INSTRUCTION MANUAL

FOR

NEGATIVE SEQUENCE OVERCURRENT RELAY

BE1-46N
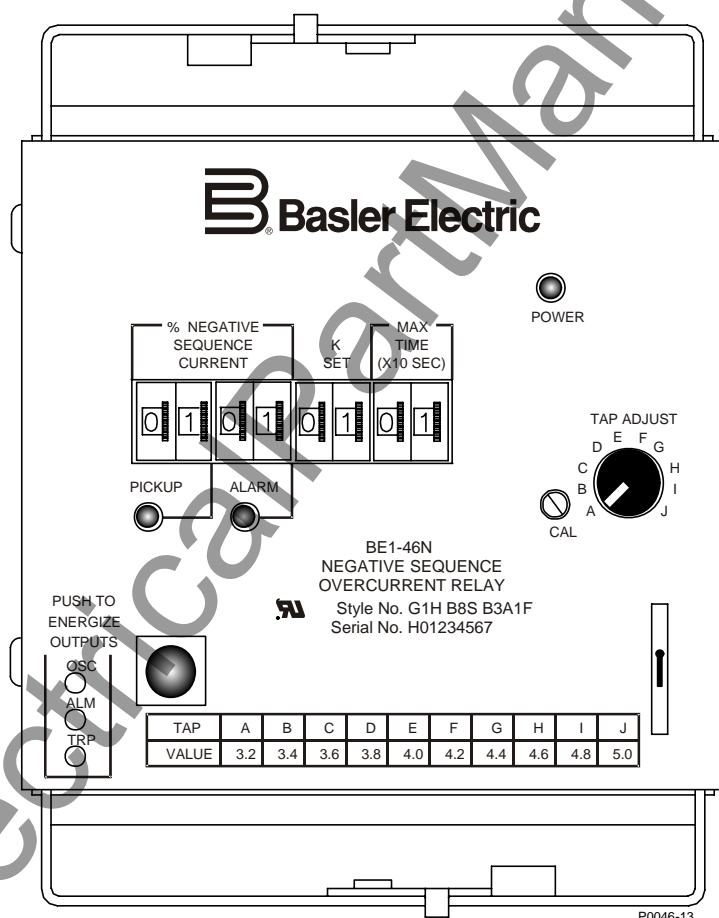
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B Basler Electric

INTRODUCTION

This instruction manual provides information about the operation and installation of the BE1-46N Negative Sequence Overcurrent relay. To accomplish this, the following information is provided:

- General Information and Specifications

- Controls and Indicators

- Functional Description

- Installation

- Testing

WARNING!

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

NOTE

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

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 BE1-46N instruction manual (9170000990). Revisions are listed in reverse chronological order.

Manual Revision and Date	Change
G, 09/07	• Updated *Output Contacts* ratings in Section 1. • Moved content of Section 6, *Maintenance* to Section 4. • Updated front panel illustrations to show laser graphics. • Moved content of Section 7, *Manual Change Information* to manual introduction. • Added manual part number and revision to all footers. • Updated cover drawings. • Updated power supply burden data in Section 1. • Updated Target Indicator description in Section 3.
F, 02/01	• Updated the drawings in Section 4 to reflect the latest S1 Case drawings.
E, 11/95	• Deleted all references to Service Manual. • Corrected Figure 1-1, *Style Chart,* Power Supply Type T from 230 Vac to 240 Vac, and Type S, removed "Switchable". • Deleted IEC 255-5 from Isolation Specification and Section 4 under Dielectric Test. • Added UL Recognition to *Specifications.* • Added 1 amp CT values to Section 3 for setting considerations. • Changed Section 3 to include power supply status output. Changed Figures 3-1, 4-9, and 4-11 to reflect this change. • Added "Max Time" to Section 3. • Timing in Section 5, changed Step 5 from "MAX TIME" to "time required for". • Changed the format of the manual and corrected minor errors.
D, 08/95	• Changed all sections to include one ampere sensing input range as standard styles. • Changed Section 1, *Specifications,* and Section 3 to reflect the changes in the relay. • Changed Figures 4-9 and 4-11 to remove power supply status references. • Updated Figures 1-1 and 3-2 to reflect changes made in the relay.
C, 02/95	• Changed Section 1, *Specifications,* and Section 4, *Installation* to reflect ECA changes in the relay. • Corrected typographical errors in Section 3. • Divided Section 4, *Installation* into two sections Section 4, *Installation* and Section 5, *Testing.*
B, 09/91	• Changed Instruction Manual format and presentation to increase readability and correct minor errors.
A, 04/85	• Changed case terminal polarity for the remote indicator.
—, 05/85	• Initial release

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CONTENTS

SECTION 1 • GENERAL INFORMATION

DESCRIPTION

BE1-46N Negative Sequence Overcurrent Relays are three-phase solid state relays designed to provide protection for generators and motors from unbalanced loading or power system faults. These relays protect the machinery from damage when the protective scheme or other equipment, external to the generator, fails to eliminate the unbalanced condition.

BE1-46N Negative Sequence Overcurrent Relays accurately monitor the magnitude and control the duration of the negative sequence current component. These relays incorporate a time delay that replicates the machinery heating and cooling characteristics. An alarm element in the relays may be used to provide time to locate and isolate the fault. Doing this avoids damage to the machinery, prevents an undesired trip, and precludes a potentially prolonged outage of the machinery.

BE1-46N relays are designed for use with any poly-phase generating system having known $(I_2)^2 t$ limits between 1 and 99. Relays that operate using phase currents to determine the negative sequence component are phase rotation sensitive. BE1-46N relays are phase rotation sensitive.

PRINCIPLES OF SYMMETRICAL COMPONENTS

Principles of symmetrical components allow an unbalanced system to be considered as three separate, balanced subsystems. These balanced subsystems may then be analyzed as single phase quantities. These quantities are the positive, negative, and zero sequence components of current and voltage.

The positive sequence component of current (I_1) represents the portion of the total current which has normal phase rotation and produces no adverse effect on the system. An ideally balanced system contains only positive sequence phase currents and voltages.

The zero sequence component of current (I_0) also has no adverse effect on a three-phase, three-wire (no neutral connection) power system because it produces no appreciable magnetic flux and causes no excessive heating in the generator rotor or windings.

The negative sequence component of current (I_2) produces a magnetic flux in the stator that has the same rotational speed as the rotor flux, but in the opposite direction. This causes the stator magnetic flux to rotate at twice the system frequency and induce eddy currents into the rotor. These eddy currents create excessive heat in the rotor iron and windings, and, if allowed to persist, could result in severe damage to the system.

MODEL AND STYLE NUMBER

Electrical characteristics and operational features included in a specific relay are defined by a combination of letters and numbers that make up the style number. Model number BE1-46N designates the relay as a Basler Electric Negative Sequence Overcurrent Relay. The model number, together with the style number, describes the options included in a specific device and appears on the front panel, draw-out cradle, and inside the case assembly.

The style number identification chart for the BE1-46N relay is illustrated in Figure 1-2.

STYLE NUMBER IDENTIFICATION CHART
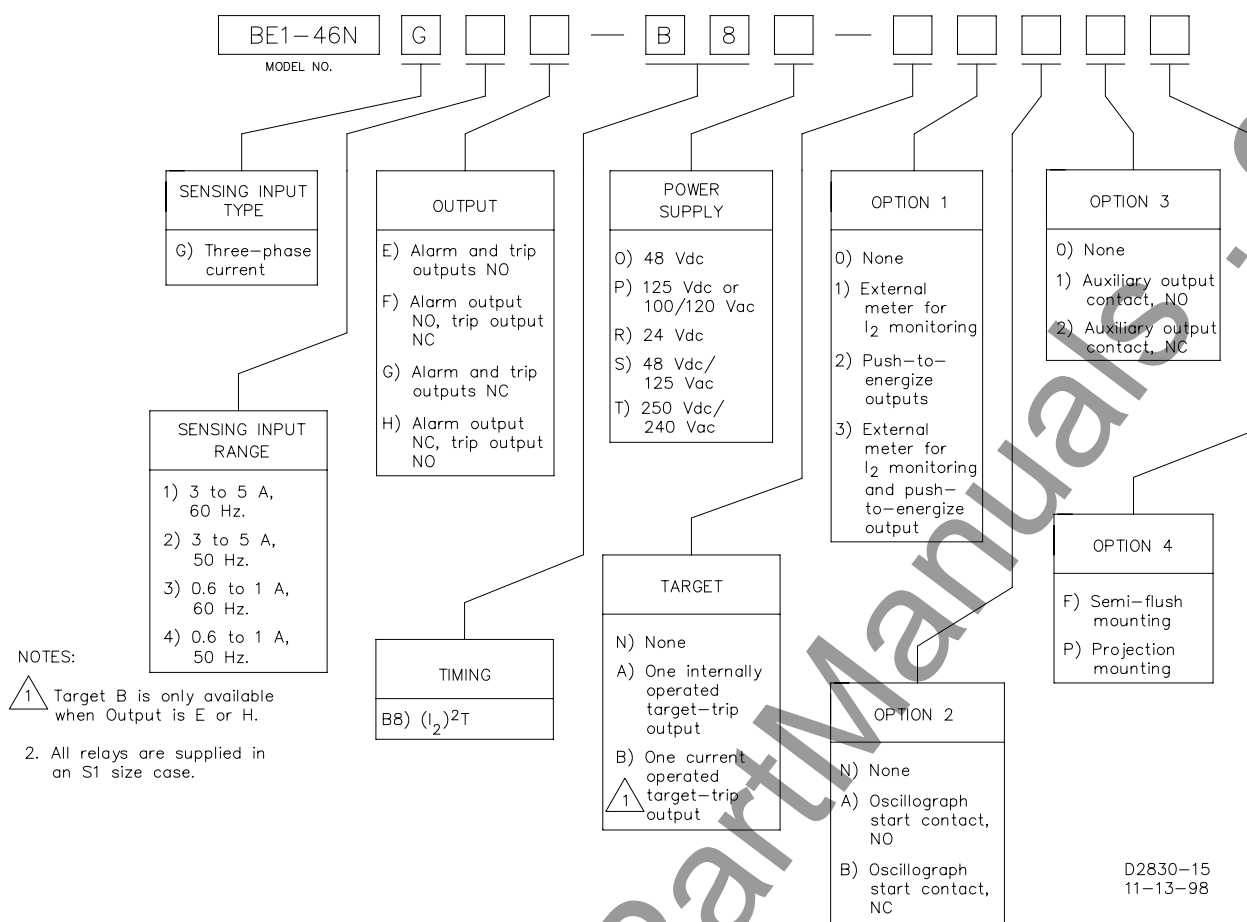
Figure 1-1. Style Number Identification Chart

Style Number Example

If a BE1-46N relay has a style number of **G1H–B8S–B1B1F**, the relay has the following features:

G ------- Three-phase negative sequence current sensing

1 -------- Sensing input range of 3.0 to 5.0 A nominal at 60 hertz

H ------- Alarm output relay contacts NC and trip output relay contacts NO

B8 ------ $(I_2)^2t$ timing characteristics

S ------- Field selectable 48 or 125 Vdc power supply

B ------- One current operated target for the trip circuit

1 -------- A remote meter for monitoring I_2 levels is supplied

B ------- An oscillographic start function with NC contacts

1 -------- An auxiliary output relay with NO contacts

F -------- Semi-flush mounting case

SPECIFICATIONS

Electrical and physical specifications are listed in the following paragraphs.

Current Sensing

5 Ampere CT: 5 amperes nominal (50/60 hertz) current transformers; 10 amperes continuous current, 250 amperes one second current, 2 VA burden maximum per phase, frequency range 45 to 55 hertz for 50 hertz systems and 55 to 65 hertz for 60 hertz systems.

1 Ampere CT: 1 ampere nominal (60 hertz) current transformers; 2 ampere continuous current, 50 ampere one second current, 2 VA burden maximum per phase, frequency range 60 $\pm$5 hertz.

Tap Adjust Selection Range

5 Ampere CT: Continuously adjustable over the range of 3.0 amperes to 5.0 amperes. This adjustment establishes the full load reference level (I_N) for the application.

1 Ampere CT: Continuously adjustable over the range of 0.6 to 1.0 A. This adjustment establishes the full load reference level (I_N) for the application.

Pickup

Range: Adjustable over the range of 1 to 50% in increments of 1%.

Accuracy: $\pm$5% of I_2.

Dropout: Better than 98% of pickup.

Alarm

Range: Adjustable over the range of 1 to 50% in increments of 1%.

Accuracy: $\pm$5% of I_2.

Dropout: Better than 98% of ALARM pickup level.

Time Delay: Factory set at 3.0 seconds.

K SET

Timing Accuracy: $\pm$5% of the selected curve.

Minimum Trip Timer Accuracy

200 $\pm$25 milliseconds

MAX TIME (X 10 SEC)

Selection Range: Adjustable over the range of 10 to 990 seconds in increments of 10 seconds.

Accuracy: $\pm$5% of the setting.

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)

Power Supply

Power supply types and specifications are listed in Table 1-1.

Table 1-1. Power Supply Ratings

Type	Nominal Input Voltage	Input Voltage Range	Burden at Nominal
O (midrange)	48 Vdc	24 to 150 Vdc	2.9 W
P (midrange)	125 Vdc	24 to 150 Vdc	3.3 W
	120 Vac	90 to 132 Vac	13.8 VA
R (low range)	24 Vdc	12 to 32 Vdc ∗	3.0 W
S (midrange)	48 Vdc	24 to 150 Vdc	2.9 W
	125 Vdc	24 to 150 Vdc	3.1 W
T (high range)	250 Vdc	68 to 280 Vdc	3.2 W
	240 Vac	90 to 270 Vac	20.6 VA

∗ Type R power supply initially requires 14 Vdc to begin operating. Once operating, the input voltage may be reduced to 12 Vdc and operation will continue.

Target Indicator

An electronically latched, manually reset target indicator is optionally available to indicate closure of the trip output contact. Either an internally operated or a current operated target may be specified. An internally operated target should be selected when a normally closed (NC) output contact is specified.

Current Operated Targets

Minimum Rating:	200 mA flowing through the trip circuit
Continuous Rating:	3 A
1 Second Rating:	30 A
2 Minute Rating:	7 A

Type Tests

Shock:	Withstands 15 G in each of three mutually perpendicular planes without structural damage or performance degradation.
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, without structural damage or degradation of performance.
Isolation:	Tested in accordance with ANSI/IEEE C37.90-1989 one minute dielectric (high potential) test as follows:
	All circuits to ground: 2,121 Vdc
	Input to output circuits: 1,500 Vac or 2,121 Vdc
Radio Frequency Interference:	Field tested using a five watt, hand-held transceiver operating at random frequencies centered around 144 megahertz and 440 megahertz, with the antenna located six inches from the relay in both horizontal and vertical planes.
Fast Transient:	Qualified to ANSI/IEEE C37.90.1-1989.
Surge Withstand Capability:	Qualified to IEEE C37.90.1-1989, *Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems*.

Physical

Temperature

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

Weight: 13.5 lbs (6.12 kg)

Case Size: S1 (See Section 4 for panel cutting/drilling 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

INTRODUCTION

Controls and indicators are located on the front panel. The controls and indicators are shown in Figure 2-1 and described in Table 2-1. Figure 2-1 illustrates a relay with the maximum number of controls and indicators. Your relay may not have all of the controls and indicators shown and described here.
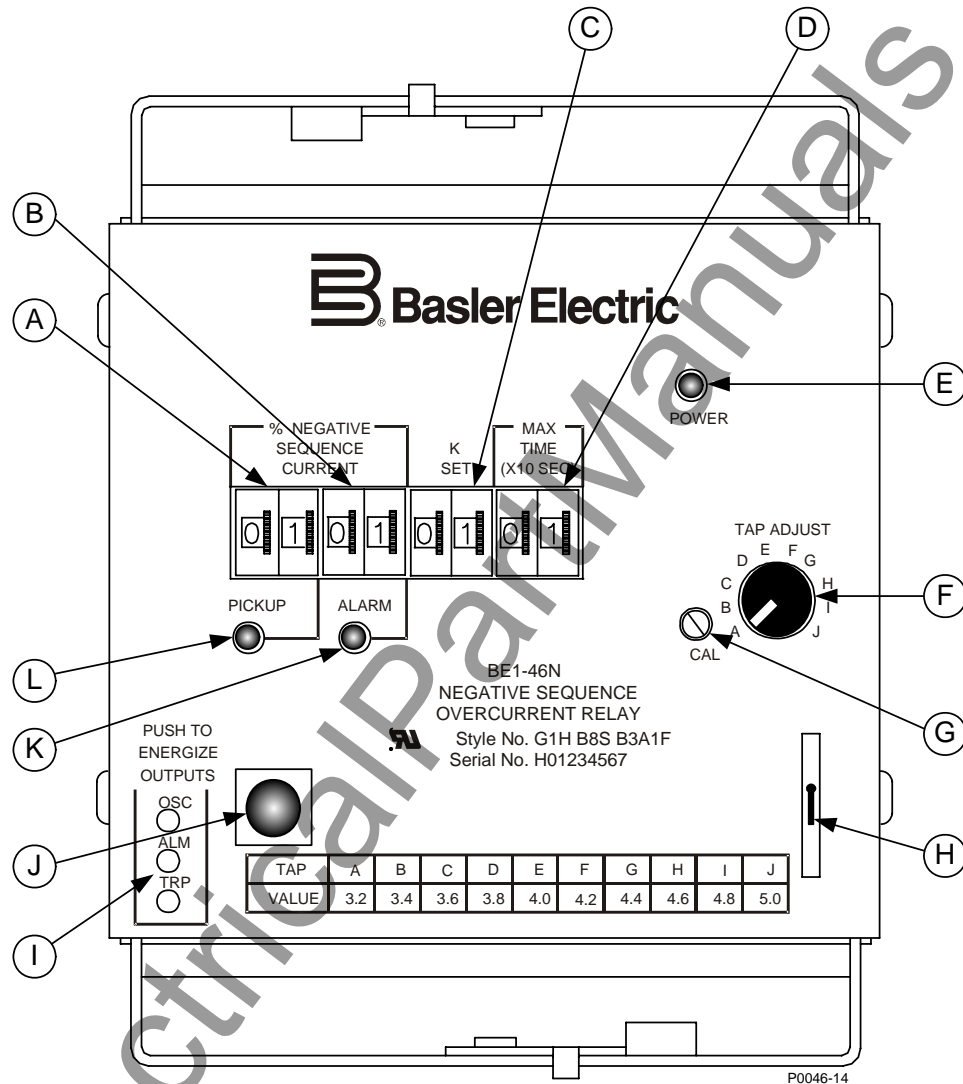
Figure 2-1. Location of Controls and Indicators

Table 2-1. Control and Indicator Descriptions

Locator	Description
A	*PICKUP (Trip Level).* Front-panel thumbwheel switch provides selection of the negative sequence overcurrent pickup point that, when exceeded, initiates timing. Setting is continuously adjustable over the range of 1 to 50% in increments of 1%. A setting of 00 will be recognized as 1%. Any setting beyond 50 will be recognized as 50%.
B	*ALARM (Trip Level).* Front-panel thumbwheel switch provides pickup point for the ALARM trip level and is continuously adjustable over the range of 1 to 50% in increments of 1%. A setting of 00 will be recognized as 1%. Any setting beyond 50 will be recognized as 50%.

Locator	Description
C	*K SET.* Front-panel thumbwheel switch provides adjustment of the relay timing characteristic over the range of 1 to 99 in increments of 1. Allows the relay to match the characteristics of the protected machine. See Figure 3-2 for characteristic curves. A setting of 00 will be recognized as a K-setting of 100.
D	*MAX TIME (X 10 SEC).* Front-panel thumbwheel switch provides selection of the maximum trip time over the range of 10 to 990 seconds in increments of 10 seconds. Refer to Figure 3-2 for characteristic curves. A setting of 00 will be recognized as 1,000 seconds.
E	*POWER LED.* LED illuminates when proper operating power is applied to the relay internal circuitry.
F	*TAP ADJUST.* Front-panel mounted, 10-position rotary switch establishes the full-load current reference level (I_N) for the application. The 5 ampere model is adjustable from 3.0 A to 5.0 A in increments of 0.2 A. The one ampere model is adjustable from 0.6 to 1.0 A in increments of 0.04 A.
G	*CAL Adjust.* Provides a vernier adjustment between the selected TAP ADJUST setting and the next lower TAP ADJUST setting. A fully CW adjustment of the CAL control provides the indicated TAP ADJUST setting. CCW adjustment of the CAL control provides adjustments to the next lower setting.
H	*Target Reset Switch.* Provides manual reset of the target indicator (locator J).
I	*PUSH TO ENERGIZE OUTPUTS.* These pushbuttons allow manual actuation of the output relays. Output relay actuation is achieved by inserting a nonconductive rod through the front panel access holes.
J	*Trip Target Indicator.* This electronically latched red target indicator illuminates when the trip output relay energizes. To ensure proper operation of a current-operated target, the current flowing through the trip circuit must be 200 mA or higher. The target indicator is reset by operating the target reset switch (locator H).
K	*ALARM LED.* LED illuminates when level of I_2 exceeds the ALARM (trip level) setting.
L	*PICKUP LED.* LED illuminates when level of I_2 exceeds PICKUP (trip level) setting.

BE1-46N Controls and Indicators

SECTION 3 • FUNCTIONAL DESCRIPTION

INTRODUCTION

BE1-46N relay functions are illustrated in Figure 3-1 and described in the following paragraphs.

Figure 3-1. Function Block Diagram

INPUT SENSING

Three-phase currents are applied to the negative sequence filter network which removes the zero and positive sequence components of sensed currents.

Resolved negative sequence currents (I_2) are scaled by the TAP ADJUST switch. The TAP ADJUST switch selects resistive loading to establish per unit (pu) current values. Switch positions, A through J, select tap values from 3.2 amperes to 5.0 amperes in increments of 0.2 ampere. The CAL potentiometer is a vernier control for selecting tap values between the settings of the TAP ADJUST switch.

The output from the filter is applied to the analog to digital (A/D) conversion network and to the buffer amplifier to drive the external meter (optional) for I_2 level monitoring.

MEASURING I_2

The input from the filter network is converted to an absolute value and applied to a comparator and a times four amplifier. The amplified output is also sent to a comparator. Both the direct and amplified values are measured by the microprocessor. When I_2 values are small, the amplified output is used. This improves resolution and accuracy.

Successive approximation measuring techniques allow the microprocessor to measure the level of I_2. A digital number with only the most significant digit set high is sent from the microprocessor to the digital to analog (D/A) converter. The analog output from the D/A is compared with I_2 by both comparators and the results sent to the microprocessor. Based on the results of that comparison, another digital number is sent from the microprocessor to the D/A converter. The analog output is again compared with I_2 and the results sent to the microprocessor. This continues until the microprocessor number equals the I_2 value. The microprocessor then compares that number with the selected inputs from the thumbwheels. When the magnitude of I_2 exceeds the setting of the trip level, the microprocessor begins timing and calculates the $(I_2)^2 dt$. The microprocessor compares the continuously calculated value with the maximum

permissible heating constant K. Tripping occurs when the calculated value exceeds the K setting. If I_2 falls below the pickup setting, the relay will reset at a linear rate of 2.5 seconds per percent of full scale trip time.

MICROPROCESSOR

BE1-46N relays use an 8-bit, low power, CMS microprocessor which control all timing, measurements, computations, and outputs.

PROGRAM MONITOR

During power-up, the program monitor initializes program sequencing. During operation, the microprocessor outputs a series of pulses at regular intervals. The program monitor senses these pulses and, if the pulses are disrupted in any way, resets the microprocessor. Reset initializes the program sequence and provides for fail safe operation.

OUTPUTS

Output relays are provided for trip and alarm functions. An auxiliary output relay is available that operates at the same time as the trip relay. Trip and auxiliary output relays are available with either normally open (NO) or normally closed (NC) contacts. The alarm output and oscilloscope start relays are also available with NO or NC contacts. Power supply output contacts are monitored at the mother board. Normal supply voltage causes the status relay to be continually energized. However, if at any time the voltage falls below requirements, the relay drops out, and closes the normally closed contacts.

An optional remote meter calibrated to display the magnitude of I_2 is a percentage of the full load current is also available. Full scale deflection of the meter corresponds to 50%.

If this option is specified, a standard 4.5 inch switchboard type meter is available and must be ordered separately. Specify Basler Electric part number 9170000001.

> **NOTE**
>
> Connection between relay and meter must be made using no less than a 20 AWG, shielded, twisted pair with the shield grounded only at the relay case. (Belden Manufacturing Company part number 9962 or equivalent is recommended.)

PUSH-TO-ENERGIZE OUTPUT PUSHBUTTONS

Small pushbutton switches may be provided as an option to allow testing the output contacts. To prevent accidental operation, the pushbuttons are recessed behind the front panel and are depressed by inserting a thin, non-conducting rod through an access hole in the front panel.

POWER SUPPLY STATUS OUTPUT

The power supply status relay has a set of normally closed contacts and energizes when operating power is applied to the relay. If relay operating power is lost or either side of the power supply output (+12 Vdc or –12 Vdc) fails, the power supply status relay de-energizes and opens the power supply status output contacts.

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 1-1.

TARGET INDICATOR

The target indicator is an optional component selected when a relay is ordered. The electronically latched and reset target consists of a red LED indicator 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, an illuminated (latched) target is extinguished. When relay operating power is restored, the previously latched target is restored to its latched state.

A relay can be equipped with either an internally operated target or a current operated target.

Internally Operated Target

The relay trip output is directly applied to drive the target indicator. The indicator is illuminated regardless of the current level in the trip circuit.

Current Operated Target

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

> **NOTE**
>
> Prior to September 2007, the BE1-46N target indicator consisted of a magnetically latched, disc indicator. This mechanically latched target indicator has been replaced by the electronically latched LED target in use today.

SETTING CONSIDERATIONS

As the generator is subjected to unbalanced currents, the heating of the generator can be expressed in terms of negative sequence current and time. The following mathematical relationship defines the permissible heat energy tolerable to the generator without causing damage:

$$Heat\ Energy = \int_0^T (i_2)^2\, dt$$

To avoid damage to the generator, the heat energy must be less than some value K as provided by the generator manufacturer. The K value is a machine constant representing maximum permissible heating. This value varies depending upon the generator design. K values normally range from 4 to 40. The allowable heat energy is then expressed as:

$$Heat\ Energy = \int_0^T (i_2)^2\, dt \langle K$$

Or, as: the instantaneous negative sequence current is equal to some constant I_2 which is expressed in per unit of full load stator current. The formula is now expressed as:

$$Heat\ Energy \langle (i_2)^2 T$$

For clarification, the following definitions are included.

K   =   machine constant supplied by generator manufacturer representing the maximum permissible thermal capacity of the generator rotor

T   =   time in seconds

I_2 =   instantaneous negative sequence current

I_2pu =   negative phase sequence overcurrent expressed in per unit of full load stator current

Where:
$$I_2\ per\ unit = \frac{(i_2)}{Full\ Load\ Stator\ Current}$$

BE1-46N relays are featured with the following settings:

- TAP ADJUST and TAP ADJUST CAL to establish a reference level (full load stator current)
- ALARM and PICKUP
- K SET
- MAX TIME (X 10 SEC)

I_n Reference Level (Tap Value)

An adjustment is provided to establish the stator full load current reference level I_n. This adjustment has a range of 3.0 to 5.0 amperes. This is provided by a 10 position switch and vernier control. The switch positions are marked from position A through J and provide a TAP VALUE as follows:

A - 3.2
B - 3.4
C - 3.6
D - 3.8
E - 4.0
F - 4.2
G - 4.4
H - 4.6
I - 4.8
J - 5.00

The vernier calibration control (CAL) is provided to adjust the full load current level I_n in between the TAP ADJUST range settings.

Alarm and Pickup

The I_2 output of the filter network is applied to the alarm and trip level detector circuits. The alarm circuit pickup adjustment is settable from 0.01 to 0.50 which represents the ratio of magnitude of the negative sequence current to the full load current rating of the machine. The alarm circuit compares the level of I_2 from the filter network to the selected ALARM pickup setting. When I_2 is greater than or equal to the setting and exists for three seconds (a fixed three second time delay), the alarm output contact closes. The alarm setting is usually set lower than the trip level to warn the station operator that corrective action is required.

After pickup (I_2 pu $\geq I_2 \div I_n$), the trip level detector circuit applies the sensed negative sequence current I_2 pu to the minimum and maximum trip timers and the network which integrates the value $(I_2)^2$dt equal to the machine constant K. The minimum trip time circuitry, after a 0.2 second time delay, applies a signal to initiate the operation of the oscillograph (optional). The maximum trip time circuitry maintains the same I_2 pu and triggers the output trip contact when the time delay expires. The setting of the maximum trip time setting is based upon the maximum time allowed for a particular K constant. For a conventionally cooled synchronous generator, the permissible $(I_2)^2$ rating is 30 (reference C37.102-1987). Therefore, a setting of 0.35 pu would allow the generator to carry a negative sequence current condition for 245 seconds without damage. For I_2 currents of less than 0.35 pu, the generator will be adequately protected.

When the value of I_2 pu applied to the microprocessor integrator network falls below the pickup setting, the integration will cease and reset at a linear rate of 2.5 seconds per percent of full scale trip time. This linear reset approximates generator cooling.

K Setting

The K setpoint should be set so that the I_2t characteristic of the relay matches the permissible heating characteristic of the generator.

MAX TIME

The maximum timer function prevents negative sequence current from being above pickup for long periods of time. The maximum timer is ORed with the inverse timer such that if either time out occurs, the unit trips.

CALCULATION EXAMPLE

Assume the generator to be protected is rated:

5 Amp CT	**1 Amp CT**
15 MVA	15 MVA
13.8 kV	13.8 kV
CT Ratio 800/5 A	CT Ratio 800/1 A

The calculated full load current would be:

5 Amp CT

$$I_{full\,load} = \frac{15\,MVA \times 1000}{\sqrt{3}\left(13.8\,(KW)\right)} = 627.55\,A$$

1 Amp CT

$$I_{full\,load} = \frac{15\,MVA \times 1000}{\sqrt{3}\left(13.8\,(KW)\right)} = 627.55\,A$$

The current being applied to the relay would be:

5 Amp CT

$$I_{secondary} = 627.56 \times \frac{5}{800} = 3.92\,A$$

1 Amp CT

$$I_{secondary} = 627.56 \times \frac{1}{800} = 0.784\,A$$

The relay TAP ADJUST should be set for this value of full load current.

SETTING TAP ADJUST

Two methods for setting the TAP ADJUST are the single-phase and three-phase methods. In each of these methods, the amount of negative sequence current at which the relay is to trip must be calculated and then applied to the relay. The TAP ADJUST CAL control is then adjusted so that the PICKUP LED lights at that amount of negative sequence current.

Method 1, Single-Phase

If a single-phase quantity is to be applied to the relay, the following equations need to be developed and used in the calculations.

$$I_2 = \frac{1}{3}\left(I_A + \propto^2 I_B + \propto I_C\right)$$

$$\text{If, } I_B = I_C = 0$$

$$\text{Then, } I_2 = \frac{I_A}{3} = \frac{I_{single-phase}}{3}$$

$$\therefore \quad I_2\,pu = \frac{I_2}{I_{nominal}} = \frac{1}{3}\left(\frac{I_{single-phase}}{I_{nominal}}\right)$$

Solving for $I_{nominal}$
Equation A is:

$$I_{nominal} = \frac{1}{3}\left(\frac{I_{single-phase}}{I_2\,pu}\right)$$

Solving for $I_{single-phase}$
Equation B is:

$$I_{single-phase} = 3\left(I_{nominal}\right)\left(I_2\,pu\right)$$

To set the nominal current value (current being applied to the relay as derived in the calculation example), perform the following steps.

Step 1.   Set the TAP ADJUST switch to the next higher current value (4.0 A, position E for 5 A CT or 0.80 A, position E for 1 A CT) of the desired current value (3.92 A for 5 A CT or 0.784 A for 1 A CT).

NOTE

For the following step, any % value can be used. In this example, 50% has been chosen only for convenience.

Step 2.   Set the % I_2 PICKUP thumbwheel switch to a value of 50 (0.5 pu).

Step 3.   Using equation B, solve for $I_{single\text{-}phase}$.

5 Amp CT | **1 Amp CT**

Equation B is:

$$I_{single-phase} = 3(I_{nominal})(I_2 pu)$$

$$I_{single-phase} = 3(3.92)(0.5)$$

$$I_{single-phase} = 5.88\,A$$

$$I_{single-phase} = 3(I_{nominal})(I_2 pu)$$

$$I_{single-phase} = 3(0.784)(0.5)$$

$$I_{single-phase} = 1.176\,A$$

Step 4.   Apply the calculated $I_{single\text{-}phase}$ to one of the phase inputs of the relay (example, phase A input, relay case terminals 8, 9) and adjust the TAP CAL control from a fully clockwise until the front-panel PICKUP LED is ON.

The nominal current value is set at 3.92 amperes (for 5 A CT) or 0.784 amperes (for 1 A CT) for this application.

Method 2, Three-Phase

If any two phases of a balanced three phase source are rotated, $I_{input} = I_2$ because a reverse phase quantity is being applied. The relay sees this as a 100% negative sequence condition.

To set the nominal current value (current being applied to the relay as derived in the calculation example):

Step 1.   Set the TAP ADJUST switch to the next higher current value (4.0 amperes, position E for 5 A CT or 0.80 amperes, position E for 1 A CT) of the desired current value (3.92 amperes for 5 A CT or 0.784 amperes for 1 A CT).

NOTE

For the following step, any % value can be used. In this example, 50% has been chosen only for convenience.

Step 2.   Set the % I_2 PICKUP thumbwheel switch to a value of 50 (0.5 pu).

Step 3.   If applying A-C-B sequence,

5 Amp CT | **1 Amp CT**

$$|I_2| = |I_A| = |I_B| = |I_C|$$

$$\text{then,}\quad 0.5 \times |I_2| = 0.5 \times |I_{INPUT}|$$

$$\therefore\quad 0.5 \times 3.92 = 1.96\,A$$

$$|I_2| = |I_A| = |I_B| = |I_C|$$

$$\text{then,}\quad 0.5 \times |I_2| = 0.5 \times |I_{INPUT}|$$

$$\therefore\quad 0.5 \times 0.784 = 0.392\,A$$

Step 4.   Apply 1.96 amperes (for 5 A CT) or 0.392 amperes (for 1 A CT), and adjust the TAP CAL control from a fully clockwise position, counter-clockwise until the front-panel PICKUP LED is ON.

The nominal current value is now set at 3.92 amperes (for 5 A CT) or 0.784 amperes (for 1 A CT) for this application.

FURTHER CONSIDERATIONS (FOR 5 AMP CT)

Relay Pickup should be based on series unbalances, particularly an open phase, rather than on unbalanced faults. The limiting case for pickup settings may be an open beyond the generator leads where the negative-sequence current is distributed among several generators. This is in contrast to an open pole on the generator breaker, where the total negative sequence current resulting from the open flows in the generator being protected.

Reference 1∗ specifies the continuous negative sequence current limit in per unit after 120 seconds as:

Salient Pole:	With connected dampers	0.10
	With unconnected dampers	0.05
Cylindrical Rotor:	Indirectly cooled	0.10
	Directly cooled to 960 MV A	0.08
	961 to 1,200 MV A	0.06
	1,201 to 1,500 MV A	0.05

∗ IEEE Committee Report, *A Standard for Generator Continuous Unbalanced Current Capability,* IEEE Transactions, PAS 92, No. 5, Sept./Oct. 1973, pp 1547-49.

Assume an indirectly cooled cylindrical rotor generator and set PICKUP (trip unit) at 0.06 or 6%. Set alarm pickup below the PICKUP value (trip unit), but above maximum expected unbalance due to untransposed lines, etc.: at 4%. Assume that the manufacturer or the ANSI standard has specified a K factor of 30. Set K = 30.

The maximum negative-sequence current I_2 for an open phase occurs when the open is in the generator leads whether at the generator voltage or on the high side of the unit transformer. Current I_2 for this case can be approximated:

Equation C is:

$$I_2 = I_1\left(\frac{X_0}{X_2 + X_0}\right)$$

Where:

X_2 = negative-sequence reactance of an entire system, including the generator

X_0 = zero-sequence reactance of system connected to an open phase

I_1 = positive-sequence current

Assume that X_0 = 1.6 times X_2 and I_1 = 1.0 pu. Then, from Equation C:

$$I_2 = \frac{1.0 \times 1.6}{1.0 + 1.6} = 0.62 \; pu$$

Then, 0.62 pu is approximately the maximum expected current for an open phase for this case. At this level, the inverse delay based on $I_2^2 t = K = 30$ will be:

$$\frac{30}{(0.62)^2} = 78 \; sec$$

The operator will probably not react fast enough in reducing loading to prevent tripping with a 78 second relay delay. However, at lower levels the alarm unit may provide sufficient advanced warning to allow effective operator corrective action. Accordingly, the MAX TIME setting should permit such possible action. Set MAX TIME at 500 seconds (8.3 minutes).

FURTHER CONSIDERATIONS (FOR 1 AMP CT)

To determine the negative sequence current pickup setting, calculate the sensitivity required to ensure relay operation at the expected minimum load condition with one pole of the generator breaker open. Assume the value of negative sequence current under this condition is 0.14 A (secondary) or 0.18 per unit. Then, for our example, the relay must be at least this sensitive. This value must be considered as the upper limit for the pickup setting. A lower setting is recommended. For this example, a value of 12 percent (0.12 per unit) will be used. Set the PICKUP thumbwheel to this value.

To set the value for the ALARM level of negative sequence current, it is only necessary to determine the level that will give an operator sufficient time to attempt to correct the condition. A value of 08 may be set on the thumbwheel.

The K value for this example has been provided by the generator manufacturer. Set this value (25) on the K SET thumbwheel.

The MAX TIME thumbwheel establishes the maximum time allowed for the negative sequence current tripping condition (defined by the PICKUP setting) to persist. If it is determined that this value is 500 seconds, set the thumbwheel at 50.

Since $(I_2)^2 t = K$ establishes the limit of operation, t = 25 divided by 0.12^2 = 1,736 seconds.
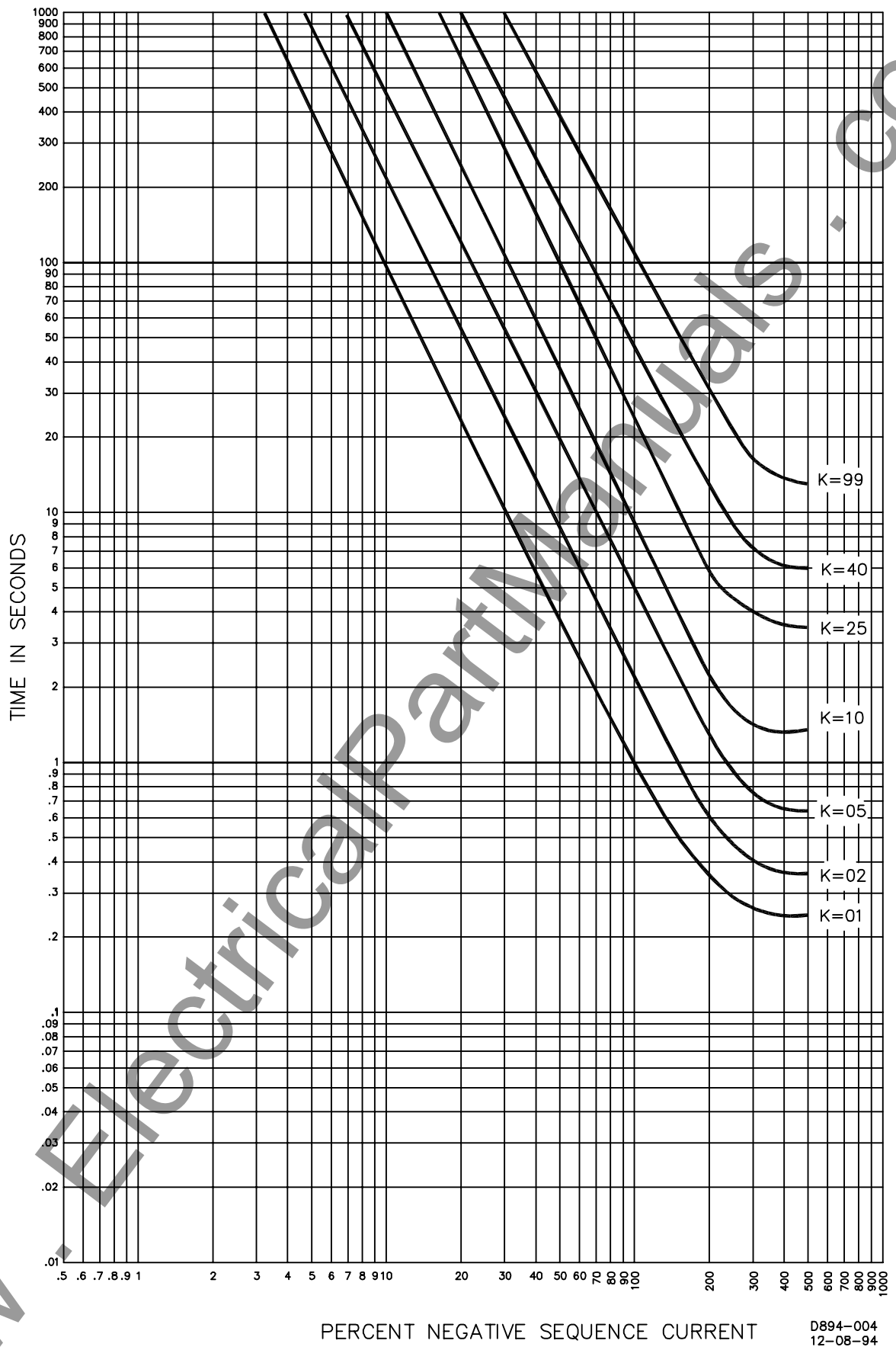
Figure 3-2. Characteristic Curves

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SECTION 4 • INSTALLATION

INTRODUCTION

BE1-46N relays are shipped in sturdy cartons to prevent damage during transit. Upon receipt of a relay, check the model and style number against the requisition and packing list to see that they agree. Inspect the relay for shipping damage. If there is evidence of damage, file a claim with the carrier, and notify your sales representative or Basler Electric.

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

RELAY OPERATING GUIDELINES AND PRECAUTIONS

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

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

CAUTION

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

NOTE

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

MOUNTING

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

Panel cutting and drilling dimensions are shown in Figures 4-1 and 4-2. Remote meter dimensions and drilling diagram is shown in Figure 4-3. Case dimensions are illustrated in Figures 4-4 through 4-7. Case cover dimensions are shown in Figure 4-8.
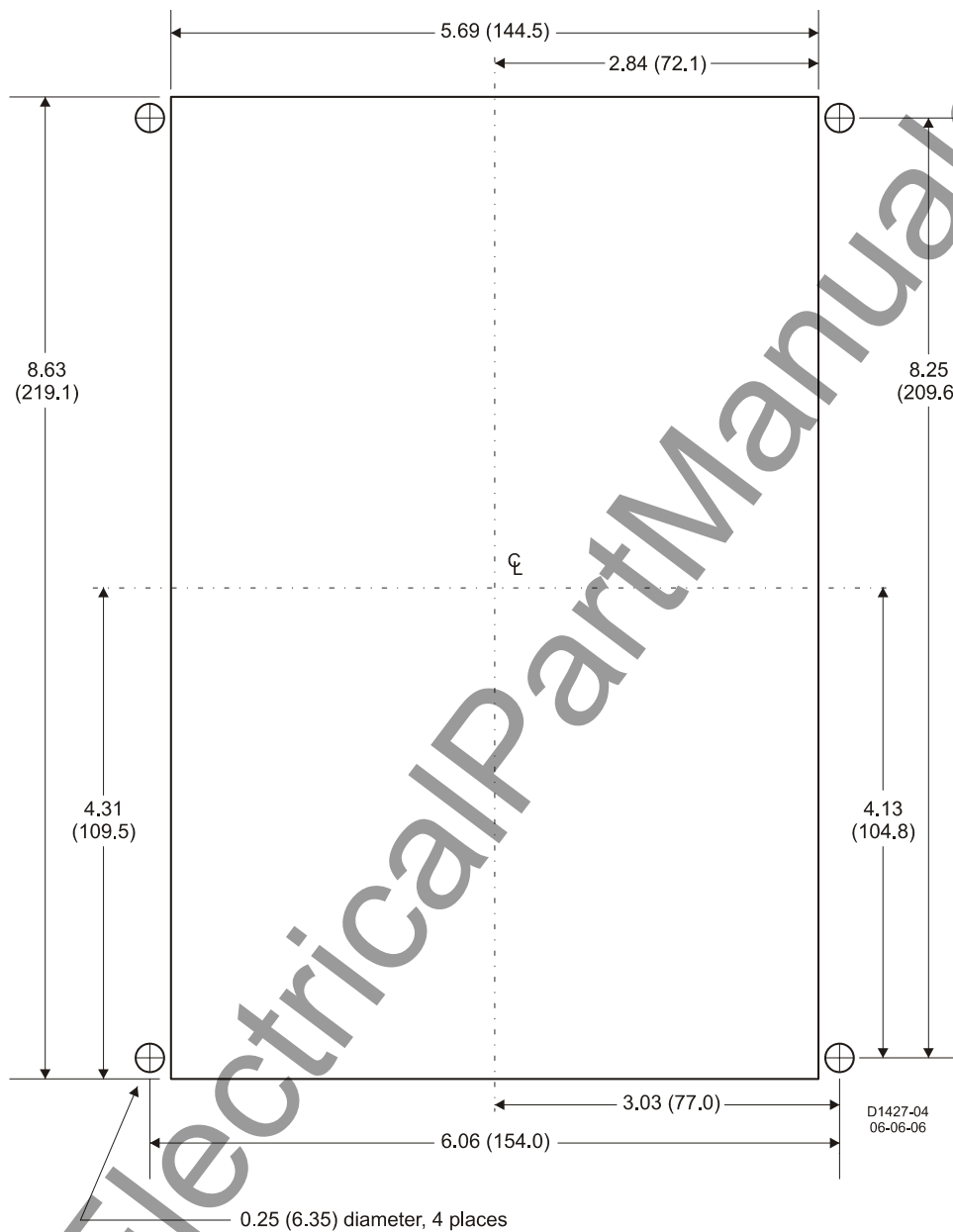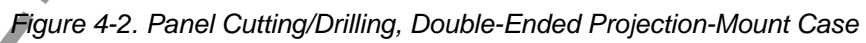
5.69 (144.5)

2.84 (72.1)

8.63 (219.1)

8.25 (209.6)

C̵L

4.31 (109.5)

4.13 (104.8)

3.03 (77.0)

D1427-04
06-06-06

6.06 (154.0)

0.25 (6.35) diameter, 4 places

Figure 4-1. Panel Cutting/Drilling, Semi-Flush Case

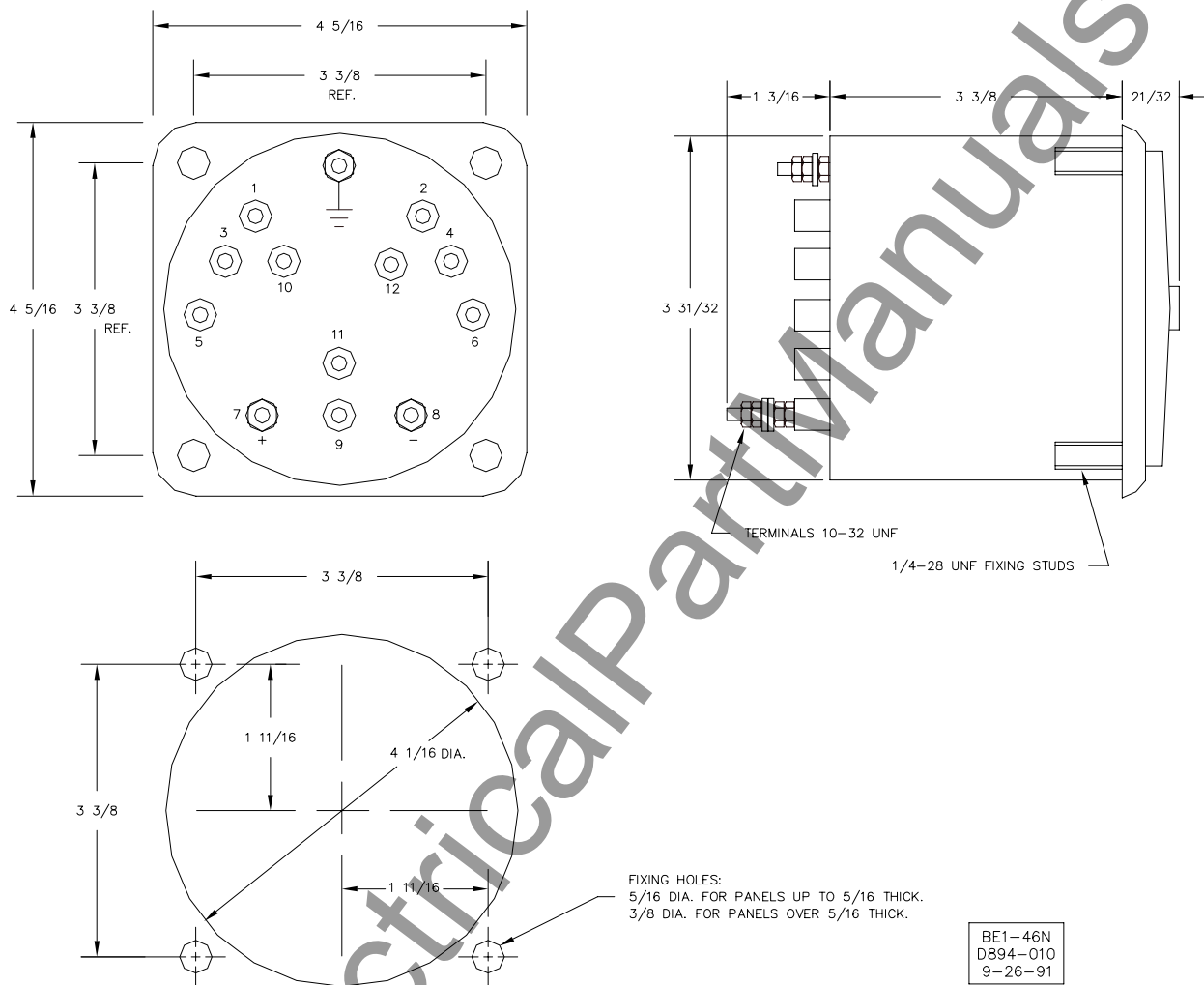*Figure 4-2. Panel Cutting/Drilling, Double-Ended Projection-Mount Case*
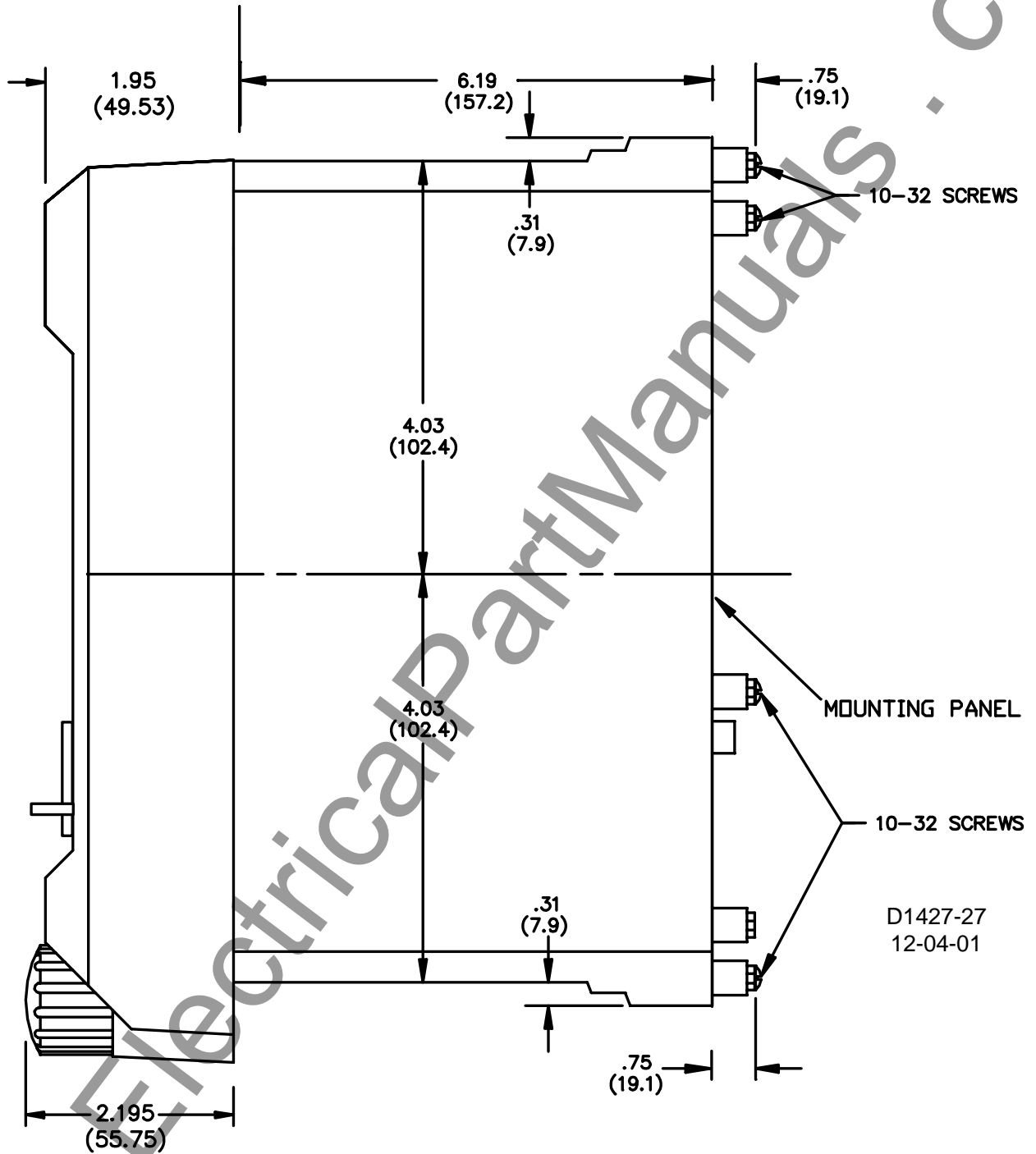
Figure 4-3. Remote Meter Dimensions and Drilling Diagram

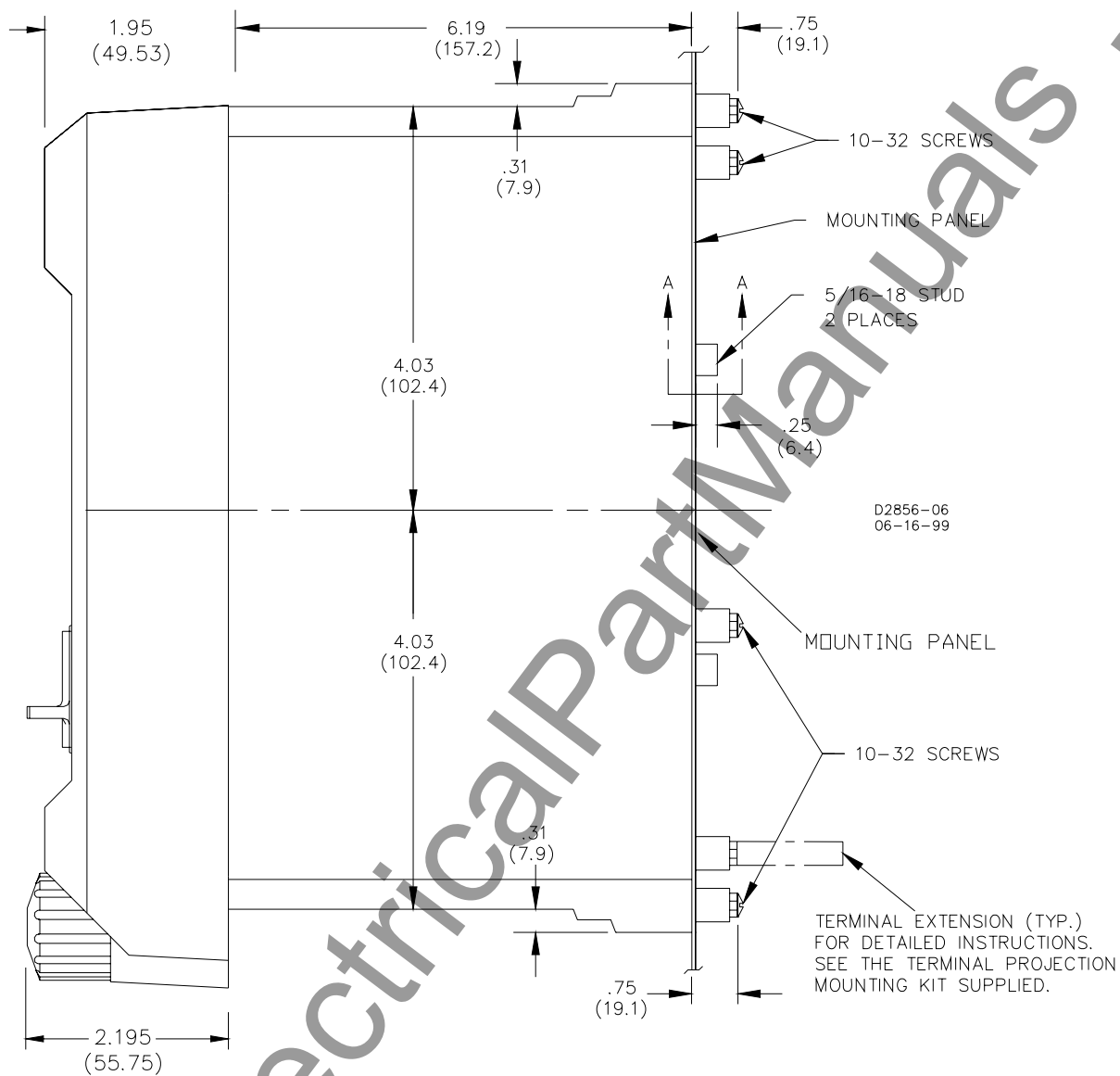*Figure 4-4. Case Dimensions, Side View, Double-Ended Semi-Flush Case*
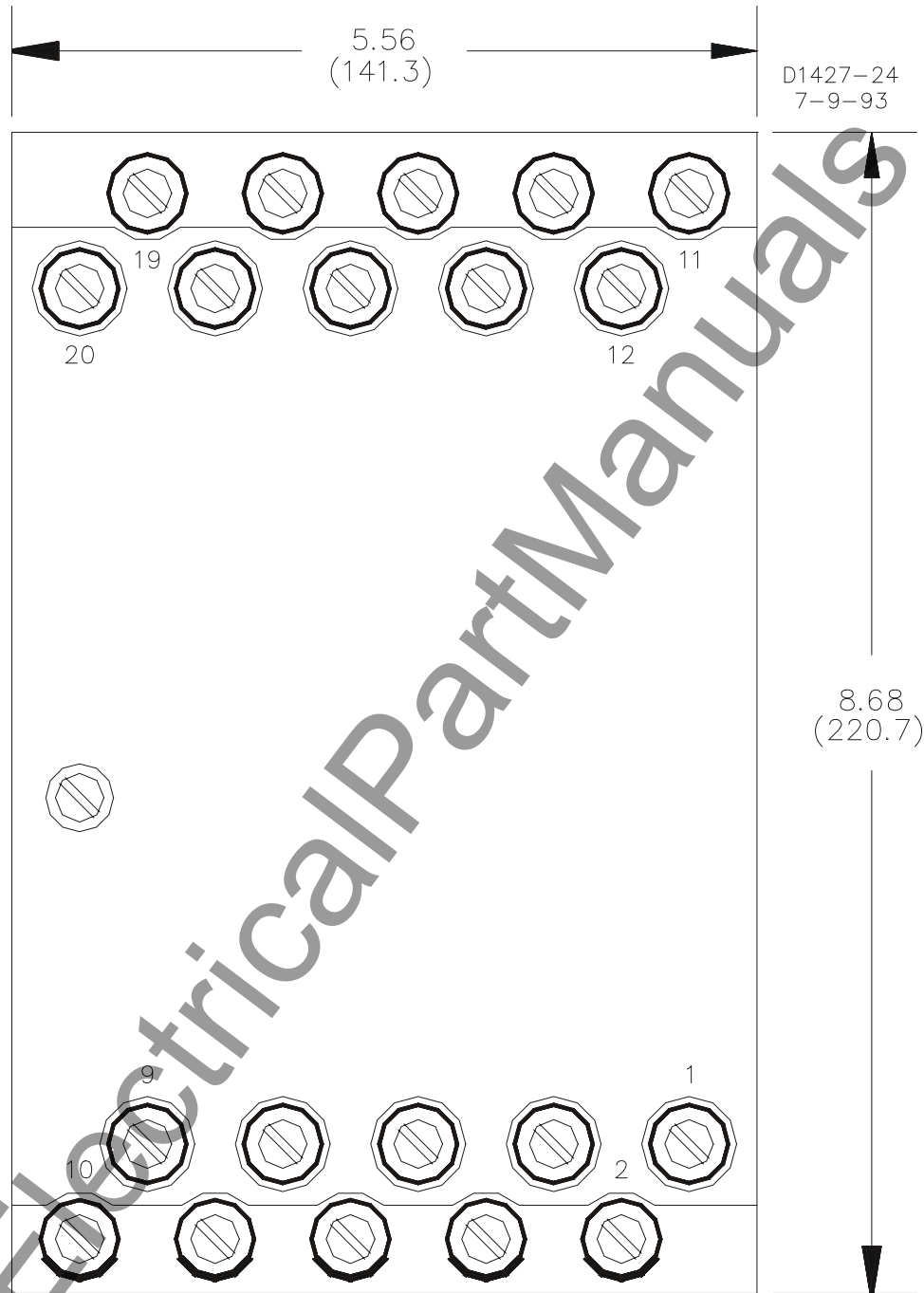
Figure 4-5. Case Dimensions, Side View, Double-Ended Projection-Mount Case
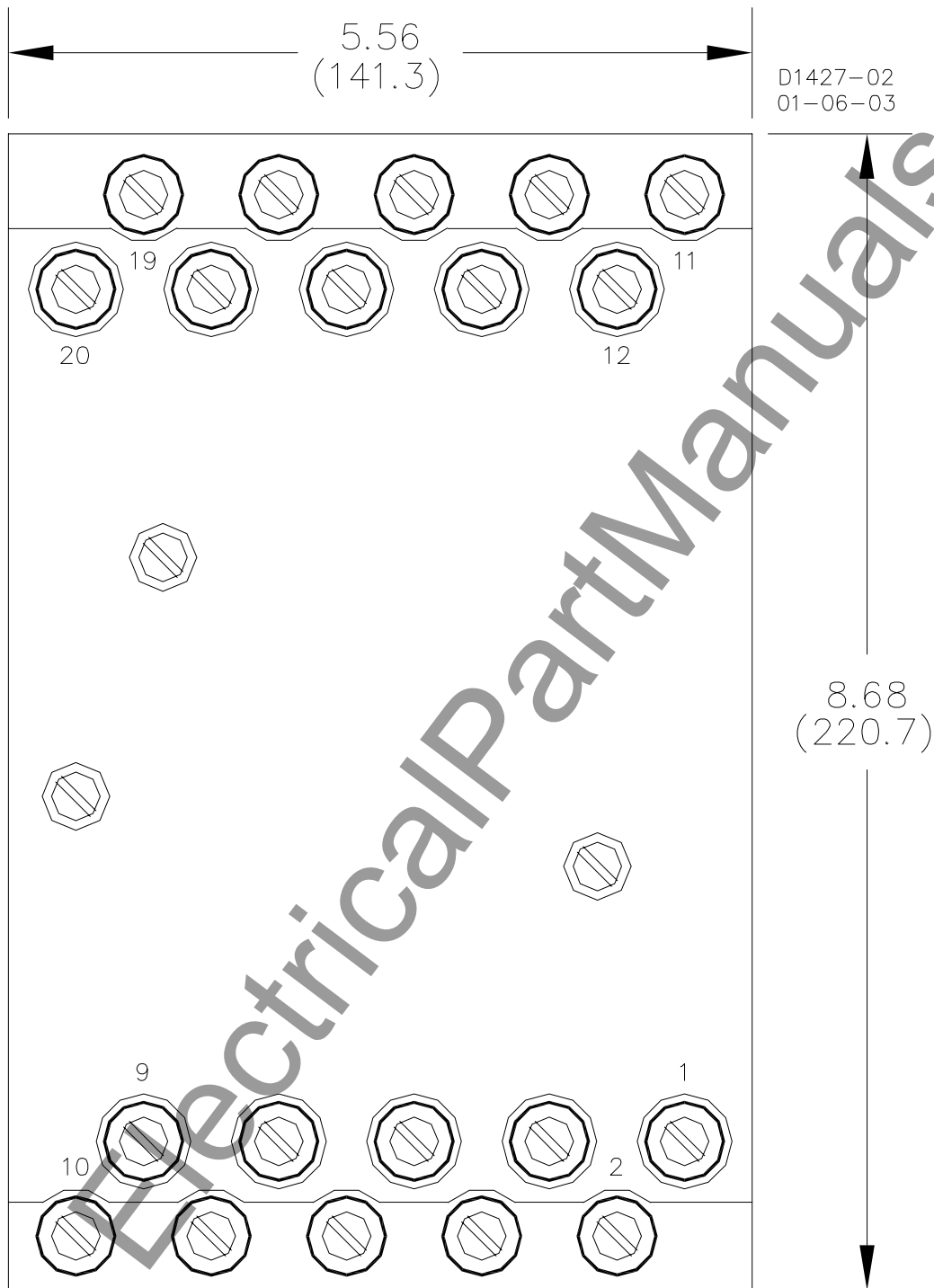
Figure 4-6. Case Dimensions, Rear View, Semi-Flush Case

5.56
(141.3)

D1427-02
01-06-03

19   11
20   12

8.68
(220.7)

9   1
10   2

Figure 4-7. Case Dimensions, Rear View, Projection-Mount Case

6.65
(168.91)

9.32
(236.73)

P0002-12
01-31-01
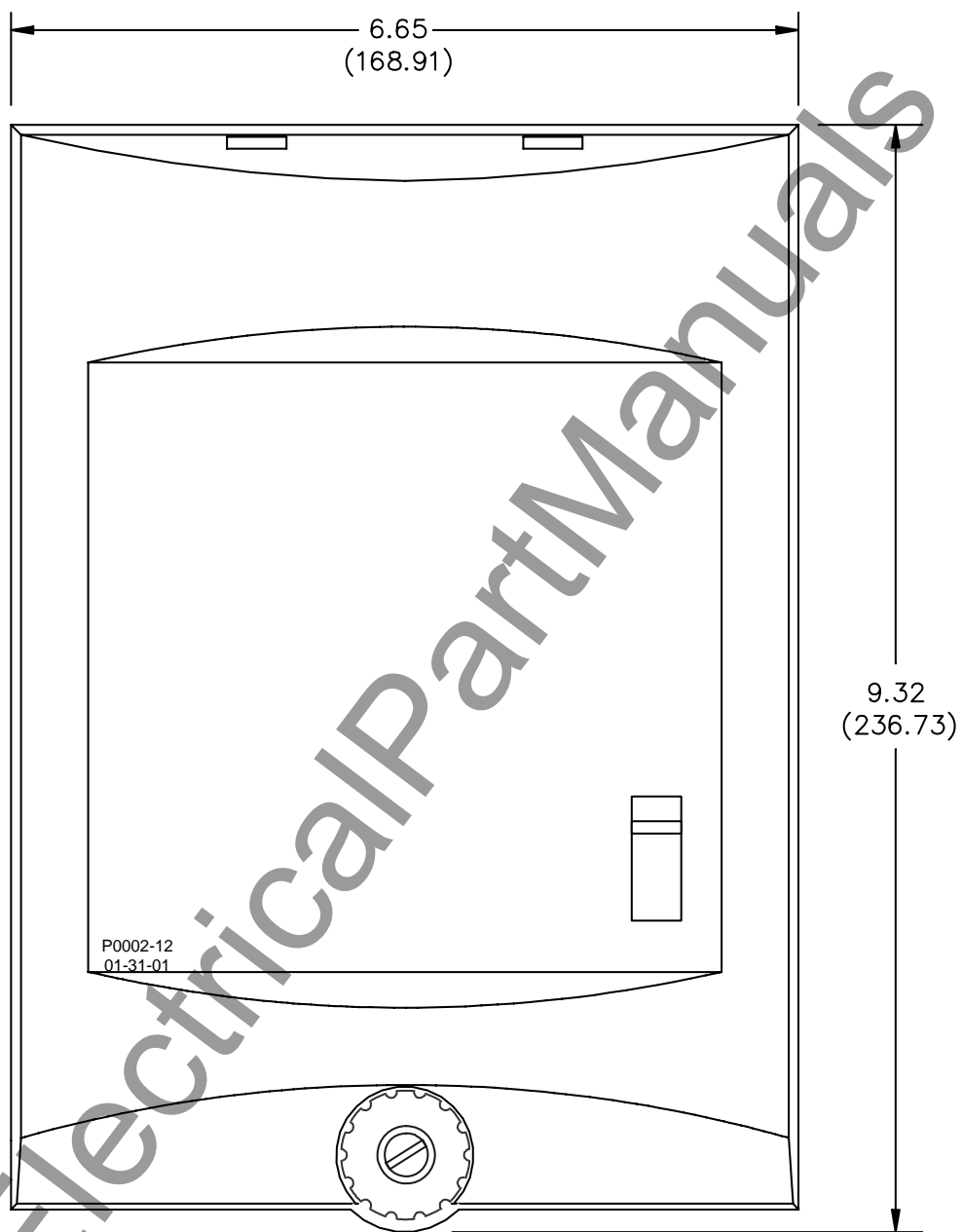
Figure 4-8. Case Cover Dimensions, Front View

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 dc control connections are shown in Figure 4-9. Typical ac sensing connections are shown in Figure 4-10. Typical internal connections are shown in Figure 4-11.
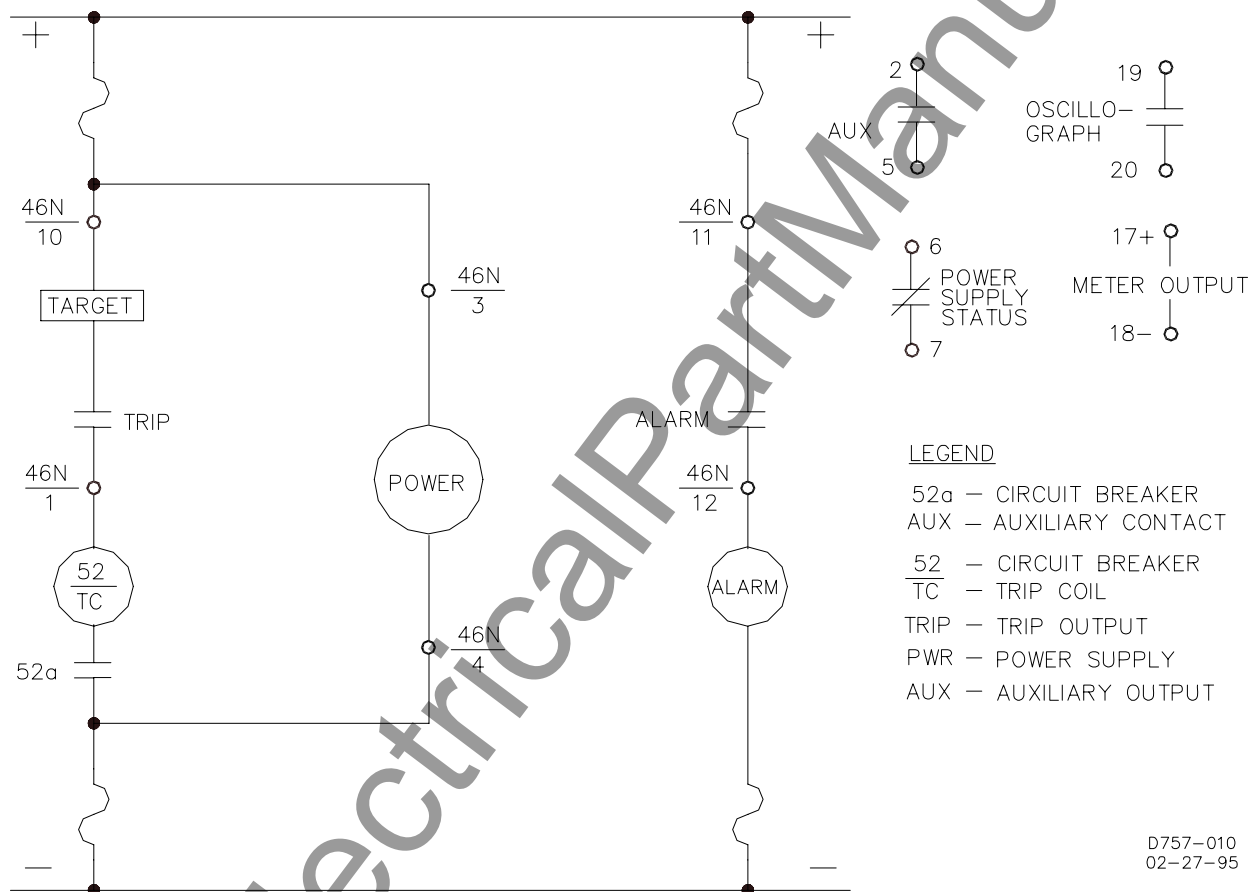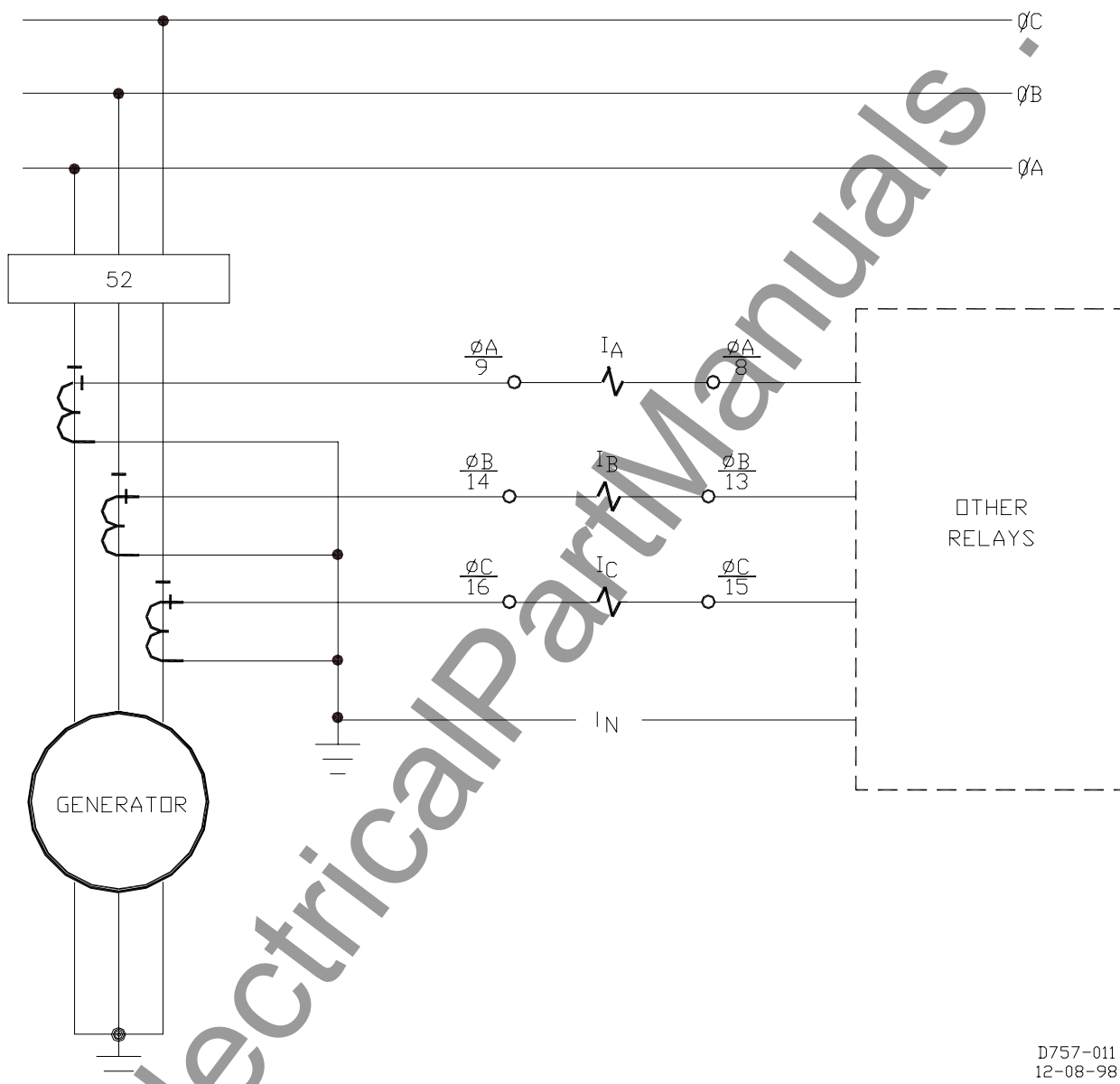
Figure 4-9. Typical DC Connections
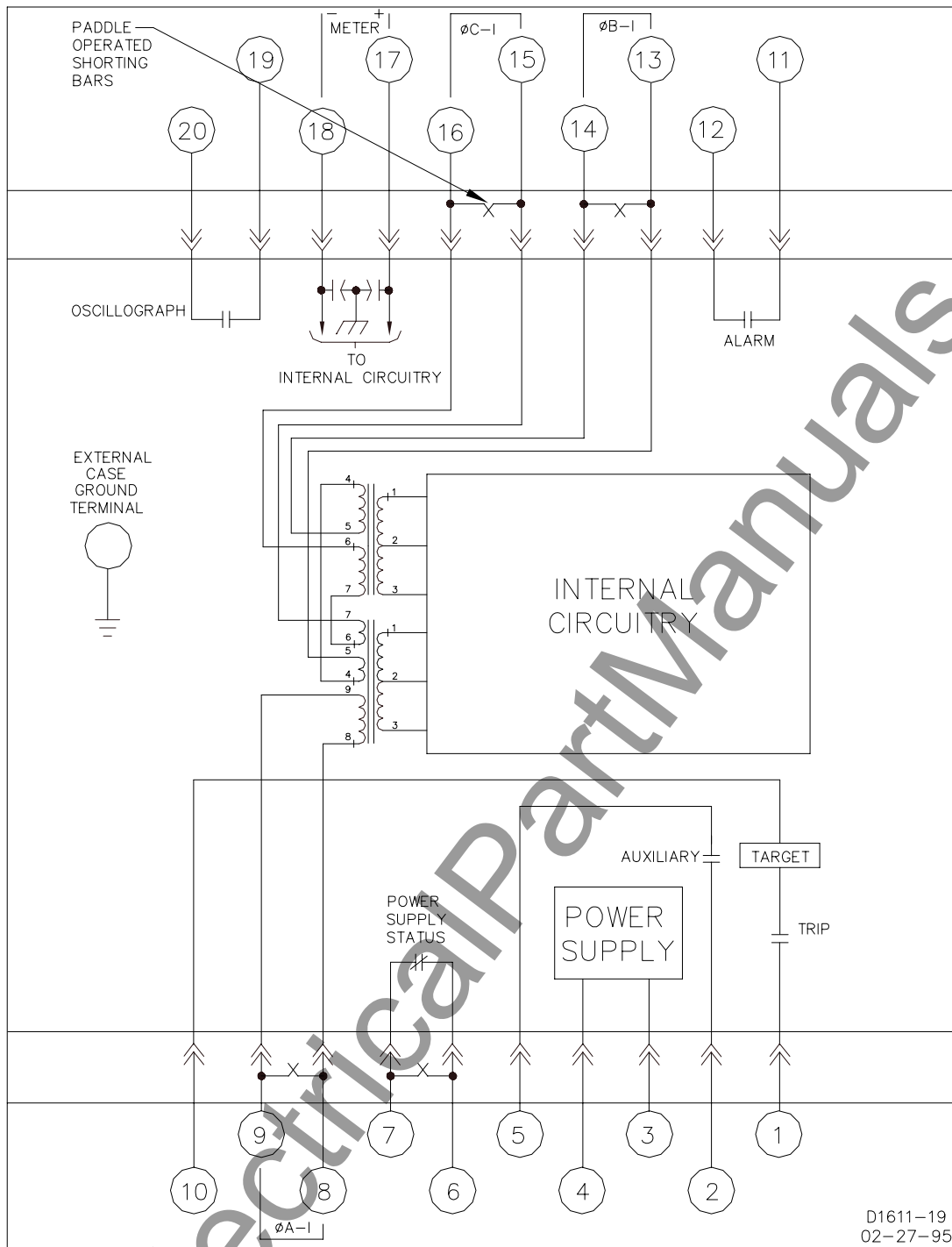
Figure 4-10. Typical AC Sensing Connections

Figure 4-11. Typical Internal Connections

MAINTENANCE

BE1-46N 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.

SECTION 5 • TESTING

INTRODUCTION

Although the BE1-46N is designed to monitor three-phase currents, verification of the relay pickup and dropout can be accomplished by using a single-phase source. To verify all three phases using a single-phase current source, repeat the operational test procedure for each of the three phases.

The test is divided into the following three functional areas:

- Pickup and Alarm
- Timing
- MAX Time

OPERATIONAL TEST

Pickup and Alarm

Additional testing to verify trip and alarm circuit pickup and dropout may be implemented by changing the PICKUP and ALARM thumbwheel settings. The procedures remain the same but the values differ. To determine the correct values, the following formula and derivatives are given.

$$I_N = TAP\ ADJUST\ value$$
$$I_2\,pu = \frac{I_2}{I_N}$$
$$also,\quad \%\,I_2 = (I_2\,pu)(100\%)$$

Equation A

$$Negative\ Sequence\ I = I_2 = \frac{1}{3}\Big(I_A + \propto^2 I_B + \propto I_C \Big)$$
$$I_2\,pu = \frac{I_2}{I_N} = \frac{1}{3(I_N)}\Big(I_A + \propto^2 I_B + \propto I_C \Big)$$

If testing single phase ($I_B = 0$, and $I_C = 0$) then:

$$I_2\,pu = \frac{1}{3(I_N)}\Big(I_A + \propto^2 I_B + \propto I_C \Big)$$

Equation B

$$I_2\,pu = \frac{1}{3(I_N)}\big(I_A \big)$$

Note that the results obtained from these procedures may not fall within specified tolerances. When evaluating results, consideration must be given to three important factors.

1. The inconsistent method of testing. (Example: The start pulse to the timer does not always begin on the zero crossing.)

2. The inherent error of the test equipment used. Test equipment should be accurate to within 1.0% or better.

3. The tolerance level of components used in the test setup. Components should be specified to within 1.0% or better.

Step 1. Set the TAP ADJUST to the A position and turn the CAL control fully CW (5 A CT = 3.2 A) (1 A CT = 0.64 A).

Step 2. Set the PICKUP and ALARM thumbwheel switches to 33 (33%).

Step 3. Connect a current source to the phase A input terminals.

NOTE

Time delay for the ALARM trip circuit is factor set at 3.0 seconds ±5%. Three seconds after the ALARM LED lights, the ALARM output contacts actuate.

Step 4. Slowly increase the magnitude of the phase A current until the ALARM and PICKUP LEDs just light. Do not increase the current any further.

Step 5. Measure and record the applied current and observe the remote meter.

RESULT: The recorded pickup value should be 3.168 A ±0.048 A for 5 A CTs and 0.634 A ±0.048 A for 1 A CTs, and the meter should correspond to 33%.

Step 6. Slowly decrease the input current until the PICKUP and ALARM LEDs go out.

Step 7. Measure and record the applied current and observe the remote meter.

RESULT: The recorded value for dropout should be no less than 98% of the pickup level or 0.064 A (for a 5 A CT) or 0.12 (for a 1 A CT) less than that recorded for PICKUP, and the meter should correspond.

Timing

The results obtained from these procedures are sufficient to determine the relay timing characteristics.

Step 1. Connect the test circuit as shown in the test setup diagram, Figure 5-1, set TAP ADJUST to A position, and the CAL control fully CW.
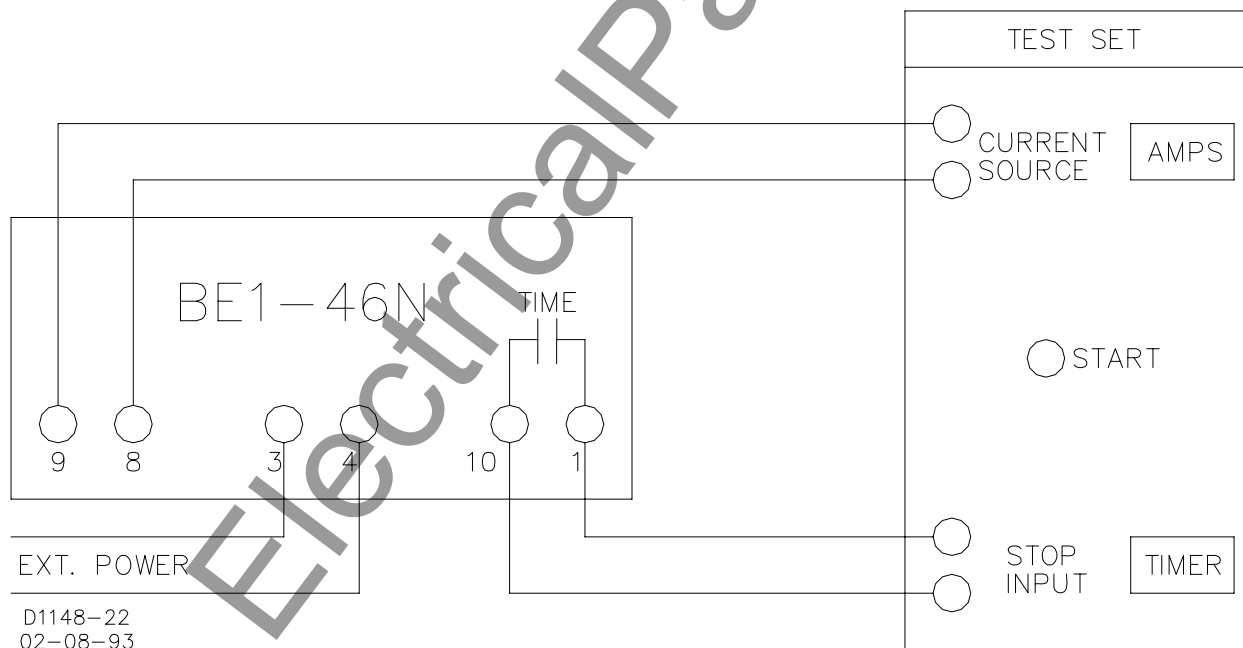

Figure 5-1. Test Setup Diagram

Step 2. Adjust current source to apply 4.8 A for the 5 A CT or 0.96 A for the 1 A CT (50% I_2 or 0.5 pu) to the phase A input and set the front panel controls as follows:

- PICKUP and ALARM to 05
- K SET to 10
- MAX TIME to 10

> **NOTE**
>
> Three seconds after the closing of switch A the ALARM input contacts actuate. (Time delay is factory set at 3 seconds.)

Step 3.   Close switch A to apply current to relay and initiate timer.

Step 4.   Observe timer reading after PICKUP LED lights.

RESULT: Timer should indicate 40 ±2 seconds.

> **NOTE**
>
> Relay power must be cycled OFF and ON between each timing test to ensure that the reset time has been defeated.

Step 5.   To calculate the time required for the timing function, use the following formula:

$$t = \frac{K}{(I_2 pu)^2}$$

$$t = \frac{10}{(0.5)^2} = 40 \; seconds$$

MAX Time

The following procedure will show how the MAX Time affects relay timing.

Step 1.   Connect the test circuit shown in the test setup diagram, Figure 5-1, set the TAP ADJUST switch to A position, and CAL control fully CW.

Step 2.   Adjust current source to apply 2.4 A (25% I_2 or 0.25 pu) to the phase A input and set the front panel controls as follows:

- PICKUP and ALARM to 05
- K SET to 10
- MAX TIME to 10

Step 3.   Close switch A to apply current to relay and initiate timer.

Step 4.   Observe timer reading after PICKUP LED lights.

RESULT: Timer should indicate 100 ±5 seconds.

Step 5.   To calculate the time required for the timing function, use the following formula:

$$t = \frac{K}{(I_2 pu)^2}$$

$$t = \frac{10}{(0.25)^2} = 160 \; seconds$$

We find t = 160 seconds. But, because the MAX TIME was set for 10 (100 seconds), trip occurred at 100 seconds.

This concludes the operational test. To test all three phase input, repeat the test procedures applying the single-phase current source input to phase B input and then phase C input.

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