INSTRUCTION MANUAL

FOR

VARIABLE PERCENTAGE DIFFERENTIAL RELAY

BE1-87G
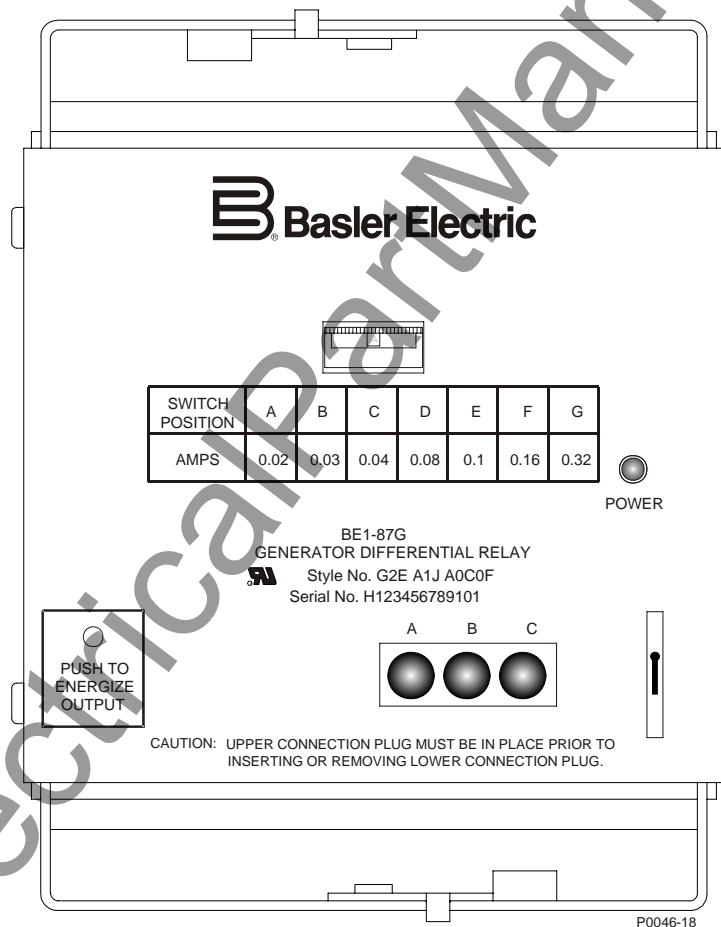
Basler Electric

SWITCH POSITION	A	B	C	D	E	F	G
AMPS	0.02	0.03	0.04	0.08	0.1	0.16	0.32

POWER

BE1-87G
GENERATOR DIFFERENTIAL RELAY
Style No. G2E A1J A0C0F
Serial No. H123456789101

A   B   C

PUSH TO ENERGIZE OUTPUT

CAUTION: UPPER CONNECTION PLUG MUST BE IN PLACE PRIOR TO INSERTING OR REMOVING LOWER CONNECTION PLUG.

P0046-18

Basler Electric

INTRODUCTION

This instruction manual provides information about the operation and installation of the BE1-87G Variable Percentage Differential relay. To accomplish this, the following information is provided:

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

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 BE1-87G instruction manual (9170800990). Revisions are listed in reverse chronological order.

Manual Revision and Date	Change
L, 09/07	• Replaced magnetic type targets with electronic type targets.
K, 06/07	• Updated power supply burden data and output contact ratings. • Updated front panel illustrations to show laser graphics. • Added dimensional drawings for single-ended cases. • Updated all applicable illustrations to show revised case covers. • Added three-phase sensing connection diagram for delta-connected machine. • Moved content of Section 6, *Maintenance* to Section 4. • Moved content of Section 7, *Manual Change Information* to manual Introduction.
J, 05/99	• Updated format of the manual. • Corrected Figure 1-2. • Corrected terminal numbering reference on page 1-4, last paragraph. • Corrected Figures 4-11 and 4-12.
H, 05/96	• Added sensing input range 2 (1 Aac nominal) to the available models. • Changed high speed operation from 20 ms to 30 ms. • Changed all connection diagrams to include ground connections, where applicable. • Added internal connection diagrams. • Corrected Table 1-1. • Clarified setting example for motor differential application. • Added *Setting Example #2.* • Split Section 4 into two sections. New section is Section 5, *Testing and Setting.*
G, 10/91	• Added I^2t rating for stabilizer reactor. • Added Figure 4-1, *Stabilizing Reactor Impedance Characteristics.*
F, 07/91	• Changed pickup accuracy for Ir > 5 A from 30 A, ±5% to 20 A, ±8% of the operate pickup characteristic or 150 mA, whichever is greater.
E, 07/91	• Modified Figures 1-1 and 1-2. • Added warning information to pages 1-1 and 4-2.
D, 03/91	• Removed On/Off switch material. • Added material documenting stabilizing reactor. • Added illustrations for typical connections, sensing input connections, test setup, extended operational characteristics, and pickup response timing. • Added table for current sensing burden. • Added relay setting material to Section 5.
C, 03/87	• Added power supply status output material.
B, 10/86	• Grammatical changes to specifications of Section 1. • Changed comparator functional description in Section 3. • Changed operational test procedure in Section 5.

Manual Revision and Date	Change
A, 05/86	• Added qualifications to specifications of Section 1. • Revised isolation test and dielectric test information in specifications of Section 1.
—, 12/85	• Initial release

CONTENTS

SECTION 1 • GENERAL INFORMATION

DESCRIPTION

BE1-87G Variable Percentage Differential Relays are single- or three-phase solid-state devices designed to provide selective, high-speed, differential protection for generators, motors, and shunt reactors.

Differential relaying selectivity is based on the ability of a relay to distinguish between an internal fault (within the protected zone) and an external fault. Under normal operating conditions, the current flowing into the protected zone equals the current flowing output of the protected zone with a net operating current equal to zero. Internal faults upset this balance and result in a difference between the input and output currents. External faults have relatively little effect on the balance because the protected zone input current still equals the output current. Therefore, by comparing the currents on both sides of the protected element or zone and detecting when these currents are not equal, a differential relay acts to isolate the element or zone from the system with unsurpassed effectiveness.

BE1-87G relays typically trip a lockout (86) relay which in turn trips the generator breaker and, when present, the field and/or neutral breakers.

APPLICATION

When used with current transformers (CTs) of an accuracy class of either\ C20, T20 or better, BE1-87G relays are recommended for the following specific applications:

- Generators:
  - o Any terminal voltage and a rating of 1,000 kVA and above
  - o Any kVA rating and a terminal voltage of 5 kV and above
  - o A terminal voltage of 2,200 V or higher and a rating of more than 500 kVA
- Motors rated at 1,500 horsepower and above
- As primary protection on shunt reactors for transmission lines
- Generator ground differential

Differential relaying is the most selective form of fault protection which may be applied to the individual elements or zones of ac power systems. Various types of differential relays and relaying systems have evolved to take advantage of the differential principle.

> **WARNING!**
>
> Relays manufactured prior to July 22, 1991 (EIA date code symbol 9129 and previous) do not have case jumpers between terminals 7 and 8 (single-phase units). This also applied to terminals 7 and 8, 13 and 14, and 17 and 18 of three-phase relays. Exercise caution when grounding or testing current transformer circuits connected to these terminals.

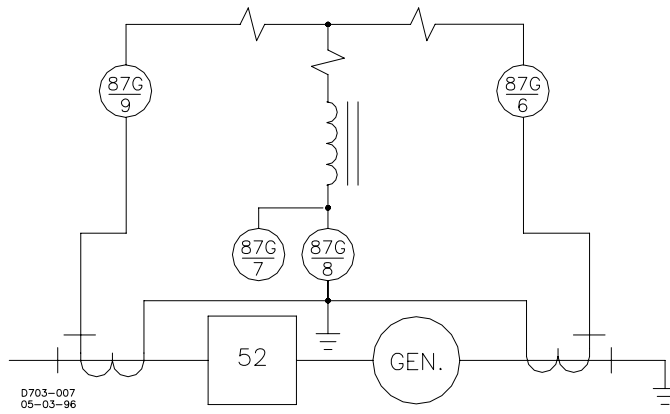Typical application schemes are illustrated in Figures 1-1 and 1-2.

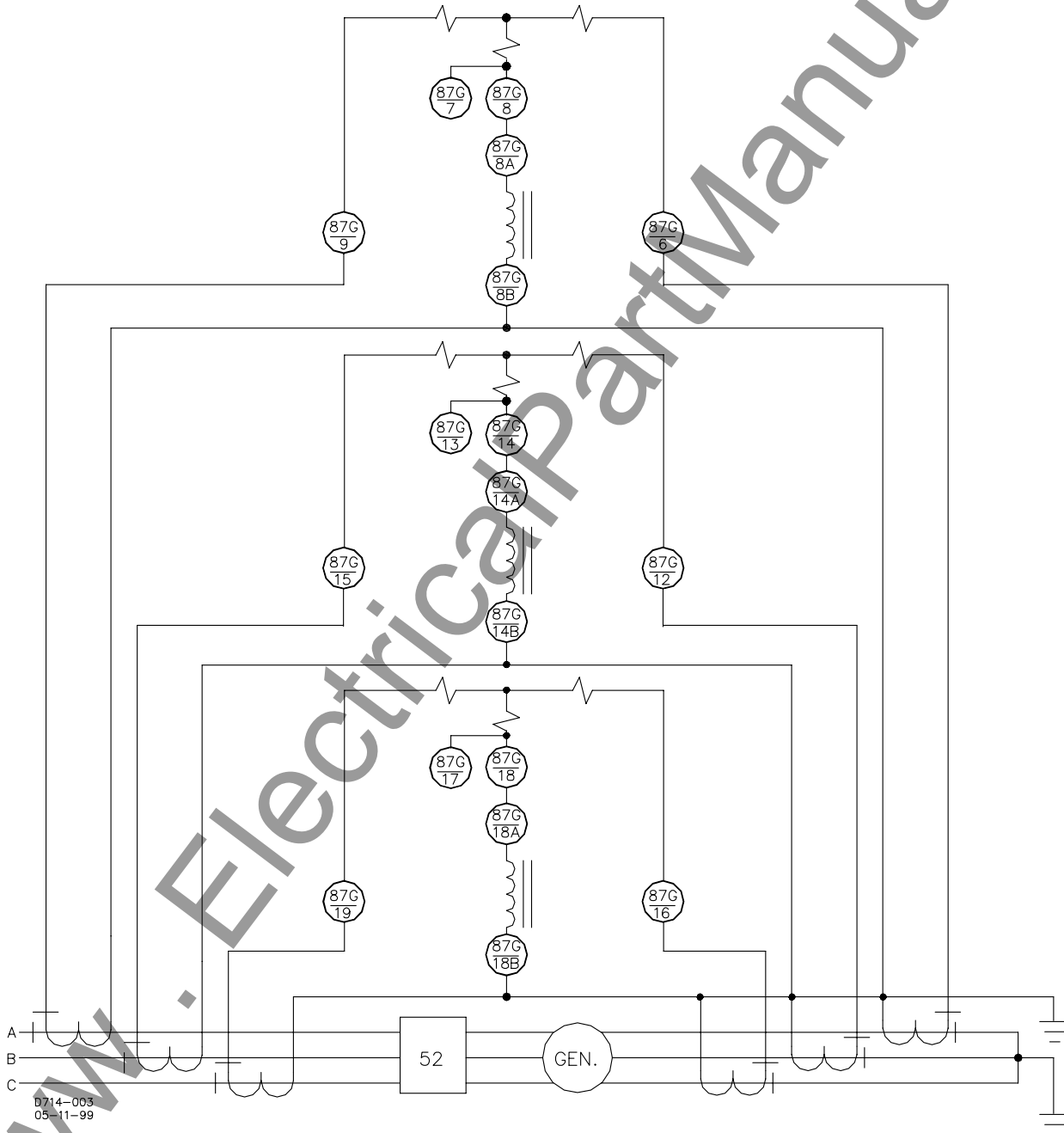*Figure 1-1. Typical Single-Phase Application Scheme*

Figure 1-2. Typical Three-Phase Application Scheme

Variable Restraint Characteristic

At high current levels, the inevitable difference in the saturation characteristics between current transformers indicates a need for a compensating decrease in relay sensitivity. The design of the BE1-87G provides a restraint factor that is proportional to input current when the restraining current (I_R) is greater than nominal (5 Aac for sensing input range 1 or 1 Aac for sensing input range 2). The BE1-87G compares the protected zone sensed input and output currents. The lesser of the two sensed current levels becomes the restraining current. The difference between the two sensed currents (the operating current) is compared to a reference established by the sensitivity setting, and adjusted by an amount proportional to the restraining current. This makes the BE1-87G more sensitive to low current internal faults, and less sensitive to external faults with high levels of through current.

When the restraining current is at nominal (5 Aac for sensing input range 1 or 1 Aac for sensing input range 2) or less, the relay trips if the differential current exceeds the relay setting (I_S). But when the restraining current is greater than nominal, the overall sensitivity is a combination of the front panel setting and the restraint factor.

Design Highlights

Some of the many advantages of the BE1-87G relay are summarized below:

- Seven sensitivity levels on each of the two sensing input ranges. The seven levels allow compensation for CT mismatch and provide the flexibility and adaptability necessary for many special applications such as split-winding generator protection.
- Stabilizing reactor. Minimizes dissimilar performance of system CTs. Reactor can be located on the back of the relay or remotely from the BE1-87G for flexibility of system installation.
- Variable restraint. The variable restraint characteristic allows increased sensitivity to low-current, internal faults while providing increased security against high levels of through-current caused by external faults.
- Single- or three-phase availability. Either configuration is available in the Basler Electric S1 draw-out case.
- High-speed operation. The BE1-87G operates in 30 milliseconds for fault levels of 10 times the sensitivity setting. This high-speed operation minimizes potential damage to the protected equipment. Response characteristics for sensing input ranges 1 and 2 are shown in Section 5, *Testing and Setting*.

MODEL AND STYLE NUMBER

The model number BE1-87G designates the relay as a Basler Electric, Class 100, Variable Percentage Differential Relay.

The electrical characteristics and operational features of the BE1-87G relay are defined by a combination of letters and numbers which constitutes the relay style number. The style number describes the features and options of the BE1-87G relay and appears on the front panel, draw-out cradle, and inside the case assembly.

Style Number Chart

The BE1-87G style number chart is illustrated in Figure 1-3.

Style Number Example

As an example, if the style number of a BE1-87G were **G1EA1JA0C0F**, the relay would have the following characteristics and features:

G three-phase current sensing
1 switch-selectable sensing input range for 0.1, 0.15, 0.2, 0.4, 0.5, 0.8, or 1.6 Aac
E one normally-open output relay
A1 instantaneous timing
J relay operating power derived from 125 Vdc or 100/120 Vac
A internally operated targets (one per phase)
0 option 1 not available
C push-to-energize outputs (pushbuttons)
0 no auxiliary output contacts
F semi-flush mounting case

STYLE NUMBER

| | | | A1 | | | 0 | | | |

Sensing Input Type
G) Three-phase current
S) Single-phase current

Output
E) One NO relay
G) One NC relay

P0047-04

Power Supply
J) 125 Vdc and 120 Vac
K) 48 Vdc
L) 24 Vdc
Y) 48/125 Vdc
Z) 250 Vdc and 240 Vac

Option 1
0) None

Option 3
0) None
1) NO auxiliary relay
2) NC auxiliary relay
6) Power supply status output

Sensing Input Range
1) Switch-selectable: 0.1, 0.15, 0.2, 0.4, 0.5, 0.8, or 1.6 A
2) Switch selectable: 0.02, 0.03, 0.04, 0.08, 0.1, 0.16, or 0.32 A

Timing
A1) Instantaneous

Targets
N) None
A) Internally operated targets
B) Current operated targets △1

Option 2
N) None
C) Push-to-energize outputs

Option 4
F) Semi-flush mounting
P) Projection mounting

NOTES

△1 If TARGET is B, OUTPUT must be E.

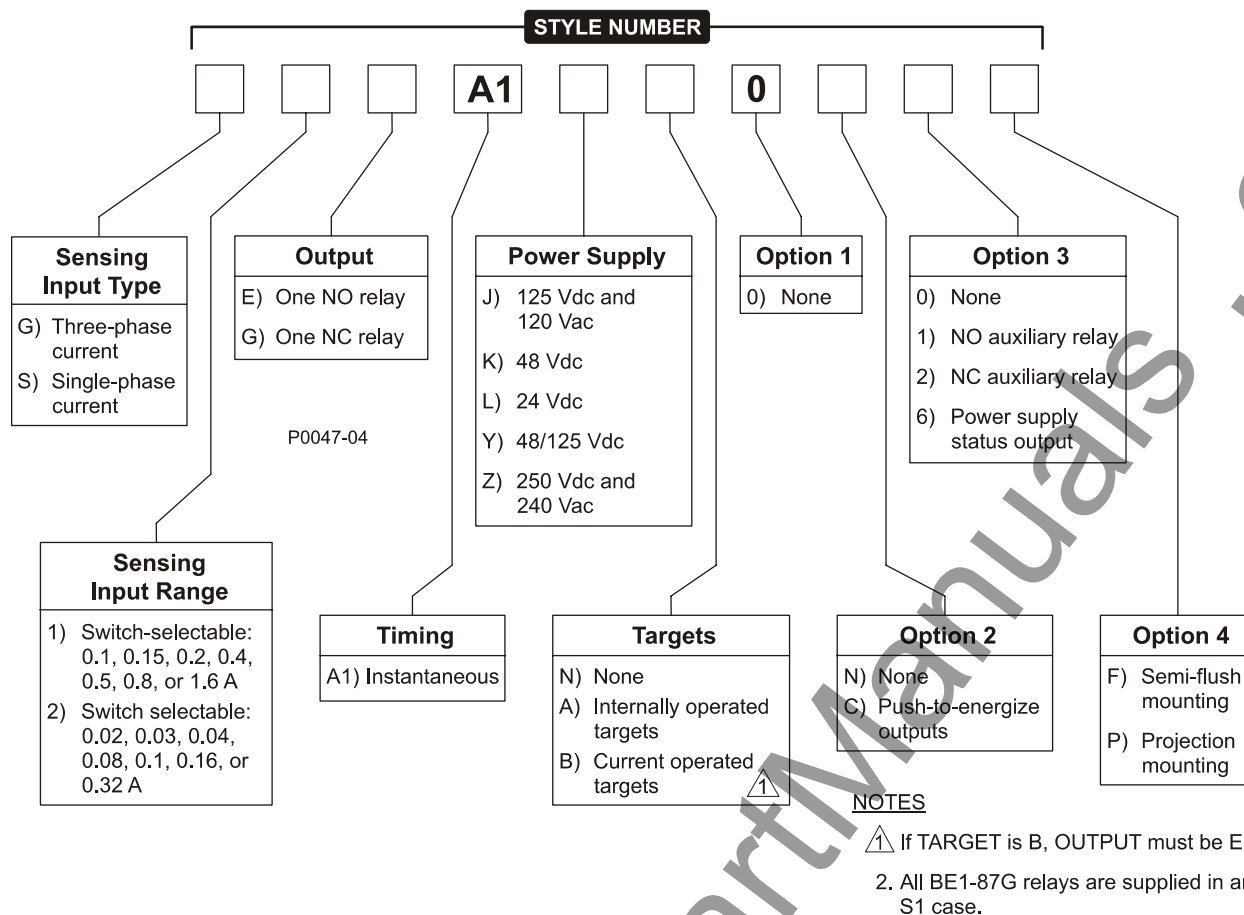2. All BE1-87G relays are supplied in an S1 case.

Figure 1-3. Style Number Identification Chart

SPECIFICATIONS

BE1-87G relays have the following features and capabilities.

Current Sensing Inputs

Sensing Input Range 1

Nominal Rating:	5 Aac
Maximum Continuous Rating:	10 Aac
1 Second Rating:	250 Aac
Frequency Range:	45 to 65 Hz
Burden:	<0.05 Ω per input

Sensing Input Range 2

Nominal Rating:	1 Aac
Maximum Continuous Rating:	2 Aac
1 Second Rating:	50 Aac
Frequency Range:	45 to 65 Hz
Burden:	<0.25 Ω per input

Stabilizer Reactor

Refer to Section 3, *Functional Description* for stabilizer reactor impedance characteristic curves.

I^2t Rating ($I^2t = 4225$)

Sensing Input Range 1:	65 A for 1 s at 70°C ambient
Sensing Input Range 2:	13 A for 1 s at 70°C ambient

Pickup

Graphs of the actual operating characteristics are shown in Section 5, *Testing and Setting*.

Control

A front panel sensitivity switch permits selection of minimum differential (operate) current. This sensitivity is constant for restraint currents less than the nominal current (5 Aac for sensing input range 1 or 1 Aac for sensing input range 2).

Minimum Differential (Operate) Current

Sensing Input Range 1:   0.1, 0.15, 0.2, 0.4, 0.5, 0.8, or 1.6 A
Sensing Input Range 2:   0.02, 0.03, 0.04, 0.08, 0.10, 0.16, or 0.32 A

The ideal operating characteristic is approximated by the following equations∗:

Sensing Input Range 1:   For $I_R \leq 5$ A: $I_{OP} = I_S$
                           For $I_R > 5$ A: $I_{OP} = I_S + 0.5\ (I_R - 5)$
Sensing Input Range 2:   For $I_R \leq 1$ A: $I_{OP} = I_S$
                           For $I_R > 1$ A: $I_{OP} = I_S + 0.5\ (I_R - 1)$

∗ I_R is the restraint current, defined as the lesser of the input currents
    I_{OP} is the operate current
    I_S is the front panel setting

Accuracy

Sensing Input Range 1

For $I_R \leq 5$ A: ±5% of the operate pickup characteristic or ±25 mA, whichever is greater
For $I_R > 5$ A (20 A max.):   ±8% of the operate pickup characteristic or ±150 mA, whichever is greater

Sensing Input Range 2

For $I_R \leq 1$ A: ±5% of the operate pickup characteristic or ±25 mA, whichever is greater
For $I_R > 1$ A (4 A max.):   ±8% of the operate pickup characteristic or ±150 mA, whichever is greater

Dropout

>90% of operate characteristic

Timing

<30 ms at 10 times pickup setting, 70 ms maximum

Operating Power Input

Relay operating power may be obtained from a wide variety of external voltage sources. When ordering, any one of five internal power supply types may be selected to match the operating power voltage level available at your site. Available power supply types are listed in Table 1-1.

Table 1-1. Power Supply Types

Type	Input Voltage		Burden at Nominal
	Nominal	**Range**	
K (midrange)	48 Vdc	24 to 150 Vdc	2.75 W
J (midrange)	125 Vdc	24 to 150 Vdc	2.96 W
	120 Vac	90 to 132 Vac	7.87 VA
L (low range)	24 Vdc	∗ 12 to 32 Vdc	2.85 W
Y (mid range)	48 Vdc	24 to 150 Vdc	2.75 W
	125 Vdc	24 to 150 Vdc	2.96 W
Z (high range)	250 Vdc	68 to 280 Vdc	3.13 W
	230 Vac	90 to 270 Vac	9.20 VA

∗   The type L power supply initially requires 14 Vdc to begin operating. Once operating, the voltage may be reduced to 12 Vdc and operation will continue.

Output Contacts

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, break 0.3 Adc
500 Vdc:	Make and carry 15 Adc for 0.2 s, carry 7 Adc continuously, break 0.3 Adc

Inductive Ratings

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

Targets

Electronically latched, manually reset target indicators may be optionally selected as either internally operated or current operated.

Current operated targets require a minimum trip circuit current of 200 milliamperes and have a continuous rating of 3 amperes, a two-minute rating of 7 amperes, and a one-second rating of 30 amperes.

Internally operated targets should be selected if the relay has normally-closed output contacts.

Type Tests

Dielectric Strength

In accordance with ANSI/IEEE C37.90, passes one-minute dielectric tests as follows:

All Circuits to Ground:	2,121 Vdc
Input Circuits to Output Circuits:	1,500 Vac or 2,121 Vdc

Surge Withstand Capability

Qualified to ANSI/IEEE C37.90.1-1989

Fast Transient Immunity

Qualified to ANSI/IEEE C37.90.1-1989

Impulse Testing

Qualified to IEC 255-5

Radio Frequency Interference

Maintains proper operation when tested for interference in accordance with IEEE C37.90.2

Shock

Withstands 15 G in each of three mutually perpendicular planes.

Vibration

Withstands 2 G in each of three mutually perpendicular planes, swept over the range of 10 to 500 Hz for a total of six sweeps, 15 minutes each sweep.

Physical

Temperature

Operating:	–40 to 70°C (–40 to 158°F)
Storage:	–65 to 100°C (–85 to 212°F)

Weight

Single-Phase Sensing Units:	14.3 lb (6.5 kg) maximum
Three-Phase Sensing Units:	19.2 lb (8.7 kg) maximum

Case Size

All units are supplied in an S1 case size. See Section 4, *Installation* for case dimensions.

Agency Recognition/Certification

UL Recognition:	UL recognized per Standard 508, File E97033
	NOTE: Output contacts are not UL recognized for voltages greater than 250 volts.
Gost-R Certification:	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.

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SECTION 2 • CONTROLS AND INDICATORS

GENERAL

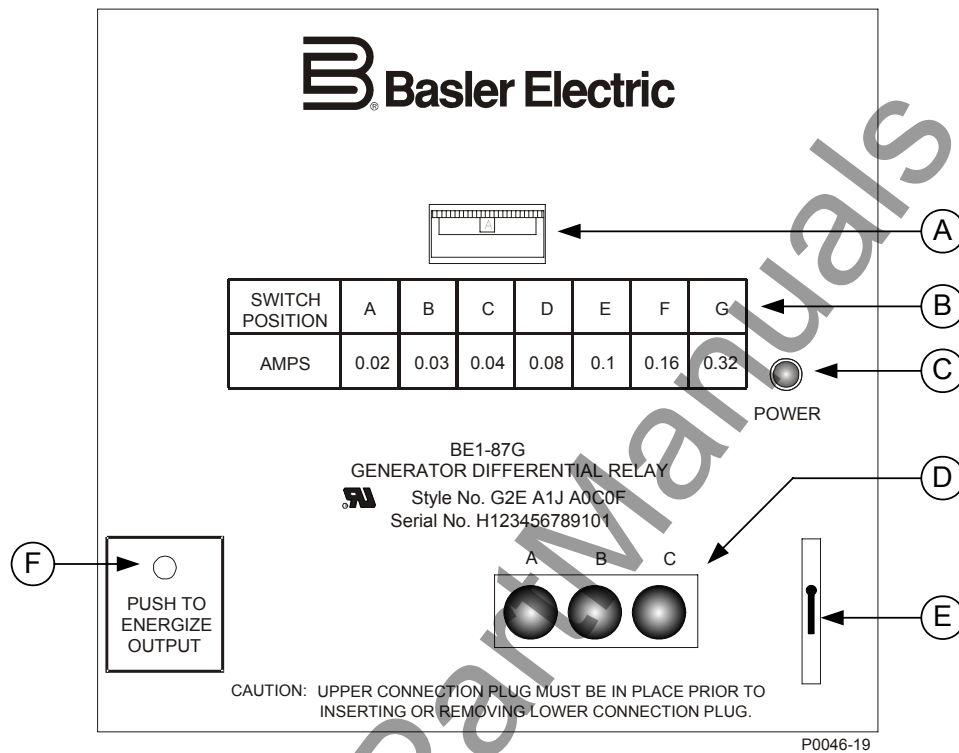BE1-87G controls and indicators are illustrated in Figure 2-1 and described in Table 2-1.

Figure 2-1. Controls and Indicators

Table 2-1. Control and Indicator Descriptions

Locator	Description
A	*Sensitivity Switch.* This thumbwheel switch has seven positions labeled A through G and sets the desired level of operating current that will cause the relay to trip.
B	*Switch Position Chart.* This chart relates the switch position to the operating current required for tripping when the restraint current is less than or equal to the nominal value of sensing current (5 Aac for sensing input range 1 or 1 Aac for sensing input range 2).
C	*Power Indicator.* This LED lights when operating power is applied to the relay.
D	*Target Indicators.* Electronically-latching red target LEDs light when a trip condition exists on the corresponding phase of current. When the optional targets are specified, a target LED is provided for each phase protected.
E	*Target Reset Switch.* Operating this switch resets all of the target indicators (locator D).
F	*Output Test Switch.* This momentary-action pushbutton switch operates the output and auxiliary relays. The switch is accessed by inserting a ⅛" diameter, non-conducting rod through the access hole in the front panel.

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SECTION 3 • FUNCTIONAL DESCRIPTION

INTRODUCTION

This section describes how the BE1-87G functions and explains its operating features.

BE1-87G FUNCTION BLOCKS

BE1-87G function blocks are illustrated in Figure 3-1 and described in the following paragraphs.
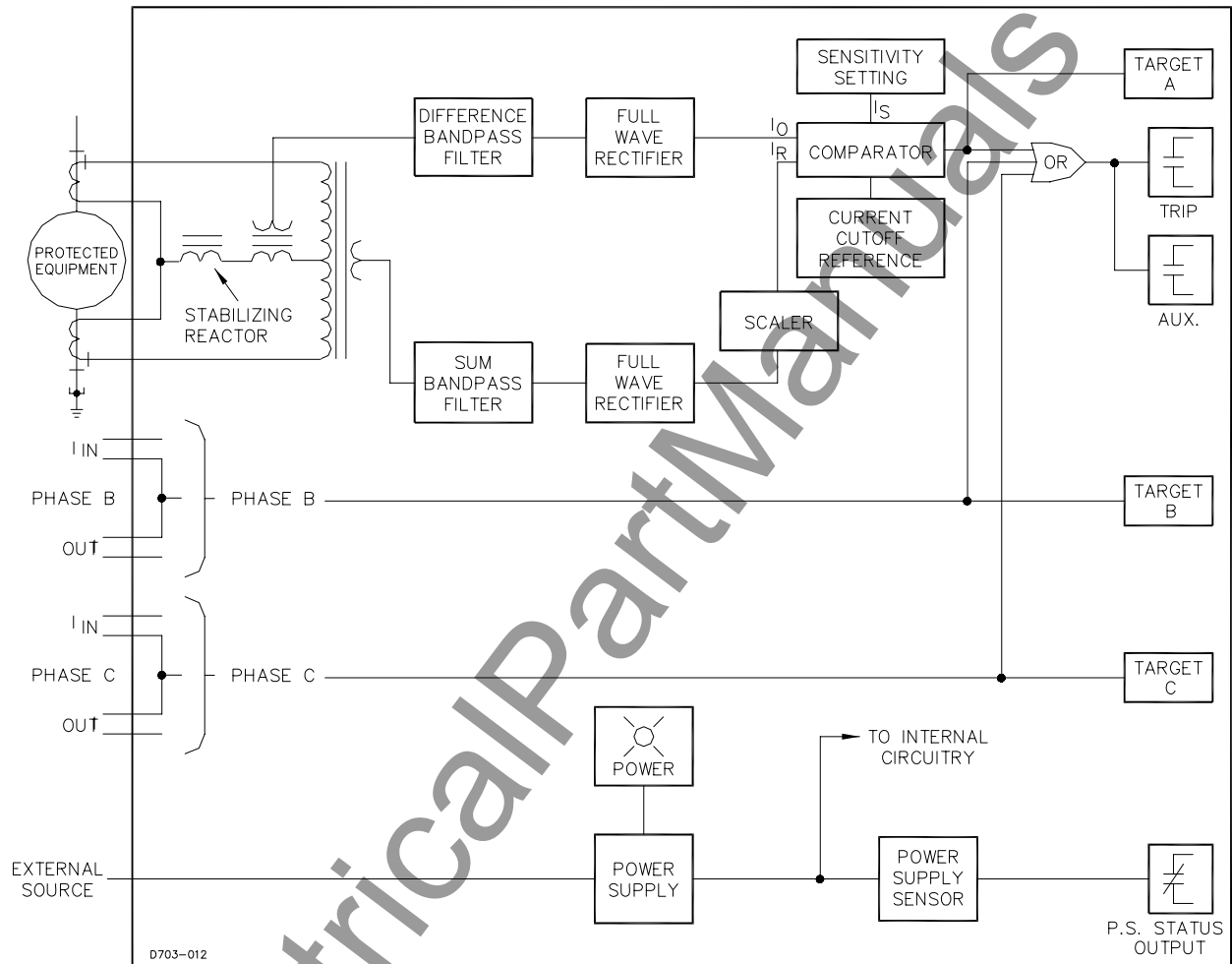

Figure 3-1. Function Block Diagram

Current Sensing Inputs

Sensing current for each monitored phase is provided by two user-provided, system CTs with secondary windings that match the BE1-87G's sensing input range. BE1-87G relays with sensing input range 1 (style x1x-xxx-xxxx) require CTs with 5 Aac secondary windings. Relays with sensing input range 2 (style x2x-xxx-xxxx) require CTs with 1 Aac secondary windings. Two CTs are used on each phase—one CT on each side of the protected machine. Sensing current is applied to internal transformers that provide system isolation and determine the differential and sum currents. These CTs are gapped to withstand dc offset.

Stabilizing Reactor

To minimize dissimilar performance of the system CTs, the stabilizing reactor acts as a stabilizing impedances during external faults. Stabilizing reactors are current rated based on time and ambient temperature (refer to Section 1, *General Information, Specifications*). Figures 3-2 and 3-3 illustrate the stabilizing reactor impedance characteristic.
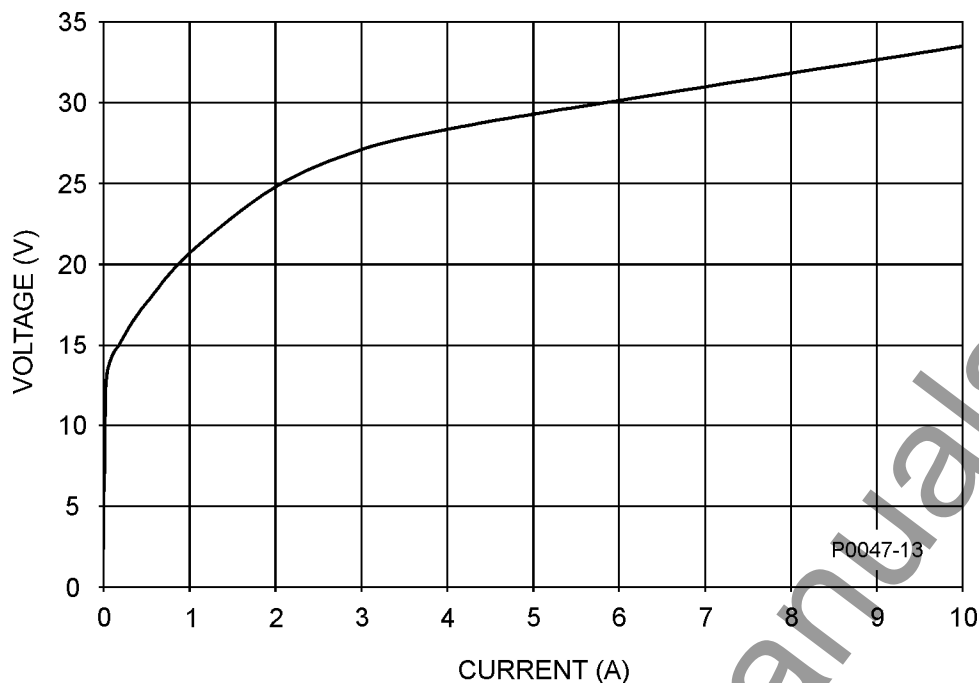
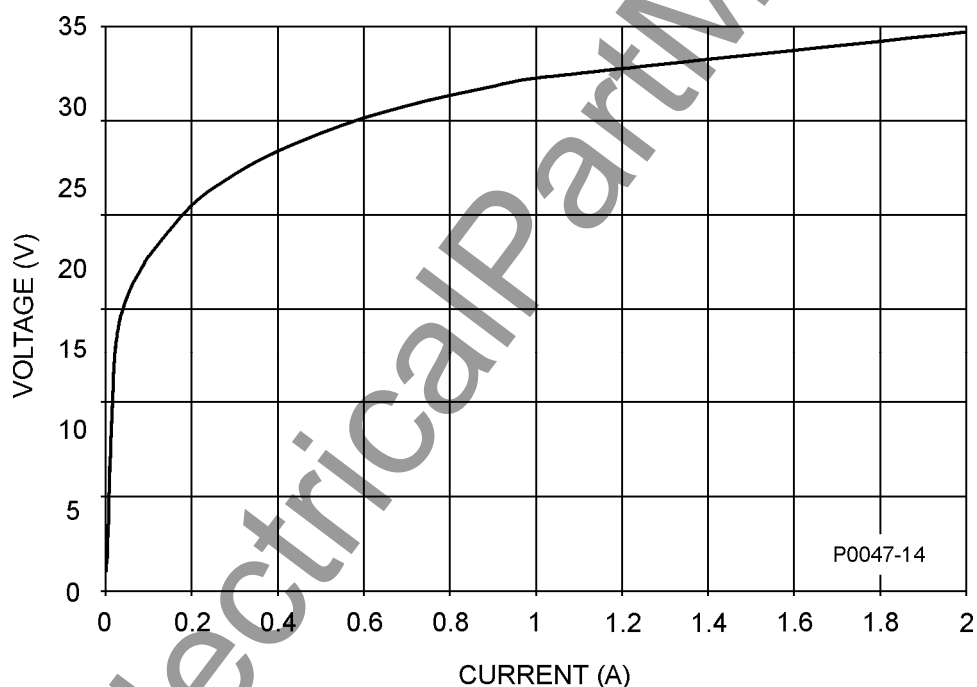*Figure 3-2. Stabilizing Reactor Impedance Characteristic, Sensing Input Range 1*

Figure 3-3. Stabilizing Reactor Impedance Characteristic, Sensing Input Range 2

Band-Pass Filters

The outputs of the relay's internal transformers are filtered to eliminate the third harmonic and minimize the effect of dc offset caused by CT saturation (as may occur during synchronization or asymmetrical faults). Two band-pass filters are used: difference and sum.

The output of the difference band-pass filter is applied to a full-wave rectifier. The rectifier scales the differential and applies the output to the comparator as the operating current (I_{OP}) signal.

The output of the sum band-pass filter is also applied to a full-wave rectifier. The scaled sum of the two inputs represents the restraint current (I_R). The restraint current is scaled for a 50% slope above nominal input current (5 Aac for sensing input range 1 or 1 Aac for sensing input range 2).

Comparator

The comparator provides the variable percentage characteristic of the relay as follows.

Restraint Current Less Than Nominal

When I_R is less than nominal (5 Aac for sensing input range 1 or 1 Aac for sensing input range 2), the comparator provides an output signal whenever I_{OP} exceeds the front panel sensitivity setting.

Restraint Current Greater Than Nominal

When I_R is greater than nominal (5 Aac for sensing input range 1 or 1 Aac for sensing input range 2), the front panel sensitivity switch setting (threshold) is increased by adding it to a scaled value representing one half of I_R minus nominal (5 Aac for sensing input range 1 or 1 Aac for sensing input range 2).

Output Relays

When the current difference exceeds the variable percentage limit (sensitivity switch setting), the comparator output energizes the output relays. (In BE1-87G models with three-phase sensing, the outputs are ORed together so that the output relays energize if the current difference of any one phase exceeds the limit.) When the current difference decreases below 90% of the variable percentage threshold, the output relays reset.

Main Output Relay

The main output relay contacts are either normally-open or normally-closed and are accessed at case terminals 1 and 10. Normally-open contacts are provided on BE1-87G relays with a style number of xxE-xxx-xxxxx and normally-closed contacts are provided on relays with a style number of xxG-xxx-xxxxx.

Auxiliary Output Relay (Optional)

An optional pair of contacts, accessed at case terminals 2 and 5, can be specified. The auxiliary output contacts change state when the main output contacts operate and are available in a normally-open or normally-closed configuration. Normally-open auxiliary contacts are provided on BE1-87G relays with style number xxx-xxx-xxx1x and normally-closed auxiliary contacts are provided on relays with style xxx-xxx-xxx2x.

Optionally, the auxiliary output relay can be specified to function as a power supply status output. This normally-closed output is energized open during normal operation. When relay control power is lost or an internal power supply failure occurs, the relay de-energizes and closes the contacts at terminals 2 and 5.

Target Indicators (Optional)

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. Latched targets are 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. Both target types are reset by operating the target reset switch.

Internally Operated Targets

The relay trip outputs are directly applied to drive the target indicators. The indicators are illuminated regardless of the current level in the trip circuits.

Current Operated Targets

Current operated targets are 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

Prior to September 2007, the BE1-87G 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.

Output Test Pushbutton

A relay with style number xxx-xxx-xxCxx is equipped with a momentary-action pushbutton accessible through the front panel. When pressed, the switch energizes the main and auxiliary output relays. To prevent accidental relay tripping, the pushbutton is recessed behind the front panel. The button is pressed by insertion of a thin, non-conducting rod through the button access hole in the front panel.

Power Supply

Relay operating power is developed by a wide-range, isolated, low-burden, switching power supply that delivers ±12 Vdc to the relay's internal circuitry. The power supply is not sensitive to the input power polarity. A front panel LED power indicator lights to indicate that the power supply is functioning properly.

Style number designations and input voltage ranges for the available power supply models are provided in Section 1, *General Information.*

SECTION 4 • INSTALLATION

INTRODUCTION

Upon receipt of a relay, check the model and style number against the requisition and packing list to ensure that they agree.

If there is any evidence of shipping damage, file a claim with the carrier and notify Basler Electric.

If the relay won't be installed immediately, store it in its original shipping carton in a moisture- and dust-free environment.

MOUNTING

Because the relay is of solid-state design, it does not have to be mounted vertically. Any convenient mounting angle may be chosen.

Cutting and Drilling Dimensions

Panel cutting and drilling dimensions for semi-flush mounted relays (style number xxx-xxx-xxxxF) are shown in Figure 4-1. Panel drilling dimensions for projection mounted relays (style number xxx-xxx-xxxxP) are shown in Figures 4-2 and 4-3. Figure 4-2 illustrates the panel drilling dimensions for double-ended, projection-mounted cases. (Double-ended cases have terminals at both the bottom and top ends of the case. BE1-87G relays with three-phase current sensing (style number Gxx-xxx-xxxxx) are supplied with a double-ended case. Figure 4-3 illustrates the panel drilling dimensions for single-ended, projection-mounted cases. (Single-ended cases have terminals only at the bottom end of the case. BE1-87G relays with single-phase current sensing (style number Sxx-xxx-xxxxx) are supplied with a single-ended case.

Case Dimensions

Side views showing semi-flush mounted case dimensions are provided in Figures 4-4 and 4-5. Figure 4-4 illustrates a side view of the case dimensions for a double-ended, semi-flush mounted case. Figure 4-5 illustrates a side view of the case dimensions for a single-ended, semi-flush mounted case.

Side views showing projection mounted case dimensions are provided in Figures 4-6 and 4-7. Figure 4-6 illustrates a side view of the case dimensions for a double-ended, projection mounted case. Figure 4-7 illustrates a side view of the case dimensions for a single-ended, projection mounted case.

Rear views showing semi-flush mounted case dimensions are provided in Figures 4-8 and 4-9. (The rear-view dimensions for semi-flush mounted cases and projection-mounted cases are identical.) Figure 4-8 illustrates a rear view of the case dimensions for a double-ended case and Figure 4-9 illustrates a rear view of the case dimensions for a single-ended case.

A front view showing the dimensions of the case cover is provided in Figure 4-10.

Stabilizing Reactor

For three-phase relays, the stabilizing reactor consists of a module attached to the rear of the mounting case. For projection mounting or convenience, the stabilizing reactor module can be removed and relocated. To remove the stabilizing reactor, remove the four screws that secure the module to the mounting plate. The mounting plate is separated from the case by removing the two hex-head bolts.

When the stabilizing reactor is relocated, it should be rewired in accordance with the connection diagrams shown later in this section.

The overall dimensions of the stabilizing reactor are shown in Figure 4-11. A side view showing the dimensions of a semi-flush mounting case with attached stabilizing reactor is provided in Figure 4-12.
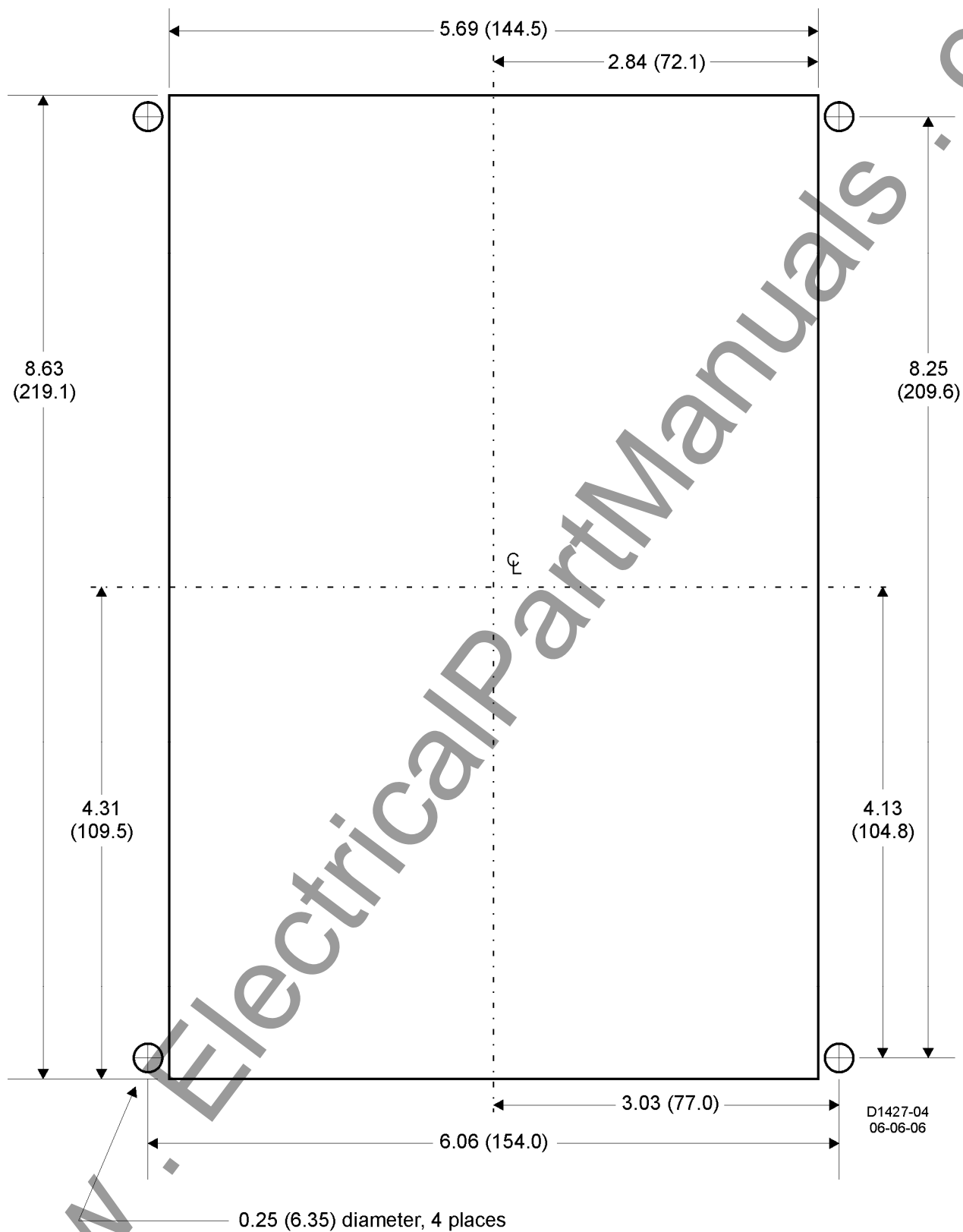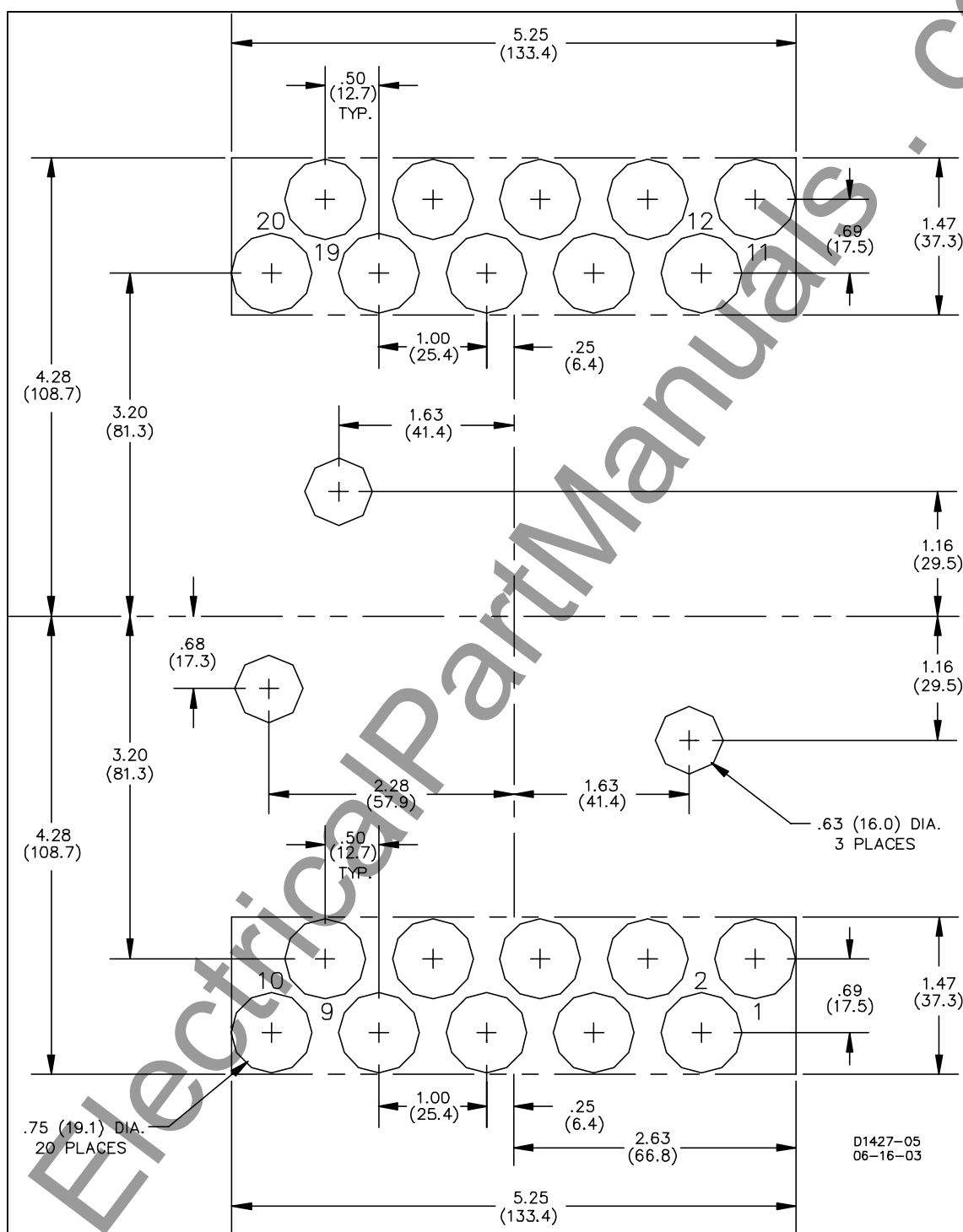
5.69 (144.5)

2.84 (72.1)

8.63 (219.1)

8.25 (209.6)

CₗL

4.31 (109.5)

4.13 (104.8)

3.03 (77.0)

6.06 (154.0)

D1427-04
06-06-06

0.25 (6.35) diameter, 4 places

Figure 4-1. Panel Cutting and Drilling Dimensions, Semi-Flush Mounting, Double- or Single-Ended Case

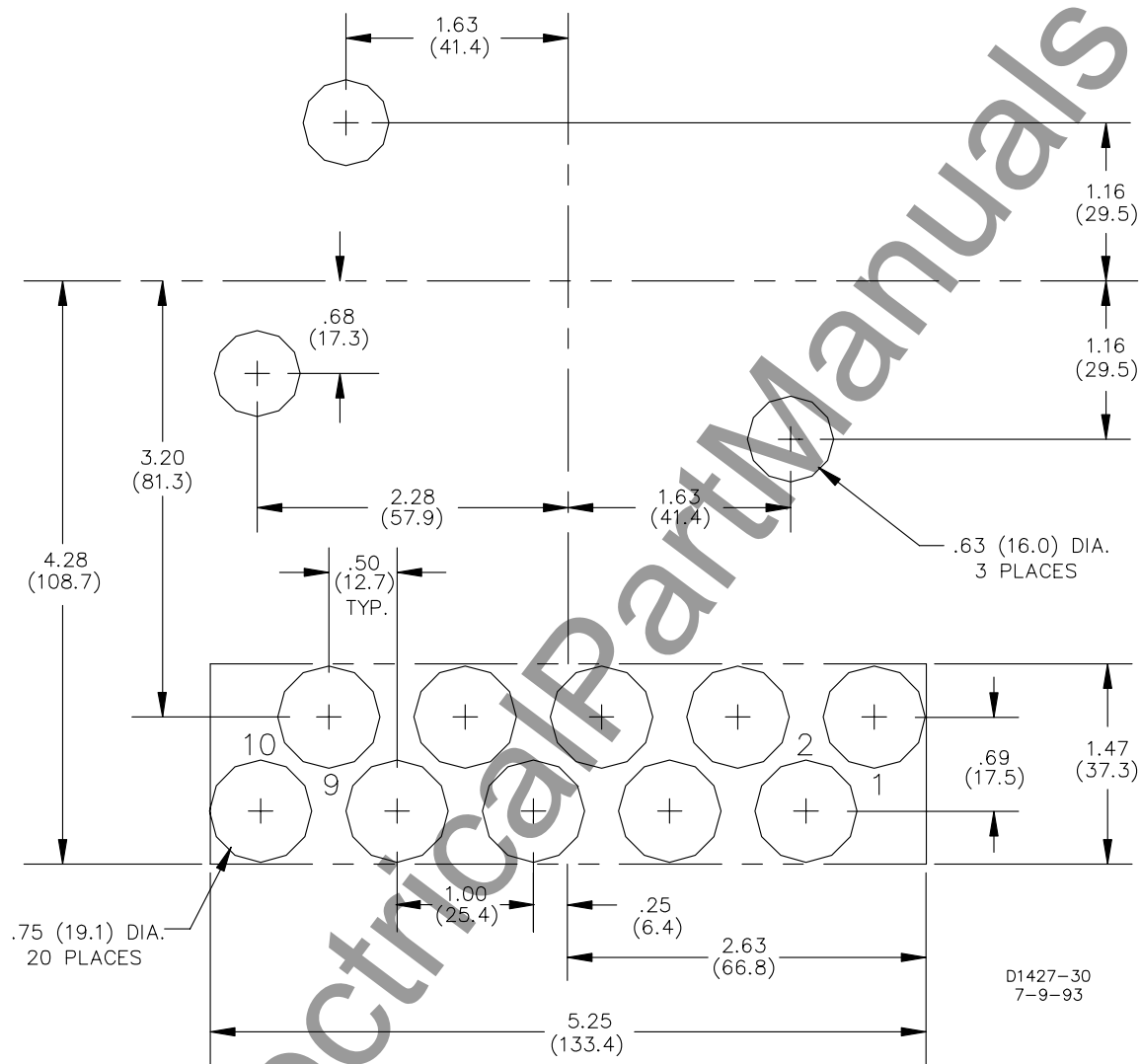◆ *Figure 4-2. Panel Drilling Dimensions, Projection Mounting, Double-Ended Case*

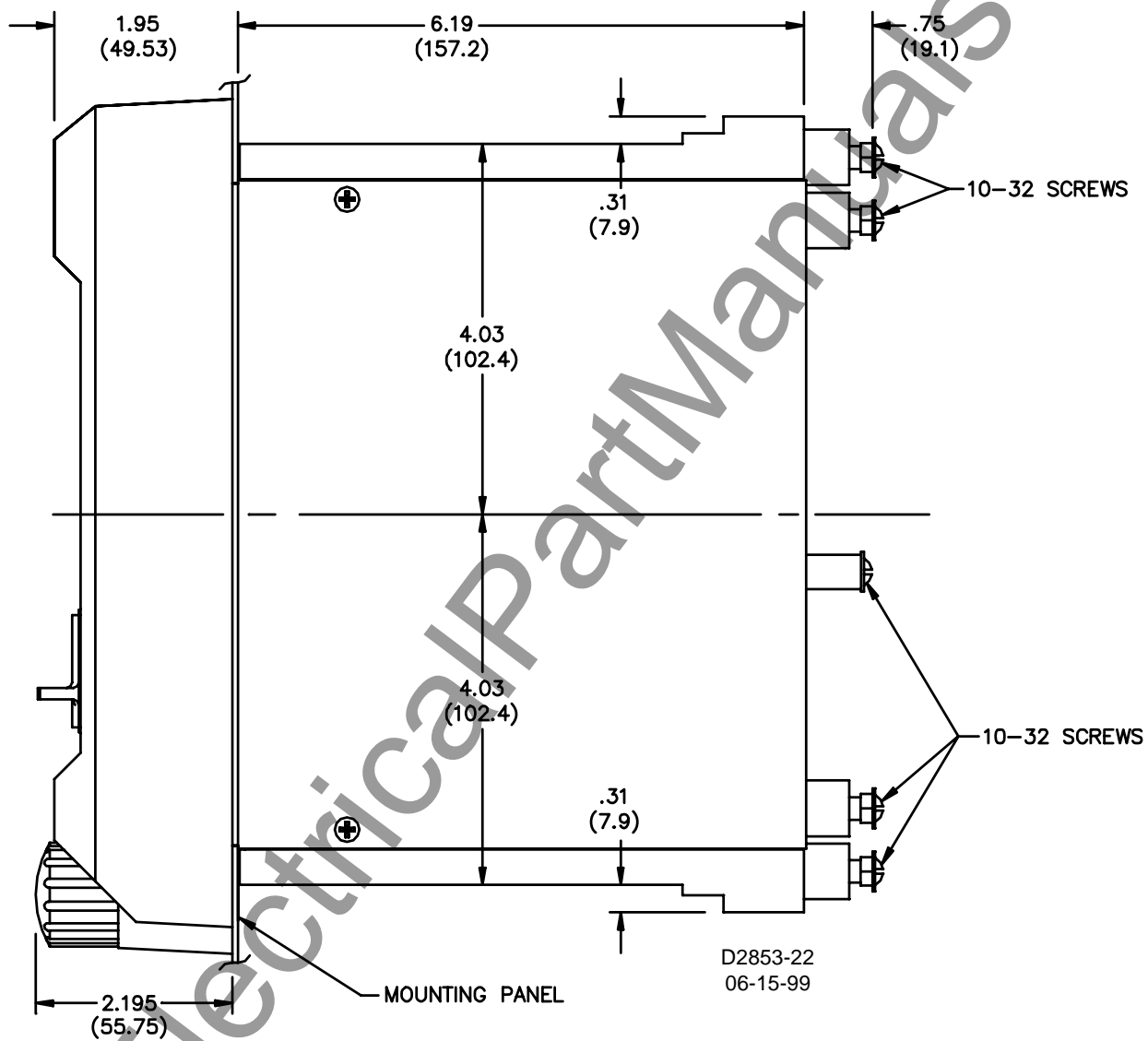*Figure 4-3. Panel Drilling Dimensions, Projection-Mounting, Single-Ended Case*

BE1-87G Installation **9170800990 Rev L**

1.95
(49.53)

6.19
(157.2)

.75
(19.1)

10−32 SCREWS

.31
(7.9)

4.03
(102.4)

4.03
(102.4)

10−32 SCREWS

.31
(7.9)

D2853-22
06-15-99

2.195
(55.75)

MOUNTING PANEL

Figure 4-4. Outline Dimensions, Side View, Semi-Flush Mounted, Double-Ended Case

1.95
(49.53)

6.19
(157.2)

.31
(7.9)

4.03
(102.4)

4.03
(102.4)

.31
(7.9)

10−32 SCREWS

D2856-23
06-15-99

2.195
(55.75)

MOUNTING PANEL
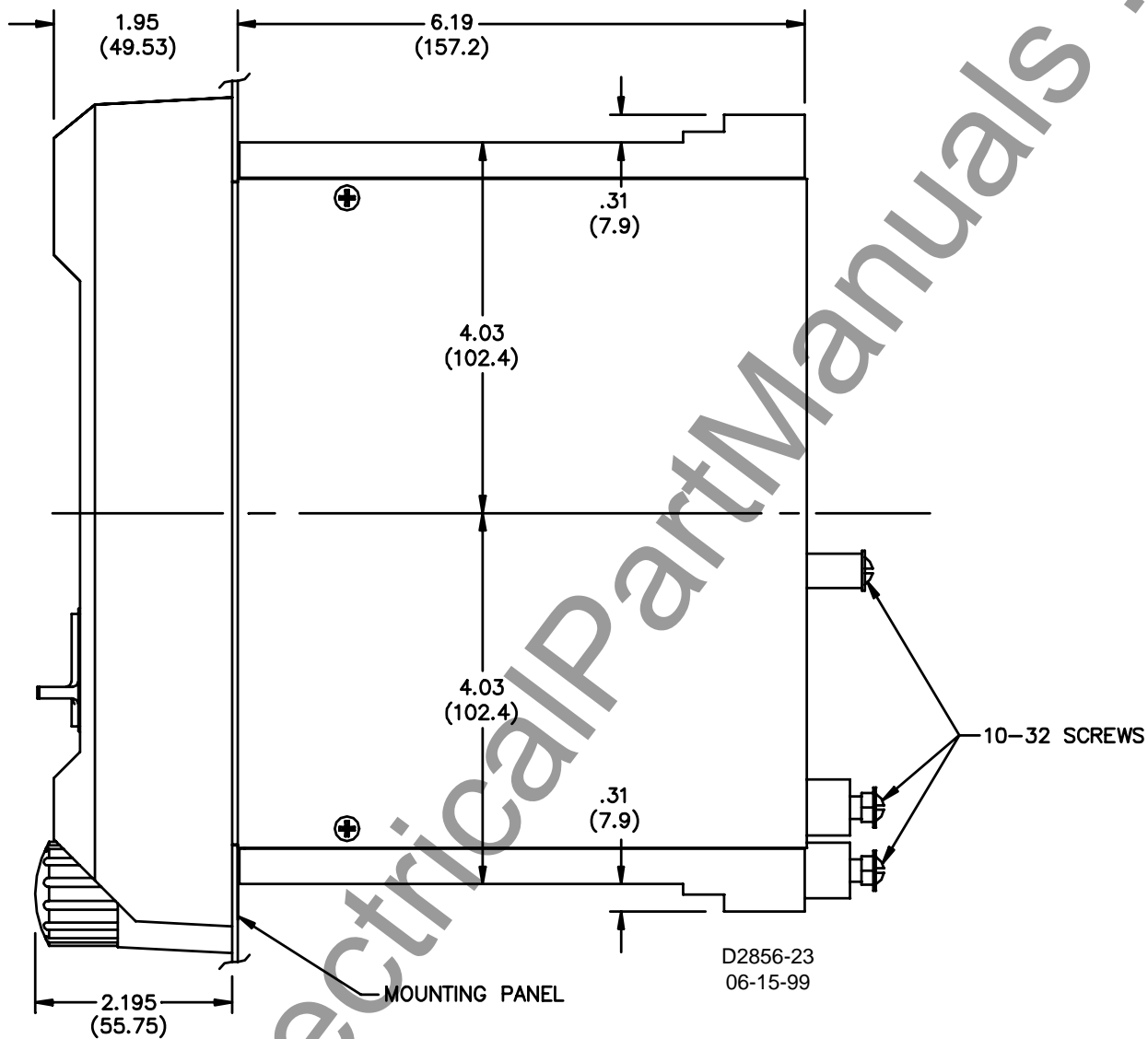
Figure 4-5. Outline Dimensions, Side View, Semi-Flush Mounted, Single-Ended Case
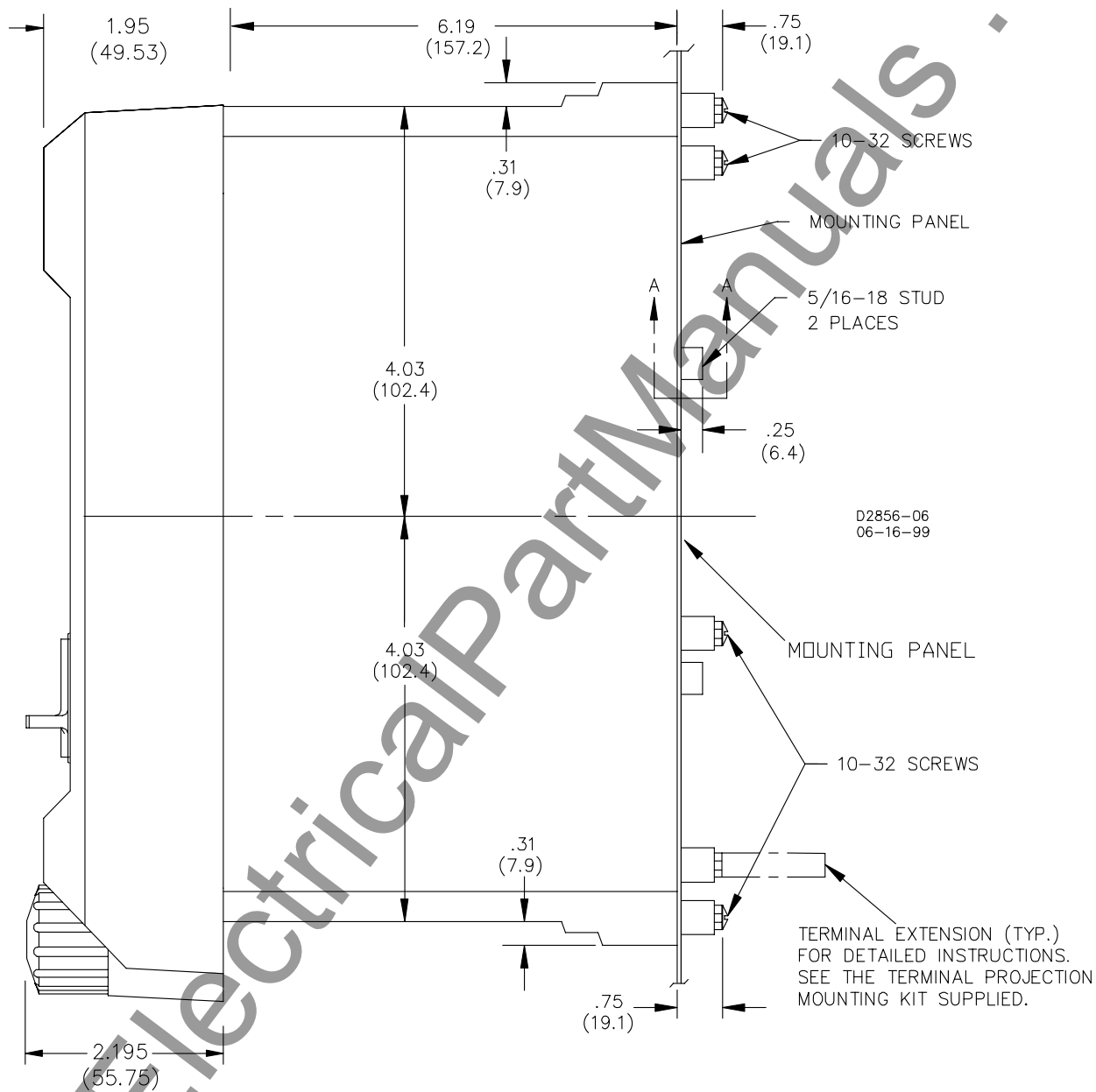
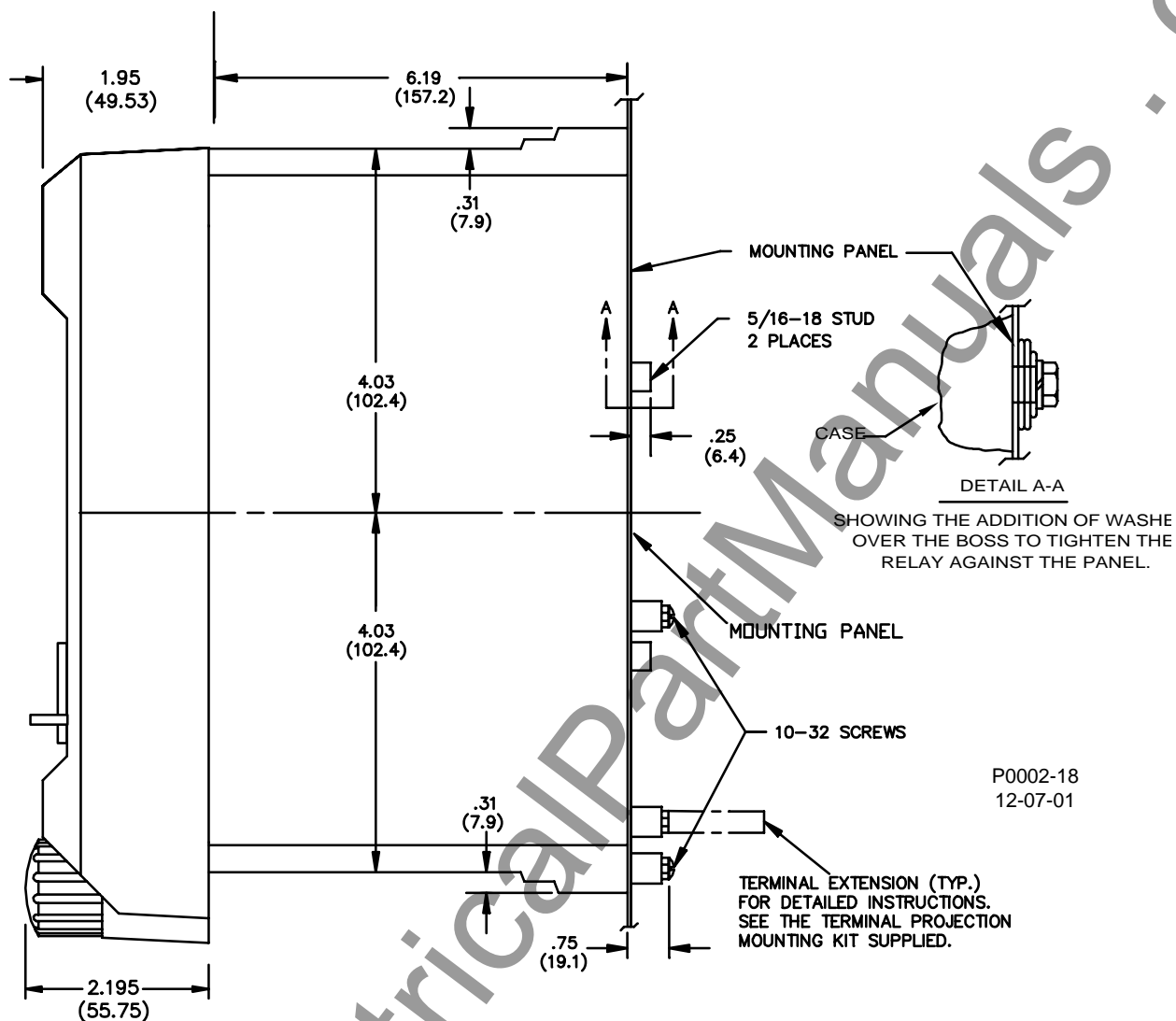*Figure 4-6. Outline Dimensions, Side View, Projection Mounted, Double-Ended Case*

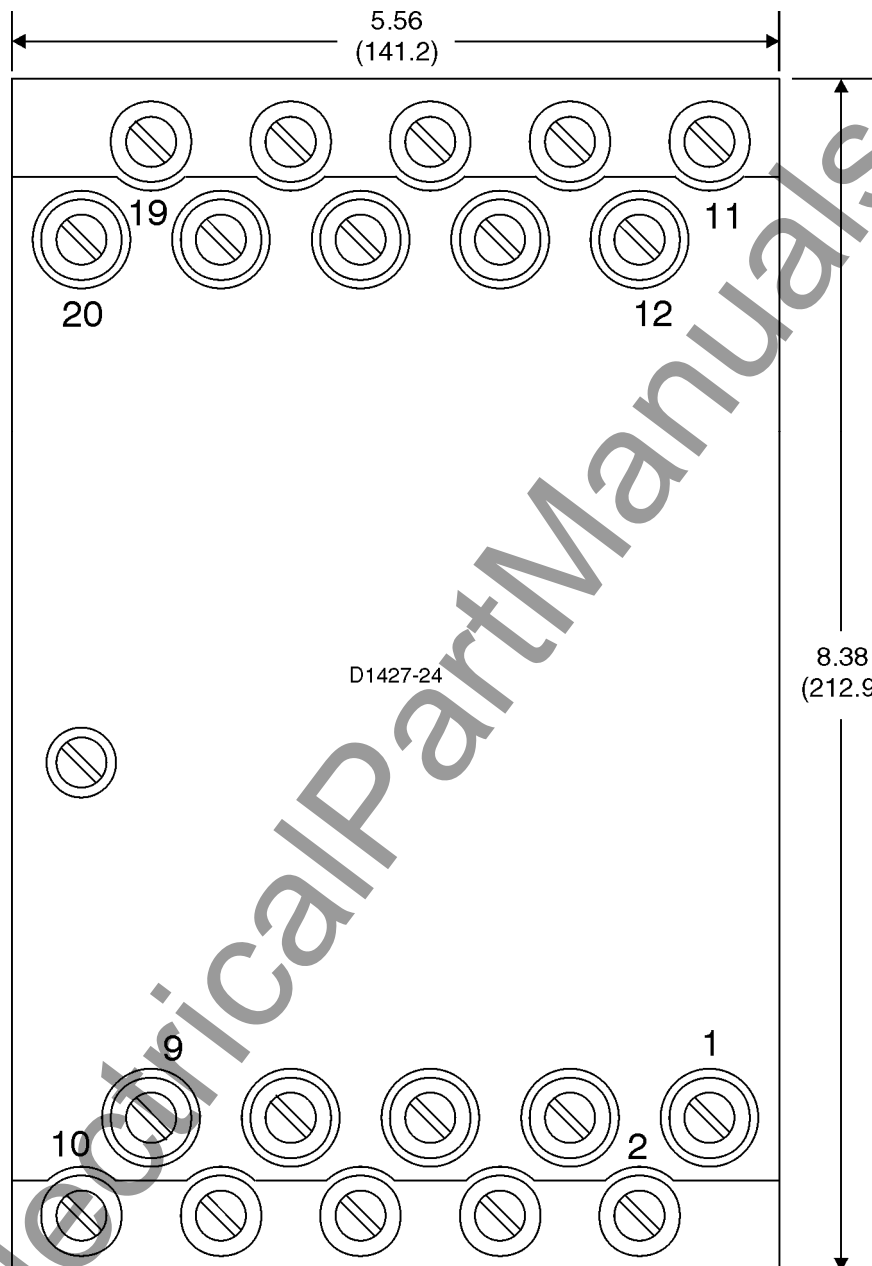*Figure 4-7. Outline Dimensions, Side View, Projection Mounted, Single-Ended Case*

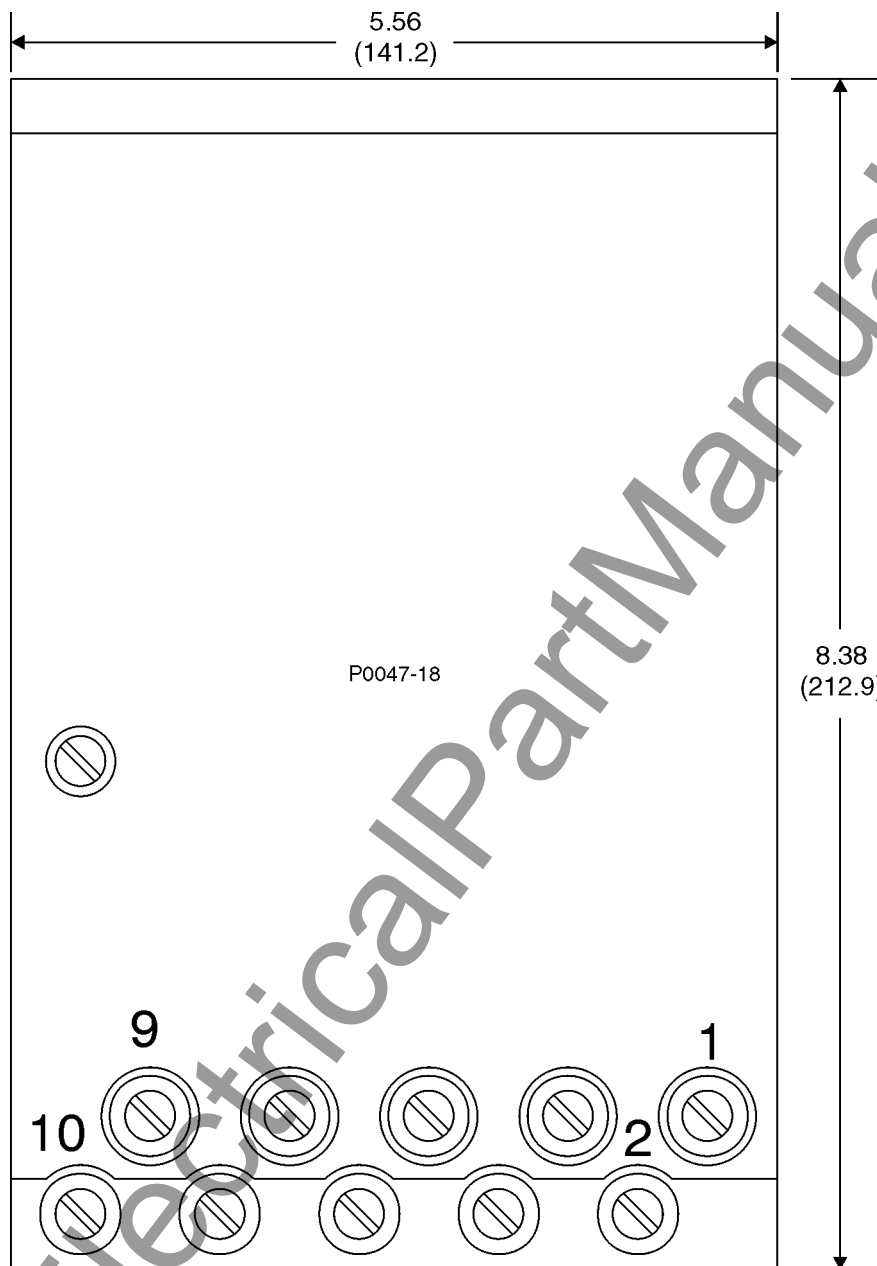*Figure 4-8. Outline Dimensions, Rear View, Double-Ended Mounting Case*

Figure 4-9. Outline Dimensions, Rear View, Single-Ended Mounting Case
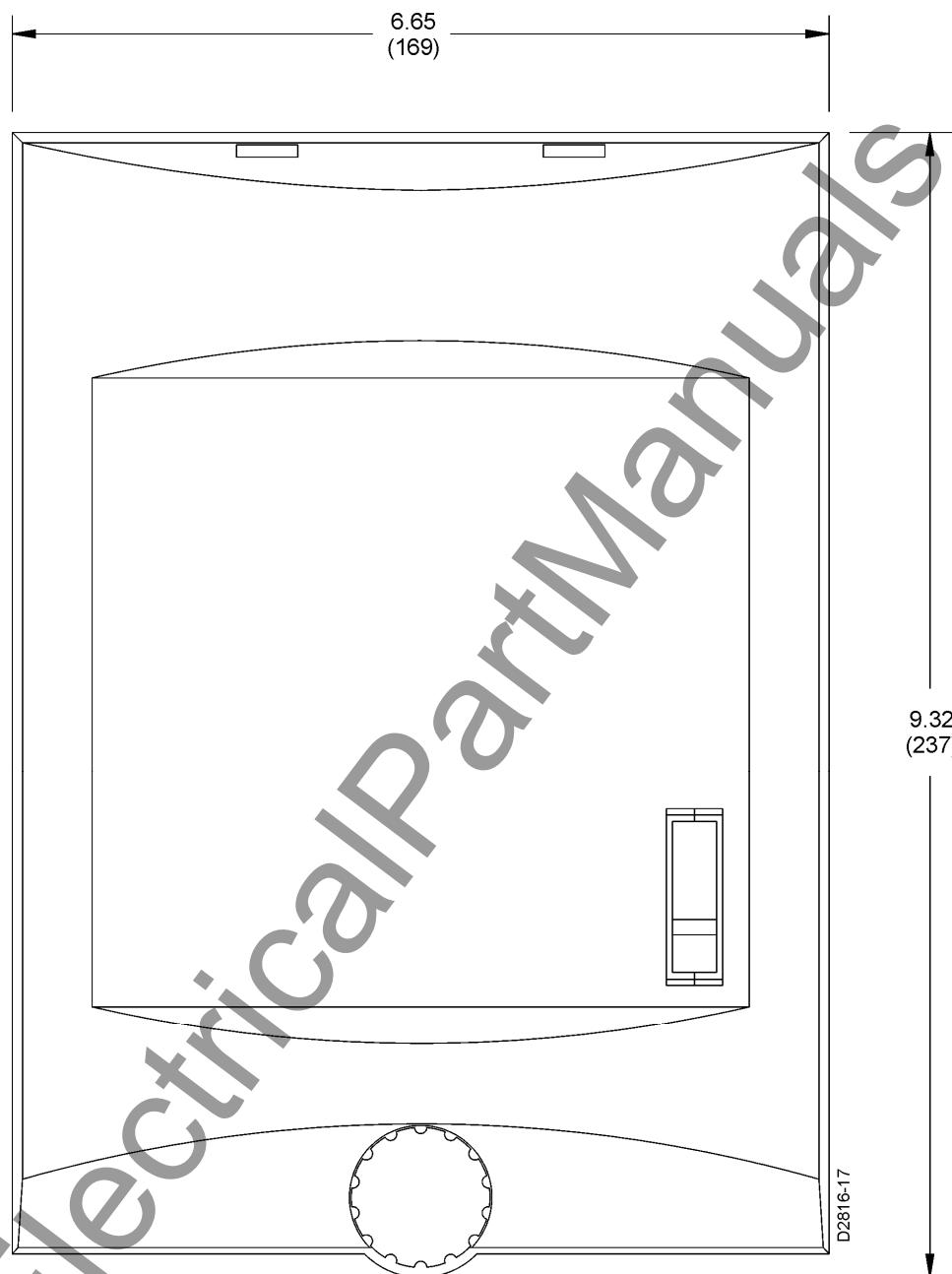
6.65
(169)

9.32
(237)

D2816-17

Figure 4-10. Outline Dimensions, Front View, Case Cover

0.187 (4.8) diameter mounting hole (6 places)

Weight: 4.2 lb (1.9 kg)

Basler Electric
Highland, Illinois

REACTOR CHASSIS
P/N 9170818100
FOR BE1-87G
GENERATOR DIFFERENTIAL
RELAY

L3 — 18A / 18B
L2 — 14A / 14B
L1 — 8A / 8B

P0047-15

1.90 (48.3)
5.024 (127.6)
1.90 (48.3)
0.61 (15.5)
0.20 (5.1)
4.821 (122.4)
5.221 (132.6)
2.588 (65.7)
3.12 (79.2)
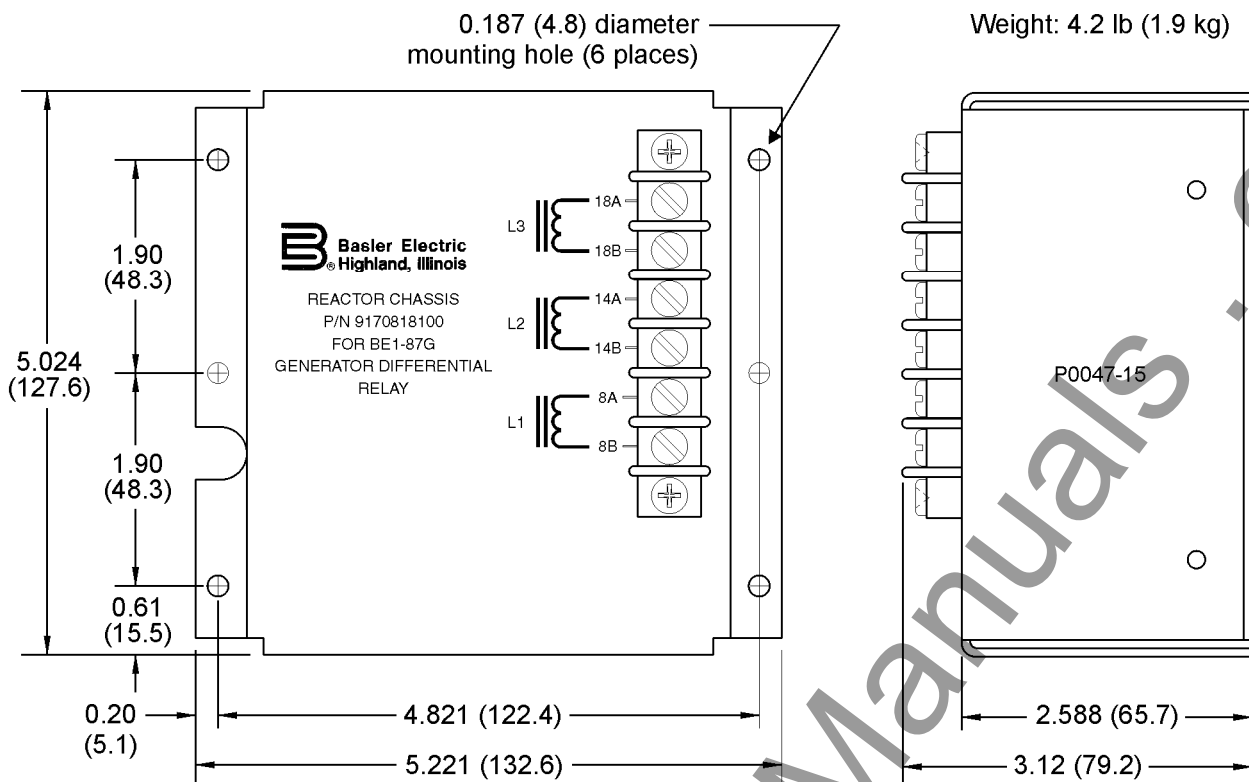
Figure 4-11. Overall Dimensions, Stabilizing Reactor

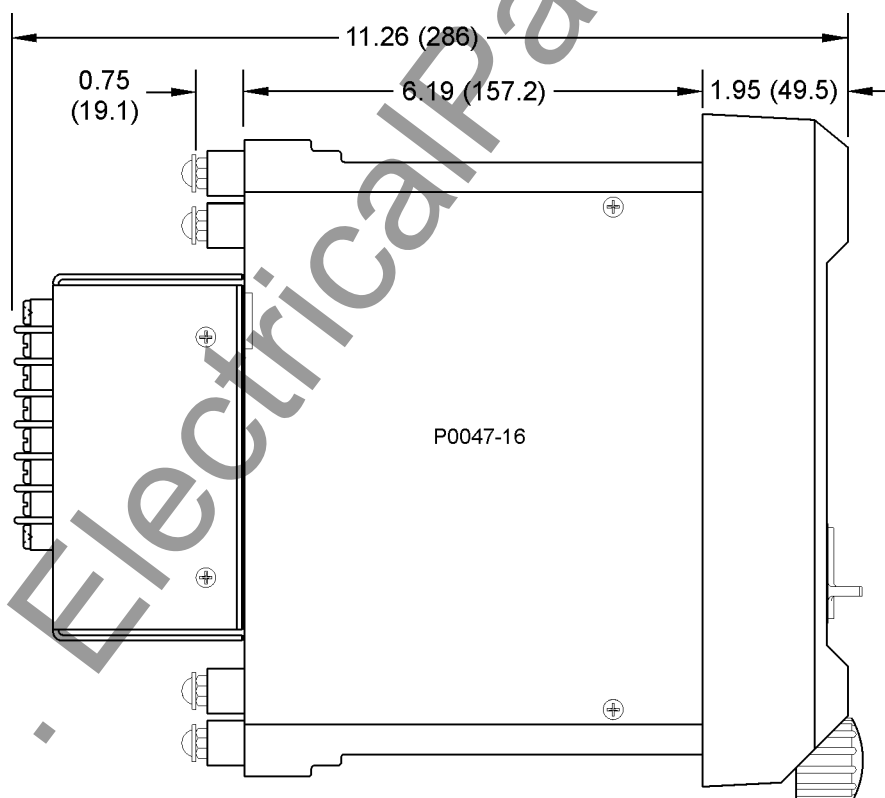11.26 (286)
0.75 (19.1)
6.19 (157.2)
1.95 (49.5)

P0047-16

*Figure 4-12. Outline Dimensions, Side View,
Semi-Flush Mounted Case with Attached Stabilizing Reactor*

CONNECTIONS

Verify the relay model and style number before connecting and energizing the relay. Incorrect wiring may result in damage to the relay. Except where otherwise noted, connections should be made with minimum wire size of 14 AWG.

Internal Connections

Internal connections/terminal assignments for a single-phase relay are illustrated in Figure 4-13. Internal connections/terminal assignments for a three-phase relay are illustrated in Figure 4-14. These figures may show options that may not apply to your relay.

Control Connections

Typical dc control connections are shown in Figure 4-15.

Sensing Connections

Typical sensing current connections for a single-phase application are shown in Figure 4-16.

Three-phase sensing current connections are illustrated in Figures 4-17 and 4-18. Figure 4-17 shows the sensing inputs connected in a wye configuration. Figure 4-18 shows the sensing inputs connected in a delta configuration.
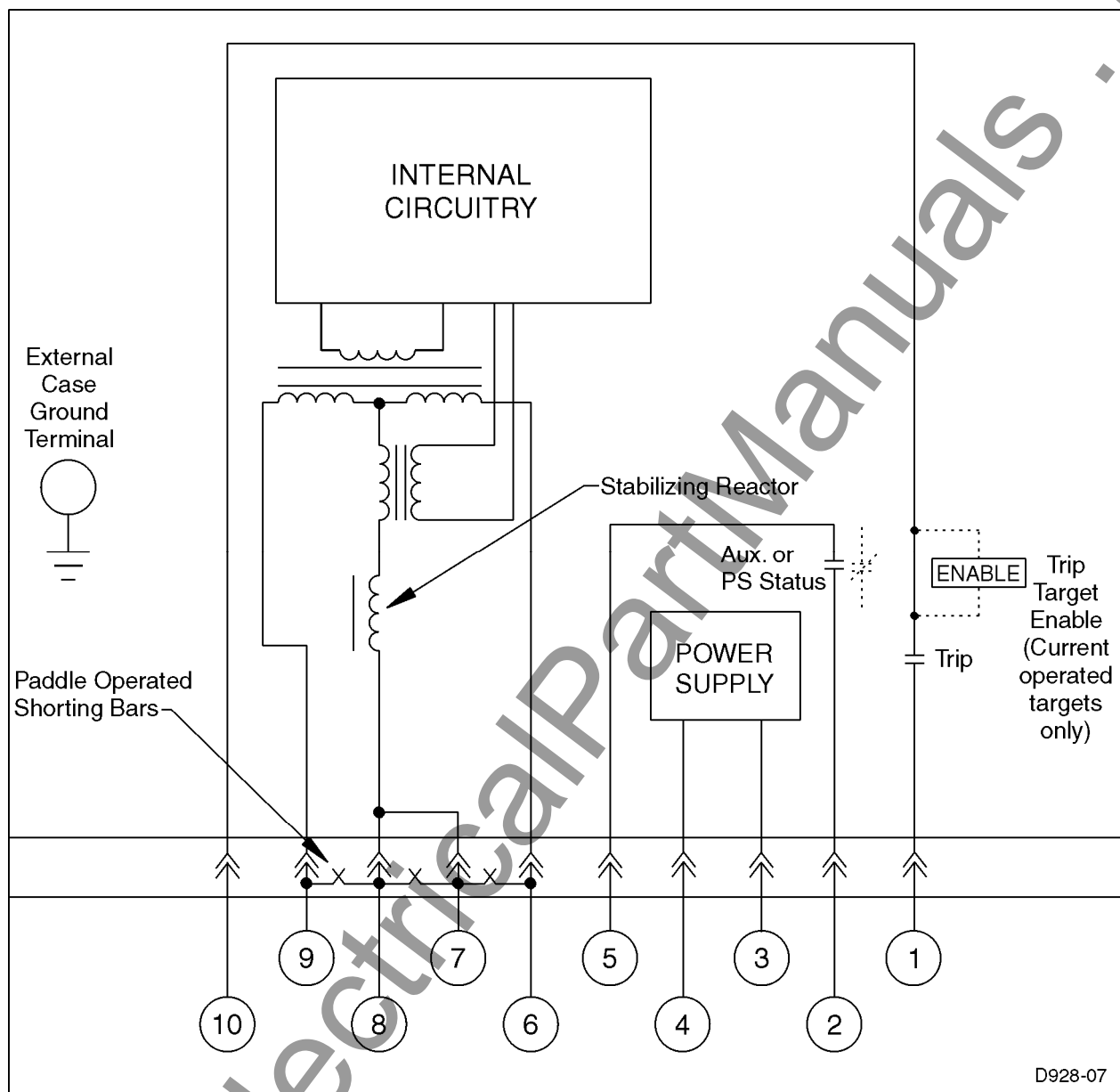
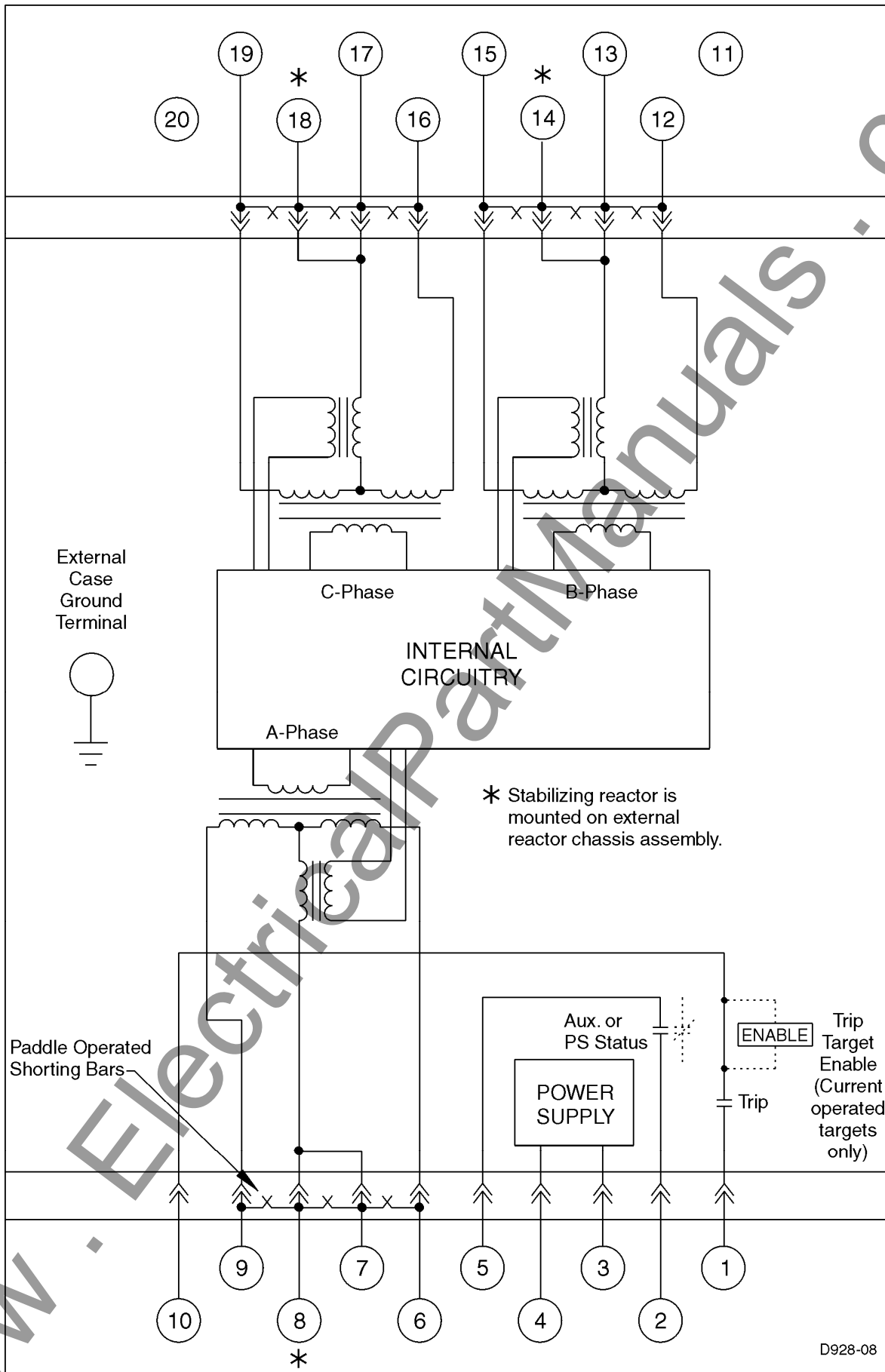*Figure 4-13. Internal Connections/Terminal Assignments, Single-Phase Relay*

Figure 4-14. Internal Connections/Terminal Assignments, Three-Phase Relay
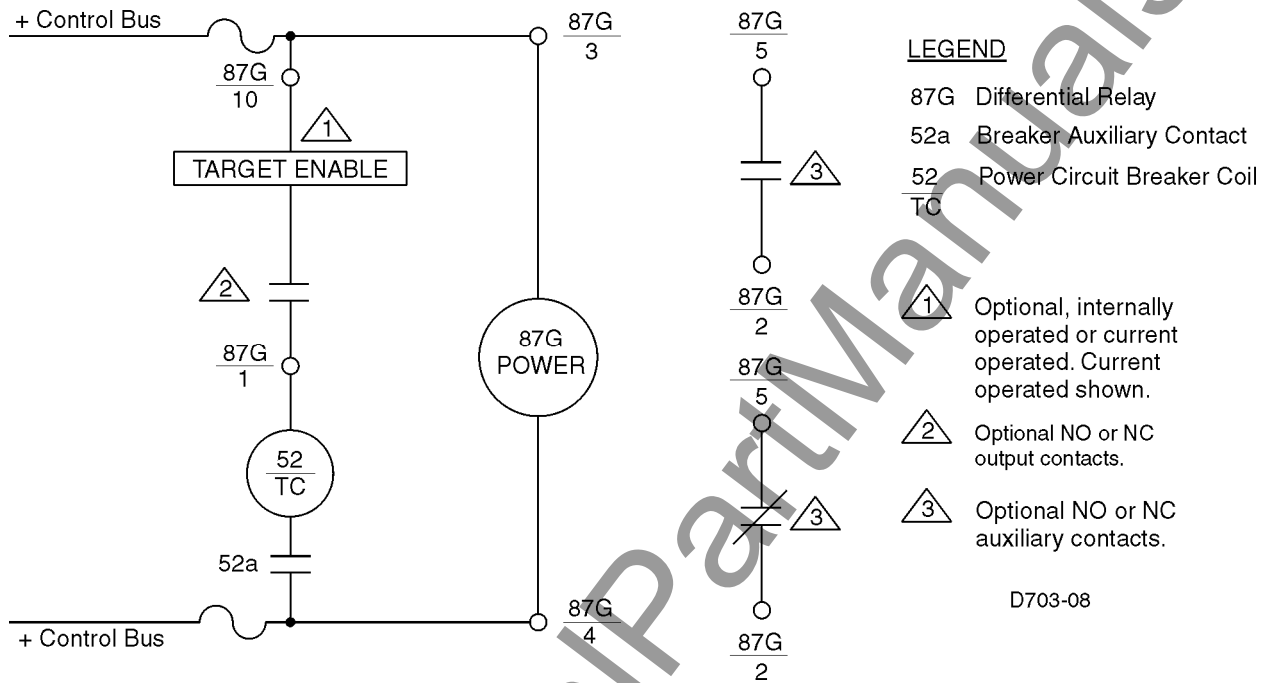
Figure 4-15. Typical DC Control Connections

LEGEND

87G   Differential Relay

52a   Breaker Auxiliary Contact

52 TC   Power Circuit Breaker Coil

△1   Optional, internally operated or current operated. Current operated shown.

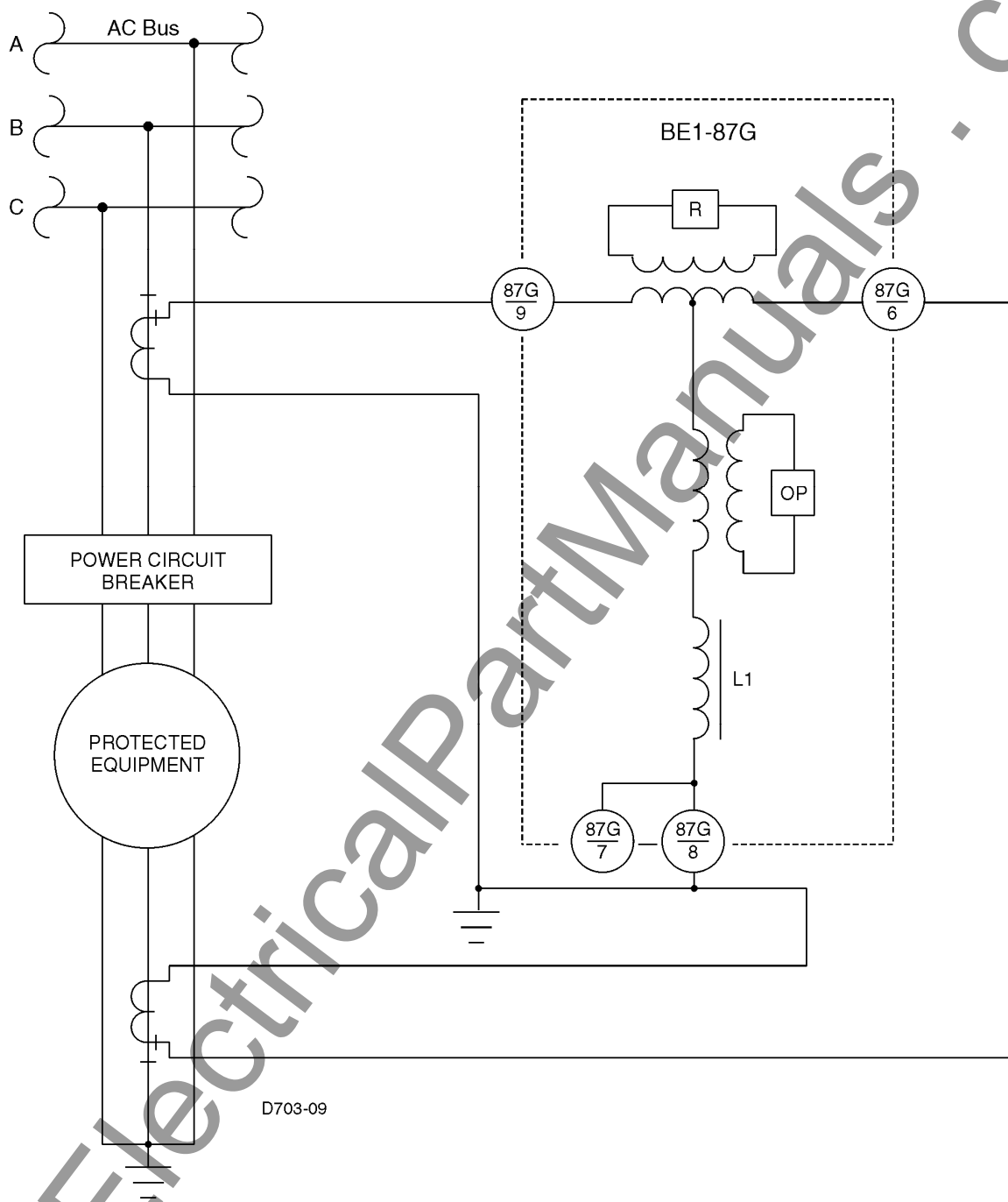△2   Optional NO or NC output contacts.

△3   Optional NO or NC auxiliary contacts.

D703-08

Figure 4-16. Single-Phase Sensing Connections

Figure 4-17. Three-Phase Sensing Connections, Wye Connected Generator

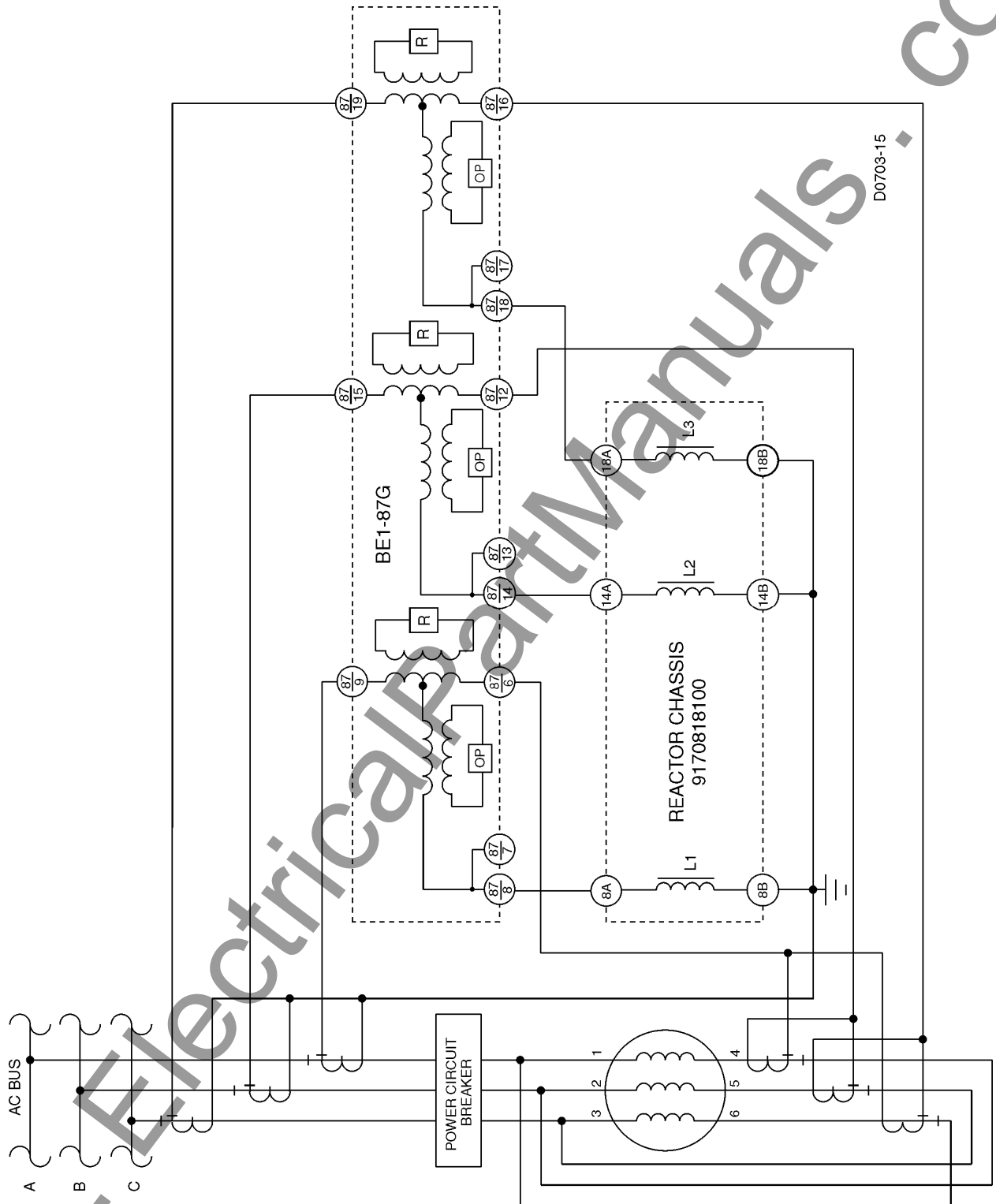*Figure 4-18. Three-Phase Sensing Connections, Delta Connected Generator*

MAINTENANCE

BE1-87G relays require no preventive maintenance other than the periodic inspection of the relay case and stabilizing reactor terminal connections to ensure that they are clean and tight.

Repair

If repairs are needed, contact the Technical Sales Support department at Basler Electric for assistance.

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 the capacitor is cut in half for every 10°C (50°F) 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.

SECTION 5 • TESTING AND SETTING

INTRODUCTION

Proper relay operation can be confirmed by performing the test procedures in this section. This section also contains recommendations for selecting an appropriate sensitivity switch (operating current) setting.

Relay Operating Precautions

Before operating the relay, note the following precautions:

CAUTION

To avoid false tripping on three-phase relays, the upper connection plug must be in place prior to inserting or removing the lower connection plug.

- A minimum of 200 mA in the output circuit is required to ensure operation of current operated targets (relays with style number xxx-xxB-xxxxx)
- If a wiring insulation test is required, remove the connection plugs and withdraw the cradle from its case
- When the connection plugs are removed, the relay is disconnected from the operating circuit and will not provide system protection. Before removing a relay from service, be sure that external operating (monitored) conditions are stable.
- The relay case must be hard-wired to earth ground with no smaller than 12 AWG copper wire. A separate ground lead is recommended for each device.

OPERATIONAL TEST PROCEDURE

The procedures that follow verify proper operation of the BE1-87G relay

---

CAUTION

During testing, do not apply a continuous operate current greater than 3 Aac. Sustained operate current higher than 3 Aac will increase the temperature in the stabilizing reactor and cause insulation breakdown.

NOTE

Because of the reactance of the stabilizing reactors, the burden may be too high for large values of operate current with solid-state test sets.

The internal stabilizing reactor in relays with single-phase sensing (style number Sxx-xxx-xxxxx) may be bypassed by placing a jumper across the terminals illustrated in Figure 5-1. The jumper used should be capable of carrying 5 Aac of current.

To bypass the external stabilizing reactor used on relays with three-phase sensing(style number Gxx-xxx-xxxxx), the current source may be connected directly to the relay case terminals

---

Restraint current applied to any one relay input must not exceed either of the following conditions:

- 10 amperes continuous or 250 amperes for 1 second (relay style number x1x-xxx-xxxxx)
- 2 amperes continuous or 50 amperes for 1 second (relay style number x2x-xxx-xxxxx)

Whenever this current level is exceeded, provisions must be made to cut off the sensing current as the relay trips.
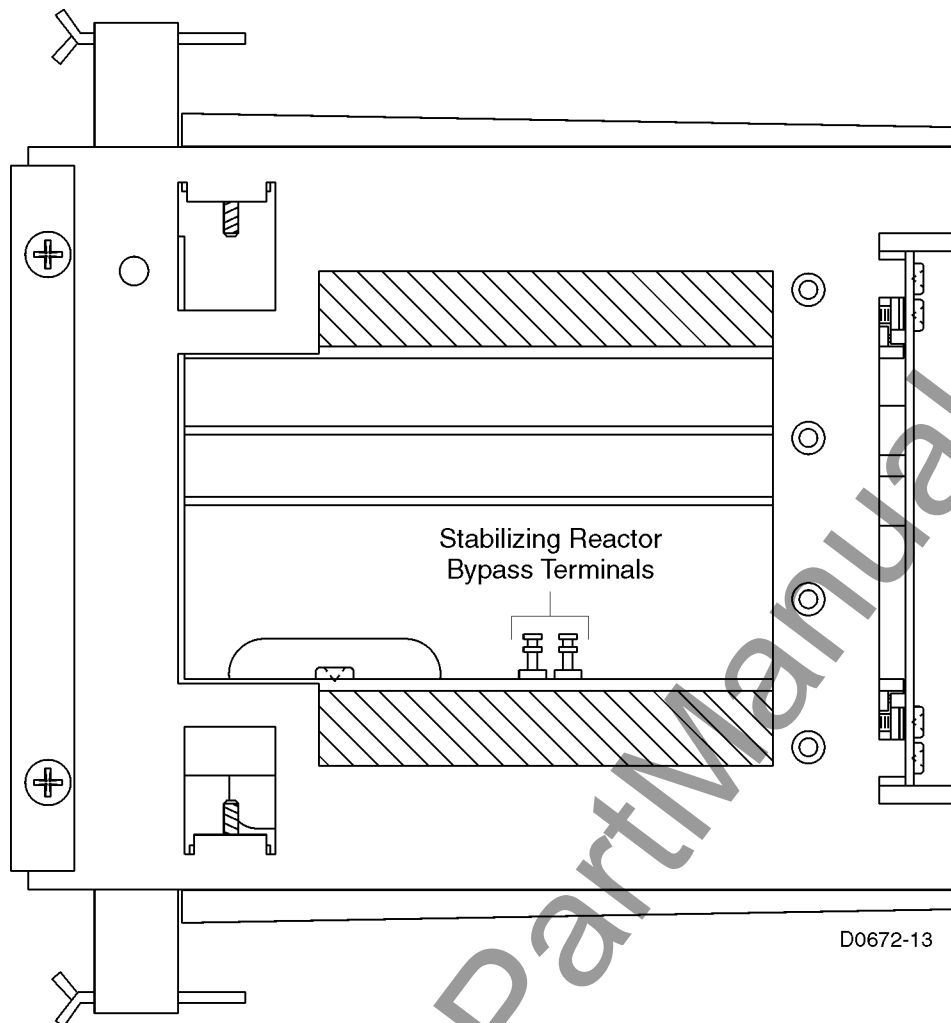
Figure 5-1. Location of Stabilizing Reactor Bypass Terminals (Single-Phase Relays)

Equipment Required

Because of the speed and sensitivity of the BE1-87G, test equipment with appropriate accuracy and stability must be used to test the sensitivity switch settings. For example, at the most sensitive switch setting (0.1 ampere), the relay monitors a current difference that is only 1% for a sensing input of 10 amperes.

- Two adjustable current sources (Doble, AVO, or equivalent equipment)
- Digital voltmeter (±1% accuracy or better)
- Digital ammeter (±1% accuracy or better)
- Variable, 0 to 250 Vac/Vdc power supply (for relay operating power)
- DC power supply (for current operated targets)

Single-Phase/A-Phase Trip and Dropout Test

Perform the following steps to test the trip and dropout accuracy of relays with single-phase sensing (style number Sxx-xxx-xxxxx) or phase A of relays with three-phase sensing (style number Gxx-xxx-xxxxx).

1. Connect the test setup shown in Figure 5-2. Current sensing connections should be made at terminals 6, 7, 8, and 9.

2. Set the sensitivity switch at position A.

3. Apply the appropriate voltage to relay operating power terminals 3 and 4. (A power supply model/input voltage cross-reference is provided in Table 1-1.)

4. Using a regulated, independently adjustable current source, apply the restraint current to relay terminals 6 and 9. A current value of 0.1 Aac is applied for relays with style number x1x-xxx-xxxxx and a current value of 0.02 Aac is applied for relays with style number x2x-xxx-xxxxx.

5. Slowly increase the operate current applied to terminals 6 and 8 until the relay trips. A relay with a style number of x1x-xxx-xxxxx should trip at 0.1 Aac and a relay with a style number of x2x-xxx-xxxxx should trip at 0.02 Aac. Tolerance is ±5% or 25 mA, whichever is greater.

> **NOTE**
>
> Depending upon the relay style number, the relay may be equipped with normally-open or normally-closed trip contacts. Check continuity at terminals 1 and 10 with the relay tripped and not tripped to verify correct response for the type of contacts specified.

6. Slowly decrease the operate current source until dropout occurs. Dropout should occur at a current value that is greater than or equal to 90% of I_S (the sensitivity switch setting value).

7. Repeat steps 2 through 6 for the other sensitivity switch settings. If desired, a sufficient number of trip points may be taken to verify any or all of the performance curves shown in Figure 5-3.

    For restraint current (I_R) less than or equal to nominal ($I_R \leq 5$ amperes for style number x1x-xxx-xxxxx or $I_R \leq 1$ ampere for style number x2x-xxx-xxxxx), the tolerance is $\pm 0.05 \cdot I_{OP}$ or 25 mA, whichever is greater.

    For I_R > nominal (up to a maximum of 20 amperes for style number x1x-xxx-xxxxx or 4 amperes for style number x2x-xxx-xxxxx), the tolerance is $\pm 0.08 \cdot I_{OP}$ on the characteristic curve or 150 mA, whichever is greater.

    See Figures 5-3 through 5-6 for the operating characteristic curves and trip response timing curve.
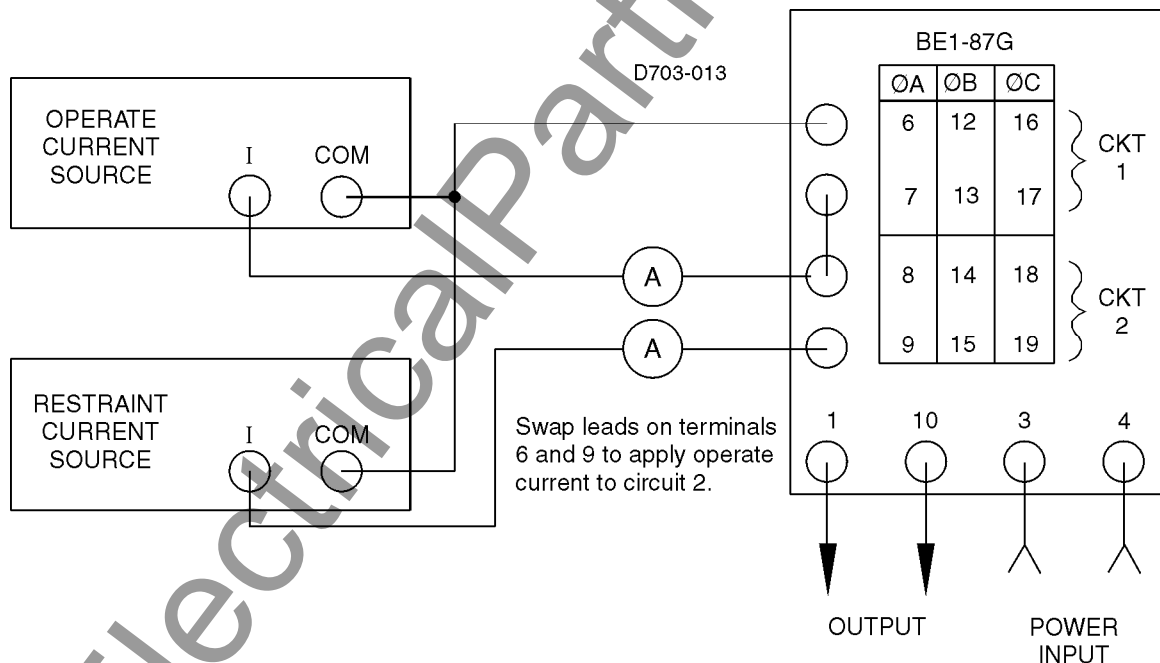

Figure 5-2. Operational Test Setup

B-Phase and C-Phase Trip and Dropout Test

Perform the following steps to test the trip and dropout accuracy of phases B and C of relays with three-phase sensing (style number Gxx-xxx-xxxxx).

Perform steps 1 through 7 under *Single-Phase/A-Phase Trip and Dropout Test* for phases B and C.
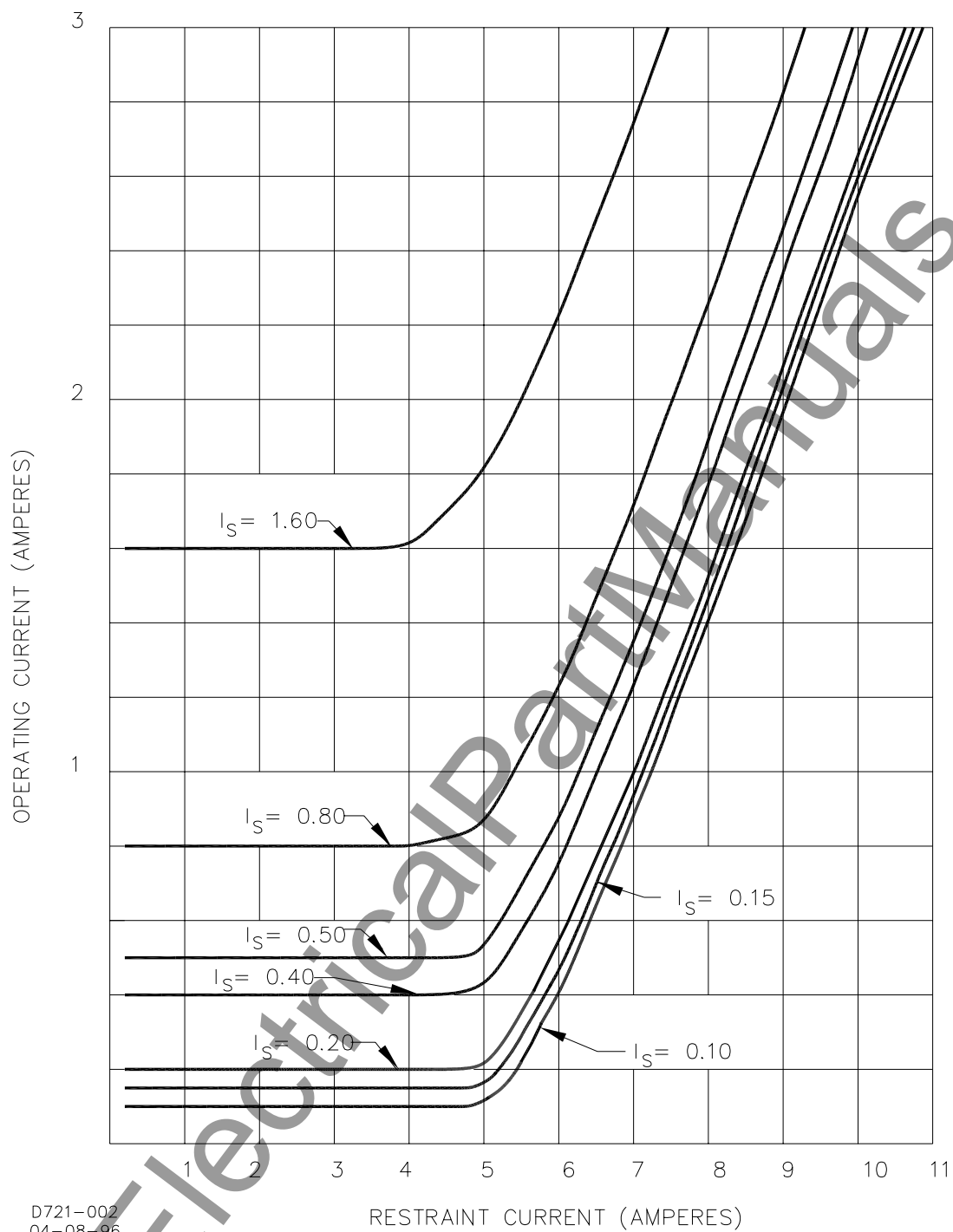
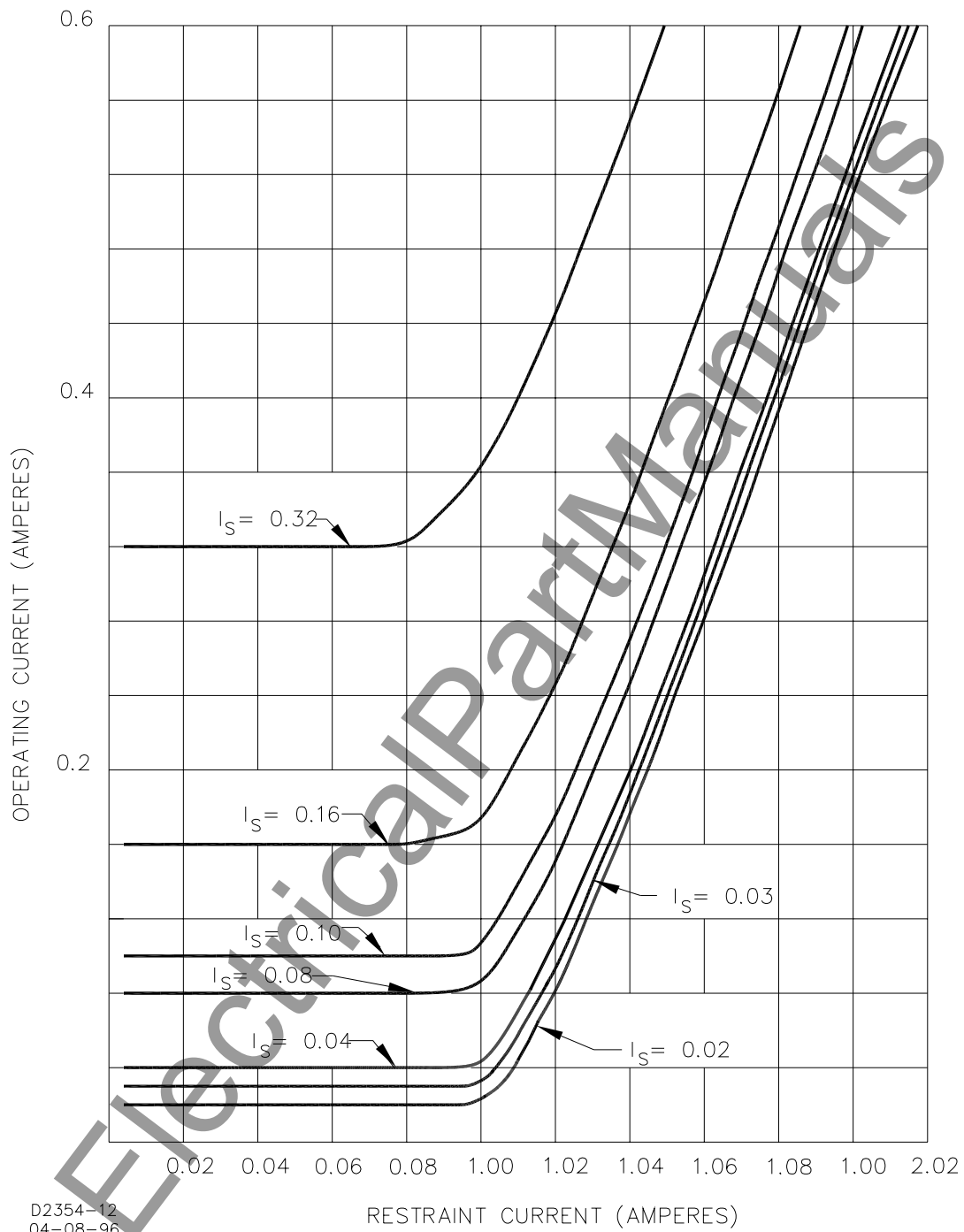Figure 5-3. Operating Characteristics, Relay Style x1x-xxx-xxxxx

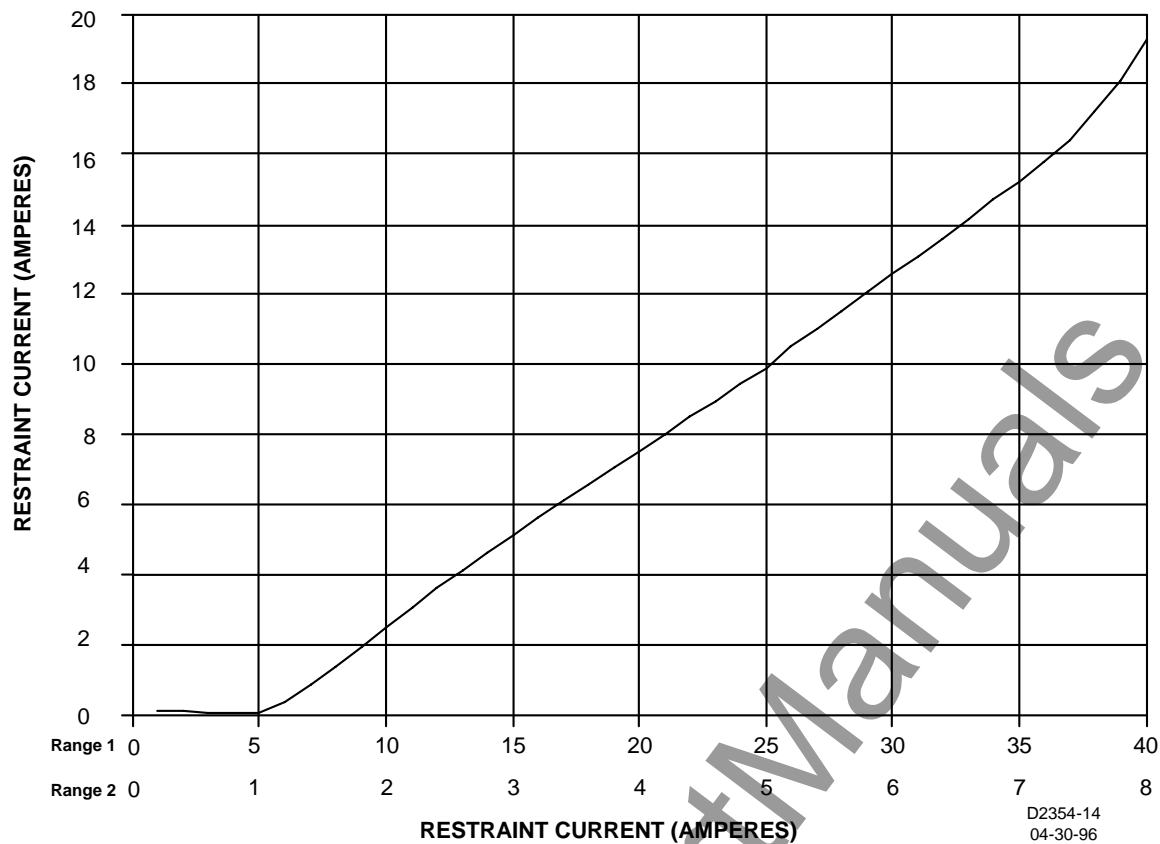*Figure 5-4. Operating Characteristics, Relay Style x2x-xxx-xxxxx*

Figure 5-5. Extended Restraint Operating Characteristic
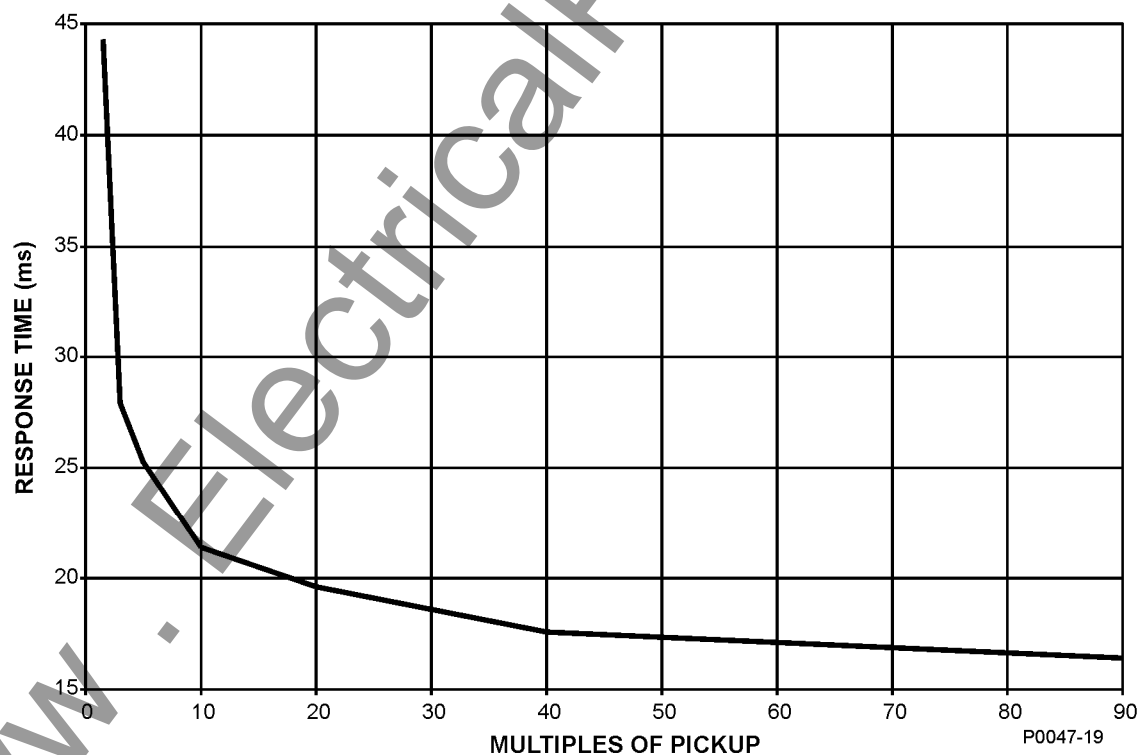

Figure 5-6. Pickup Response Timing

Target Indicator Test

If the relay is equipped with target indicators, verify proper operation of each phase when the relay is tripped. Verify that the targets reset when the target reset switch is operated during a non-tripped condition.

> **NOTE**
>
> Relays with a style number of xxx-xxB-xxxxx have current operated targets. These targets will operate only when a minimum of 200 mA is flowing in the trip output circuit (terminals 1 and 10).

Auxiliary Output Test

Check output contact operation at terminals 2 and 5 of relays equipped with auxiliary output contacts.

Relays with style number xxx-xxx-xxx1x have normally-open auxiliary contacts. These contacts close when the relay trips.

Relays with style number xxx-xxx-xxx2x have normally-closed auxiliary contacts. These contacts open when the relay trips.

Power Supply Status Output Test

Relays with a style number of xxx-xxx-xxx6x are equipped with a set of power supply status output contacts.

1. Apply operating power to the relay and verify that the power supply status output contacts (terminals 2 and 5) are energized open.
2. Remove relay operating power and confirm that contact closure occurs across terminals 2 and 5.

Push-to-Energize Output Test

If an output test switch is present (relay style number xxx-xxx-xxCxx) verify operation by depressing the switch and observing that the trip output (terminals 1 and 10) and the auxiliary output (terminals 2 and 5) cycle.

SETTING THE RELAY

The following recommendations are provided for selecting the current sensitivity switch setting. Figures 5-3 and 5-4 show how this setting corresponds to the operating current pickup over the restraint current range.

Assuming that the CTs on both sides of the zone (generator, motor, or reactor) perform identically, operating current will be equal to zero. The sensitivity setting serves to accommodate dissimilar CT performance, resulting from differences in CT quality, burden, and core remanence.

During normal operation, the pickup on the flat part of the operating characteristic (see Figures 5-3 and 5-4) must exceed the difference in steady-state CT errors. The relay must also override the error differences in the presence of dc components developed by external faults or switching. Currents will be offset during external faults on generator applications, during motor starting, and during switching of shunt reactors.

Out-of-phase synchronizing of machines will also produce offset components. These so-called dc components will produce significant CT saturation. For high current faults, the relay relies on the 50% slope characteristic to override large operating currents. Significant operating current can also be developed at restraint levels that fall on the flat part of the characteristic if the offset component persists. The sensitivity setting needs to be above this operating current.

Terms for Calculations

I''_d Sub-transient current
N Total number of CT turns
N_a Number of CT turns in use (for multi-ratio type)
R_l One-way lead resistance in ohms
R_r Relay restraint circuit resistance in ohms
R_w CT winding resistance in ohms

Rt Total CT burden $= R_i + R_r + R_w$ (for phase faults and switching)
$= 2R_i + 2R_r + R_w$ (for external ground faults)

SFR Saturation factor ratio $= [(Vce)_1 \div (Vce)_2] \times [(Rt)_2 \div (t)_1]$ (if SFR is <1, use 1/SFR)

Vc CT accuracy class voltage rating

Vce Effective CT accuracy class voltage rating $= Vc(N_a \div N)$

$X"_d$ Sub-transient reactance

CT Quality

CTs should have an accuracy class of either C20 or better or T20 or better.

Burden Limit

The CTs should be operating below the knee point under symmetrical current conditions, that is, no ac saturation. For a generator, ac saturation should not occur for the maximum external fault current. For a motor, ac saturation should not occur during starting. For a shunt reactor, high current fundamental-frequency currents will not flow unless the reactor becomes faulted.

Assuming a maximum current of 20 times the CT rating: $R_t < 0.007Vce$, where $V_{knee} = 70\%$ of Vce and 20 $\times$ 5 A nominal rating = 100 A so that:

$$R_t = V_{knee} \div Imax = 0.7Vce \div 100\ A = 0.007Vce$$

Relative CT Performance

Table 5-1 lists the recommended minimum pickup settings to provide security during external faults and switching.

Table 5-1. Recommended Pickup Settings

Vce (Lower Value)	SFR				
	1	**1.5**	**2**	**3**	**4**
20	0.2	0.4	0.5	0.8	1.6
50	0.2	0.4	0.4	0.5	0.8
100	0.2	0.2	0.4	0.4	0.5
200	0.1	0.1	0.2	0.4	0.5
>200	0.1	0.1	0.2	0.4	0.5

Note: Use next higher setting if CTs are a mix of C classification and T classification.

The saturation factor ratio, SFR, represents an index of the relative performance of the two sets of CTs. This performance is a function of the relative quality of the CTs (Vce), the relative burdens (R_t), and neglecting the remanence. If SFR is less than 1, use 1/SFR for SFR.

Setting Example 1

Select the pickup setting for the motor application in Figure 5-7. In this application, the settings need to be based on the probability of significant dissimilar CT saturation due to the very slow decaying dc component of the starting current. Since the motor is not grounded, no ground current can flow during starting of an unfaulted motor. Therefore, one-way lead burden is used to determine the total CT burden. Each phase CT carries just the burden for the lead of that phase.

$(R_t)_1 = R_l + R_w = 0.22 + 0.14 = 0.36$; $(Vce)_1 = 50$; $R_t < 0.007(Vce)_1 = 0.35$

$(R_t)_2 = 0.09 + 0.10 = 0.19$; $(Vce)_2 = 100$; $R_t < 0.007(Vce)_2 = 0.7$

Inequality (1) is met with CT #2, but not with CT #1. However, since the locked rotor current is only 4.8 times the CT rating (versus the assumption of 20 times rated for inequality (1)), the application is suitable.

$SFR = (100 \div 50) \times (0.36 \div 0.19) = 3.8$

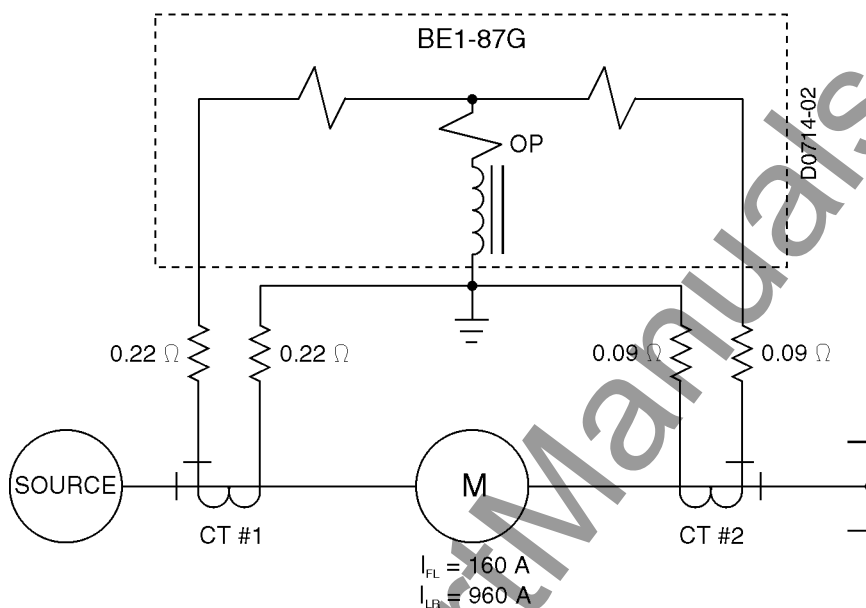| Parameter	CT #1	CT #2
Accuracy Class	T50	C100
Ratio	200/5	200/5
Winding Resistance	0.14	0.10

Figure 5-7. Motor Differential Application

Using the SFR 4 column of Table 5-1, a 0.8 ampere setting is indicated. However, based on the note accompanying this table, choose the next higher setting of 1.6, because CT #1 has a T classification and CT #2 has a C classification. The T classification indicates that the CT has significant secondary leakage inductance which somewhat degrades the transient performance. This is a concern during motor starting because a slowly decaying offset component develops in at least one phase.

Setting Example 2

Select the pickup setting for the generator application in Figure 5-8. In this application, the settings need to be based on the probability of significant dissimilar CT saturation during an external fault. Since the generator is resistance grounded, the three-phase fault current will be much larger than the ground fault level. Moreover, the resistor will rapidly dampen any offset-current component. Accordingly, determine the sub-transient current (I''_d).

$$I''_d = \frac{1000 \div (4.16 \times \sqrt{3})}{0.15 \times 200} = \frac{138.8}{30} = 4.6 \times CT\ rating$$

Since a three-phase fault is involved, one-way lead burden is used to determine the total CT burden. Each phase CT carries just the burden for the lead of that phase.

$(R_t)_1 = R_l + R_w = 0.22 + 0.14 = 0.36$; $(Vce)_1 = 50$; $R_t < 0.007(Vce)_1 = 0.35$

$(R_t)_2 = 0.09 + 0.10 = 0.19$; $(Vce)_2 = 100$; $R_t < 0.007(Vce)_2 = 0.7$

Inequality (1) is met with CT #2 but not with CT #1. However, since the maximum external fault current is only 4.6 time the CT rating (versus the assumption of 20 times rated for inequality (1)), the application is suitable.

SFR = $(1000 \div 50) \times (0.36 \div 0.19) = 3.8$

Using the SFR 4 column of Table 5-1, a 0.8 ampere setting is indicated. However, based on the note accompanying Table 5-1, choose the next higher setting of 1.6 because CT #1 has a T classification and CT #2 has a C classification. The T classification indicates that the CT has significant secondary leakage inductance which somewhat degrades the transient performance. This is a concern during motor starting because a slowly decaying offset component develops in at least one phase.

Parameter	CT #1	CT #2
Accuracy Class	T50	C100
Ratio	200/5	200/5
Winding Resistance	0.14	0.10
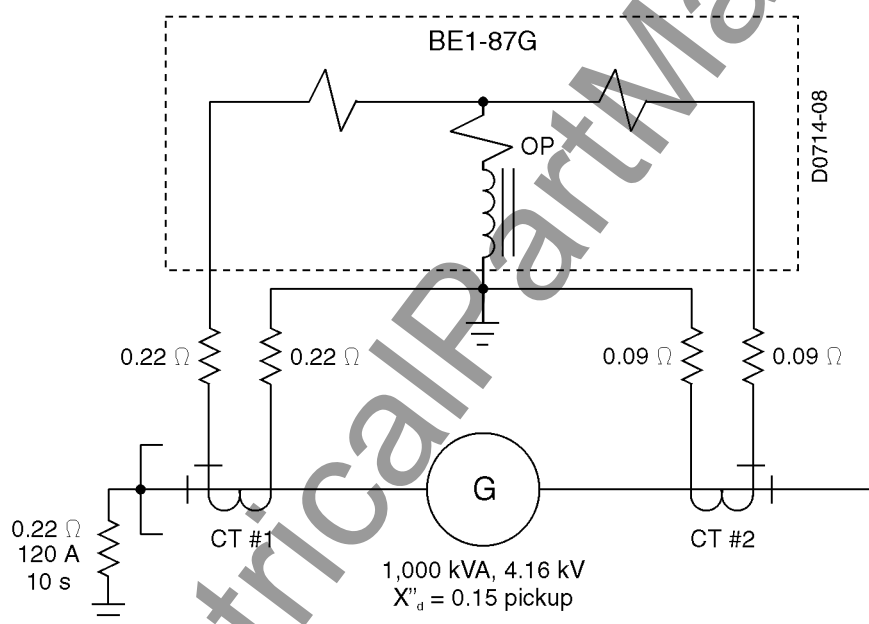
Figure 5-8. Generator Differential Application

B. Basler Electric

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PHONE +1 618-654-2341   FAX +1 618-654-2351