycles
	TDUR: Minimum Trip Duration Timer: (0 Disables the OPEN Command)	0.0 - 2,000 cycles

TDPU = Time Delayed Pickup
TDDO = Time Delayed Dropout

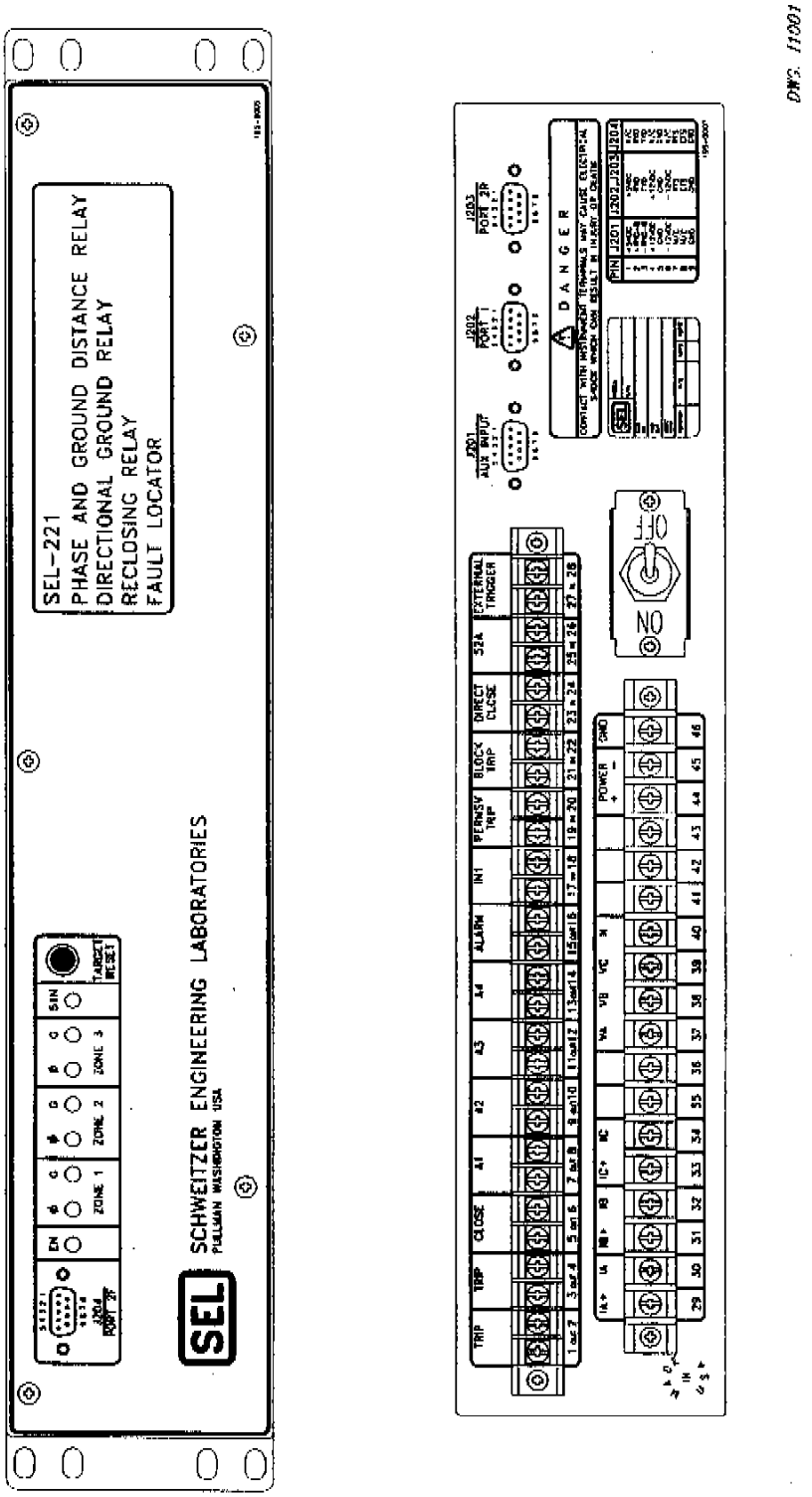

Figure 4: SEL-221-16 Horizontal Front and Real Panel Drawings

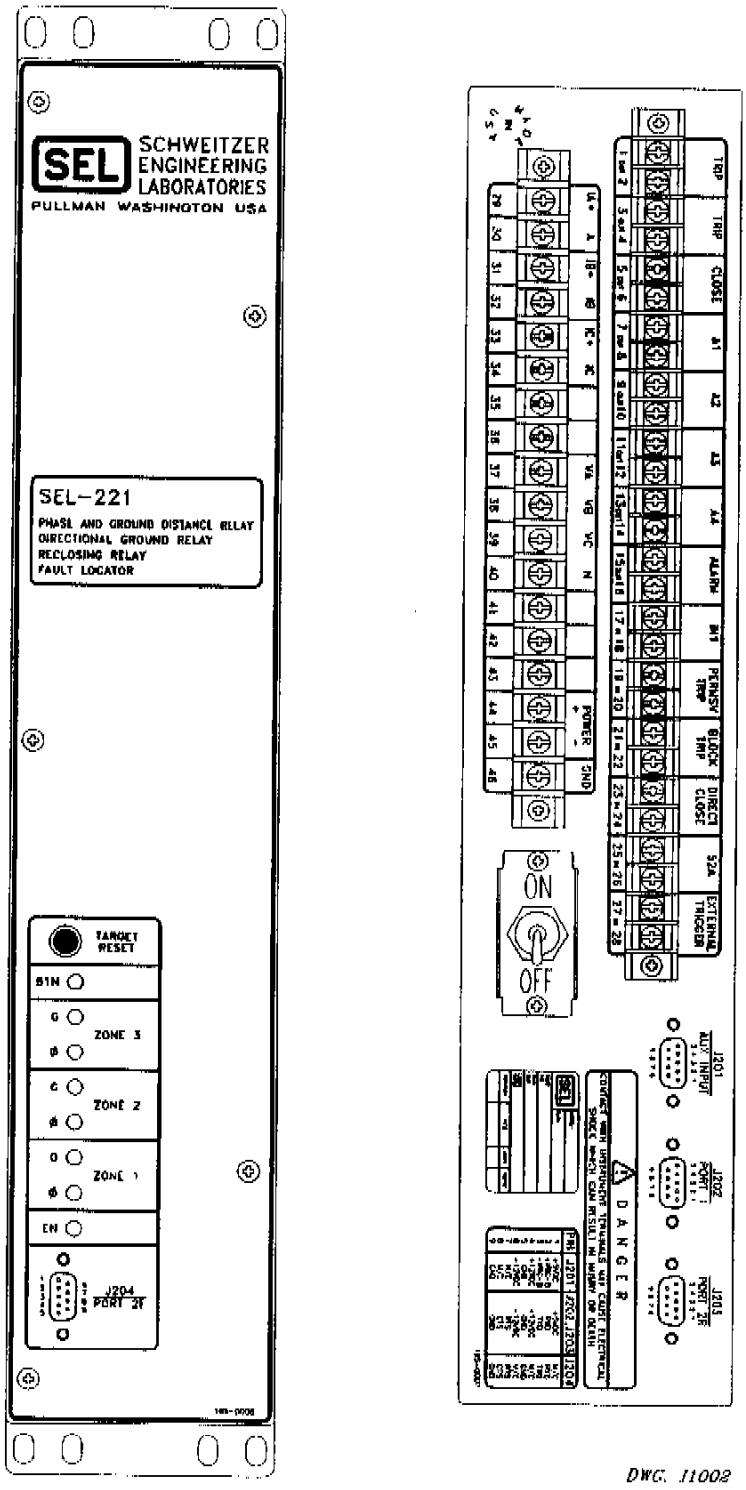

Figure 5: SEL-221-16 Vertical Front and Rear Panel Drawings

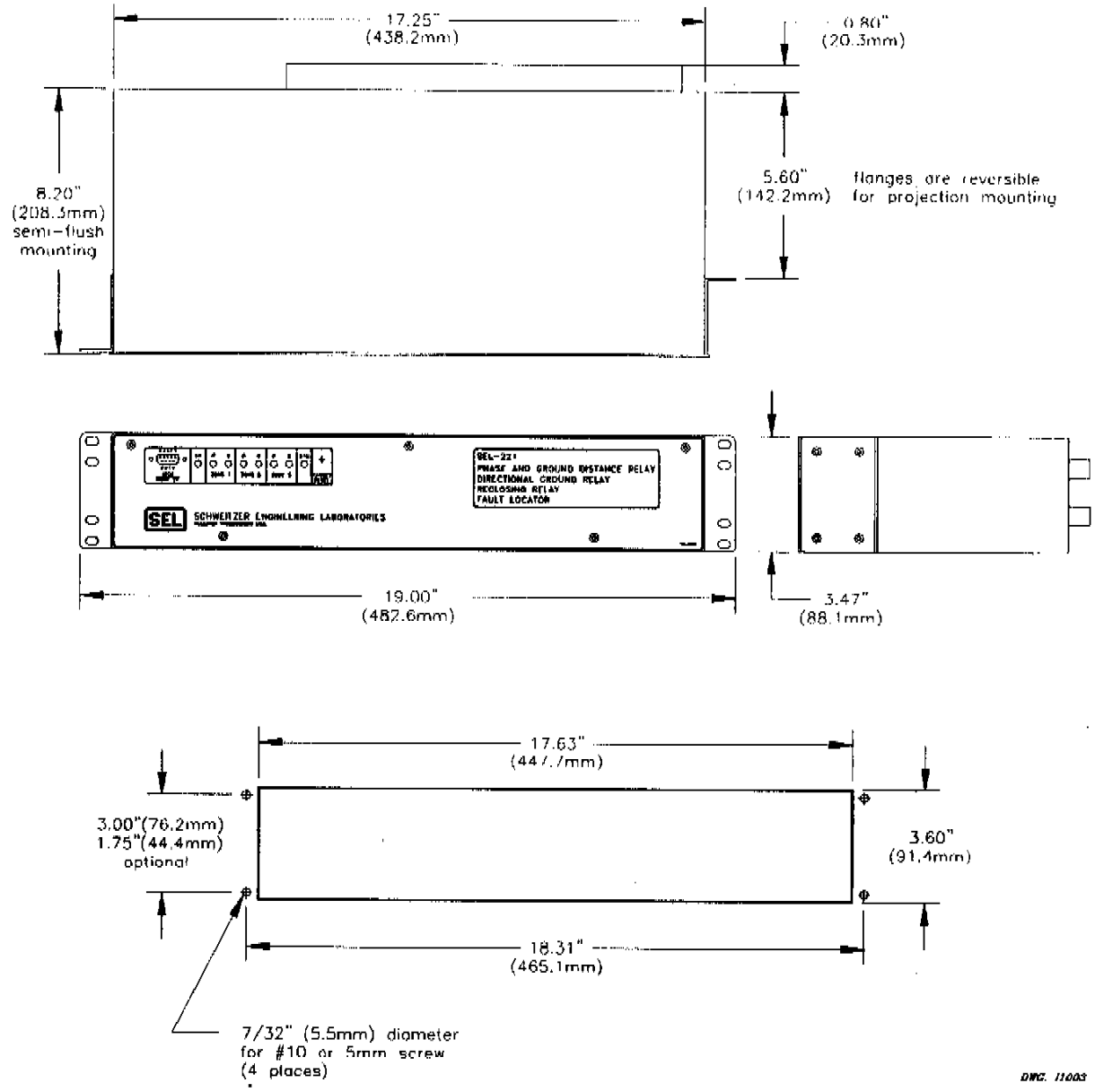

Figure 6: SEL-221-16 Relay Dimensions, Panel Cutout, and Drill Plan