INSTRUCTION MANUAL

FOR

TIME OVERCURRENT RELAY WITH VOLTAGE RESTRAINT

BE1-51/27R

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

P0050-11
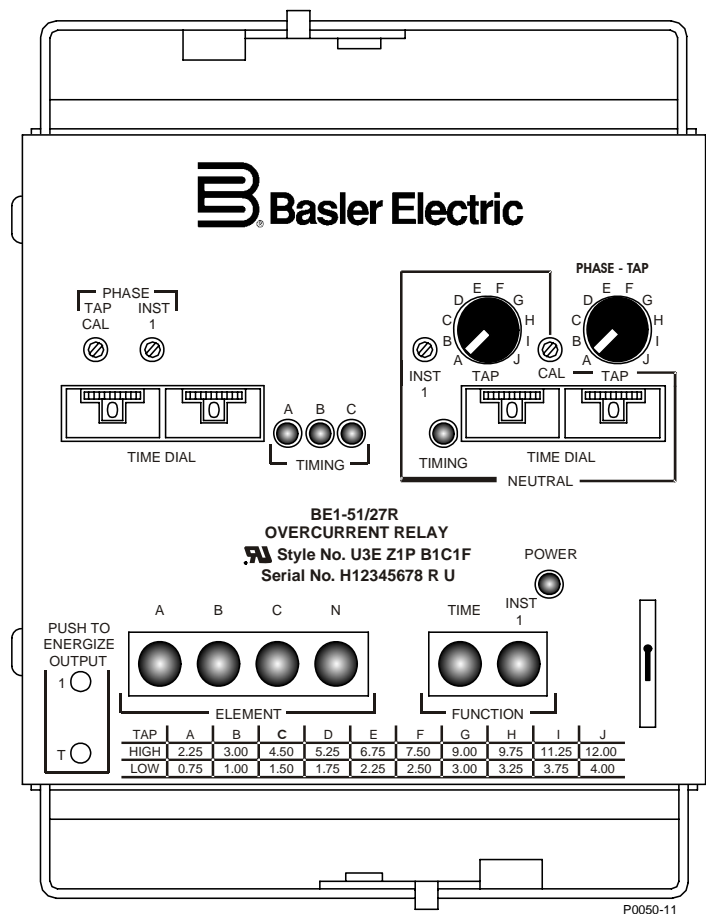
Basler Electric

INTRODUCTION

This instruction manual provides information about the operation and installation of the BE1-51/27R Time Overcurrent Relay with Voltage Restraint. To accomplish this, the following information is provided:

- General Information and Specifications

- Controls and Indicators

- Functional Description

- Installation

- Tests and Adjustments

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.

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.

REVISION HISTORY

The following information provides a historical summary of the changes made to the BE1-51/27R instruction manual (9137200999). Revisions are listed in reverse chronological order.

Manual Revision and Date	Change
C, 08/07	• Moved content of Section 6, *Maintenance* to Section 4. • Move Time Curve Graphs from Section 1 to Appendix A. • Updated front panel illustrations to show laser graphics. • Added manual part number and revision to all footers. • Updated manual to current style used. • Updated power supply burden data in Section 1. • Updated Target Indicator description in Section 3.
B, 05/05	• Added new information on wide range power supplies. • Added new information on case covers. • Changed *Specifications, Accuracy,* Page 1-10 and *Isolation,* Page 1-11. • Corrected Figure 1-51 and Table 2-4. • Deleted Figures 4-8 and 4-9, and references to the Service Manual (obsolete) in the *Introduction* and Section 6.
A, 09/03	• Enhanced the description of the B and C curves in Section 1. • Changes *Specifications: Time Overcurrent Pickup Accuracy; Time Overcurrent Dropout Ratio,* and *Isolation.* • Added formula for pickup current and Chart 1-1, *Instantaneous Response Time.* • Corrected Table 1-3, Figure 1-49, and Tables 2-2 and 2-4. • Corrected Figures 5-1 through 5-6 and *Test Procedures* to reflect changes in the *Specifications.* • Added Section 7, *Changes.*
—, 09/93	• Initial release

This page intentionally left blank.

CONTENTS

This page intentionally left blank.

SECTION 1 • GENERAL INFORMATION

TABLE OF CONTENTS

Tables

SECTION 1 • GENERAL INFORMATION

DESCRIPTION

BE1-51/27R Time Overcurrent Relays are microprocessor-based devices that provide voltage restraint of the phase time overcurrent function. With voltage restraint, the current pickup decreases proportionately with decreasing voltage over the rated voltage range. Instantaneous overcurrent element(s) and the neutral time overcurrent element, when supplied, operate independently of the voltage restraint function. Each relay is available with one, three, or four time overcurrent elements.

APPLICATION

Voltage restraint provides an added means of discriminating between load and fault conditions. This allows the time overcurrent pickup to be set below the maximum load (or swing) current. This feature permits the relay to provide dual protection on a generator. For example, either backing up the differential protection for generator faults and/or backing up other relays external to the generator zone. As a back-up function, it must be set with a relatively long delay. Prior to relay time-out, the synchronous impedance of the generator may be limiting fault current to a level comparable to rated. If the regulator is not in service to boost excitation, the steady-state fault current, even for a fault on the machine terminals, will usually be less than rated. The relay pickup must be below generator rated current to insure dependable operation.

Backup Protection

This relay is useful for generator time overcurrent back-up protection for other relaying external to the system. It also provides primary (first line) phase fault protection for small generators not equipped with differential protection.

Phase overcurrent units should be supplied on all three phases. Either three single-phase relays or one three-phase relay when the objective is to protect for phase-phase faults on the other side of a delta-wye power transformer. Currents at the relay for a three-phase fault are in the proportions of 2:1:1 in the three phases, so only one phase sees the higher current level. For this application, each phase time-overcurrent element should be restrained by the phase-to-ground voltage on its phase, rather than by the phase-phase voltage.

Following fault inception, current varies continuously as the field current decays. In addition, for other than a bolted fault on the terminals of a generator, the voltage will not be zero and will vary with time as the fault current decays. If the restraint voltage is between 25 and 100 percent, the time overcurrent element pickup will also vary with the time because of the changing voltage. Because the pickup varies with time, the multiples of pickup, and therefore the timing, will also change. These factors must be considered when coordinating with external protective devices. Section 4 of this manual provides additional coordination information in the paragraphs on setting the relay.

Instantaneous overcurrent elements would not ordinarily be used for a generator back-up function. They would not have acceptable operation for faults external to the generator zone.

Because the phase time-overcurrent pickup will be less than the maximum non-fault current, the relay can misoperate if the voltage signal is interrupted (e.g., a blown voltage transformer fuse). Where two sources of signal voltage are available, the BE1-60 Voltage Balance relay can prevent such a misoperation. This relay compares the output of two signal sources to detect an anomaly in one of these sources and block the operation of those devices connected to that signal source.

Residually Connected

A neutral (ground) overcurrent element can be applied and connected residually to a set of three current transformers on solidly grounded applications or on impedance grounded systems that provide ground fault current approximating rated current level. The neutral element can also be connected to a 10/1 ampere, zero-sequence window current transformer to provide protection on systems producing a minimum of about 20 amperes primary current. Still another alternative would be connecting this device to a current transformer in the neutral of a generator.

Operating Characteristics at Reduced Voltages

BE1-51/27R relays adjust the operating parameters based on system voltage. The sensitivity of the relay is increased as the system voltage drops. This provides a means of discriminating between load and fault conditions.

A decrease of the sensed voltage to a point between 100 percent and 25 percent of nominal results in a proportional decrease in the time overcurrent pickup point. Thus, at 50 percent nominal voltage, the time overcurrent relay will pickup at 50 percent of the setting (TAP + Calibration). At voltages above 100 percent nominal, the pickup will be the same as the setting. At voltages below 25 percent of nominal, the pickup will be 25 percent of the setting. Note that the BE1-51/27R is designed to trip at currents less than the setting if the voltage is depressed.

The timing characteristics of the BE1-51/27R continue to operate on multiples of pickup basis. Pickup refers not to the setting, but to the operating point as adjusted for voltage. Thus, with a setting of 5.0 amperes, and system voltage of 50 percent, a current of 5.0 amperes represents 2 times pickup. For a given fault current magnitude, the relay will trip faster at reduced voltage, because the multiples of pickup increases.

Table 1-1 shows the timing characteristics at normal and reduced voltages. The curve is B4 and the time dial is five. The pickup is five amperes. Tables 1-2 and 1-3 show the timing characteristics for multiples of setting as it relates to multiples of pickup with the BE1-51/27R at 25 percent voltage.

Table 1-1. Timing, Characteristic Curve B4, with BE1-51/27R at 100% and 50% Voltages

Fault Current	System Voltage	Effective Pickup	Multiples of Pickup	Approximate Trip Time
4.25 A	100%	5.0 A	<1.0	No Trip
4.25 A	50%	2.5 A	1.7	1.499 s
4.25 A	0%	1.25 A	3.4	0.507 s
7.50 A	100%	5.0 A	1.5	1.873 s
7.50 A	50%	2.5 A	3.0	0.772 s
7.50 A	0%	1.25 A	6.0	0.474 s
15.00 A	100%	5.0 A	3.0	0.772 s
15.00 A	50%	2.5 A	6.0	0.474 s
15.00 A	0%	1.25 A	12.0	0.355 s

Table 1-2. Timing, Curve B4, BE1-51/27R at 25% Voltage (00 to 10 Time Dial Settings)

Multiple of Setting	Multiple of Pickup	Time Dial Setting (Seconds)						
		00	01	02	03	05	07	10
0.38	1.50	0.604	0.856	1.111	1.370	1.873	2.384	3.142
0.43	1.70	0.480	0.688	0.899	1.104	1.499	1.930	2.504
0.50	2.00	0.382	0.539	0.705	0.866	1.194	1.517	1.994
0.55	2.20	0.344	0.484	0.633	0.775	1.063	1.349	1.780
0.63	2.50	0.300	0.419	0.548	0.663	0.918	1.168	1.542
0.68	2.70	0.278	0.387	0.508	0.620	0.850	1.073	1.420
0.75	3.00	0.250	0.354	0.461	0.561	0.772	0.977	1.284
0.88	3.50	0.218	0.308	0.403	0.494	0.672	0.855	1.127
1.00	4.00	0.202	0.281	0.360	0.445	0.602	0.772	1.016
1.13	4.50	0.186	0.261	0.334	0.410	0.557	0.709	0.936
1.25	5.00	0.176	0.243	0.308	0.377	0.506	0.649	0.831
1.50	6.00	0.159	0.220	0.285	0.347	0.474	0.599	0.790
1.75	7.00	0.151	0.204	0.263	0.320	0.435	0.553	0.727

Multiple of Setting	Multiple of Pickup	Time Dial Setting (Seconds)						
		00	01	02	03	05	07	10
2.00	8.00	0.142	0.191	0.246	0.300	0.412	0.520	0.683
2.25	9.00	0.136	0.185	0.240	0.290	0.939	0.499	0.654
2.50	10.00	0.130	0.180	0.227	0.277	0.372	0.477	0.622
3.00	12.00	0.123	0.170	0.215	0.262	0.355	0.453	0.593
3.50	14.00	0.118	0.163	0.208	0.250	0.341	0.433	0.566
4.00	16.00	0.117	0.159	0.201	0.243	0.329	0.420	0.548
4.50	18.00	0.112	0.153	0.195	0.237	0.322	0.406	0.537
5.00	20.00	0.111	0.154	0.188	0.231	0.316	0.400	0.526

Table 1-3. Timing, Curve B4, BE1-51/27R at 25% Voltage (20 to 99 Time Dial Settings)

Multiple of Setting	Multiple of Pickup	Time Dial Setting (Seconds)						
		20	30	40	50	60	80	99
0.38	1.50	5.671	8.222	10.788	13.344	15.919	20.918	25.707
0.43	1.70	4.533	6.556	8.527	10.662	12.694	16.698	20.464
0.50	2.00	3.593	5.207	6.808	8.407	9.986	13.164	16.276
0.55	2.20	3.198	4.636	6.041	7.482	8.906	11.694	14.486
0.63	2.50	2.766	4.003	5.218	6.454	7.682	10.146	12.453
0.68	2.70	2.569	3.720	4.848	5.986	7.130	9.381	11.557
0.75	3.00	2.322	3.358	4.372	5.409	6.434	8.489	10.454
0.88	3.50	2.026	2.931	3.829	4.726	5.627	7.406	9.120
1.00	4.00	1.833	2.647	3.450	4.258	5.076	6.688	8.214
1.13	4.50	1.691	2.438	3.188	3.932	4.673	6.166	7.597
1.25	5.00	1.464	2.117	2.749	3.380	4.022	5.303	6.513
1.50	6.00	1.424	2.060	2.688	3.314	3.949	5.200	6.396
1.75	7.00	1.318	1.897	2.479	3.060	3.644	4.802	5.899
2.00	8.00	1.234	1.792	2.329	2.884	3.430	4.518	5.561
2.25	9.00	1.184	1.704	2.229	2.748	3.273	4.298	5.290
2.50	10.00	1.120	1.604	2.093	2.589	3.070	4.053	4.977
3.00	12.00	1.073	1.551	2.018	2.498	2.971	3.917	4.817
3.50	14.00	1.028	1.481	1.928	2.390	2.841	3.741	4.603
4.00	16.00	0.989	1.430	1.866	2.304	2.741	3.610	4.443
4.50	18.00	0.958	1.392	1.818	2.243	2.667	3.514	4.328
5.00	20.00	0.944	1.372	1.786	2.200	2.619	3.454	4.252

STANDARD FEATURES

Time Overcurrent Functions

Time overcurrent elements pick up over a range of 0.1 to 0.8 amperes, 0.3 to 2.4 amperes, 0.5 to 4.0 amperes, 1.5 to 12.0 amperes, 0.1 to 2.4 amperes, or 0.5 to 12.0 amperes and provide an adjustable time delay that is proportional to the overcurrent. Time delay is initiated when the sensed current exceeds the pickup point. When the current drops below the pickup point, the timing circuit is reset immediately. At reset, the output contacts, if operated, are restored to normal.

Adjustment of the overcurrent pickup point is provided by controls on the relay front panel. Time delay is a function of the characteristic curve that has been selected. Time delay is settable from 00 to 99 on the

TIME DIAL thumbwheel switch located on the front panel. Curve type is selected either as an option or, in some models, is switch selectable.

Sixty-nine characteristic curves and three timing options are available. They are:

Characteristic curves:

- Seven inverse time
- Nine I^2t
- Seven inverse time with extended timing range
- Nine I^2t with extended timing range
- Five British Standard 142 (E curves)
- Seven integrating inverse time
- Nine integrating I^2t
- Seven integrating inverse time with extended timing range
- Nine integrating I^2t with extended timing range

Timing option Z1 (switch selectable - 16 position) B and C curves:

- Seven inverse time
- Nine I^2t

Timing option Z1 with option 2-D or 2-E (switch selectable - 16 position) B and C curves:

- Seven inverse time with extended timing range
- Nine I^2t with extended timing range

Timing option Z2 (switch selectable - 16 position) B and E (British Standard 142) curves:

- Seven inverse time
- One I^2t
- Five British Standard (BS) 142 (E curves)

Timing option Z2 with option 2-D or 2-E (switch selectable - 16 position) B and E (BS142) curves:

- Seven inverse time with extended timing range
- One I^2t with extended timing range
- Five British Standard 142 (E curves)

Timing option Z3 (switch selectable - 16 position) integrating B and C curves:

- Seven integrating inverse time
- Nine integrating I^2t

Timing option Z3 with option 2-D or 2-E (switch selectable - 16 position) integrating extended B and C curves:

- Seven integrating inverse time with extended timing range
- Nine integrating I^2t with extended timing range

Characteristic curves are shown by the graphs in Appendix A, *Time Overcurrent Characteristic Curves.* Note that each graph (i.e. function) consists of a set of representative curves. Each curve (as well as any between-curve interpolation) is selectable by the front panel **TIME DIAL** using a two-digit destination from 00 to 99. Because of space limitations, each graph shows only 14 of the 100 possible selections.

Non-Integrating Timing

Timing options Z1 and Z2 and the characteristic curves available with those options use non-integrating timing. Non-integrating timing is accomplished by timing at a gate that is not solely dependent on the magnitude of the applied multiple of pickup current. The time-out value is calculated based on the type of time curve characteristic selected, time dial setting, and the magnitude of the applied multiple of pickup current. The time-out value is continuously updated during the timing cycle. When pickup is exceeded, a timer is initiated. When the timer elapsed time exceeds the calculated time-out value, a time trip output signal is generated.

This type of non-integrating time delay characteristic exhibits a dynamic characteristic that is immediately responsive to changes of the applied multiple of pickup current.

Integrating Timing

Timing option Z3 and the characteristic curves available for that option uses integrating timing. Integrating timing is accomplished by summing time increments that are based on the magnitude of the applied multiple of pickup current, the time curve characteristic selected, and the time dial value. These time

increments are summed until a predetermined value is exceeded, then a time trip output signal is generated.

This type of integrating time delay characteristic simulates the operating characteristics of an electromechanical overcurrent relay.

Built-In Test

A built-in test (BIT) switch mounted on the Logic Board provides diagnostic troubleshooting and calibration.

OPTIONS

Timing

An extended timing option multiplies by approximately 5.7, the standard time delays. The resulting curves are shown following the standard curves in Appendix A - e.g., Figure A-1 is timing type B1 and Figure A-2 is the timing type B1 with extended timing range.

When timing option Z1, Z2, or Z3 is specified, a printed circuit board mounted selector switch allows a choice of up to sixteen different time overcurrent functions. Timing option Z1 or Z3 may be further specified as standard or extended time, depending upon option 2 selection.

Sensing Input Type

When single-phase, two-phase-and-neutral, three-phase, or three-phase-and-neutral sensing has been specified, the front panel **TAP** selector and the front panel **TAP CAL** control set the pickup point for all phases. An independent front panel **TAP (NEUTRAL)** selector and front panel **CAL (NEUTRAL)** control set the neutral pickup point. In addition, for three-phase-and-neutral sensing units, one of the seven sensing input range combinations must be specified.

Relay circuits provide a voltage restraint circuit that varies the selected time overcurrent pickup point proportional to the monitored voltage. As the monitored voltage varies between 100 percent and 25 percent of nominal, the pickup point for each phase varies between 100 percent and 25 percent. Nominal voltage is 100 Vac for 50-hertz systems and 120 Vac for 60-hertz systems. Neutral time overcurrent elements are not restrained. Three-phase voltages are measured phase-to-phase for three wire connections and phase-to-neutral for four wire connections.

Sensing Input Range

For three-phase-and-neutral sensing units, input ranges are:

- 0.5 to 4.0 amperes (phase and neutral)
- 1.5 to 12 amperes (phase) and 0.5 to 4.0 amperes (neutral)
- 0.5 to 4 amperes (phase) and 1.5 to 12 amperes (neutral)
- 1.5 to 12 amperes (phase and neutral)
- 0.1 to 0.8 amperes (phase and neutral)
- 0.3 to 2.4 amperes (phase) and 0.1 to 0.8 amperes (neutral)
- 0.3 to 2.4 amperes (phase and neutral)

For all other units, two ranges are available. They are 0.5 to 12 amperes and 0.1 to 2.4 amperes.

Power Supply

Five power supply options are available. They are:

- 24 Vdc
- 48 Vdc
- 125 Vdc and 100/125 Vac
- 48 Vdc or 125 Vdc and 100/125 Vac
- 250 Vdc and 240 Vac

Targets

Single-phase relays have two function targets that indicate when the time delay or instantaneous element(s) have operated. On multiple phase relays, additional targets indicate which phase or neutral element(s) operated.

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.

Outputs

Optional normally opened, normally closed, or SPDT auxiliary output contacts may be selected. Contacts actuate when the output relay is energized. Internally operated front panel mounted targets, and front panel targets operated by the dc current in the output circuit are available for the time overcurrent and instantaneous overcurrent functions. Optional front panel mounted **PUSH-TO-ENERGIZE-OUTPUT** pushbuttons allow direct actuation of each output relay for external circuit testing.

Instantaneous Outputs

One or two instantaneous overcurrent outputs are optionally available. Each is adjustable up to 40 times the time overcurrent pickup point. When the sensed current exceeds the instantaneous overcurrent pickup point, an output relay is energized. An independent front panel control **(INST 1** or **INST 2)** adjusts the pickup point for each optional output. If more than one phase is applied to the relay, the instantaneous pickup point will be the same for all phases. If neutral current is sensed, a front panel **INST 1 (NEUTRAL)** provides adjustment of the neutral pickup point. Instantaneous overcurrent elements are not voltage controlled.

Packaging

Each relay is mounted in a drawout cradle and enclosed in a standard utility style case with either semi-flush or projection mounting (depending upon case style selected). Circuit components are accessed by removing the individual printed circuit boards from the relay cradle. Use an extender card (Basler Electric part number: 9165500199) to test and troubleshoot the relay. An available test plug (Basler Electric part number: 10095 or G.E. part number 12XLA12A1) allows the relay to be tested in place without disturbing external control circuit wiring.

MODEL AND STYLE NUMBER DESCRIPTION

BE1-51/27R Time Overcurrent Relay electrical characteristics and operational features are defined by a combination of letters and numbers that make up its style number. 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.

Style Number Identification Chart (Figure 1-1) illustrates the manner in which the relay style number is determined. For example, if the style number were **U3E-Z1P-B1C1F,** the device would have the following characteristics:

|		
U	-	Three-Phase-and-Neutral sensing, 3-phase, 4-wire voltage restraint
3	-	Sensing input range of 1.5 to 12.0 amperes for phase and 0.5 to 4.0 amperes for neutral
E	-	Normally open outputs
Z1	-	Switch selectable time curves
P	-	Operating power derived from 125 Vdc or 120 Vac
B	-	Current operated targets
1	-	One instantaneous element
C	-	Push-to-energize outputs
1	-	Normally open auxiliary timed output relay
F	-	Semi-flush mounting
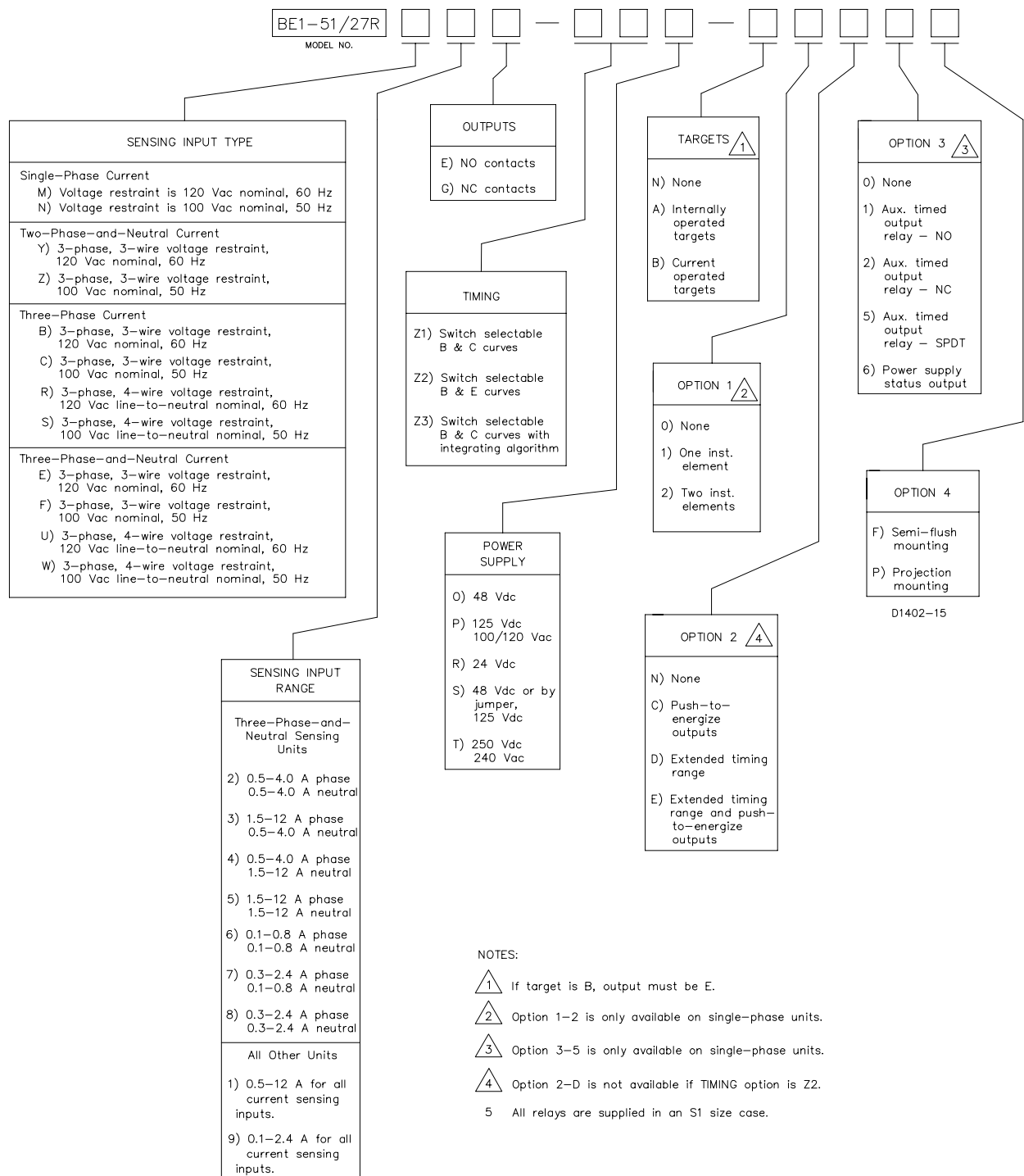
Figure 1-1. Style Number Identification Chart

SPECIFICATIONS

BE1-51/27R Time Overcurrent Relays electrical and physical specifications are as follows:

Voltage Sensing Inputs

Rated for 160 Vac continuous at 40 to 70 Hz (nominal frequency 50 or 60 Hz) with a maximum burden of 1 VA.

Sensing Input Burden

Less than 0.1 ohms per phase or neutral.

Sensing Input Rating

The maximum continuous rating is 20 A, 1 second current rating is 50X (times) the maximum tap current selected, or 500 A, whichever is less. For ratings other than those specified by the time curves, the rating is calculated as follows:

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

Where: I = Maximum current

T = Time that current flows (in seconds)

Time Overcurrent Pickup Selection Range

Continuously adjustable over the current sensing input ranges specified in the Style Chart (Figure 1-1).

Time Overcurrent Pickup Accuracy

Voltages ≥ Nominal

±5% of front panel tap selector setting with **TAP CAL** control fully CW or ±7% of minimum tap, whichever is greater.

Voltages < Nominal

±10% of calculated pickup value or ±7% of the minimum tap, whichever is greater.

To find the effective multiple of pickup current use the formula:

$$M = \frac{I}{I_t} \times \frac{V_N}{V}$$

Where: M = Multiple of tap value current

I = Applied current level

I_T = Tap value

V_N = Nominal voltage

V = Applied voltage level

Time Overcurrent Dropout Ratio

Better than 92% of pickup level.

Instantaneous Overcurrent Pickup Range

Continuously adjustable over the range of 1 to 40 times the time overcurrent pickup setting.

Instantaneous Overcurrent Measuring Accuracy

±2% of pickup setting.

Instantaneous Overcurrent Dropout Ratio

Better than 98% of pickup level.

Instantaneous Response

Figure 1-2 shows the typical response for the instantaneous pickup element.
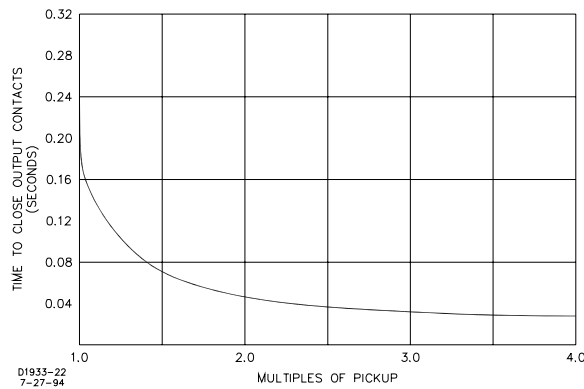
Figure 1-2. Typical Instantaneous Response Time

Time Delay Accuracy

±5% of the characteristic curve (Figures A-1 through A-69) for any combination of the front panel **TIME DIAL** setting and the front panel **TAP/TAP CAL** overcurrent pickup setting.

Repeatability is within ±2% of setting at 25°C.

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)

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.

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**	
O (mid range)	48 Vdc	24 to 150 Vdc	1.6 W
P (mid range)	125 Vdc 120 Vac	24 to 150 Vdc 90 to 132 Vac	1.9 W 8.9 VA
R (low range)	24 Vdc	12 to 32 Vdc *	1.7 W
S (mid range)	48 Vdc 125 Vdc	24 to 150 Vdc 24 to 150 Vdc	1.6 W 1.9 W
T (high range)	250 Vdc 240 Vac	68 to 280 Vdc 90 to 270 Vac	2.1 W 14.2 VA

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

Radio Frequency Interference (RFI)

Field-tested using a five-watt, hand-held transceiver operating at random frequencies centered around 144 MHz and 440 MHz, with the antenna located six inches from the relay in both horizontal and vertical planes.

Isolation

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

All circuits to ground: 2,828 Vdc
Input to output circuits: 2,000 Vac or 2,828 Vdc

Surge Withstand Capability

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

UL Recognized

UL recognized per Standard 508, UL File No. E97033. Note: Output contacts are not UL recognized for voltages greater than 250 volts and input power supply voltages greater than 150 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.

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 six sweeps, 15 minutes each sweep without structural damage or degradation of performance.

Weight

Single-Phase: 13.0 lbs. (5.90 kg)
Two-Phase and Neutral: 14.0 lbs. (6.35 kg)
Three-Phase: 14.0 lbs. (6.35 kg)
Three-Phase and Neutral: 14.4 lbs. (6.53 kg)

Case Size

S1 (Refer to Section 4 for case dimensions.)

SECTION 2 • CONTROLS AND INDICATORS

TABLE OF CONTENTS

This page intentionally left blank.

SECTION 2 • CONTROLS AND INDICATORS

INTRODUCTION

BE1-51/27R controls and indicators are located on the front panel and front interior. The controls and indicators are shown in Figure 2-1 and described in Table 2-1. Your relay may not have all of the controls and indicators shown and described here.
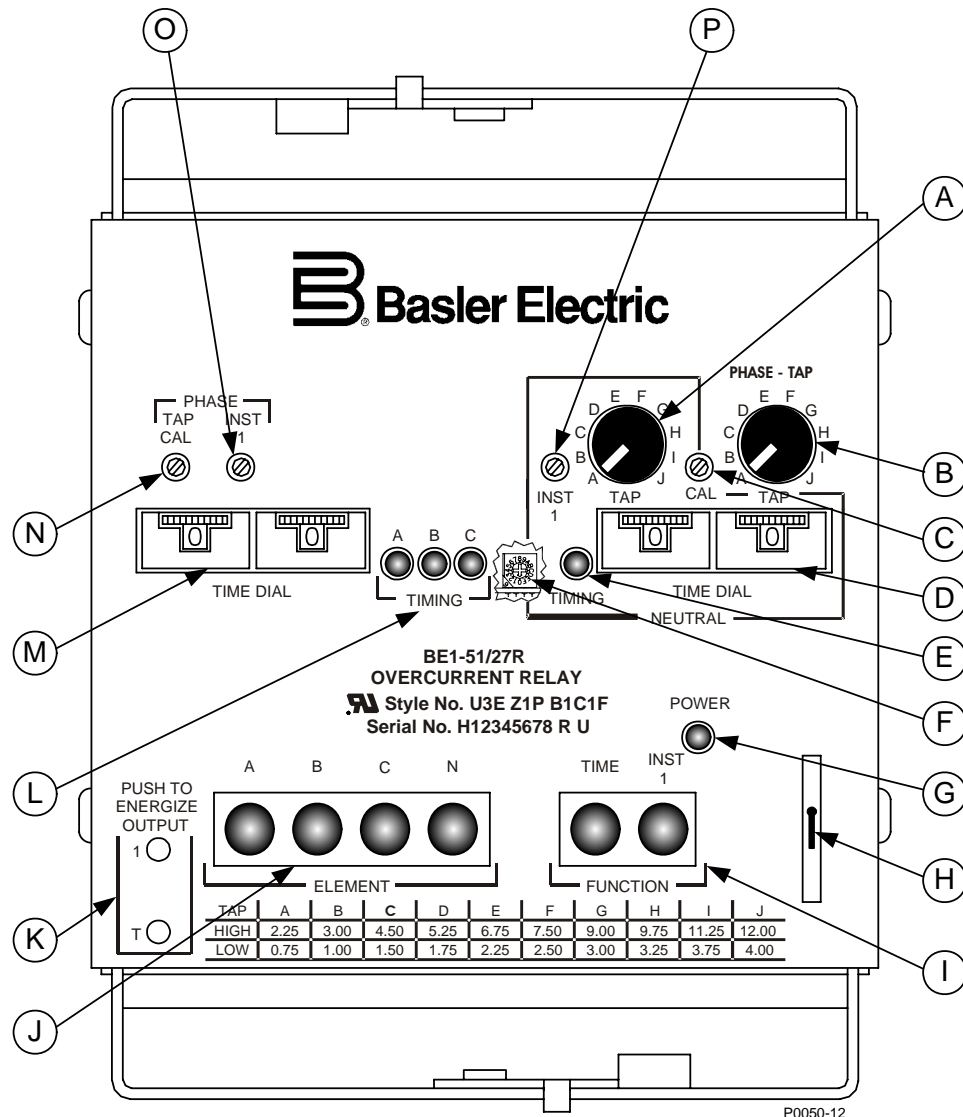
Figure 2-1. Location of Controls and Indicators

Table 2-1. Controls and Indicators

Call-Out	Control or Indicator	Function
A	**TAP NEUTRAL** Selector	Provides selection of the Neutral Overcurrent Pickup Point in conjunction with the front panel **NEUTRAL CAL** control.
B	**PHASE-TAP** Selector	Provides the selection of the Overcurrent Pickup Point in conjunction with the front panel **TAP CAL** control.
C	**CAL NEUTRAL** Control (On Relays with Phase-and-Neutral Sensing Only)	A single turn potentiometer provides adjustment of the Neutral Overcurrent Pickup Point between the selected tap setting and the next lower tap setting.
Not Shown	**TAP RANGE** Plate High/Low	Plate position indicates the terminal connections (high or low) used to select the current sensing input range. Refer to Table 2-2 for sensing input ranges.
D	**TIME DIAL NEUTRAL** (If present)	Determines the time delay between sensing of the overcurrent condition and the closing of the output relay. Refer to Appendix A and Table A-2 for curve selection information.
E	**TIMING NEUTRAL** (If present)	LED illuminates when the neutral pre-set Overcurrent Pickup Point is reached and exceeded.
F	Time Current Characteristic Curve Selector (Z1, Z2, and Z3 Timing Options Only)	Provides selection of the time current characteristic curves. Refer to Appendix A and Table A-2 for curve selection information. Cutaway view shows switch behind the front panel.
G	**POWER** Indicator	LED illuminates to indicate that the Relay Power Supply is functioning.
H	Target Reset Switch	Manually resets all targets (both element and function type).
I	**FUNCTION** Targets - **TIME, INST1, INST2**	Front panel **FUNCTION** targets light when the corresponding output relay is energized by an overcurrent condition. Refer to Table 2-3 for target installation configurations.
J	**ELEMENT** Targets∗	Front panel **ELEMENT** targets light when an output relay is energized by an overcurrent condition. Refer to Table 2-3 for target installation configurations.
K	**PUSH-TO-ENERGIZE OUTPUT** Pushbutton	Actuation of this function is by a thin non-conducting rod (do not use a screwdriver) through a hole in the front panel. This allows the Output Relays to be manually energized for testing of the external trip circuit(s).
		ELEMENT Targets, where supplied, are not operated by this control.
L	**TIMING** Indicator	LEDs light when the preset Overcurrent Pickup Point is reached and exceeded.
M	**TIME DIAL** Selector	Determines the time delay between sensing of the overcurrent condition and the closing of the output relay. Refer to Appendix A and Table A-2 for curve selection information.
N	**TAP CAL** Control	A single turn potentiometer provides adjustment of the Phase Overcurrent Pickup Point between the selected tap setting and the next lower tap setting.
O	**INST 1** Control (Options 1-1 and 1-2 Only)†	A four-turn potentiometer provides adjustment of the front panel **INST 1** trip setting over the range of 1 to 40 times the selected phase time overcurrent pickup (TAP) value.

Call-Out	Control or Indicator	Function
P	**INST 1 NEUTRAL** Control (Options 1-1 and 1-2 Only)†	A four-turn potentiometer provides adjustment of the front panel **INST 1 NEUTRAL** trip setting over the range of 1 to 40 times the selected neutral time overcurrent pickup (TAP) value.
Not Shown	**INST 2** Control (Option 1-2 Only)†	A four-turn potentiometer provides adjustment of the front panel **INST 2** trip setting of the range of 1 to 40 times the selected phase time overcurrent pickup (TAP) value.
Not Shown	N/T (Normal/Test) Switch S1	This switch is mounted internally on the Logic Board. Switch S1 provides stored built-in-test (BIT) programs to validate the calibration of the relay.

∗ The number of phases and neutral sensed by the relay is defined by the sensing input type (see the *Style Identification Chart,* Figure 1-1).

† This instantaneous overcurrent sensing circuit detects levels that are multiples of the level selected for the time overcurrent sensing circuit. Any change of the tap selector or calibration (CAL) controls will cause a directly proportional change of the instantaneous overcurrent levels.

Table 2-2. Sensing Input Ranges

TAP Range Plate or Pickup	TAP Selector										Current Sensing Terminals			
	A	B	C	D	E	F	G	H	I	J	ØA	ØB	ØC	N
Sensing Input Range 1, 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	—	—	—
LOW	0.75	1.00	1.50	1.75	2.25	2.50	3.00	3.25	3.75	4.00	9,7	—	—	—
Sensing Input Range 1, 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	—
Sensing Input Range 1, Two-Phase-and-Neutral ∗														
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
Sensing Input Range 2, Three-Phase-and-Neutral														
Phase or Neutral	0.75	1.00	1.50	1.75	2.25	2.50	3.00	3.25	3.75	4.00	8,9	13,14	15,16	17,18
Sensing Input Range 3, Three-Phase-and-Neutral														
Phase	2.25	3.00	4.50	5.25	6.75	7.50	9.00	9.75	11.25	12.00	8,9	13,14	15,16	—
Neutral	0.75	1.00	1.50	1.75	2.25	2.50	3.00	3.25	3.75	4.00	—	—	—	17,18
Sensing Input Range 4, Three-Phase-and-Neutral														
Phase	0.75	1.00	1.50	1.75	2.25	2.50	3.00	3.25	3.75	4.00	8,9	13,14	15,16	—
Neutral	2.25	3.00	4.50	5.25	6.75	7.50	9.00	9.75	11.25	12.00	—	—	—	17,18
Sensing Input Range 5, Three-Phase-and-Neutral														
Phase or Neutral	2.25	3.00	4.50	5.25	6.75	7.50	9.00	9.75	11.25	12.00	8,9	13,14	15,16	17,18

TAP Range Plate or Pickup	TAP Selector										Current Sensing Terminals			
	A	B	C	D	E	F	G	H	I	J	ØA	ØB	ØC	N
Sensing Input Range 6, Three-Phase-and-Neutral														
Phase or Neutral	0.15	0.20	0.30	0.35	0.45	0.50	0.60	0.65	0.75	0.80	8,9	13,14	15,16	17,18
Sensing Input Range 7, Three-Phase-and-Neutral														
Phase	0.45	0.60	0.90	1.05	1.35	1.50	1.80	1.95	2.25	2.40	8,9	13,14	15,16	—
Neutral	0.15	0.20	0.30	0.35	0.45	0.50	0.60	0.65	0.75	0.80	—	—	—	17,18
Sensing Input Range 8, Three-Phase-and-Neutral														
Phase or Neutral	0.45	0.60	0.90	1.05	1.35	1.50	1.80	1.95	2.25	2.40	8,9	13,14	15,16	17,18
Sensing Input Range 9 (All Other Sensing Types) ∗														
HIGH	0.45	0.60	0.90	1.05	1.35	1.50	1.80	1.95	2.25	2.40	Same as Range 1			
LOW	0.15	0.20	0.30	0.35	0.45	0.50	0.60	0.65	0.75	0.80	Same as Range 1			

∗ For relays with sensing input ranges 1 or 9, connect the system wiring to the current sensing terminals for the desired range (HIGH or LOW).

Table 2-3. Target Installation Configurations

Sensing Input Type	Number of Instantaneous Elements			Targets Installed (Types A and B)						
	None	One	Two	Element				Function		
				A	B	C	N	TIME	INST 1	INST 2
M, N	X							X		
		X						X	X	
			X					X	X	X
R, S	X			X	X	X				
		X		X	X	X		X	X	
U, W	X			X	X	X	X			
		X		X	X	X	X	X	X	
B, C		X		X	X	X		X	X	
			X	X	X	X		X		X
E, F		X		X	X	X	X	X	X	
			X	X	X	X	X	X		X
Y, Z	X			X		X	X	X		
		X		X		X	X	X	X	

SECTION 3 • FUNCTIONAL DESCRIPTION

TABLE OF CONTENTS

This page intentionally left blank.

SECTION 3 • FUNCTIONAL DESCRIPTION

GENERAL

BE1-51/27R Time Overcurrent Relays are microprocessor-based devices that provide voltage restraint of the phase time overcurrent functions.

BLOCK DIAGRAM ANALYSIS

The following block diagram analysis is referenced to Figure 3-1. A microprocessor (not illustrated in Figure 3-1) processes signals, performs logic functions, and all of the time overcurrent computations.
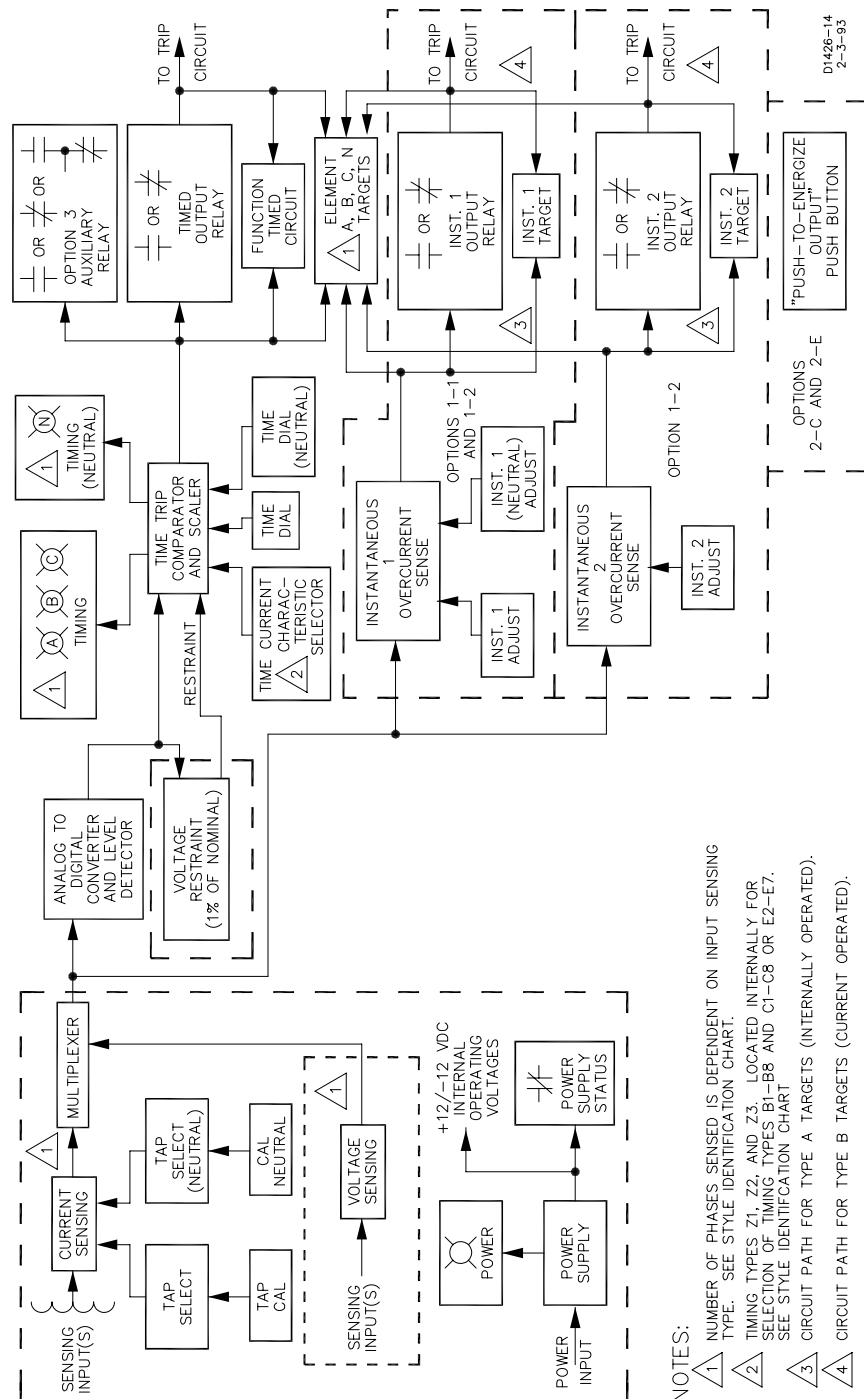
Figure 3-1. Functional Block Diagram

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.

Current Sensing

All relay models (except three-phase-and-neutral units) have two sensing ranges for each phase. Each high/low sensing range has its own set of input terminal connections.

- Five ampere CTs have: LOW (0.5 A to 4.0 A) and HIGH (1.5 A to 12.0 A).
- One ampere CTs have: LOW (0.1 A to 0.8 A) and HIGH (0.3 A to 2.4 A).

Three-phase-and-neutral sensing units, however, have one of four possible combinations of input sensing ranges with one range for neutral and one range for the phases.

- Five ampere CTs have: 0.5 A to 4.0 A and 1.5 A to 12.0 A.
- One ampere CTs have: 0.1 A to 0.8 A and 0.3 A to 2.4 A.

Tap Select and Tap Cal

Front panel **TAP** selectors and **TAP CAL** controls are provided for selection and precise adjustment of the phase and neutral (if provided) time overcurrent pickup points. The front panel **TAP** selectors, ten-position BCD weighted rotary switches, select the desired current sensing pickup point, while the front panel **TAP CAL** controls provide precise adjustment between the selected setting and the next lower setting.

Voltage Sensing

Input voltage for each phase to be monitored are applied to the voltage sensing circuits. Each voltage sensing circuit consists of an input transformer, rectifier, and filter Analog voltages from the voltage sensing circuits are applied to the multiplexor. Note that neutral is not monitored for voltage.

Multiplexor

The multiplexor sequentially switches a voltage representing each of the sensed input currents to the analog-to-digital converter and level detector.

Analog-To-Digital Converter and Level Detector

When the voltage representing the actual sensed inputs meets or exceeds the selected pickup point, this circuit converts the level to a corresponding binary number and applies it to a time trip comparator and scaler circuit and to a counter for calculation of the required time delay.

Time Trip Comparator and Scaler

This circuit accepts both the binary number representing the detected current level and the desired time delay characteristic selected by the front panel **TIME DIAL**, then computes the required time delay before the timed output relay will be energized. Time delay characteristics are shown in the curves located in Appendix A. If extended timing range options 2-D or 2-E is present, the time delay characteristic curves are modified so that the time delay is approximately 5.7 times the derived value.

Time delay computations are updated continuously so that changes in the overcurrent condition are monitored and result in a corresponding change in the time delay. A software counter begins counting when the initial binary number is received from the analog-to-digital converter and level detector. The counter measures the elapsed time of the overcurrent condition, and resets if the current decreases below the pickup point. This continuously increasing binary number is then passed to the comparator.

Voltage Restraint

Voltage restraint compares the binary number representing the monitored voltage with the fixed nominal voltage limit (100 Vac for 50-hertz systems and 120 Vac for 60-hertz systems). When the voltage is between 100 percent and 25 percent of the nominal voltage, the circuit automatically lowers the selected time overcurrent pickup point proportionally. Instantaneous overcurrent operation, if present, is not affected. Neutral is not monitored for voltage, nor is the neutral time overcurrent pickup point restrained.

When the voltage is above the 100 percent limit, the pickup point is restrained to 100 percent. When the voltage is below the 25 percent limit, the pickup point remains at the 25 percent point.

For a given level of current above pickup, a lowering of the pickup point, via voltage restraint effectively increases the multiples of current. This shifts the time delay characteristic to the right on the multiples-of-pickup-current axis (characteristic curves) as voltage drops from 100 percent to 25 percent.

To find the effective multiple of pickup current use the formula:

$$M = \frac{I}{I_t} \times \frac{V_N}{V}$$

Where: M = Multiple of tap value current
I = Applied current level
I_T = Tap value
V_N = Nominal voltage
V = Applied voltage level

Microprocessor (Not Shown)

Some of the circuitry already discussed is part of the microprocessor and no definite lines are drawn to separate the functions. The microprocessor compares the desired time delay (from the time trip comparator and scaler) with the actual elapsed time from the counter. When the elapsed time reaches the intended delay, the timed output relay is energized. During the time delay period, the front panel TIMING indicator (i.e. pickup) associated with the detected phase is illuminated.

If targets are present, the front panel **TIME FUNCTION** target will be tripped, and the **A, B, C,** or **N ELEMENT** target associated with the detected phase will be tripped. See Table 2-3 for the types of targets that are present (depending upon relay configuration).

If option 3 is present, an auxiliary output relay (with either N.O., N.C., or SPDT contacts) is also actuated when the timed output relay energizes.

Instantaneous Overcurrent (Options 1-1 and 1-2)

Input current levels applied to the time overcurrent circuitry are also passed to the instantaneous overcurrent circuitry. These levels are compared to the setting of the front panel **INST 1** adjust and the front panel **INST 1 (NEUTRAL)** adjust (if present). If the input current level is above the setting, the output driver energizes the instantaneous 1 output relay. If the instantaneous 2 option is present, the input level is also compared with the setting of the front panel **INST 2** adjust to energize the instantaneous 2 output relay. Not that the current level settings for the instantaneous overcurrent element will always be from 1 to 40 times above the front panel **TAP** and **TAP (NEUTRAL)** settings of the time overcurrent element.

If target type A or B is present, the front panel **INST 1** target and the front panel **INST 2** targets are tripped when their respective output relay is energized, along with the front panel **A, B, C** or **N ELEMENT** targets (if present) associated with the detected phases. (See Section 2, *Controls and Indicators,* for the types of targets that can be present depending upon the relay configuration.)

Timed and Instantaneous Outputs

Each output signal (representing either time overcurrent or instantaneous overcurrent) from each monitored phase (or neutral) is applied to the respective output driver. Each output driver supplies operating current to energize the associated output relay. Either normally open (output type E) or normally closed (output type G) contacts may be specified. (The contact configurations of all output relays for a given model will be the same.)

Auxiliary Outputs

In addition to the output relays, an auxiliary relay, having the same or a different contact configuration, may be specified. Both the output and the auxiliary relays will remain energized for the duration of the overcurrent condition.

Push-to-Energize Pushbuttons

If either option 2-C or 2-E is present, each individual output relay can be directly energized for test purposes by the actuation of a front panel **PUSH-TO-ENERGIZE OUTPUT** pushbutton. The pushbutton is actuated by the insertion of a thin, non-conducting rod through an access hole in the front panel.

Power Supply Status Output (Option 3-6)

Power supply status output relays have a set of normally closed contacts that are energized open during power-up. If either or both power supply output legs (+12 Vdc or -12 Vdc) fails, the power supply status output relay is de-energized and the output contacts close. Shorting bars across the output contacts are held open by the installed connection plug. When the relay is removed from service by removing the connection plug, the shorting bars are closed.

Target Indicators

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

The relay trip outputs 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 <u>and</u> the presence of at least 200 milliamperes of current flowing in the trip circuit.

Note that the front panel function targets (**TIMED, INST 1,** etc.) may be either internally or current operated. Phase and neutral indicators are current operated <u>only</u> if the instantaneous options are not included <u>and</u> if current operated targets are specified.

NOTE

Prior to August 2007, BE1-51/27R 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

TABLE OF CONTENTS

This page intentionally left blank.

SECTION 4 • INSTALLATION

INSTALLATION

BE1-51/27R 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, *Tests and Adjustments* 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. Refer to Figures 4-1 through 4-5 for relay outline dimensions and panel drilling diagrams.
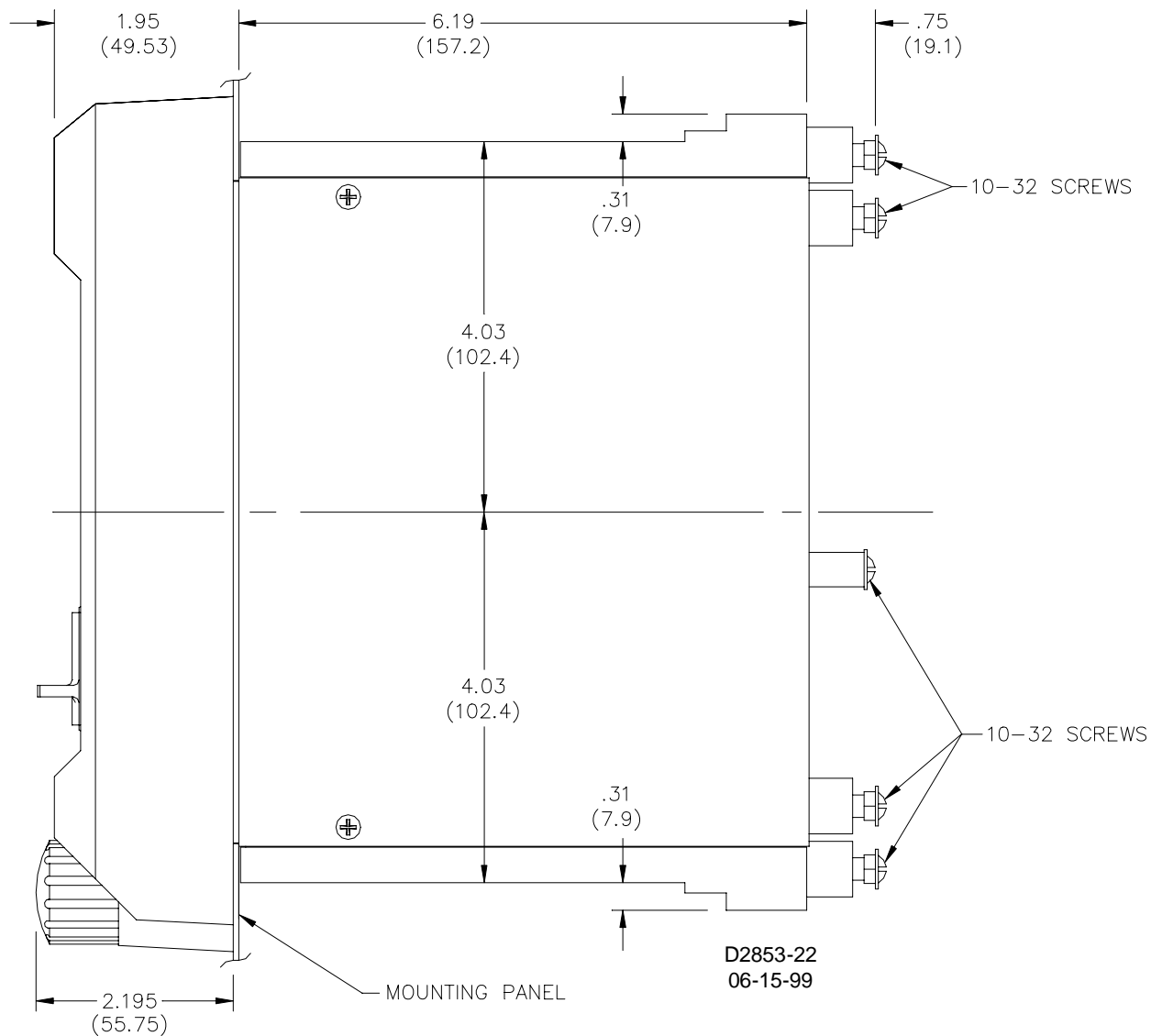
Figure 4-1. Outline Dimensions, Side View, Semi-Flush Mounted, Double-Ended Case

1.95
(49.53)

6.19
(157.2)

.75
(19.1)

.31
(7.9)

10-32 SCREWS

MOUNTING PANEL

A   A

5/16-18 STUD
2 PLACES

4.03
(102.4)

.25
(6.4)

D2856-06
06-16-99

4.03
(102.4)

MOUNTING PANEL

10-32 SCREWS

.31
(7.9)

TERMINAL EXTENSION (TYP.)
FOR DETAILED INSTRUCTIONS.
SEE THE TERMINAL PROJECTION
MOUNTING KIT SUPPLIED.

.75
(19.1)

2.195
(55.75)
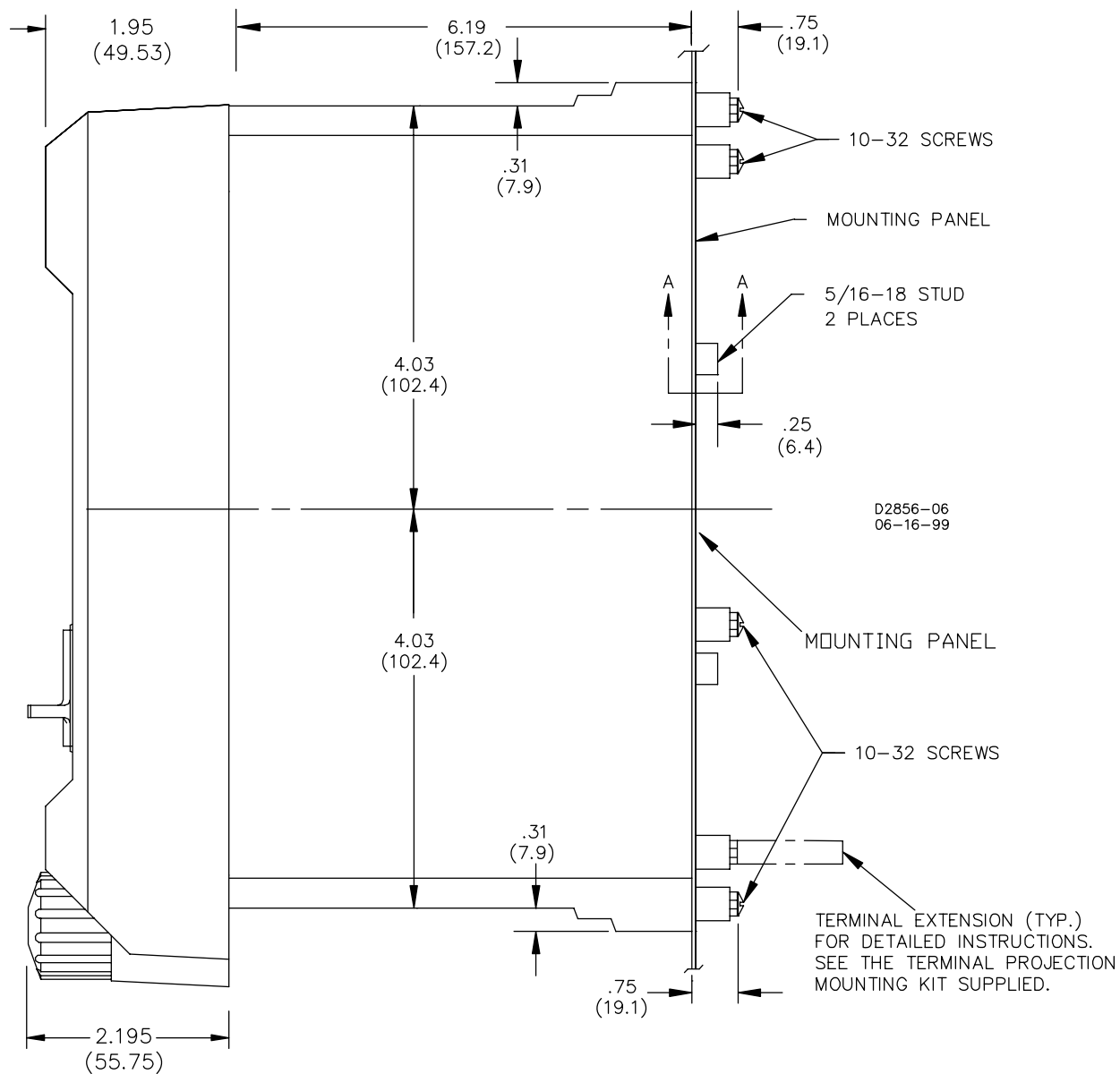
Figure 4-2. Outline Dimensions, Side View, Projection Mounted, Double-Ended Case

6.65
(169)

9.32
(237)

D2816-17
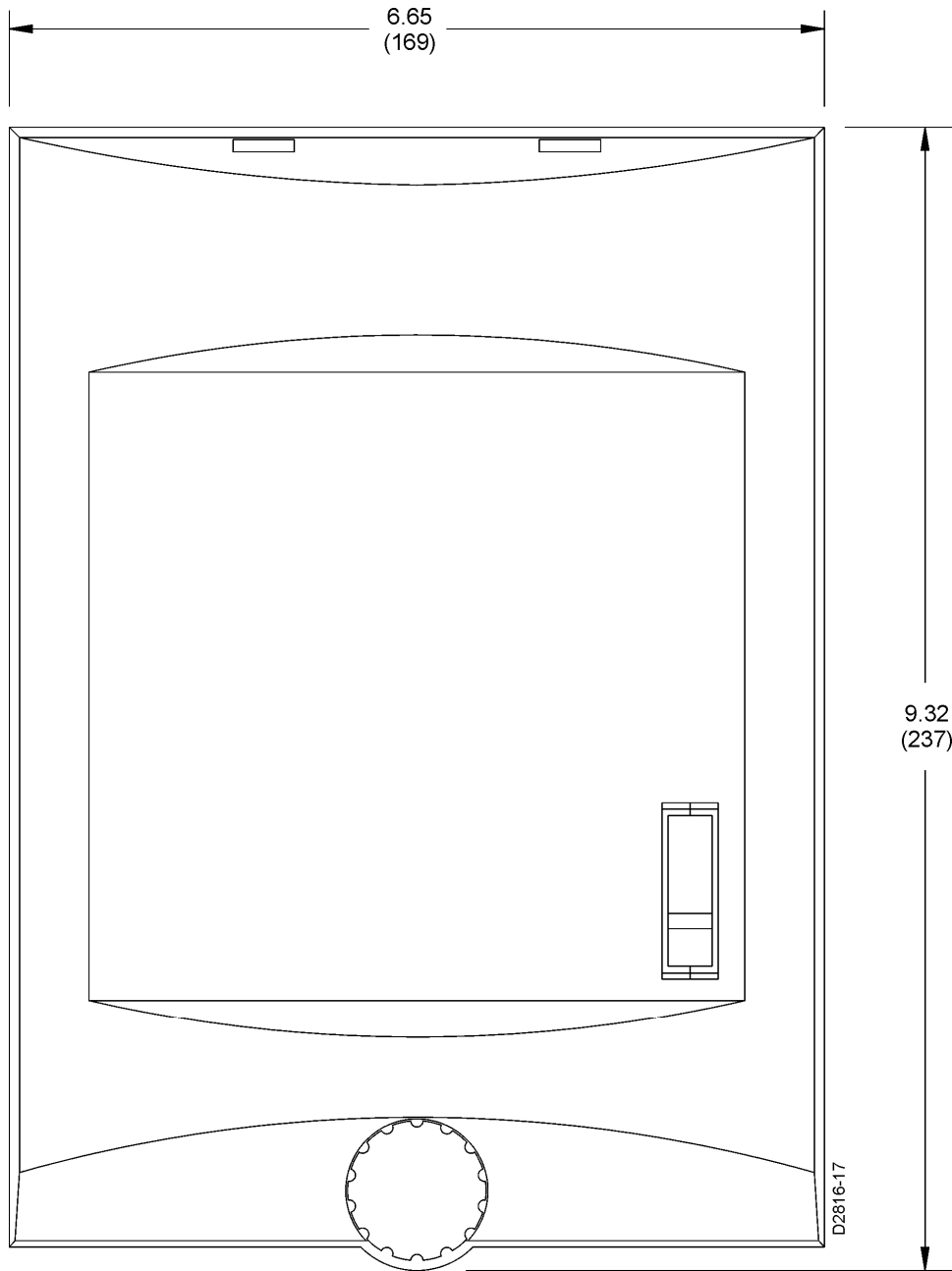
Figure 4-3. Outline Dimensions, Front View, Case Cover
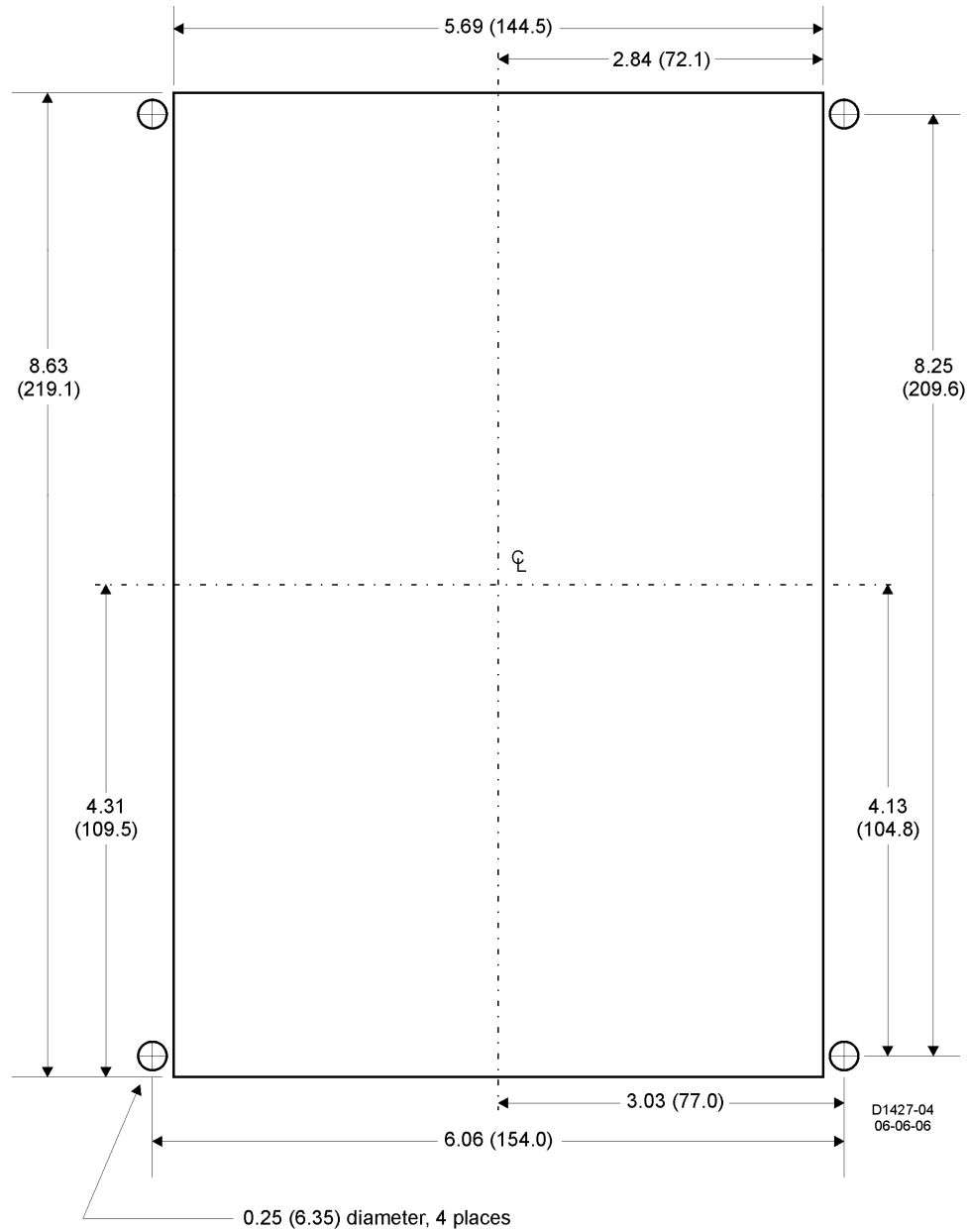
Figure 4-4. Panel Cutting and Drilling Dimensions, Semi-Flush Mounting, Double-Ended Case
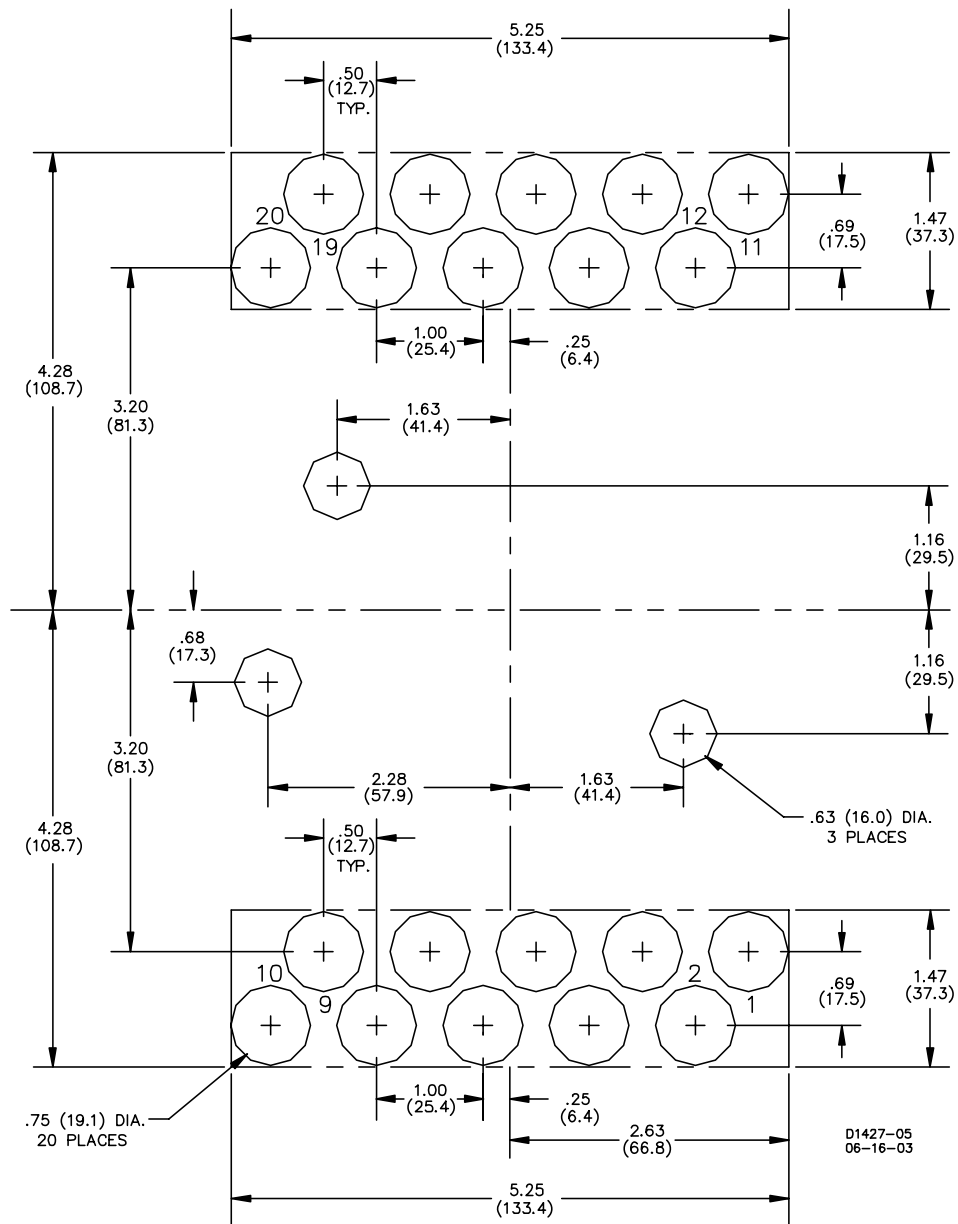
Figure 4-5. Panel Drilling Dimensions, Projection Mounting, Double-Ended Case

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.

Typical external connections are shown in Figures 4-6 through 4-12. Internal connections are shown in Figures 4-13 though 4-18.

To prevent an inductive overload of the relay contacts, it is necessary to break the trip circuit externally through the 52a contacts.

Relay circuitry is connected to the case terminals by removable connection plugs (1 plug for 10-terminal cases and 2 plugs for 20-terminal cases). Removal of the connection plug(s) opens the normally open trip contact circuits and shorts the normally closed trip circuits before opening the power and sensing circuits.
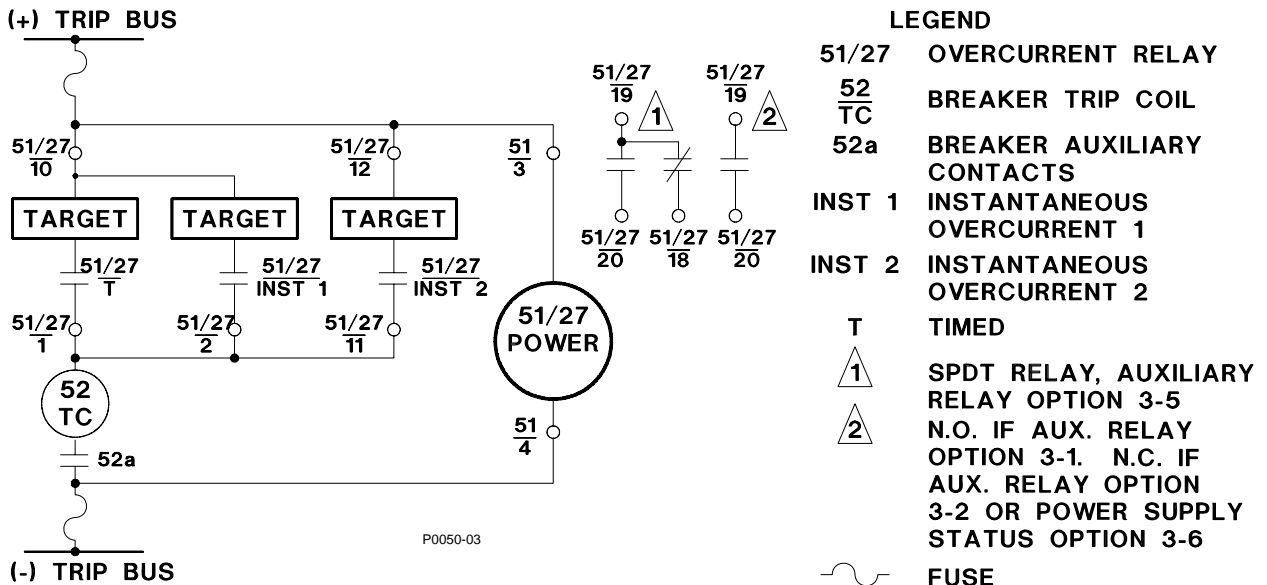
Figure 4-6. Typical External Connections, Current Operated Targets, DC Powered
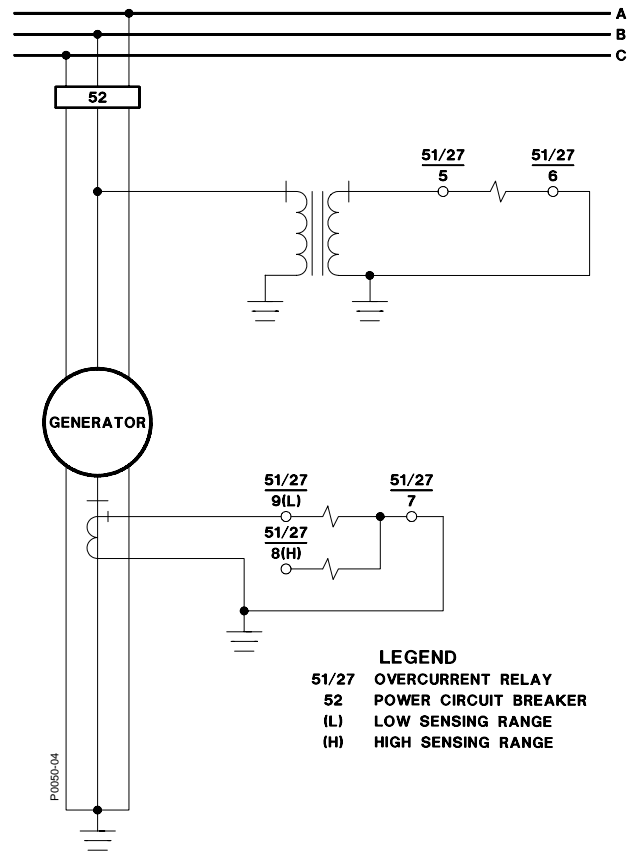
Figure 4-7. Typical Sensing External Connections, Sensing Input Type M or N
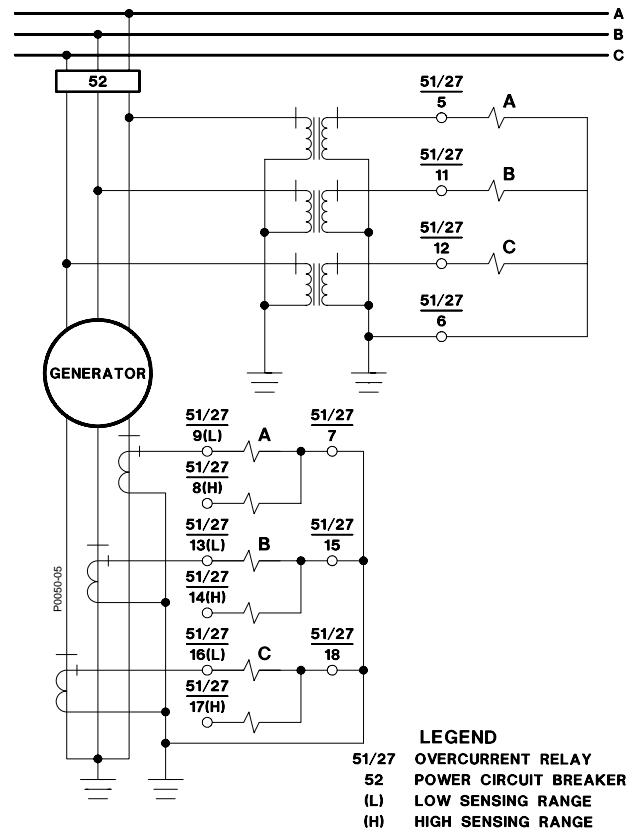
Figure 4-8. Typical Sensing External Connections, Sensing Input Type R or S
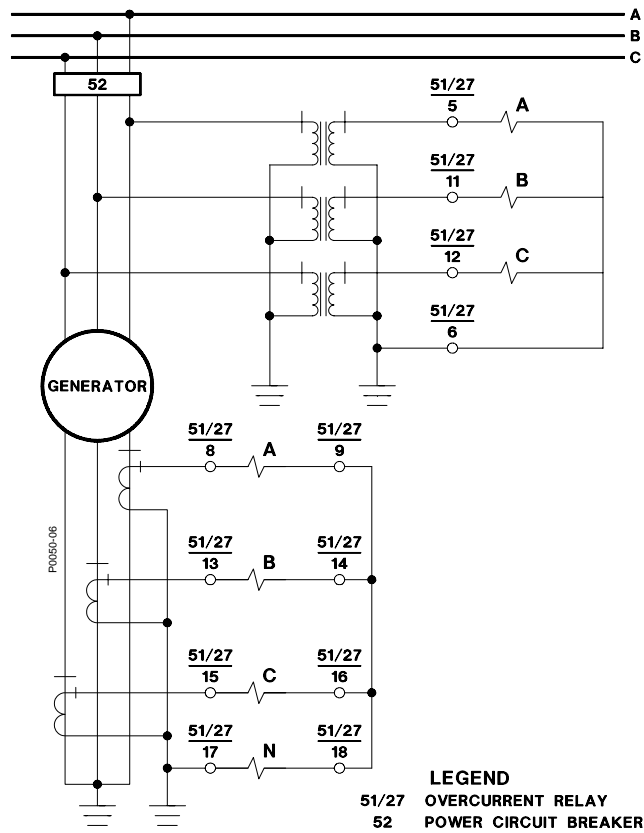
Figure 4-9. Typical Sensing External Connections, Sensing Input Type U or W
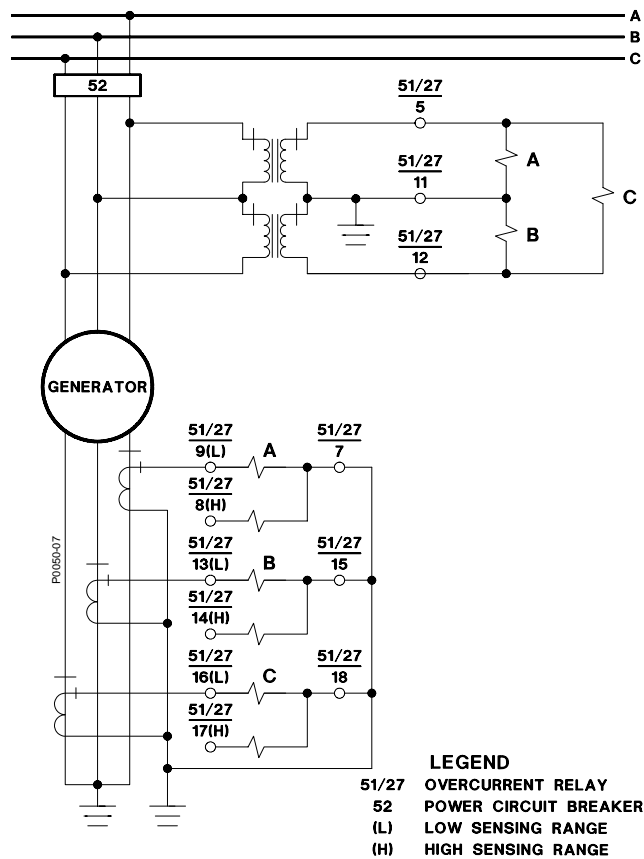
Figure 4-10. Typical Sensing External Connections, Sensing Input Type B or C
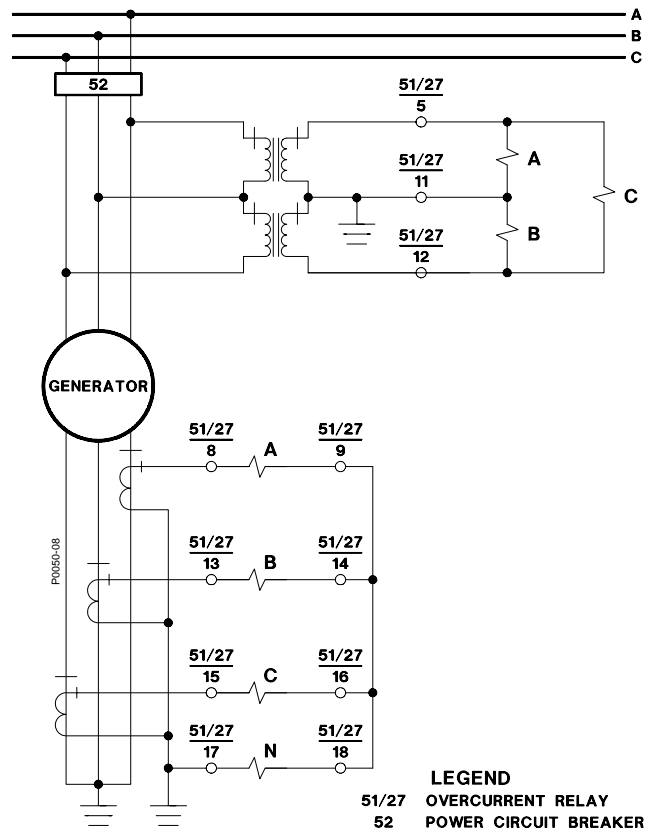
Figure 4-11. Typical Sensing External Connections, Sensing Input Type E or F
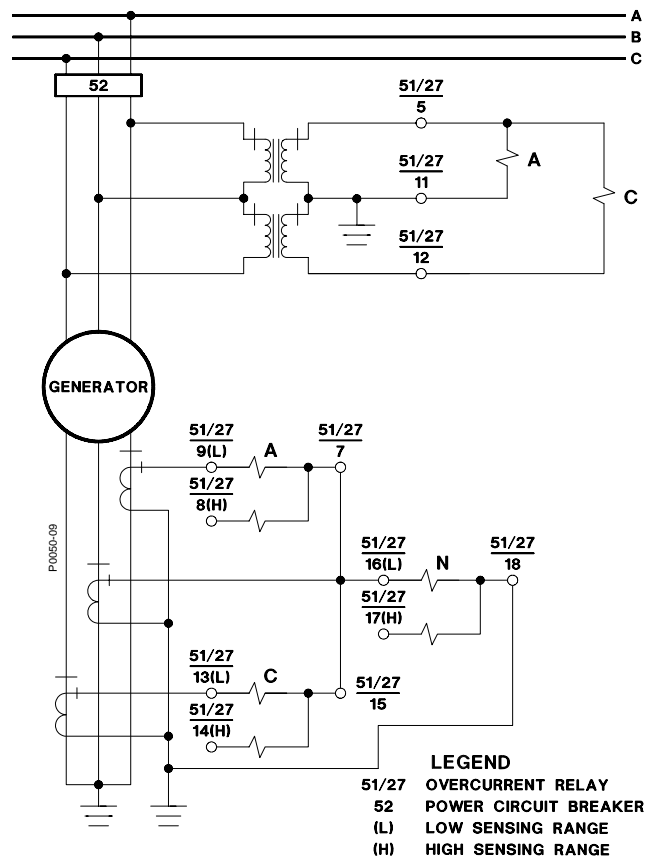
Figure 4-12. Typical Sensing External Connections, Sensing Input Type Y or Z
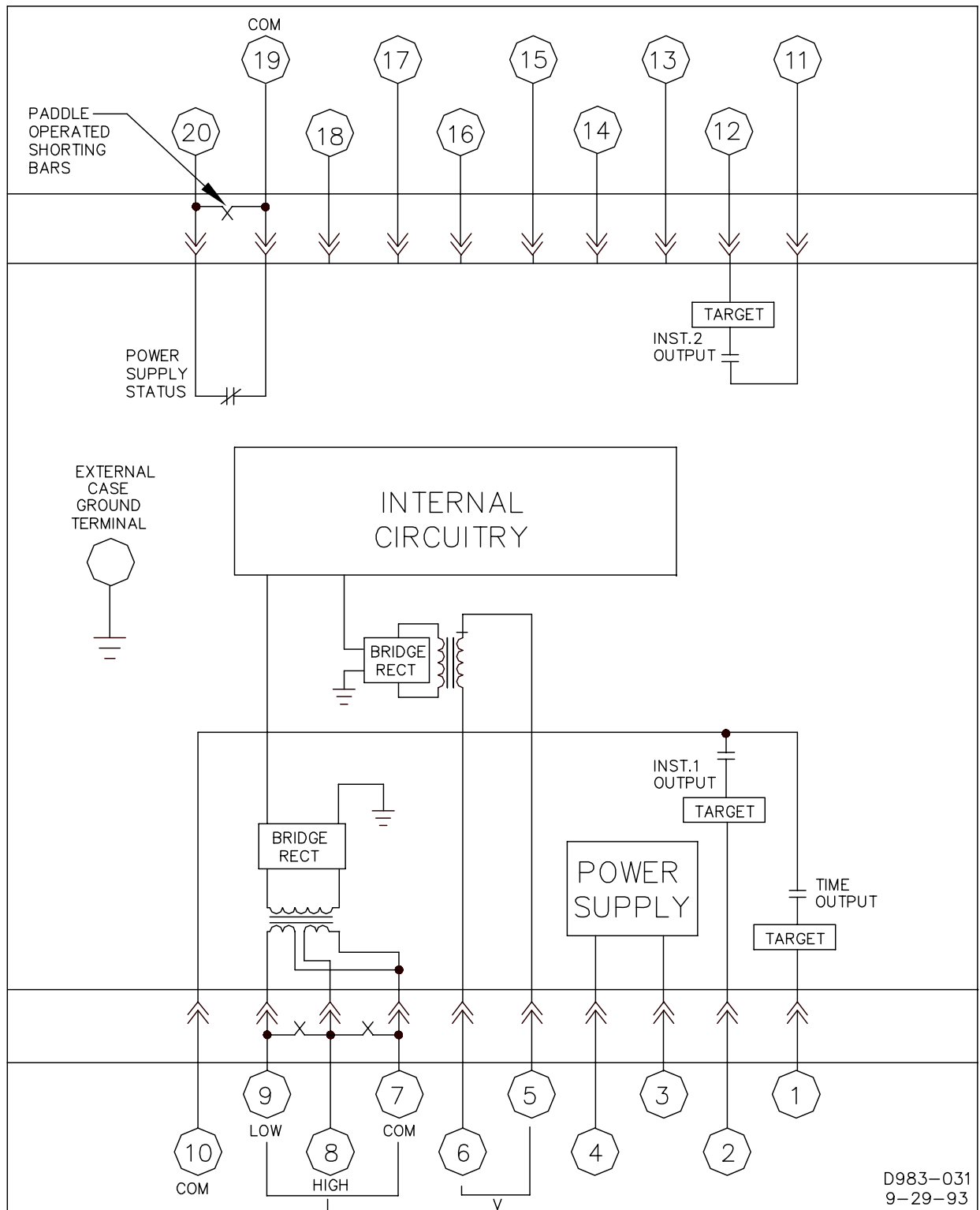
Figure 4-13. Typical Internal Diagram, Sensing Input Type M or N
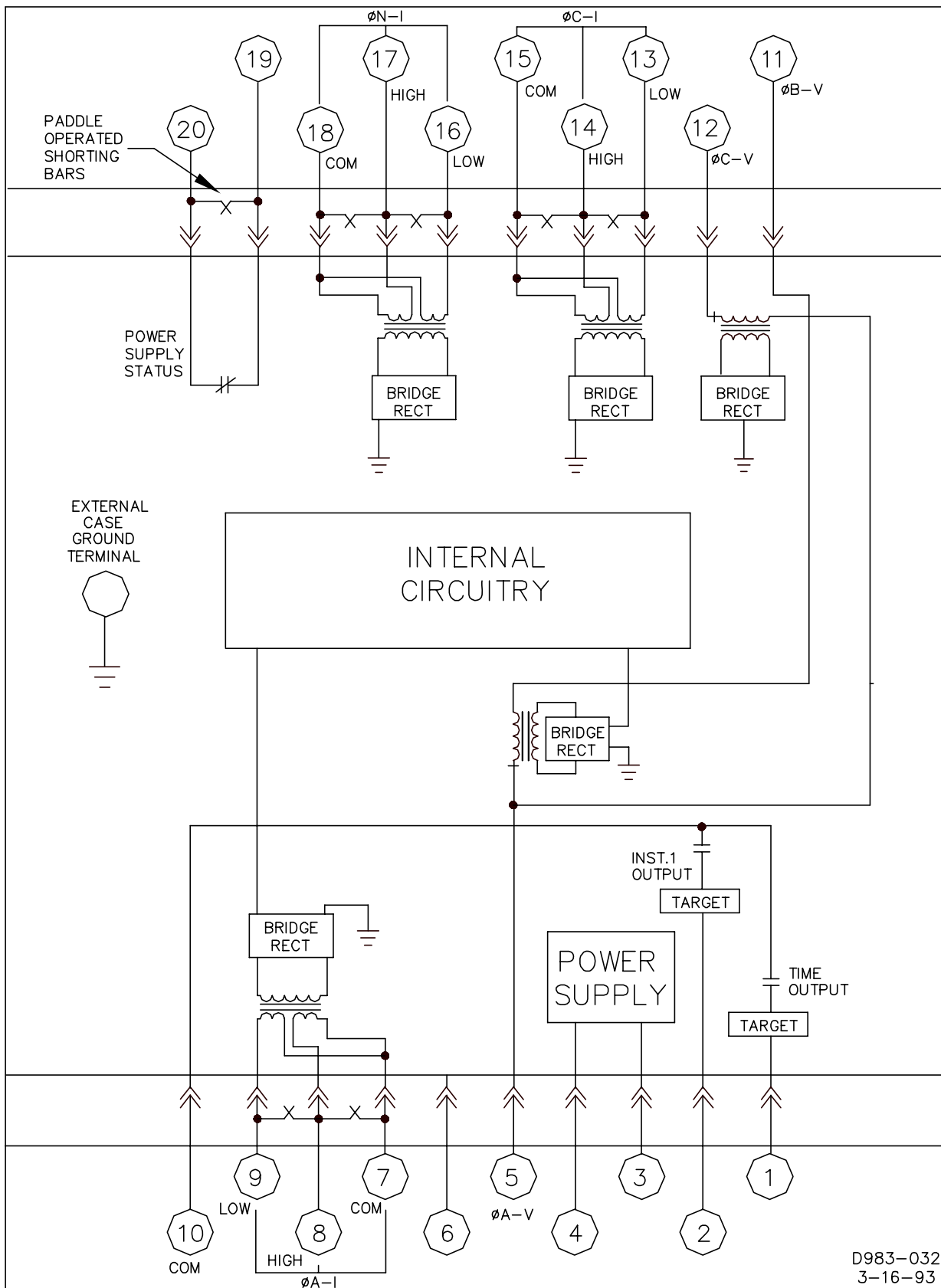
Figure 4-14. Typical Internal Diagram, Sensing Input Type Y or Z
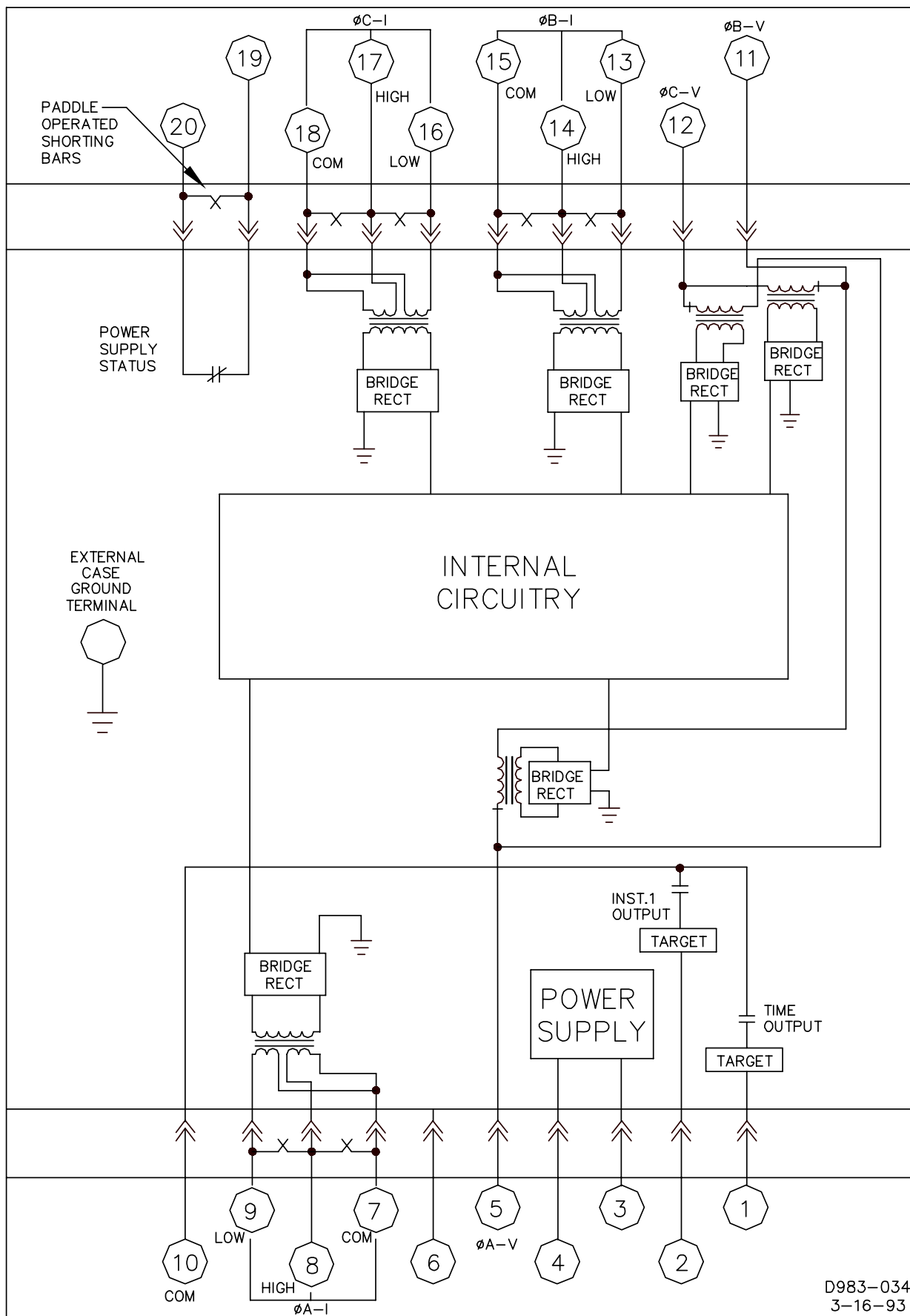
Figure 4-15. Typical Internal Diagram, Sensing Input Type B or C
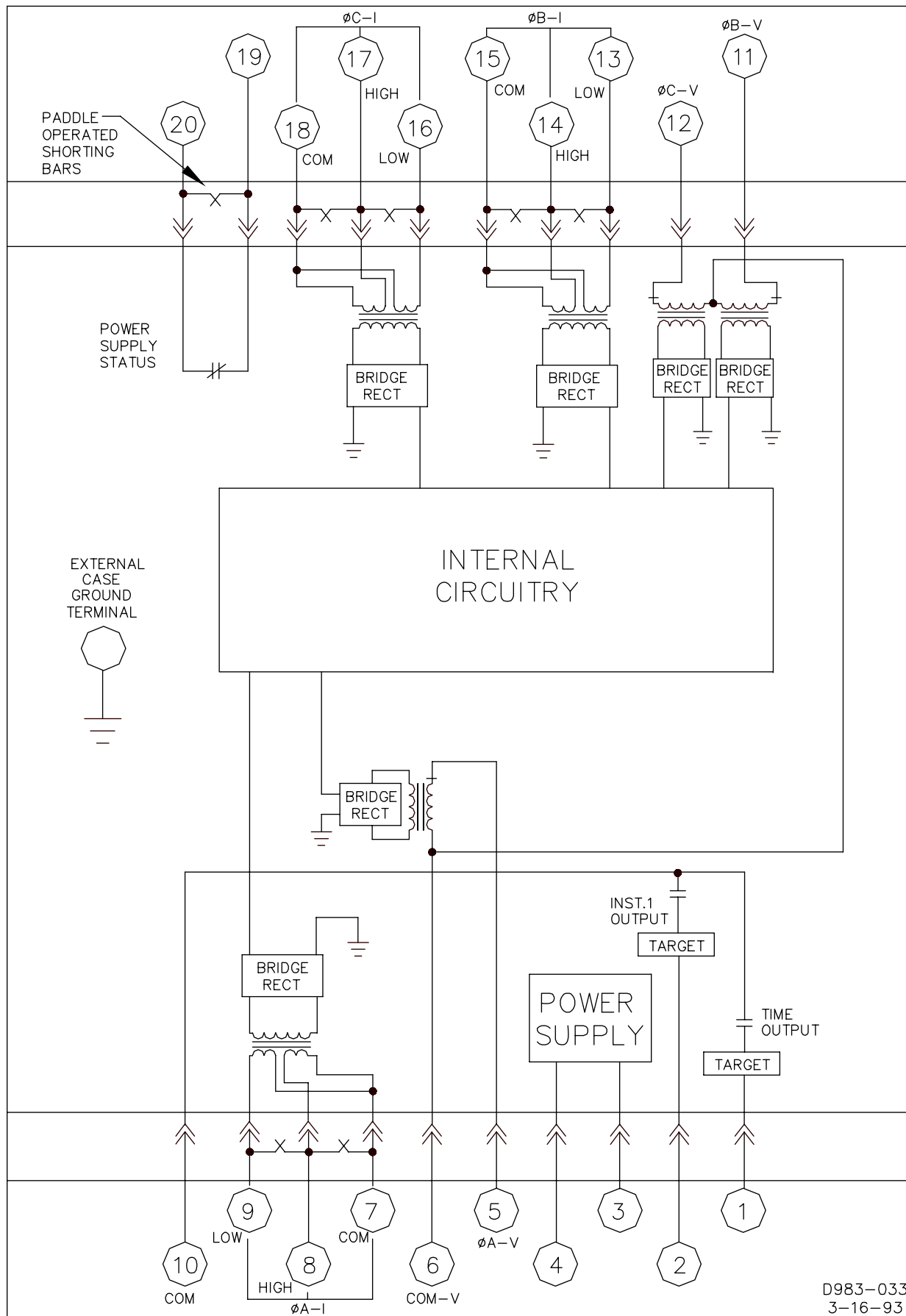
Figure 4-16. Typical Internal Diagram, Sensing Input Type R or S
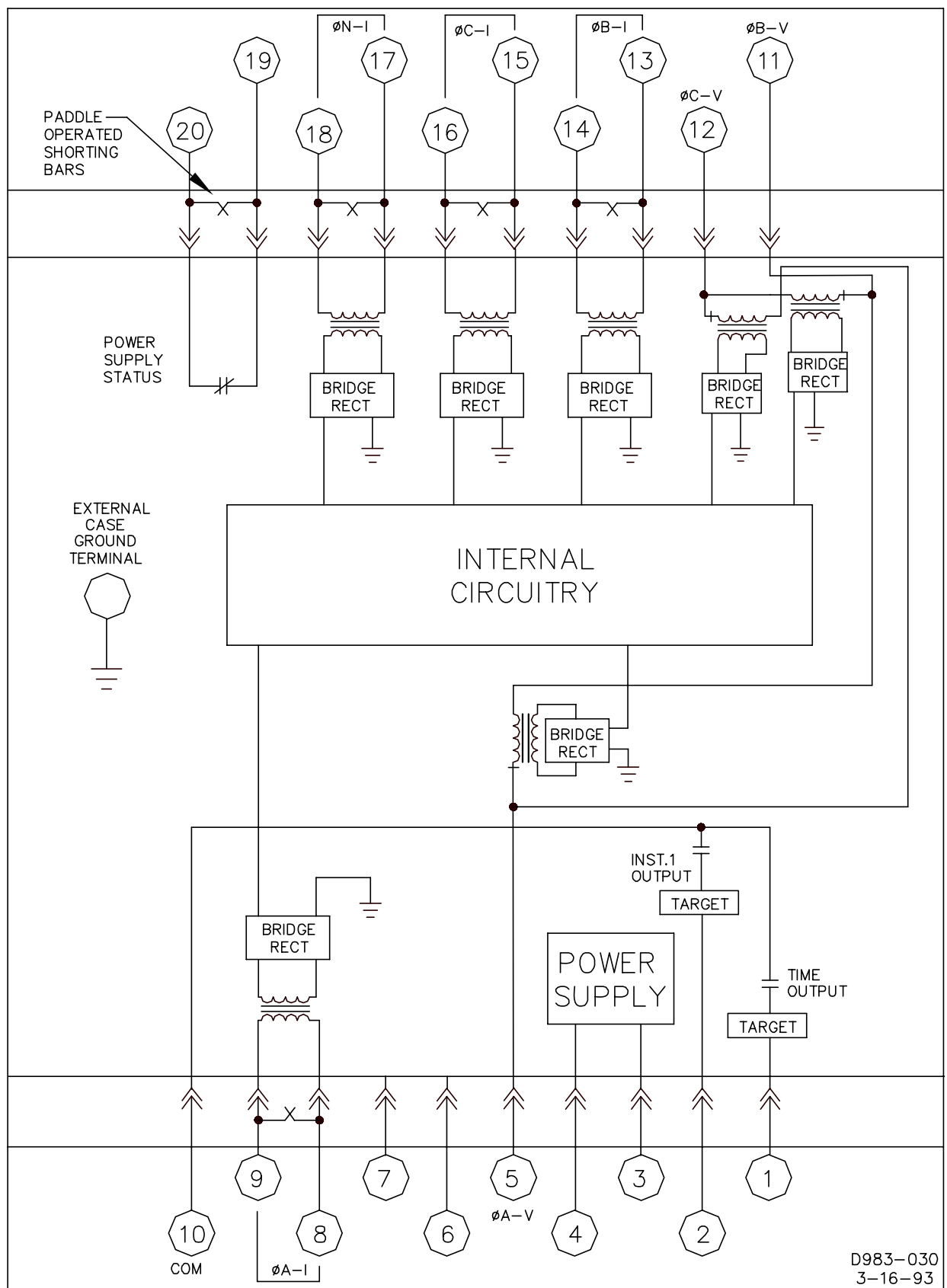
Figure 4-17. Typical Internal Diagram, Sensing Input Type E or F

Figure 4-18. Typical Internal Diagram, Sensing Input Type U or W
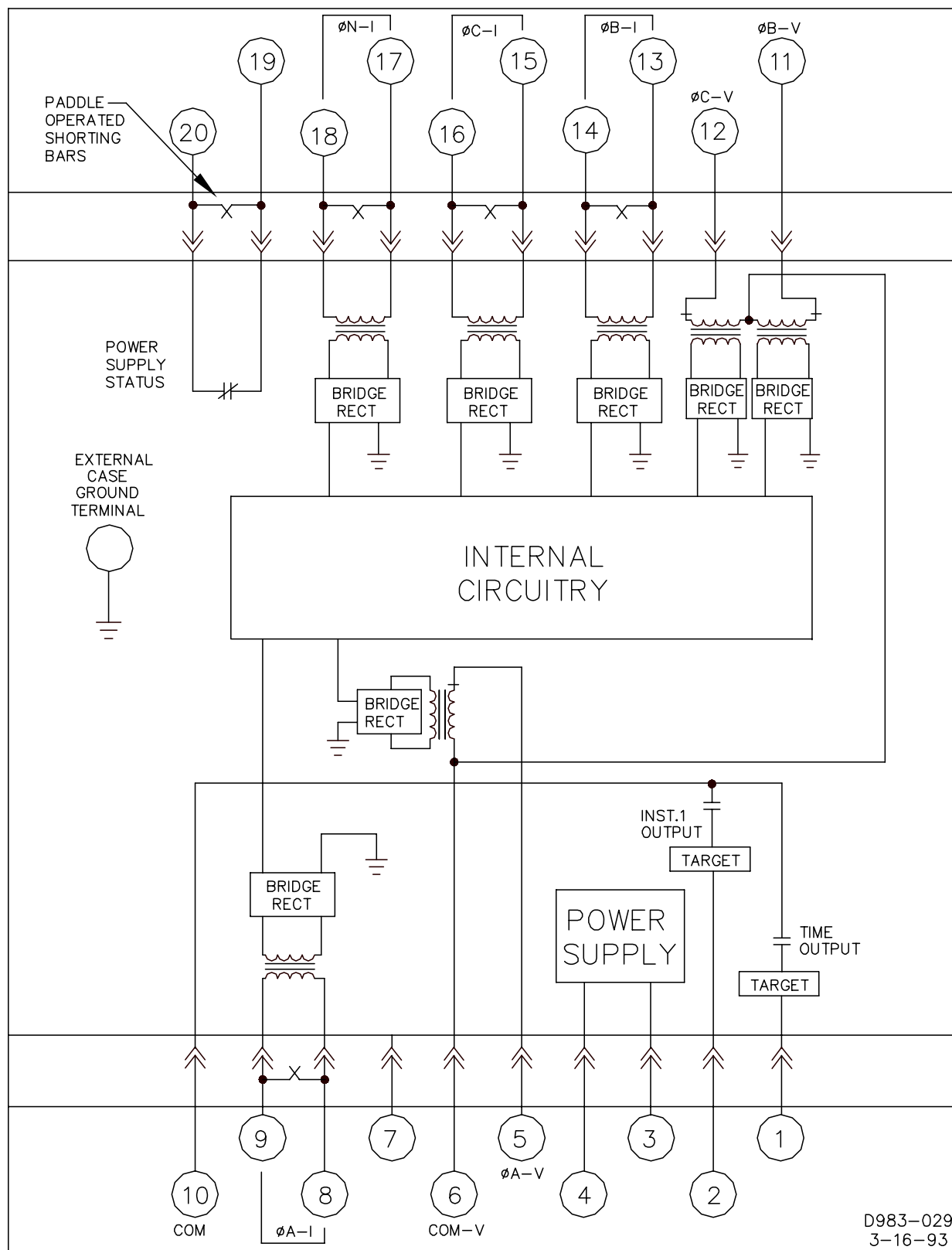
MAINTENANCE

BE1-51/27R 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.

SETTING THE RELAY

General

Phase time overcurrent elements (BE1-51/27R relays) can be coordinated with external protection in a conventional manner by assuming that the pickup current is 25 percent of nominal. This is the case when the restraint voltage is 25 percent or less. When the restraint voltage exceeds 25 percent, pickup current exceeds 25 percent of nominal and the relay is slower than if pickup current was fixed at 25 percent. Assuming a fixed 25 percent pickup simplifies calculations and provides an added safety margin because the BE1-51/27R relay is the last step in the coordination for an external fault.

Neutral (ground) time overcurrent and all instantaneous overcurrent functions operate independently of the voltage control circuits. Therefore, these elements (overcurrent functions) can be set in the normal manner. They are set independently of each other except that the instantaneous setting is 1 to 40 times the associated time overcurrent element pickup. The instantaneous element pickup should be set for at least 120 percent of the maximum current that can be seen by the relay for an external fault where operation is not desired.

Neutral time overcurrent pickup must be set above the maximum expected normal unbalance. In addition, for residually connected elements, added relay current can result from dissimilar errors in the three current transformers. These errors are greater for the lower accuracy class current transformers. A neutral element pickup of ten percent of the circuit rating will ordinarily be above non-fault unbalances for a solidly grounded system. Lower settings are appropriate and safe for impedance grounded systems or for ungrounded protected equipment connections.

When choosing the time delay setting in a generator back-up application, for a motor starting application, or during acceleration after a fault is cleared, the limiting condition may be the percentage of generator rating that is motor load and not coordination for an external fault. The percentage of generator rating that is motor load needs to be considered when setting the relay.

A nominal phase time overcurrent pickup (with rated restraint voltage) of 200 percent of generator rating can prevent undesirable tripping during a severe recoverable swing. This pickup is still low enough to provide sufficient sensitivity for faults.

Relay Setting Concepts

Figure 4-19 plots fault current in multiples of generator rating (assuming no voltage regulator boosting) and relay pickup as a percent of nominal. The relay tap must be selected so that pickup in multiples of generator rating is less than the fault current shown in the Figure 4-19 example.

Restraint voltage (V) is proportional to the drop across external reactance (X_E), and decays along with the fault current (I) that is developed by the generator. Initial voltage is 40 percent of rated, so the phase time overcurrent pickup is also 40 percent of nominal. At about 0.04 seconds after fault inception, restraint voltage drops below 25 percent and the pickup current flattens to 25 percent. During the shaded portion of the graph, the relay operates slower than it would if the pickup current was constant at 25 percent of nominal. This occurs for a minor interval compared to the total relay operating time, so the increased pickup has a negligible effect on operating time.
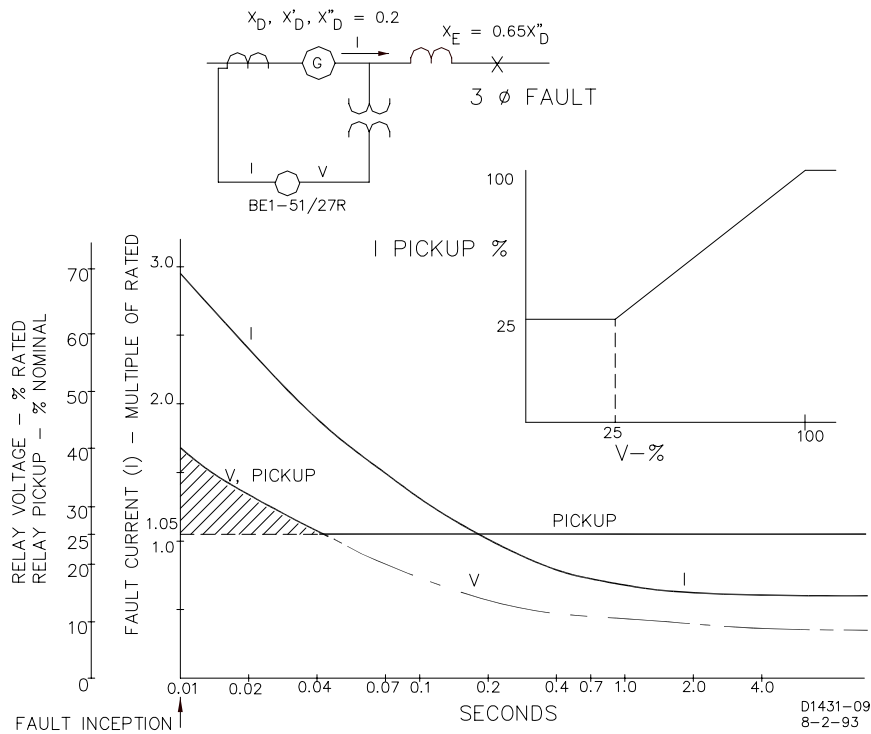
Figure 4-19. Relay Signals and Current Pickup Example for 3-Phase Fault (X_E=0.65 $X"_D$)

Figure 4-20 shows an example similar to Figure 4-19, but the higher external reactance (X_E = 2$X"_D$) to the fault develops a higher restraint voltage. In Figure 4-20, the shaded area of the graph where pickup exceeds 25 percent of nominal is much larger than the shaded area in Figure 4-19. (This is the area where the relay operates slower.) If we assume a fixed 25 percent of nominal pickup current, a significant margin in the time coordination with external protection is added, although the log scale tends to exaggerate this effect.
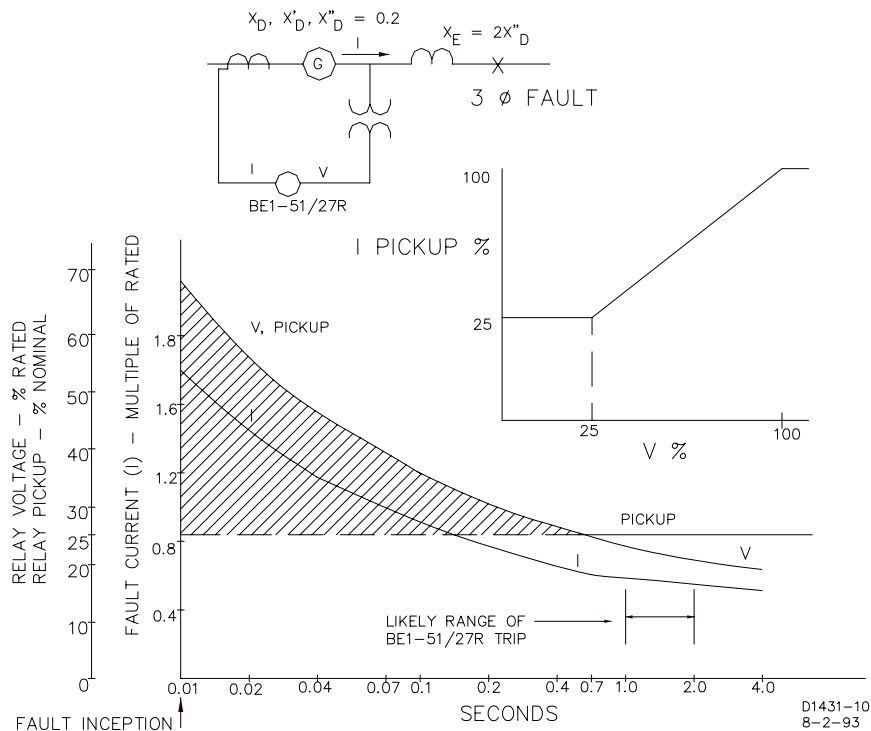
Figure 4-20. Relay Signals and Current Pickup Example for 3-Phase Fault (X_E=2 $X"_D$)

Setting Example

Figure 4-21 illustrates generator relay elements that are to be set in this example. Plant 11 kV feeders are supplied by a 115 kV system that is supplemented by two local 3,700 kVA generators. Line 1 is illustrated completely; line 2 is the same as line 1 and only shows major components. Settings are provided for the BE1-51/27R Time Overcurrent Relay with voltage restraint, BE1-51 Time Overcurrent Relay, and BE1-67 Phase Directional Overcurrent Relay.

Generator Backup (Breaker A)

    BE1-51/27R (51/27), relay style number: U3E B6S B2C0F

    Three-phase-and-neutral overcurrent

    1.5 to 12 A phase (instantaneous trip is out of service

    0.5 to 4 A neutral (instantaneous is in service

    Very inverse timing (B6)

    300/5 CTs

Feeder (Breaker F)

    BE1-51 (51)

    0.5 to 12 A

    Very inverse timing (B6)

    800/5 CTs

    No instantaneous

    Pickup set to 6 A

    Time Dial set to 08

Phase Directional (Breaker L)

    BE1-67 (67)

    0.5 to 12 A

    Definite timing (B3)

    3,000/5 CTs

    Pickup set to 0.5 A

    Time Dial set to 02

Generator Reactance (Per Unit)

Sub transient	0.18
Transient	0.25
Steady State	1.5
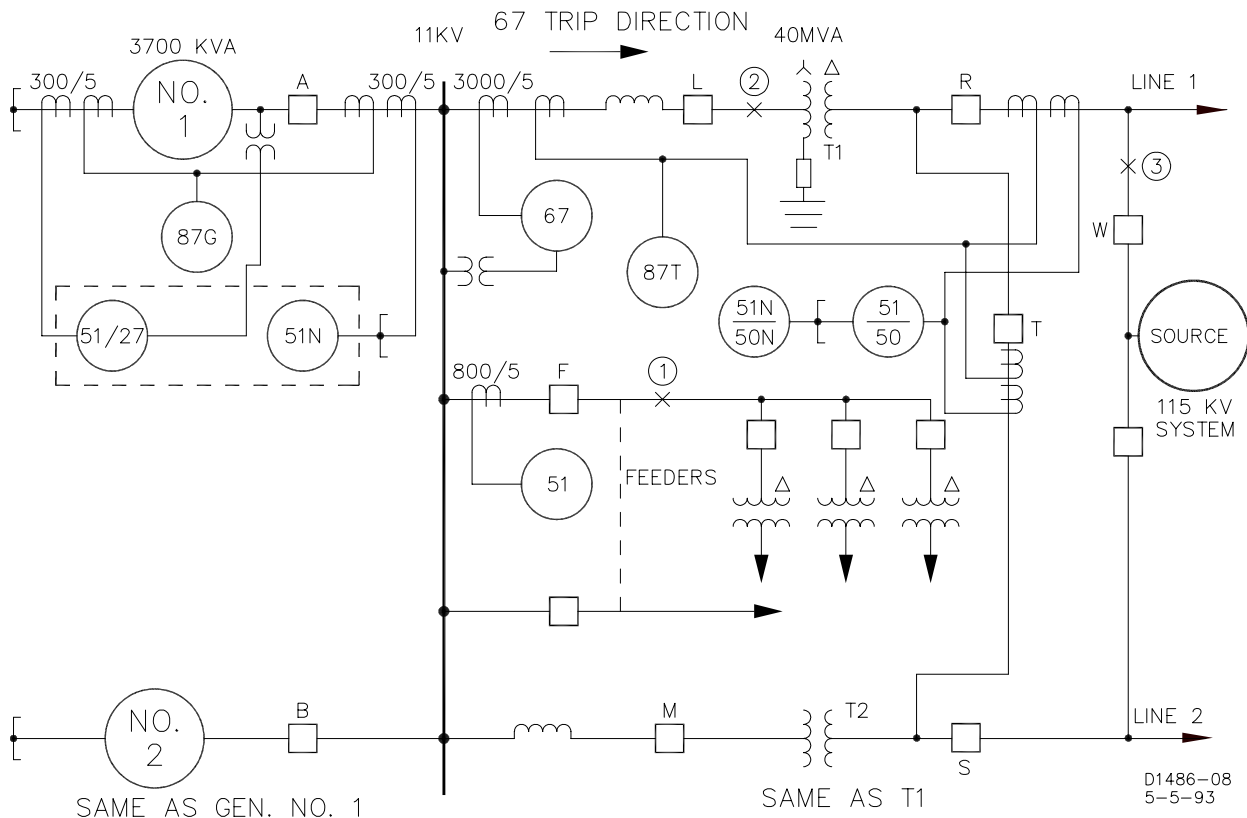
Figure 4-21. System Example

Downstream current in Table 4-1 is the current in the downstream relay with which the BE1-51/27R elements must coordinate. The currents are the changes resulting from the fault assuming a driving point voltage of 11 kV. Actual currents will be the sum of the table values plus the pre-fault load currents. Transient level currents are based on use of the generator transient reactance. Steady-state level currents are based on use of generator steady-state reactance and assuming no generator regulator boost. Note that the table values apply for 3-phase faults. Transient level currents in generators for a phase-to-phase fault will be about equal to the 3-phase current values. Steady-state level currents in the generators will be higher for a phase-to-phase fault.

Table 4-1. Three-Phase Fault Currents

Level	Out of Service	Fault Loc.	Fault Current - A @ 11 kV	
			Downstream	Generator
Transient	T2	1	7256	776
Steady State	T2	1	5961	129
Transient	—	2	7256	776
Transient	T2	2	1552	776
Steady State	T2	2	258	129
Transient	—	3	713	713
Steady State	—	3	127	127

Coordination with Feeder 51 Relay for Fault 1

(1)   Multiples of pickup in 51 relay at transient level:

$$\frac{7256}{(800/5)\,6} = \frac{7256}{960} = 7.6$$

(2)   Relay 51 time at 7.6 multiples (from B6 curves) @ 08 time dial: **0.31 s.**

(3)   Set 51/27 pickup:

$$\frac{1.75\,(3700)}{11\,(1.73)} = 340 \text{ A Primary} \qquad \frac{340}{(300/5)} = 5.7 \text{ A Secondary}$$

(4)   Set the 51/27 time to provide 0.3 s coordinating interval:

$$0.31 + 0.3 = 0.61\,\text{s @ 776 A}$$

(5)   51/27 voltage equals 0, so pickup = 0.25 x 5.7 = 1.4 A (84 A Primary)

(6)   51/27 multiples:

$$\frac{776}{1.4 \times \dfrac{300}{5}} = 9.2$$

(7)   51/27 **TIME DIAL** (from B6 curve, @ 9.2 multiple and 0.61 s): **23.**

(8)   Multiples of pickup in 51 relay at steady-state level:

$$\frac{5961}{(800/5)\,6} = 6.2$$

(9)   51/27 time at 6.2 multiples: **0.36 s.**

(10)   51/27 multiples at 129 A:

$$\frac{129}{1.4 \times \dfrac{300}{5}} = 1.5$$

(11)   51/27 time at 1.5 multiples: **9.0 s.**

(12)   Relay 51/27 coordinates with relay 51 over the full range of fault currents with transformer T2 out of service. With both T1 and T2 in service, relay 51 sees more current and operates faster than the above times. If the fault is not interrupted by the feeder breaker, the generators will be tripped at time falling between 0.61 s and 9.0 s.

Checking Coordination with Relay 67 for Fault 2

(1)   67 multiples at transient level with T2 in service:

$$\frac{7256}{0.5\,(3000/5)} = 24$$

(2)   67 time at 24 multiples (B3 curve, **TIME DIAL** 02): **0.15 s.**

(3)   67 multiples at transient level with T2 out of service:

$$\frac{1552}{300} = 3$$

(4)   67 time at 3 multiples: **0.23 s.**

(5)   Note that a failure of the differential protection (87T) for fault 2 with T2 out of service is a double contingency. Coordination of 51/27 relays with 67 relays does occur at the transient level (0.61 vs. 0.35 s). As the current decays, the times converge and cross because the 67 relay pickup is 300 amperes vs. 97 amperes for 51/27 relays (see calculation below for steady-state multiple of 0.86 for the 67 relays). So coordination may not be achieved for this double contingency with the generator

regulators out of service. Boosting by the regulators will partially arrest the decay of current. In addition, the decay will be less for a phase-phase fault.

(6)   67 multiples at steady-state level with T2 out:

$$\frac{258}{300} = 0.86$$

(7)   For a failure of Breaker L to open, the 51 relays on transformer T2 will operate as well as the generator relays to clear fault 2. For a failure of the T1 differential relays (87T), the T2 51 relays should coordinate with the 67 relays so T2 and the generators will remain in service.

Checking Coordination with Relay 67 for Fault 3

(1)   67 multiples at transient level with T2 in service:

$$\frac{713}{300} = 2.4$$

(2)   67 time at 2.4 multiples: **0.26 s.**

(3)   51/27 transient level voltage (reactor and transformer T1 drop): **8%.**

(4)   51/27 multiples at transient level:

$$\frac{713}{97} = 7.4$$

(5)   51/27 transient level time at 7.4 multiples and **TIME DIAL** setting of 22: **0.72 s.**

(6)   51/27 relays coordinate with 67 relays for a high-side fault at the transient level. However, it appears that the current may drop below the 67 relay pickup (300 amperes) before this relay can operate. Should the 67 relays fail to operate, the 51/27 relays will trip the generators. Figure 4-22 plots these two relay characteristics. If the generator is fully loaded at 194 amperes with a 0.85 PF, the superposition of this current and the fault current at -90° yields a total current of 831 amperes at the transient level and 282 amperes at the steady-state level with no regulator boosting. The relays are selective down to about 350 amperes.

(7)   Assuming that the 67 relays will not operate for fault 3, the generators will be unnecessarily tripped if the line relaying fails to operate or if breaker R fails to interrupt the fault. Redundant line relaying will minimize the need for generator tripping. Use of a breaker-failure timer set to about 0.25 seconds would avoid generator tripping for a failure of breaker R to interrupt.
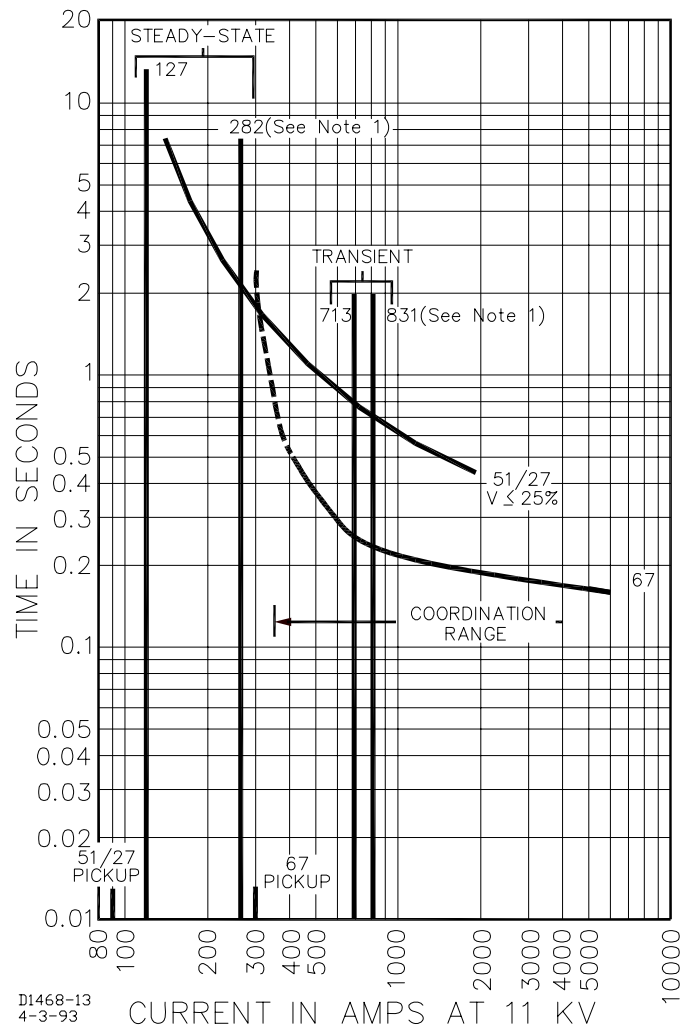
Figure 4-22. Relay 51/27 Coordination with Relay 67 for Fault 3 Example

Neutral Element Backup Settings

(1) The 51N element has no relays to coordinate with because the generators are ungrounded. An instantaneous element, if used, must be set above the maximum false residual current that can be developed due to dissimilar current transformer saturation during an external three-phase fault. Similarly, the time setting of the time overcurrent element must ride through this transient resulting from current transformer saturation.

(2) Ground current contribution from each transformer is 485 amperes. Normal total current level is:

$$2 \times 485 = 970 \text{ A}$$

(3) Set the time element for 0.8-ampere pickup.

(4) Set the time element (51N) at 0.2 s for 970 amperes primary (see B3 curve):

$$\frac{970}{60 \times 0.8} = 20 \text{ multiples and } 08 \text{ TIMEDIAL}$$

(5) Set the instantaneous (50N) pickup at 5 amperes:

$$\frac{5}{0.8} = 6.7$$

The maximum ground fault current is:

$$\frac{970}{300} = 3.2 \text{ times the Relay pickup}$$

This page intentionally left blank.

SECTION 5 • TESTS AND ADJUSTMENTS

TABLE OF CONTENTS

This page intentionally left blank.

SECTION 5 • TESTS AND ADJUSTMENTS

GENERAL

Procedures in this section are for use in testing and adjusting a relay for the desired operation in a protective scheme. If a relay fails an operational test, or if an adjustment discloses a faulty relay, refer to Section 4, *Installation, Maintenance.*

REQUIRED TEST EQUIPMENT

Minimum test equipment required for relay testing and adjustment is listed below. Refer to Figures 5-1 through 5-6 for test setups.

- Appropriate ac or dc power source for relay operation.
- Appropriate ac source (50 or 60 hertz as appropriate) for voltage and current testing.
- Dc external power source for output relay(s) test setup and timer input.
- Relay test set capable of delivering 40 amperes. A higher capability is needed for instantaneous settings above 40 amperes.
- Timer.
- One shunt resistor for providing minimum target load.

OPERATIONAL TEST

Preliminary Instructions

Perform the following steps before going on to any testing.

Step 1.   Connect the relay test setup in accordance with Figures 5-1 through 5-6, depending upon the sensing input type for your relay (see Figure 1-1, *Style Number Identification Chart*).

(a)   *Sensing Input Type M or N (Single-Phase Sensing).* Refer to Figure 5-1.

NOTE

For relays having the above sensing, only the front panel **LOW** range current sense terminal(s) should be connected for a complete check of the relay.

Ensure that timed output terminals 1 and 10 are connected.

(b)   *Sensing Input Type R or S (Three-Phase Sensing).* Refer to Figure 5-2.

NOTE

For relays having the above sensing, only the from panel **LOW** range current sense terminal(s) should be connected for a complete check of the relay.

For all three-phase relays, the test signals must connect to both the current and voltage terminals for the same phase.

Ensure that timed output terminals 1 and 10 are connected.

(c)   *Sensing Input Type U or W (Three-Phase with Neutral Sensing).* Refer to Figure 5-3.

Ensure that the timed output terminals 1 and 10 are connected. Also, verify that either A, B, or C current sense terminals are connected initially (N terminals will be connected later in the test).

(d)   *Sensing Input Type B or C (Three-Phase Sensing).* Refer to Figure 5-4.

Ensure that the timed output terminals 1 and 10 are connected. Also, verify that either A, B, or C current sense terminals are connected initially (N terminals will be connected later

in the test). Ensure that the voltage sense terminals and the current sense terminals are connected to the same phase.

(e) *Sensing Input Type E or F (Three-Phase with Neutral Sensing).* Refer to Figure 5-5.

Ensure that the timed output terminals 1 and 10 are connected. Also, verify that either A, B, or C current sense terminals are connected initially (N terminals will be connected later in the test).

(f) *Sensing Input Type Y or Z (Two-Phase with Neutral Sensing).* Refer to Figure 5-6.

Ensure that the timed output terminals 1 and 10 are connected. Also, verify that either A, B, or C current sense terminals are connected initially (N terminals will be connected later in the test).

Step 2. Remove the relay front cover.

Step 3. Set the front panel **TIME DIAL** selector and, if present, the front panel **TIME DIAL (NEUTRAL)** selector to 99.

Step 4. Adjust the front panel **INST 1** and **INST 2** controls, if present, fully clockwise (CW).

Step 5. Adjust the front panel **TAP CAL** control, and if present, the front panel **TAP (NEUTRAL)** control fully CW.

Step 6. Ensure that the relay front panel **TARGETS**, if present, are reset.

Step 7. Apply 100% of nominal voltage based on the sensing input type for your relay.
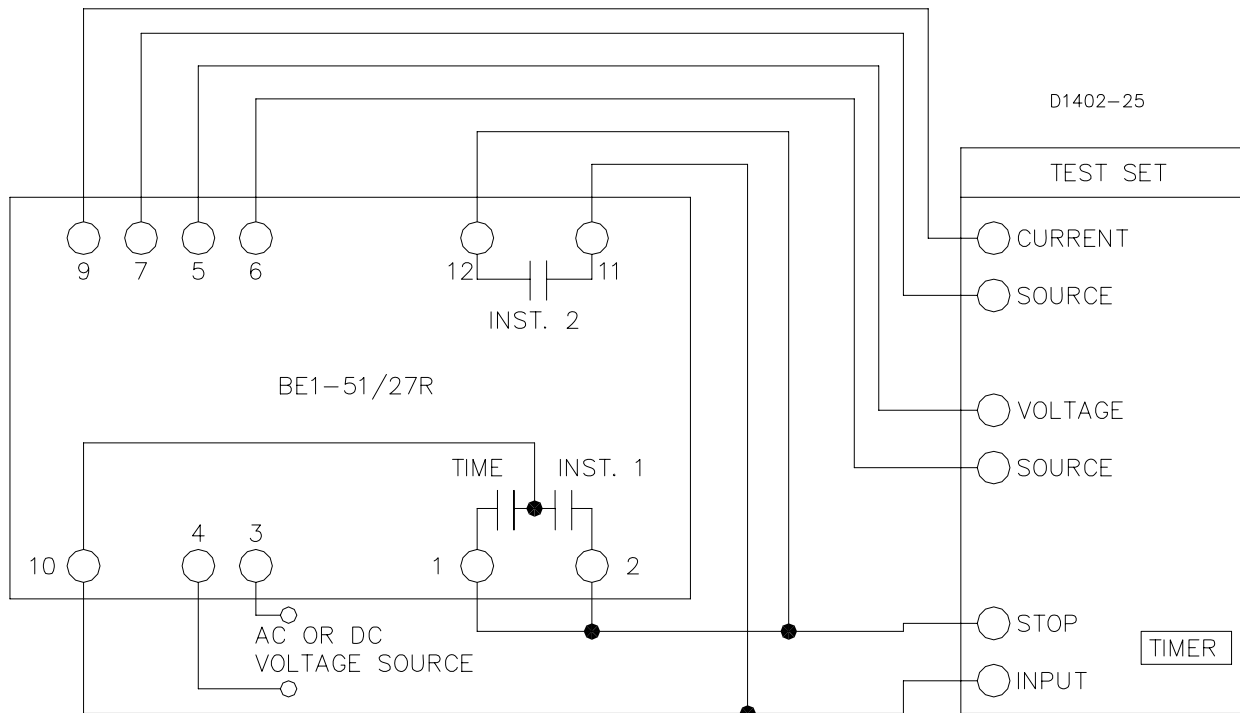
Figure 5-1. Test Setup for Sensing Input Type M or N (Single-Phase Sensing)
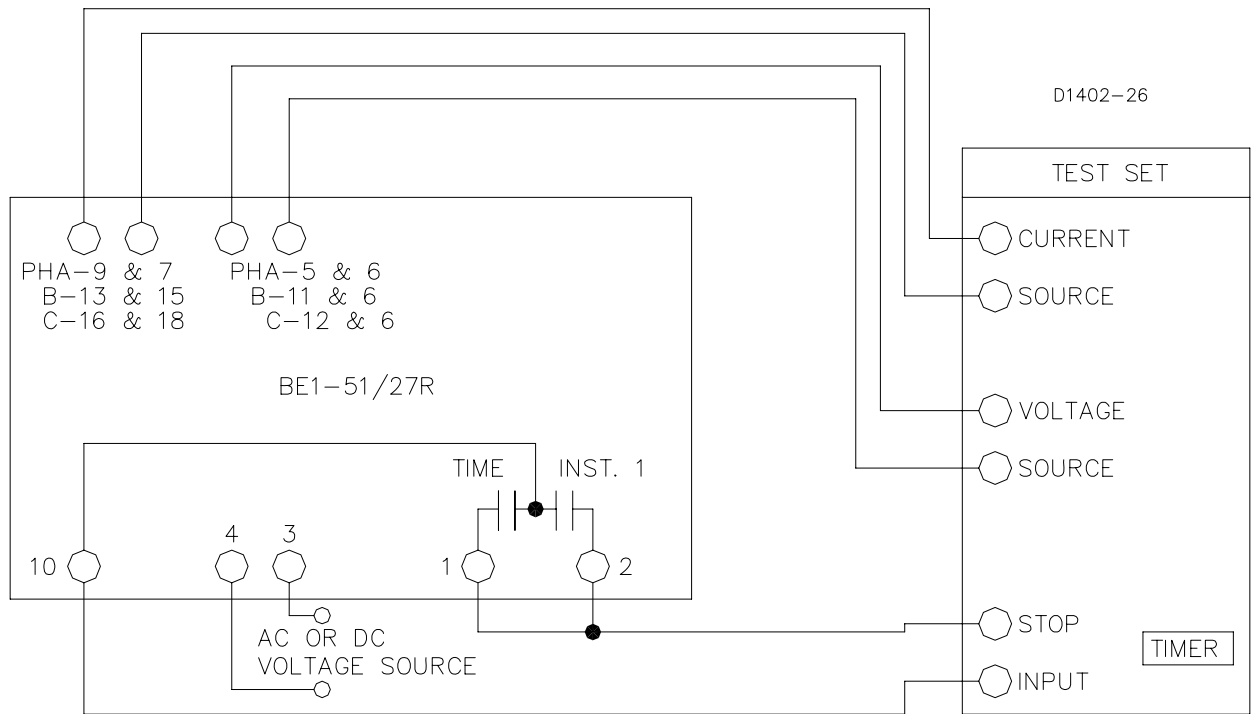
Figure 5-2. Test Setup for Sensing Input Type R or S (Three-Phase Sensing)
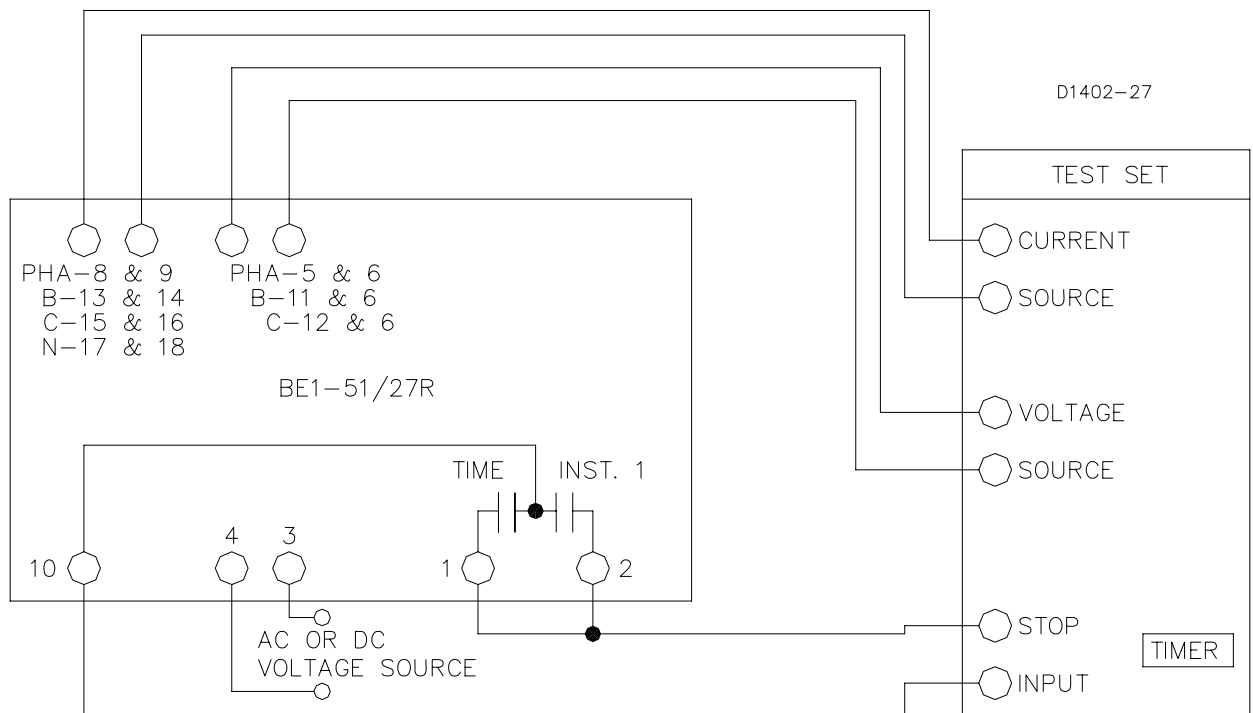
Figure 5-3. Test Setup for Sensing Input Type U or W (Three-Phase with Neutral Sensing)
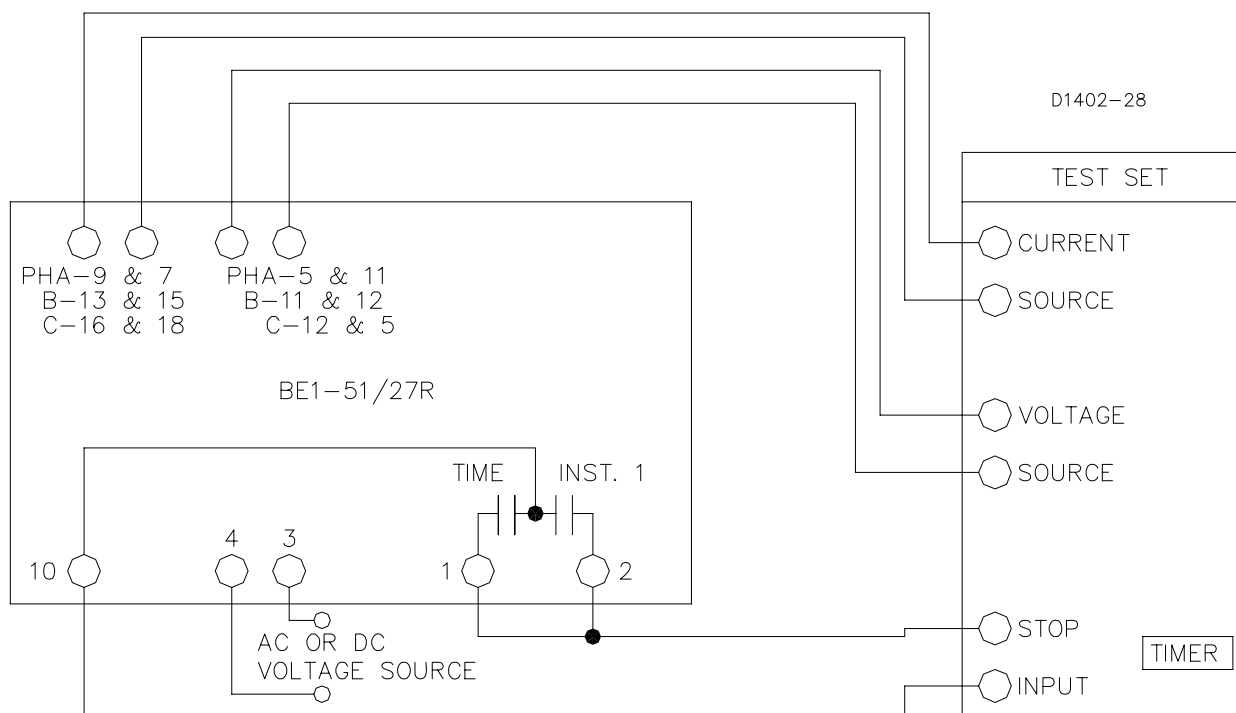
Figure 5-4. Test Setup for Sensing Input Type B or C (Three-Phase, Delta Configuration)
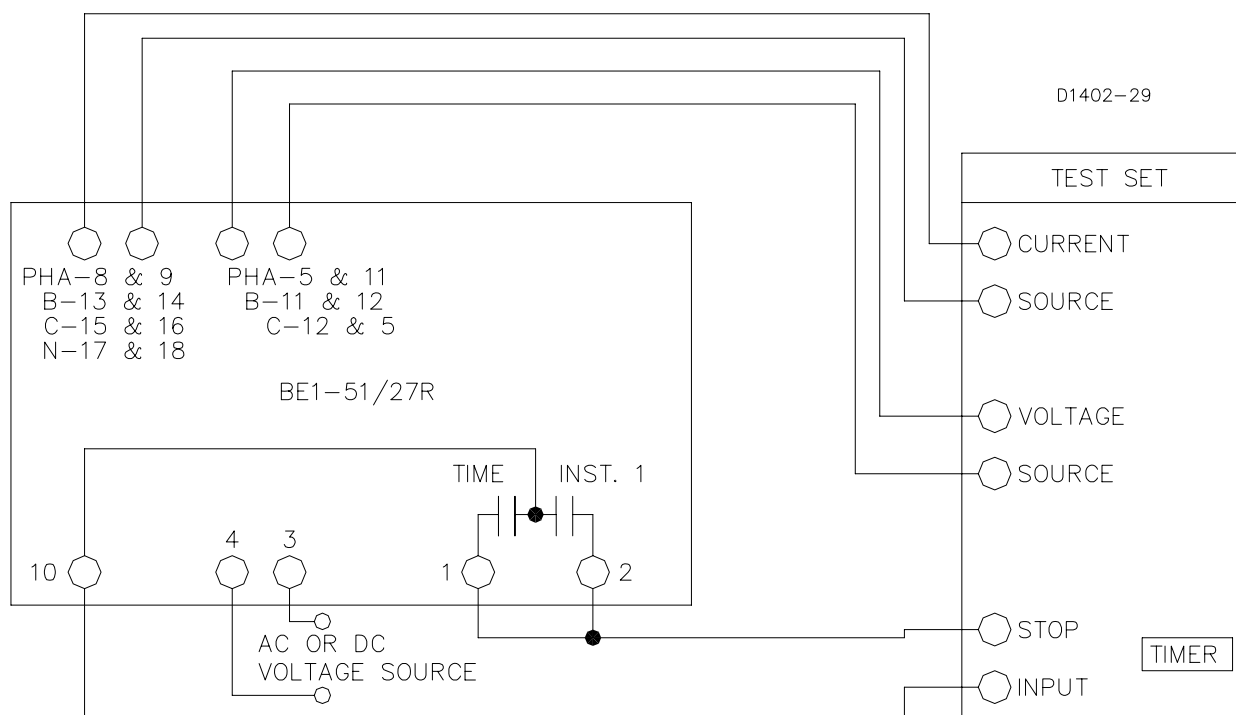
Figure 5-5. Test Setup for Sensing Input Type E or F (Three-Phase with Neutral Sensing)
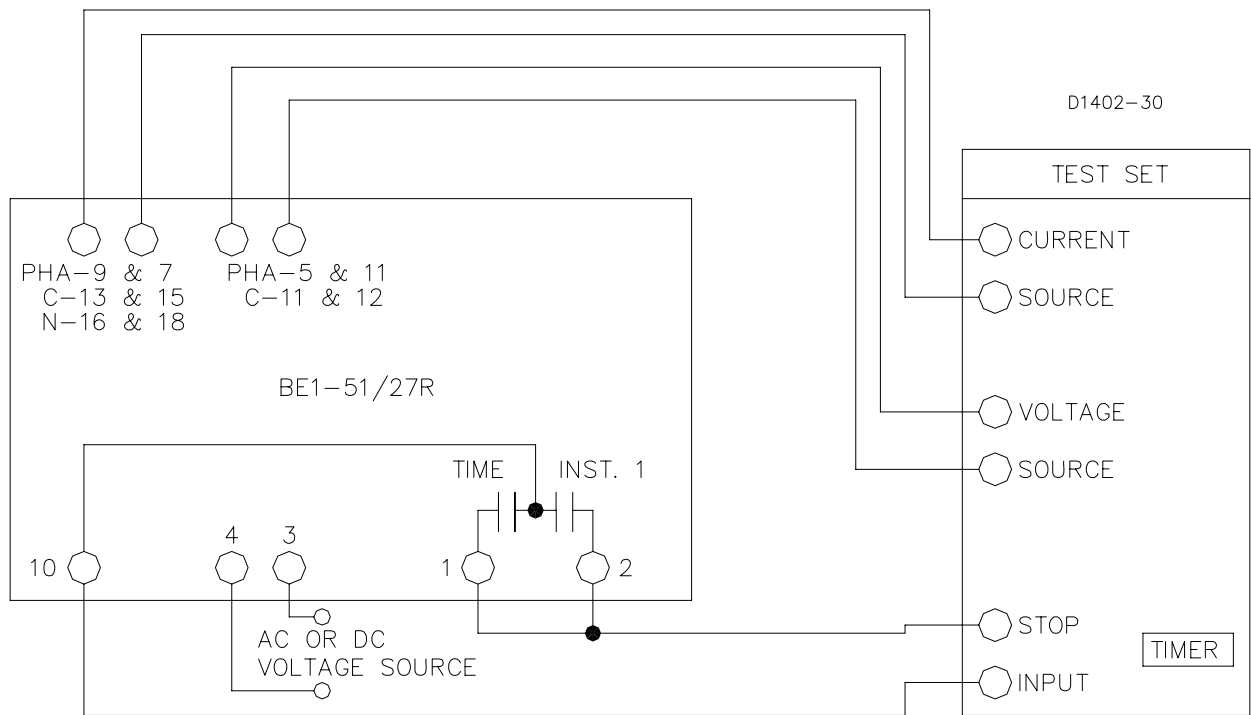
Figure 5-6. Test Setup for Sensing Input Type Y or Z (Two-Phase with Neutral Sensing)

Time Overcurrent Pickup Test

This test checks the minimum and maximum overcurrent pickup points of the time overcurrent element.

NOTE
During this test, disregard any indication on the test setup timer.

Step 1.   Perform the preliminary instructions.

Step 2.   Set the front panel **TAP** selector to **A**.

Step 3.   Adjust the test set, for an overcurrent threshold having one of the following values:

    (a)   0.5 for relays with Sensing Input Range 1, 2, or 4.

    (b)   1.5 A for relays with Sensing Input Range 3 or 5.

Step 4.   Slowly adjust the front panel **TAP CAL** control CCW until the front panel **TIMING** indicator illuminates.

    RESULT: For the phase minimum overcurrent pickup point of 0.5 A (Step 3a, above) or 1.5 A (Step 3b, above) the front panel **TAP CAL** control should be near its maximum CCW limit.

Step 5.   Adjust the front panel **TAP CAL** control fully CW to allow measurement of the actual overcurrent pickup point at the **A** setting of the front panel **TAP** selector. Note that the front panel **TIMING** indicator will extinguish. Do not disturb this setting.

Step 6.   Slowly increase the current toward the value of the front panel **TAP** selector **A** setting until the front panel **TIMING** indicator illuminates. Do not disturb this setting.

Step 7.   Record the current reading and remove input current.

    RESULT: The recorded value should be within ±5% of the front panel **TAP** selector **A** setting for the phase minimum overcurrent pickup point for the time overcurrent.

Step 8.   Set the front panel **TAP** selector to **J**.

Step 9.   Slowly adjust the test set, increasing the overcurrent threshold toward the value of the front panel **TAP** selector **J** setting until the front panel **TIMING** indicator just illuminates. Do not disturb this setting.

Step 10.   Record the current reading and remove input current.

RESULT: The recorded value should be within ±5% of the front panel **TAP** selector **J** setting for the phase maximum overcurrent pickup point for the time overcurrent element.

Step 11.   Perform the following steps as appropriate for the correct sensing input types.

> **NOTE**
>
> Ensure that the voltage sense terminals and current sense terminals are connected to the same phase.

(a)   *Sensing Input Type M or N (Single-Phase Sensing).* This concludes the time overcurrent test. Proceed to the timed output test.

(b)   *Sensing Input Type Y or Z (Two-Phase and Neutral Sensing).* Remove the power and reconnect the input sensing to the remaining phases as shown in Figure 5-6, each time repeating Steps 1 through 10. For neutral testing, continue with Step 12.

(c)   *Sensing Input Type B, C, R, or S (Three-Phase Sensing).* Remove the power and reconnect the input sensing to each of the remaining phases as shown in Figures 5-4 and 5-6, each time repeating Steps 1 through 10.

(d)   *Sensing Input Type E, F, U, or W (Three-Phase with Neutral Sensing).* Remove the power and reconnect the input sensing to each of the remaining phases as shown in Figure 5-3 and 5-5, each time repeating Steps 1 through 10. For neutral testing, continue with Step 12.

Step 12.   Perform the preliminary instructions.

For the neutral sensing (terminals 17 and 18), connect the relay as shown in Figures 5-3 and 5-5, then perform the following steps (Steps 13 through 21).

Step 13.   Set the front panel **TAP (NEUTRAL)** selector to **A**.

Step 14.   Adjust the test set for an overcurrent threshold having one of the following values:

(a)   0.5 A for relays with Sensing Input Range 2 or 3.

(b)   1.5 A for relays with Sensing Input Range 4 or 5.

Step 15.   Slowly adjust the front panel **CAL (NEUTRAL)** control CCW until the front panel **TIMING** indicator illuminates.

RESULT: For the neutral minimum overcurrent pickup point of 0.5 A (Step 16a, above) or 1.5 A (Step 16b, above) the front panel **CAL (NEUTRAL)** control should be near its maximum CCW limit.

Step 16.   Adjust the front panel **CAL (NEUTRAL)** control fully CW to allow measurement of the actual overcurrent pickup point at the **A** setting of the front panel **TAP (NEUTRAL)** selector. Note that the front panel **TIMING (NEUTRAL)** indicator will extinguish. Do not disturb this setting.

Step 17.   Slowly increase the current toward the value of the front panel **TAP (NEUTRAL)** selector **A** setting until the front panel **TIMING (NEUTRAL)** indicator illuminates. Do not disturb this setting.

Step 18.   Record the current reading and remove input current.

RESULT: The recorded value should be within ±5% of the front panel **TAP (NEUTRAL)** selector **A** setting for the neutral minimum overcurrent pickup point for the time overcurrent.

Step 19.   Set the front panel **TAP (NEUTRAL)** selector to **J**.

Step 20.   Slowly adjust the test set, increasing the overcurrent threshold toward the value of the front panel **TAP (NEUTRAL)** selector **J** setting until the front panel **TIMING (NEUTRAL)** indicator just illuminates. Do not disturb this setting.

Step 21.   Record the current reading and remove input current.

RESULT: The recorded value should be within ±5% of the front panel **TAP (NEUTRAL)** selector **J** setting for the neutral maximum overcurrent pickup point for the time overcurrent element.

Timed Output Test

This test checks the accuracy of the time overcurrent characteristic delay.

NOTE

For relays having three-phase sensing (Sensing Input Type B, C, R, or S) only a single input phase needs to be connected, since this is sufficient for a complete test of the Time Delay. For relays that include neutral sensing (Sensing Input Type E, F, U, N, Y, or Z), this test includes reconnecting the Test Output to the Neutral Sensing terminals for testing the Timed Output during neutral sensing.

Step 1.   Verify that the preliminary instructions have been performed.

Step 2.   (Timing type Z1, Z2, or Z3 only.) Select the desired time current characteristic curve.

Step 3.   Set the front panel **TAP** selector to **B**.

Step 4.   Adjust the front panel **TIME DIAL** to **20**.

Step 5.   Adjust the test set for an overcurrent threshold of precisely 5 times the front panel **TAP** selector **B** setting.

Step 6.   Apply input current to the relay and initiate the test setup timer.

Step 7.   Observe that the appropriate front panel **TIMING** indicator illuminates and when the time delay ends that the timed output relay is energized.

        RESULTS: (1) The appropriate front panel **TIMING** indicator extinguishes.

                      (2) The test setup timer stops. (Record count for use in Step 9.)

                      (3) If target type A or B is present:

                                (a) The front panel **FUNCTION-TIME** target (if present) trips.

                                (b) The appropriate front panel **ELEMENT** target **A**, **B**, or **C** (if present) trips.

Step 8.   Remove input current and (if present) reset the relay front panel targets.

NOTE

Due to delays inherent in the test equipment, the time delay for the following test may appear to exceed these limits.

Step 9.   On the appropriate time overcurrent curve chart (Figures A-1 through A-69), locate the line representing 5 times the tap value (from Step 5) where it intersects the particular curve representing the front panel **TIME DIAL** setting of **20** (from Step 4). The resulting time delay value in seconds should be within ±5% of the timer reading [from Step 7(2)].

Step 10.   Adjust the front panel **TIME DIAL** to **40**, **60**, and **99**, each time repeating Steps 6 through 9.

NOTE

For relays having two-phase-and-neutral, three-phase, or three-phase-and-neutral sensing (Sensing Input Types B, C, E, F, R, S, U, W, Y, or Z) it is not necessary to repeat this test for the remaining phases.

For relays having two-phase-and-neutral, or three-phase-and-neutral sensing (Sensing Input Types E, F, U, W, Y, or Z) perform Steps 11 through 20.

For relays having single-phase or three-phase sensing (Sensing Input Types B, C, M, N, R, or S) with instantaneous overcurrent option 1-1 or 1-2, proceed to the instantaneous overcurrent test. All other relays proceed to the voltage restraint test.

Step 11. Remove the power and reconnect the test output to the neutral current sensing input of the relay as shown in Figures 5-3 and 5-5 (terminals 17 and 18).

Step 12. Set the front panel **TAP (NEUTRAL)** selector to **B**.

Step 13. Rotate the front panel **CAL (NEUTRAL)** control fully CW.

Step 14. Rotate the front panel **TIME DIAL (NEUTRAL)** to **20**.

Step 15. Ensure that all relay targets have been reset.

Step 16. Adjust the test set for an overcurrent threshold of precisely 5 times the front panel **TAP (NEUTRAL)** selector **B** setting as measured by the ammeter.

Step 17. Apply input current to the relay and initiate the test setup timer.

   RESULTS: Observe that the appropriate front panel **TIMING (NEUTRAL)** indicator illuminates.

Step 18. When the time delay ends, the timed output relay is energized.

   RESULTS: (1) The front panel **TIMING (NEUTRAL)** indicator extinguishes.

   (2) The test setup timer stops. (Record count for use in Step 20.)

   (3) If target Type A or B is present:

   (a) Front panel **FUNCTION-TIME** target (if present) trips.

   (b) Appropriate front panel **ELEMENT** target **A**, **B**, or **C** (if present) trips.

Step 19. Remove input current and (if present) reset the relay front panel targets.

Step 20. On the appropriate time overcurrent curve chart (Figures A-1 through A-69), locate the line representing 5 times the tap value (from Step 5) where it intersects the particular curve representing the front panel **TIME DIAL (NEUTRAL)** setting of **20** (from Step 14). The resulting time delay value in seconds should be within ±5% of the timer reading [from step 18(2)].

NOTE

Due to delays inherent in the test equipment, the time delay may appear to exceed these limits. This concludes the timed output test.

Relays having instantaneous overcurrent option 1-1 or 1-2 <u>only</u> proceed to the Instantaneous Overcurrent Pickup Test.

Instantaneous Overcurrent Pickup Test

This test checks the minimum overcurrent pickup points for Instantaneous 1 and (if present) Instantaneous 2 outputs.

NOTE

For relays having three-phase sensing (Sensing Input Types B, C, R, or S), only a single input phase is connected since this is sufficient for a complete test of the instantaneous overcurrent sensing and output.

For relays that include neutral sensing (Sensing Input Types E, F, U, W, Y, or Z), this test includes reconnecting the test output to the neutral sensing terminals for testing the instantaneous 1 output during neutral sensing.

Step 1. Perform the preliminary instructions.

Step 2. Reconnect the test setup to the INST 1 output terminals 2 and 10 as shown in Figures 5-1 through 5-6. Note that the timer may be removed from the test setup at this time.

Step 3. Set the **TAP** selector to **A**.

Step 4. Turn the front panel **INST 1** control fully CCW to establish a pickup point of 1 times the **TAP** selector **A** setting.

Step 5. Slowly adjust the test set, increasing the overcurrent threshold toward the value of the front panel **TAP** selector **A** setting until the Instantaneous 1 output relay energizes.

   RESULT: If target Type A or B is present:

(a) The front panel **FUNCTION-INST 1** target (if present) will trip.

(b) The appropriate front panel **ELEMENT** target **A**, **B**, or **C** (if present) will trip.

Step 6.   Remove input current. Record the test set current setting.

RESULT: The recorded value should be equal to or less than the front panel **TAP** selector **A** setting for the minimum overcurrent pickup point for the instantaneous 1 overcurrent element.

Step 7.   Reset the relay front panel targets (if present).

Step 8.   Turn the front panel **INST 1** control fully CW to establish a pickup point of 40 times the front panel **TAP** selector **A** setting.

Step 9.   Adjust the test set to approximately 35 times the front panel **TAP** selector **A** setting.

Step 10. Slowly adjust the test set further toward an overcurrent threshold of 40 times the front panel **TAP** selector **A** setting until the instantaneous 1 output relay energizes. Do not disturb this setting.

RESULT: If target Type A or B is present:

(a) The front panel **FUNCTION-INST 1** target (if present) will trip.

(b) The appropriate front panel **ELEMENT** target **A**, **B**, or **C** (if present) will trip.

Step 11. Record the current reading. Remove input current (the front panel **TIMING** indicator should extinguish).

RESULT: The recorded value should be greater than 40 times the front panel **TAP** selector **A** setting for the maximum overcurrent pickup point for the instantaneous 1 overcurrent element.

NOTE

For relays having neutral sensing (Sensing Input Types E, F, U, W, Y, or Z) perform Step 12. For relays with option 1-2 (inst 2 elements), perform Step 13. Otherwise, the test ends here.

Step 12. For the neutral sensing, connect the relay as shown in Figures 5-3 and 5-5, then repeat Steps 2 through 11, substituting the following:

(a) The front panel **TAP (NEUTRAL)** selector instead of the front panel **TAP** selector (Step 3).

(b) The front panel **INST 1 (NEUTRAL)** control instead of the front panel **INST 1** control (Step 4).

Step 13. Reconnect the test setup to the INST 2 output terminals (11 and 12) as shown in Figure 5-1, then repeat Steps 4 through 11, substituting the following:

(a) Front panel **INST 2** control instead of the front panel **INST 1** control (Step 3).

(b) Front panel **FUNCTION-INST 2** target instead of the front panel **INST 1** target (Step 4).

(c) Instantaneous 2 output relay instead of the instantaneous 1 output relay (Step 2).

NOTE

This concludes the instantaneous overcurrent sensing and output test.

Voltage Restraint Test

This test checks the overcurrent pickup points at 50 and 100 percent of nominal voltage levels.

Step 1.   Perform the preliminary instructions.

Step 2.   Set the front panel **TAP** selector to **A**.

Step 3.   Verify that test voltage is 100% of nominal voltage based on the sensing input type for your relay.

Step 4.   Slowly increase the input current from 0 until the appropriate phase timing indicator just illuminates.

RESULT: The overcurrent pickup point should be 100 ±5% of the front panel setting.

Step 5.   Apply 50% of nominal voltage based on the sensing input type for your relay.

Step 6.   Slowly increase the input current from 0 until the appropriate phase timing indicator just illuminates.

RESULT: The overcurrent pickup point should be whichever is greater: 50 ±10% of the front panel setting or 50 mA (Sensing Input Ranges 1, 2, 3, 4, and 5) or 10 mA (Sensing Input Ranges 6, 7, 8, and 9).

ADJUSTMENTS OF CONTROLS FOR RELAY OPERATION

The following procedures set up the relay for use in a protective scheme. The procedures are arranged in a logical sequence that prevents upsetting previous control settings. For relays not having certain options, skip the corresponding adjustment paragraph. These paragraphs are identified by their headings.

TAP and TAP (NEUTRAL) Selector Setting

NOTE

Selection of one of the specific overcurrent pickup points provided by the front panel **TAP** selector (and with the front panel **TAP CAL** control fully CW) will permit a pickup point within ±5% of the selector value without having to connect the relay to a test setup to verify the setting. If present, the front panel **TAP (NEUTRAL)** selector and the front panel **CAL (NEUTRAL)** control provide this function for the neutral overcurrent pickup point

However, if the desired pickup point falls between these front panel **TAP** selector settings, or if the instantaneous overcurrent option 1-1 or 1-2 is present, the relay should be connected to a test setup for a precise setting, then the following steps should be performed.

Step 1.   Connect the test setup to the relay according to the sensing input type present in the relay as follows:

(a) *Sensing Input Type M or N:* Refer to Figure 5-1. Because the relay front panel **TIMING** indicator provides the needed pickup indication, do not connect the test setup to the output terminals. The current sense terminals for the desired range (HIGH or LOW), however, should be connected to the relay.

(b) *Sensing Input Type Y or Z:* Refer to Figure 5-6. Because the relay front panel **TIMING** indicator provides the needed pickup indication, do not connect the test setup to the output terminals. The front panel **TAP** selector is ganged and the adjustment of one input phase automatically aligns the other, thus, only one set of current sense terminals need be connected. For adjustment of the front panel **TAP (NEUTRAL)** selector, the relay is reconnected for neutral sensing by this procedure.

(c) *Sensing Input Types B, C, R, or S:* Refer to Figures 5-2 and 5-4. Because the relay front panel **TIMING** indicator provides the needed pickup indication, do not connect the test setup to the output terminals. The desired range terminals (HIGH or LOW), however, should be connected to the relay. The front panel **TAP** selector is ganged and the adjustment of one input phase automatically aligns the others, thus, only one set of current sense terminals need be connected.

(d) *Sensing Input Types E, F, U, or W:* Refer to Figures 5-3 and 5-5. Because the relay front panel **TIMING** indicator provides the needed pickup indication, do not connect the test setup to the output terminals. The front panel **TAP** selector is ganged and the adjustment of one input phase automatically aligns the others, thus, only one set of current sense terminals need be connected. For adjustment of the front panel **TAP (NEUTRAL)** selector, the relay is reconnected for neutral sensing by this procedure.

Step 2.   Remove the relay front cover.

Step 3.   *Sensing Input Types B, C, M, N, R, or S.* Verify that the front panel **TAP RANGE** plate is installed and the correct range (HIGH or LOW) is visible.

Step 4.   Adjust the test voltage to 100 percent of nominal voltage for your relay and the test current to the desired time overcurrent pickup point for the relay.

Step 5.   Set the front panel **TAP** selector to the closest setting above the desired pickup point.

Step 6.   Adjust the front panel **TAP CAL** control fully CW.

Step 7.   Apply current to the relay.

Step 8.   Slowly adjust the front panel **TAP CAL** control CCW until the front panel **TIMING** indicator just illuminates which indicates the desired time overcurrent pickup point for phase sensing. For relays with two-phase-and-neutral, three-phase, or three-phase-and-neutral sensing, this pickup point will be the same for all the phases.

Step 9.   Remove input current.

Step 10.   Reconnect the test set output to the neutral sense terminals. See Figures 5-3, 5-5, or 5-6.

Step 11.   Adjust the current to the desired time overcurrent pickup point for the relay.

Step 12.   Set the front panel **TAP (NEUTRAL)** selector to the closest setting above the desired pickup point.

Step 13.   Rotate the front panel **CAL (NEUTRAL)** control fully CW.

Step 14.   Slowly adjust the front panel **CAL (NEUTRAL)** control CCW until the front panel **TIMING (NEUTRAL)** indicator just illuminates to establish the desired time overcurrent pickup point for neutral sensing.

Step 15.   Remove input current.

Time Overcurrent Curve Selection (Timing Type Z1, Z2, and Z3 Only)

Step 1.   Remove the relay cradle front cover to gain access to the logic board time overcurrent characteristic curve selector.

Step 2.   Remove the Phillips screws from both sides of the unit and remove the front panel. See Figure 2-1 for the location of the logic board and curve selector.

Step 3.   Select the desired curve. See Table A-2 for the desired curve and selector position.

Step 4.   Re-install the front panel and the front cover.

Time Delay Selection

<table>
<tr><td colspan="1" align="center">**NOTE**</td></tr>
<tr><td>If Timing Type Z1, Z2, or Z3 is installed, refer to time overcurrent curve selection to obtain the desired set of time overcurrent curves (see Figures A-1 through A-69). Then proceed to Step 1, following.

If Timing Type Z1, Z2, or Z3 is not installed, determine the timing type from the model and style number for a specific relay. Then select the appropriate timing curve (see Figures A-1 through A-69). Proceed to the following, Step 1.</td></tr>
</table>

Step 1.   Referring to the appropriate time overcurrent characteristic curve, select the desired time delay on the front panel **TIME DIAL** for the anticipated input overcurrent difference (multiples-of-pickup current) from the selected time overcurrent pickup point as follows:

(Selected Pickup Point) - (Anticipated Input Overcurrent) = Overcurrent Difference from Pickup

Step 2.   Set the front panel **TIME DIAL** as follows:

(a) On the appropriate curve, plot upward from the ***multiples-of-pickup-current*** value until the horizontal line opposite the desired time delay ***(time-in-seconds)*** is reached. The setting curve nearest the plot point should then be entered on the front panel **TIME DIAL**.

(b) Using Figure 1-6 as an example, if the overcurrent is expected to be 4 times the pickup point value and time delay of 4 seconds is desired, plot upward from the point 4 on the ***multiples-of-pickup-current*** axis until the point 4 from the ***time-in-seconds*** axis is crossed. The curve for a setting of **52** crosses the plot point and should be entered on the front panel **TIME DIAL**.

(c) For a lesser overcurrent difference from the pickup point, the time delay will be greater, so that for a multiple of 3 times the pickup current, the time delay for the previous front panel setting of **52** will be 5.8 seconds.

Neutral Time Delay Selection

Step 1.   Use the same characteristic curve used in the previous paragraph (*Time Delay Selection*). However, ***the multiples-of-pickup current, time-in-seconds,*** and the resulting front panel **NEUTRAL TIME DIAL** setting can differ.

Step 2.   Set the front panel **NEUTRAL TIME DELAY** as follows:

(a) On the appropriate curve, plot upward from the ***multiples-of-pickup-current*** value until the horizontal line opposite the desired time delay ***(time-in-seconds)*** is reached. The setting curve nearest the plot point should then be entered on the front panel **NEUTRAL TIME DELAY**.

(b) Using Figure 1-6 as an example, if the overcurrent is expected to be 4 times the pickup point value and time delay of 4 seconds is desired, plot upward from the point 4 on the ***multiples-of-pickup-current*** axis until the point 4 from the ***time-in-seconds*** axis is crossed. The curve for a setting of **52** crosses the plot point and should be entered on the front panel **NEUTRAL TIME DIAL**.

(c) For a lesser overcurrent difference from the pickup point, the time delay will be greater, so that for a multiple of 3 times the pickup current, the time delay for the previous front panel setting of **52** will be 5.8 seconds.

INST 1 Control Setting

<table>
<tr><td colspan="1" align="center">**NOTE**</td></tr>
<tr><td>Because the lower limit for this pickup is determined by the front panel **TAP** selector setting and the front panel **TAP (CAL)** control position, ensure that these adjustments have been performed as in the paragraph *TAP and TAP (NEUTRAL) Selector Setting.*</td></tr>
</table>

Step 1. Verify that the test setup is as described in *TAP and TAP (NEUTRAL) Selector Setting,* Steps 1 through 6.

Step 2. Connect the test setup to the instantaneous 1 element output terminals (2 and 10) as shown in Figures 5-1 through 5-6. The timer should not be connected.

CAUTION

Steps 3 through 8 provide the application of overcurrent for short periods to allow adjustment while avoiding overheating of the input sensing transformers. To avoid damaging the relay, do not attempt to apply a constant high level of input current for adjustment of the front panel **INST 1**, **INST 1 (NEUTRAL)**, or **INST 2** controls.

Step 3. Set the front panel **INST 1** control to a position approximating the desired instantaneous 1 overcurrent pickup point for the relay.

Step 4. Apply current to the relay.

Step 5. Rapidly increase the overcurrent input to the relay until the instantaneous output relay just energizes. Note the overcurrent threshold reading on the ammeter.

Step 6. Remove input current.

Step 7. Reset the **INST TARGET** (if present).

Step 8. If the overcurrent threshold reading from Step 5 was too high or low, adjust the front panel **INST 1** control CCW to lower (or CW to raise) the instantaneous 1 overcurrent pickup point. Repeat Steps 4 through 8. If the overcurrent threshold reading from Step 5 was **NOT** too high or low, proceed to Step 9.

NOTE

For relays with two-phase-and-neutral or three-phase-and-neutral sensing (Sensing Input Types E, F, U, W, Y, or Z), perform Steps 9 through 14.

Step 9. Reconnect the output to the neutral current sense terminals. See Figures 5-3, 5-5, or 5-6.

Step 10. Set the front panel **INST 1 (NEUTRAL)** control to a position approximating the desired neutral instantaneous 1 overcurrent pickup point for the relay.

Step 11. Apply current to the relay.

Step 12. Rapidly increase the overcurrent input to the relay until the instantaneous output relay just energizes. Note the test set overcurrent threshold reading on the ammeter.

Step 13. Remove the input current.

Step 14. Reset the **INST TARGET** (if present).

Step 15. If the overcurrent threshold reading from Step 13 was too high or low, adjust the front panel **INST 1 (NEUTRAL)** control CCW to lower (or CW to raise) the Neutral Instantaneous 1 Overcurrent Pickup Point. Repeat Steps 9 through 14. If **NOT**, proceed to the next test.

INST 2 Control Setting

For this adjustment, repeat *INST 1 Control Setting,* but substitute instantaneous 2 output terminals (11 and 12) and the front panel **INST 2** controls. Because neutral sensing does not apply to this pickup point, ignore Steps 9 through 15.

This page intentionally left blank.

APPENDIX A • TIME OVERCURRENT CHARACTERISTIC CURVES

TABLE OF CONTENTS

Tables

APPENDIX A • TIME OVERCURRENT CHARACTERISTIC CURVES

EXPLANATION OF CURVES

Graphs on the following pages illustrate sample characteristic curves for all of the time overcurrent functions individually as options, or selectable by switch (if the Z1, Z2, or Z3 timing option is specified). Z1 option can select any of the timing types designated as B1 through B8, and C1 through C8. Z2 option can select any of the timing types designated as B1 through B8, and the British Standard timing types: E2, E4, E5, E6, and E7. Z3 option can select the integrating algorithm for any of the timing types designated as B1 through B8, and C1 through C8.

Note that there are two versions of each timing type: standard and extended timing. Both types are located on the same page. The exception to this is the British Standard curves, which do not have an extended timing version. For any given relay, either the standard or the extended range version will apply, never both.

Table A-1 lists timing choices with available curves. Table A-2 lists the positions of the timing curve selector switch. (See Figure 2-1 for switch location).

Table A-1. Timing Choices with Available Curves

Timing Choices	Z1	Z2	Z3 (Integrating)
Available Curves	Short Inverse	Short Inverse	Short Inverse
	Long Inverse	Long Inverse	Long Inverse
	Definite Time	Definite Time	Definite Time
	Moderately Inverse	Moderately Inverse	Moderately Inverse
	Inverse Time	Inverse Time	Inverse Time
	Very Inverse	Very Inverse	Very Inverse
	Extremely Inverse	Extremely Inverse	Extremely Inverse
	I^2t	BS 142 Long Inverse	I^2t
	I^2t with Limit 1	BS142 Inverse (1.3 sec)	I^2t with Limit 1
	I^2t with Limit 2	BS142 Inverse (2.9 sec)	I^2t with Limit 2
	I^2t with Limit 3	BS142 Very Inverse	I^2t with Limit 3
	I^2t with Limit 4	BS142 Extremely Inverse	I^2t with Limit 4
	I^2t with Limit 5	N/A	I^2t with Limit 5
	I^2t with Limit 6	N/A	I^2t with Limit 6
	I^2t with Limit 7	N/A	I^2t with Limit 7
	I^2t with Limit 8	N/A	I^2t with Limit 8

Table A-2. Timing Curve Selection Table

Timing Type	Selector Position *	Selector Position †	Standard Curves Z1, Z2 Fig. No.	Extended Curves Z1, Z2 Fig. No.	Standard Curves Z3 Fig. No.	Extended Curves Z3 Fig. No.
B1 - Short Inverse	3	3	A-1	A-2	A-38	A-39
B2 - Long Inverse	1	1	A-3	A-4	A-40	A-41
B3 - Definite Time	5	5	A-5	A-6	A-42	A-43
B4 - Moderately Inverse	2	2	A-7	A-8	A-44	A-45
B5 - Inverse	4	4	A-9	A-10	A-46	A-47
B6 - Very Inverse	6	6	A-11	A-12	A-48	A-49
B7 - Extremely Inverse	7	7	A-13	A-14	A-50	A-51
B8 - I^2t	0	0	A-15	A-16	A-52	A-53
C1 - I^2t with Limit #1	8	—	A-17	A-18	A-54	A-55
C2 - I^2t with Limit #2	9	—	A-19	A-20	A-56	A-57
C3 - I^2t with Limit #3	A	—	A-21	A-22	A-58	A-59
C4 - I^2t with Limit #4	B	—	A-23	A-24	A-60	A-61
C5 - I^2t with Limit #5	C	—	A-25	A-26	A-62	A-63
C6 - I^2t with Limit #6	D	—	A-27	A-28	A-64	A-65
C7 - I^2t with Limit #7	E	—	A-29	A-30	A-66	A-67
C8 - I^2t with Limit #8	F	—	A-31	A-32	A-68	A-69
E2 - Long Inverse	—	8	A-33	—	—	—
E4 - Inverse (1.3 Sec.)	—	9	A-34	—	—	—
E5 - Inverse (3.0 Sec.)	—	A	A-35	—	—	—
E6 - Very Inverse	—	B	A-36	—	—	—
E7 - Extremely Inverse	—	C,D,E,F	A-37	—	—	—

∗ Timing option Z1 and Z3.

† Timing option Z2 only.
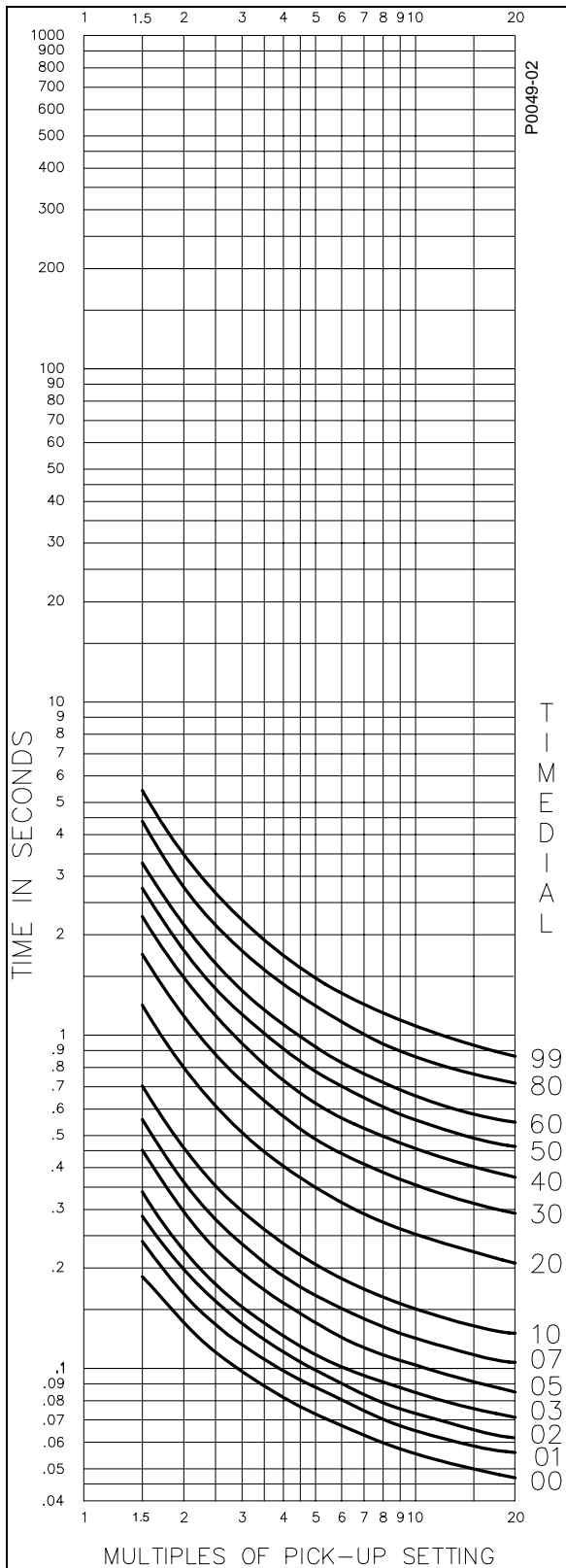
Figure A-1. Timing Type B1, Short Inverse
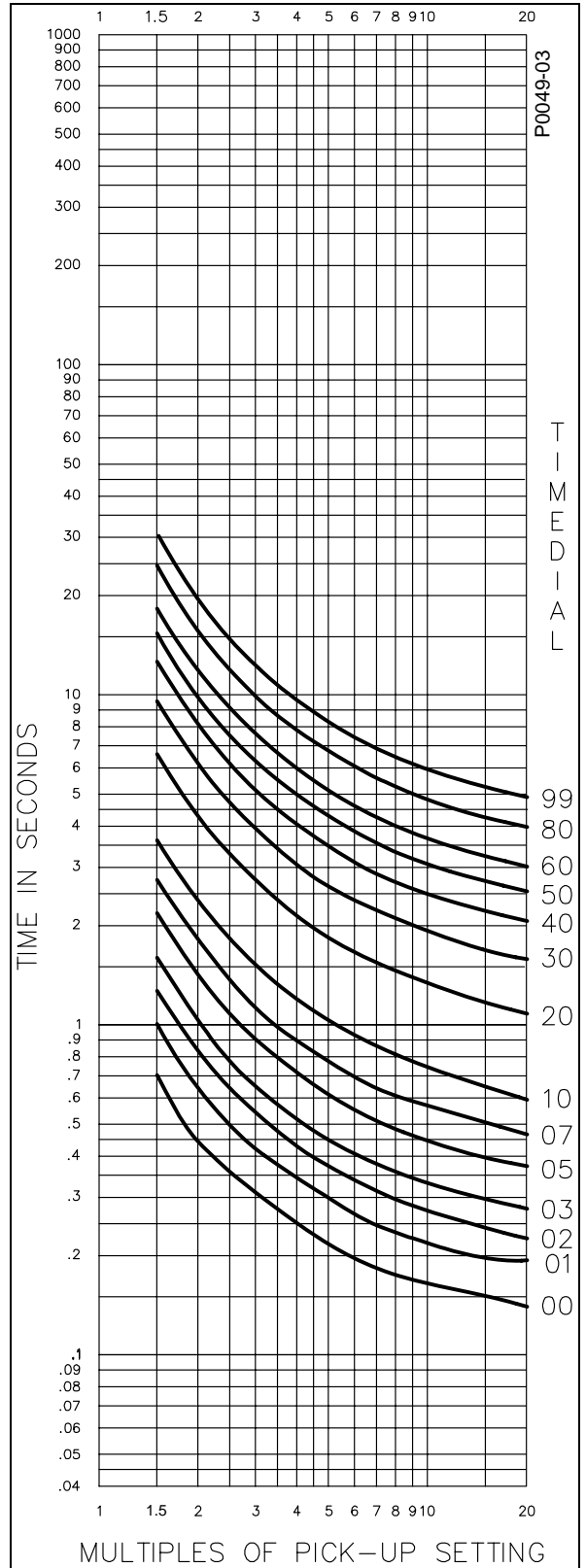
Figure A-2. Timing Type B1, Short Inverse with Extended Timing Range
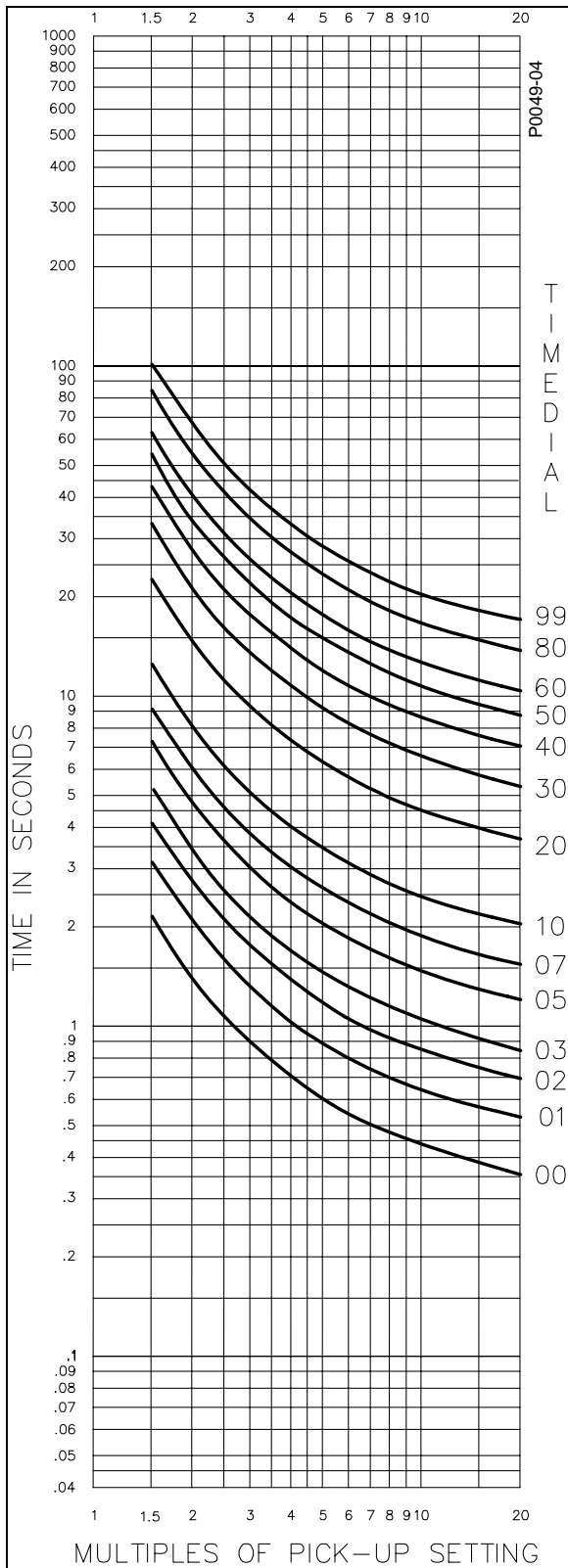
Figure A-3. Timing Type B2, Long Inverse
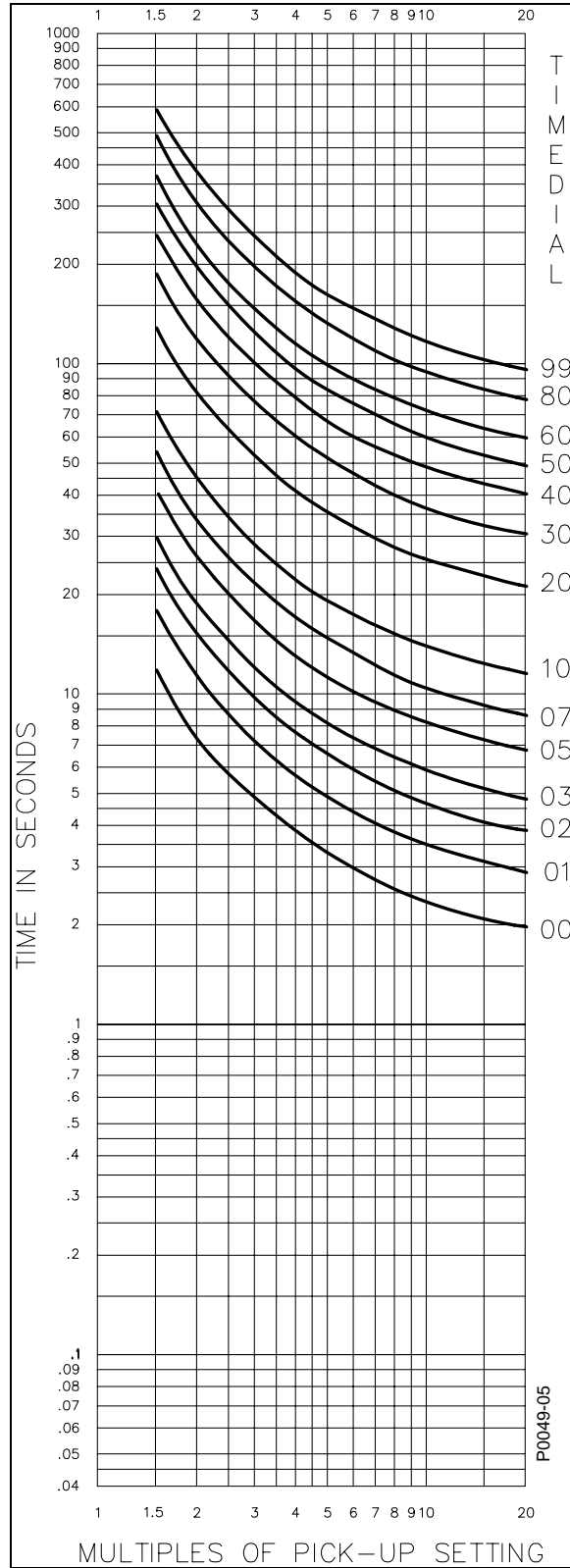
Figure A-4. Timing Type B2, Long Inverse
with Extended Timing Range
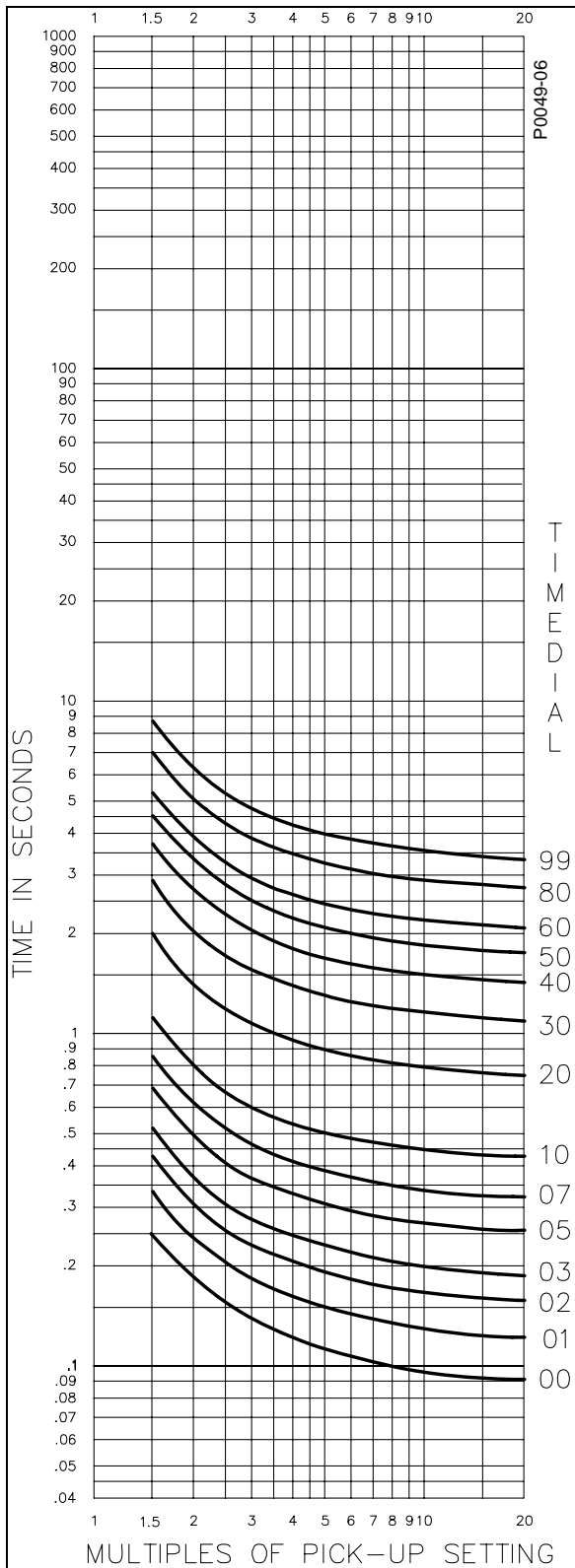
Figure A-5. Timing Type B3, Definite Time
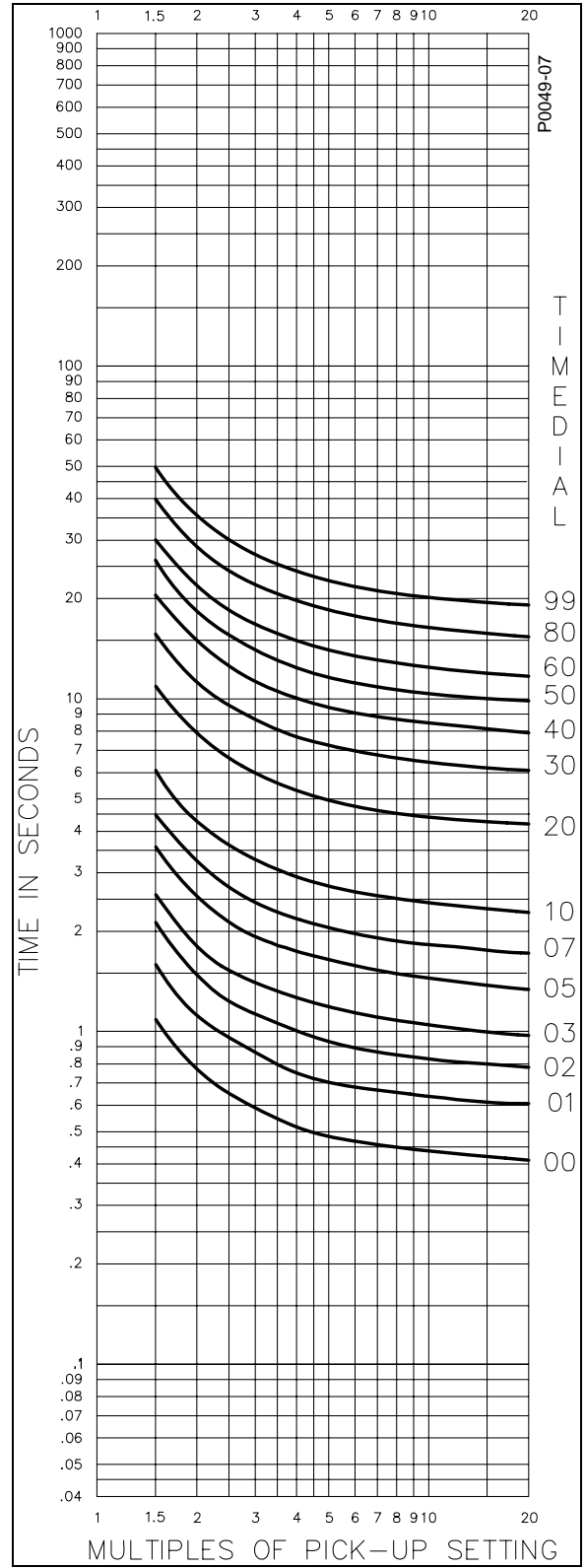
Figure A-6. Timing Type B3, Definite Time with Extended Timing Range
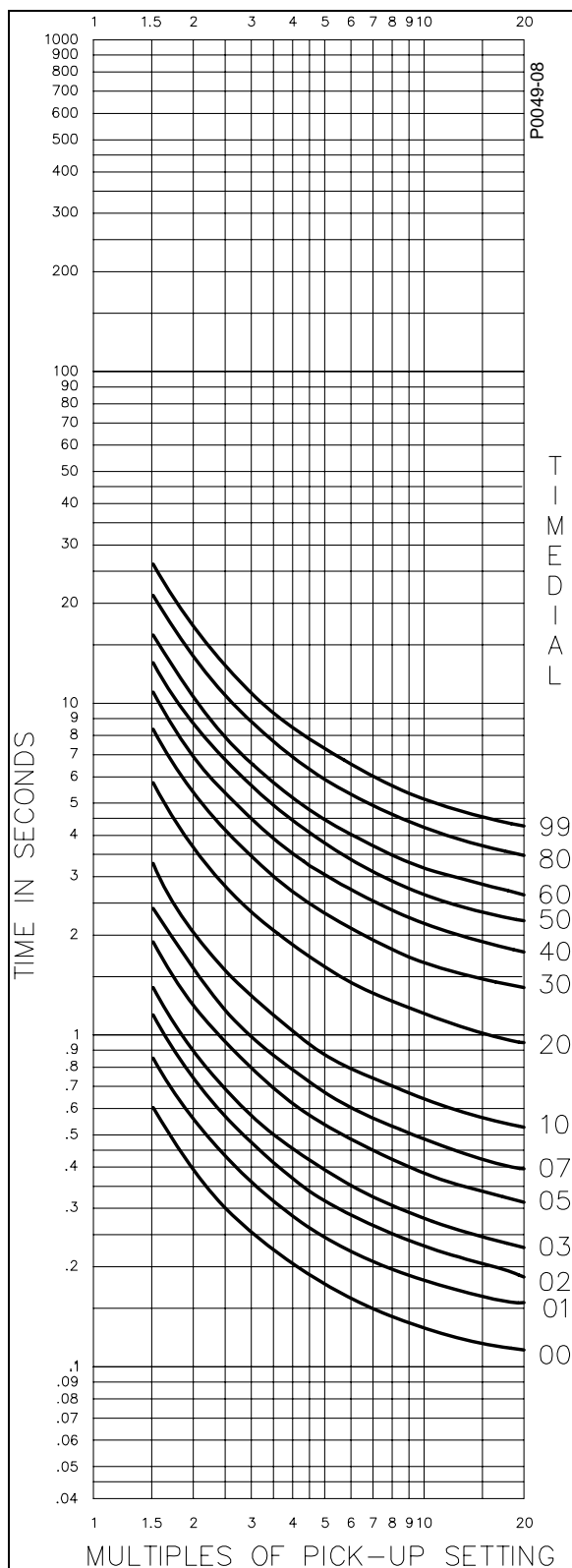
Figure A-7. Timing Type B4, Moderately Inverse
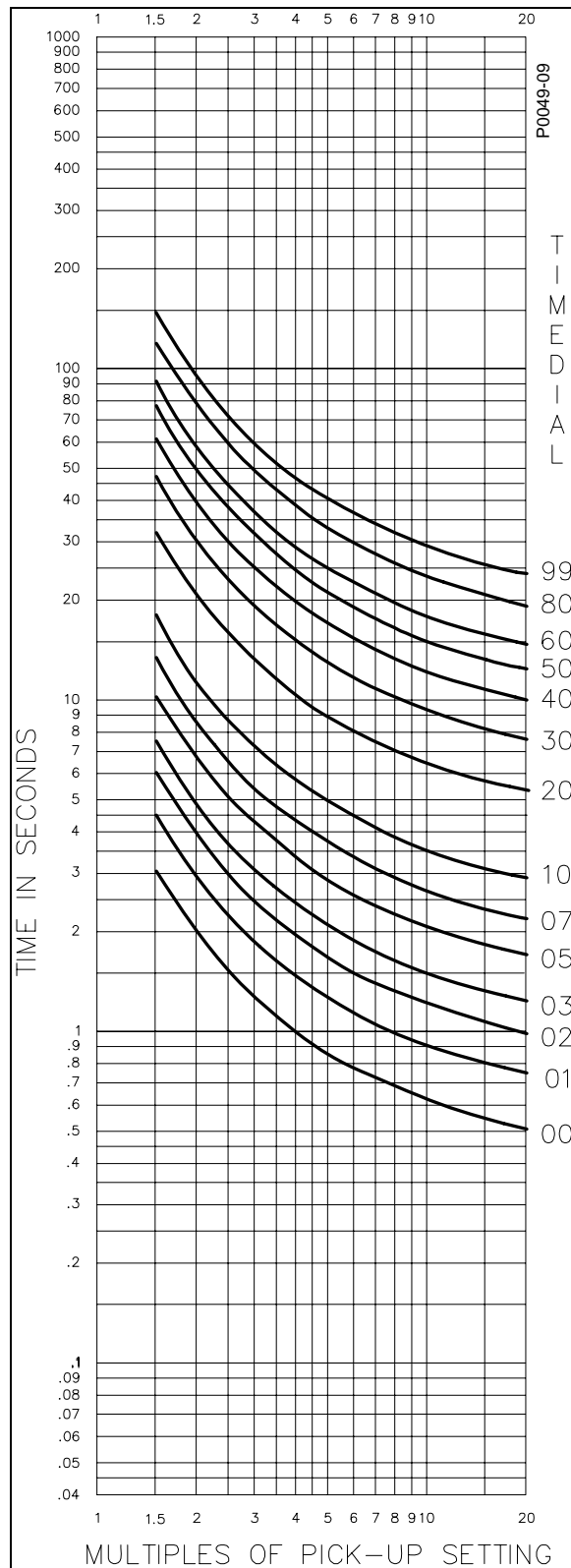
Figure A-8. Timing Type B4, Moderately Inverse with Extended Timing Range
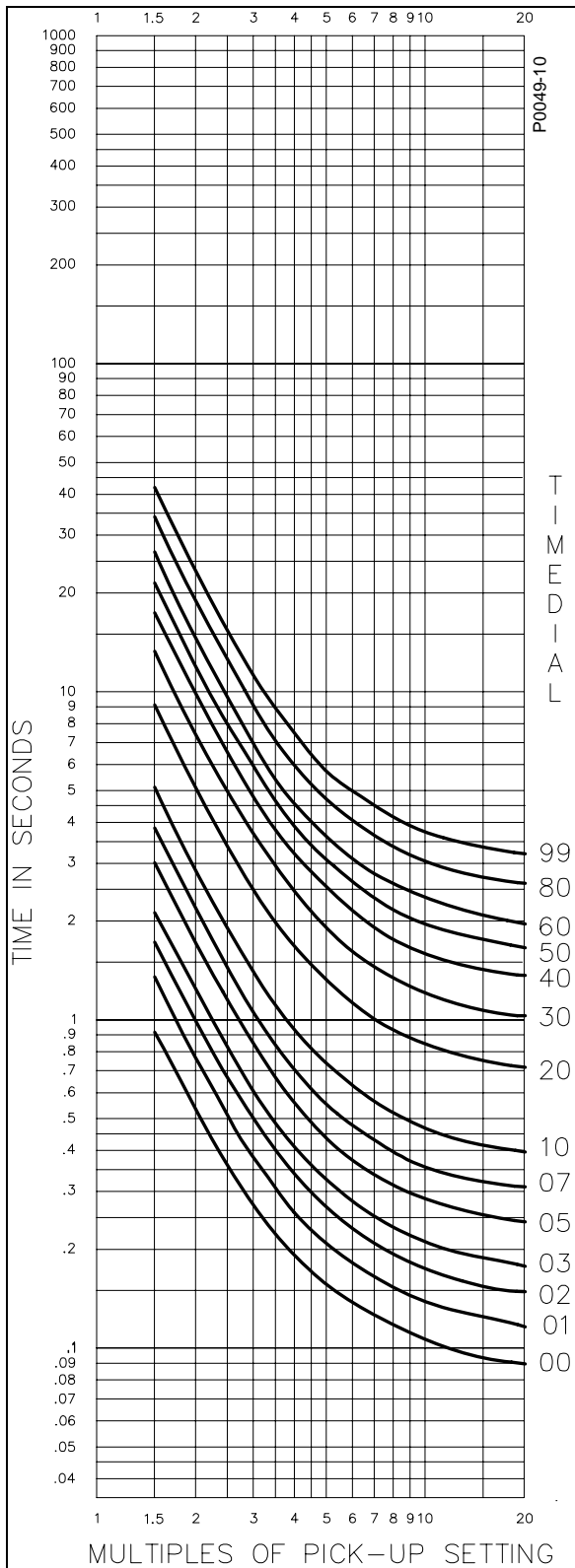
Figure A-9. Timing Type B5, Inverse
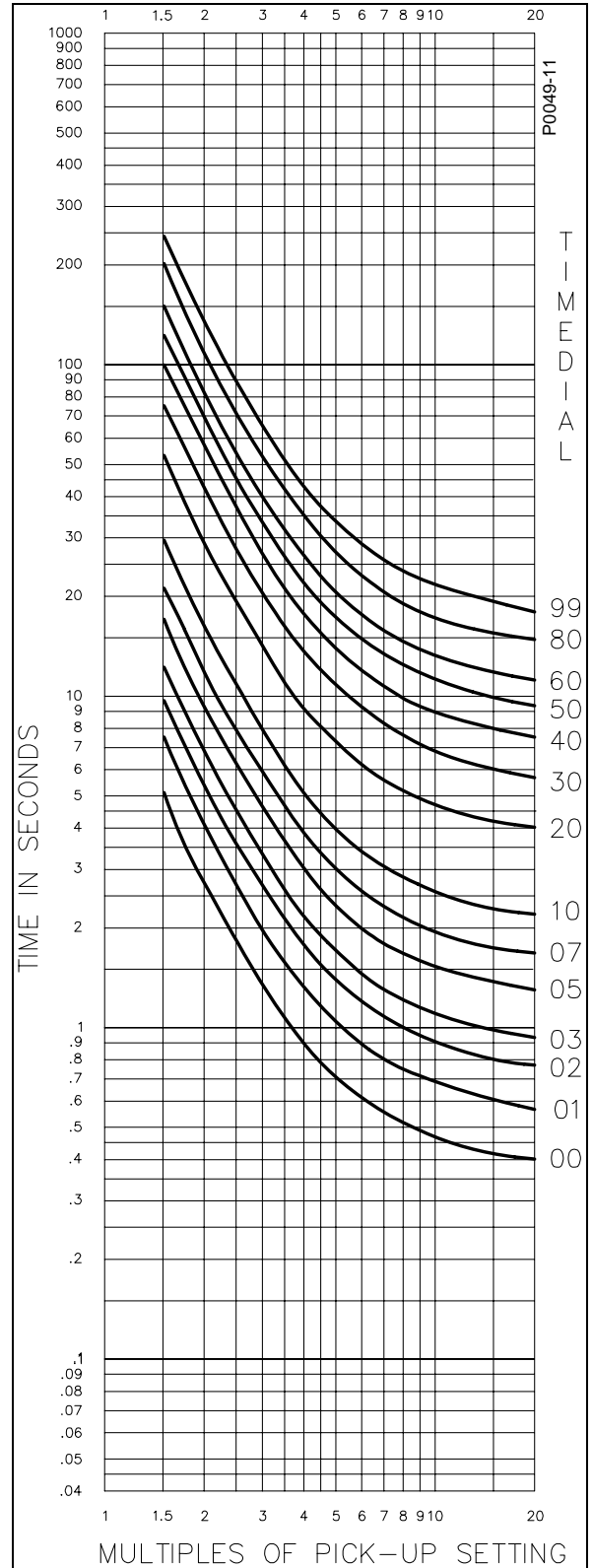
Figure A-10. Timing Type B5, Inverse with Extended Timing Range
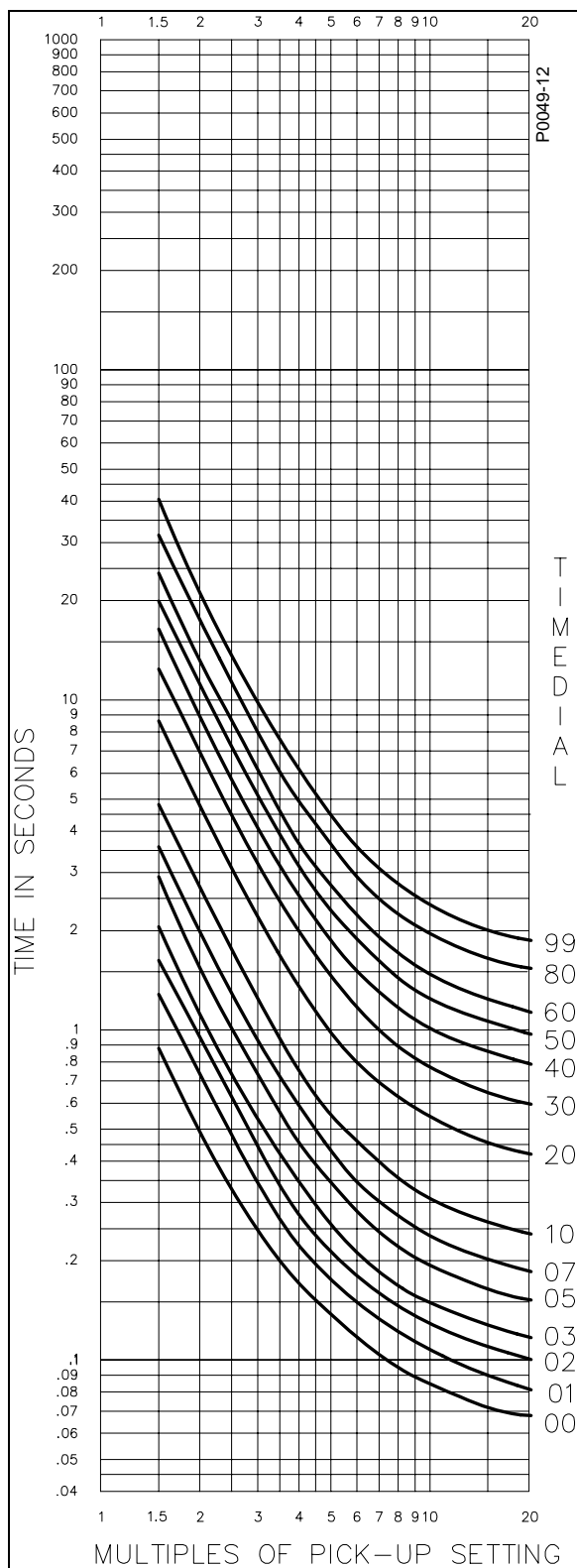
Figure A-11. Timing Type B6, Very Inverse
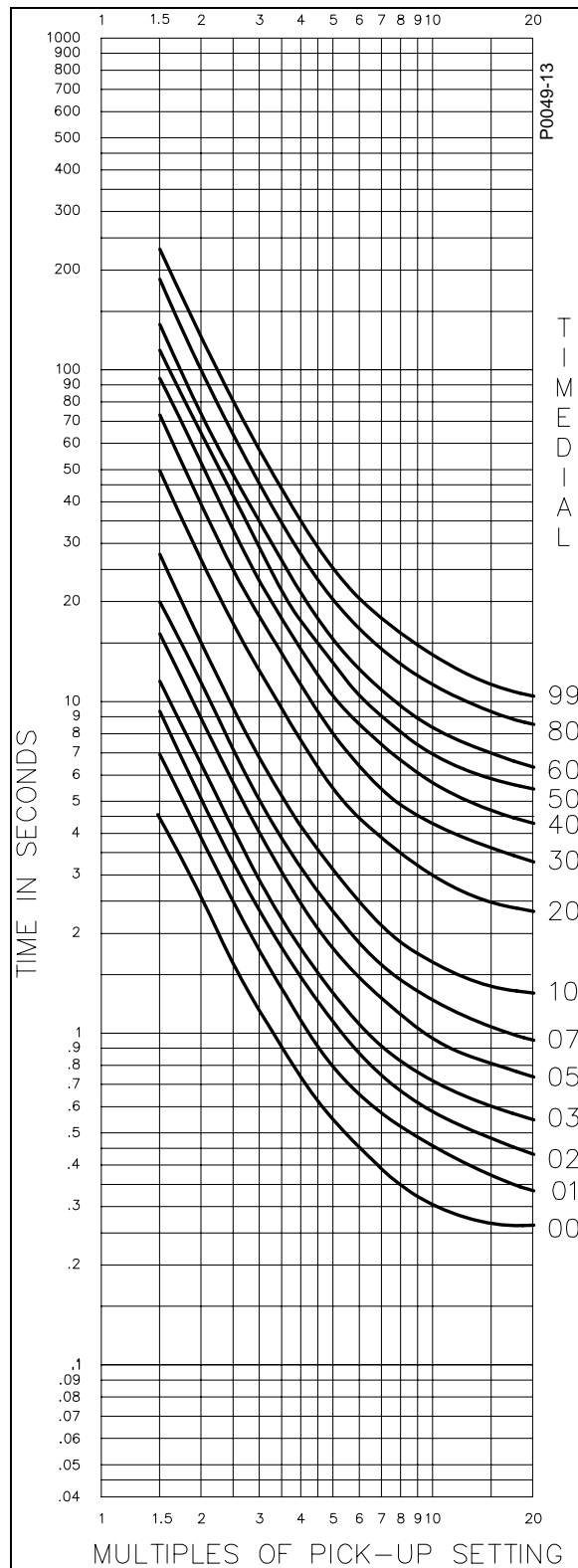
Figure A-12. Timing Type B6, Very Inverse with Extended Timing Range
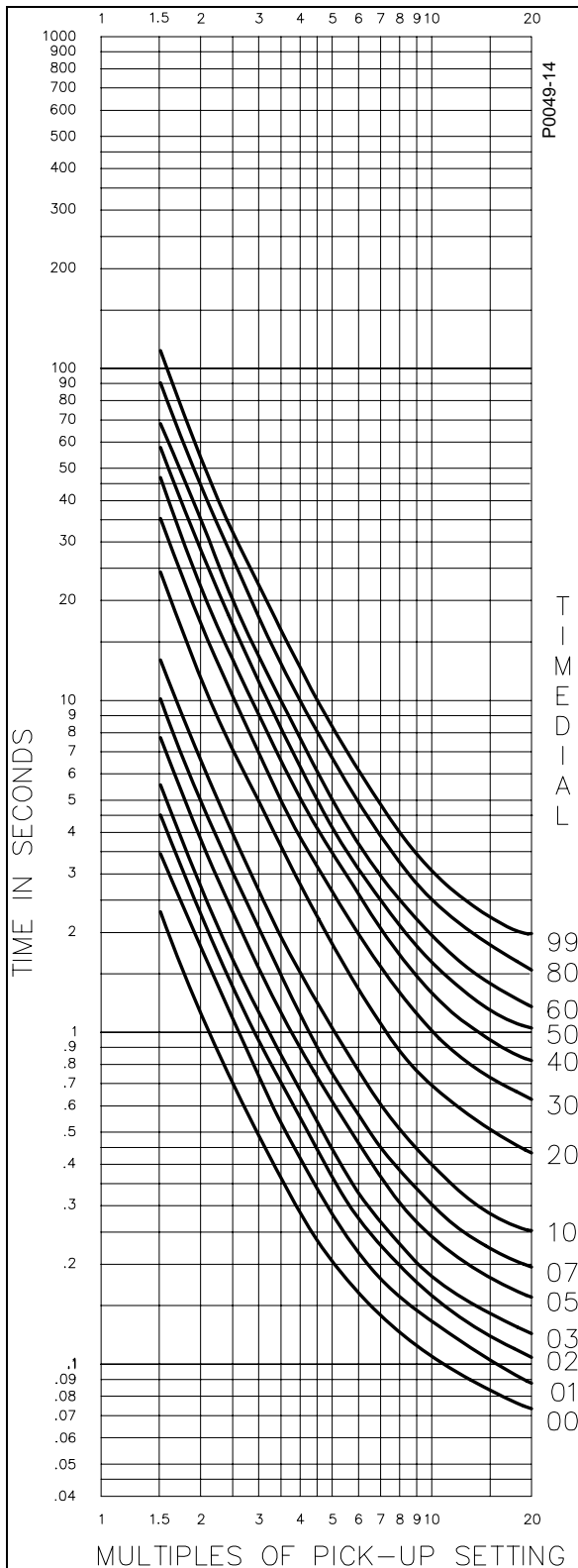
Figure A-13. Timing Type B7, Extremely Inverse
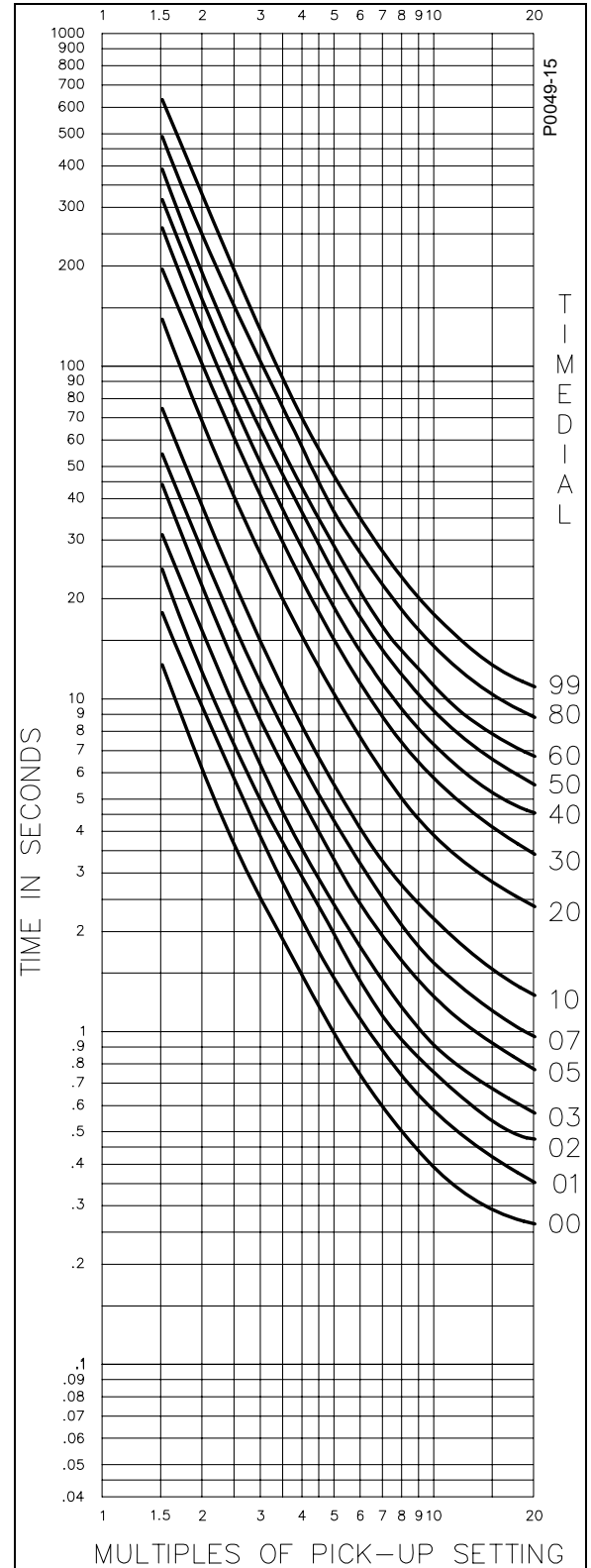
Figure A-14. Timing Type B7, Extremely Inverse with Extended Timing Range
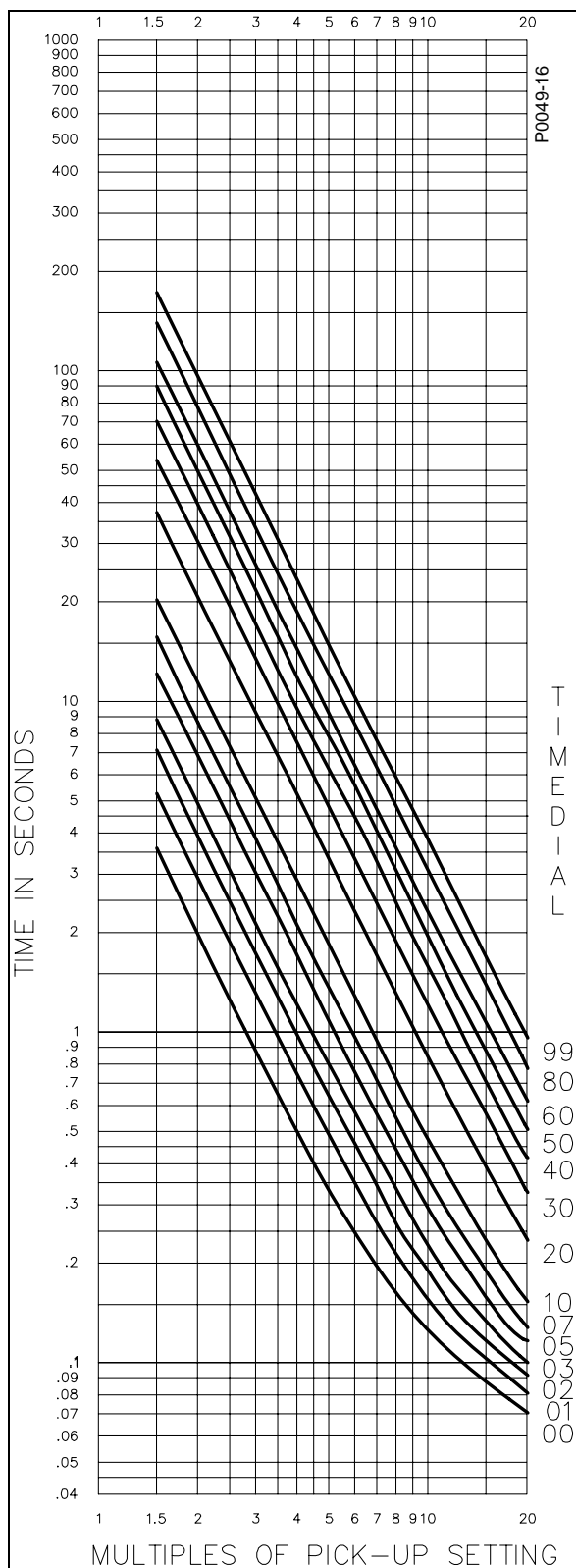
Figure A-15. Timing Type B8, I^2t
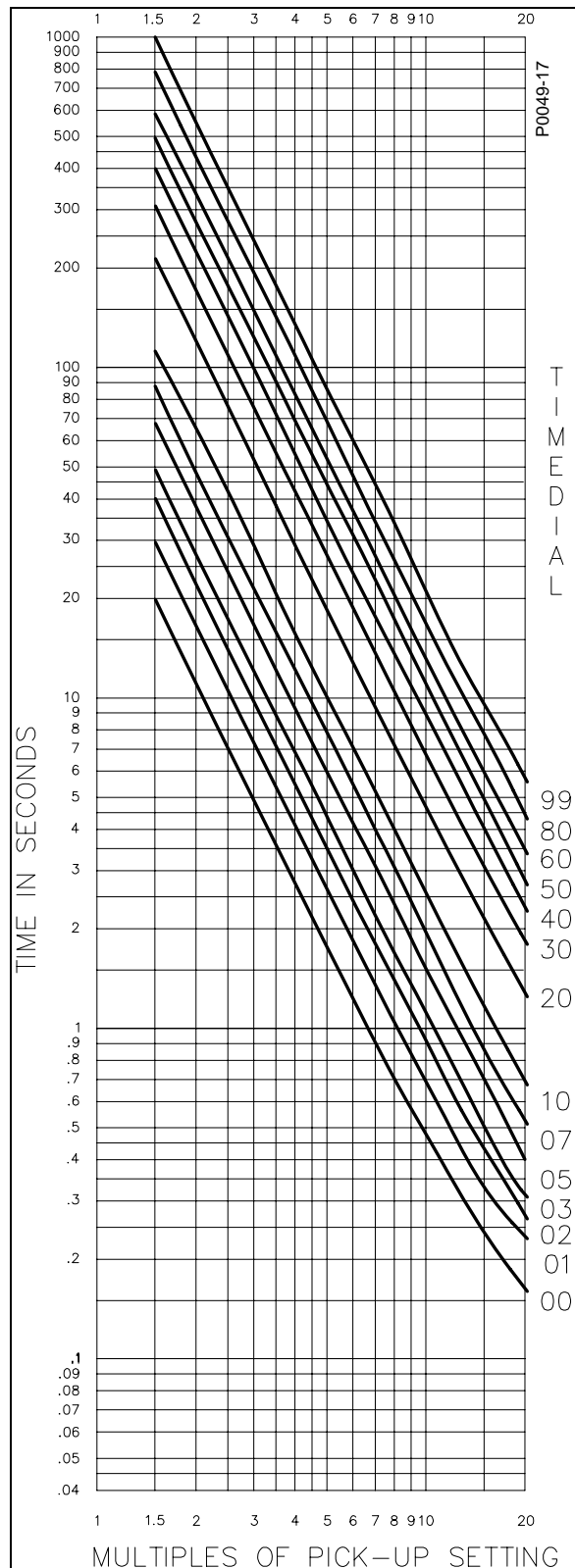
Figure A-16. Timing Type B8, I^2t
with Extended Timing Range
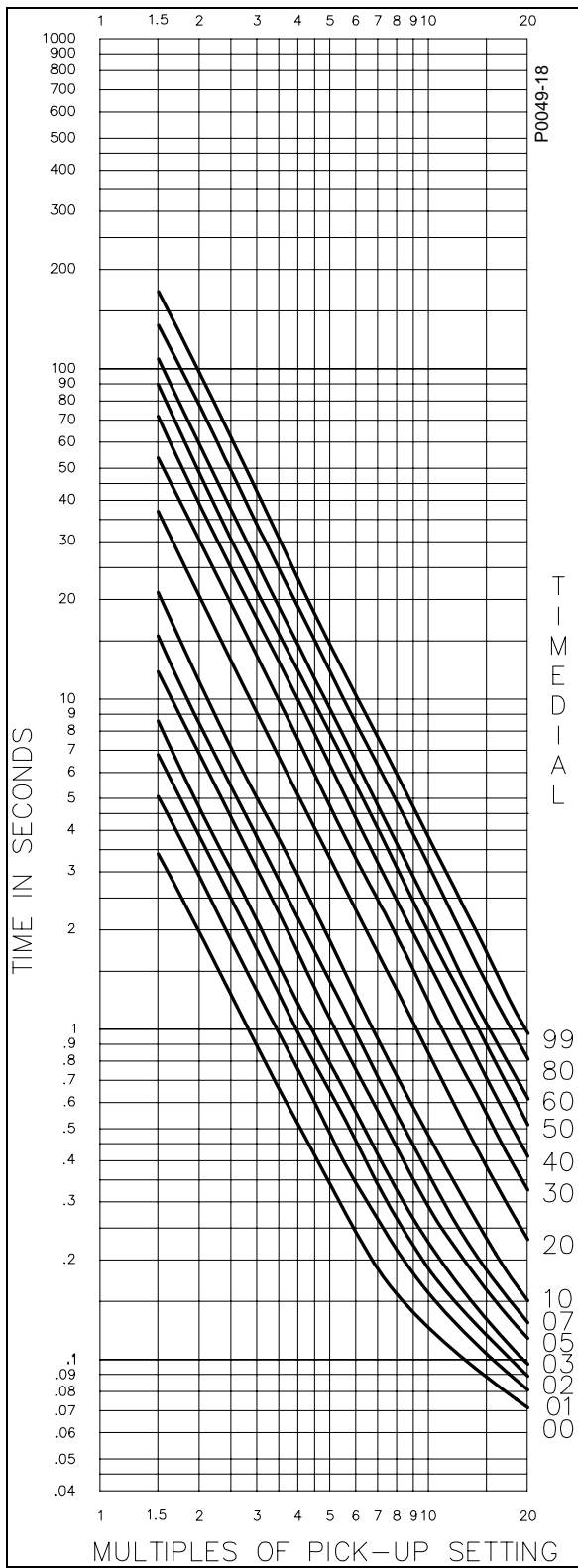
Figure A-17. Timing Type C1, I^2t with Limit #1
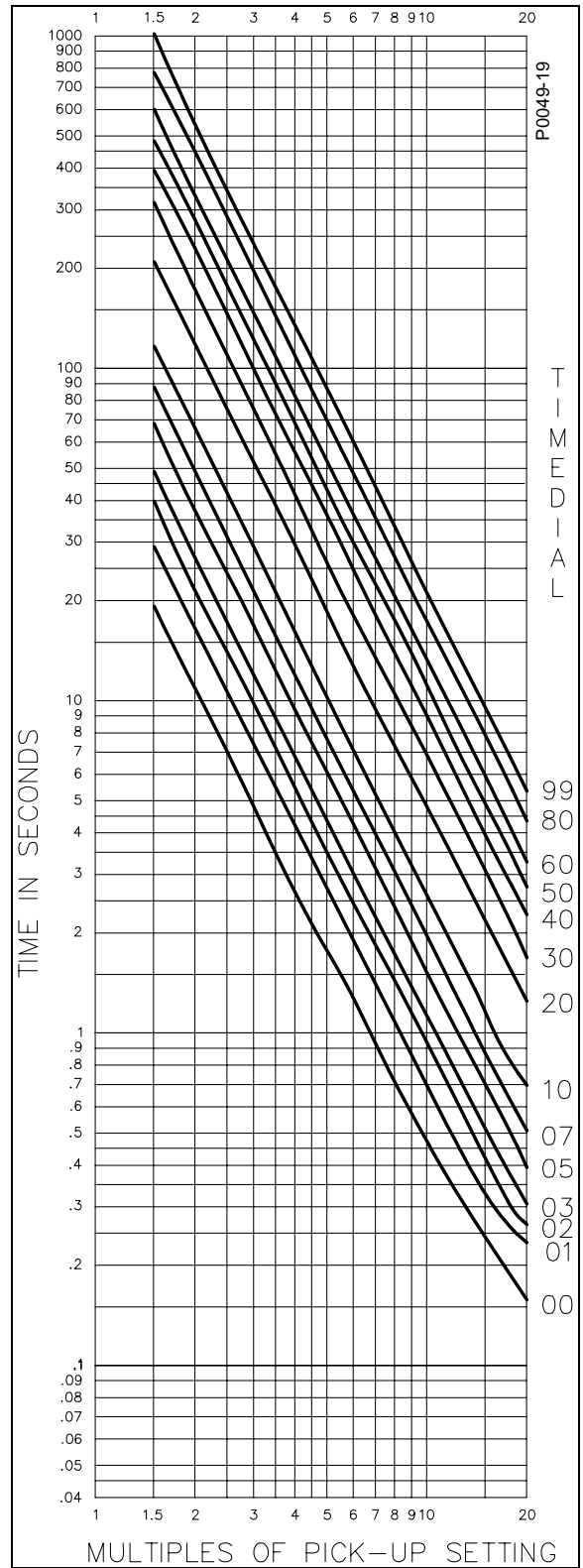
Figure A-18. Timing Type C1, I^2t with Limit #1 and Extended Timing Range
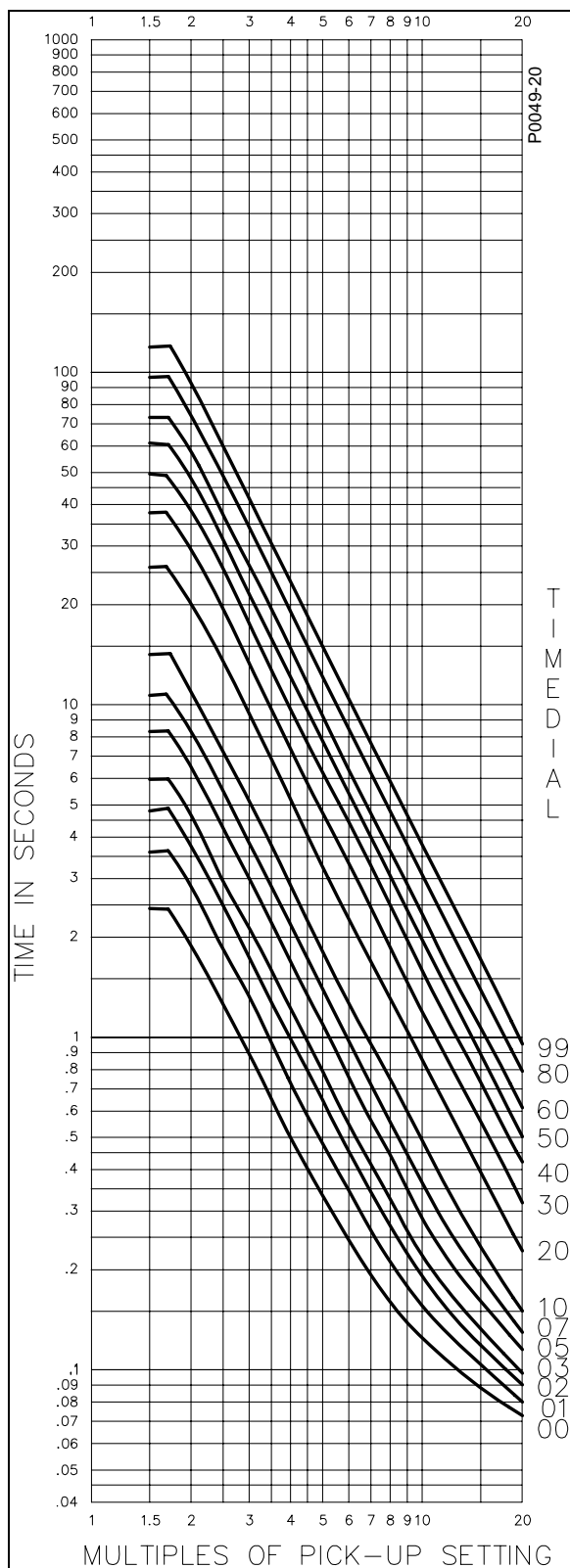
Figure A-19. Timing Type C2, I^2t with Limit #2
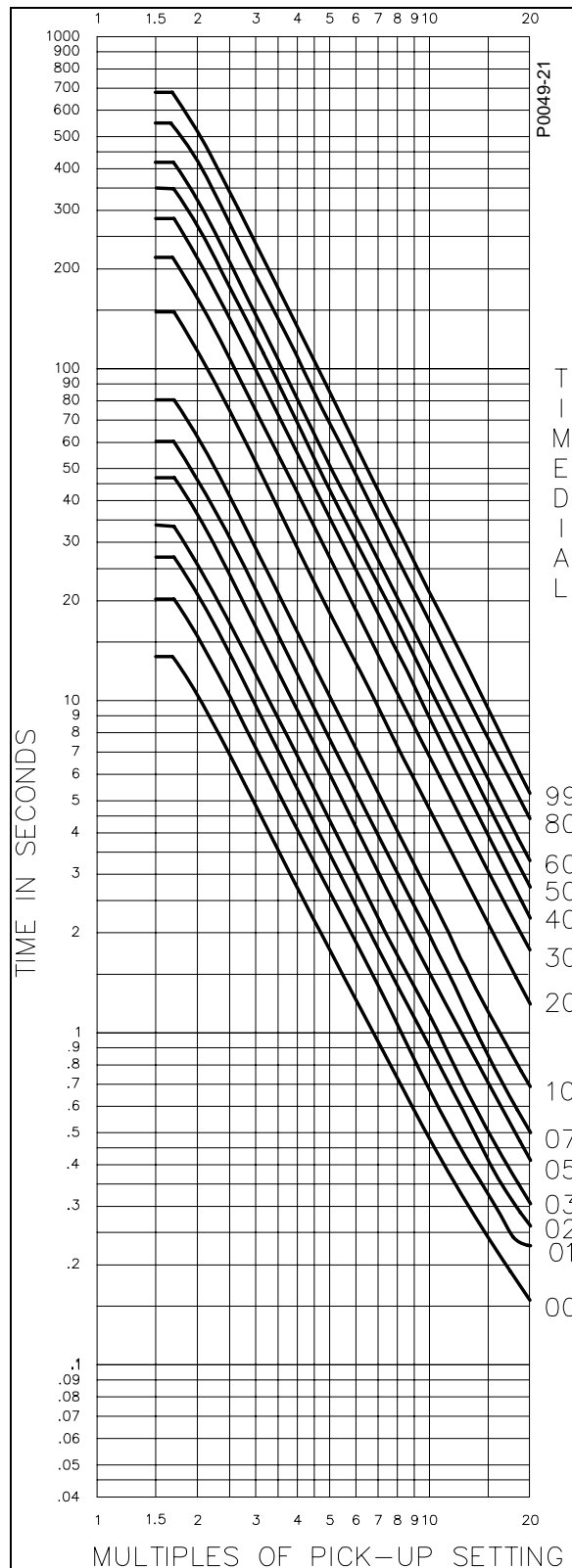
Figure A-20. Timing Type C2, I^2t with Limit #2 and Extended Timing Range
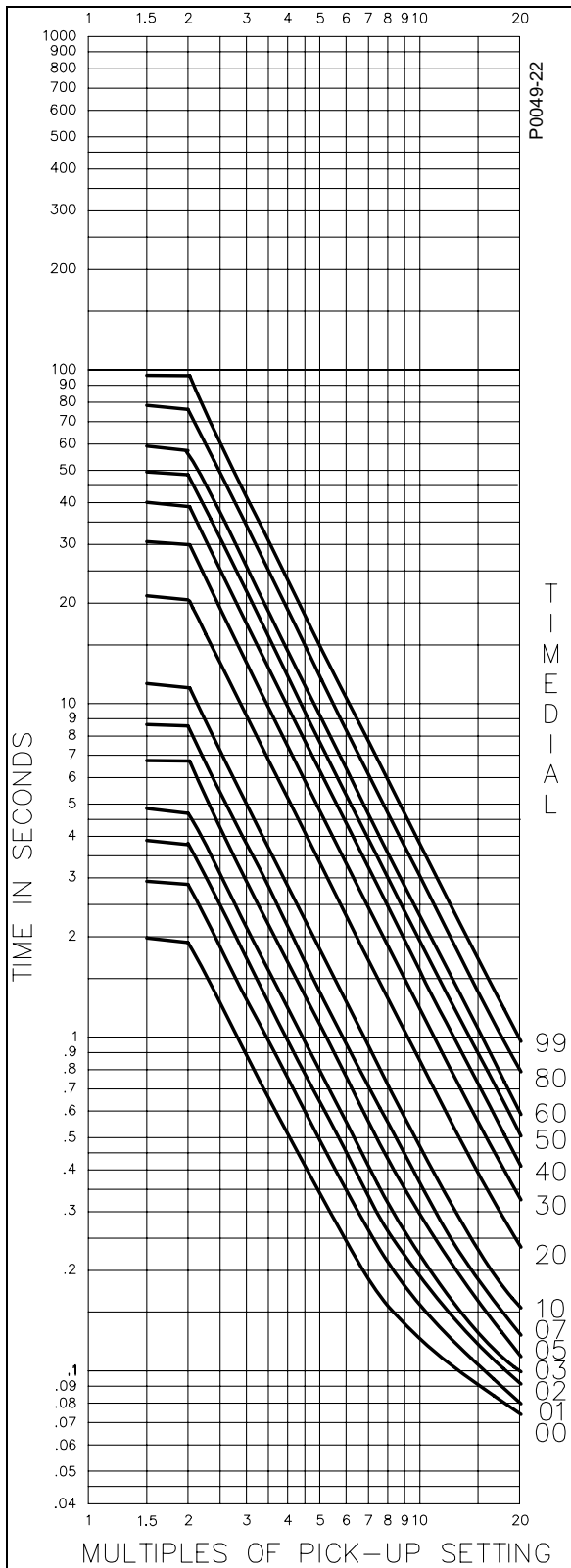
Figure A-21. Timing Type C3, I^2t with Limit #3
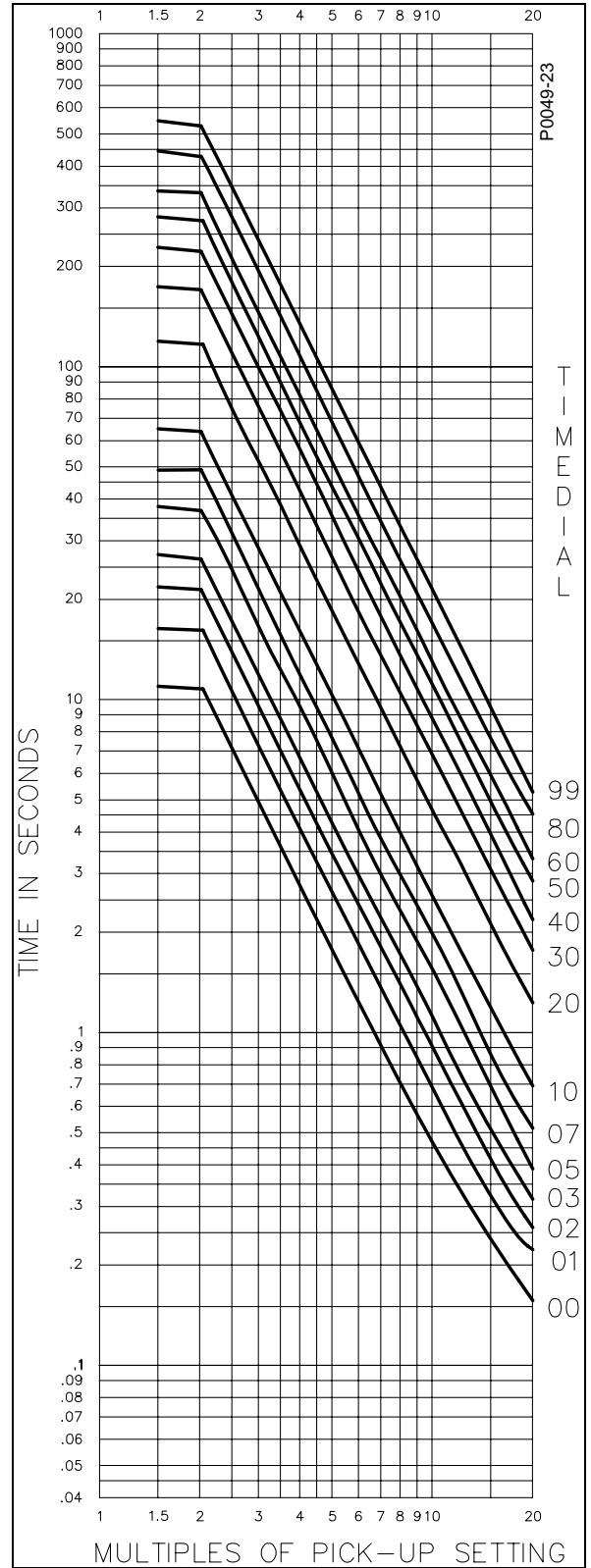
Figure A-22. Timing Type C3, I^2t with Limit #3 and Extended Timing Range
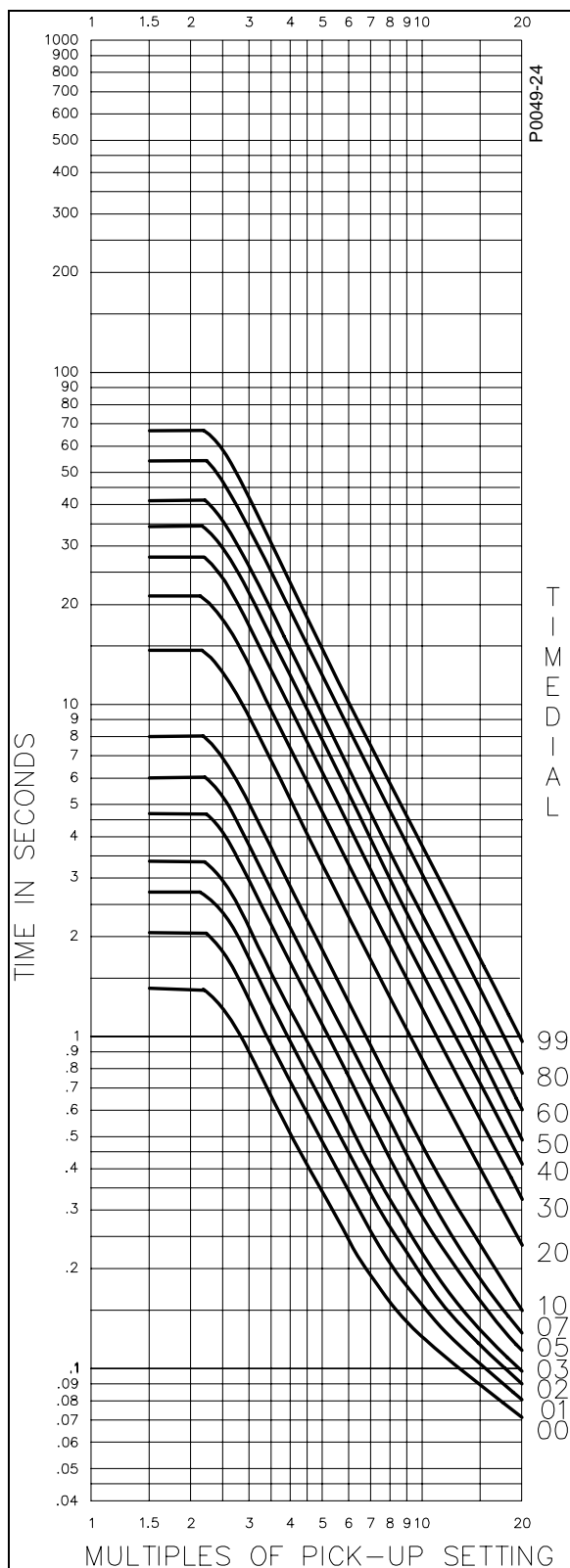
Figure A-23. Timing Type C4, I^2t with Limit #4
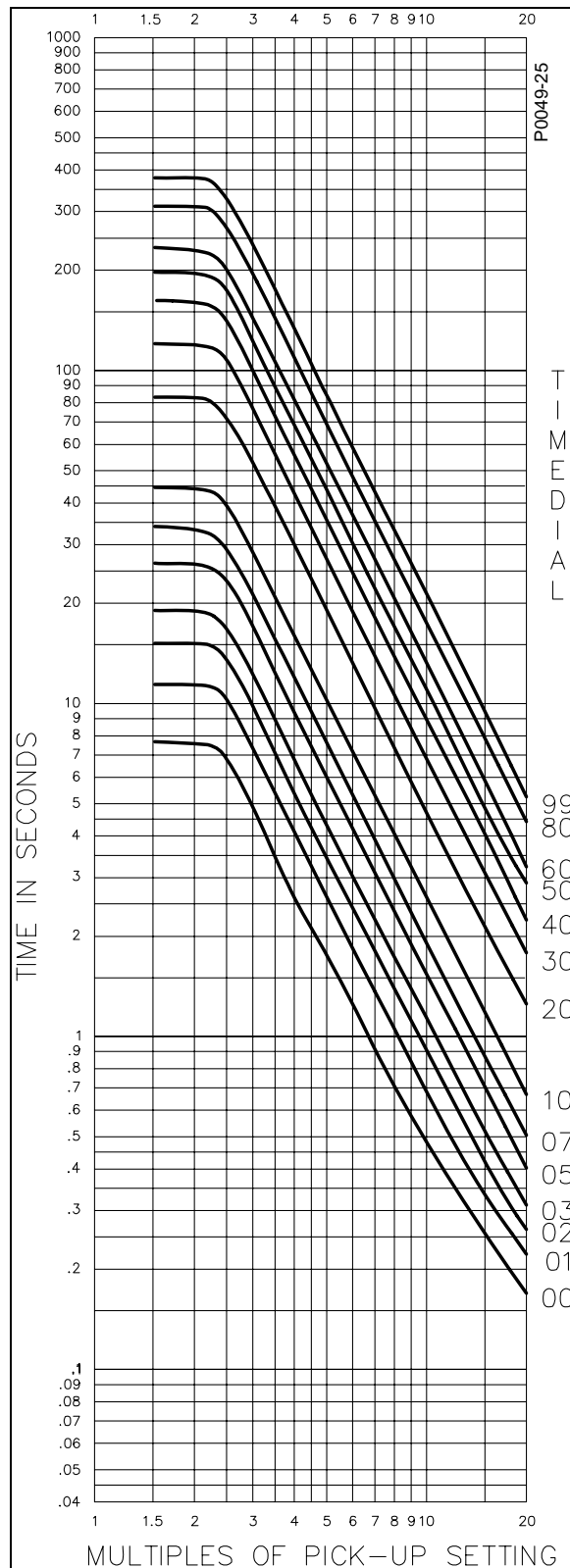
Figure A-24. Timing Type C4, I^2t with Limit #4 and Extended Timing Range
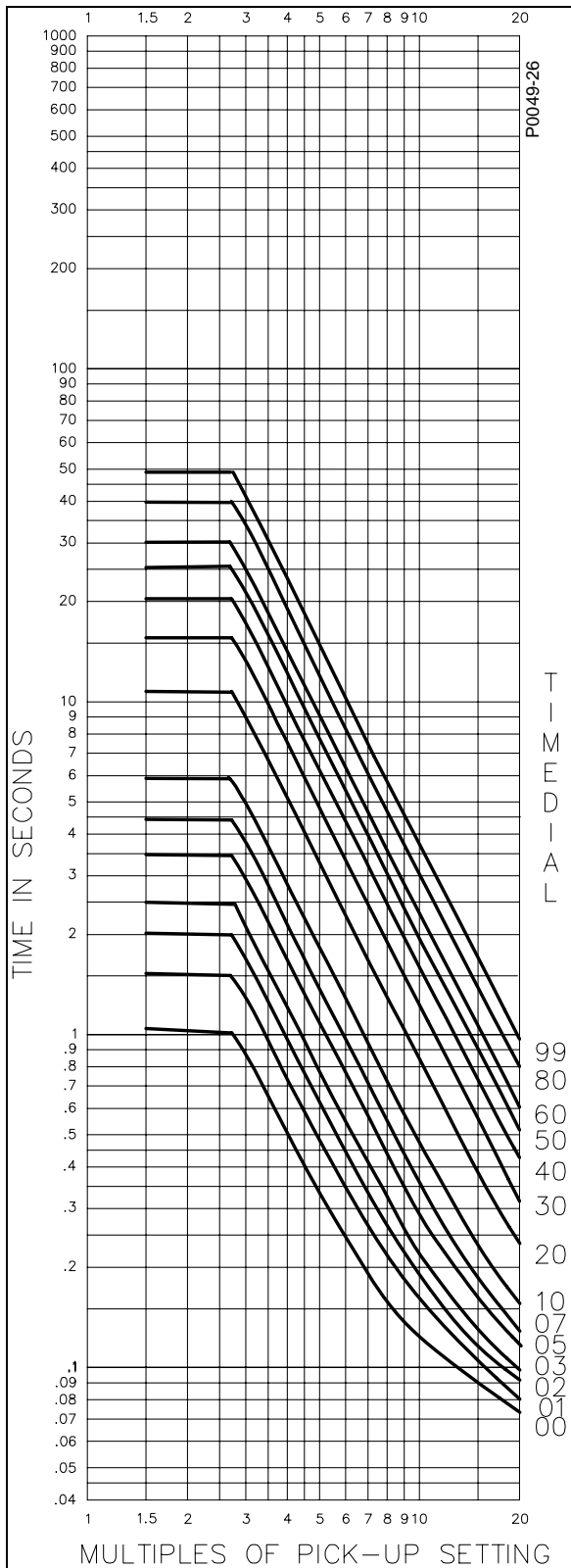
Figure A-25. Timing Type C5, I^2t with Limit #5
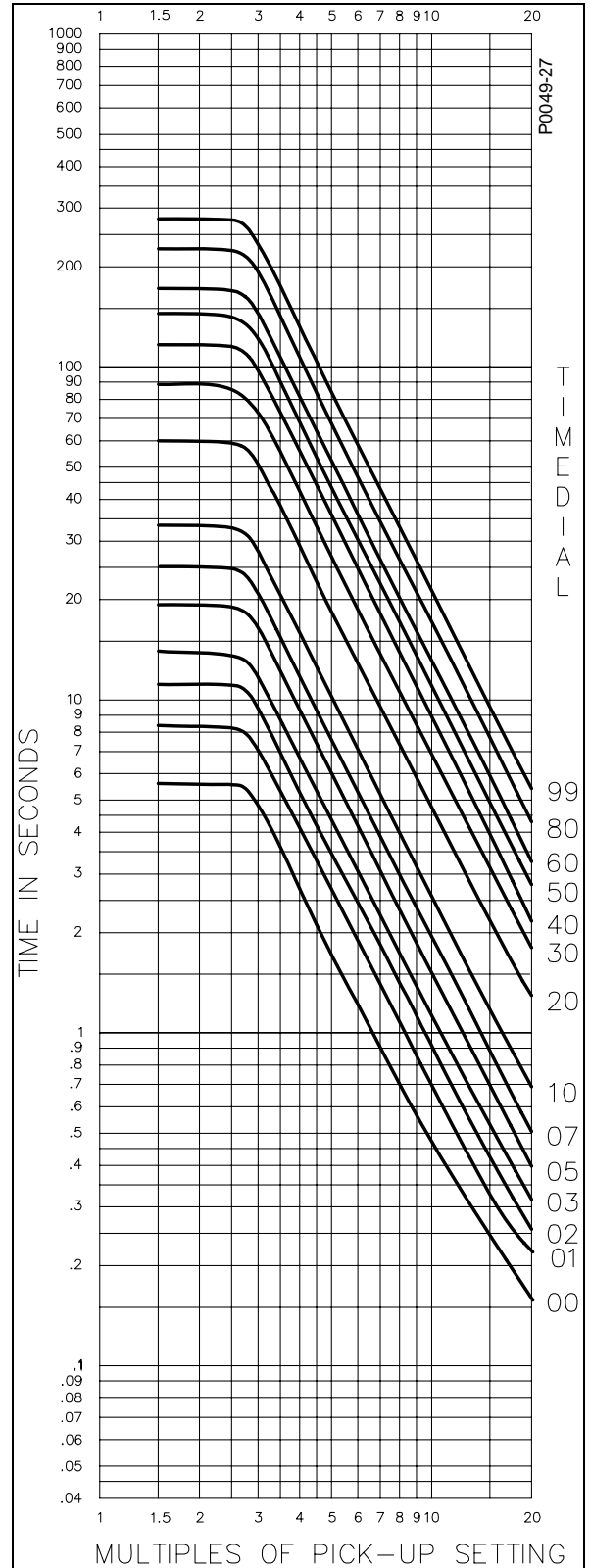
Figure A-26. Timing Type C5, I^2t with Limit #5 and Extended Timing Range
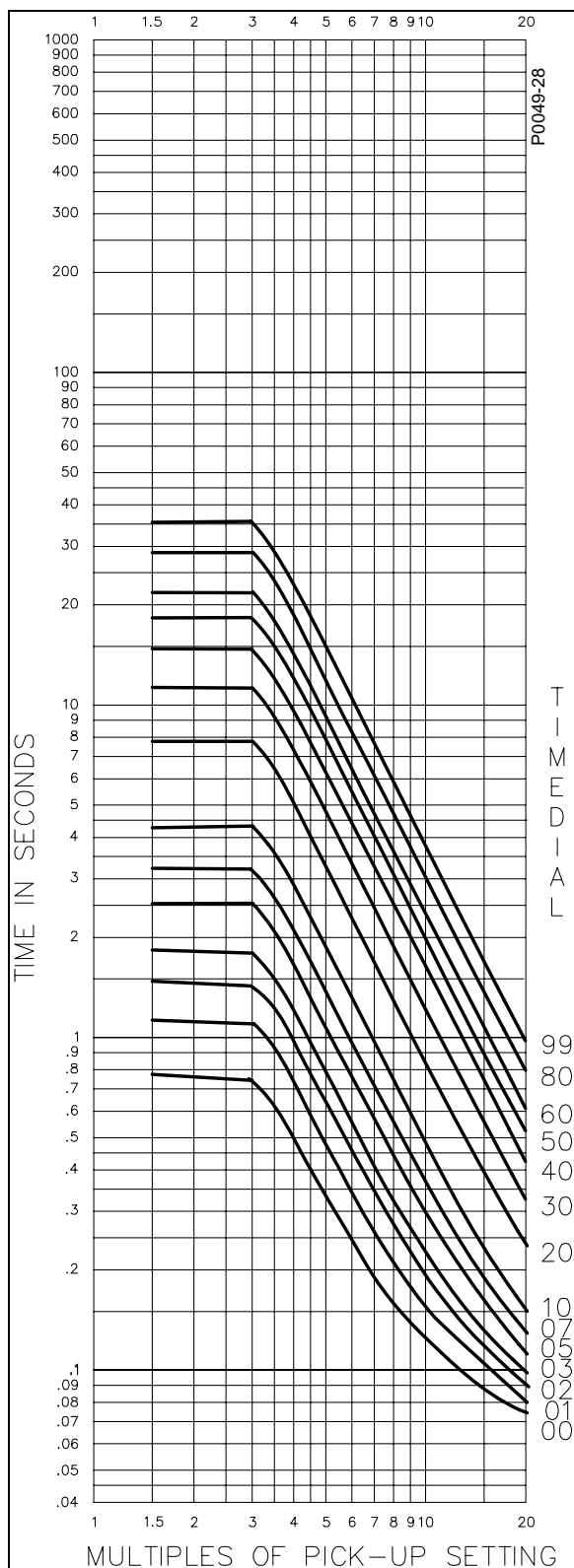
Figure A-27. Timing Type C6, I^2t with Limit #6
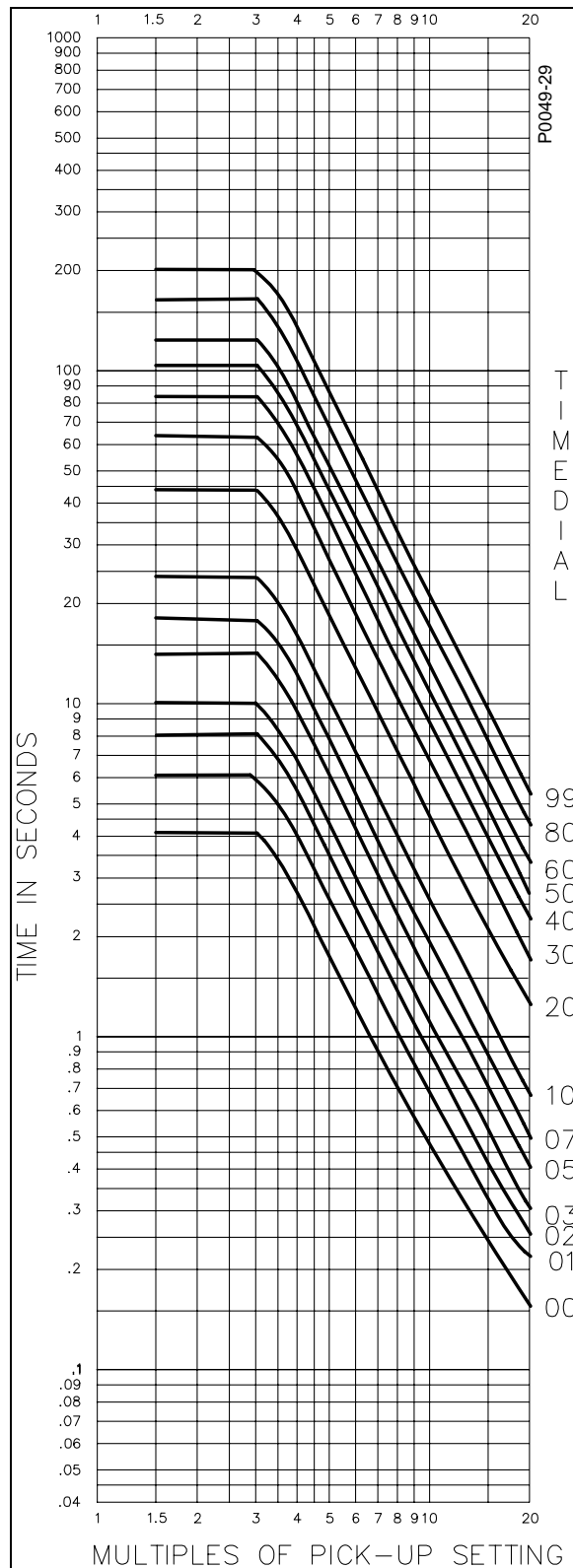
Figure A-28. Timing Type C6, I^2t with Limit #6 and Extended Timing Range
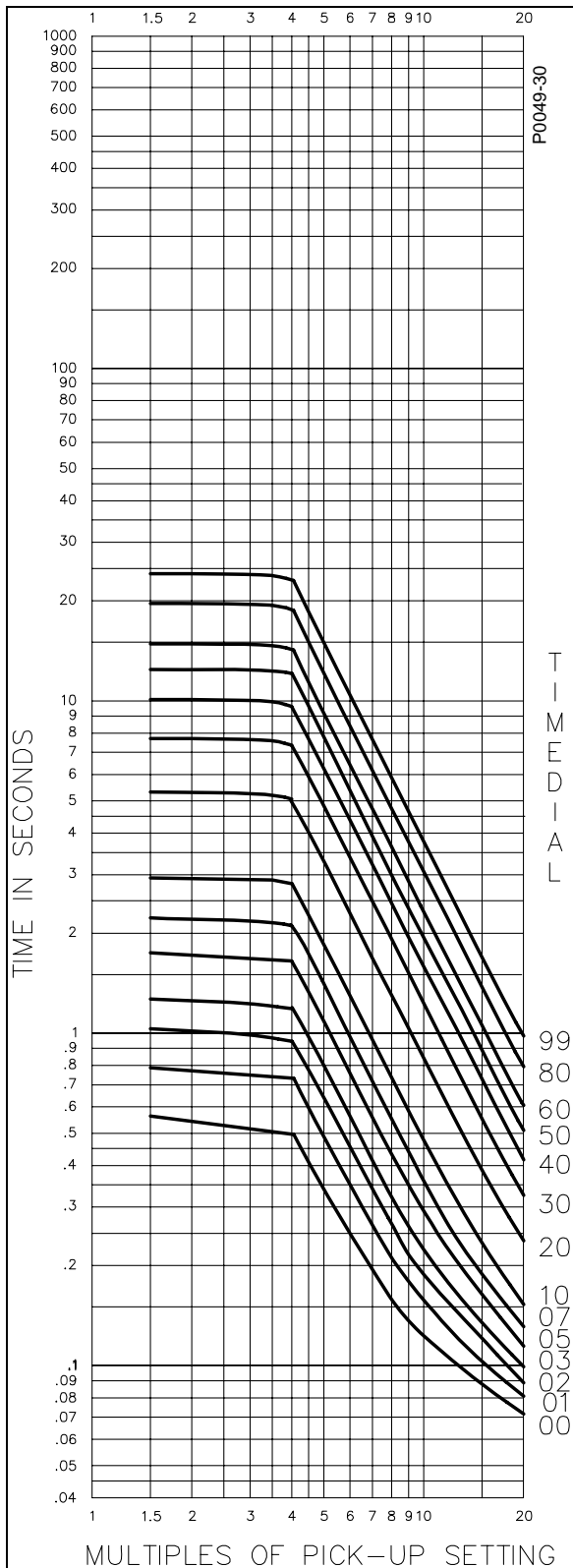
Figure A-29. Timing Type C7, I^2t with Limit #7
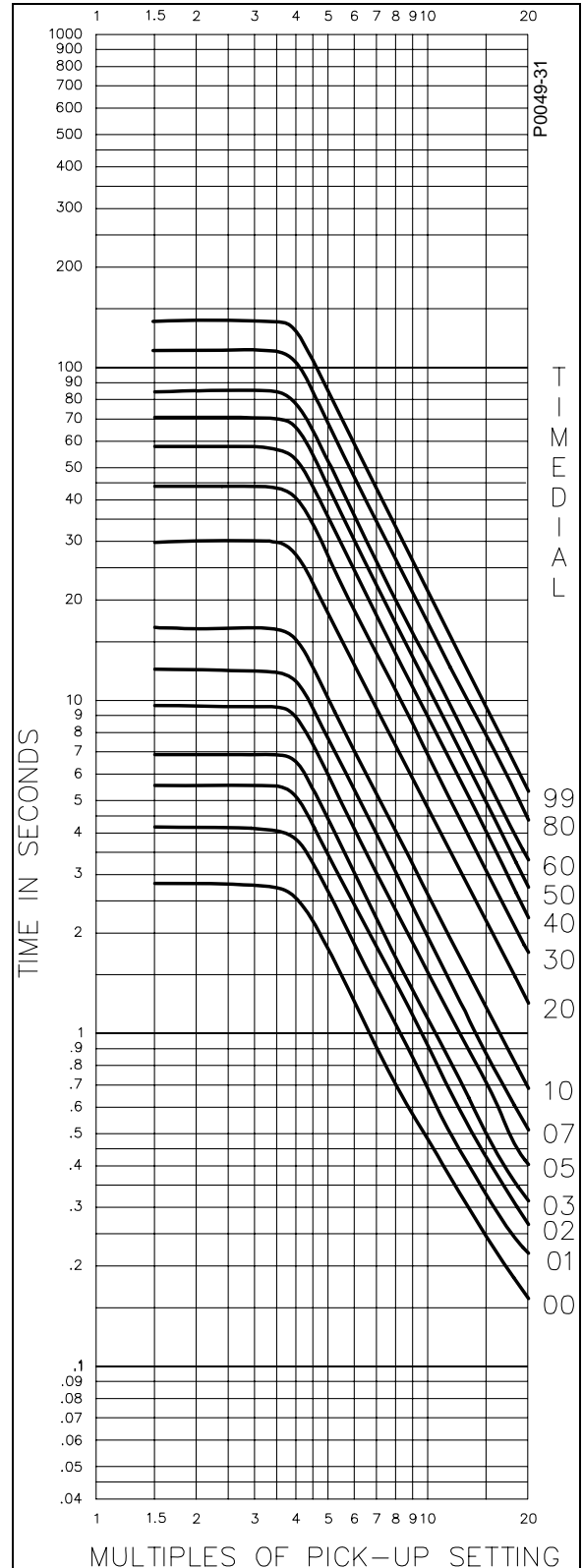
Figure A-30. Timing Type C7, I^2t with Limit #7 and Extended Timing Range
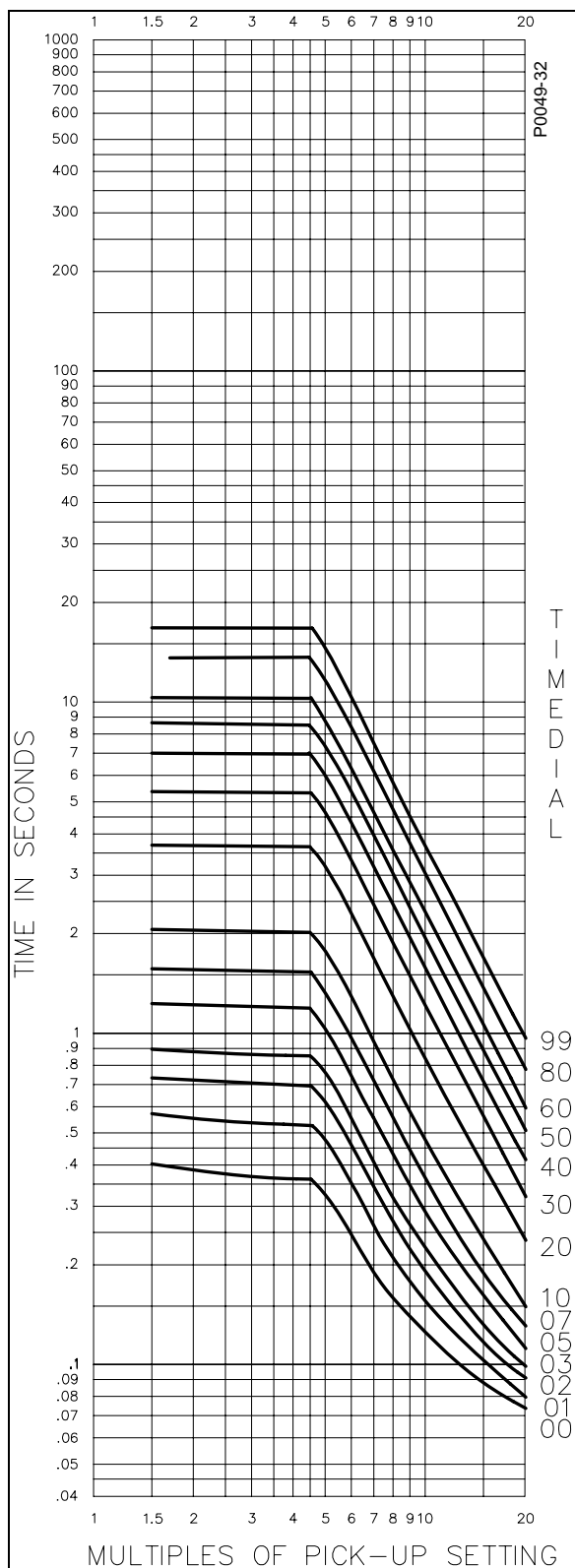
Figure A-31. Timing Type C8, I^2t with Limit #8
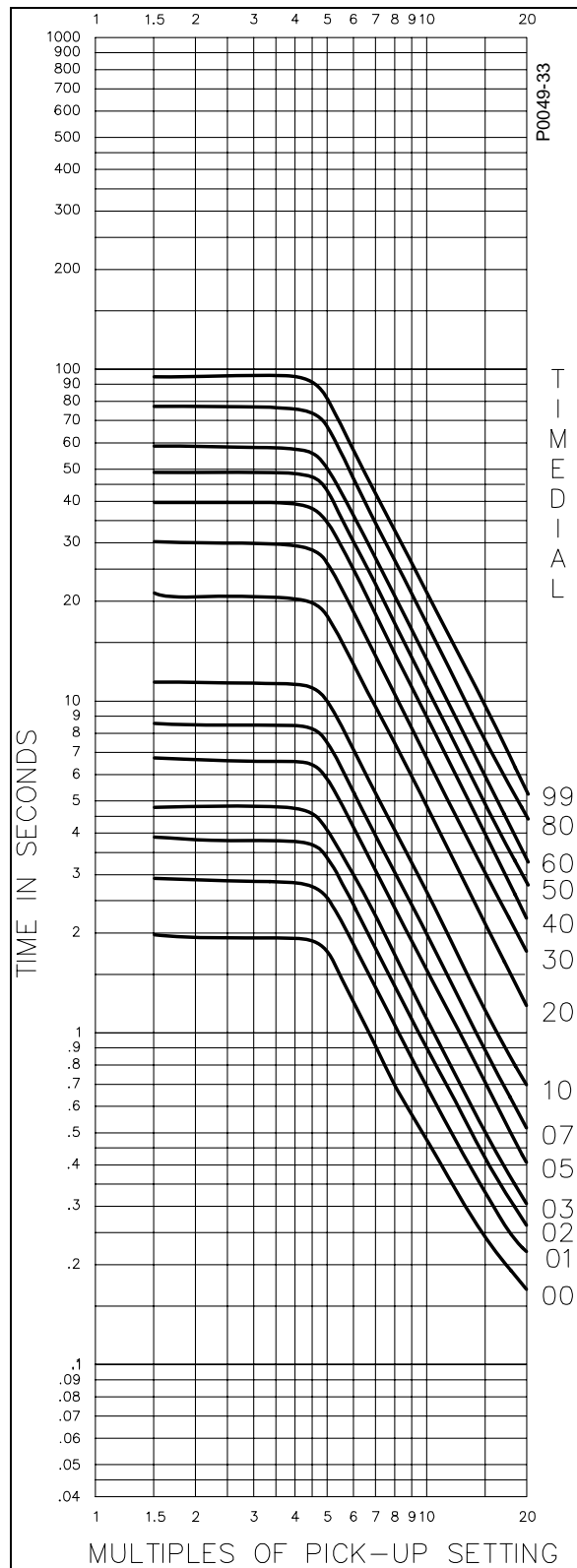
Figure A-32. Timing Type C8, I^2t with Limit #8 and Extended Timing Range
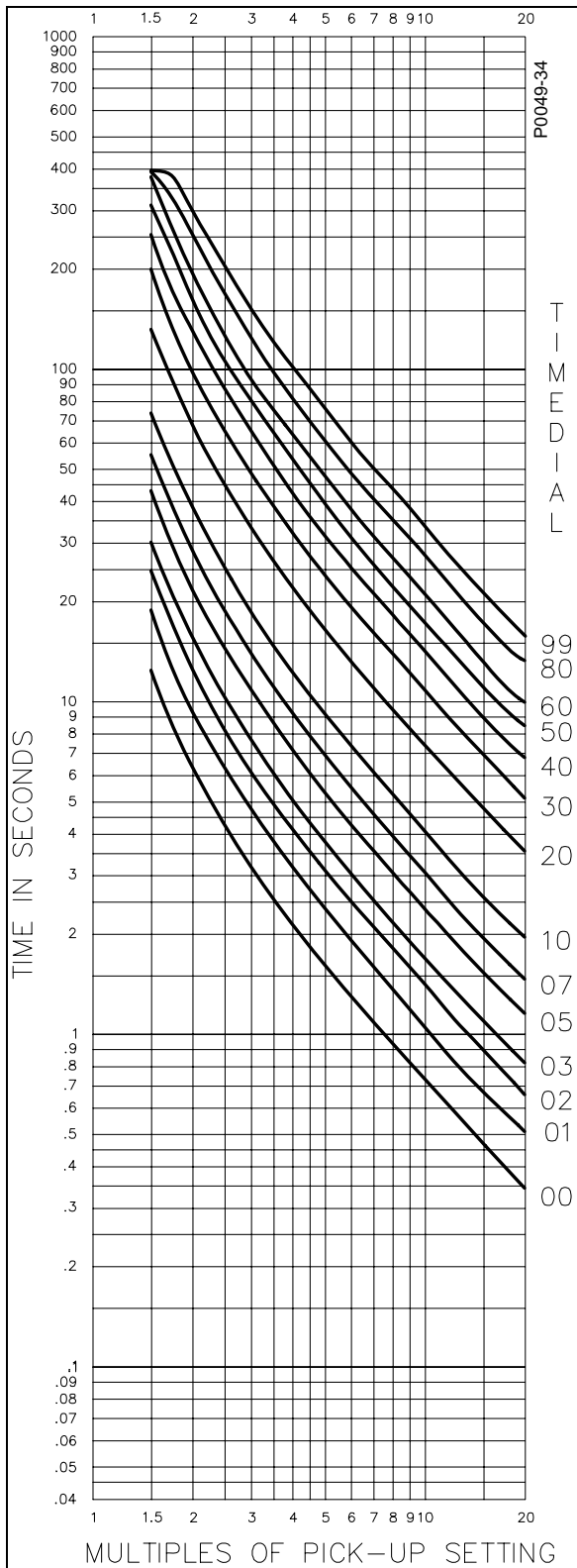
Figure A-33. Timing Type E2, BS 142
Long Inverse
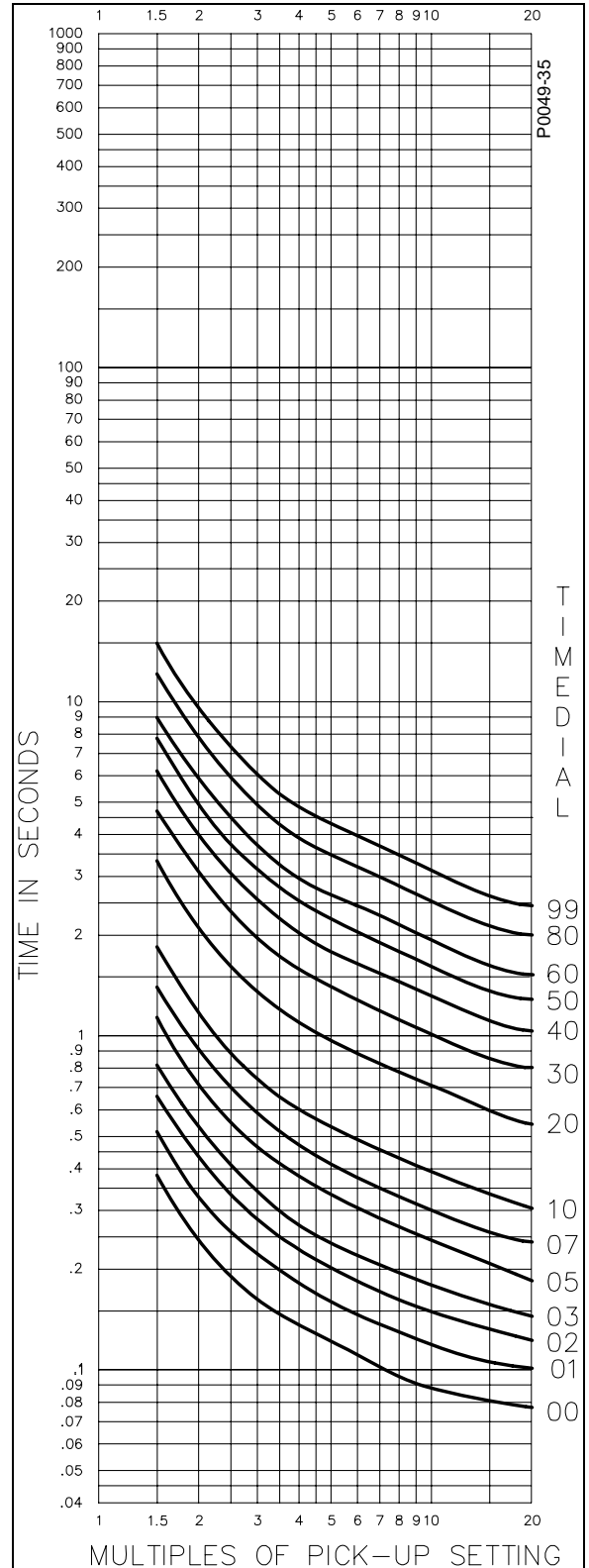
Figure A-34. Timing Type E4,
BS 142 Inverse (1.3 Sec)
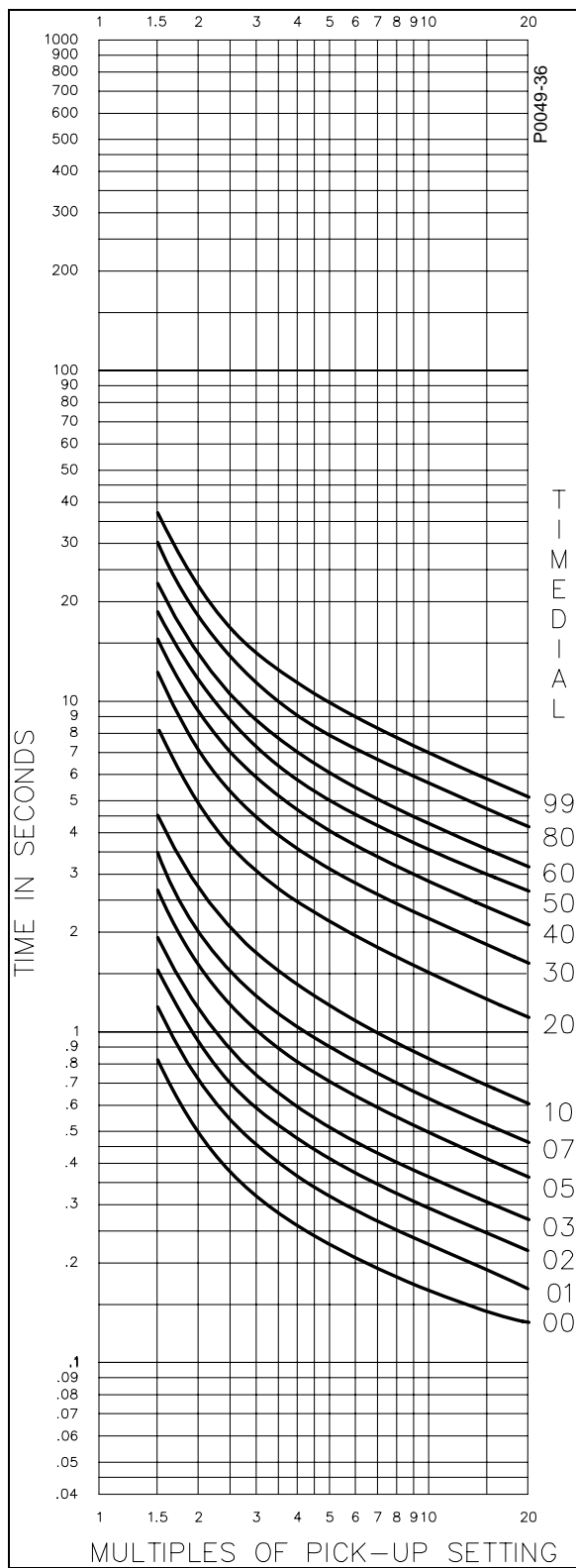
Figure A-35. Timing Type E5,
BS 142 Inverse (2.9 Sec)
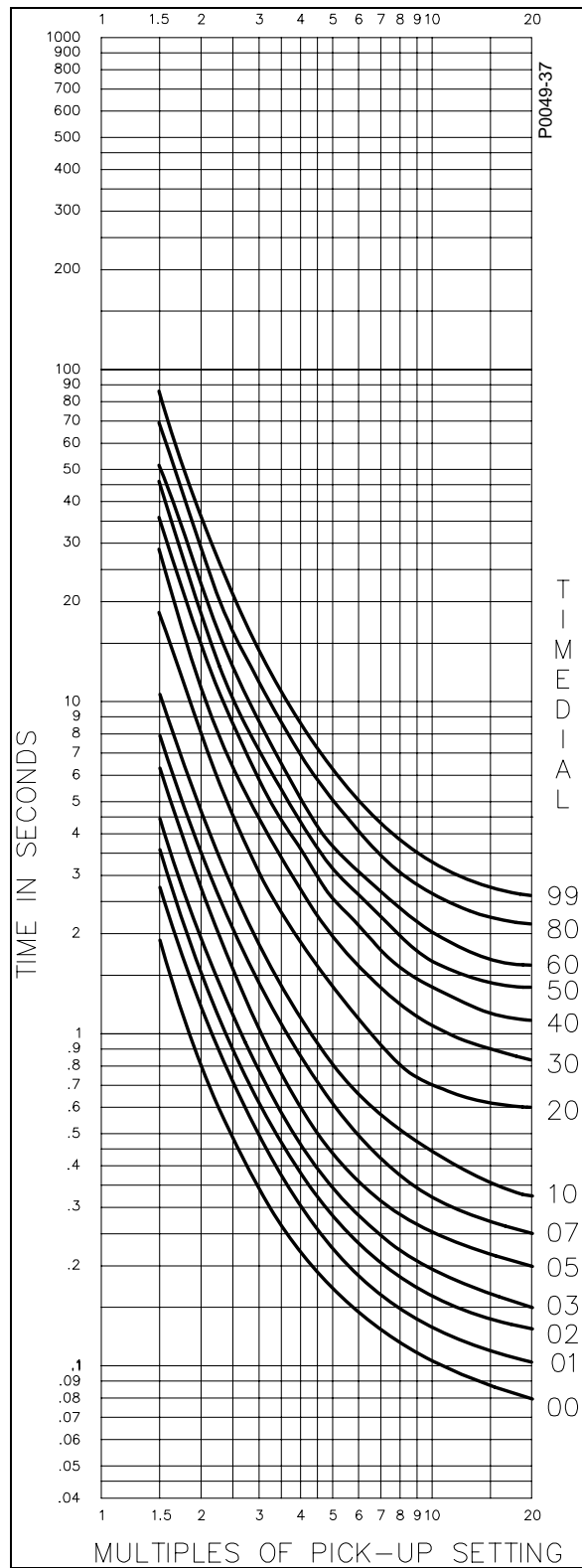
Figure A-36. Timing Type E6,
BS 142 Very Inverse
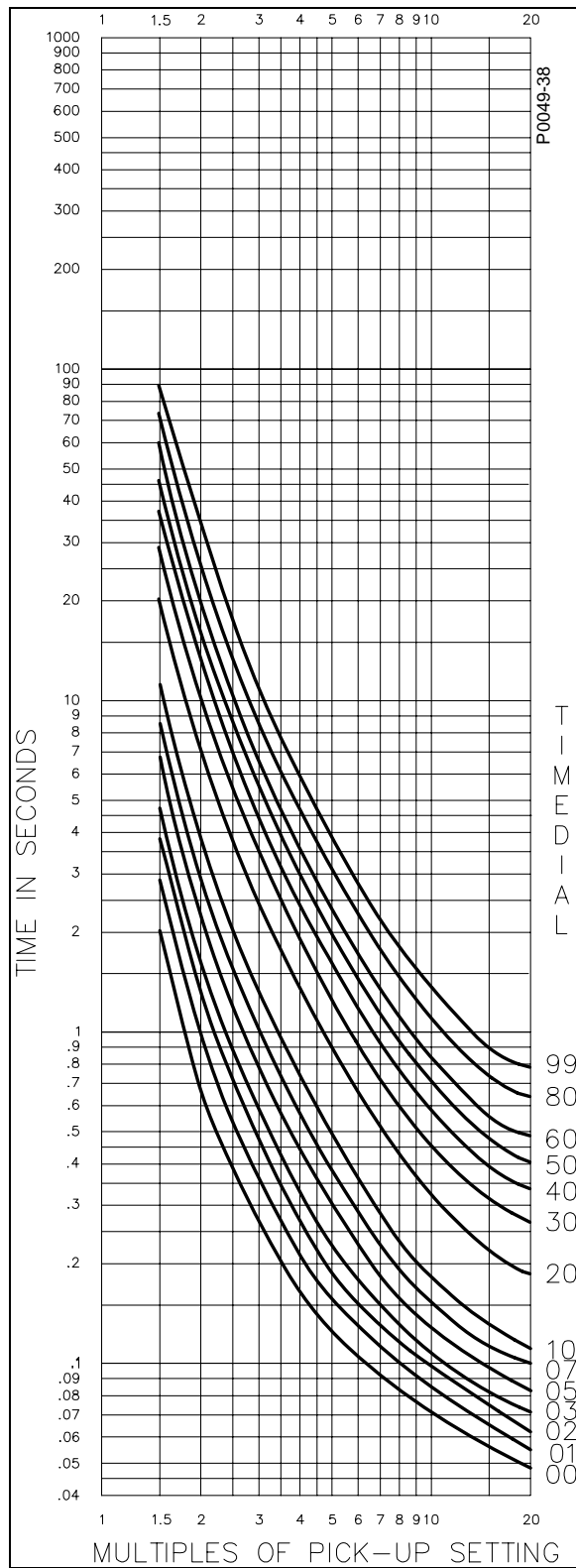
Figure A-37. Timing Type E7,
BS 142 Extremely Inverse
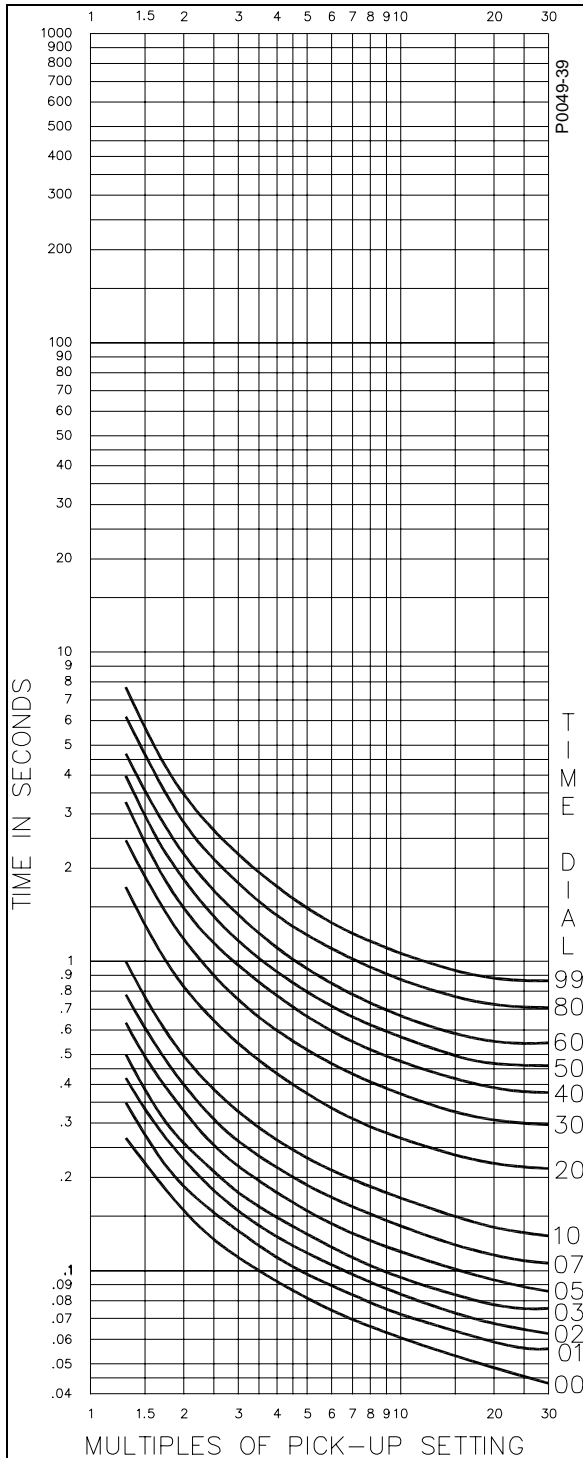
*Figure A-38. Timing Type B1, Short Inverse
with Integrated Algorithm*
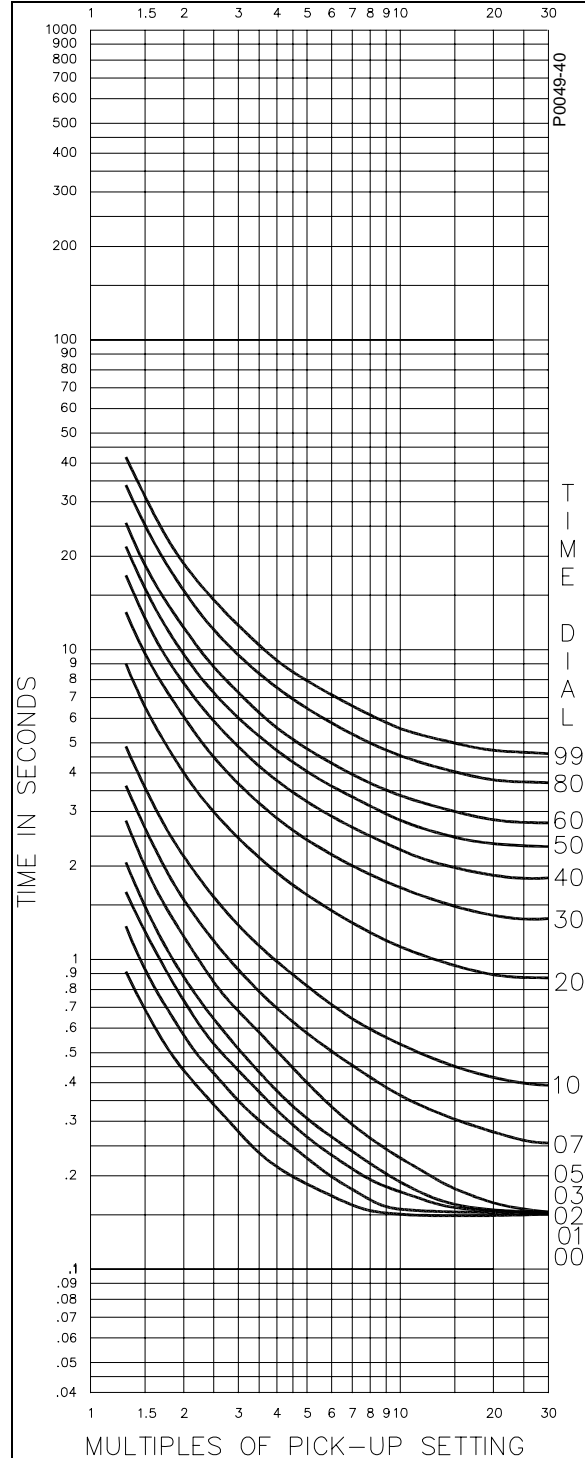
*Figure A-39. Timing Type B1, Short Inverse with
Integrated Algorithm and Extended Timing*
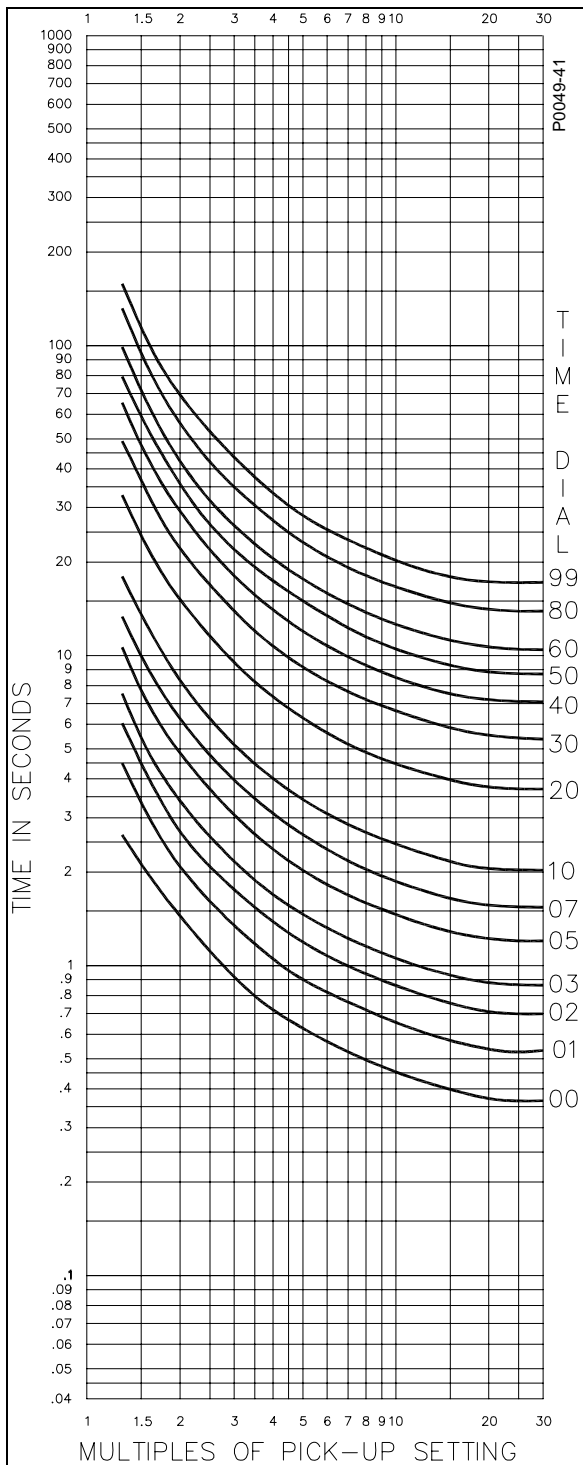
Figure A-40. Timing Type B2, Long Inverse with Integrated Algorithm
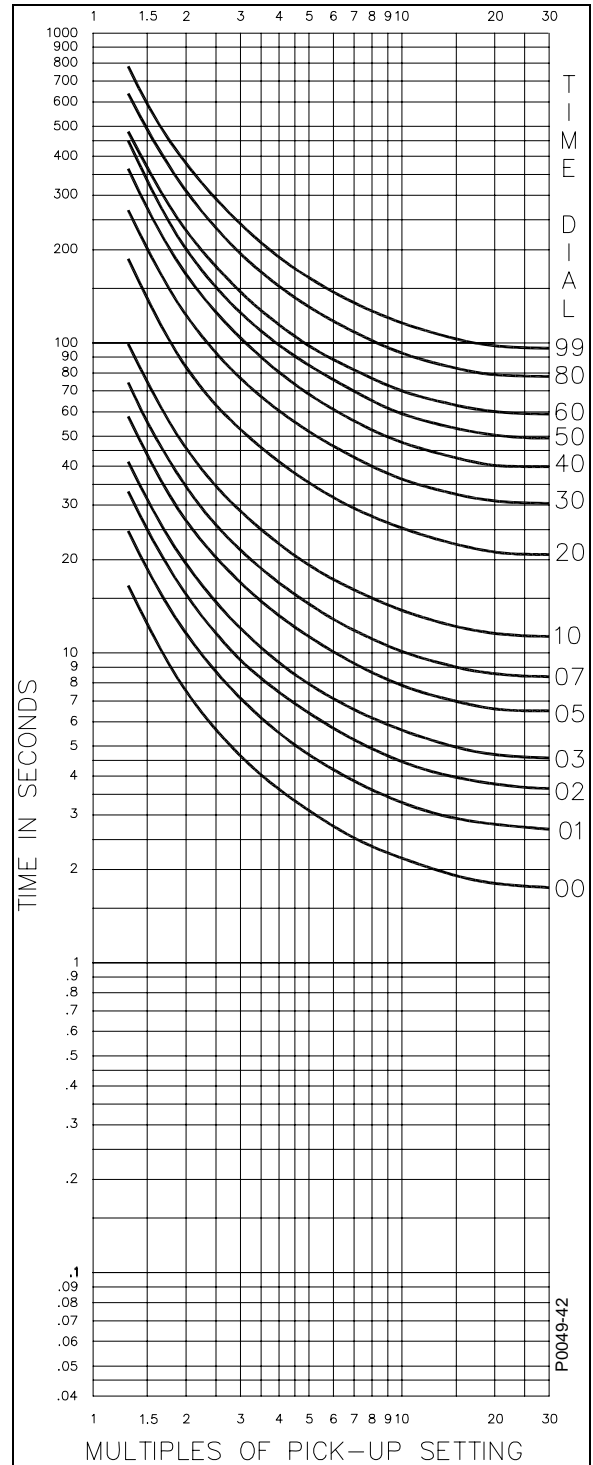
Figure A-41. Timing Type B2, Long Inverse with Integrated Algorithm and Extended Timing
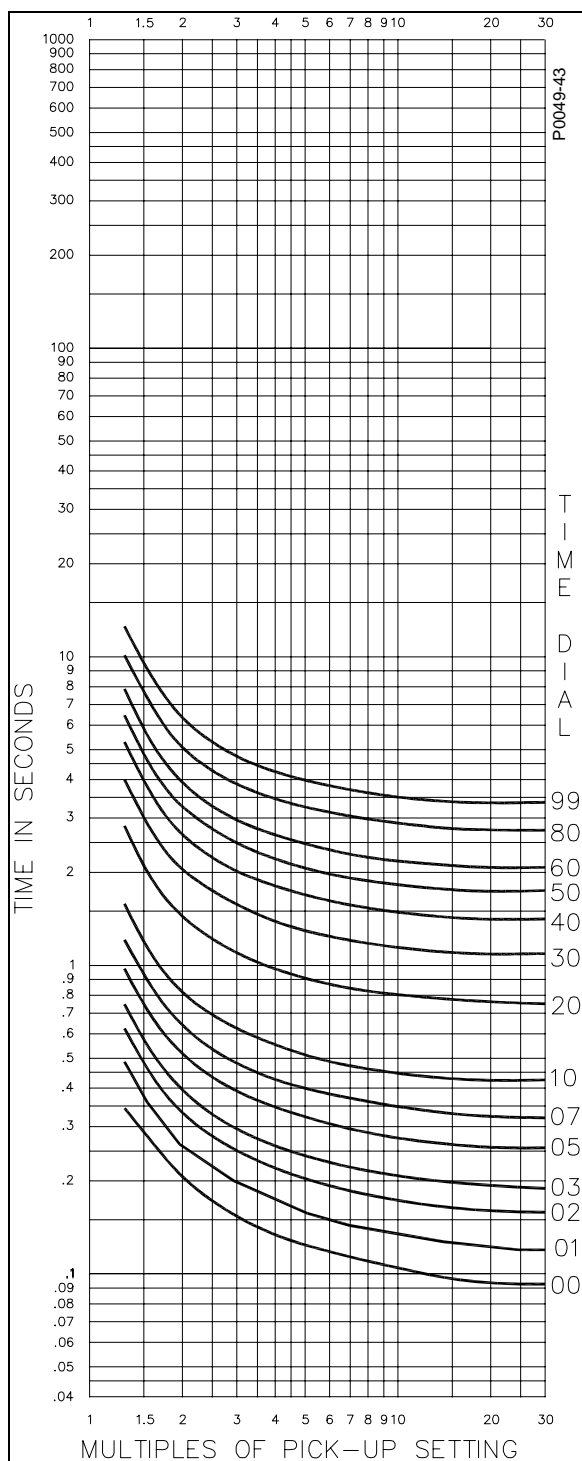
Figure A-42. Timing Type B3, Definite Time with Integrated Algorithm
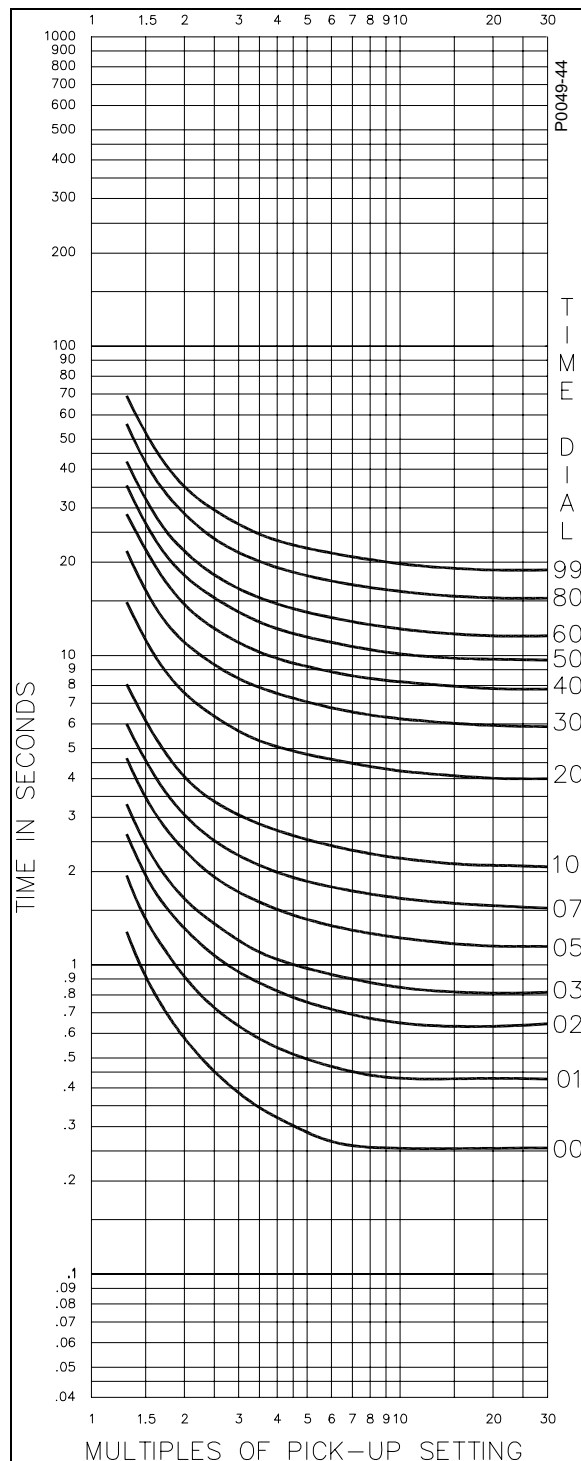
Figure A-43. Timing Type B3, Definite Time with Integrated Algorithm and Extended Timing
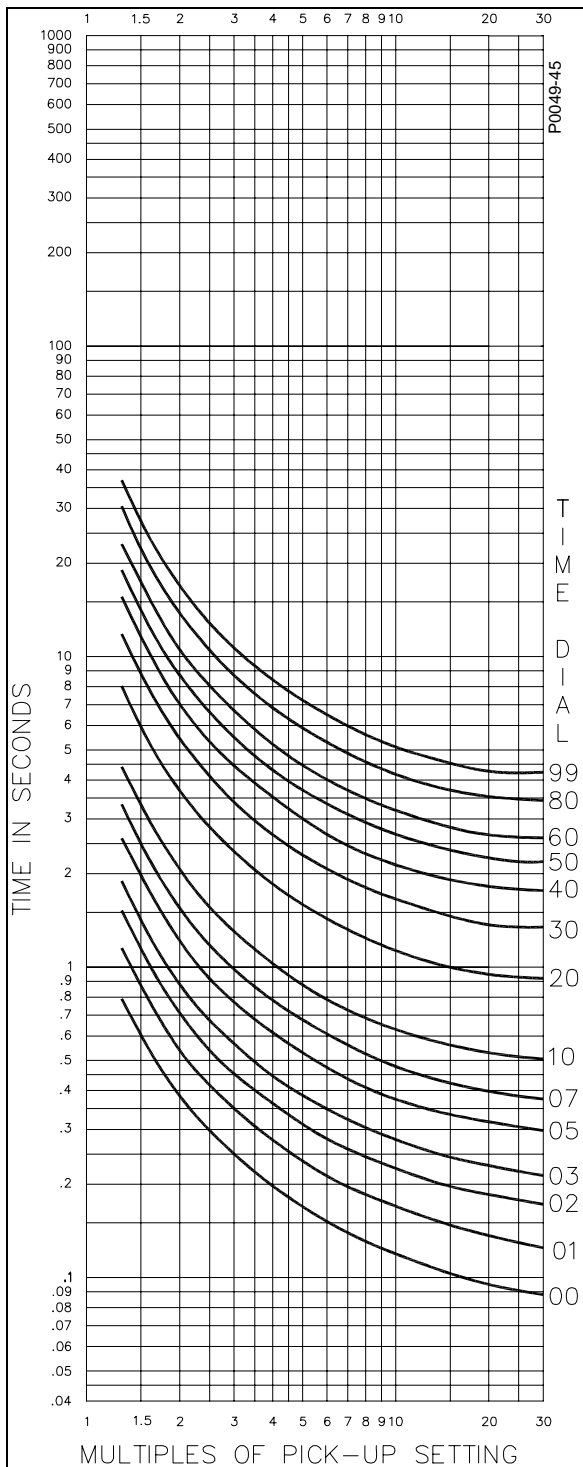
Figure A-44. Timing Type B4, Moderately Inverse with Integrated Algorithm.
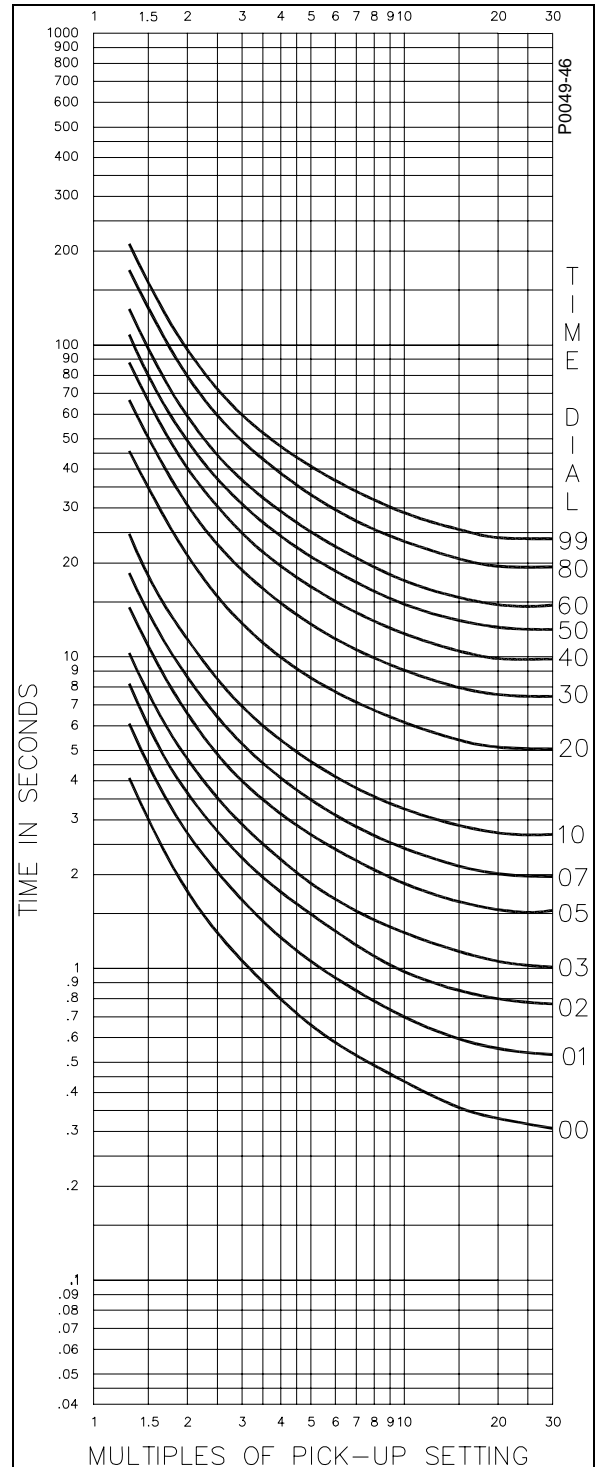
Figure A-45. Timing Type B4, Moderately Inverse with Integrated Algorithm and Extended Timing
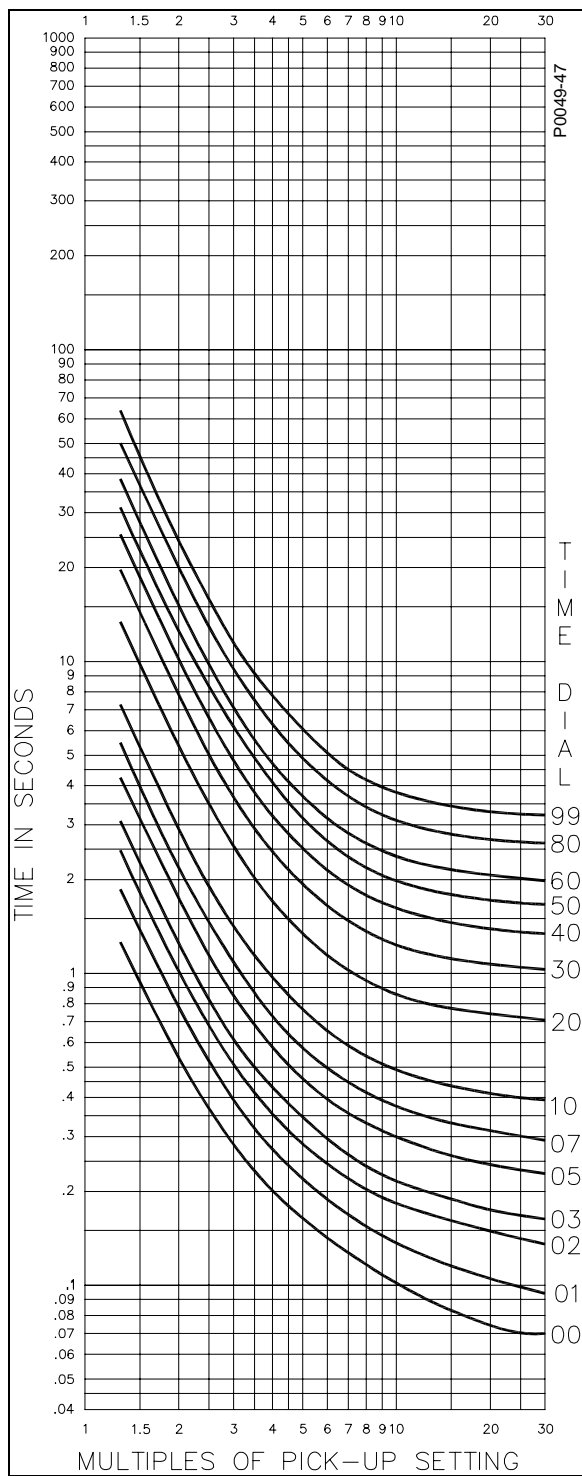
Figure A-46. Timing Type B5, Inverse with Integrated Algorithm
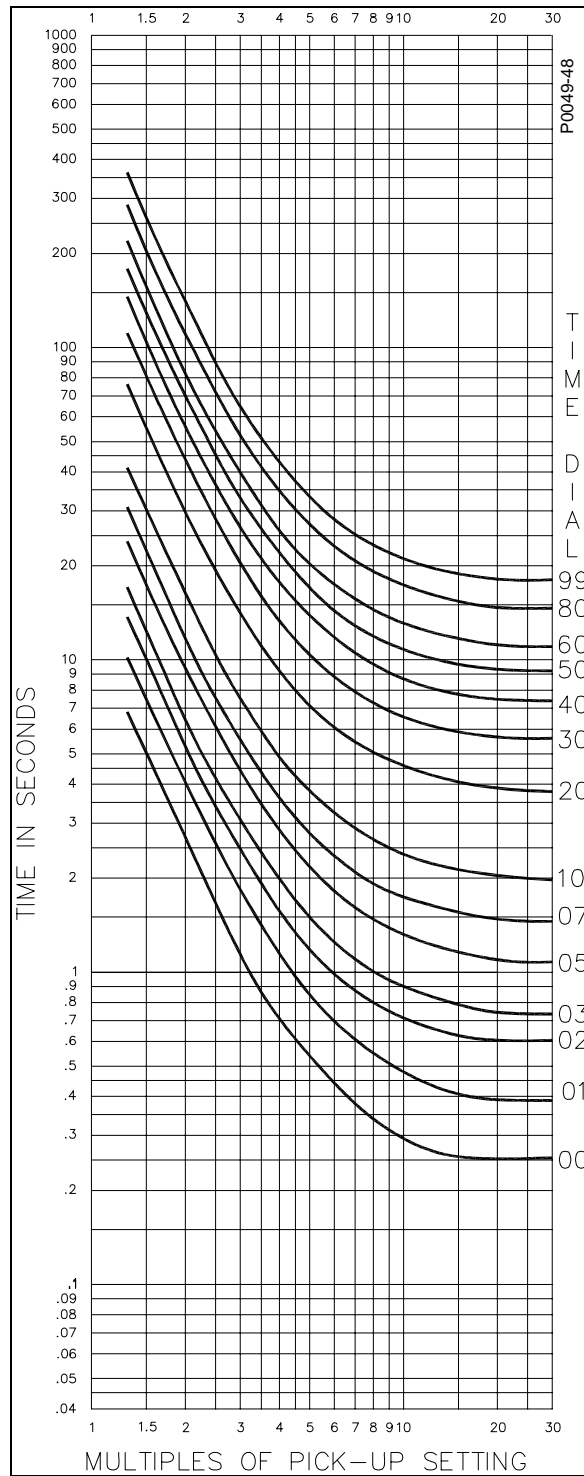
Figure A-47. Timing Type B5, Inverse with Integrated Algorithm and Extended Timing
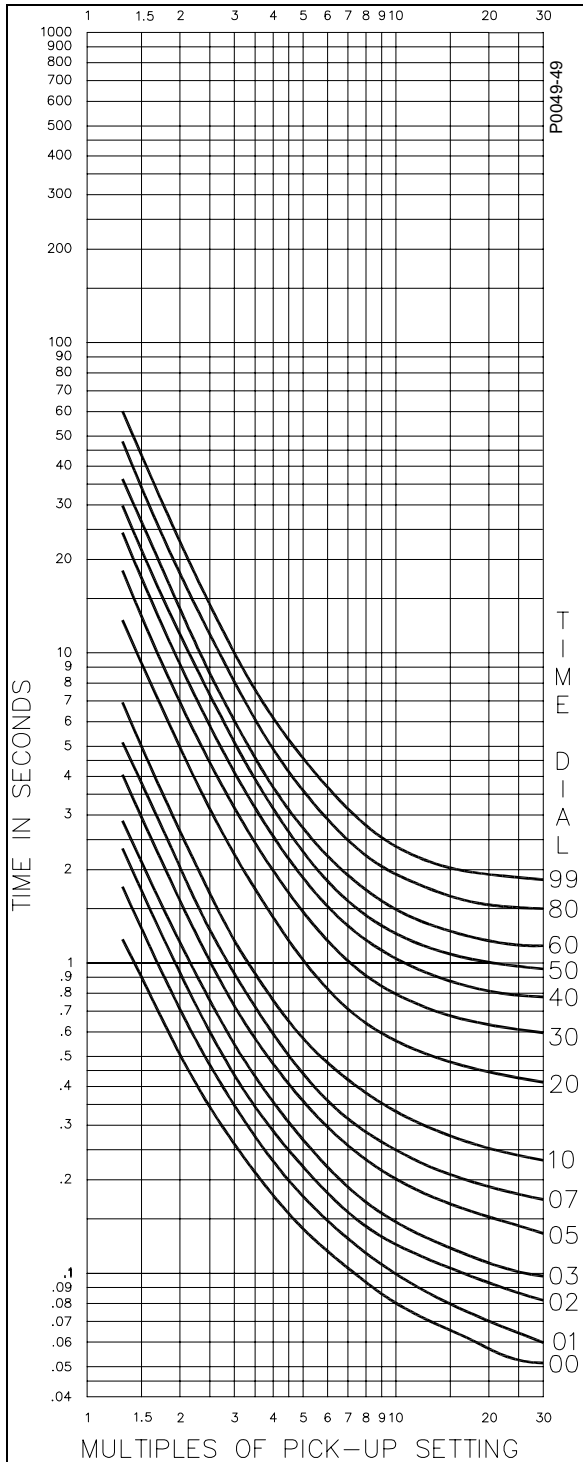
Figure A-48. Timing Type B6, Very Inverse with Integrated Algorithm
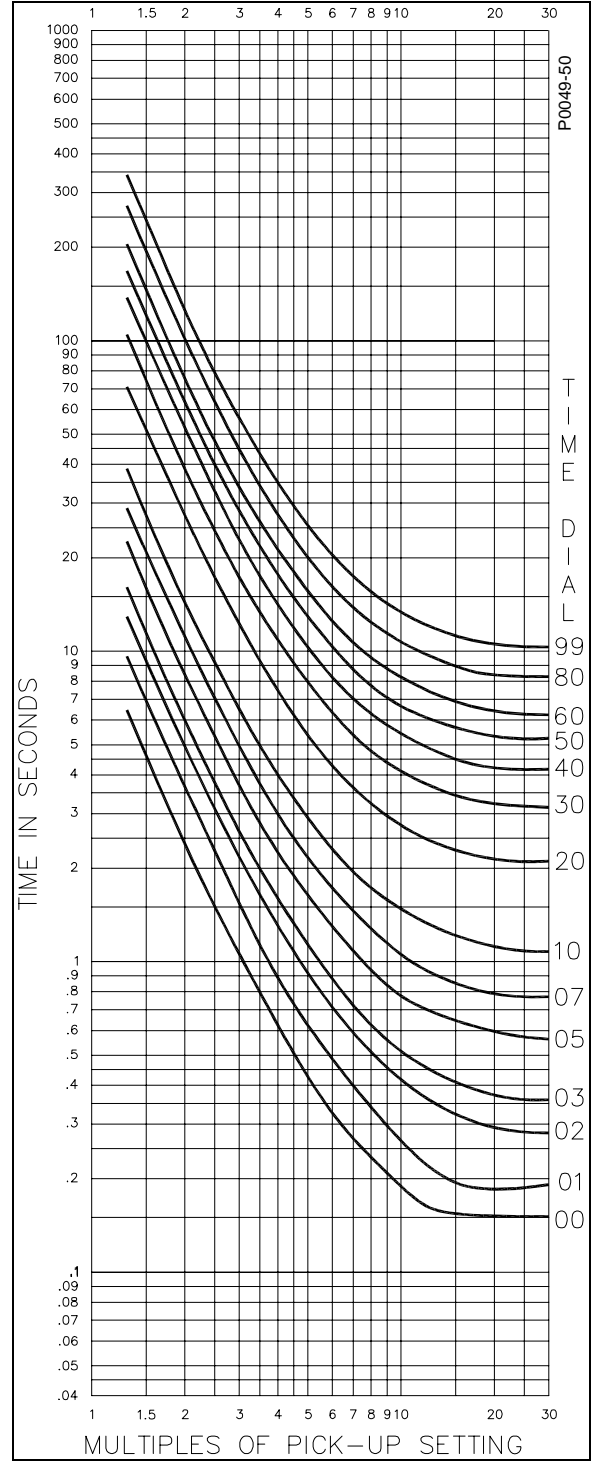
Figure A-49. Timing Type B6, Very Inverse with Integrated Algorithm and Extended Timing
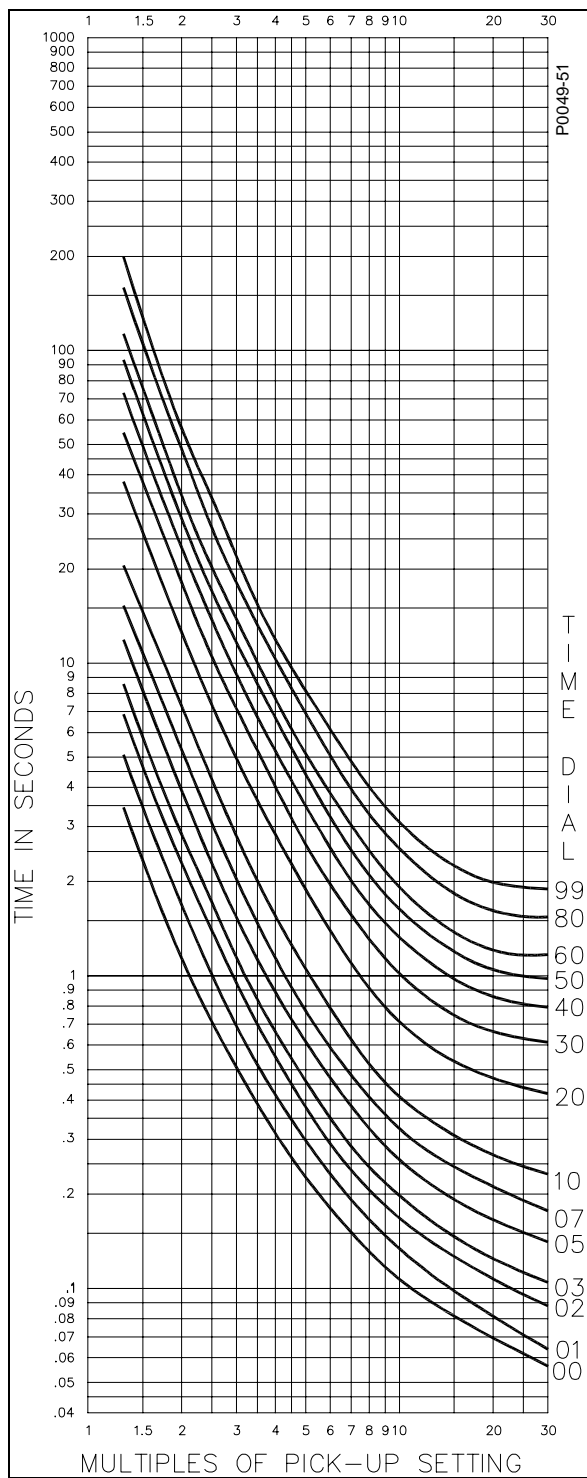
Figure A-50. Timing Type B7, Extremely Inverse with Integrated Algorithm
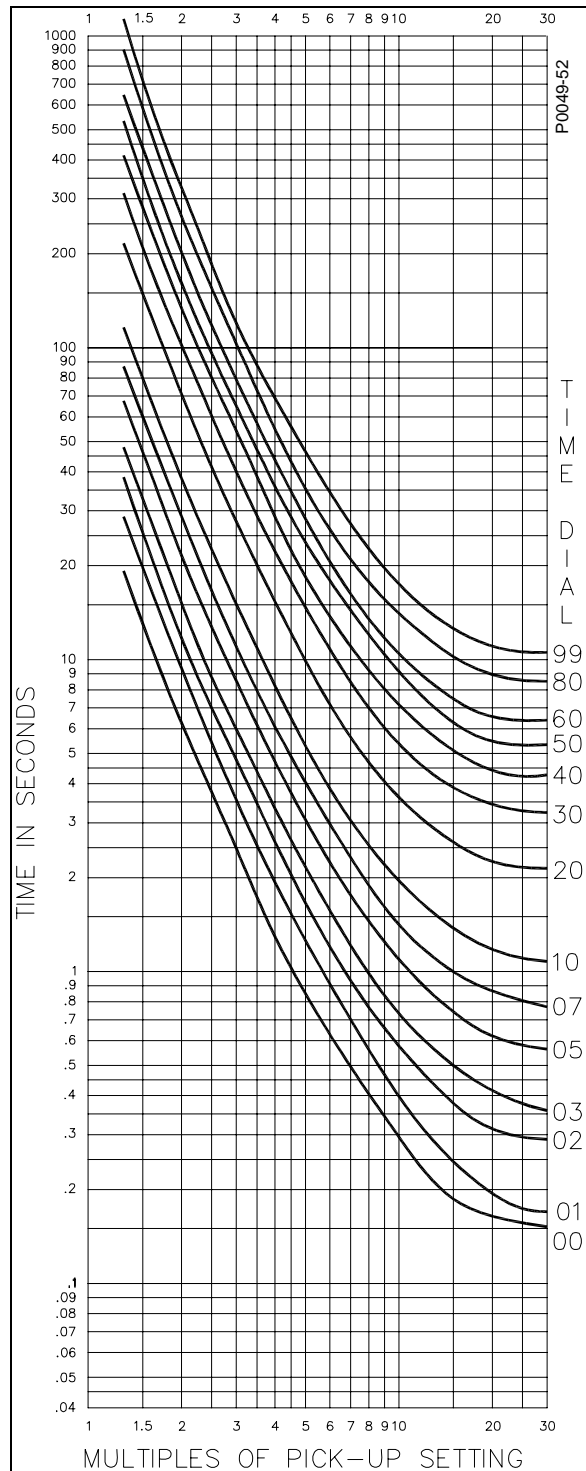
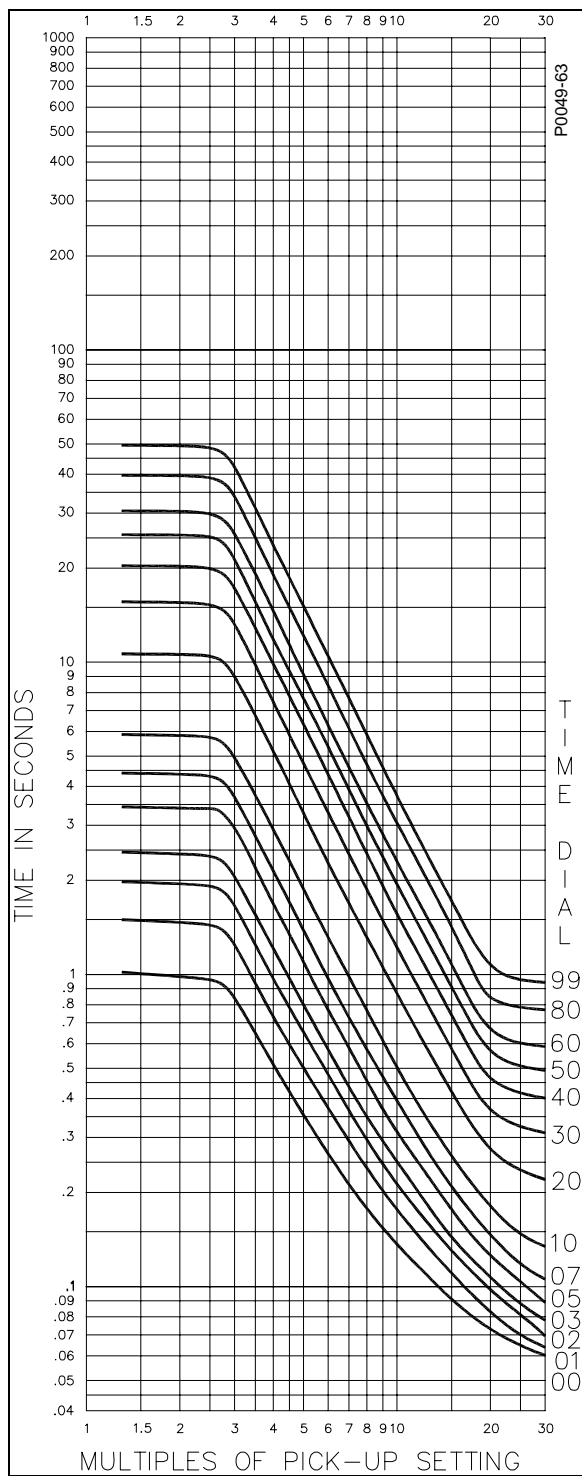*Figure A-51. Timing Type B7, Extremely Inverse with Integrated Algorithm and Extended Timing*
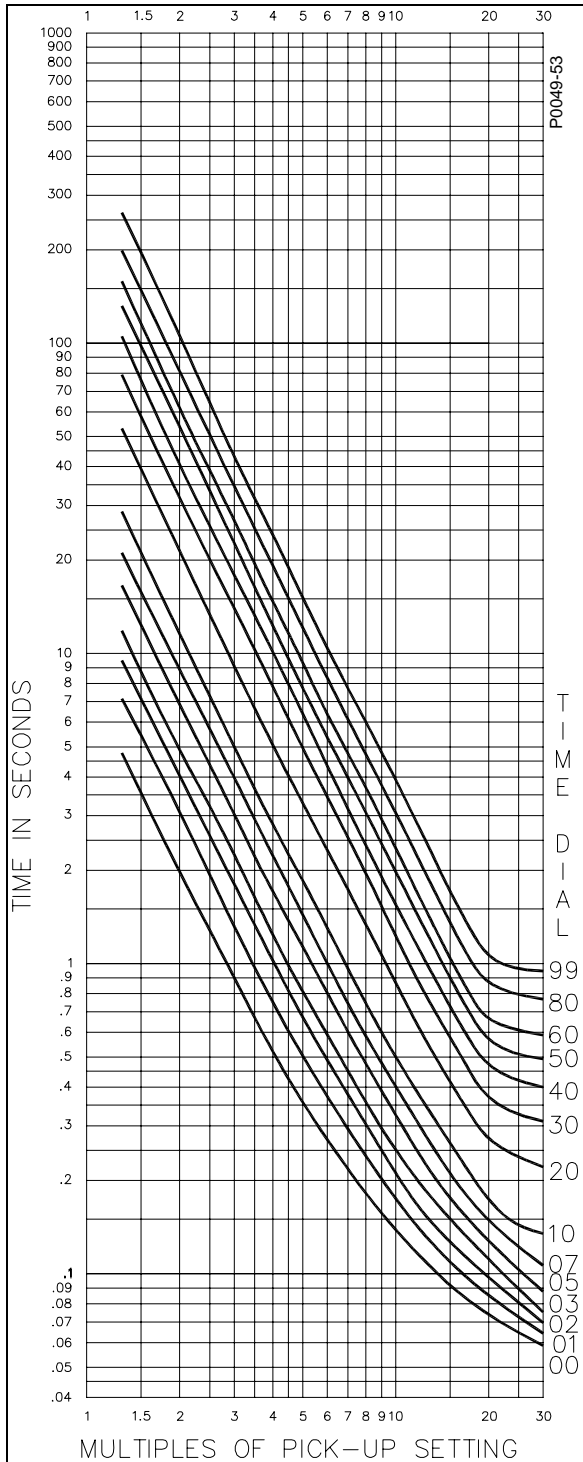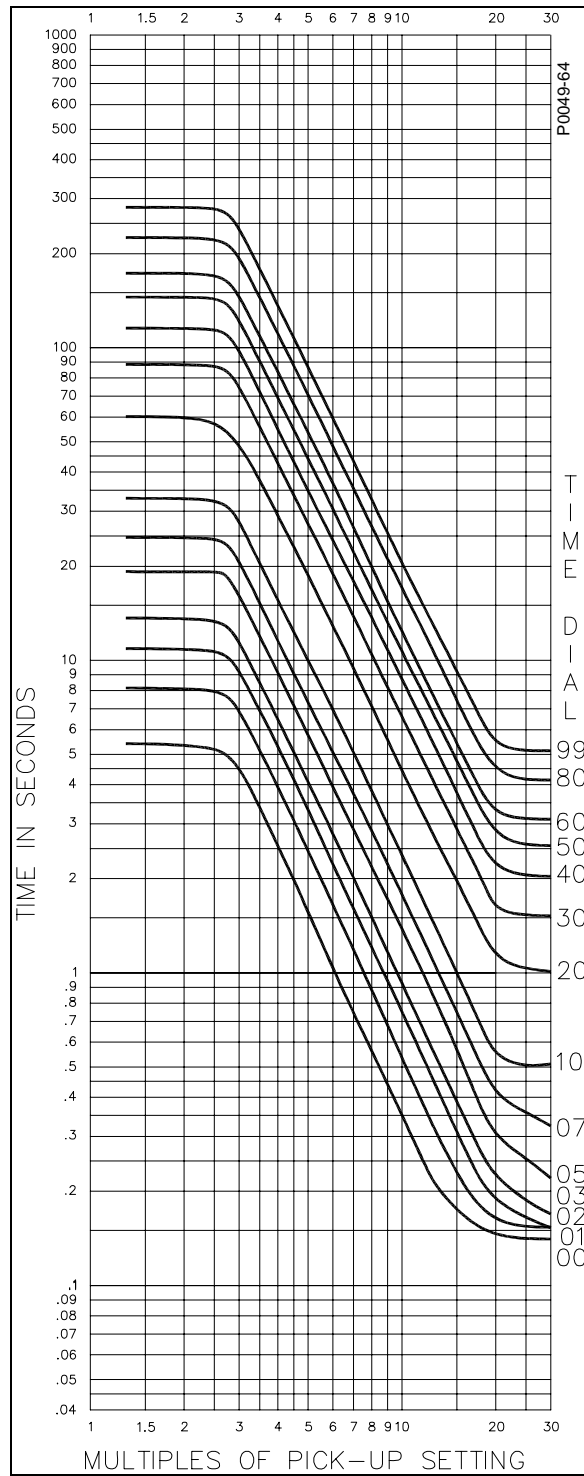
Figure A-52. Timing Type B8, I^2t
with Integrated Algorithm
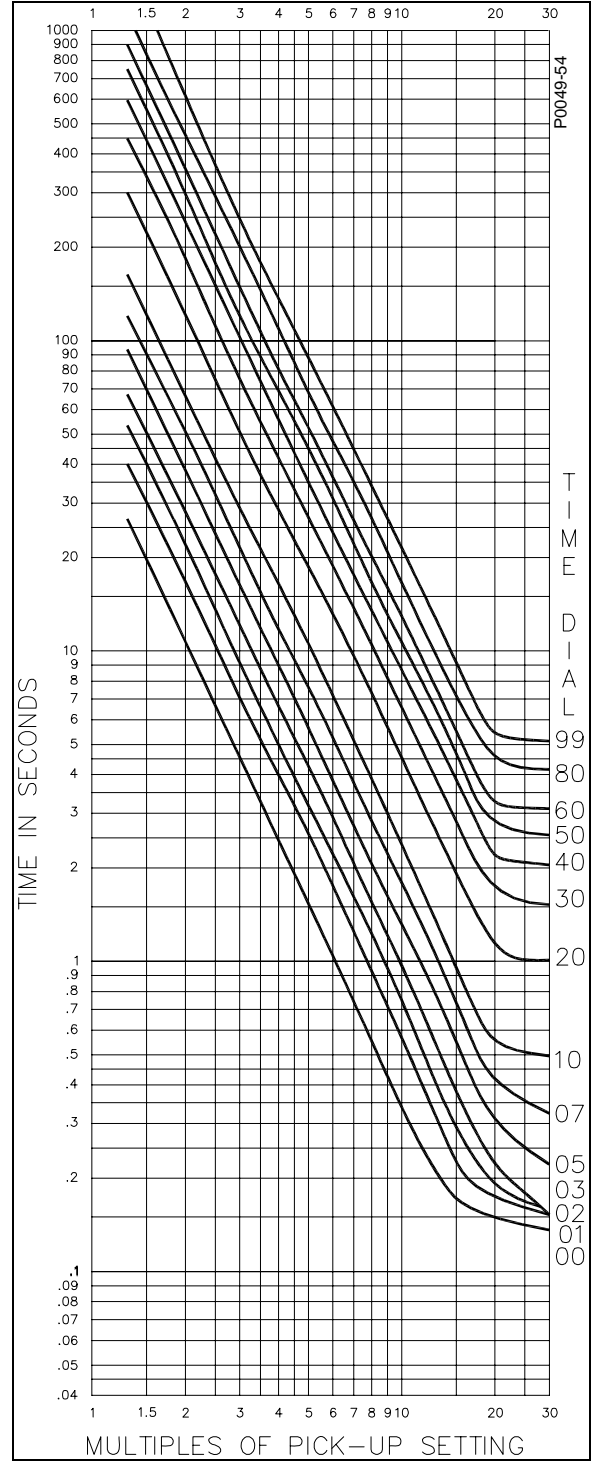
Figure A-53. Timing Type B8, I^2t with Integrated
Algorithm and Extended Timing
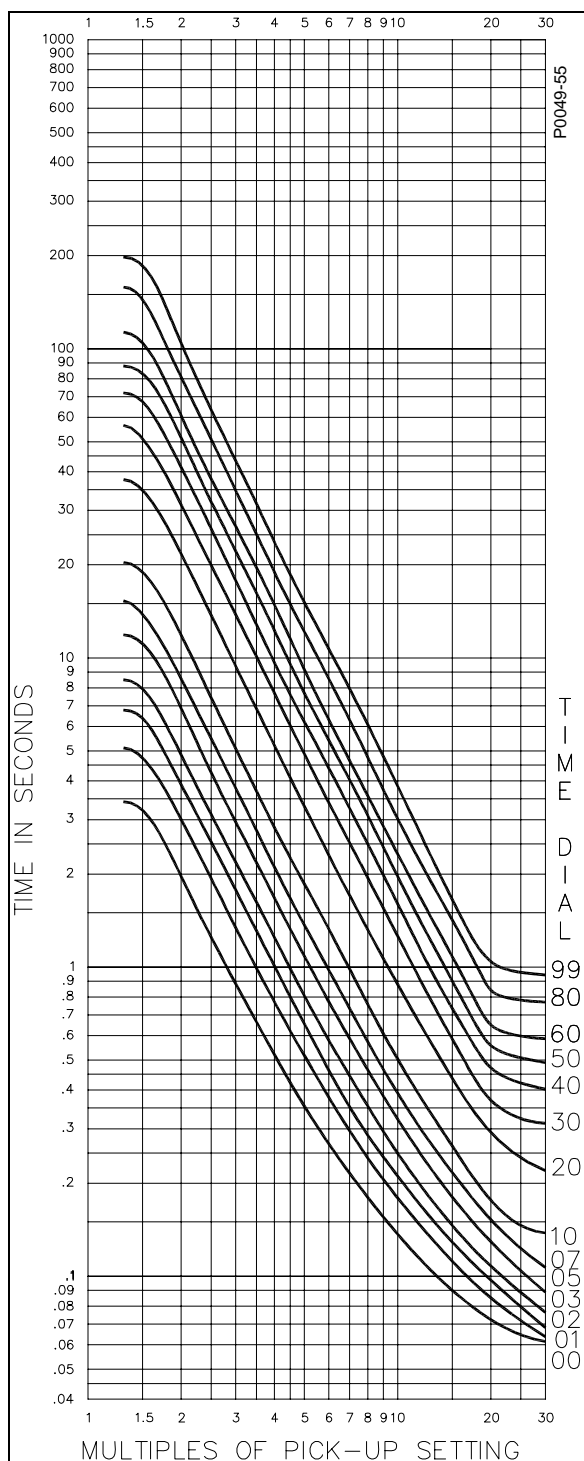
Figure A-54. Timing Type C1, I^2t Limit #1 with Integrated Algorithm
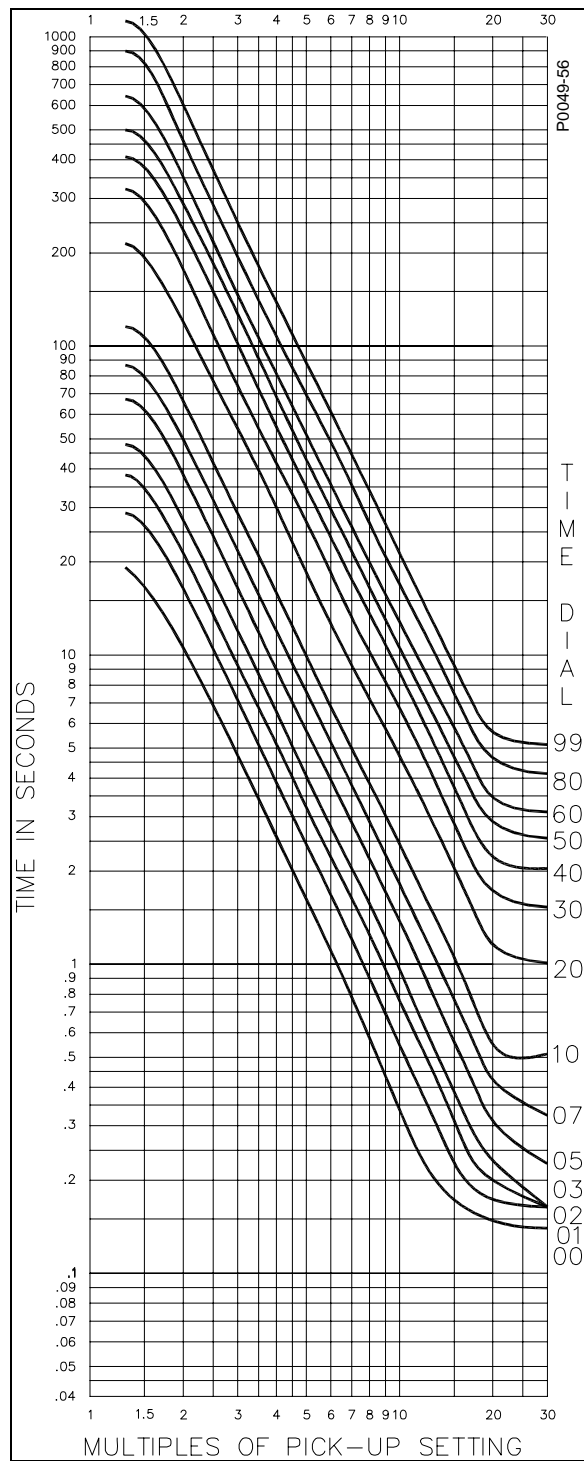
Figure A-55. Timing Type C1, I^2t Limit #1 with Integrated Algorithm
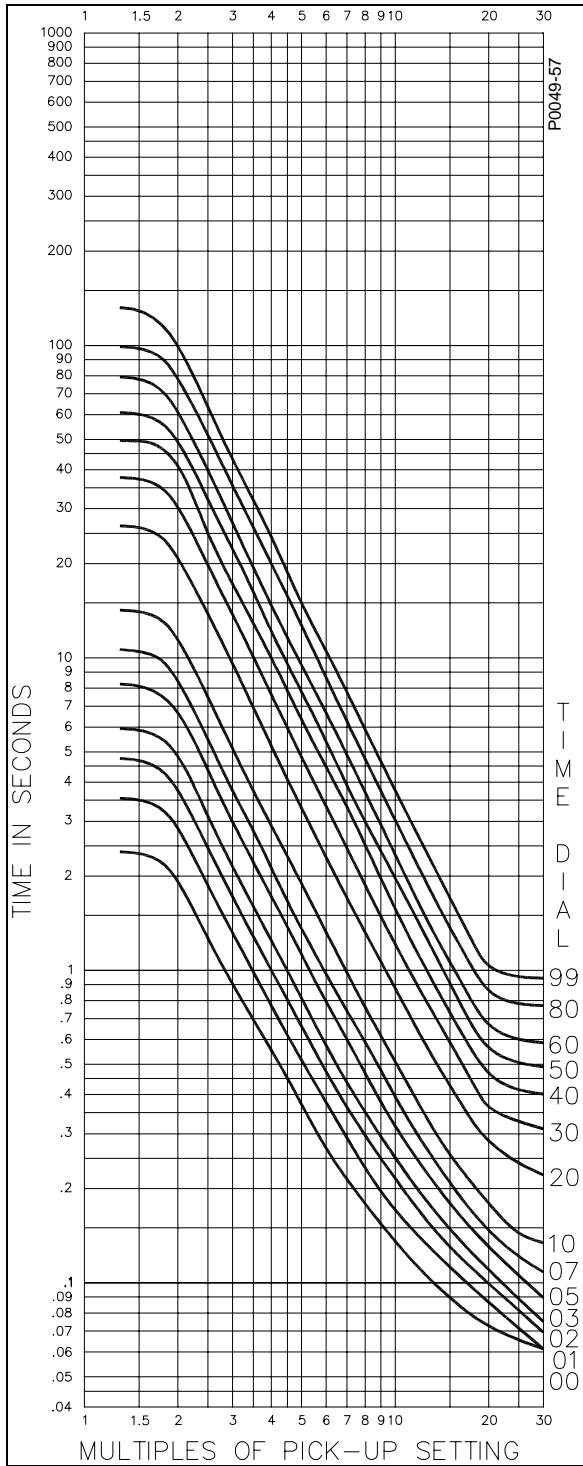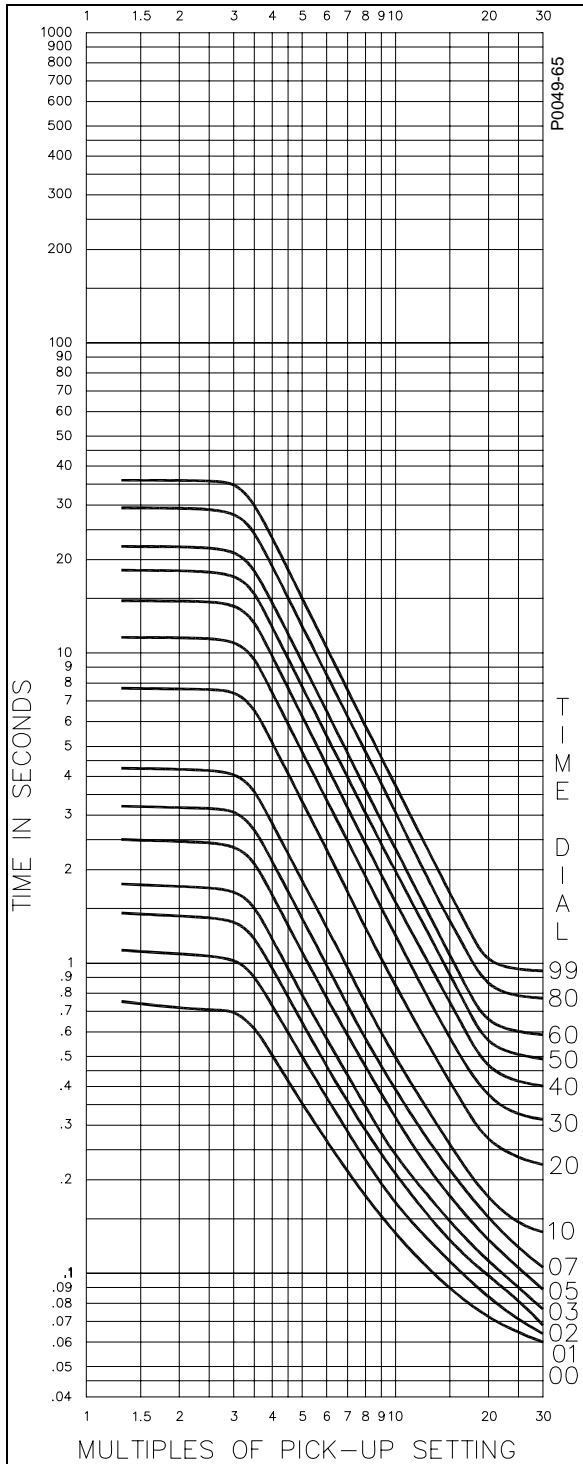
Figure A-56. Timing Type C2, I^2t Limit #2 with Integrated Algorithm
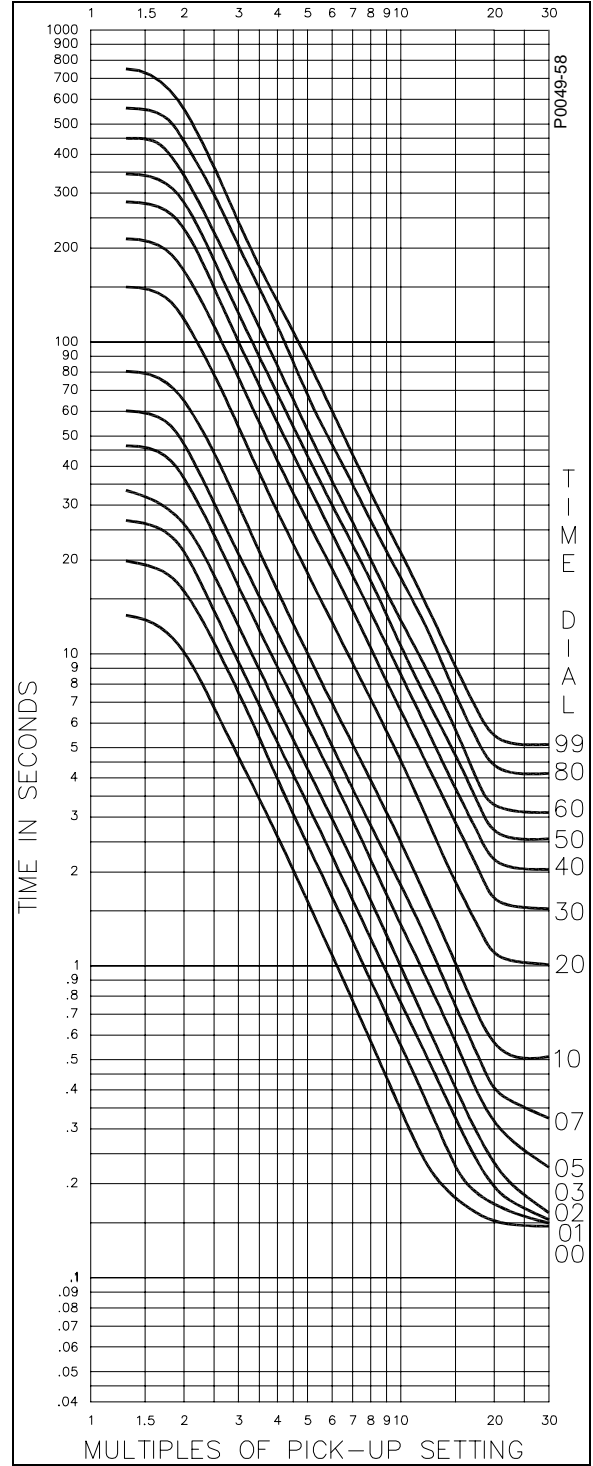
Figure A-57. Timing Type C2, I^2t Limit #2 with Integrated Algorithm and Extended Timing
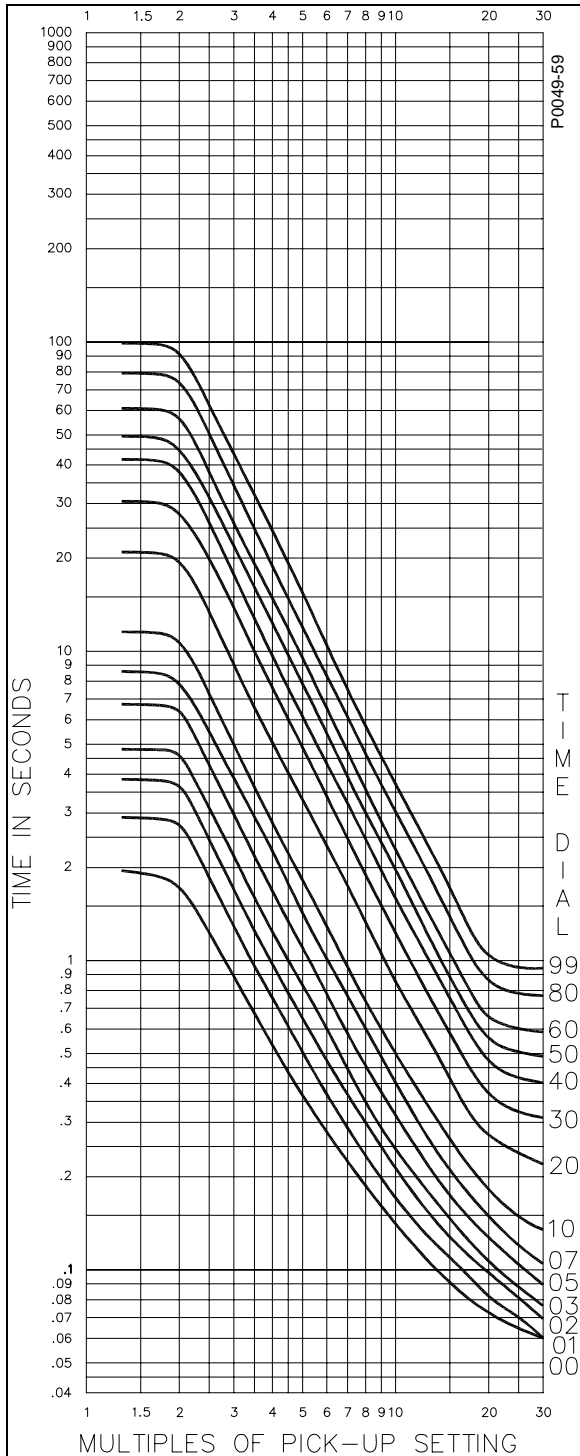
Figure A-58. Timing Type C3, I^2t Limit #3 with Integrated Algorithm
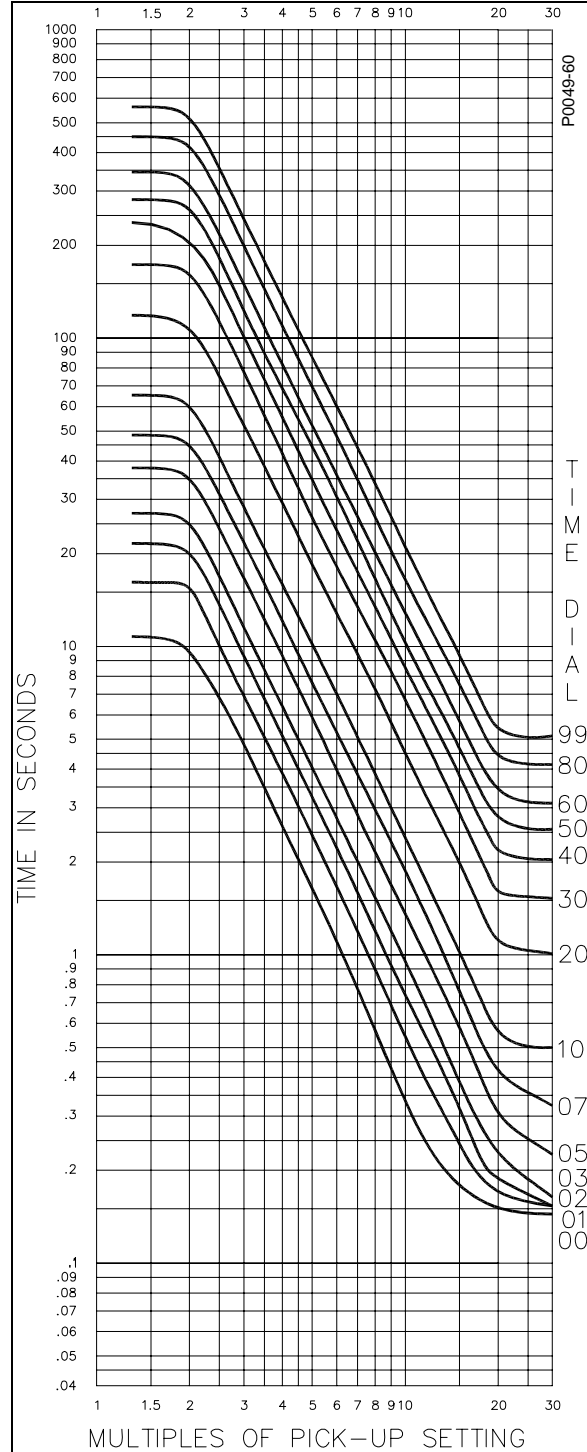
Figure A-59. Timing Type C3, I^2t Limit #3 with Integrated Algorithm and Extended Timing
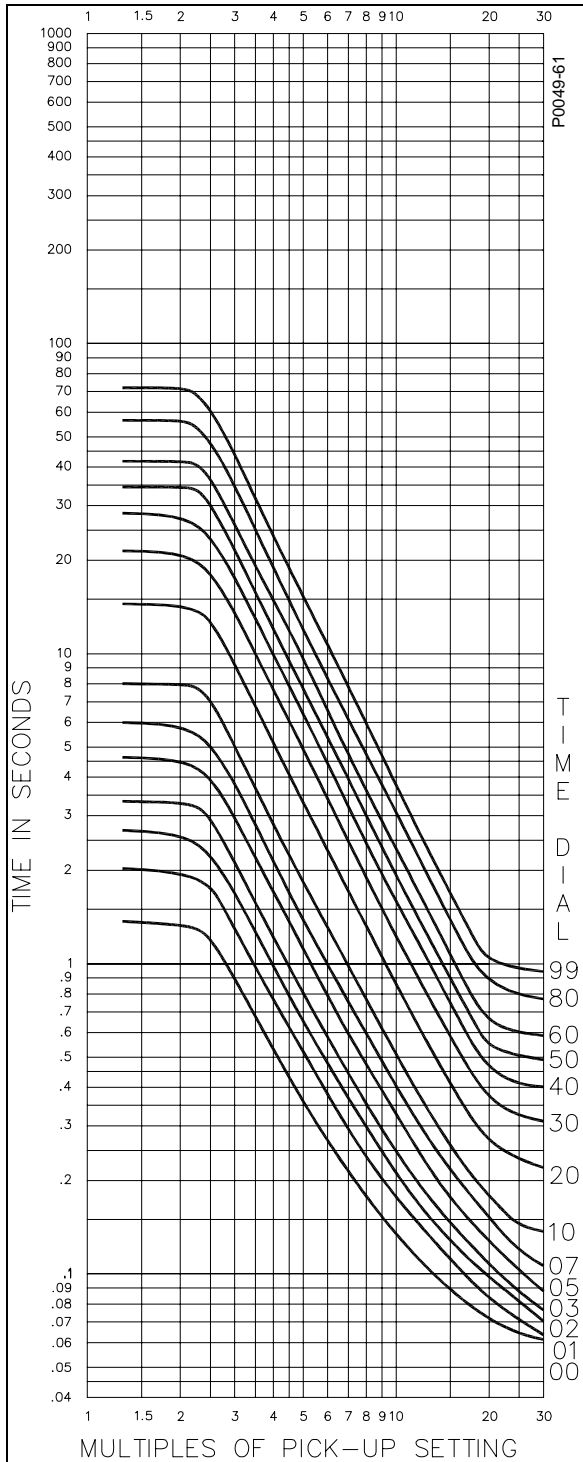
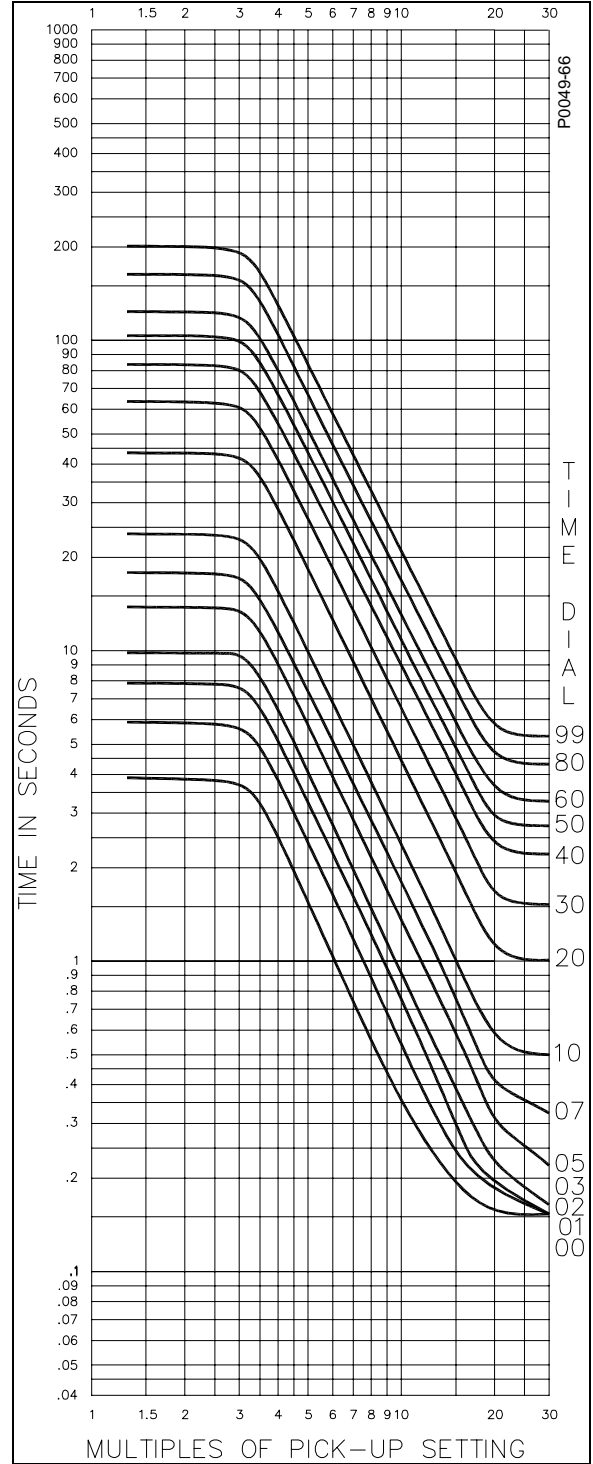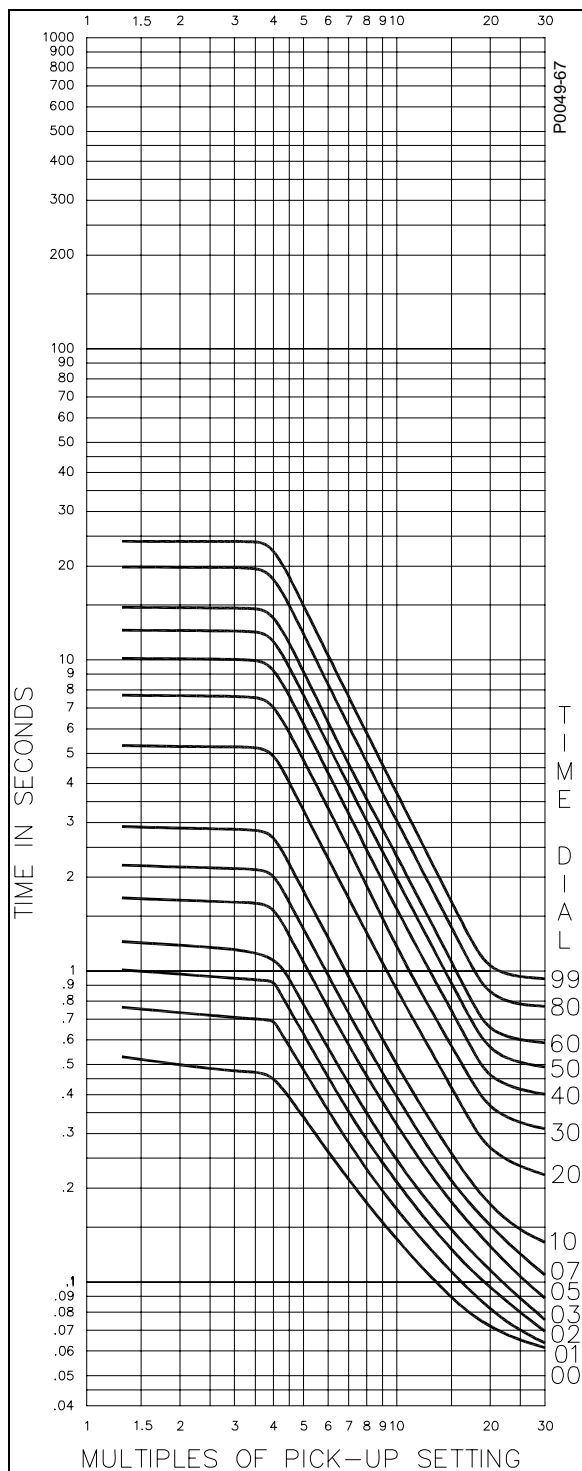*Figure A-60. Timing Type C4, I^2t Limit #4 with Integrated Algorithm*
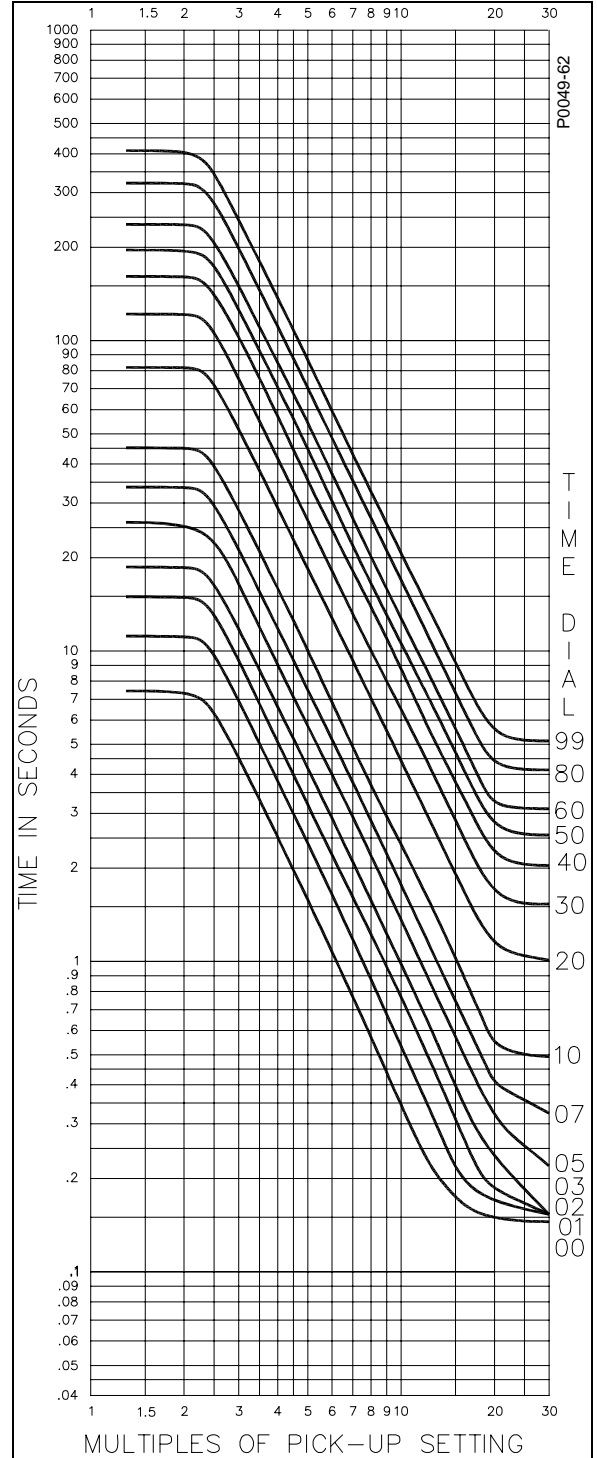
Figure A-61. Timing Type C4, I^2t Limit #4 with Integrated Algorithm and Extended Timing

Figure A-62. Timing Type C5, I^2t Limit #5
with Integrated Algorithm
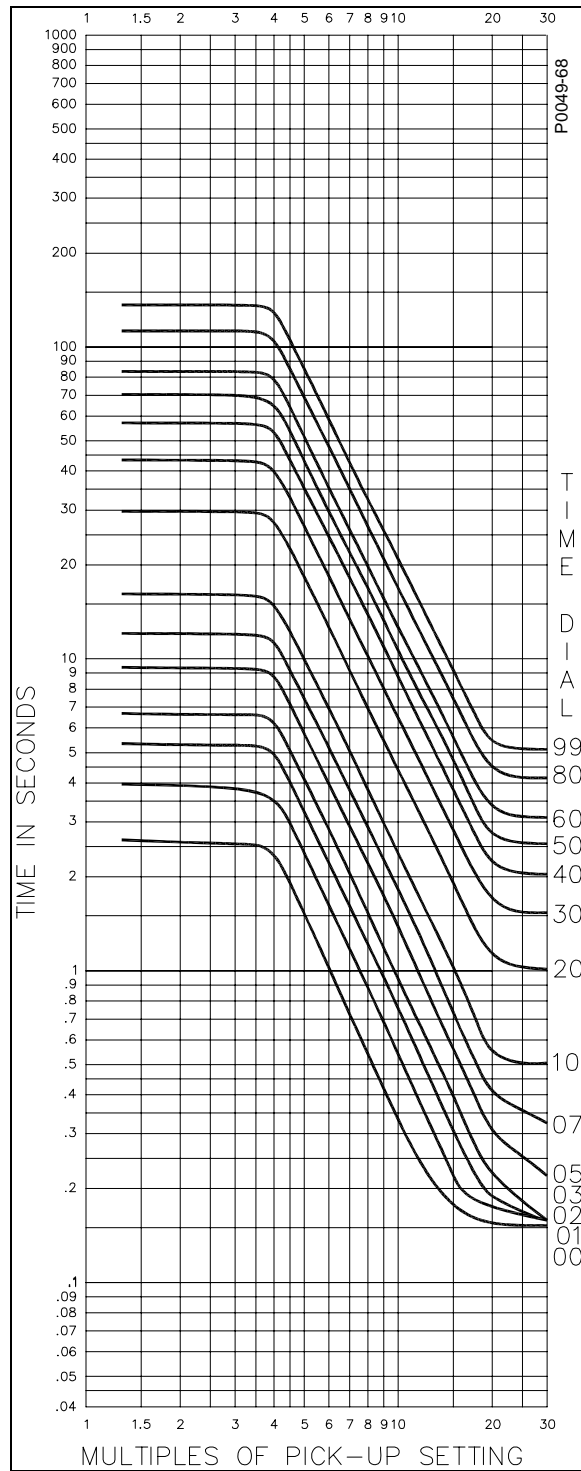

Figure A-63. Timing Type C5, I^2t Limit #5 with
Integrated Algorithm and Extended Timing

Figure A-64. Timing Type C6, I^2t Limit #6 with Integrated Algorithm

Figure A-65. Timing Type C6, I^2t Limit #6 with Integrated Algorithm and Extended Timing

Figure A-66. Timing Type C7, I^2t Limit #7 with Integrated Algorithm

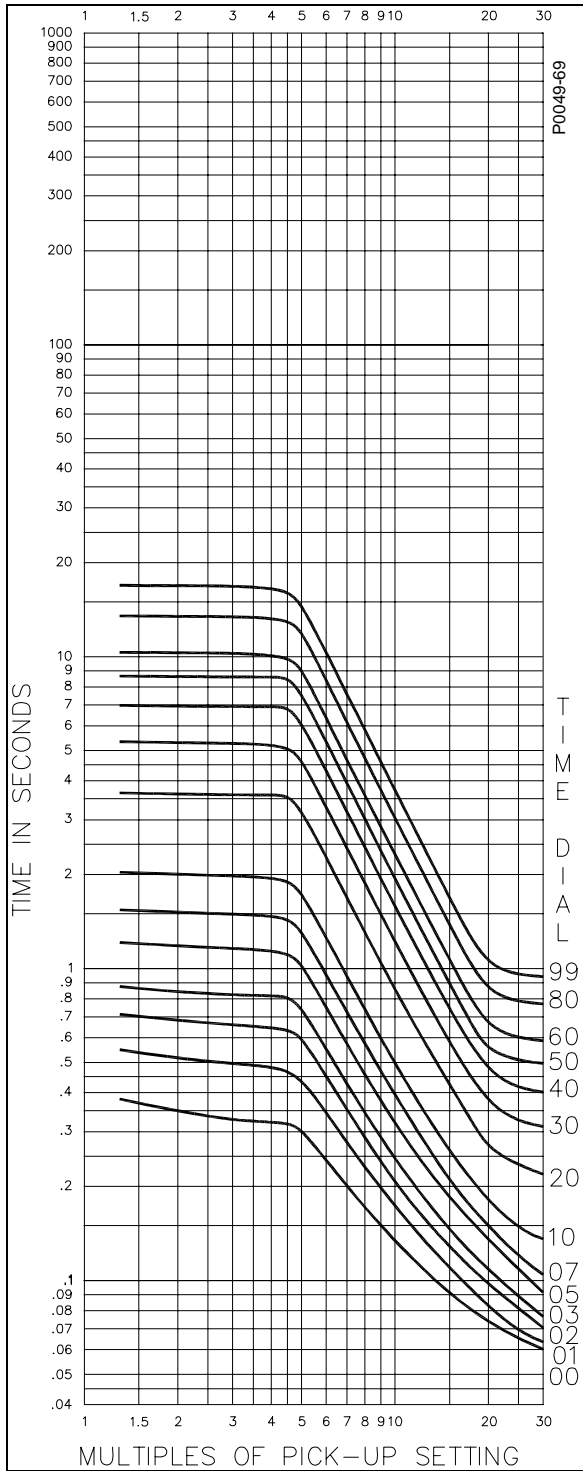Figure A-67. Timing Type C7, I^2t Limit #7 with Integrated Algorithm and Extended Timing

Figure A-68. Timing Type C8, I^2t Limit #8 with Integrated Algorithm
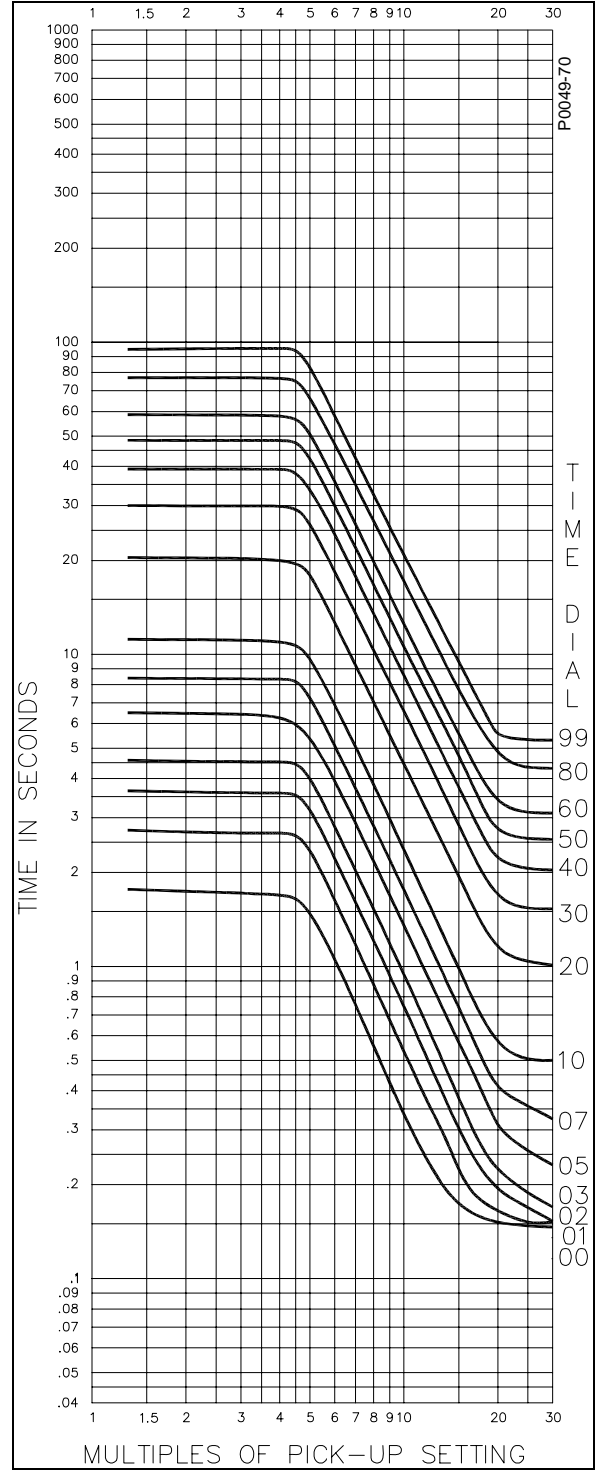

Figure A-69. Timing Type C8, I^2t Limit #8 with Integrated Algorithm and Extended Timing

This page intentionally left blank.