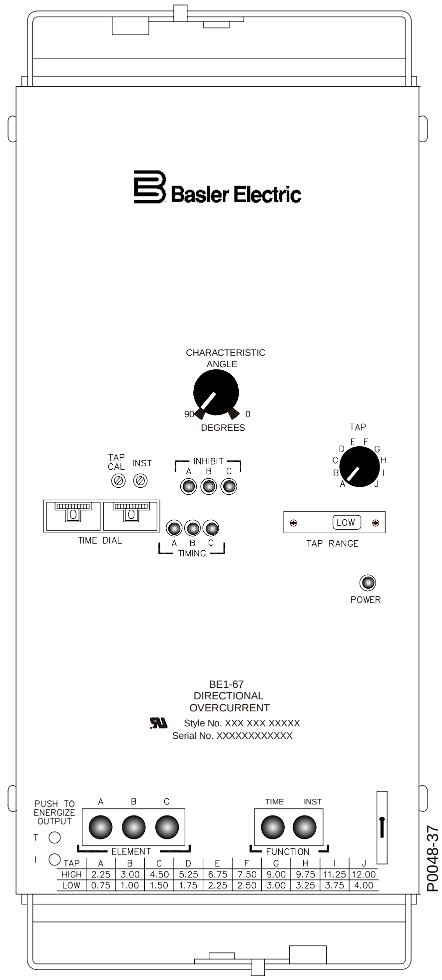
INSTRUCTION MANUAL

FOR

DIRECTIONAL OVERCURRENT RELAY

BE1-67



Basler Electric®

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INTRODUCTION

This instruction manual provides information about the operation and installation of the BE1-67 Directional Overcurrent Relay. To accomplish this, the following information is provided:

- General Information and Specifications
- Controls and Indicators
- Functional Description
- Installation
- Testing

WARNING!

To avoid personal injury or equipment damage, only qualified personnel should perform the procedures in this manual.

NOTE

Be sure that the relay is hard-wired to earth ground with no smaller than 12 AWG copper wire attached to the ground terminal on the rear of the unit case. When the relay is configured in a system with other devices, it is recommended to use a separate lead to the ground bus from each unit.

First Printing: September 1988

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August 2007

It is not the intention of this manual to cover all details and variations in equipment, nor does this manual provide data for every possible contingency regarding installation or operation. The availability and design of all features and options are subject to modification without notice. Should further information be required, contact Basler Electric.

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REVISION HISTORY

The following information provides a historical summary of the changes made to the BE1-67 instruction manual (9170900990). Revisions are listed in reverse chronological order.

Manual Revision and Date	Change
H, 08/07	• Enhanced the readability of various figures throughout the manual. • Updated *Output Contacts* ratings in Section 1. • Moved content of Section 6, *Maintenance* to Section 4. • Updated front panel illustrations to show laser graphics. • Moved content of Section 7, *Manual Change Information* to manual introduction. • Updated power supply burden data in Section 1. • Updated Target Indicator description in Section 3.
G, 05/03	• Changed Table 1-9, *Style Chart,* to make Timing match the BE1-67N. • Corrected the Basler publication number for characteristic curves on page 1-15. • Eliminated reference to a service manual on pages 2-5 and 6-1 that no longer exists. • Changed the *Power Supply* portion in Section 3 regarding wide-range power supply (similar to the BE1-60). • Updated Figures 4-1, 4-3, and 4-4 with the new style front panels. • In *Setting the Pickups,* Step 11, page 5-13, added the Basler publication where the B6, Very Inverse, drawing can be found. • Updated the manual style throughout.
F, 11/95	• Changed *Specifications* for *Isolation* in Section 1 and *Dielectric Test* in Section 4. • Corrected *Setting the Relay - An Example* in Section 5. (Changed Time Delay from 5.2 seconds to 0.6 seconds in *Example Defined* and Step 11.)
E, 08/94	• Revised the entire manual to the current instruction manual format. • Added internal connection diagrams, typical connection diagrams, and phase rotation sensitivity.
D, 07/89	• Corrected minor typographical errors.
C, 02/89	• The arrows indicating trip direction have been reversed in Figures 4-3 and 4-4.
B, 12/88	• Voltage sensing input rating corrected. • Current sensing burden statement on page 1-10 replaced former table on same page.
A, 09/88	• Test procedure simplified. • Minor editing changes.
—, 09/88	• Initial release

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SECTION 1 • GENERAL INFORMATION

DESCRIPTION

BE1-67 Phase Directional Overcurrent Relays are designed for the protection of transmission and distribution lines where the direction as well as the magnitude of the fault current (or power flow) is to be considered in the tripping decision.

BE1-67 relays are directionally controlled, microprocessor based, time overcurrent relays. The directional element is polarized by the phase-to-phase quadrature voltage of the power system. That is, the directional element monitoring the phase A current uses the voltage between phases B and C to determine the direction of current (or power) flow into the fault. Then, if enough current flows in the tripping direction of the relay, the relay will pickup, time out and trip. The angle of maximum sensitivity for the relay is also adjustable to allow the directional characteristic to be matched to the line and system conditions. Figure 1-1 illustrates the operation of the directional element and defines the terms that are used in the following discussion.

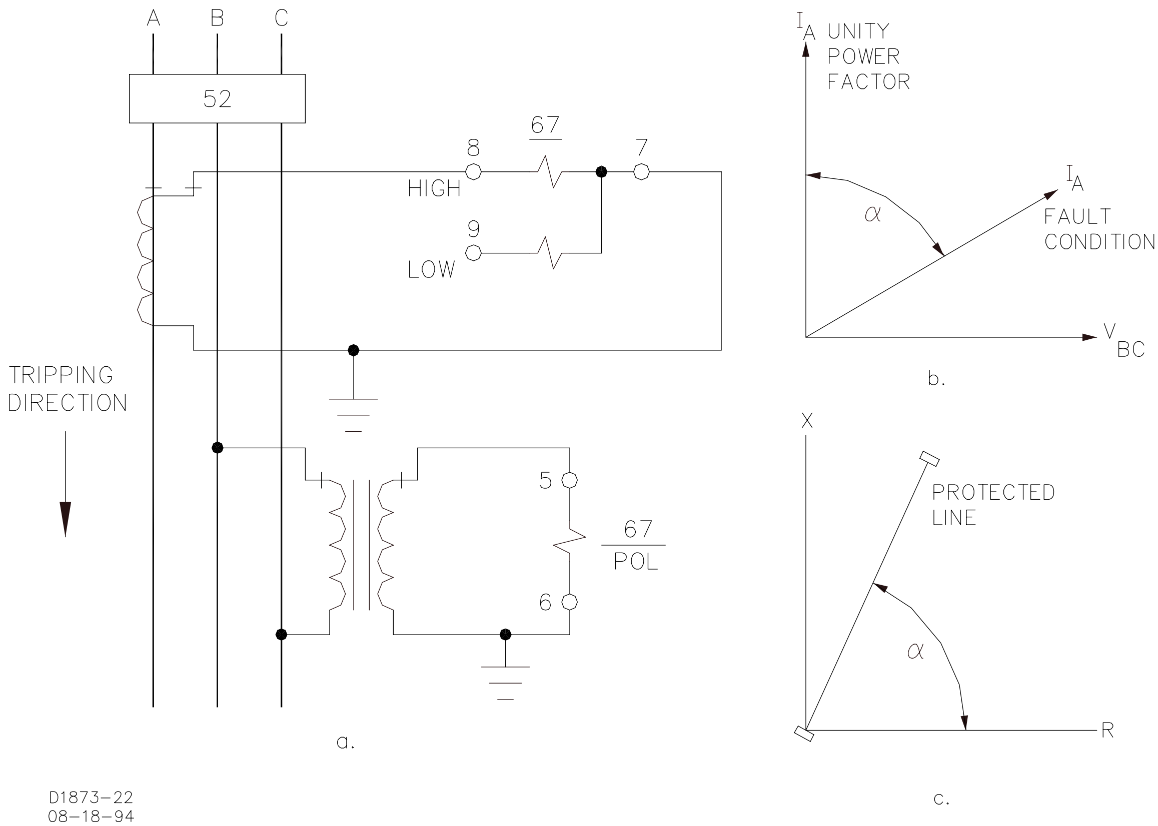

Figure 1-1. Single-Phase Directional Overcurrent

Figure 1-1a shows the connections to the sensing circuits for a single phase BE1-67. Figure 1-1b illustrates the phasor quantities monitored by the relay for a unity power factor condition, and for a single phase fault. Figure 1-1c shows the protected line on an R-X diagram. The angle alpha in Figure 1-1b and Figure 1-1c are the characteristic angle settings for the relay.

The directional characteristic of the relay is adjustable to allow the relay to be sensitive for phase faults and to maximize sensitivity at the characteristic angle representing typical power factor.

Twelve standard time-current characteristic curves are available to aid in the coordination of this relay with other protective devices in the system. These include seven characteristic curves that are standard in North America and five that are compatible with British or IEC standards requirements. In addition, an option allows the relay to be supplied with all of these curves any of which may be switch selected to suit requirements at the time of installation.

Table 1-1. Selection Considerations for Characteristic Curves

Style Designation	Characteristic Shape	Special Characteristics
B1	Short Inverse	Relatively short time, desirable where preserving system stability is a critical factor.
B2, E2	Long Inverse	Provides protection for starting motors and overloads of short duration.
B3	Definite Time	Definite Time Fixed time delay according to the time dial setting. Useful for sequential tripping schemes.
B4, E4	Moderately Inverse	Accommodates moderate load changes as may occur on parallel lines where one line may occasionally have to carry both loads.
B5, E5	Inverse	Provide additional variations of the inverse characteristic, thereby allowing flexibility in meeting load variations, or in coordinating with other relays.
B6, E6	Very Inverse	
B7, E7	Extremely Inverse	

If the supply to the protected portion of the system is constant, and if the magnitude of the fault current is determined primarily by the location of the fault on the line, the selection of a more inverse time characteristic is more desirable to provide selective coordination with adjacent line protection. However, if the capacity of the supply varies significantly over a period (such as a day), a less inverse time or even the definite time characteristic, may be preferred to provide smoother coordination.

LIMITED REGION OF OPERATION

A limited region-of-operation option is available to provide additional protection against false tripping on mutually coupled lines. Faults on adjacent lines that share the same poles, towers, or right-of-way may induce currents on the protected line which appear as fault currents in the tripping direction. The limited region of operation mode provides discrimination between faults on the protected line and faults on the adjacent line. To order this option, specify option 3-5 or 3-6.

One consideration in applying a phase directional overcurrent relay is the definition of trip direction. For most applications, the setting of the relay directional element is based upon the impedance characteristics of a given circuit. This angle is then used as the maximum torque angle and any current flowing in the half-plane defined by this angle is considered to be in the trip direction.

Figure 1-2 illustrates the trip and non-trip directions.

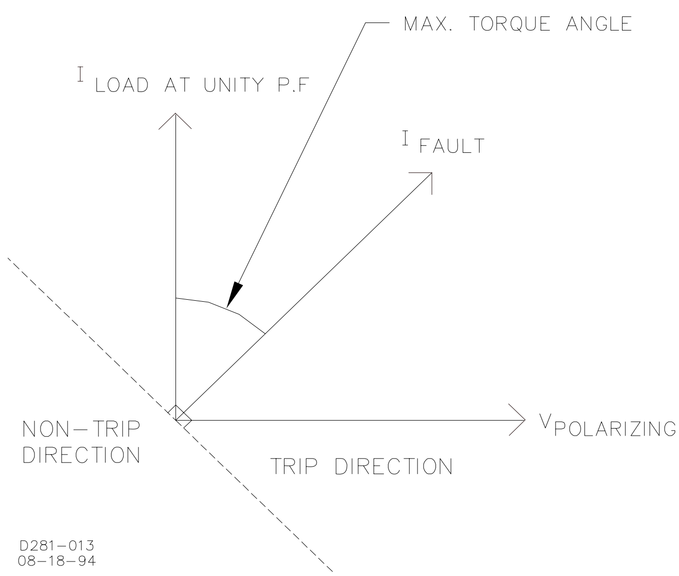

Figure 1-2. Trip Direction Defined

However, there are at least two situations where the half-plane trip region is not adequate. They are when load current approaches the fault current and when leading current flows in the non-trip direction above the relay pickup setting.

Load Current Approaches Fault Current

Pickup settings on a phase overcurrent device are normally set below the expected fault current levels on that line by some margin. Consequently, it is possible for load current to approach (or exceed) the pickup setting on the relay. This could lead to an undesirable trip for an acceptable load condition.

Weak Infeed Condition

During a period of abnormally low system voltage, leading power factor current above relay pickup can flow in the non-trip direction of a line. Probable current sources are outlying capacitor banks. This could cause the current to be sensed as lagging current flowing in the trip direction and leading to an undesirable trip. (A condition often referred to as *weak infeed* because the lower voltage system - where load is present - attempts to correct the undervoltage condition on the higher voltage system.) Refer to Figure 1-3.

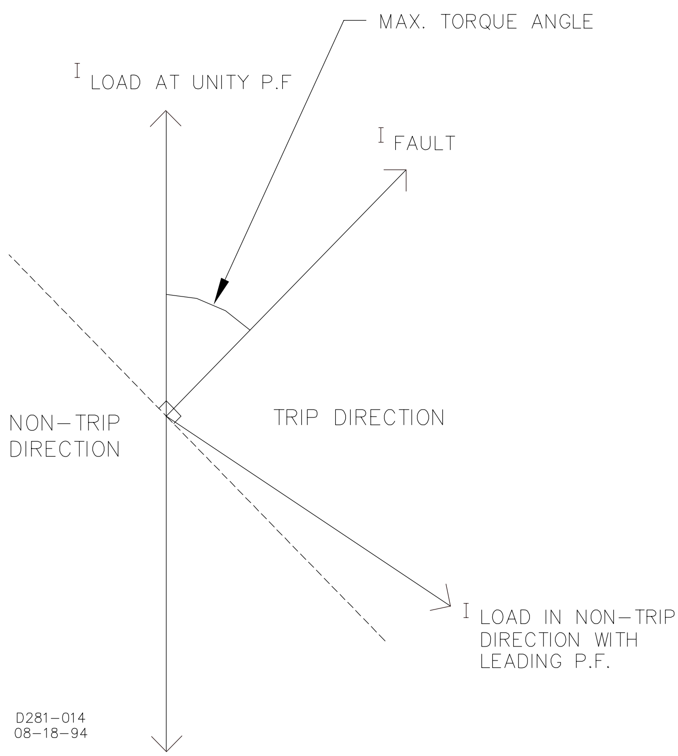

Figure 1-3. Weak Infeed Phenomenon

Both of the previous conditions can be eased by limiting the area of the trip region. Specifically, the angle on each side of the torque angle vector can be adjusted to be less than 90 degrees. This limits the trip region area to only a portion of the half-plane usually defined as the trip direction. This limited region-of-operation characteristic (shown in Figure 1-4) is available by specifying option 3-5 or 3-6.

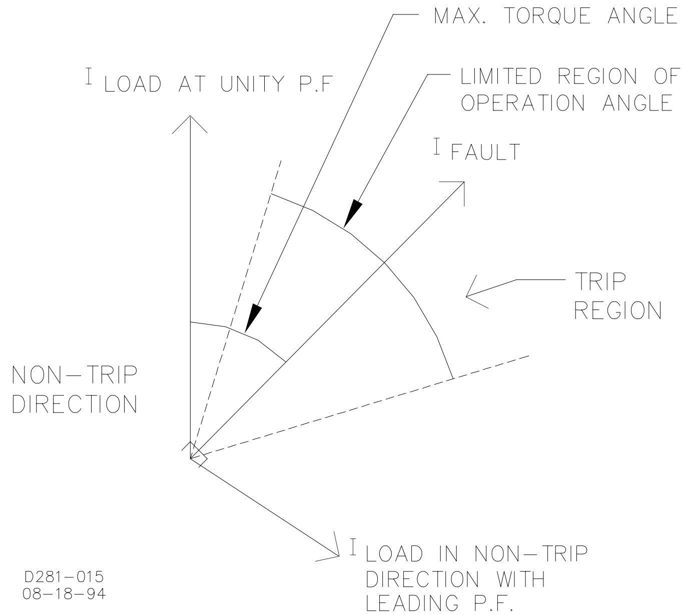

Figure 1-4. Limiting the Region of Operation

APPLICATION

Without the ability to act on the direction of current flow, it is difficult to coordinate the settings of time overcurrent relays on lines that interconnect a series of substations. Without this capability, either undesired tripping of adjacent lines may occur or a fault may go undetected because of the high settings required by non-directional relays.

With directional time overcurrent relays, the settings and time delays can be decreased and the undesired tripping eliminated. Figure 1-5 illustrates the use of directional overcurrent relays on a group of interconnected distribution substations fed from a common source. In this example, non-directional overcurrent relays (51) are used to protect the lines leaving the supply bus because there is only one source of fault current. However, the breakers at the load buses (C, D, E, and F) are protected by directional time overcurrent relays (67) to prevent overtripping in the event of a fault. This will remove the faulted line and retain service to the connected loads.

In the case where two sources of power can supply fault current, as shown in Figure 1-6, directional overcurrent relays will need to be applied to each end of the protected lines to prevent undesired tripping.

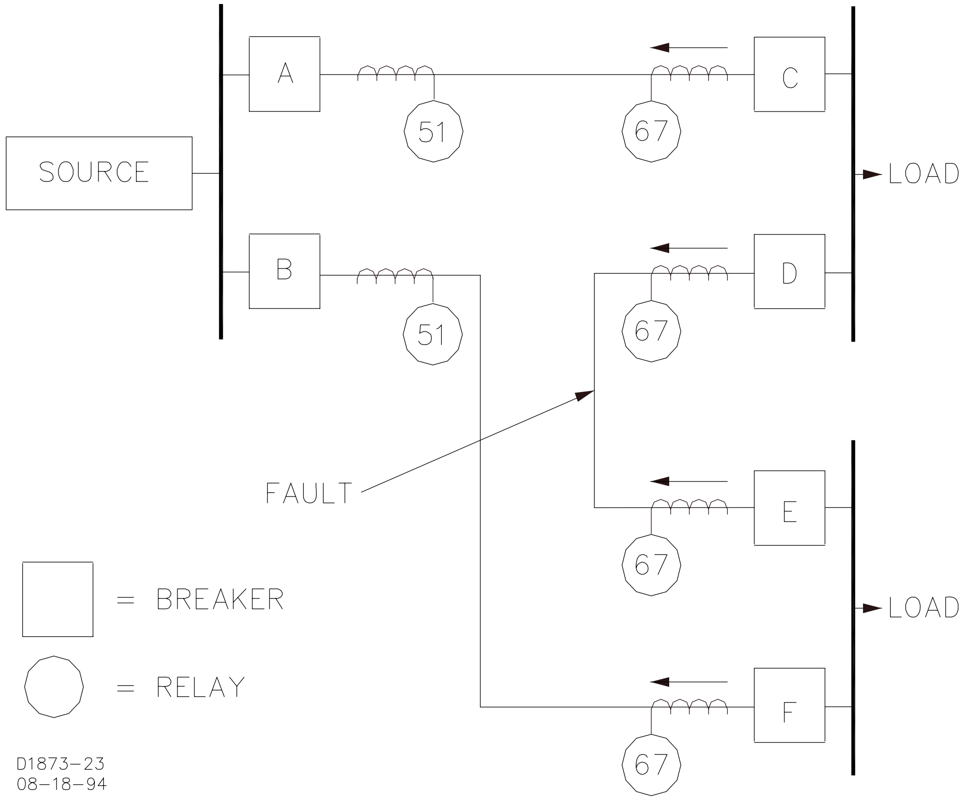

Figure 1-5. Substations Fed from One Source

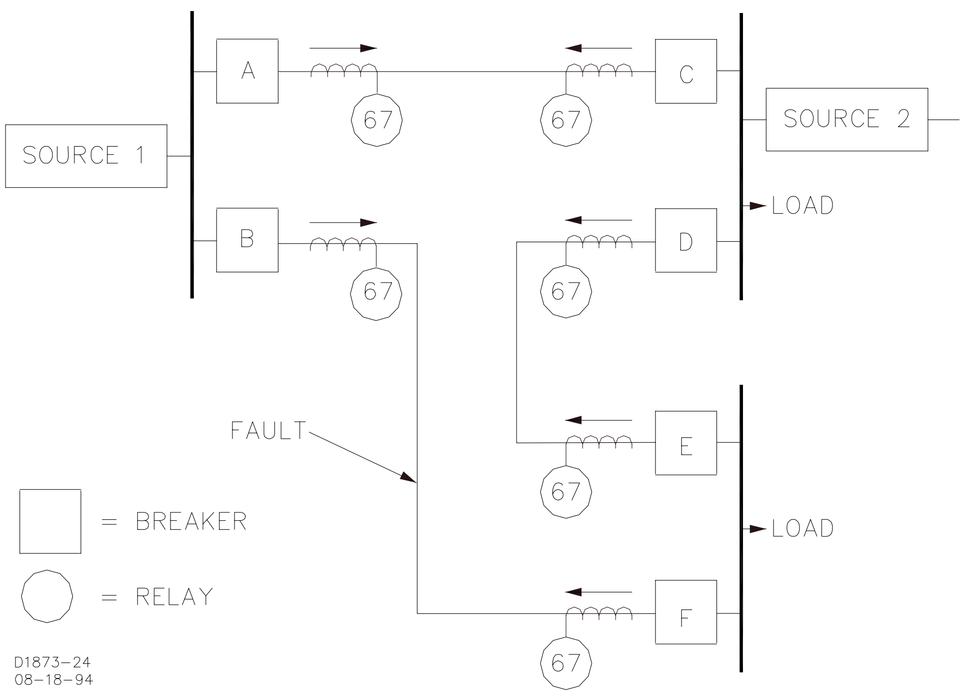

Figure 1-6. Substations Fed from Two Sources

SAMPLE APPLICATION CALCULATIONS

In this sample illustrated by Figure 1-7, a three-phase, 60 hertz, BE1-67 relay is used at breaker position A. Assumed options for the relay include switch-selectable characteristic curves, switch-selectable characteristic angle and a directional instantaneous output.

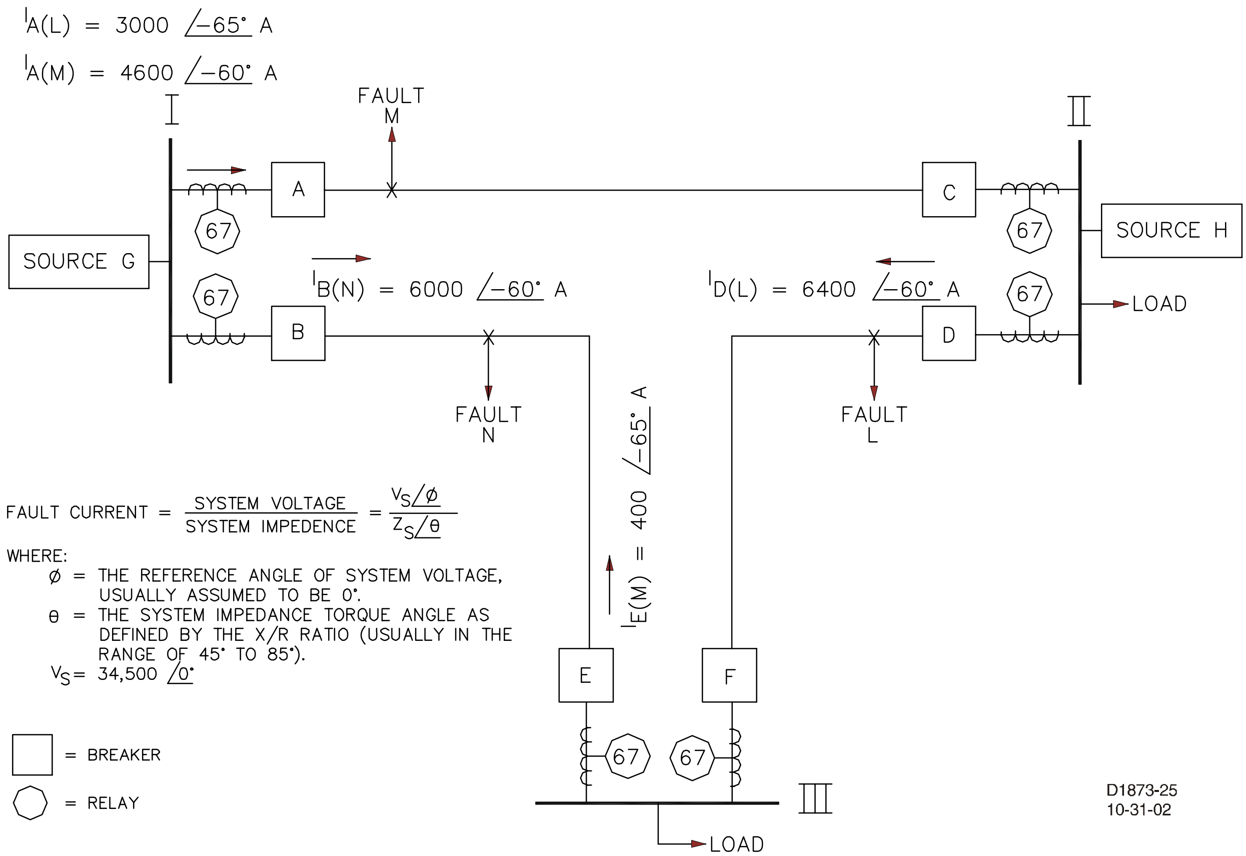

Figure 1-7. Significant Faults for Breaker A

Using this relay under the stated conditions, there are five settings to be established:

- Pickup of the timed element
- Time dial
- Timing characteristic
- Torque angle
- Pickup of the directional instantaneous unit

In arriving at a satisfactory setting for each variable, consideration must be given as to how the relay coordinates with other upstream and downstream tripping devices. In particular, the time-current characteristics of all relevant devices must be systematically considered for each fault condition that can occur.

The ensuing analysis considers pickup settings first, followed by a detailed examination of the three scenarios indicated in Figure 1-7 as faults L, M, and N. These will be individually considered with regard to the five settings listed previously and particularly the last four.

Pickup

When considering relay pickup, it is desirable to set the relay above the maximum load that the feeder is expected to supply at any given time in the defined direction. Often this quantity is limited only by the breaker size or the current carrying capacity of the line itself.

Returning to Figure 1-7, if it is assumed that the maximum lead current is 1,200 amperes for line AC and a maximum CT ratio of 400:1, then:

Timed pickup setting = (1200) (1 ÷ 400) (1.25) = 3.75 amperes

(The 1.25 factor represents a margin of safety.)

Analysis of Fault L

In Figure 1-7, assume the following fault L currents.

- $I_{A(L)}$ = 3,000 amperes at an angle of -65 degrees
- $I_{D(L)}$ = 6,400 amperes at an angle of -60 degrees

Based on these fault currents, the BE1-67 relay at A will pickup and begin to time out. But the primary concern is that the relay at D trips before the one at A. This is accomplished by selecting the appropriate pickup, time dial, and characteristic for the 67_A device. Note in Figure 1-8, illustration a, that the 67_D characteristic curve must be completely under the 67_A curve for current greater than the 67_A pickup point. A coordinating time interval of 0.2 to 0.5 seconds between the curves is usually recommended to accommodate breaker clearing time plus a safety margin. The *Time Dial* should be set to provide this coordination margin.

Usually, time-characteristic curves are chosen to coordinate with existing system devices. Consequently, if 67_D is extremely inverse, the 67_A relay might well be set to the B7 curve (extremely inverse). To select the curve, use the rotary switch behind the front panel of the relay.

The fault current level seen by I_A (3,000 amperes) also confirms that the setting chosen (3.75 A x 400 = 1,500 primary amperes) is sensitive enough to detect remote end faults. This is assuming that the fault current is not limited by fault impedance.

Analysis of Fault M

In Figure 1-7, assume the following fault M currents:

- $I_{A(M)}$ = 4,600 amperes at an angle of -60 degrees
- $I_{E(M)}$ = 400 amperes at an angle of -65 degrees

The 67_A must be coordinated with the upstream 67_E device. Again, the primary concern is that the 67_A relay trips before the 67_E relay. Accordingly, the time current characteristic curve for each relay must be selected such that the 67_A curve is entirely under the 67_E curve for currents above the 67_E pickup, plus some margin. (See Figure 1-8, illustration b.)

Be sure to check time dial settings to verify proper coordination. The fault current level seen by I_A also allows the directional instantaneous unit to be set to trip for high current close-in faults.

Directional Instantaneous Setting = 4,600 (1 ÷ 400) (0.8 margin) = 9.2 amperes.

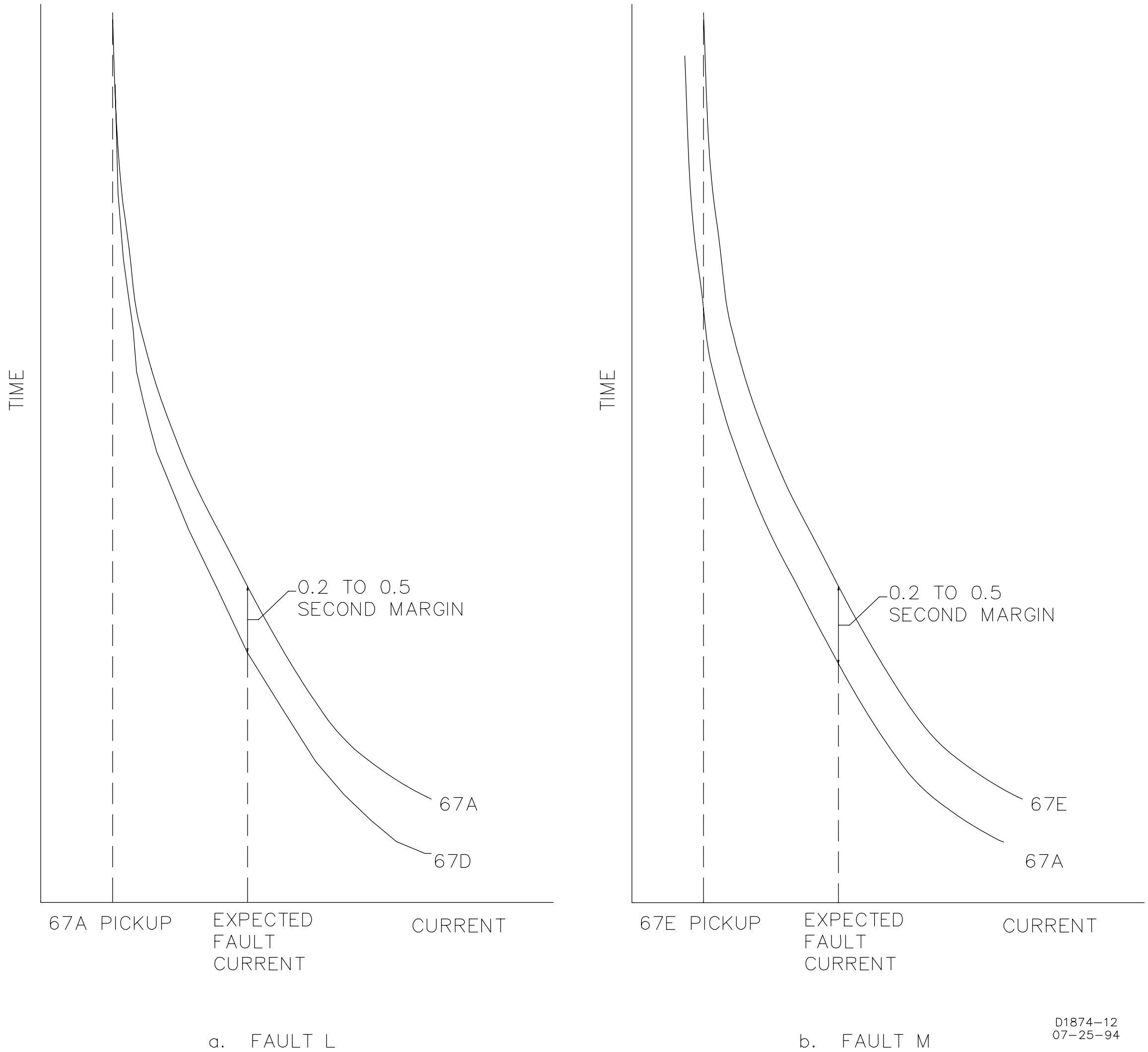

Figure 1-8. Coordination of Time Characteristic Curves

Since the impedance characteristic of the system is approximately 60 degrees (as defined by system R+jX), the torque angle should be selected as 60 degrees for maximum sensitivity. A torque angle of 60 degrees will also ensure that 67_B will see fault N, but that 67_A will not. (The response of the BE1-67 Directional Unit is approximately 1 cycle, thereby blocking the overcurrent unit before it will see the fault current in the reverse direction.)

Conclusions

Taking into consideration the requirements imposed by each of three possible fault conditions, the five required settings for the relay at breaker A in this application are summarized in Table 1-2.

Table 1-2. Required Breaker Settings

Variable	Suitable Setting
Pickup for timed element	3.75 (low range, TAP 1
Time dial	As required for proper coordination margin
Timing characteristic	B7 (rotary switch position 7)
Directional instantaneous element	9.20 A (potentiometer adjustment)
Torque angle	60° characteristic angle

MODEL AND STYLE NUMBER

Style Number Identification Chart

BE1-67 Phase Directional Overcurrent Relay electrical characteristics and operational features are defined by a combination of letters and numbers that make up the style number. Refer to Figure 1-9 for the Style Number Identification Chart. Model numbers BE1-67 designate the relay as a Basler Electric, Class 100, Phase Directional Overcurrent Relay. The model number together with the style number describes the options included in a specific device and appears on the front panel, drawout cradle and inside the case assembly. Upon receipt of a relay, be sure to check the style number against the requisition and the packing list to ensure that they agree.

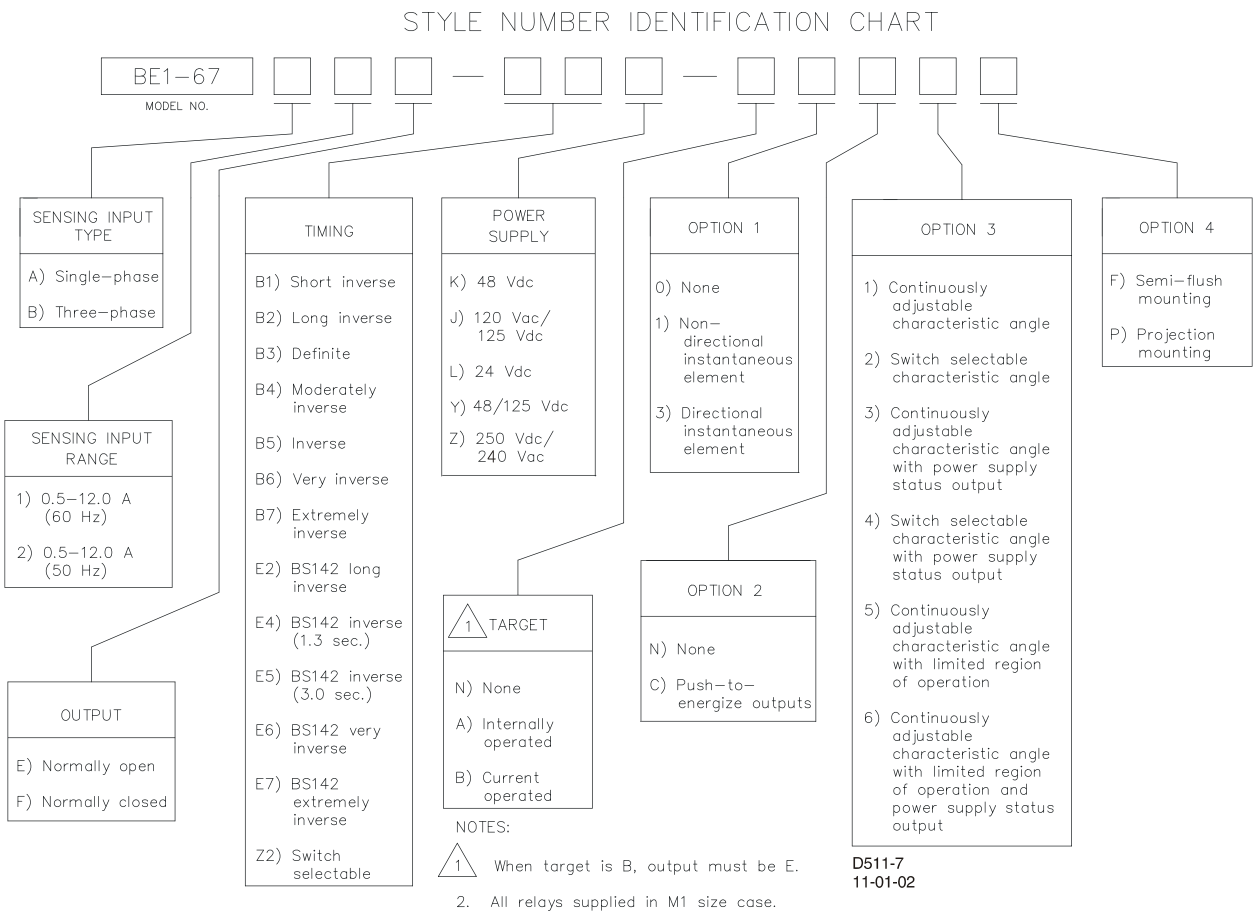

Figure 1-9. Style Number Identification Chart

Style Number Example

Suppose, for example, it was decided that three-phase packaging of the directional overcurrent function (67) would be best for an application. Then the first character of the style number would be B.

Suppose further that this is a 60 hertz power system and that the pickup setting for the time overcurrent function is to be 4.6 amperes. Then the second character of the style would then be 1. At this point it should be noted on the installation instructions and drawings that the relay should be connected for the HIGH range and that the front panel TAP RANGE plate should be adjusted so that the word HIGH shows.

If normally open output contacts are to be used for tripping the breaker, output option E is selected as the third character.

If the required characteristic curve shape is not known prior to the installation of the protection package, timing option Z2 could be specified. This allows the proper characteristic curve to be set in the field. (This also allows a relay type to be stocked and used in other applications, thereby reducing stocking requirements.)

Continuing this hypothetical example, if a majority of the substations in the system have either 48 or 125 Vdc station battery supplies, a type Y power supply option provides further standardization in the ordering and stocking process.

The next style character is B if current operated targets are desired. These have an advantage over internally operated targets because they confirm that a current signal flowed in the output circuit and resulted in a trip. (However, as the style chart notes, current operated targets are only available when a normally open contact is specified.) Internally operated targets only provide an indication that the associated contact attempted to trip the breaker.

If a directional instantaneous overcurrent element is needed, the eighth character of the style number will then be 3.

Will the breaker be periodically trip tested? If the normal procedure calls for the technician to close the relay contacts, the push-to-energize output option (C) provides the convenience to do this.

If a fixed characteristic angle is preferred to a continuously adjustable angle and it is useful to have a contact monitoring the power supply of the relay, option 3 should be a 4.

Finally, if relays are to be semi-flush mounted in the panel, the last style character is F. (These relays are always supplied in an M1-size drawout case.)

Summarizing the above example of the selection process, the total style number for the specified relay is **BE1-67 B1E-Z1Y-B3C4F:**

BE1-67 - Model number
B - Three-phase sensing
1 - 0.5 to 12 A sensing range (60 Hz)
E - Normally open output contacts
Z1 - Switch selectable timing characteristics
Y - 48/125 Vdc Power supply
B - Current operated targets
3 - Directional instantaneous overcurrent output
C - Push-to-Energize output feature
4 - Switch selectable characteristic angle and power supply status output
F - Semi-flush case mounting, M1-size case

SPECIFICATIONS

BE1-67 Phase Directional Overcurrent Relays are available in either single-phase or three-phase configurations with the following features and capabilities.

Current Sensing Input(s)

The unit is designed to operate from the secondary of a standard current transformer rated at 5 amperes. The unit has a pickup adjustment range covering 0.5 to 12 amperes. The maximum continuous current rating of each input is 20 amperes.

The one-second current rating of each input is 50 times tap or 500 amperes, whichever is less. Ratings at less than one second are calculated as follows:

$$I = \frac{\text{50 x tap or 500 amperes (whichever is less)}}{\sqrt{T}}$$

where I = Maximum current
T = Time that current flows (in seconds)

Current Sensing Burden

Less than 0.01 ohm per input.

Time Overcurrent Pickup

Range

Pickup of the time overcurrent elements is continuously adjustable over the entire range of 0.5 to 12 amperes. (See Table 1-3.) This is accomplished through the selection of external connections (LOW RANGE 0.5 to 4.0 amperes; HIGH RANGE 1.5 to 12 amperes), a TAP selector switch, and TAP CAL adjustment.

A TAP RANGE plate is provided on the front panel to define the external connections and the range of adjustment available when the unit is installed in the protection panel.

Table 1-3. Sensing Input Ranges and Connections

TAP Range Plate or Pickup	TAP Selector										Current Sensing Terminals		
	A	B	C	D	E	F	G	H	I	J	ØA	ØB	ØC
Single-Phase													
High	2.25	3.00	4.50	5.25	6.75	7.50	9.00	9.75	11.25	12.00	8, 7	N/A	N/A
Low	0.75	1.00	1.50	1.75	2.25	2.50	3.00	3.25	3.75	4.00	9, 7	N/A	N/A
Three-Phase													
High	2.25	3.00	4.50	5.25	6.75	7.50	9.00	9.75	11.25	12.00	8, 7	14, 15	17, 18
Low	0.75	1.00	1.50	1.75	2.25	2.50	3.00	3.25	3.75	4.00	9, 7	13, 15	16, 18

Pickup Accuracy

The accuracy of the pickup setting established by the TAP selector switch when the TAP CAL adjustment is fully clockwise is ±5%. The TAP CAL adjustment allows the relay to be set anywhere between the value established by the TAP selector switch position and the next lower setting position.

The setting of the relay is repeatable within ±2%.

Dropout Ratio

Better than 95% of the established pickup level.

Time Delay Accuracy

The time delay of the time overcurrent element is within ±5 percent or 50 milliseconds (whichever is greater) of the characteristic curves for any combination of TIME DIAL, TAP, and TAP CAL settings at 25° C.

Instantaneous Overcurrent

Pickup Range

Continuously adjustable over the range of one to 40 times the pickup setting established for the time overcurrent element.

Response Time

See Figure 1-10.

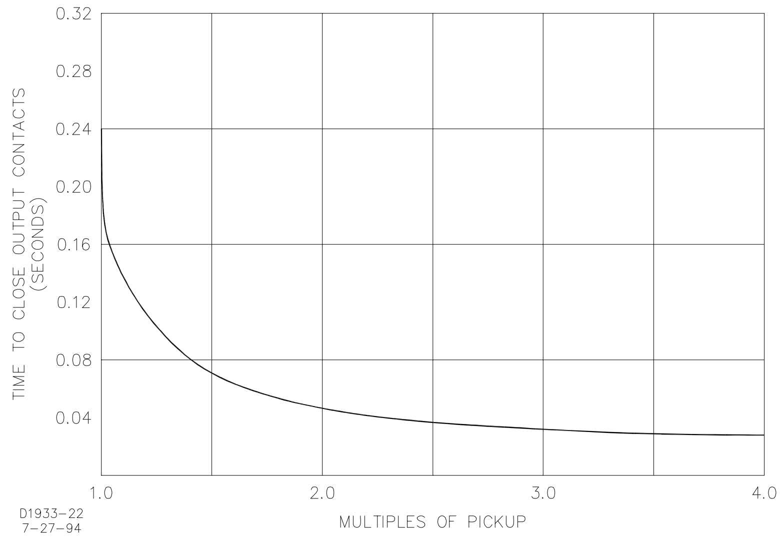

Figure 1-10. Typical Instantaneous Response Time

Pickup Accuracy

The setting of the relay is repeatable within ±2 percent.

Dropout Ratio

The dropout ratio is better than 92 percent of the established pickup level.

Voltage Sensing Inputs

The continuous rating of these inputs is 240 Vac.

Voltage Sensing Burden

The voltage sensing burden is greater than 25 kilo-ohm at 120 Vac per input.

Directional Unit

The polarizing for the directional unit is derived by the phase relationship between the measured phase current (A) and the sensed quadrature voltage (b-c). The directional element defines a region as shown in Figure 1-11 for which tripping will be allowed. The characteristic angle of the relay is defined as the angle between I_Z and its ordinate, I. Note that I_Z is normal to the characteristic boundary. Resolution of direction requires less than 1 cycle.

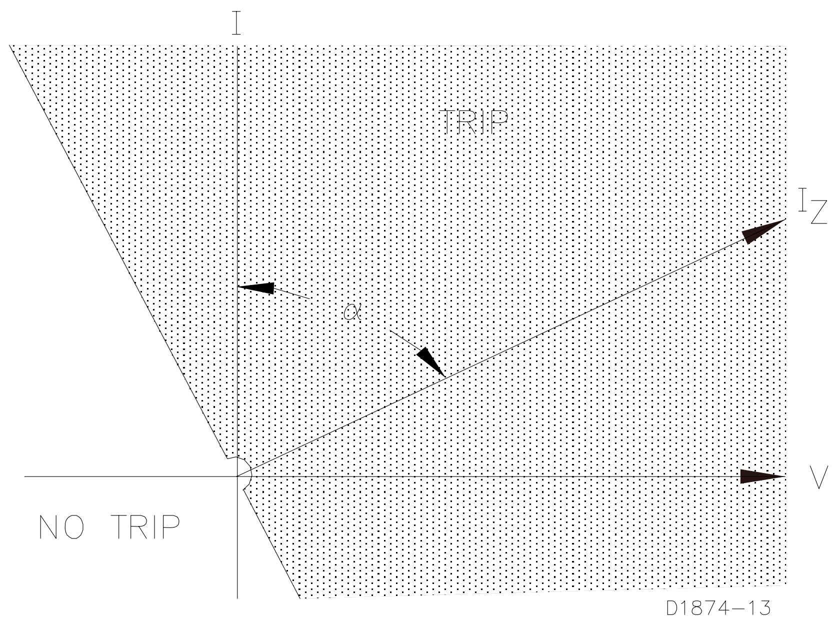

Figure 1-11. Characteristic Angle

Sensitivity

Proper directional decisions are assured when the current applied to the relay exceeds 25% of TAP value and the voltage exceeds 1.0 Vac at the setting of the characteristic angle. When polarizing voltage is less than the 1.0 Vac threshold, relay operation will be inhibited.

Characteristic Angle

Adjustment

The BE1-67 is available with two types of adjustment for the characteristic angle.

(a) Continuously adjustable over the range of 0 to 90°

(b) Switch selectable settings of 30°, 45°, 60° and 75°

Repeatability

Repeatability is ±5° from the setting at nominal system frequency.

Limited Range of Operation (Optional)

The front panel control is continuously adjustable over the range of +5° to +90°. The total individual angle of the Limited Range of Operation will accordingly vary from 10° to 180°.

Frequency Range

The unit is designed to operate on power systems with a nominal frequency of either 50 or 60 hertz. The unit has been type-tested for proper operation over the frequency range of 45 to 55 hertz for 50 hertz systems and 55 to 65 hertz for 60 hertz systems.

Power Supply

Power for the internal circuitry may be derived from a variety of ac or dc external power sources as indicated in Table 1-4.

Table 1-4. Power Supply Specifications

Type	Input Voltage		Burden at Nominal
	Nominal	Range	
J (mid range)	125 Vdc 120 Vac	24 to 150 Vdc 90 to 132 Vac	2.1 W 10.8 VA
K (mid range)	48 Vdc	24 to 150 Vdc	1.9 W
L (low range)	24 Vdc	12 to 32 Vdc ∗	2.1 W
Y (mid range)	48 Vdc 125 Vdc	24 to 150 Vdc 24 to 150 Vdc	1.9 W 2.2 W
Z (high range)	250 Vdc 240 Vac	68 to 280 Vdc 90 to 270 Vac	2.3 W 17.6 VA

∗ Type L power supply may require 14 Vdc to begin operation. Once operating, the voltage may be reduced to 12 Vdc.

Target Indicators

Function targets may be specified as either internally operated or current operated by a minimum of 0.2 amperes through the output trip circuit. When current operated, the output circuit must be limited to 30 amperes for 0.2 seconds, 7 amperes for 2 minutes, and 3 amperes continuously.

Single-Phase Units

When specified by the style number, either an internally operated or a current operated target will be supplied for each of the tripping outputs included within the relay (i.e., the time and instantaneous overcurrent functions).

Three-Phase Units

When targets are specified by the style number, internally operated targets are included to indicate the phase elements (A, B, C) involved in the tripping of the relay. Additionally, either internally operated or current operated targets (as selected) indicate the function (time or instantaneous) that caused tripping.

Output Circuits

Resistive Ratings

120 Vac:	Make, break, and carry 7 Aac continuously
250 Vdc:	Make and carry 30 Adc for 0.2 s, carry 7 Adc continuously, and break 0.3 Adc
500 Vdc:	Make and carry 15 Adc for 0.2 s, carry 7 Adc continuously, and break 0.3 Adc

Inductive Ratings

120 Vac, 125 Vdc, 250 Vdc: Break 0.3 A (L/R = 0.04)

Isolation

In accordance with IEC 255-5 and ANSI/IEEE C37.90, one minute dielectric (high potential) tests as follows:

All circuits to ground:	2,121 Vdc
Input to output circuits:	1,500 Vac or 2,121 Vdc

UL Recognized

UL recognized per Standard 508, UL File No. E97033. Note: Output contacts are not UL recognized for voltages greater than 250 volts.

GOST-R

Gost-R certified No. POCC US.Me05.B03391; complies with the relevant standards of Gosstandart of Russia. Issued by accredited certification body POCC RU.0001.11ME05.

Surge Withstand Capability

Qualified to ANSI/IEEE C37.90.1-1989, *Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems.*

Operating Temperature

The operating temperature range is from -40°C (-40°F) to +70°C (+158°F).

Storage Temperature

The storage temperature range is from -65°C (-85°F) to +100°C (+212°F).

Shock

In standard tests, the relay has withstood 15 g in each of three mutually perpendicular planes without structural damage or degradation of performance.

Vibration

In standard tests, the relay has withstood 2 g in each of three mutually perpendicular planes, swept over the range of 10 to 500 Hz for a total of six sweeps, 15 minutes each sweep without structural damage or degradation of performance.

SECTION 2 • CONTROLS AND INDICATORS

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SECTION 2 • CONTROLS AND INDICATORS

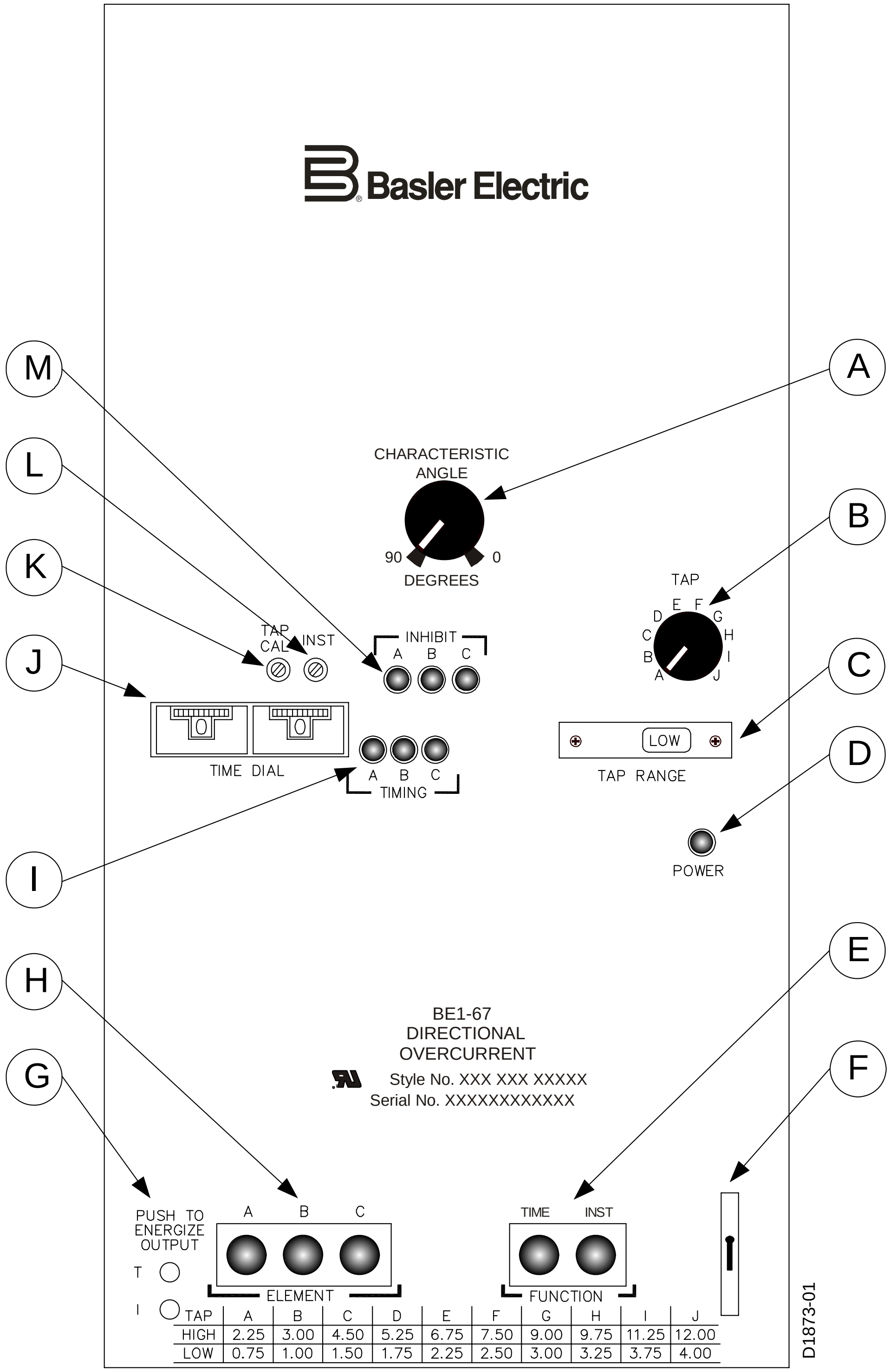
Table 2-1. Controls and Indicators (Refer to Figures 2-1, 2-2, and 2-3.)

Locator	Control or Indicator	Function
A	**CHARACTERISTIC ANGLE**	This potentiometer (options 3-1, 3-3, 3-5, or 3-6) or 4-position switch (options 3-2 and 3-4) defines the characteristic angle for the directional element of the relay. This potentiometer can adjust the characteristic angle alpha over the range of 0° to 90° while the 4- position switch can set the characteristic angle to 30°, 45°, 60°, or 75°. When the potentiometer is knob controlled (as in Figure 2-1), the max CW position represents the minimum characteristic angle (or 0°). When the potentiometer is a screwdriver-operated multi-turn potentiometer (as in Figure 2-2), the max CW position represents the maximum characteristic angle (or 90°).
B	**TAP** Selector	This 10-position rotary switch provides the primary means of setting the pickup for the overcurrent functions of the relay. When the **TAP CAL** control *(Locator K)* is in the full clockwise position, the pickup of the relay is based on the setting of the **TAP** selector switch. The setting for the time overcurrent function is the value defined by the switch position (**A** to **J**) and the external connections (HIGH/LOW tap range). This control, together with the **TAP CAL** control, establishes the pickup level of all phases monitored by the relay. Note that it is safe to switch the **TAP** selector without disconnecting the sensing current.
C	**TAP RANGE** Plate	This plate is adjusted to indicate HIGH or LOW, the setting range corresponding to the connections on the back of the relay.
D	**POWER** Indicator	A red LED is lit when the relay power supply is functioning. This provides a front panel indication of the relay status. An optional POWER SUPPLY STATUS ALARM contact (Options 3-3 and 3-4) is available to provide a remote indication of this condition.
E	**FUNCTION** Targets	These electronically latched red indicators illuminate when the corresponding TIME overcurrent or INST (instantaneous) overcurrent function causes the trip output relays to be energized or current to flow through the output contacts.
F	**TARGET RESET** Switch	This switch engages the reset mechanism behind the relay cover. When raised up, this switch resets the electronically latched target(s).
G	**PUSH TO ENERGIZE OUTPUT** Pushbutton(s)	These momentary contact pushbutton switches are accessible by inserting a 1/8" diameter non-conducting rod through the front panel. Switch **T**, when activated, closes the time output contacts. Switch **I**, when activated, closes the instantaneous output contacts.
H	**ELEMENT** Targets	Electronically latched red indicators illuminate when tripping occurs to show the phase(s) that caused the trip. Not present on single-phase relays.
I	**TIMING** Indicator(s)	Red LED's that light when the pickup setting of a TIME overcurrent element of the relay is exceeded. One LED is included for each phase monitored by the relay. LED's may be used to determine the actual pickup setting of the relay during testing.

Locator	Control or Indicator	Function
J	**TIME DIAL**	Dual thumbwheel switches determine the time delay for a particular time-current characteristic curve and specific level of overcurrent.
K	**TAP CAL** Control	A multi-turn potentiometer provides a fine adjustment for the pickup level of the TIME overcurrent function. When this control is in the full clockwise position, the setting of the TIME overcurrent element(s) is within ±5% of the selected tap setting. As the control is rotated counterclockwise, the pickup value of the element is reduced. The range of this control will allow adjustment of the TIME pickup between the **TAP** setting selected and the next lower value.
L	**INST** Control	A multi-turn potentiometer provides adjustment of the INST (instantaneous) tripping function. This setting is adjustable over the range of one to 40 times the setting of the time overcurrent elements. This setting determines the tripping level for all INST overcurrent elements in the relay.
M	**INHIBIT** Indicator(s)	Amber LED(s) light when the directional element has not enabled the time overcurrent element or the directional instantaneous overcurrent element (if present). One LED is included for each phase monitored by the relay.
N	**LIMITED REGION of OPERATION** Control	A multi-turn potentiometer (option 3-5 or 3-6) that adjusts the Limited Region of Operation from ±90° to ±5°.
O	**Time Overcurrent Characteristic Curve Selector**	This circuit board mounted switch selects the characteristic curve to be used. The switch is located behind the panel in the location shown. The switch in Figure 2-2 is set to **7** as an example. Table 2-2 defines the characteristic curve for each switch position. (The switch only comes with the Z2 option.)
P	**N/T** (**N**ormal/**T**est) Switch	This slide switch (shown in Figure 2-3) is mounted on the side of the digital board. This permits a technician to access a series of stored diagnostic routines to validate the calibration of the relay and to test and troubleshoot the device on the bench. **CAUTION** This switch must be in the normal (**N**) position for proper operation of the relay.

Table 2-2. Timing Curve Selection

Timing Type	Selector Position	Reference Figure Number
B1 Short Inverse	3	A-1
B2 Long Inverse	1	A-2
B3 Definite Time	5	A-3
B4 Moderately Inverse	2	A-4
B5 Inverse	4	A-5
B6 Very Inverse	6	A-6
B7 Extremely Inverse	7	A-7
E2 BS142 Long Inverse	8	A-8
E4 BS142 Inverse (1.3 sec)	9	A-9
E BS142 Inverse (2.9 sec)	A	A-10
E6 BS142 Very Inverse	B	A-11
E7 BS142 Extremely Inverse	C, D, E, F	A-12



TAP	A	B	C	D	E	F	G	H	I	J
HIGH	2.25	3.00	4.50	5.25	6.75	7.50	9.00	9.75	11.25	12.00
LOW	0.75	1.00	1.50	1.75	2.25	2.50	3.00	3.25	3.75	4.00

Figure 2-1. BE1-67, Three-Phase Relay with Characteristic Angle Control Knob

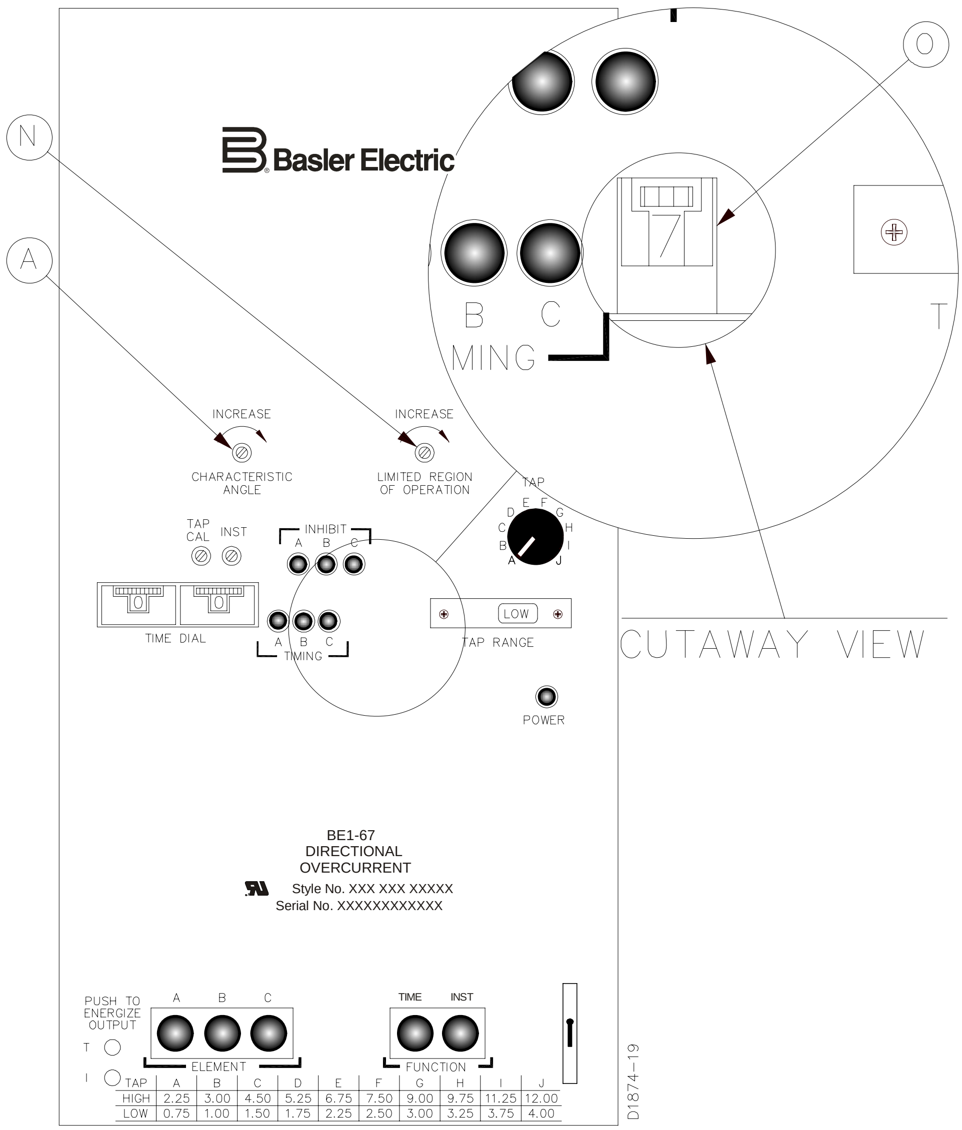


Figure 2-2. BE1-67, Three-Phase Relay with Characteristic Angle and Limited Region of Operation

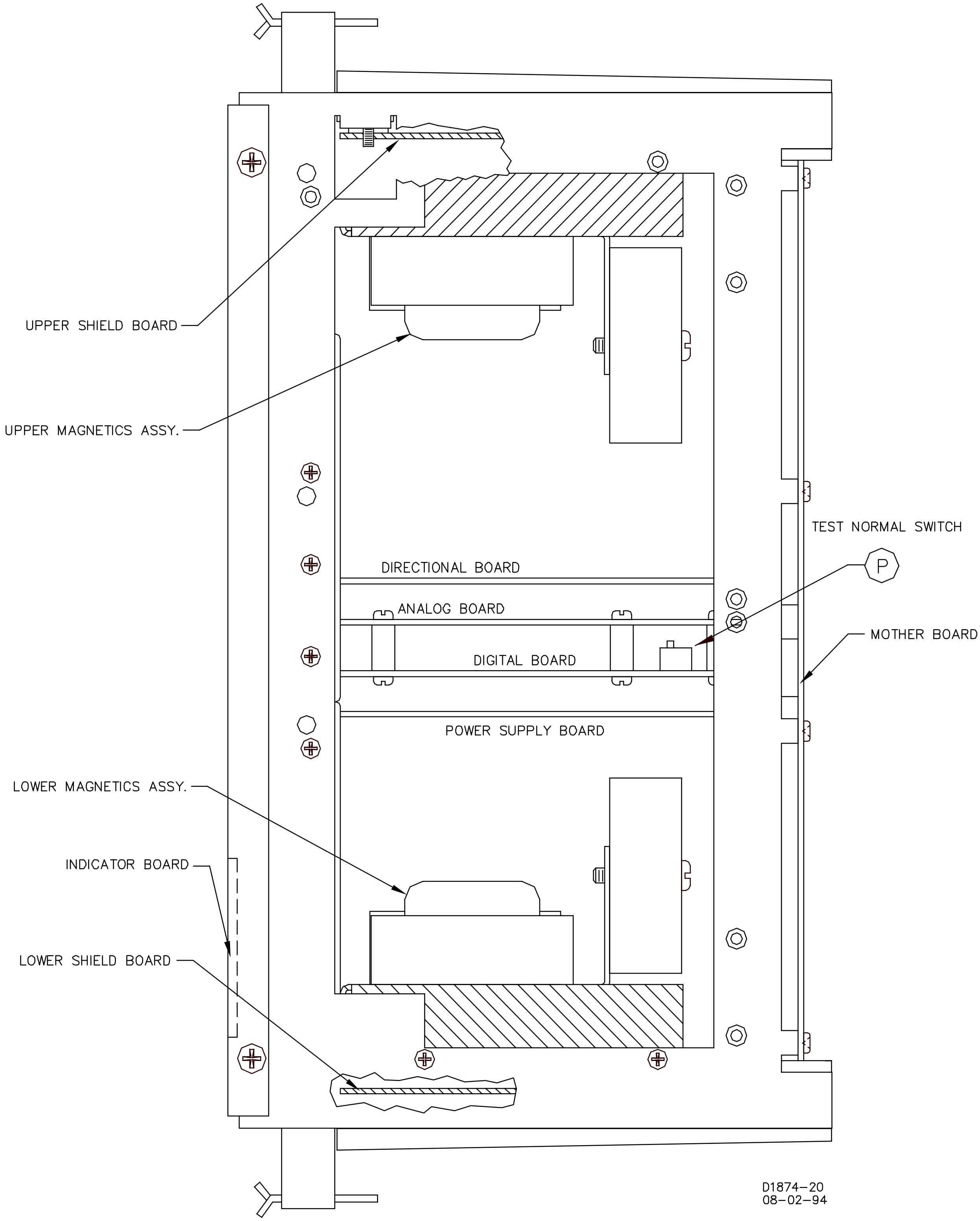


Figure 2-3. Location of Assemblies, Controls, and Indicators

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SECTION 3 • FUNCTIONAL DESCRIPTION

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SECTION 3 • FUNCTIONAL DESCRIPTION

GENERAL

BE1-67 Phase Directional Overcurrent Relays are microprocessor based time overcurrent relays with directional supervision. This allows the relay to be more effectively coordinated for the protection of transmission and distribution circuits. Figure 3-1 is a BE1-67 relay functional block diagram and illustrates the overall operation of the relay.

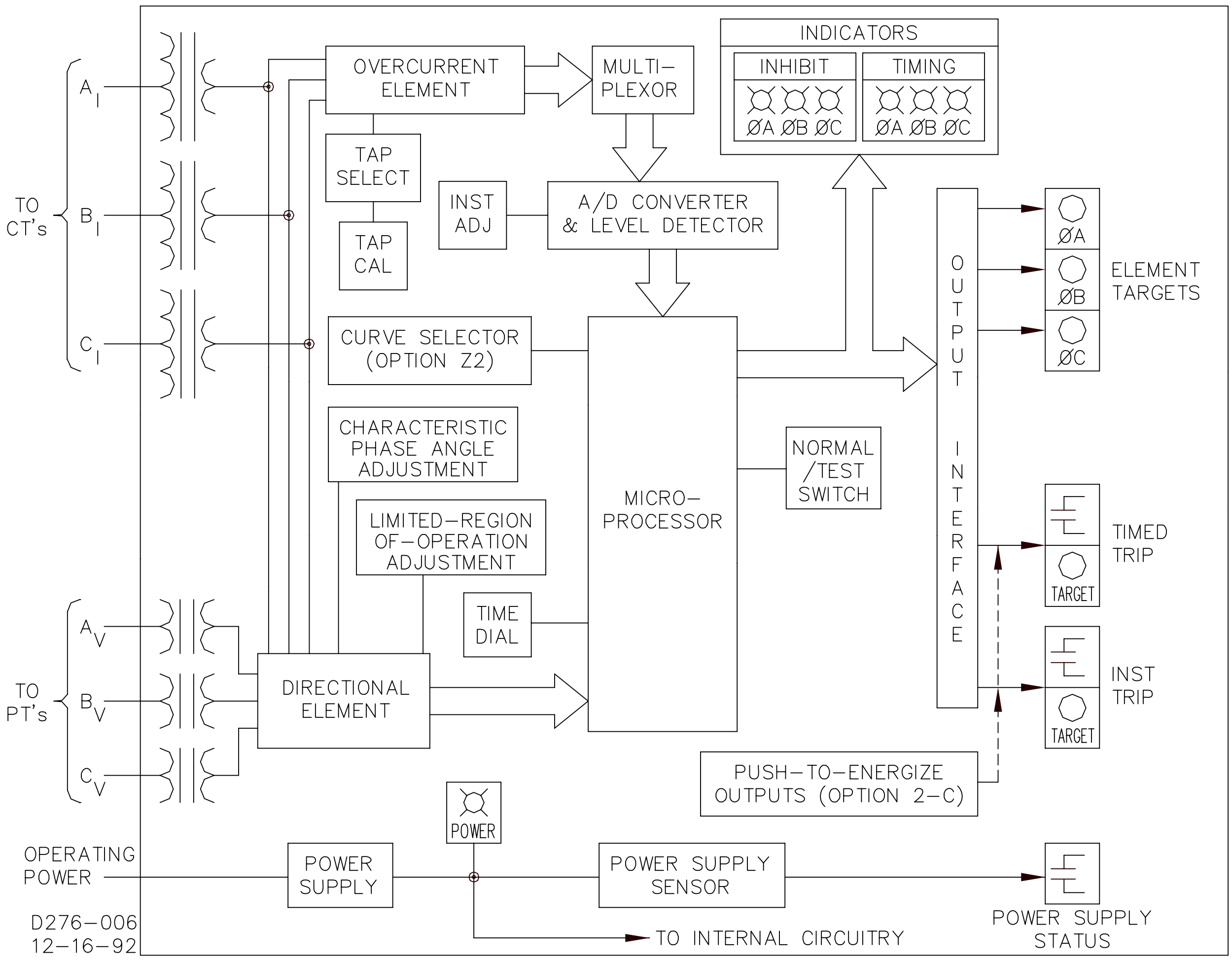

Figure 3-1. Functional Block Diagram

INPUT CIRCUITS

BE1-67 relays may be configured to sense either a single-phase current and a phase-to-phase voltage, or three -phase currents and three phase-to-phase voltages. (A three-phase unit is illustrated.)

Current Sensing

Internal current sensing transformers are designed to receive their input from the five ampere nominal secondary of a standard current transformer in the power system. These input transformers are tapped so that the range of the relay is determined by the external connections. These connections are defined in Table 3-1.

Table 3-1. Current Sensing Input Connections

Sensing Type	Phase	Terminal Numbers	
		High Range (1.5 to 12 A)	Low Range (0.5 to 4 A)
Single-Phase (Type A)	N/A	8 to 7	9 to 7
Three-Phase (Type B)	A	8 to 7	9 to 7
	B	14 to 15	13 to 15
	C	17 to 18	16 to 18

The output from the sensing input transformers are applied to a scaling circuit that converts each of the input currents to a dc voltage level that can be used within the relay. This scaling is determined by the **TAP** select switch and the **TAP CAL** control on the front of the relay. These controls adjust the scaling for all of the current inputs at one time. In the three-phase relay, this eliminates the requirement for three separate calibrations, one for each phase.

The **TAP** select switch is a ten-position rotary switch that selects one of the current ranges shown in Table 3-2. The **TAP CAL** control changes these ranges when the control is moved from the maximum clockwise position. HIGH and LOW range is determined by the connections made to the relay inputs. When the **TAP CAL** control is fully clockwise, the pickup setting of the relay will be within ±5% of the **TAP** select setting.

Table 3-2. Sensing Input Range and Setting

Range	TAP SELECT Position									
	A	B	C	D	E	F	G	H	I	J
HIGH	2.25	3.00	4.50	5.25	6.75	7.50	9.00	9.75	11.25	12.00
LOW	0.75	1.00	1.50	1.75	2.25	2.50	3.00	3.25	3.75	4.00

The **TAP CAL** control provides a means of continuous adjustment between a selected setting of the **TAP** select and the next lower setting. When the **TAP** select is set on position **A**, the **TAP CAL** control will provide an adjustment to at least 0.5 A on the LOW range connection and 1.5 A for the HIGH range connection.

Voltage Sensing

Voltage sensing inputs accept nominal 120 Vac phase-to-phase voltages and are configured to match the current sensing type defined by the style number (single-phase or three-phase).

DIRECTIONAL ELEMENT

The directional element determines the direction of the current flow by monitoring the angular phase relationship between phase current and the corresponding quadrature phase-to-phase voltage (phase A current and B-C voltage). The **CHARACTERISTIC ANGLE** adjustment and (optional) **LIMITED REGION OF OPERATION** adjustment are front-panel potentiometer controls that are described in the following paragraphs.

Characteristic Angle

The **CHARACTERISTIC ANGLE** adjustment controls the characteristic angle (alpha) shown in Figure 3-2. This rotates the characteristic angle of the directional unit so that the maximum sensitivity can match the impedance angle of the protected line. The tripping characteristic of the relay is then defined by a line, that is, perpendicular to I_Z. Note that the slight bow in this boundary about the origin is caused by the minimum sensitivity of the directional element: 0.02 ampere and 1.0 volt.

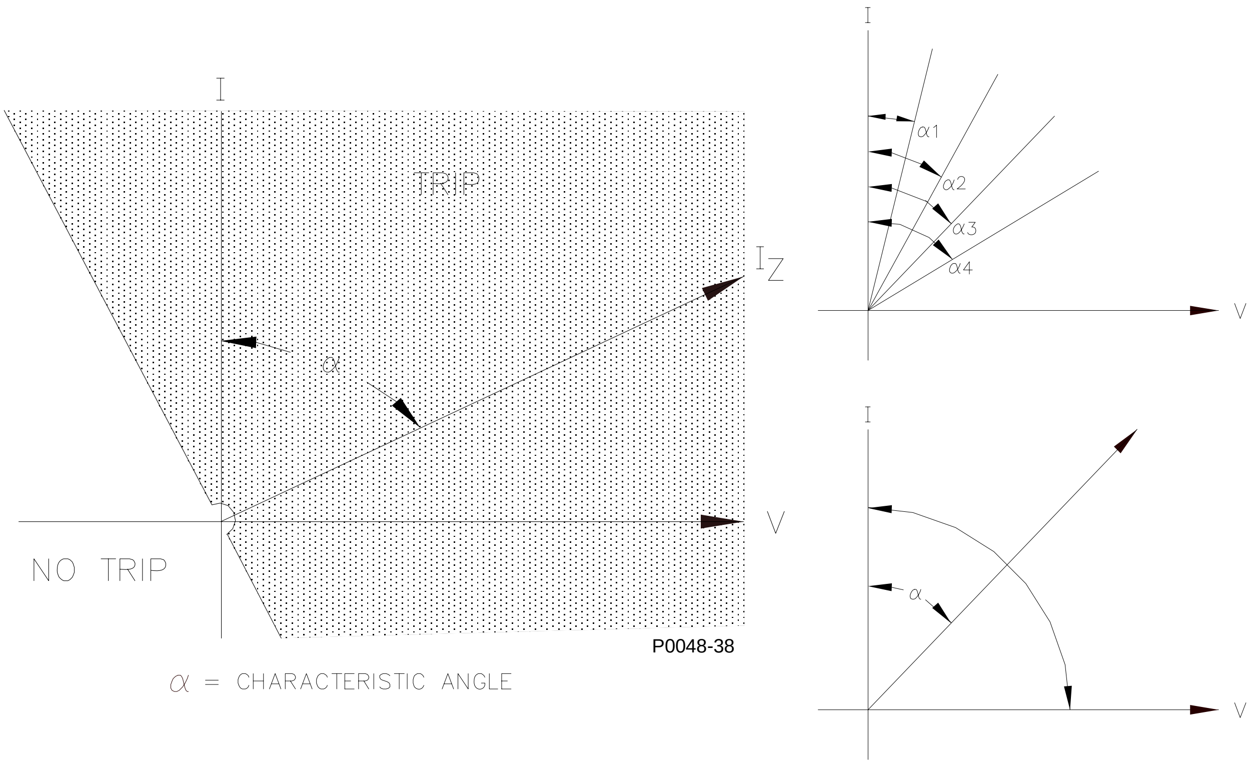

Figure 3-2. Characteristic Angle

Two types of **CHARACTERISTIC ANGLE** controls are available and are specified by the style number. (Refer to the option 3 column in Figure 1-9, *Style Number Identification Chart*.)

1. A potentiometer provides continuous adjustment of the characteristic angle over the range of 0° to +90°. Options 3-1 and 3-3 have a control knob operated potentiometer. Options 3-5 and 3-6 have a screwdriver operated, multi-turn potentiometer.
2. A four position selector switch provides discrete settings of +300°, +45°, +60°, and +75° (Options 3-2 and 3-4.)

When the phase relationship between the current(s) and voltage(s) do not meet the criteria of the directional element, an inhibit signal is output. This signal illuminates the appropriate **PHASE INHIBIT** LED on the relay front panel and prevents the operation of the time overcurrent function in the relay. This signal also inhibits the operation of the optional directional instantaneous overcurrent element. The inhibit signals within the relay are provided for each sensed phase.

Limited Region of Operation

The directional element of the standard relay defines a region for which tripping is allowed. (This is shown as the gray area in Figure 3-2.) This region (angle as shown in Figure 3-3) may be reduced by the **LIMITED REGION OF OPERATION** control (a multi-turn potentiometer accessed through the front panel). The control is continuously adjustable (with reference to I_A in Figure 3-3) from ±5 degrees to ±90 degrees.

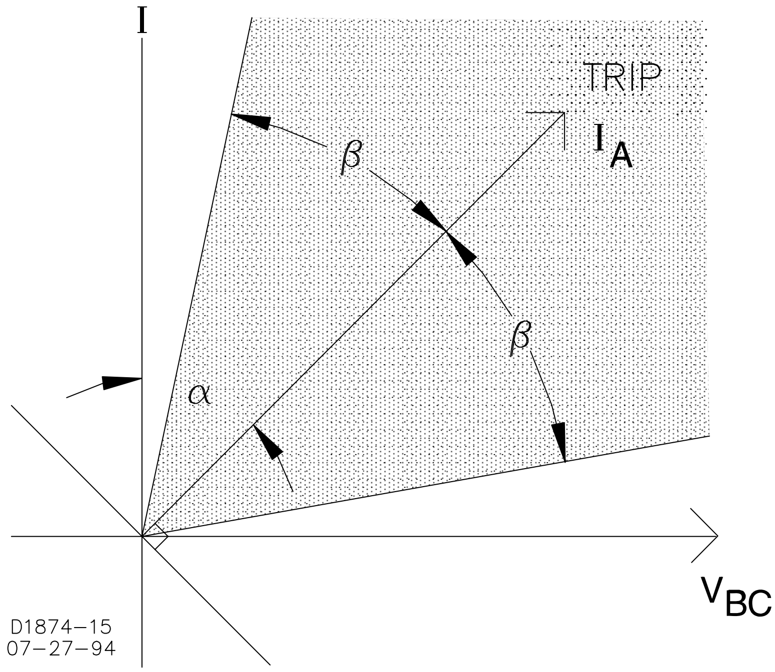

Figure 3-3. Limited Region of Operation

POWER SUPPLY

Operating power for the relay circuitry is supplied by a wide range, electrically isolated, low-burden power supply. Power supply operating power is not polarity sensitive. The front panel power LED and power supply status output indicate when the power supply is operating. Power supply specifications are listed in Table 1-4.

LOGIC CIRCUITS

The logic circuits identified in the block diagram of Figure 3-1 and briefly described in the following paragraphs are intended to show functionally how the BE1-67 relay operates.

Microprocessor

The microprocessor fulfills many of the logic and signal processing functions described in the following paragraphs and performs all of the time overcurrent computations.

Multiplexor

The multiplexor sequentially switches each of the sensed current inputs to the analog-to-digital converter and level detector circuits. (For single-phase relays, the multiplexor is bypassed.)

Analog-to-Digital Converter and Level Detector

When the dc voltage representing the actual sensed current meets or exceeds the selected pickup point, the analog-to-digital converter supplies a binary value to the trip comparator and scaler circuit and to a counter within the microprocessor for calculation of the required time delay.

When the value of a sensed phase current exceeds the pickup setting of the relay and the directional unit does not inhibit the operation of the time trip comparator, the **TIMING** LED will be illuminated for that phase. This LED will remain illuminated as long as the sensed phase current exceeds the pickup level set on the relay (representing the time overcurrent function) and the instantaneous overcurrent circuits are applied to their respective output driver.

OUTPUTS

Output Drivers

Each output driver supplies the current to energize the associated output relay. Either normally open (Output E) or normally closed (Output F) contacts may be specified for the relay. All output contacts will be of the same configuration within a given relay. These output contacts may have targets associated with them if so specified by the style number.

Push-to-Energize Output Contacts

If option 2-C has been selected, a small pushbutton switch is included for the time overcurrent functions and if present for the instantaneous function. Each switch when depressed will energize the corresponding output relay for testing purposes. To prevent accidental operation of these switches, they have been recessed behind the front panel of the relay and are accessed by inserting a thin non-conducting rod through access holes in the panel.

Appropriate power must be applied to terminals 3 and 4 (the relay power supply) for these pushbuttons to operate the output relays. However, it is not necessary to apply currents and voltages to the sensing inputs of the relay for these switches to function.

Power Supply Status Output

The power supply status output relay (option 3-3 and 3-4) has normally closed output contacts. This relay is energized by the presence of nominal voltage at the output of the power supply. Normal operating voltage then keeps the relay continuously energized and the contacts open. However, if the power supply voltage falls below requirements, the power supply status output relay will de-energize and close the contacts.

A shorting bar is included in the relay case so that the status output terminals can provide a remote indication that the subject relay has been withdrawn from the case or taken out of service by removing the connection plug.

This output is not associated with any magnetically latched target. The **POWER** LED on the relay front panel provides a visual indication of normal operating status of the power supply.

INDICATORS

Depending on the options provided, up to five different indicators are visible on the front panel. They are:

- INHIBIT LED's
- TIMING LED's
- POWER LED
- FUNCTION targets
- ELEMENT targets

INHIBIT LED's

When the phase relationship between the current(s) and voltage(s) do not meet the criteria of the directional element, an inhibit signal is output. This signal lights the appropriate **PHASE INHIBIT** LED on the relay front panel and prevents the operation of the time overcurrent function in the relay. It also inhibits the directional instantaneous overcurrent element (optional) operation.

TIMING LED's

Red LED's that light when the pickup setting of a TIME overcurrent element of the relay is exceeded. One LED is included for each phase monitored by the relay. LED's may be used to determine the actual pickup setting of the relay during testing.

POWER LED's

A red LED lights when the relay power supply is functioning. This provides a front panel indication of the relay status.

FUNCTION Targets

These electronically latched red indicators illuminate when the corresponding **TIME** overcurrent or **INST** (instantaneous) overcurrent function causes the trip output relays to be energized or current to flow through the output contacts.

ELEMENT Targets

Electronically latched red indicators illuminate when tripping occurs to show the phase(s) that caused the trip. Not present on single-phase relays.

TARGET INDICATOR CIRCUITS

Target indicators are optional components selected when a relay is ordered. The electronically latched and reset targets consist of red LED indicators located on the relay front panel. A latched target is reset by operating the target reset switch on the front panel. If relay operating power is lost, any illuminated (latched) targets are extinguished. When relay operating power is restored, the previously latched targets are restored to their latched state.

A relay can be equipped with either internally operated targets or current operated targets.

Internally Operated Targets

Outputs from the overcurrent elements are directly applied to drive the appropriate target indicator. Each indicator is illuminated regardless of the current level in the trip circuit.

Current Operated Targets

A current operated target is triggered by closure of the corresponding output contact and the presence of at least 200 milliamperes of current flowing in the trip circuit.

When targets are specified on single-phase relays (sensing input type A) only **TIMED** and **INST FUNCTION** targets are provided. These targets may be either type A or type B.

Three-phase (Sensing Input type B) relays are supplied, when specified, with **FUNCTION** (**TIME** and **INST**) targets and **ELEMENT** targets (**A**, **B**, **C**). The **FUNCTION** targets are either type A or type B as specified by the style number. The **ELEMENT** targets are always type A (internally operated) targets.

NOTE

Prior to August 2007, BE1-67 target indicators consisted of magnetically latched, disc indicators. These mechanically latched target indicators have been replaced by the electronically latched LED targets in use today.

SECTION 4 • INSTALLATION

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SECTION 4 • INSTALLATION

INTRODUCTION

BE1-67 relays are shipped in sturdy cartons to prevent damage during transit. Upon receipt of a relay, check the model and style number against the requisition and packing list to see that they agree. Inspect the relay for shipping damage. If there is evidence of damage, file a claim with the carrier, and notify your sales representative or Basler Electric.

If the relay will not be installed immediately, store it in its original shipping carton in a moisture- and dust-free environment. Before placing the relay in service, it is recommended that the test procedures of Section 5, *Testing* be performed.

RELAY OPERATING GUIDELINES AND PRECAUTIONS

Before installing or operating the relay, not the following guidelines and precautions.

- For proper current operated target operation, a minimum current of 200 milliamperes must flow through the output trip circuit.
- If a wiring insulation test is required, remove the connection plugs and withdraw the relay from its case.

CAUTION

When the connection plugs are removed, the relay is disconnected from the operating circuit and will not provide system protection. Always be sure that external operating (monitored) conditions are stable before removing a relay for inspection, test, or service.

NOTE

Be sure that the relay is hard-wired to earth ground with no smaller than 12 AWG copper wire attached to the ground terminal on the rear of the case. When the relay is configured in a system with other devices, it is recommended to use a separate lead to the ground bus from each device.

MOUNTING

Because the relay is of solid state design, it does not have to be mounted vertically. Any convenient mounting angle may be chosen. Relay dimensions and panel drilling diagrams are provided in Figures 4-1 through 4-6.

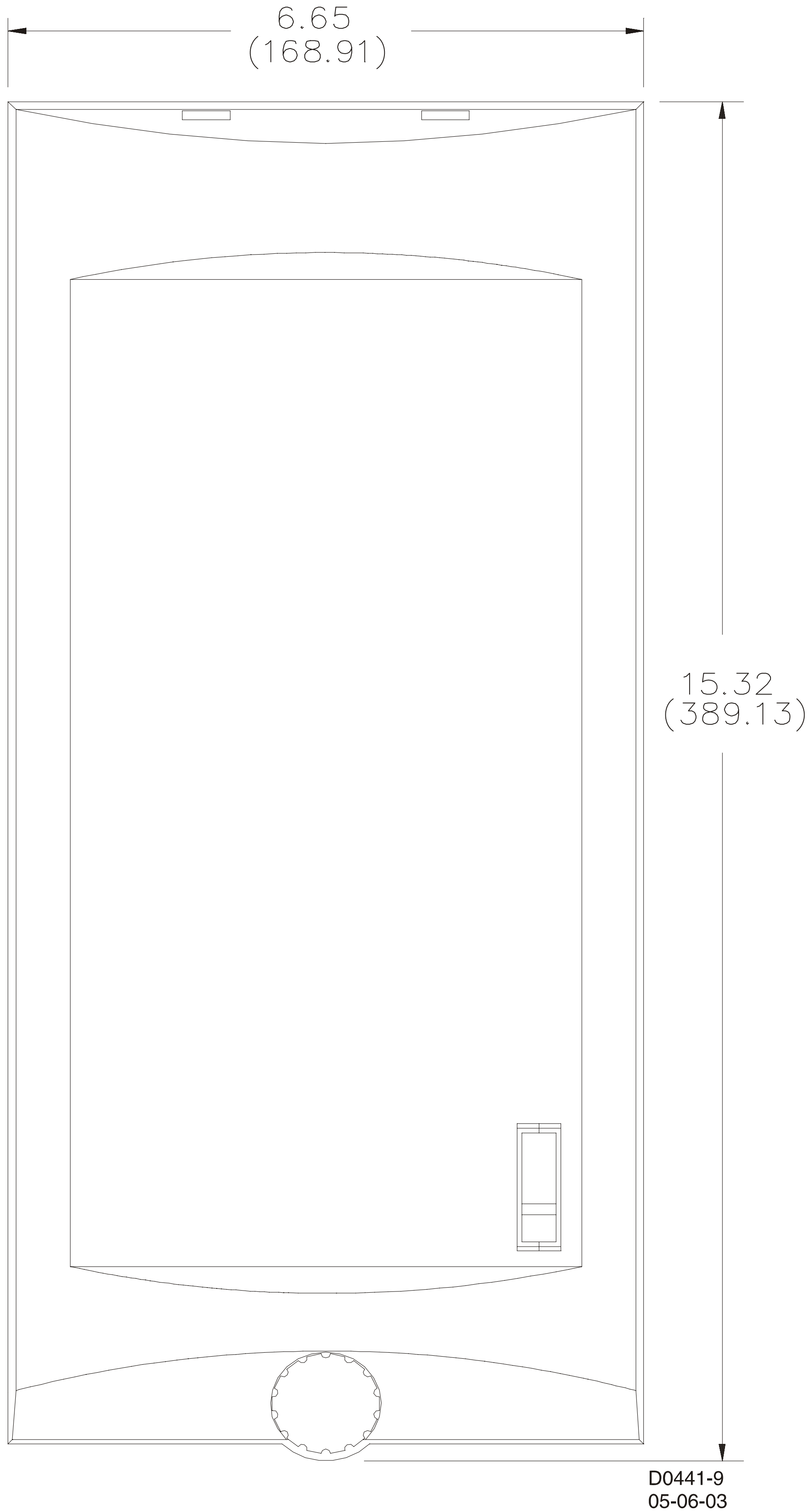

Figure 4-1. Outline Dimensions, Front View

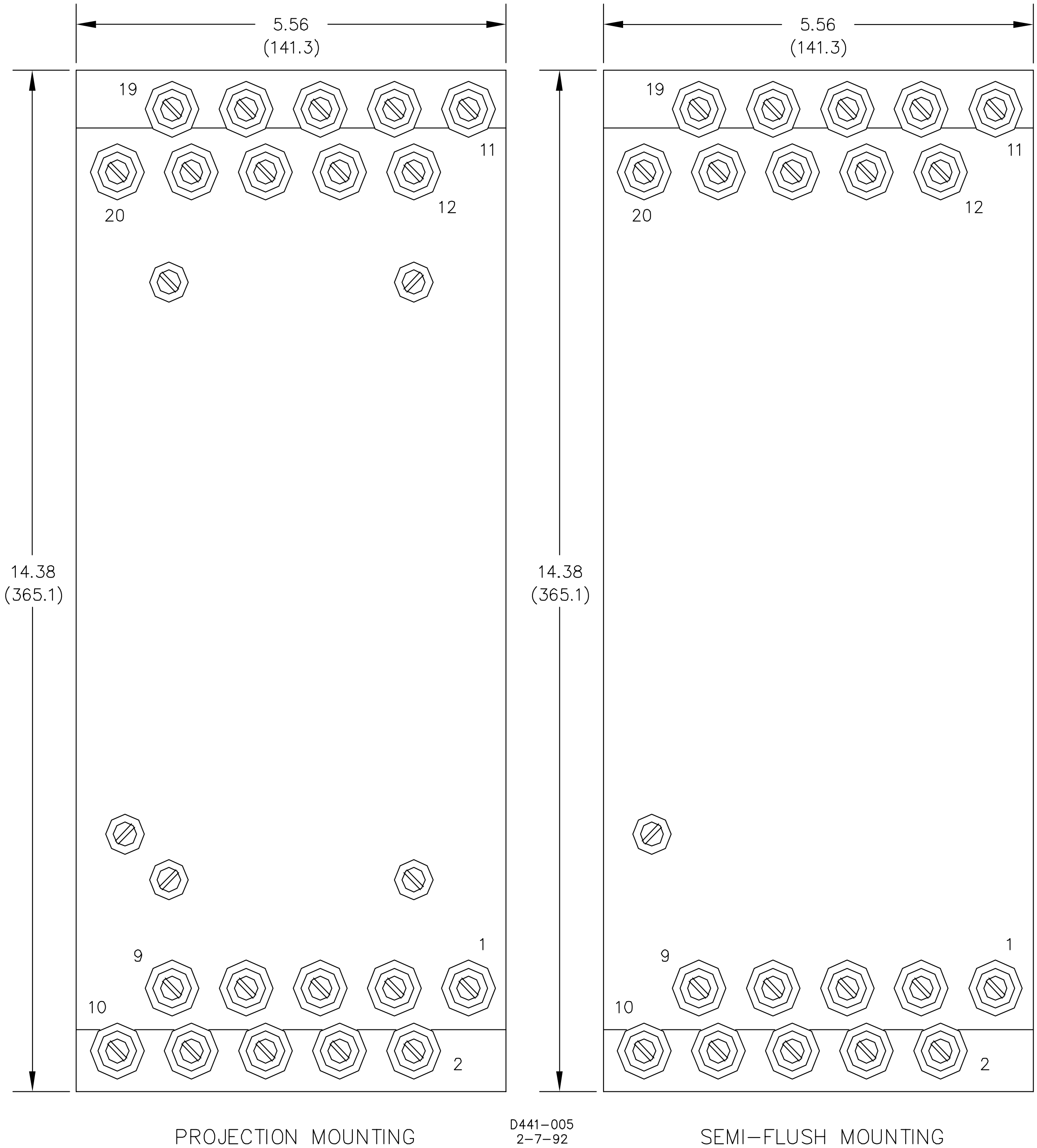

Figure 4-2. Outline Dimensions, Rear View

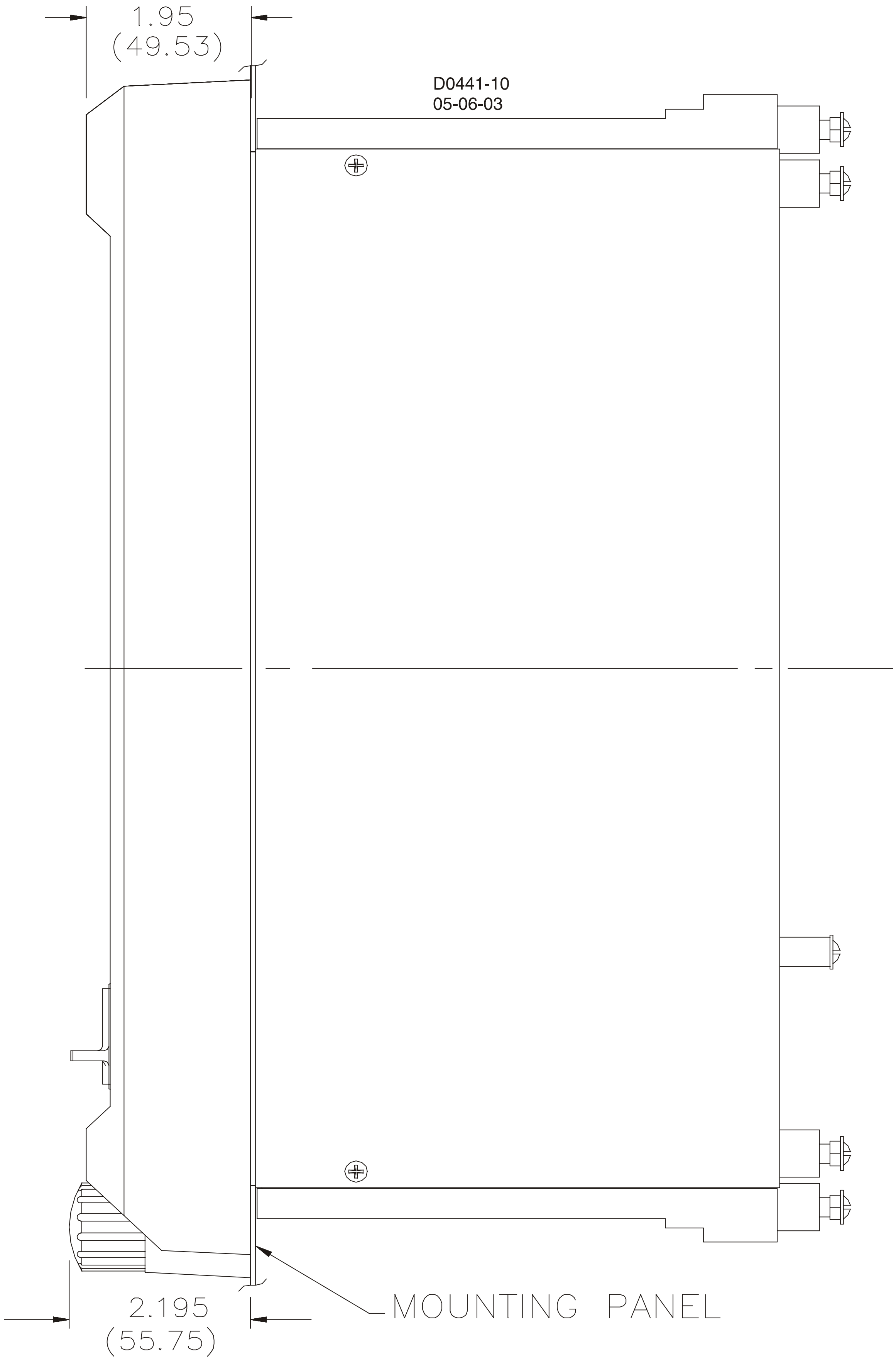

Figure 4-3. Outline Dimensions, Side View - Semi-Flush Mounting

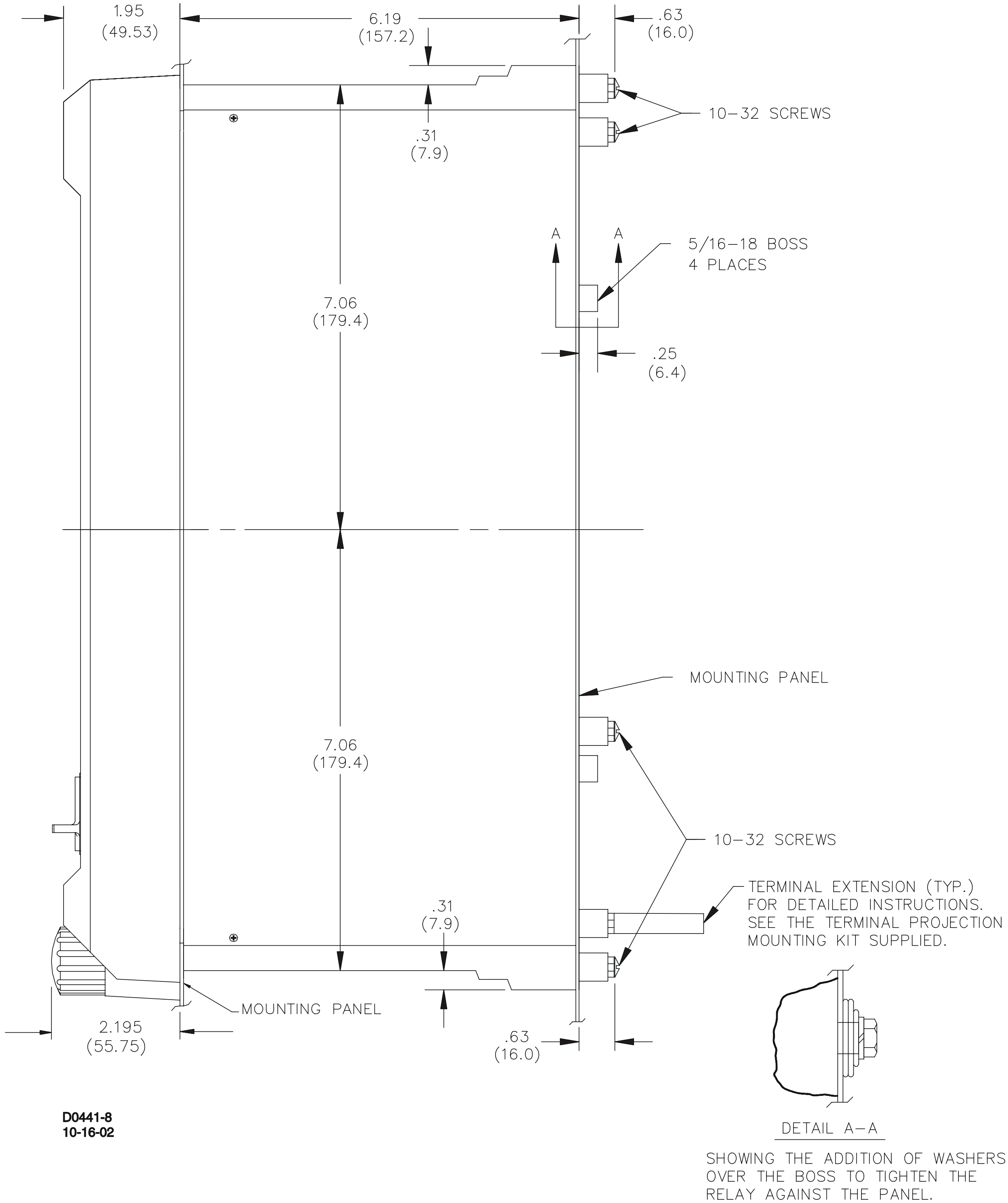

Figure 4-4. Outline Dimensions, Side View - Projection Mounting

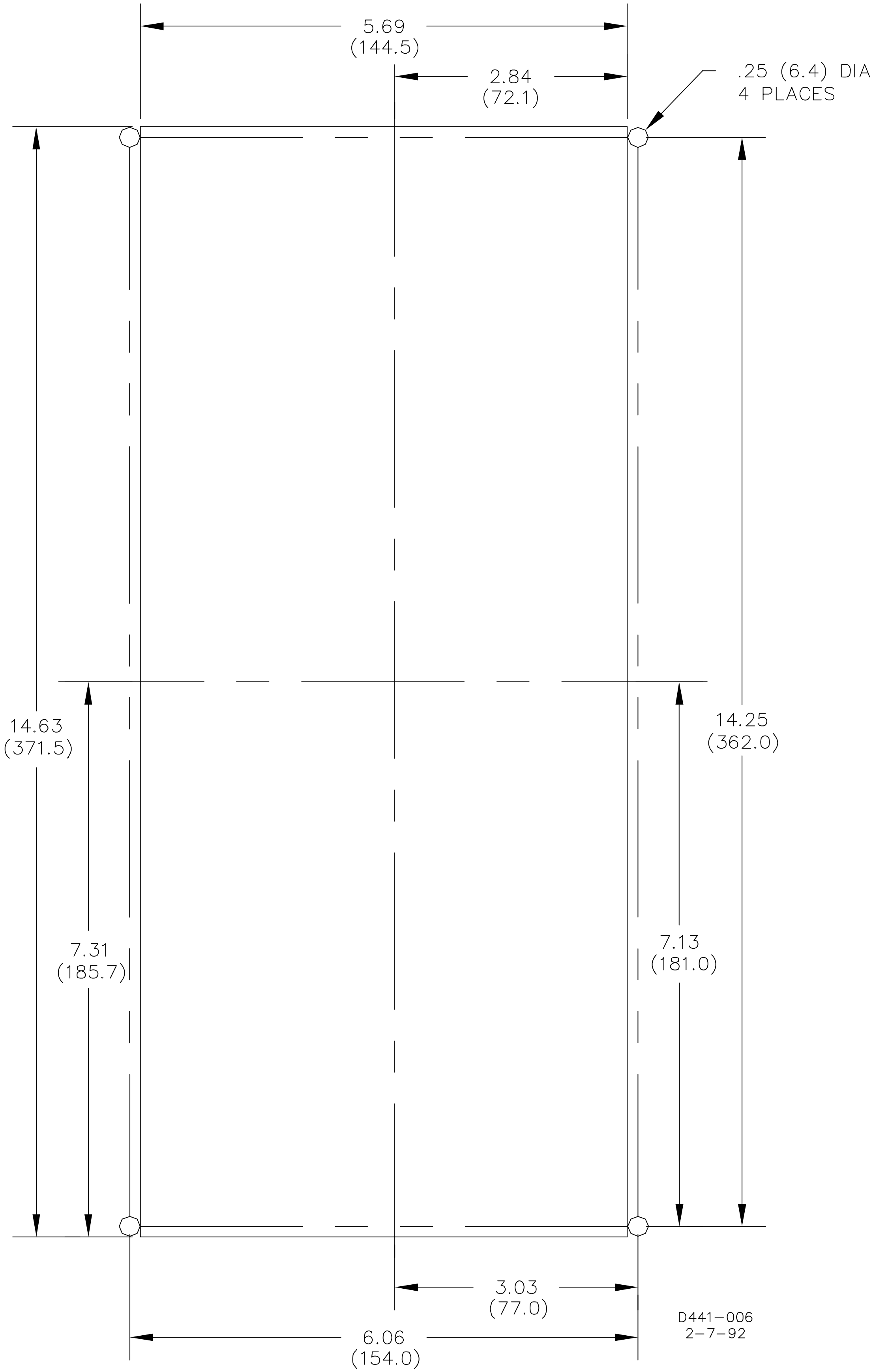

Figure 4-5. Panel Drilling Diagram - Semi-Flush Mounting

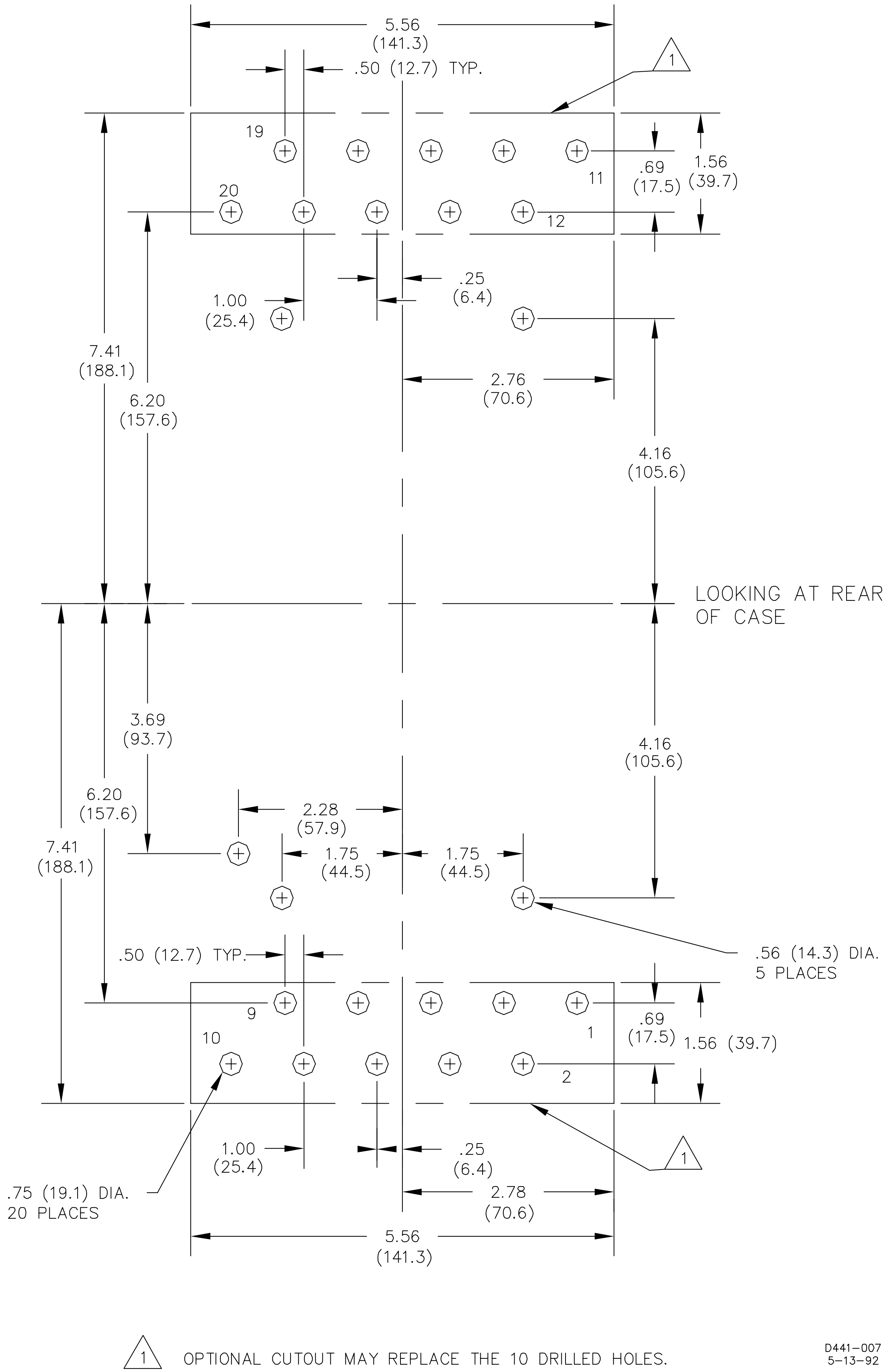

Figure 4-6. Panel Drilling Diagram - Projection Mounting

CONNECTIONS

Be sure to check the model and style number of a relay before connecting and energizing the relay. Incorrect wiring may result in damage to the relay. Except where noted, connections should be made with wire no smaller than 14 AWG.

The following illustrations provide information on relay connections.

- Control circuit connections are shown in Figure 4-7.
- Typical ac connections for single-phase relays are shown in Figure 4-8.
- Typical ac connections for three-phase relays are shown in Figure 4-9.
- Internal connections are shown in Figures 4-10 and 4-11.

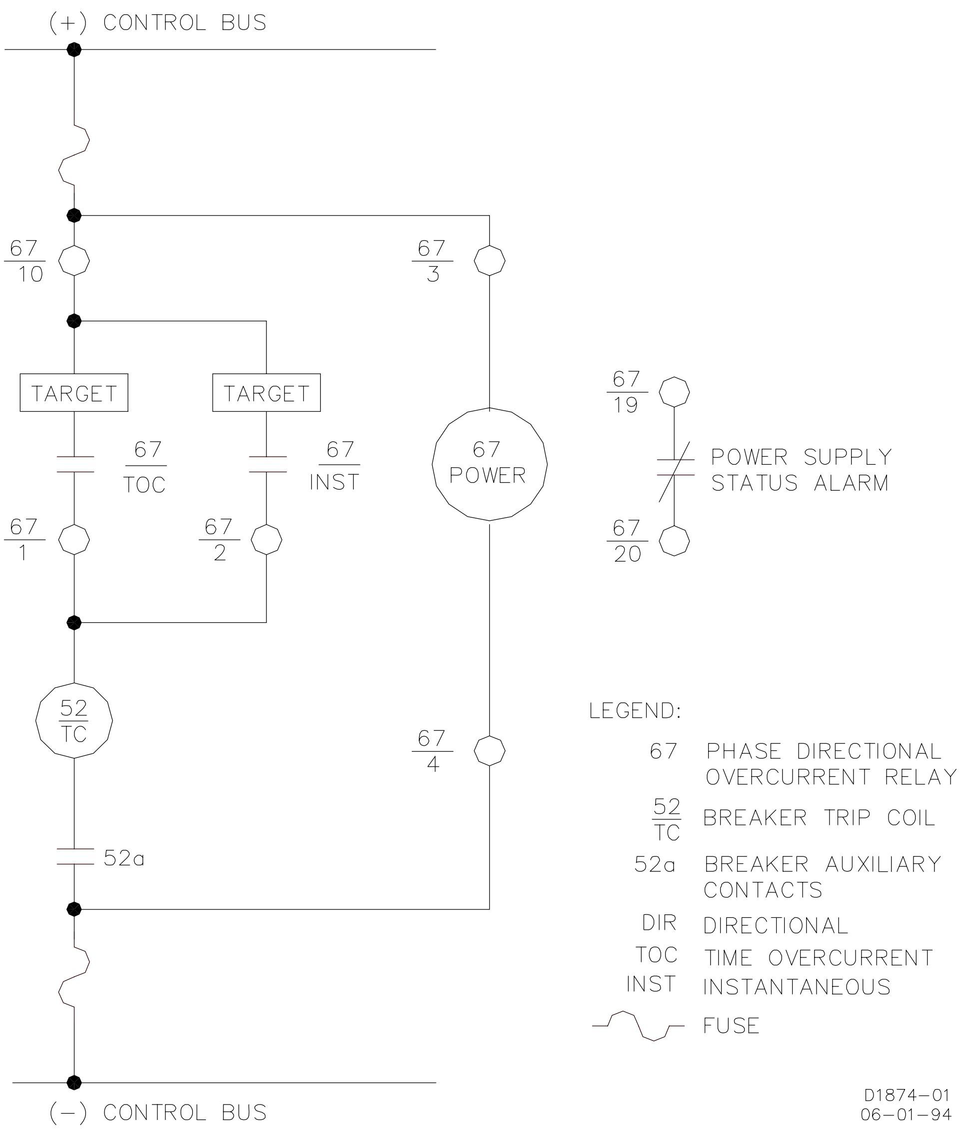

Figure 4-7. DC Control Connections

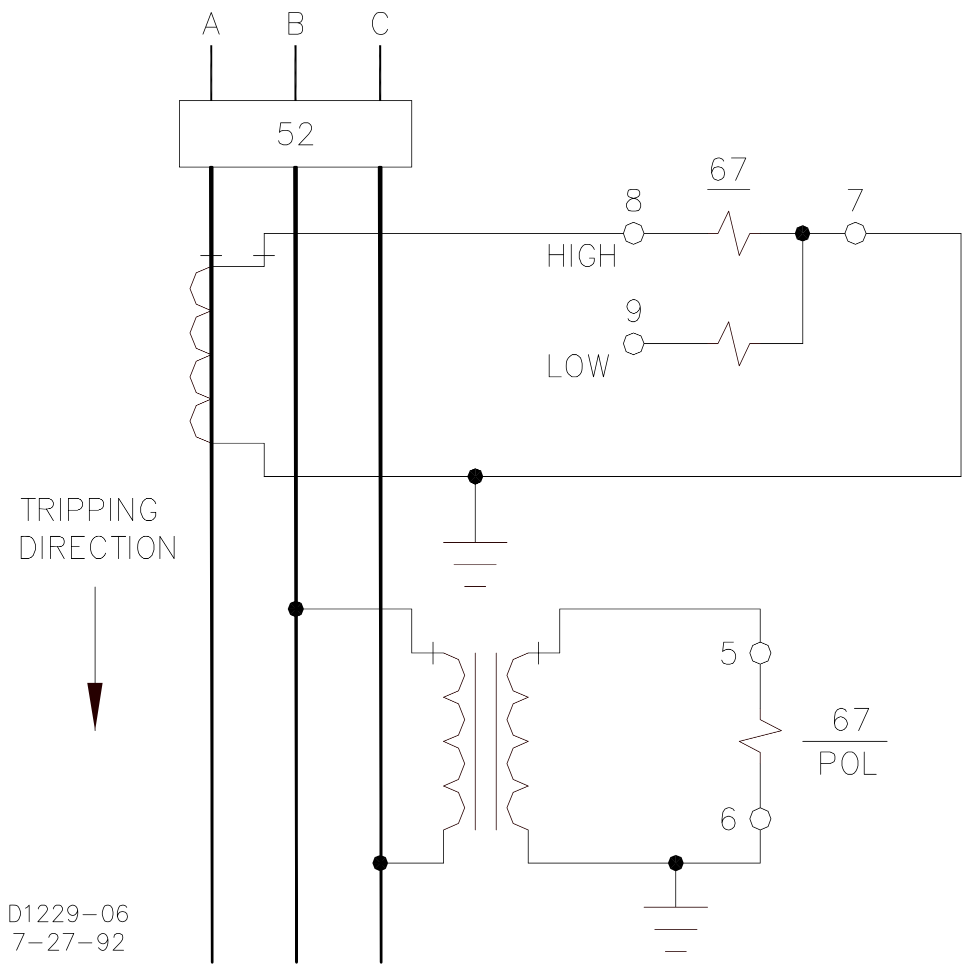

Figure 4-8. Single-Phase AC Connections

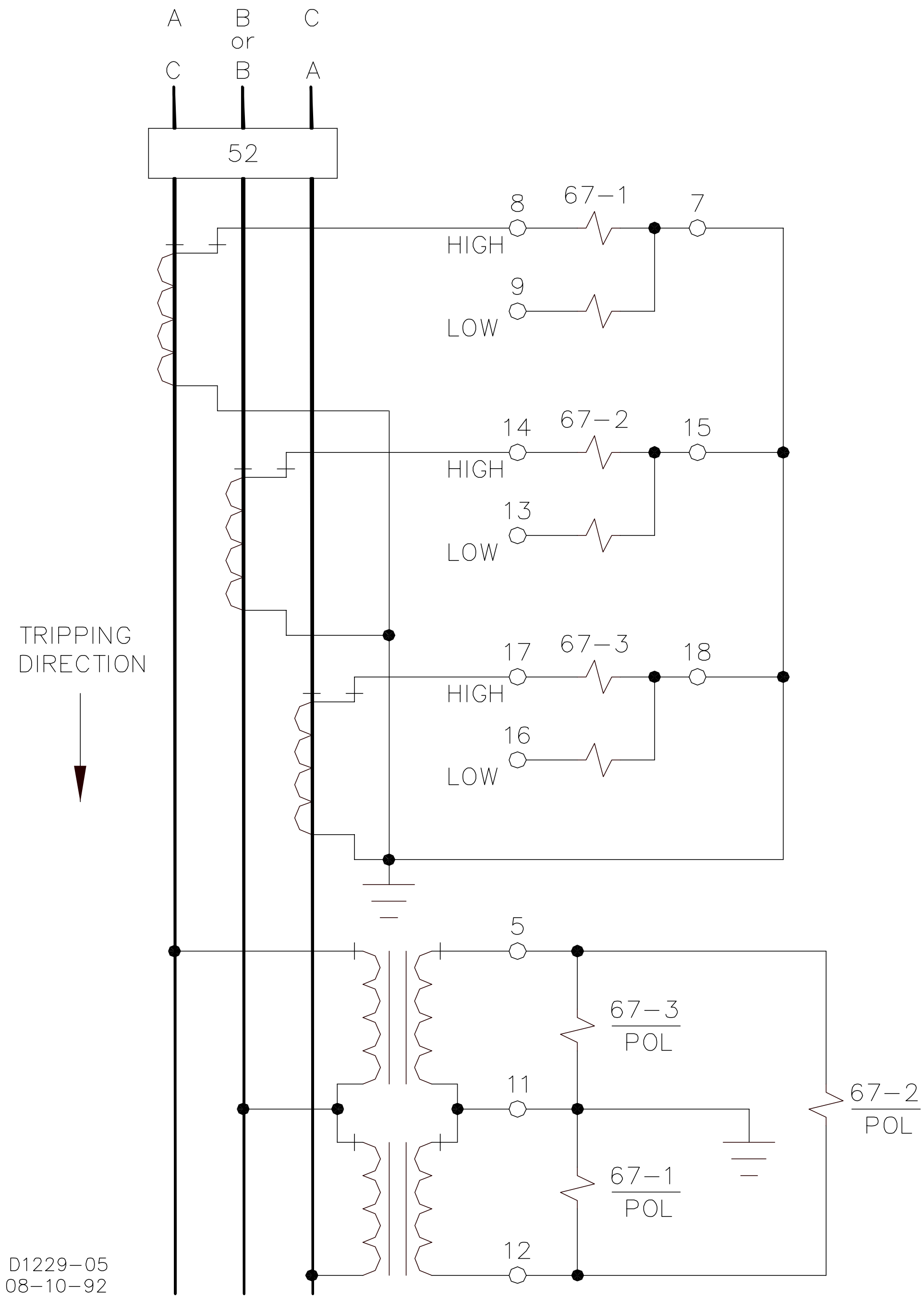

Figure 4-9. Three-Phase AC Connections

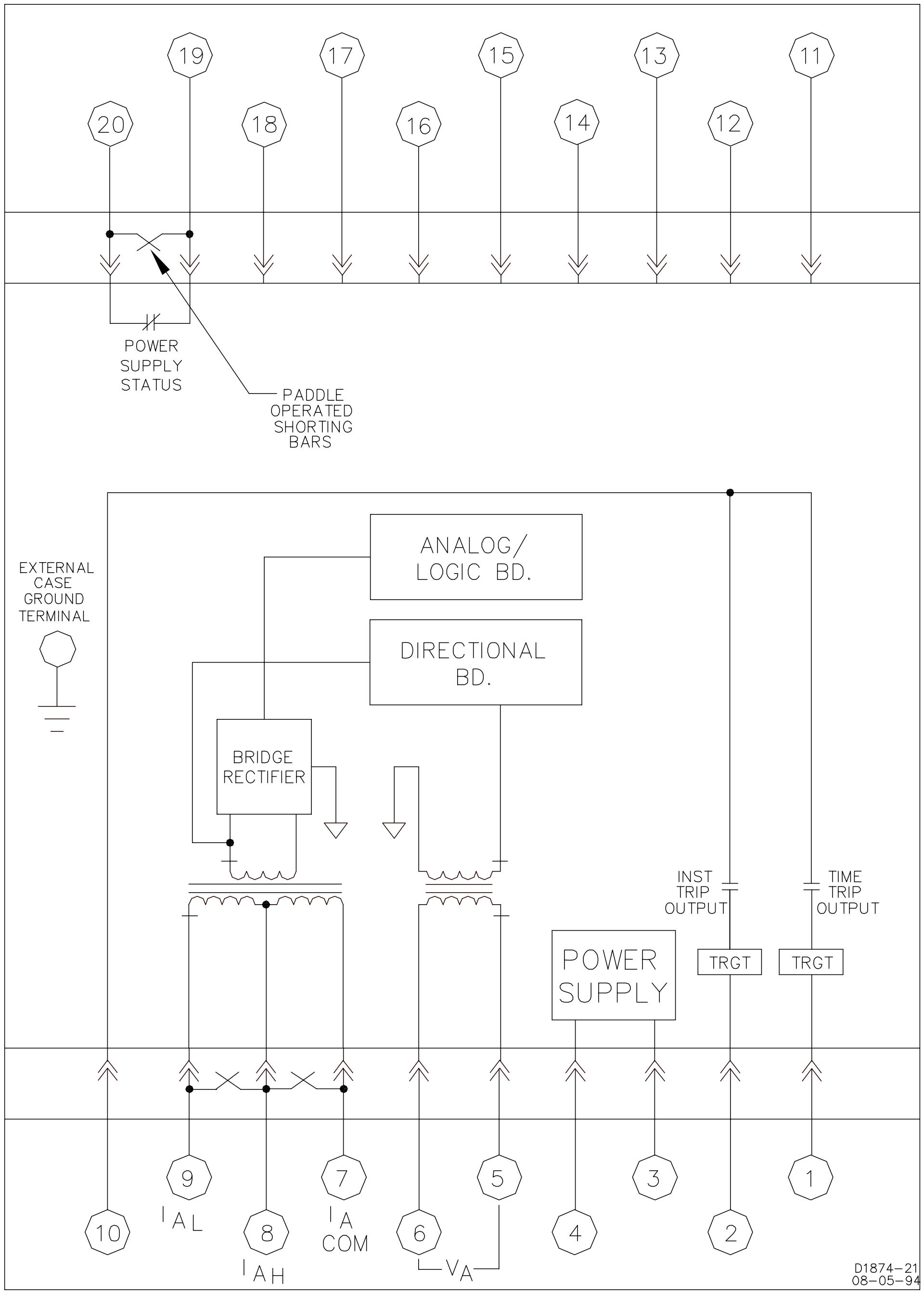

Figure 4-10. Single-Phase, Internal Connection Diagram

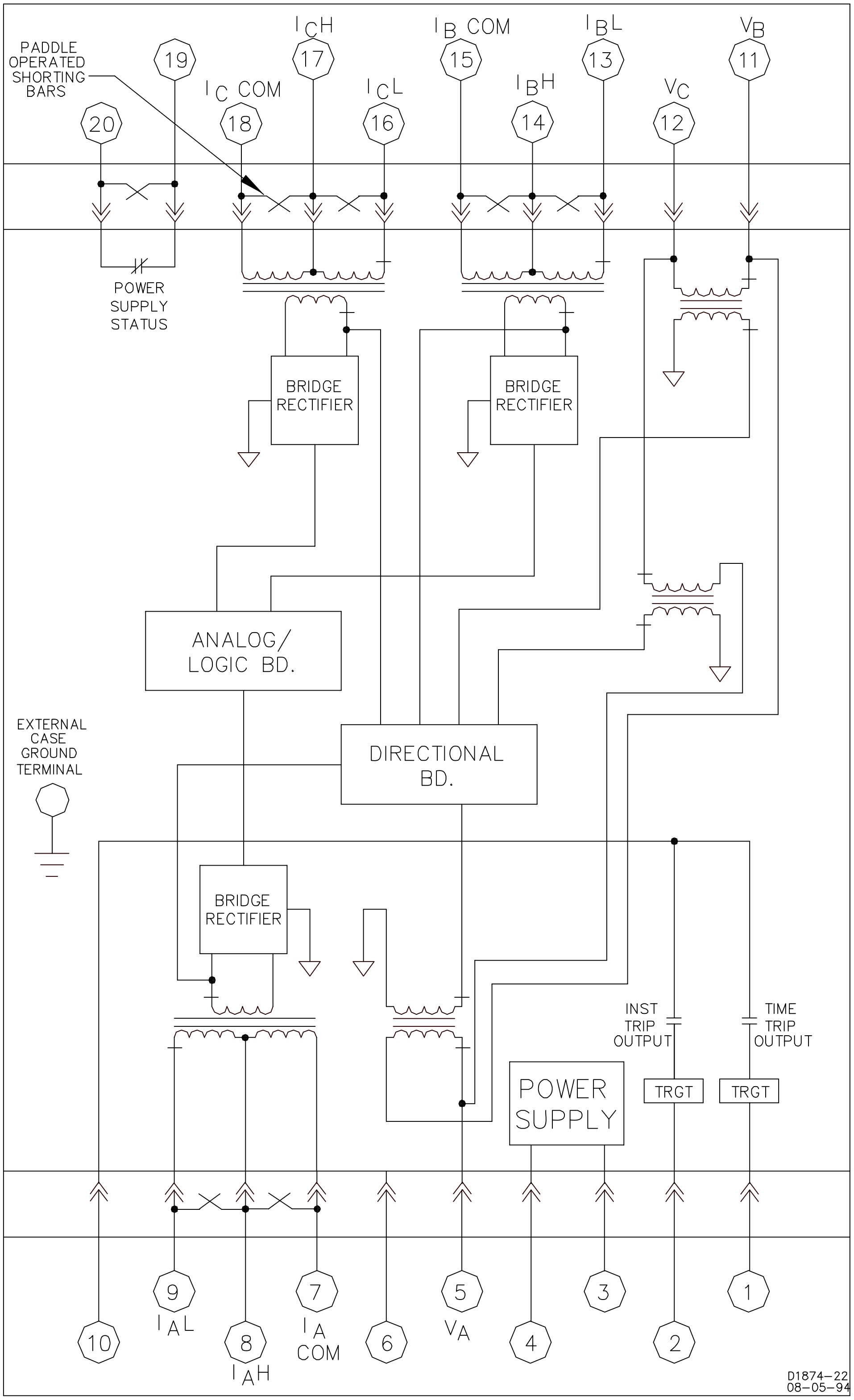

Figure 4-11. Three-Phase, Internal Connection Diagram

MAINTENANCE

BE1-67 relays require no preventative maintenance other than a periodic operational check. If the relay fails to function properly, contact Technical Sales Support at Basler Electric to coordinate repairs.

STORAGE

This protective relay contains aluminum electrolytic capacitors which generally have a life expectancy in excess of 10 years at storage temperatures less than 40°C (104°F). Typically, the life expectancy of a capacitor is cut in half for every 10°C rise in temperature. Storage life can be extended if, at one year intervals, power is applied to the relay for a period of 30 minutes.

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SECTION 5 • TESTING

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SECTION 5 • TESTING

GENERAL

The various test procedures that follow are intended to verify operation, to set pickup and time delay, and to set the characteristic angle of the relay for a specific application. Each phase of a three-phase relay may be tested as a separate single-phase device using the procedures provided.

When test results do not fall within the specified tolerances, the following should be considered:

1. Tolerance of the test equipment used.
2. Cycle-to-cycle phase stability of the test equipment.
3. Tolerances of any external components used in the test setup.

Equipment Required

The current source used in the verification testing should have the following capabilities:

1. Current output needs to be Switchable from a set position to an operate position. This allows the relay sensing circuits to see a current change from an initial current to a set (test) value.
2. The current source needs to be capable of delivering at least 20 amperes (5 VA). This is necessary to test the full capability of the instantaneous overcurrent element.
3. Because the current levels used to verify the operation of the instantaneous overcurrent element may exceed the continuous current rating of the relay, it is suggested that the current source include provision for automatic removal of the test current following a trip.

NOTE

Adjustments for **TAP CAL** and **INST** are multi-turn potentiometers and require a minimum of 15 turns from full CW to full CCW.

Preliminary Setup

Step 1. With the connection plug(s) removed (always remove lower connection plug first and insert last), connect the unit as shown in Figure 5-1 for a single phase unit (sensing input type A) or Figure 5-2 for a three-phase unit (sensing input type B).

Step 2. Adjust the **TAP CAL** control fully CW.

Step 3. Adjust the time dial to 99.

Step 4. Adjust the **TAP** selector switch to position **A**.

Step 5. Adjust the **INST** control (if present) fully CW.

Step 6. Adjust the **CHARACTERISTIC ANGLE** to the minimum setting position (0° for the continuously adjustable option, or 30° for the switch selectable type).

Step 7. Verify that the proper power supply voltage is connected to the relay case. (Refer to Table 1-4 for the ranges of each supply.)

Step 8. Insert the relay connection plug(s). (Always insert the lower connection plug last.)

Step 9. Verify that the power supply LED indicator is on and, if installed, that the proper supply status contact (terminals 19 and 20) is open.

Step 10. If there is a **LIMITED REGION OF OPERATION** control in the relay (option 3-5 or 3-6), it is necessary to set this control to an angle of 91°.

NOTE

In order to have a 180° angle as the trip direction (90° or either side of the torque angle vector), it is necessary to set the **LIMITED REGION OF OPERATION** control to 91°.

To adjust it to an angle of 91°, adjust the voltage source to 120 Vac at a phase angle of 0°. Adjust the input current source to 1.0 ampere (LOW range) or 3.0 amperes (HIGH range) and at a phase angle of -1°. Then, starting from the maximum CW position, slowly rotate the **LIMITED REGION OF OPERATION** control CCW until the **INHIBIT** LED just lights.

Step 11. Insure that the TEST/NORMAL switch (callout P of Figure 2-3) is in the **NORMAL** position.

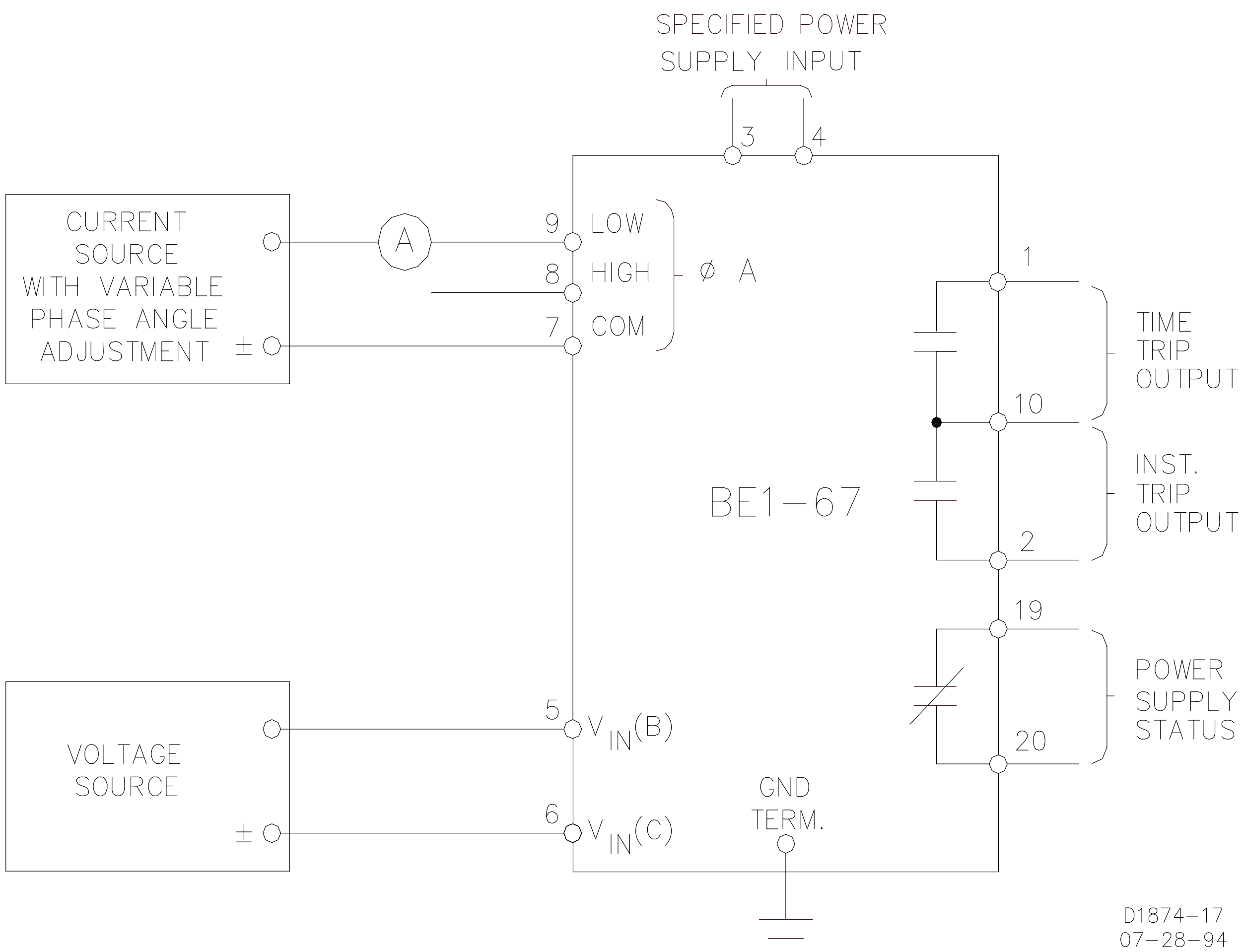
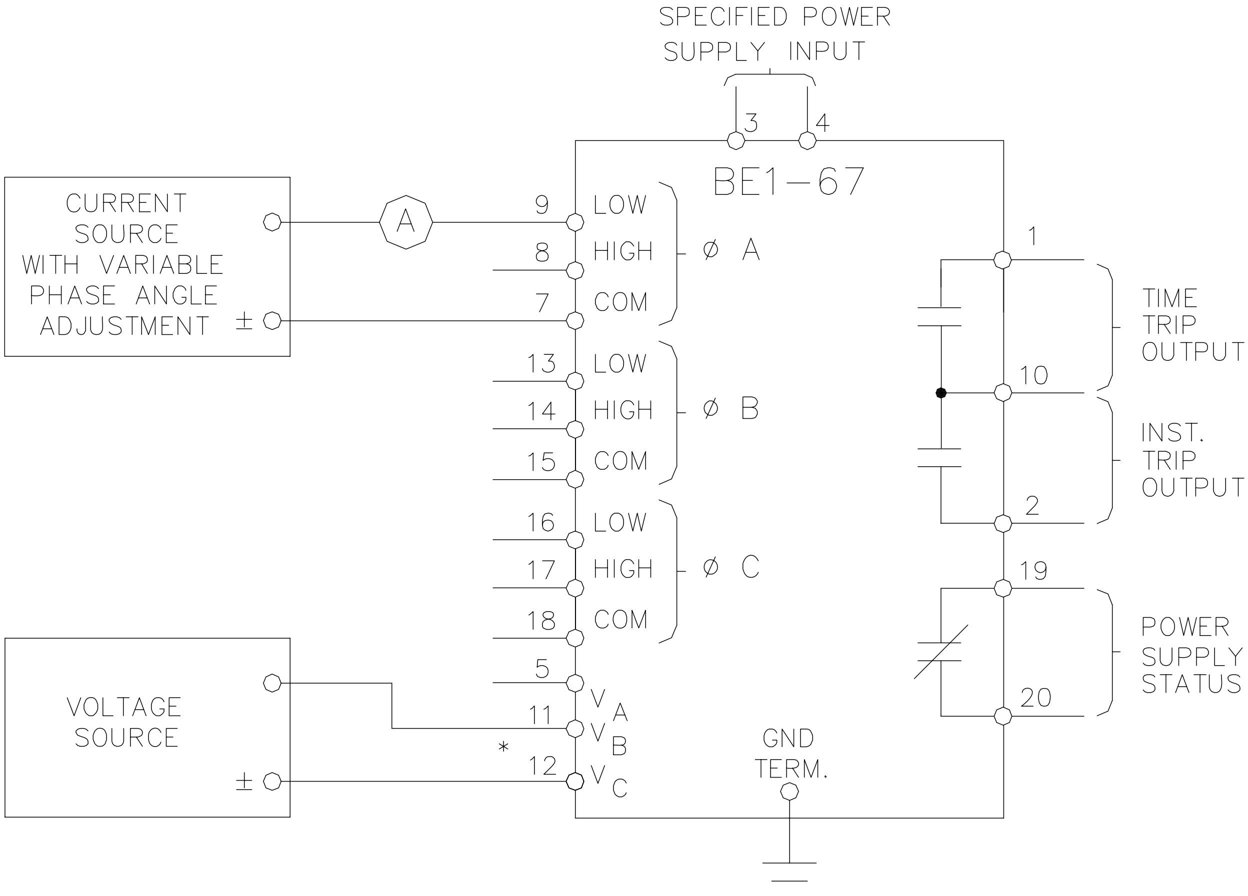


Figure 5-1. Single-Phase Test Setup



TEST PHASE	I INPUT TERM.		V INPUT TERM.	
	LOW/HIGH	RETURN ±	POLARITY	RETURN ±
* PHASE A	9/8	7	11	12
PHASE B	13/14	15	12	5
PHASE C	16/17	18	5	11

* PHASE A, LOW RANGE, ILLUSTRATED

D1874-18
07-28-94

Figure 5-2. Three-Phase Test Setup

VERIFICATION TESTING

This procedure verifies the operation of the unit. Check Figure 1-9, *Style Number Identification Chart,* for the style number of the relay to identify the options included within the specific relay to be tested.

Time Overcurrent Pickup Test

Step 1. After performing setup, adjust the input voltage source for 120 Vac at a phase angle of 0°.

Step 2. Adjust the input current source for 0.5 ampere (LOW range) or 1.5 amperes (HIGH range) at a phase angle of +90° (90° leading). The **INHIBIT** LED indicator of the phase under test should be extinguished. If not, current or voltage connections are reversed and should be corrected.

Step 3. Slowly turn the **TAP CAL** control CCW until the (associated phase) **TIMING** LED lights. This verifies the minimum pickup point of the specified range.

Step 4. Turn the **TAP CAL** control fully CW. The **TIMING** LED should extinguish. Slowly increase the magnitude of the input current to a level where the **TIMING** LED again lights. Observe the input current level. This value should be within ±5% of 0.75 ampere (LOW range) or 2.25 amperes (HIGH range). This verifies the pickup accuracy of the tap **A** setting.

Step 5. If verification of the remaining **TAP** selector positions is desired, adjust the **TAP** selector to its next CW position. Then slowly increase the magnitude of the input current to a level where the **TIMING** LED again lights. Observe that the current level is within ±5% of the value in Table 5-1.

> **NOTE**
> It is permissible to change the **TAP** selector switch position without disconnecting the current sensing inputs.

Table 5-1. Pickup Values at Indicated TAP SELECT Position

Range	A	B	C	D	E	F	G	H	I	J
HIGH	2.25	3.00	4.50	5.25	6.75	7.50	9.00	9.75	11.25	12.00
LOW	0.75	1.00	1.50	1.75	2.25	2.50	3.00	3.25	3.75	4.00

Step 6. If a three-phase unit is being tested, phase B and phase C inputs may be tested by repeating Steps 1 through 5 using the inputs as shown in Figure 5-2.

Instantaneous Overcurrent Pickup Test

Step 1. Perform the preliminary test setup.

Step 2. Adjust the **INST** control fully CCW.

Step 3. If the directional instantaneous option has been selected (option 1-3), adjust the voltage source to apply 120 Vac at a phase angle of 0°.

Step 4. Adjust the sensing current level for 0.75 amperes at 90° leading. Apply this current to the sensing input(s) of the relay. Confirm that the instantaneous output has been energized. (Terminals 2 to 10 will show continuity if the relay has been supplied with NO (type E) outputs and no continuity if the relay has been supplied with NC (type F) outputs.) This step also verifies the low end of the one to 40 times pickup setting of the instantaneous overcurrent setting range.

Step 5. Adjust the sensing current level for 0.5 ampere. Adjust the **TAP CAL** control CCW until the **TIMING** LED(s) light. Adjust the sensing current for a level of 20 amperes. Rotate the **INST** control fully CW. Then adjust CCW until the instantaneous output has been energized. (Terminals 2 to 10 will show continuity if the relay has been supplied with NO (type E) outputs and no continuity if the relay has been supplied with NC (type F) outputs.) This verifies the high end of the one to 40 times pickup setting of the instantaneous overcurrent setting range.

Directional Verification

For the following tests, it is necessary to adjust and monitor the magnitude of the voltage(s) and current(s) as well as the phase angle relationship between these sensing quantities. It may be useful to record the results on polar graph paper to more clearly understand the significance of the results. Blank forms for this purpose are furnished as Figures 5-3 and 5-4.

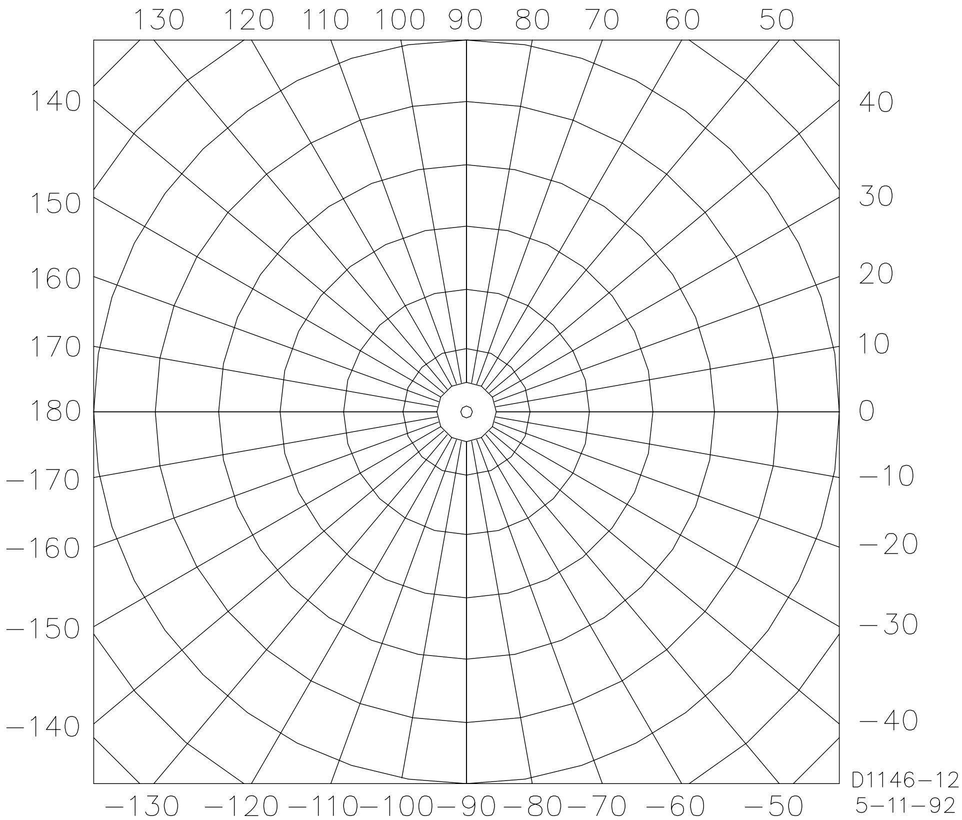


Figure 5-3. Blank Polar Graph Form

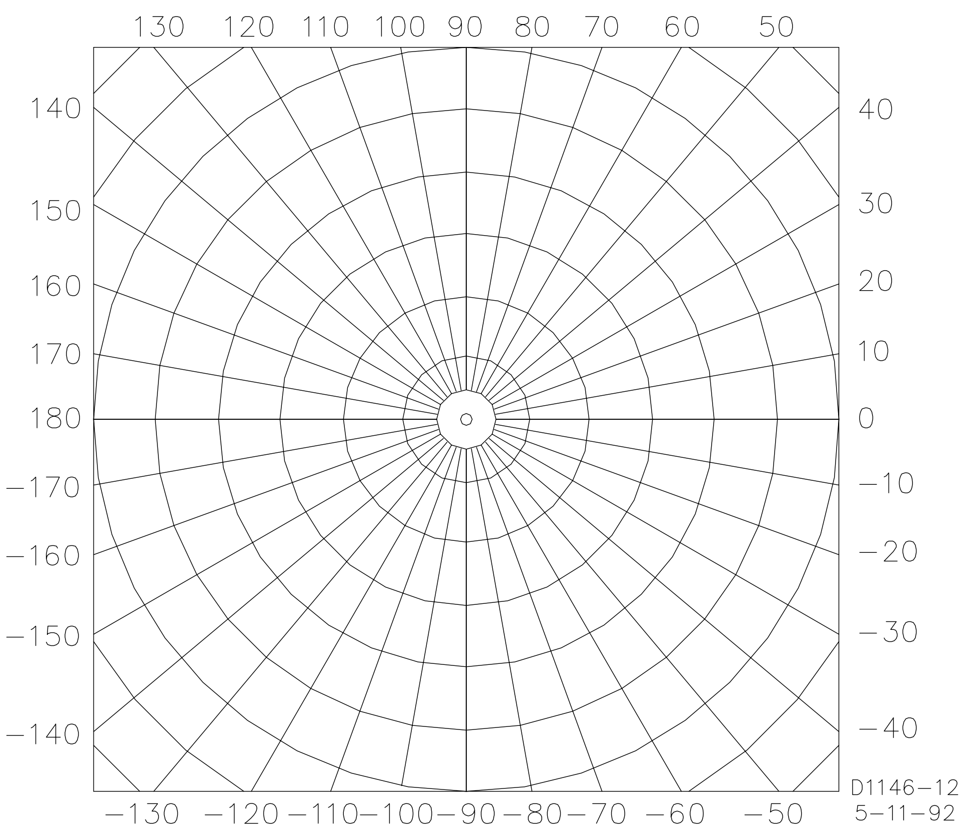


Figure 5-4. Blank Polar Graph Form

There are two types of **CHARACTERISTIC ANGLE** adjustments available with this unit:

1. A potentiometer capable of adjusting this angle over the range of 0° to 90°.
2. A 4-position switch with settings of 30°, 45°, 60°, and 75°.

If a potentiometer is provided, use Procedure 1. If a switch is supplied, use Procedure 2.

NOTE

In the polar graphs associated with the procedures for Directional Verification:

I	=	Measured current at unity power factor
I_Z	=	Fault current
V	=	Quadrature or polarizing voltage

Procedure 1

(For use with continuously adjustable **CHARACTERISTIC ANGLE**, options 3-1, 3-3, 3-5, and 3-6)

Step 1. Perform the preliminary setup.

Step 2. Adjust the input voltage source for 120 volts at a phase angle of 0°.

Step 3. Adjust the input current source for 1.0 amperes (LOW range) or 3.0 amperes (HIGH range) at a phase angle of +90° (90° leading).

RESULT: The **INHIBIT** LED indicator should be extinguished and the (appropriate phase) **TIMING** LED OFF. If not, the current or voltage connections are reversed and should be corrected.

Step 4. Vary the phase angle of the input current through 360° and record the phase angles within which the **INHIBIT** LED is OFF. When shown on a polar plot, the result should be a straight line (through the origin) from 0° to 180° ±5°. This plot defines the trip region as shown in Figure 5-5. The trip region is shown as the lightly shaded area and the tolerance region as the more densely shaded region.

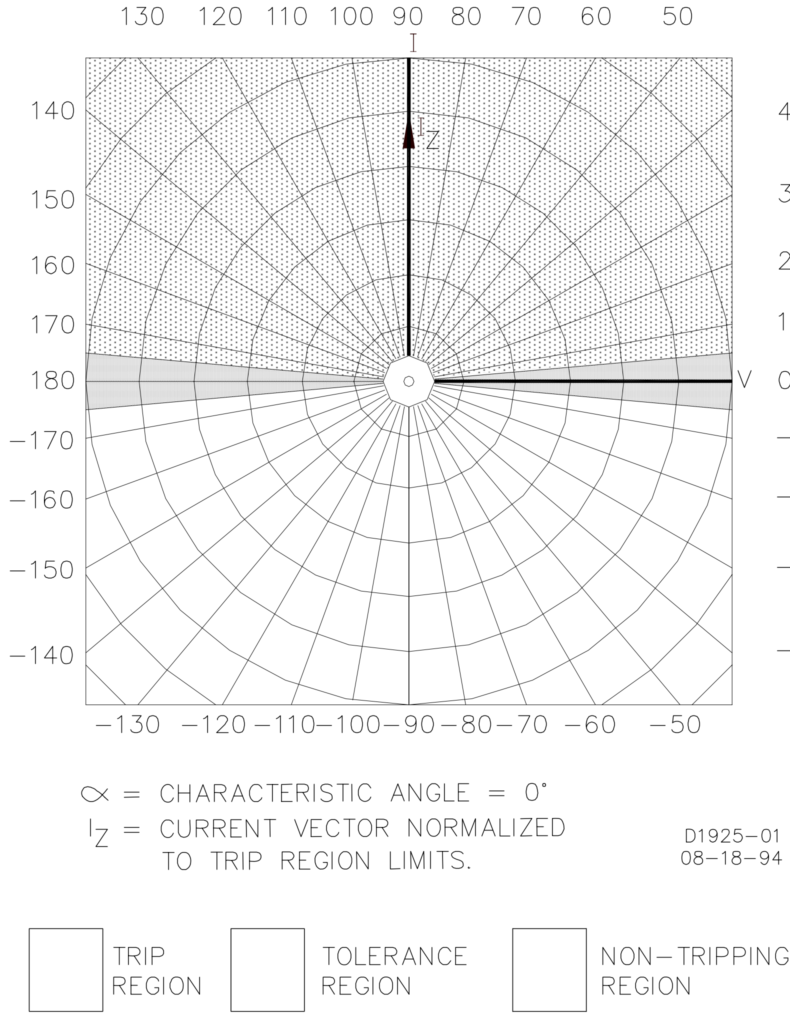


Figure 5-5. Characteristic Angle = 0 Degrees

Step 5. Rotate the **CHARACTERISTIC ANGLE** control to the maximum setting.

Step 6. Vary the phase angle of the input current through 360° and record the phase angles within which the **INHIBIT** LED is OFF. When shown on a polar plot, the result should be a straight line (through the origin) from -90° to ±90° ±5°. This plot defines the trip region as shown in Figure 5-6.

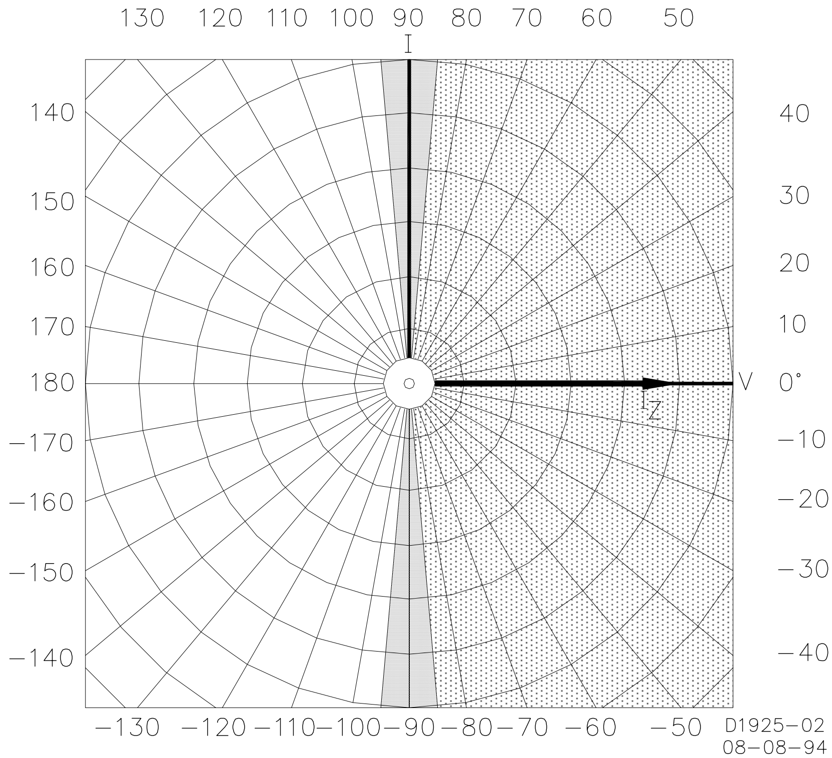


Figure 5-6. Characteristic Angle = 90 Degrees

Step 7. (Only when option 3-5 or 3-6 is present.) Rotate the **LIMITED REGION OF OPERATION** potentiometer fully CCW.

Step 8. Vary the phase angle of the input current through 360° and record the phase angles within which the **INHIBIT** LED is OFF. When shown on a polar plot, the result should be narrowed down to an included angle ≤ 10° (shown as the shaded region in Figure 5-7).

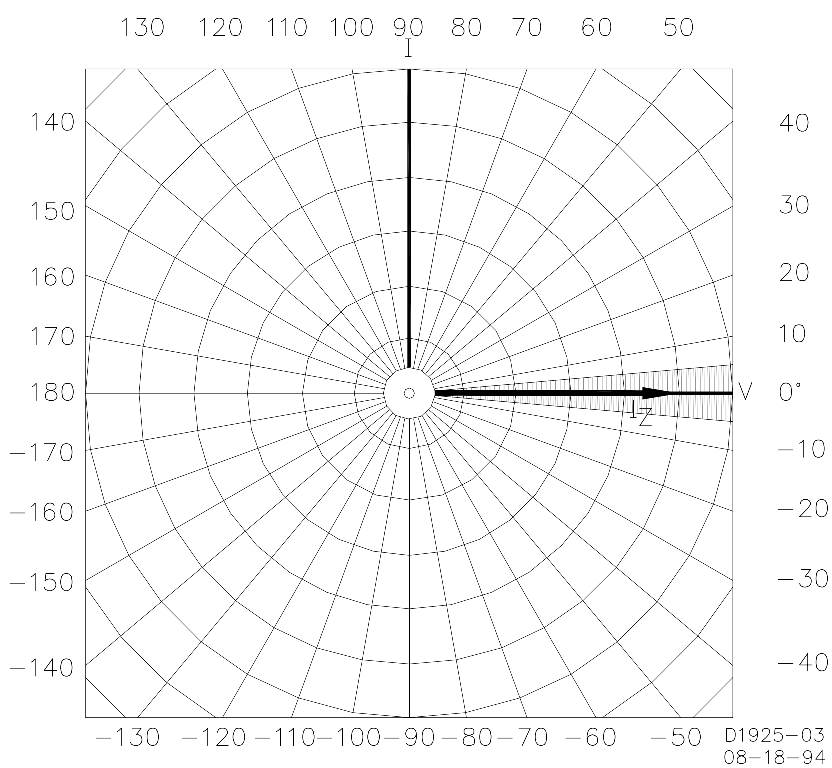


Figure 5-7. Minimum Region of Operation

Procedure 2

(For use with switch selectable **CHARACTERISTIC ANGLE**, options 3-2 and 3-4.)

Step 1. Perform the preliminary setup.

Step 2. Turn the **CHARACTERISTIC ANGLE** switch to 30°.

Step 3. Adjust the input voltage source for 120 Vac at a phase angle of 0°.

Step 4. Adjust the input current source for 1.0 ampere (LOW range) or 3.0 amperes (HIGH range) at a phase angle of +90° (90° leading). The **INHIBIT** LED indicator should be OFF, and the **TIMING** LED ON (i.e., the appropriate phase LEDs thereof on a 3-phase unit). If not, current or voltage connections are reversed and should be corrected.

Step 5. Vary the phase angle of the input current through 360° and record the phase angles at which the **INHIBIT** LED is OFF. When shown on a polar plot, the result should be a straight line (through the origin) from -30° to +150° ±5°. This plot defines the trip region as shown in Figure 5-8.

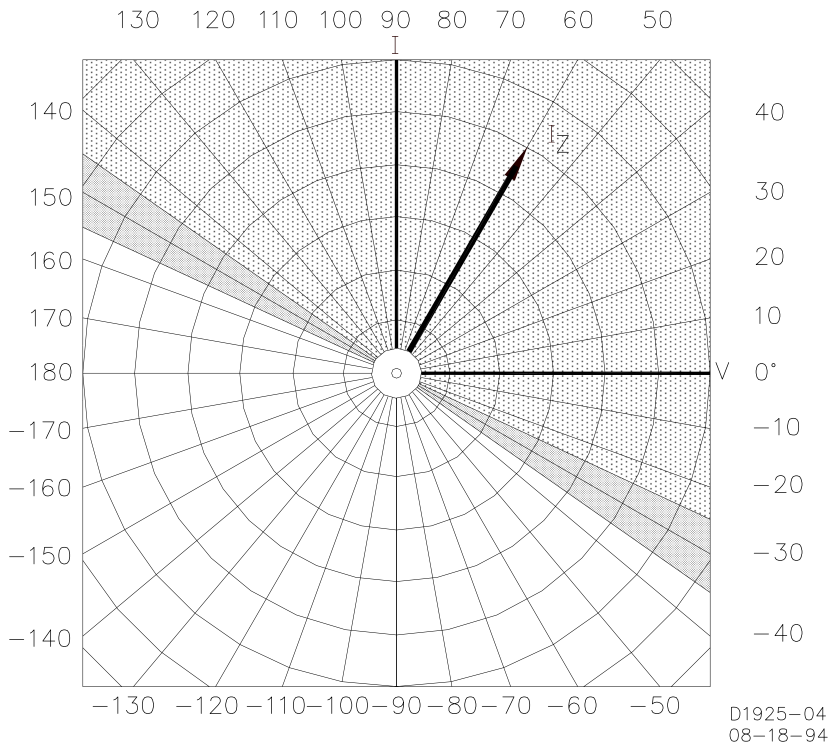


Figure 5-8. Characteristic Angle = 30 Degrees

Step 6. Adjust the **CHARACTERISTIC ANGLE** control to a setting of 45°.

Step 7. Vary the phase angle of the input current through 360° and record the phase angles within which the **INHIBIT** LED is OFF. When shown on a polar plot, the result should be a straight line (through the origin) from -45° to +135° ±5°. This plot defines the trip region as shown in Figure 5-9.

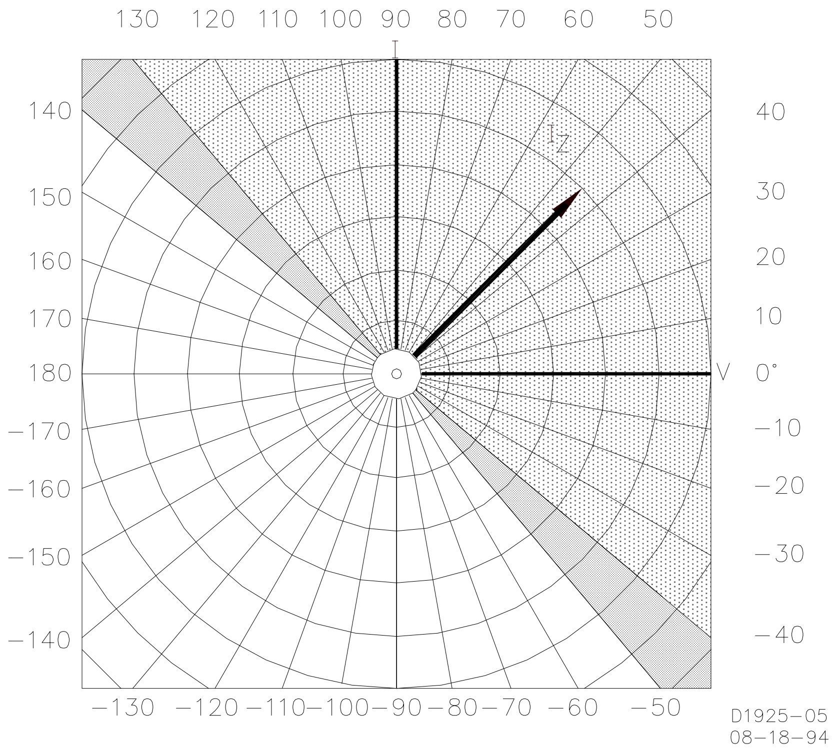


Figure 5-9. Characteristic Angle = 45 Degrees

Step 8. Adjust the **CHARACTERISTIC ANGLE** switch to 60°.

Step 9. Vary the phase angle of the input current through 360° and record the phase angles within which the **INHIBIT** LED is OFF. When shown on a polar plot, the result should be a straight line (through the origin) from a -60° to +120° ±5°. This plot defines the trip region as shown in Figure 5-10.

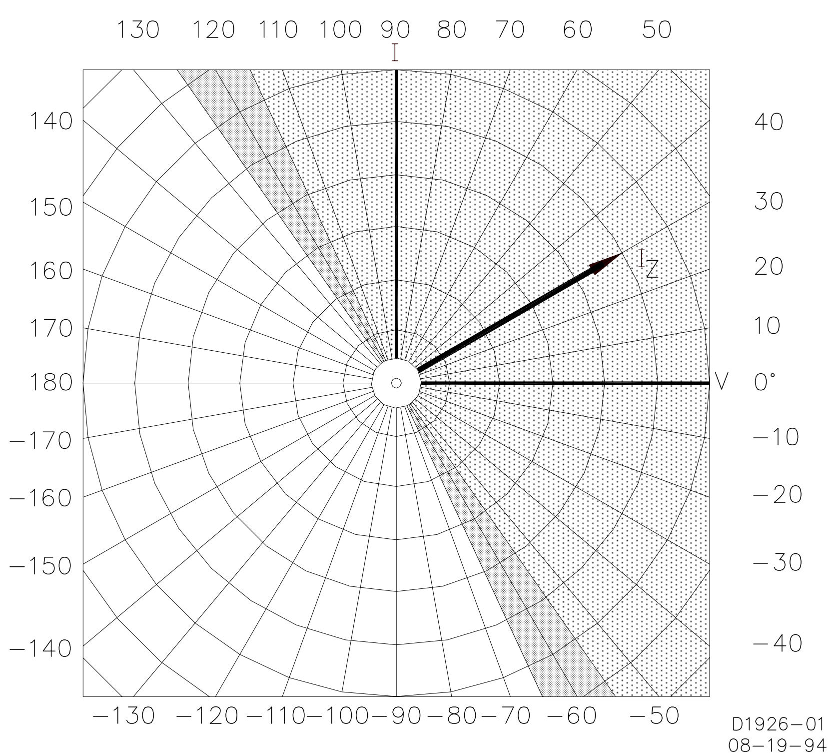


Figure 5-10. Characteristic Angle = 60 Degrees

Step 10. Adjust the **CHARACTERISTIC ANGLE** control to a setting of 75°.

Step 11. Vary the phase angle of the input current through 360° and record the phase angles within which the **INHIBIT** LED is OFF. When shown on a polar plot, the result should be a straight line (through the origin) from -75° to +105° ±5°. This plot defines the trip region as shown in Figure 5-11.

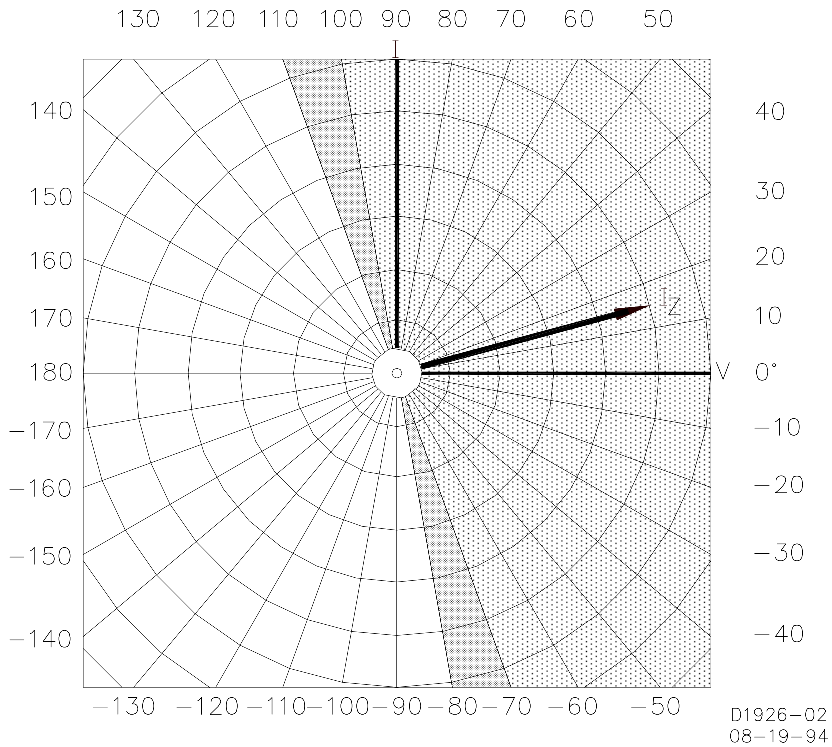


Figure 5-11. Characteristic Angle = 75 Degrees

TIMING CURVE VERIFICATION

There are many timing characteristics available for BE1-67 relays. Table 5-2 provides two checkpoints for each of the twelve timing characteristic curve types.

The characteristic included within the relay is defined in the style number by a two-character code. If this code is B1 to B7, E2, or E4 to E7, only one characteristic can be tested. If the code is Z2, the characteristic desired will need to be selected by the **TIME OVERCURRENT CHARACTERISTIC CURVE** selector switch located behind the front panel of the relay. (Refer to Figure 2-3 for switch location.) Table 5-2 defines the position of this selector for the desired characteristic.

Table 5-2. Expected Timing Values at Five Times Pickup

TIMING TYPE	Z2 Option Selector Position	Expected Times at Indicated Time Dial Setting (in seconds)	
		00	10
B1	3	0.066	0.194
B2	1	0.587	3.41
B3	5	0.103	0.494
B4	2	0.168	0.875
B5	4	0.149	0.722
B6	6	0.126	0.551
B7	7	0.195	1.011
E2	8	1.56	9.06

TIMING TYPE	Z2 Option Selector Position	Expected Times at Indicated Time Dial Setting (in seconds)	
		00	10
E4	9	0.13	0.54
E5	A	0.233	1.190
E6	B	0.16	0.77
E7	C, D, E, F	0.13	0.48

NOTE: Accuracy, with the **TAP CAL** control rotated fully CW, is ±5% or 50 milliseconds (whichever is greater) within the values shown graphically on the published characteristic curves.

Verification of the timing may be performed at a low current level for convenience. Connect the relay as shown in Figure 5-1 or 5-2. In the following steps, the timing will be measured from the point that the sensed current is applied until the output contact is energized. The equipment to accomplish this task will need to step from 0 to 3.75 amperes (if the relay is connected for LOW range) or 11.25 amperes (if the relay is connected for HIGH range).

Step 1. Set the **TAP** selector switch to position **A** and rotate the **TAP CAL** control fully CW. Rotate the INST control (if included) fully CW. Adjust the **TIME DIAL** to 00. Set the **LIMITED REGION OF OPERATION** control (if so equipped) to the maximum (fully CW) position.

Step 2. Adjust the source current for 0.75 amperes (LOW range) or 2.25 amperes (HIGH range) and apply this current to the sensing input(s) of the relay. (See Figure 5-1 or 5-2.) Voltage will also need to be applied to the sensing input of the directional element for this test. The phase angle between the current and voltage should be adjusted so that the **TIMING** LED lights when the pickup current is applied. Adjust the **TAP CAL** control (if required) such that the **TIMING** LED is ON. This sets the pickup of the relay for the following steps.

Step 3. Connect a counter to monitor the time interval from initiation of the timing condition to the output transition.

Step 4. Switch the sensing current from 0.0 amperes to 3.75 amperes (LOW range) or 11.25 amperes (HIGH range). (This is 5 times the level set in step 2.) Monitor the time required to energize the output contacts and compare that time with the value in Table 5-2.

Step 5. Adjust the **TIME DIAL** to 10 and repeat step 4.

This completes relay verification testing.

DIRECTIONAL SETTING PROCEDURE

Characteristic Angle

For switch selectable controls (options 3-2 or 3-4), simply turn the control to the desired setting in accordance with the markings on the front panel.

For potentiometer controls (options 3-1, 3-3, 3-5, or 3-6), perform the following steps:

Step 1. Perform the preliminary setup procedures at the beginning of this section.

Step 2. With the **CHARACTERISTIC ANGLE** set to minimum, apply a voltage input of 120 Vac at a phase angle of 0° and a current input of 1.0 ampere (LOW range) or 3.0 amperes (HIGH range) at a lagging phase angle equal to the desired **CHARACTERISTIC ANGLE** setting. The appropriate phase **INHIBIT** LED should be ON.

NOTE

Set the **CHARACTERISTIC ANGLE** by adjusting one end point of the 180° trip region. In Figure 5-12, the test current lags the **CHARACTERISTIC ANGLE** by 90°.

Step 3. Slowly rotate the **CHARACTERISTIC ANGLE** control CW to the position where the appropriate phase **INHIBIT** LED lights.

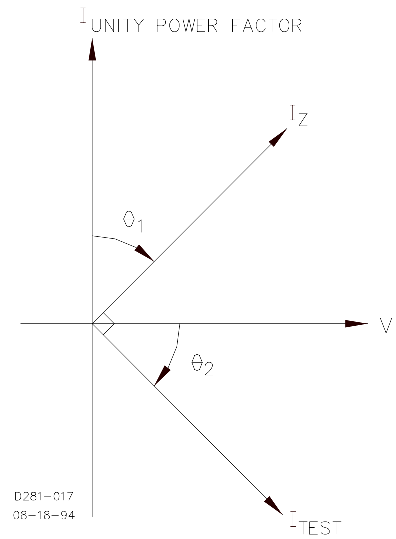


Figure 5-12. Directional Setting

Legend for Figure 5-12:

Θ_1 = Desired characteristic angle setting.
Since $\Theta_1 = \Theta_2$, apply I_{TEST} at a lagging angle equal to the desired characteristic angle setting.

Limited Region of Operation

If the relay includes the **LIMITED REGION OF OPERATION** option, perform the following steps. If this option is not included, continue with Verifying the Setting.

Step 4. Apply a voltage input of 120 Vac at a phase angle of 0° and a current input of 1.0 ampere (LOW range) or 3.0 amperes (HIGH range) at a phase angle defined by the following equation.

Refer to Figure 5-13.

$$Phase_I = +90 - |\textbf{\textit{CHARACTERISTIC ANGLE}}\ \textit{setting}| - |\beta|$$

Where:

$Phase_I$ = phase of the applied current relative to the applied voltage
B = desired **LIMITED REGION OF OPERATION** setting
\+ angle = leading current
\- angle = lagging current

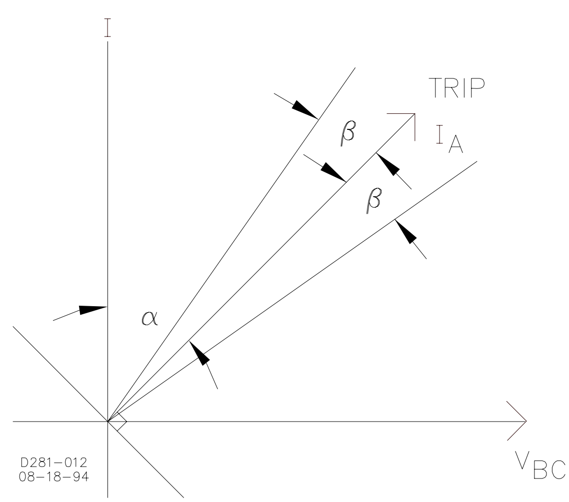


Figure 5-13. Limited Region of Operation Setting

Step 5. Slowly rotate the **LIMITED REGION OF OPERATION** control CCW until the **INHIBIT** LED just illuminates.

Verifying Relay Settings

A verification of the directional setting should now be performed.

Step 6. Vary the applied current phase angle through 360° and record the angle values at which the appropriate phase **INHIBIT** LED turns ON and OFF. Plot the results on a polar coordinate graph for future reference.

SETTING THE RELAY - AN EXAMPLE

One method of setting the relay is described here. There are other methods that may be used as well. All methods involve similar steps and equipment.

Example Defined

Before the relay can be set, the required settings need to be defined. A typical example follows:

- Time overcurrent pickup: 5.7 A
- Curve shape: Very inverse
- Time delay setting: 0.6 second at 28.5 A
- Instantaneous overcurrent pickup: 39.9 A
- Line impedance angle: 60°
- Limited region of operation: B = 45°

The relay that has been selected for this application is a BE1-67, style number B1E-Z2Y-B1N6F.

Before applying sensing inputs to the relay, a few adjustments are necessary.

Step 1. Since the relay includes the Z2 timing option, the characteristic curve needs to be selected. This is accomplished by removing the front panel and adjusting the **TIME OVERCURRENT CHARACTERISTIC CURVE** selector switch to position **6**. (See Very Inverse, Table A-1.)

Step 2. Because the time overcurrent pickup is 5.7 amperes, the sensing current input for the relay will need to be connected for the HIGH range. Adjust the **TAP RANGE** plate on the front panel to display the word HIGH. Verify that the current connections to the relay are on terminals 7 and 8 (phase A), 14 and 15 (phase B), and 17 and 18 (phase C). Terminals 9, 13, and 16 should not be connected.

Step 3. Calculate the ratio of the instantaneous overcurrent pickup setting to the time overcurrent pickup setting.

In this example, the ratio is 39.9 ÷ 5.7 = 7. (This ratio is used in Step 2, *Setting the Pickups*.)

Setting the Pickups

Step 1. Perform the preliminary test setup.

Step 2. Set the following controls to the positions indicated:

- **TAP** selector switch to position **A**. (TAP is set to minimum designated tap value of 2.25 amperes, HIGH range.)
- **TAP CAL** control fully CW.
- **INST** control to full CW.

Step 3. Apply nominal sensing voltage with a phase angle of 0° to the relay.

> **WARNING!**
>
> Each current input one-second rating is 50 times **TAP** or 500 amperes (whichever is less). Take care NOT to exceed the one-second limit. Allow one minute for cooling between each current application.

Step 4. Apply a sensing input current of 7 x 2.25 amperes = 15.75 amperes at a phase angle of -60° (equal to the **CHARACTERISTIC ANGLE** setting).

Step 5. Slowly adjust the **INST** control CCW until the instantaneous overcurrent output contact closes.

Instantaneous overcurrent pickup is now set for seven times the time overcurrent pickup setting.

Step 6. Reduce the sensing current to zero.

Step 7. Set the following controls to the positions indicated:

- **TAP** selector switch to position **E**.
- **TAP CAL** control to fully CW.

Step 8. Apply a sensing input current of 5.7 amperes.

Step 9. Slowly rotate the **TAP CAL** control CCW until the **TIMING** LED lights. Time overcurrent pickup is now set for 5.7 amperes and the instantaneous overcurrent pickup is set for 39.9 amperes.

Step 10. Reduce the sensing input current to zero.

Step 11. Adjust the **TIME DIAL** for a setting of 11. (This setting is determined from the characteristic curve for timing type B6, Very Inverse, Basler Drawing 99-0928 which is included in Basler publication 9170900990. This setting will give a time delay of 0.6 second at 5 times pickup. This is the desired coordination point based on the required setting for this example.)

Setting the Direction

To set the direction (characteristic angle) for the relay, the boundaries of the tripping region need to be determined. If, for example, the line impedance angle is known to be 60°, the boundary should be the line normal to the line impedance. This line (through the origin) should extend from +120° to -60° as shown in Figure 5-10.

Step 1. Adjust the phase angle with the sensed current level at six amperes so that the sensed current (I_{TEST}) lags the sensed nominal voltage input by 60°.

Step 2. Slowly adjust the **CHARACTERISTIC ANGLE** control until the **INHIBIT** LED just turns OFF. The characteristic angle of the relay is now set for 60°.

Setting the Limited Region of Operation

To set the limited region of operation to 40°, follow these steps:

Step 1. Adjust the current sensing input phase angle to +90° - |60°| - |40°| = -10°. (Current now lags the voltage by 10°.

Step 2. Slowly rotate the **LIMITED REGION OF OPERATION** control CCW (from maximum setting) until the **INHIBIT** LED just turns OFF.

Step 3. Vary the applied current phase angle through 360° and record the angle values at which the appropriate phase **INHIBIT** LED turns ON and OFF. Plot the results on a polar coordinate graph for future reference. The resultant plot should look like Figure 5-14.

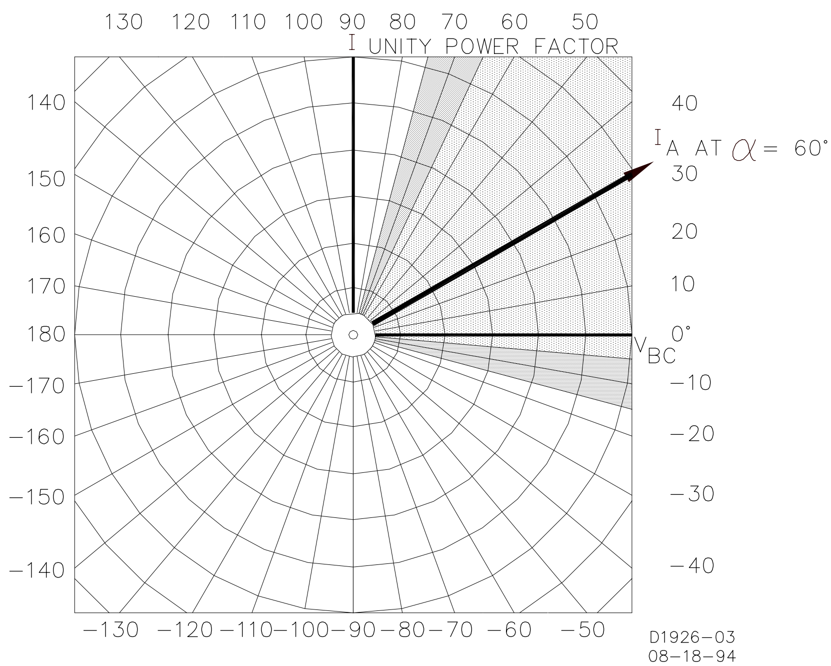


Figure 5-14. Characteristic Angle = 60 Degrees, Limited Region of Operation = 40 Degrees

APPENDIX A • CHARACTERISTIC CURVES

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Figures

Tables

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APPENDIX A • CHARACTERISTIC CURVES

BE1-67 TIME OVERCURRENT CURVES

BE1-67 time overcurrent curves are illustrated in Figures A-1 through A-12. Table A-1 lists each curve along with the corresponding characteristic curve selector switch position.

Table A-1. Characteristic Curves and Switch Positions

Switch Position	Characteristic Curve	Characteristic Description	Figure
3	B1	Short Inverse	A-1
1	B2	Long Inverse	A-2
5	B3	Definite	A-3
2	B4	Moderately Inverse	A-4
4	B5	Inverse	A-5
6	B6	Very Inverse	A-6
7	B7	Extremely Inverse	A-7
8	E2	Long Inverse (BS 142)	A-8
9	E4	Inverse (1.3 s, BS 142)	A-9
A	E5	Inverse (2.9 s, BS 142)	A-10
B	E6	Very Inverse (BS 142)	A-11
C, D, E, F	E7	Extremely Inverse (BS 142)	A-12

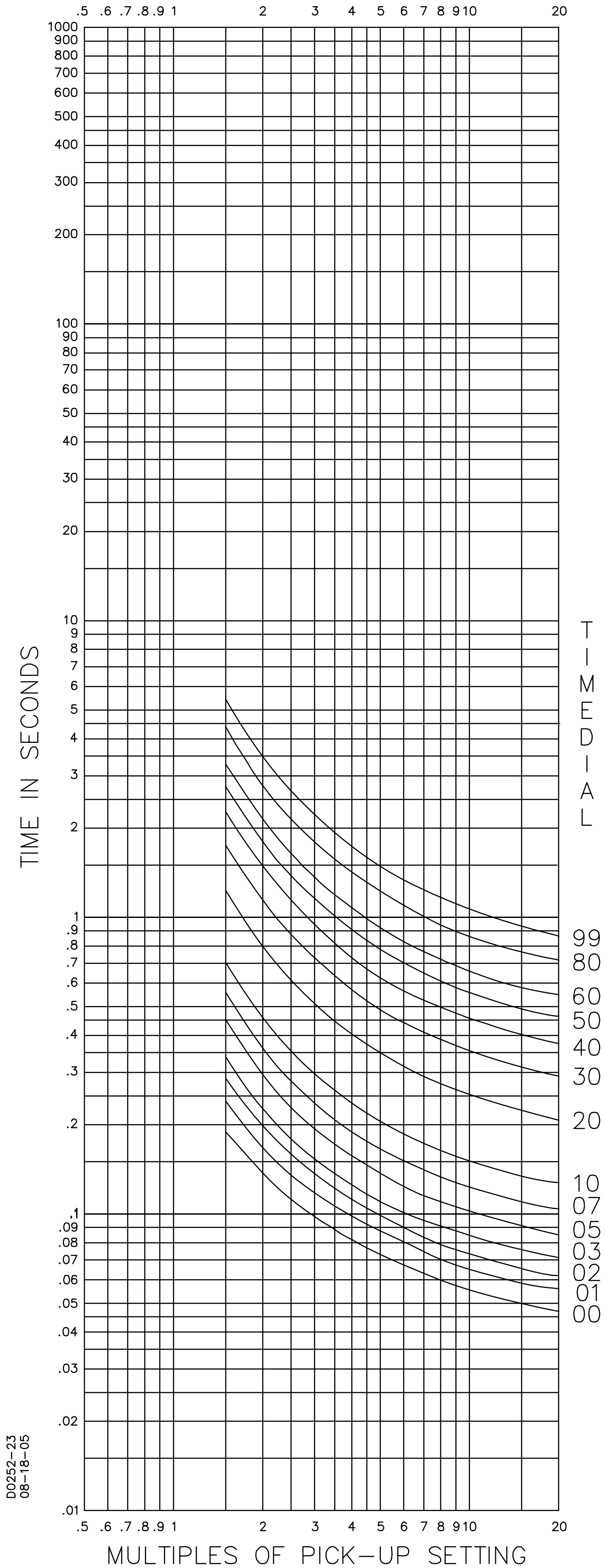

Figure A-1. Timing Type B1, Short Inverse (Switch Position 3)

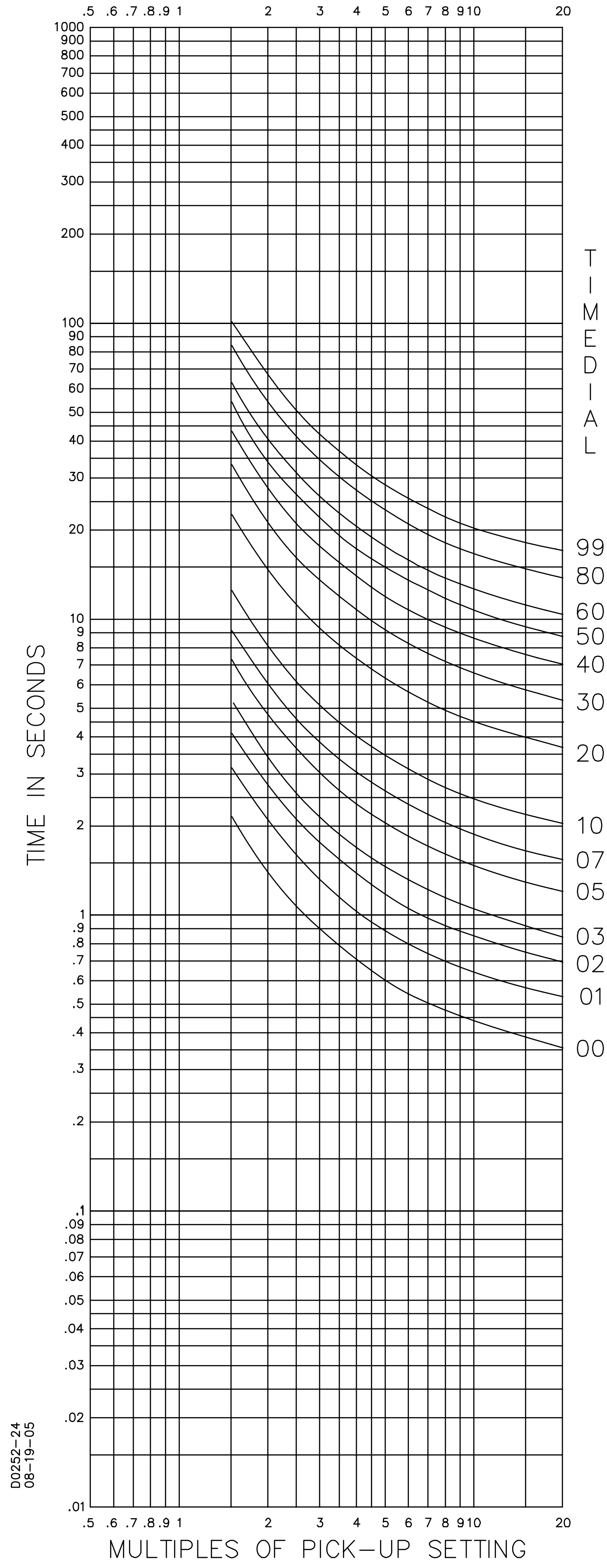

Figure A-2. Timing Type B2, Long Inverse (Switch Position 1)

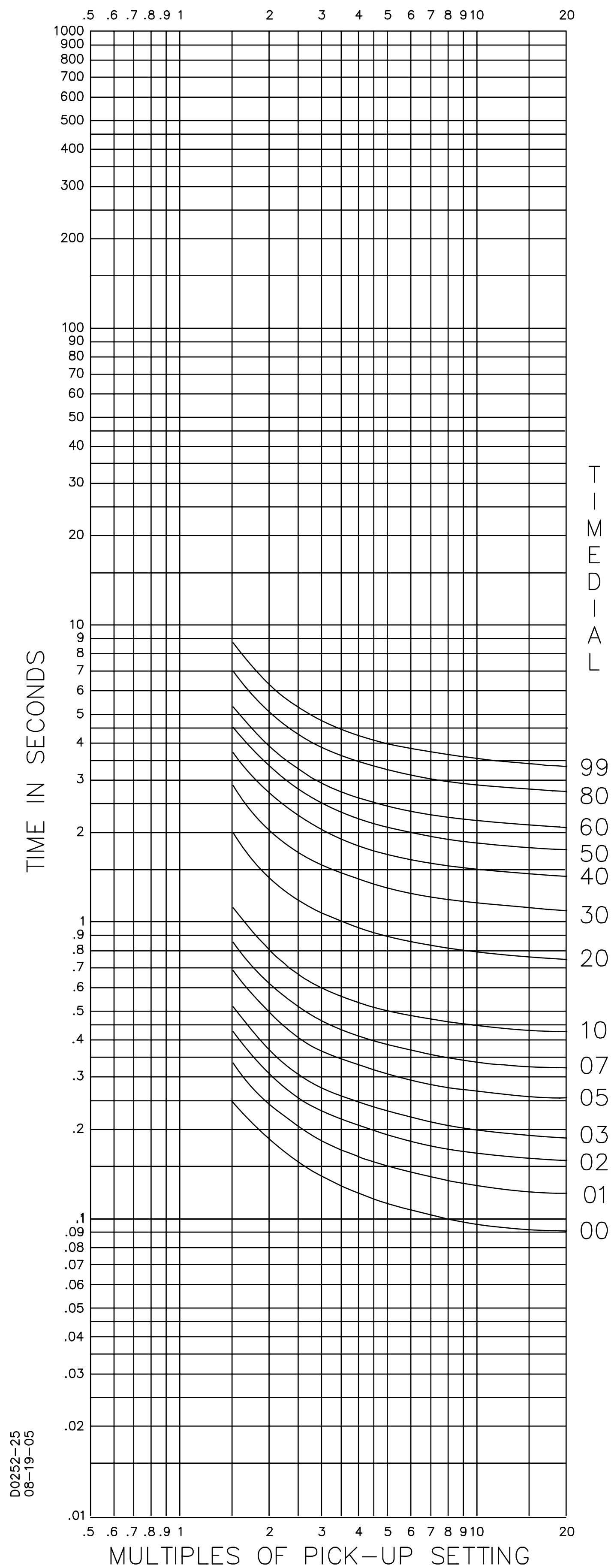

Figure A-3. Timing Type B3, Definite Time (Switch Position 5)

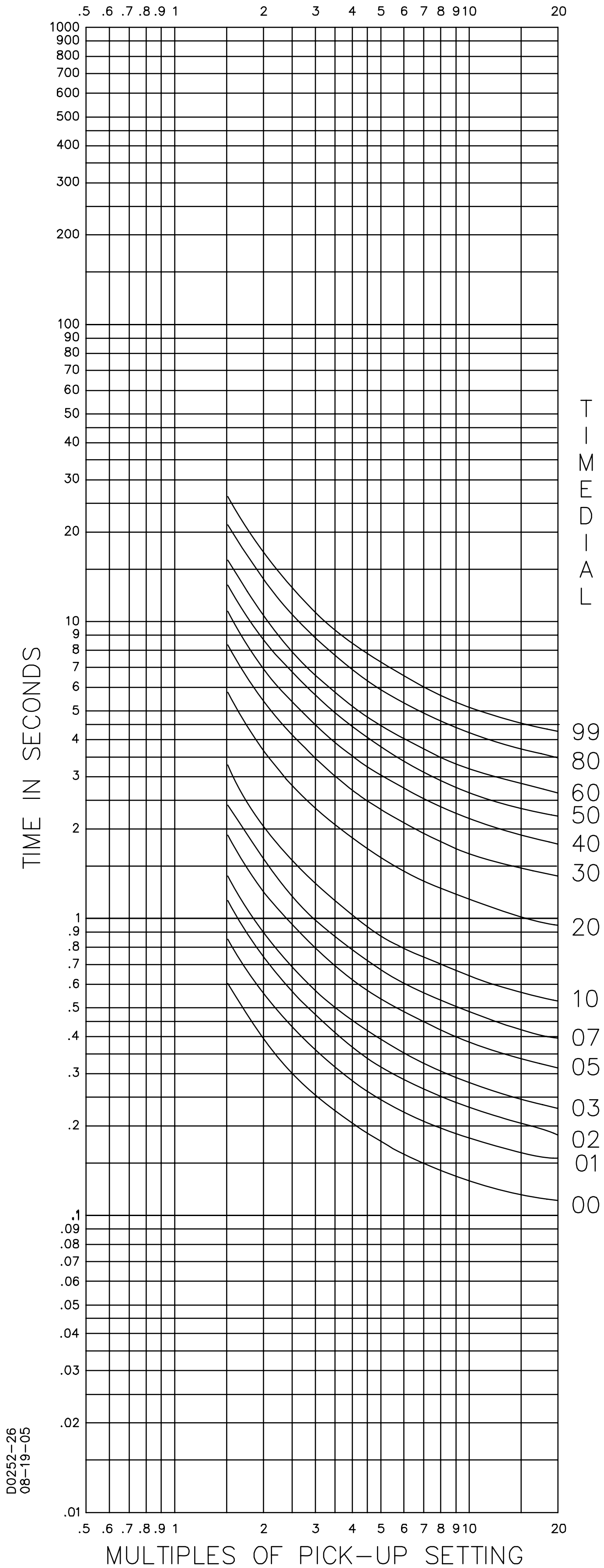

Figure A-4. Timing Type B4, Moderate Inverse (Switch Position 2)

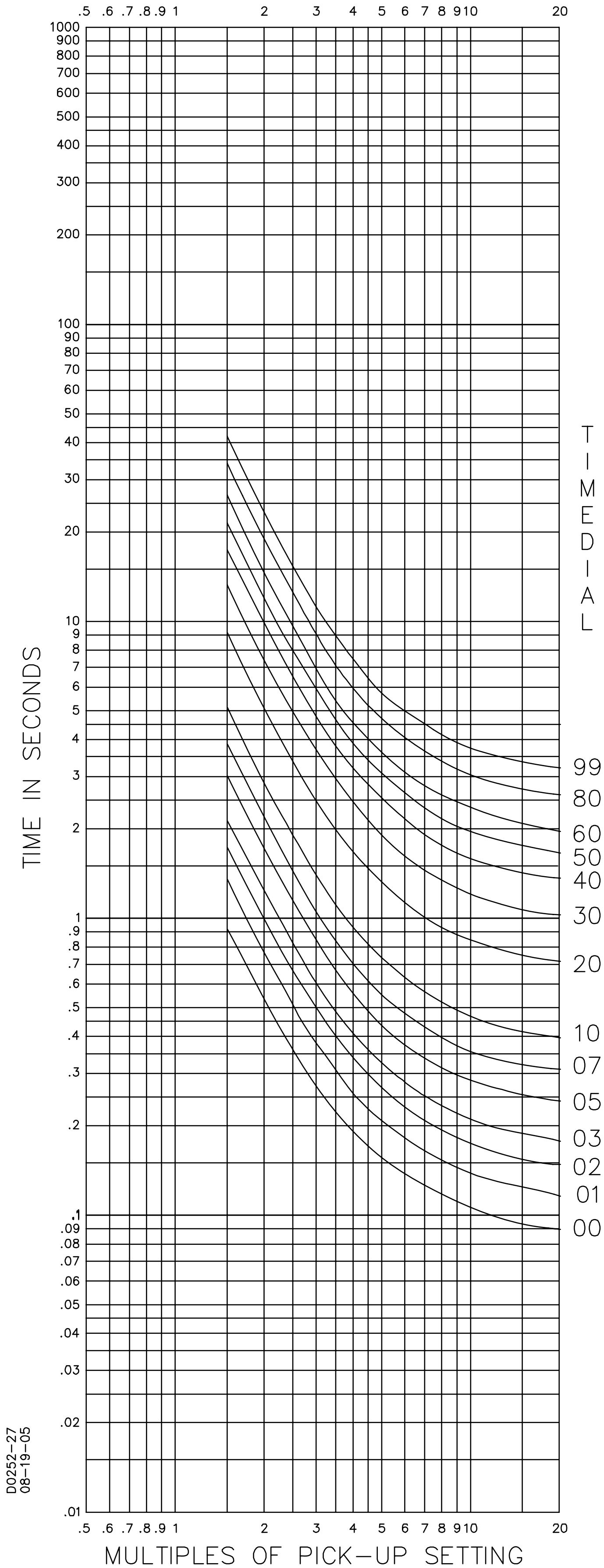

Figure A-5. Timing Type B5, Inverse (Switch Position 4)

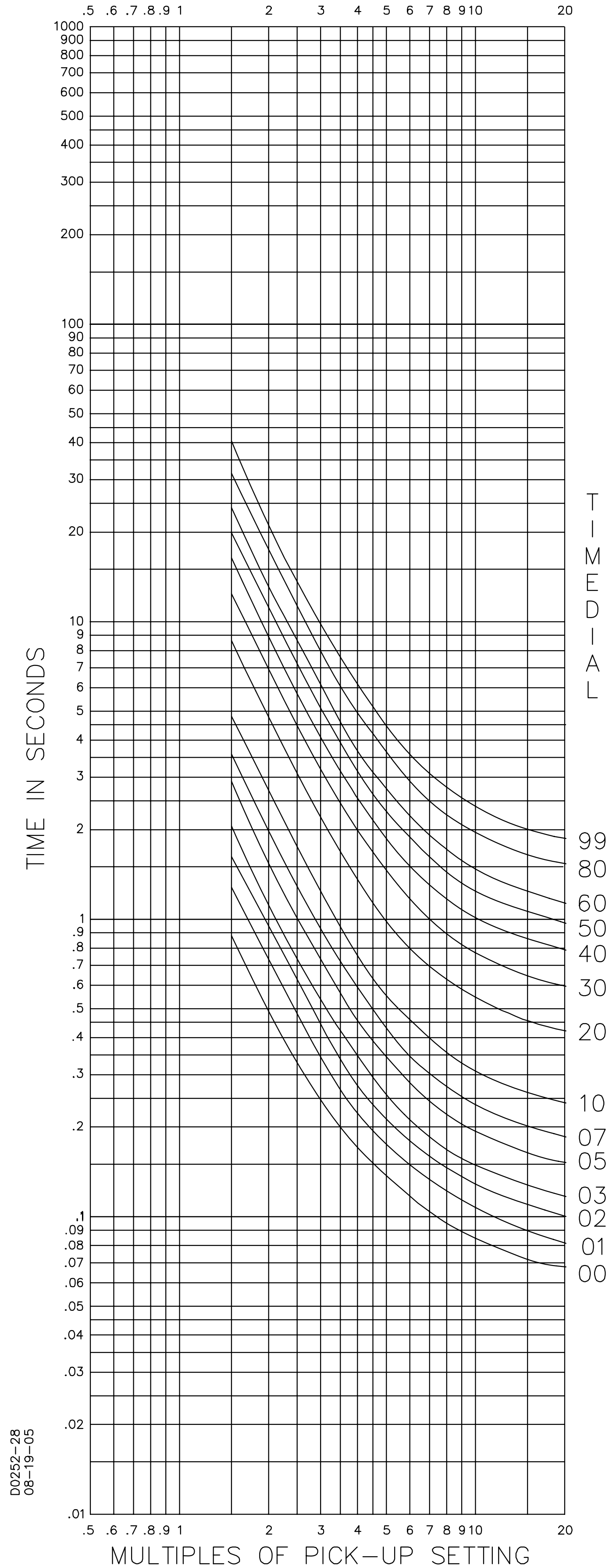

Figure A-6. Timing Type B6, Very Inverse (Switch Position 6)

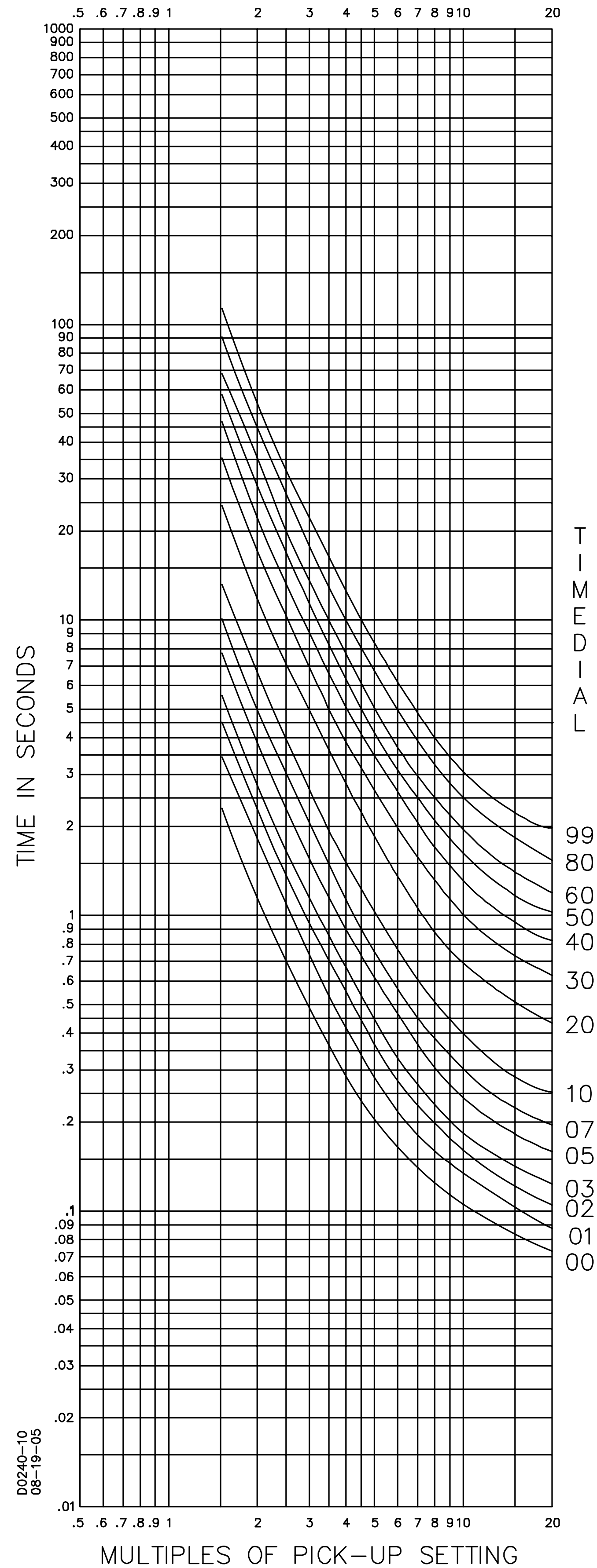

Figure A-7. Timing Type B7, Extremely Inverse (Switch Position 7)

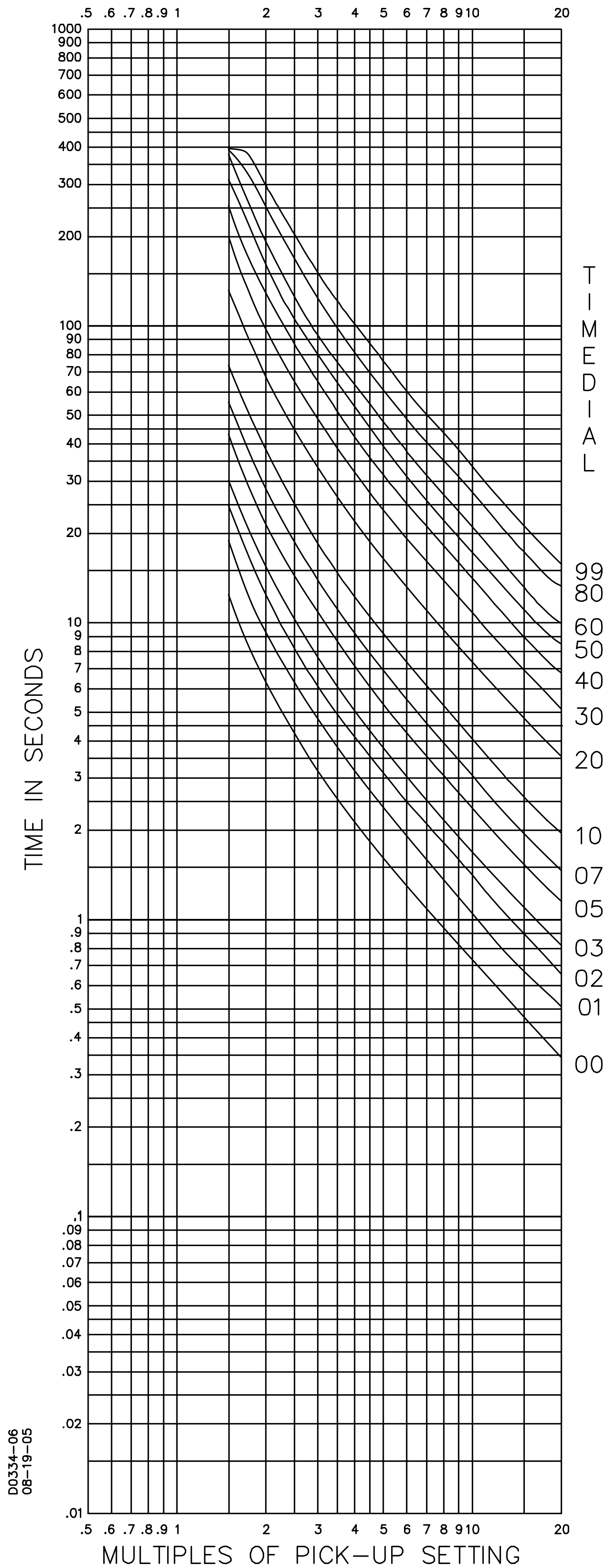

Figure A-8. Timing Type E2, BS 142 Long Inverse (Switch Position 8)

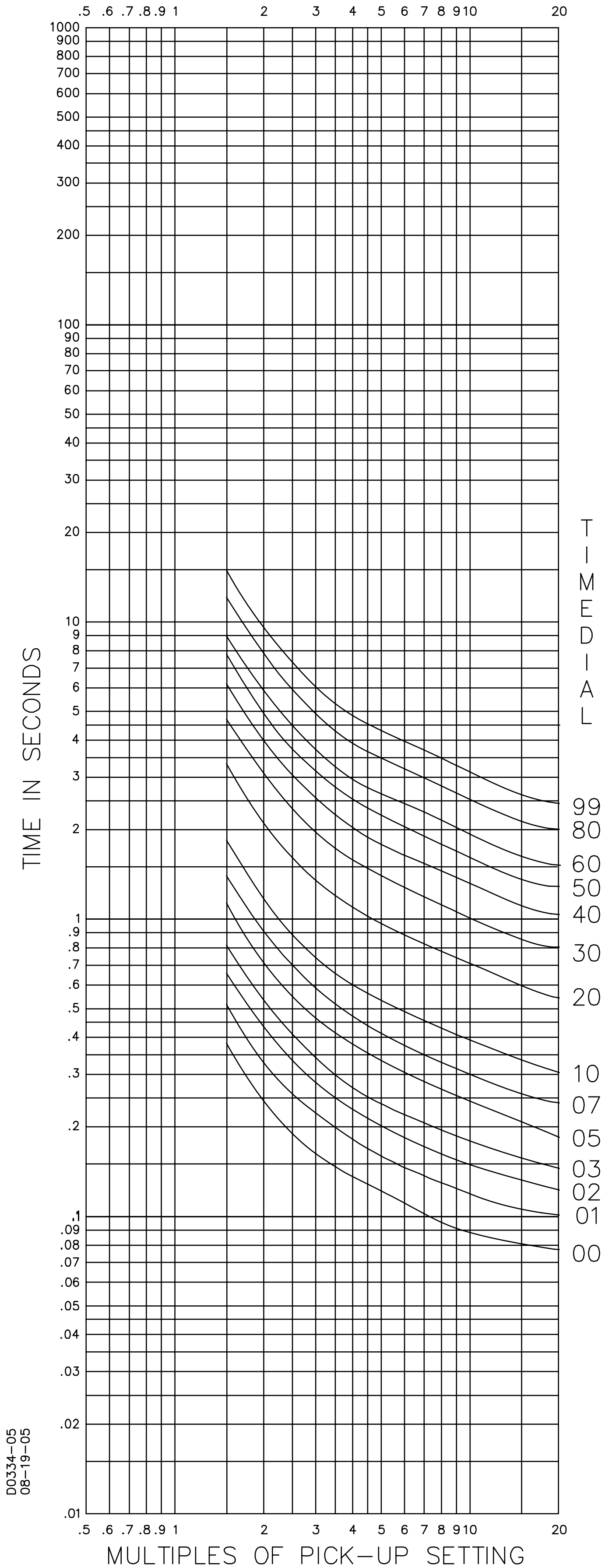

Figure A-9. Timing Type E4, BS 132 Inverse (Switch Position 9)

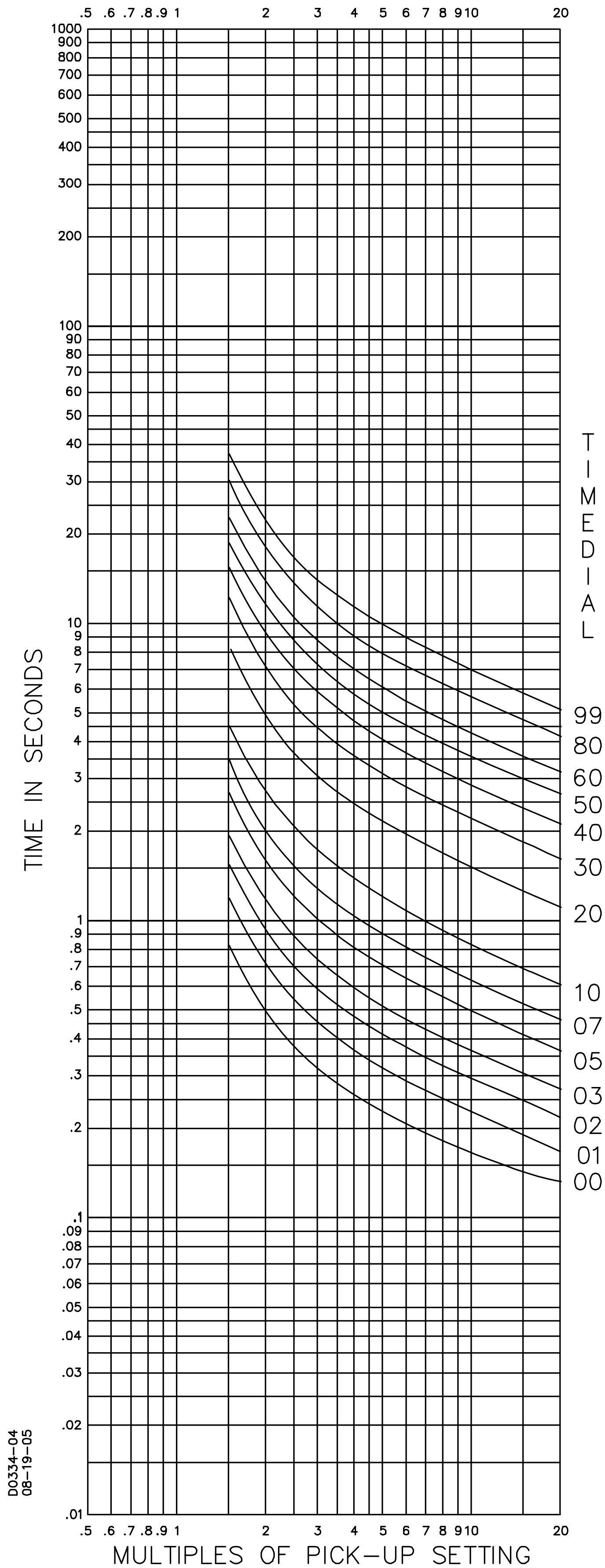

Figure A-10. Timing Type E5, BS 142 Inverse (Switch Position A)

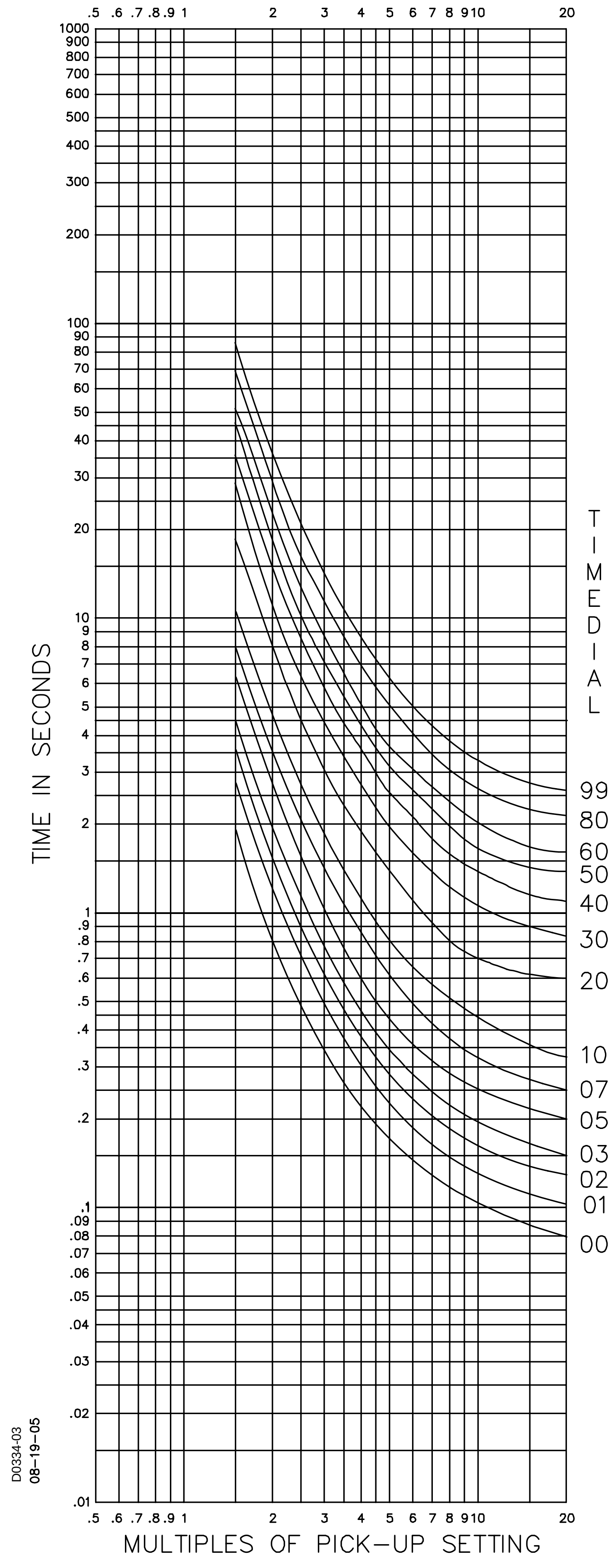

Figure A-11. Timing Type E6, BS 142 Very Inverse (Switch Position B)

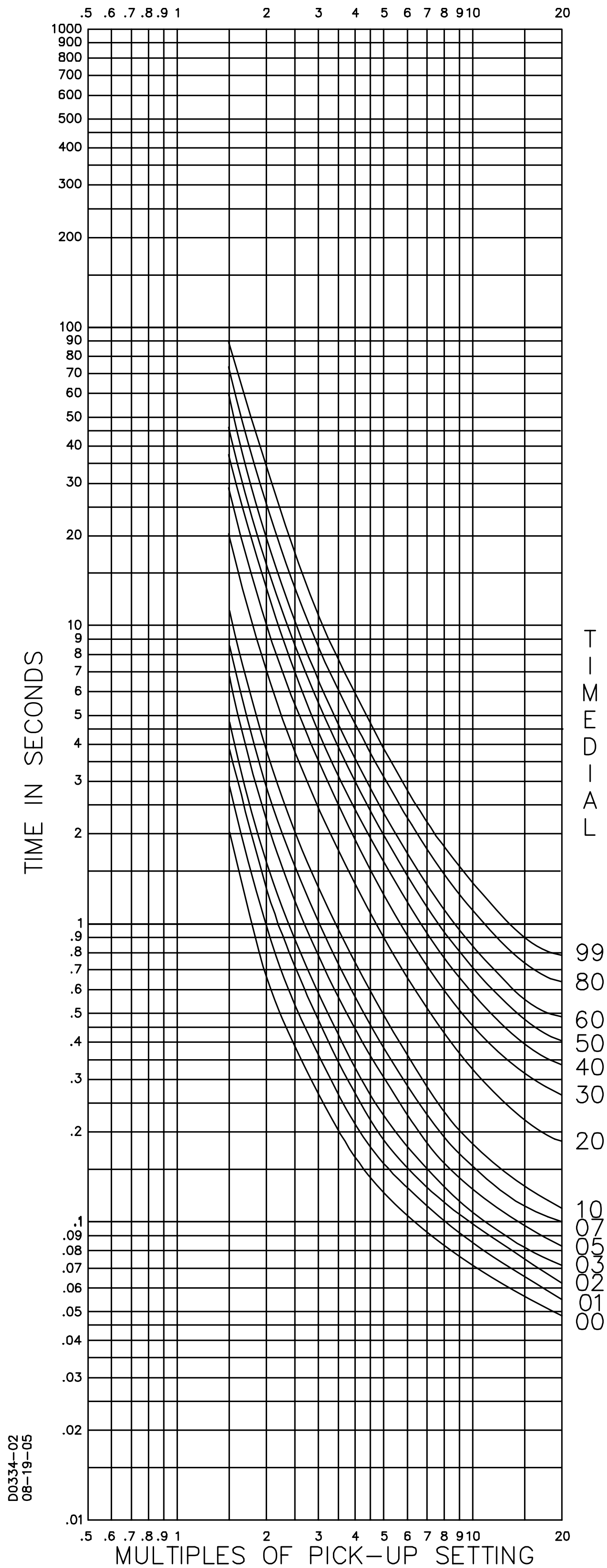

Figure A-12. Timing Type E7, BS 142 Extremely Inverse (Switch Position C, D, E, F)

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