

The Solid-State Polarization Cell Replacement



PCR: For Class I, Div. 2, Zone 2 and Non-Hazardous Locations

INTRODUCTION

The Polarization Cell Replacement (PCR) is a solid-state device commonly used in conjunction with cathodically protected structures. The PCR is an ideal replacement for electrochemical polarization cells because the solid-state design eliminates the maintenance requirements and the potentially hazardous electrolytes associated with polarization cells. Furthermore, the operating parameters offer a number of distinct advantages. Because the device has a higher DC blocking voltage, one device can often replace two or more polarization cells. The product is easy to apply because its operating parameters are precisely defined.

This product is available in two different versions to most economically accommodate the two different hazardous location listings which are available. In many applications, these products are used in a hazardous location; hence, the reason for hazardous location listings.

All model numbers with a PCR prefix are listed for use in Class I, Division 2, Groups A, B, C, and D hazardous locations per NFPA 70 (the U.S. National Electric code) and for Zone 2 locations per EN50021.

All model numbers with a PCRH prefix are listed for Class I, Division 1, Groups C and D hazardous locations. For more information on the PCRH, please see the separate PCRH literature.

These products prevent the flow of DC current when the absolute voltage (i.e., the DC plus peak AC voltage) across the terminals is between -3.0 volts and + 1.0 volt while simultaneously providing a grounding (or coupling) path for steady-state AC current, if AC current is present. A symmetrical version, which blocks +/-2.0 volts is available as an option. Custom versions with other voltage blocking levels will be considered upon request. These products also provide over-voltage protection to both lightning and AC fault current.

TYPICAL APPLICATIONS

- Over-Voltage Protection of Insulated Joints
- Mitigation of Induced AC Voltage
- Blocking Stray DC Voltage
- AC Grounding and DC Isolation of Cathodically Protected Electrical Equipment (such as Motor-Operated Valves)
- DC Isolation of Cathodically Protected Equipment from Power Utility Grounding Systems

- Over-Voltage Protection of Equipment from AC Faults, Lightning, and Switching Transients

RATING INFORMATION REQUIRED

The following information is required for each application in order to select the appropriate product rating.

- 1) The AC fault current available to flow through the device under a fault condition. (This will often be less than the total fault current available).
- 2) The steady-state AC current available to flow through the device while blocking the flow of DC current.
- 3) The DC blocking voltage required.
- 4) The hazardous location listing required for the planned installation location. If not applicable, or if a Class I, Division 2 location applies, select a PCR model. If a Class I, Division 1 location applies, the PCR is not appropriate and a PCRH model must be selected.
- 5) The environmental rating of the enclosure.

Note: Items (1) and (2) will not apply in all applications.

ELECTRICAL RATINGS

AC FAULT CURRENT RATINGS

Three different fault current ratings are offered at 60 Hz and 50 Hz with the following current-time relationship:

PCR



AC Fault Current Ratings (Amps AC-RMS Symmetrical)

60 Hz Cycles	PCR			
	3.7KA	5KA	10KA	15KA
1	6,500	8,800	20,000	35,000
3	5,000	6,800	15,000	27,000
10	4,200	5,700	12,000	21,000
30	3,700	5,000	10,000	15,000

50 Hz Cycles	PCR			
	3.5KA	5KA	9KA	14KA
1	6,100	8,800	19,000	33,000
3	4,700	6,800	14,000	25,000
10	3,900	5,700	11,000	20,000
30	3,500	5,000	9,000	14,000

Understanding 60 Hz Fault Current

To select the correct fault current rating, it is necessary to know how much AC fault current is available to flow through the PCR in the event of an AC fault.

Faults from the Primary (Power Utility) System

If the PCR is used to mitigate AC voltage on a pipeline that is in the same corridor as an electrical transmission line, the PCR could be subject to AC fault current from the transmission line in the event of a line-to-ground fault. For safety, the PCR allows all current to pass immediately to ground with minimal voltage drop across the terminals (i.e., less than 10 volts under maximum rated fault current). When the fault condition has cleared, the PCR returns to its normal operating mode, which passes low level steady-state AC current (if present) while blocking the flow of DC current. The PCR can also be installed across an insulated joint to provide over-voltage protection from lightning and AC faults. In this case, the product protects the joint by passing all AC current through the PCR around the insulating joint while limiting the voltage across the joint insulation. After the fault or lightning event, the device automatically returns to its normal mode of blocking the flow of DC current.

Faults from the Secondary (User) System

For example, consider a PCR used to provide AC grounding and DC isolation for an item of electrical equipment that is an integral part of a cathodically protected pipeline (e.g., a motor-operated valve). If the equipment has an electrical short-circuit, the PCR allows all current to flow through itself to ground, thus grounding the fault. The amount of available secondary fault current can be calculated from the data on the transformer nameplate (kVA rating, the % transformer impedance, and the transformer secondary voltage) using the information in the next section.

How to Determine Fault Current Available for a Specific Application

- If the potential fault current is from the primary (power utility) system, call the local power utility and request the phase-to-ground fault current magnitude and duration (i.e., number of cycles of current) at the specific locations of interest.
- If the potential fault current is from the secondary (user) system:

Step 1: determine the "secondary full load current" of the transformer providing power by using the appropriate following formula:

$$\text{Secondary Full Load Current} = \frac{1 \text{ Phase Transformer kVA}}{\text{kV Secondary}}$$

OR

$$\text{Secondary Full Load Current} = \frac{3 \text{ Phase Transformer kVA}}{\sqrt{3} \text{ kV Secondary}}$$

Step 2: Determine the "worst-case" fault current using the following formula.

$$\text{Available Fault Current} = \frac{\text{Secondary Full Load Current}}{\% \text{ Transformer Impedance}} \times 100$$

(This gives the fault current available directly at the transformer terminals, which is the worst case scenario. Fault current decreases rapidly with distance from the transformer.)

Select a PCR fault current rating that encompasses the fault current available. Also see the DEI website for more sizing options.

STEADY-STATE AC CURRENT RATINGS

This rating represents the maximum steady-state AC current that is allowed to flow through the device while still blocking the flow of DC current. Two ratings are available for the PCR.

The table represents maximum values. As the DC voltage approaches the maximum blocking voltage rating selected, the allowable steady-state AC current is reduced as shown in Figures 1 and 2.

Steady-State Current Ratings (Amps AC-RMS Symmetrical)

Ambient Temp	50/60 Hz Ratings	
	Standard 45A Rating PCR	Optional 80A Rating PCR
	20°C	50A
65°C	40A	70A

There are a number of applications where a PCR may be required to block DC while simultaneously carrying steady-state AC current. For example, when a pipeline is in the same corridor as an electrical transmission line, steady-state AC voltage is often induced on the pipeline. The PCR can mitigate this voltage by providing a low AC impedance path to ground while simultaneously preventing the flow of DC current.

The steady-state AC impedance of the PCR at 60 Hz is 9.8 milliohms for the standard 45 ampere rating and 4.9 milliohms for the optional 80 ampere rating. At 50 Hz, the comparable impedances are 11.9 milliohms for the standard 40 ampere rating and 5.8 milliohms for the optional 70 ampere rating. Under an AC fault or lightning current condition, these impedances momentarily become virtually zero.

Determining Steady-State Current Rating

To determine the steady-state AC current rating it is necessary to determine how much steady-state AC current is available to flow through the PCR. If this cannot be determined by analytical means, it can be measured as follows. Connect a solid jumper (i.e. short circuit) between the two points to which the PCR will be connected and measure the steady-state AC current with a clamp-on AC ammeter. For greatest accuracy, measure during a known electrical system load (on the electrical transmission system) and then ratio the results to the expected peak electrical system load. The local power utility can provide known system load and its ratio to peak system load. Select a steady-state rating that is above the maximum steady-state current to be expected for the foreseeable future.

DC BLOCKING VOLTAGE RATING

The standard, and most commonly

specified, PCR model has an asymmetrical voltage blocking rating of -3.0 volts to +1.0 volt. Either model can also be furnished with a symmetrical voltage blocking rating of +/- 2.0 volts. Other voltage blocking ratings will be considered upon request.

The reasons for symmetrical and asymmetrical choices are best described with an example. If the PCR is used to provide over-voltage protection for an insulated joint and both sides of the joint are cathodically protected, the DC voltage across the joint will be the difference in voltage between the two cathodic protection systems, normally near zero volts. For this application it is desirable to select the symmetrical +/- 2.0 volt blocking rating. In the event that the cathodic protection system is OFF on one side of the joint, the device can block $2.0 V_{DC}$ in either direction.

If one side of the insulated joint is cathodically protected and the other side is grounded, then it is preferable to select the asymmetrical version which blocks from -3.0 volts to +1.0 volt since DC current flow only needs to be blocked

in one polarity. Whenever one side is referenced to ground, the asymmetrical version is suggested because this initiates voltage clamping when any positive voltage on the cathodically protected structure attempts to exceed +1.0 volt.

The DC leakage current of any model is well under 1.0 milliampere under typical operating conditions where the DC voltage is in the 0.85 to 1.25 V range, even when the temperature is up to 65°C. See Figure 3.

LIGHTNING SURGE CURRENT RATING

All models have the same lightning surge current rating which is shown in the following table.

Lightning Surge Current Rating	
For all models PCR	
Peak Amperes	100,000

Note: 8 x 20 microsecond waveform

FIGURE 1 PCR Operating Characteristics @ 43°C (Standard 45A @ 50/60 Hz)

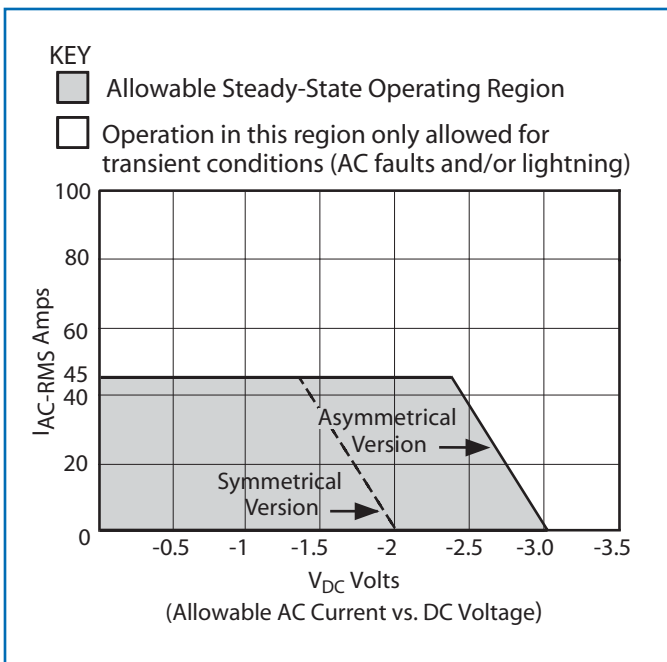
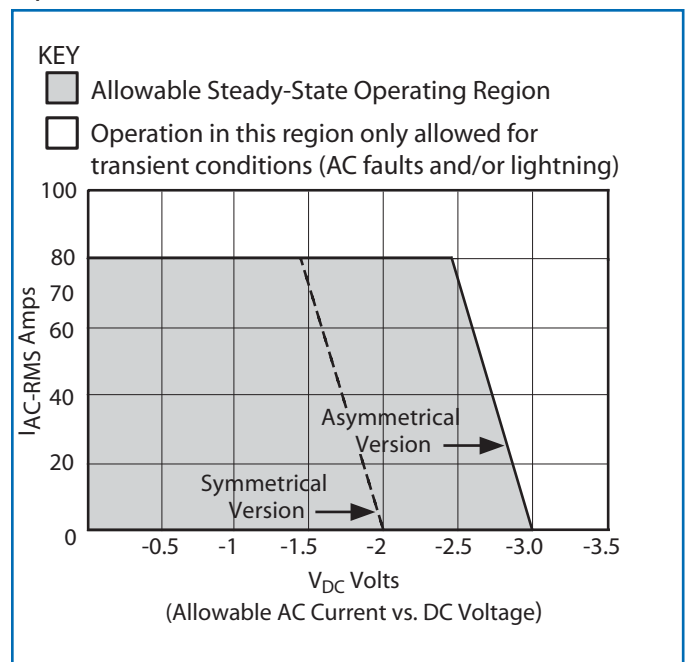


FIGURE 2 PCR Operating Characteristics @ 43°C (Optional 80A @ 50/60 Hz)



When providing over-voltage protection from lightning, the PCR should always be installed with the shortest possible lead length to minimize clamping voltage. When used across an insulated joint, the PCR can, and should, be installed with about 6" (≈ 150 -mm) leads.

The peak voltage directly across the voltage-clamping elements within the device is less than 250 volts at rated lightning surge current; however, the voltage developed between the lead connection points will be greater due to the effect of lead inductance. Leads can develop from 1 to 3 kV per foot (approx. 3 to 10 kV/meter) when subject to lightning current. This is the reason that leads should be kept as short as possible.

FEATURES AND CHARACTERISTICS

Certifications

Underwriters Laboratories (UL) has listed the PCR as meeting the criteria for "an effective grounding path" as defined in Section 250.2 and 250.4(A) (5) of the 2005 edition of the U.S. National Electrical Code (NFPA 70), thereby enabling its use as an AC grounding device. The PCR is also C-UL listed in Canada as meeting the criteria for "an effective grounding path" as defined in CSA Code Section 10-500, 10-806, and CSA C22.2 No. 0.4-M1982.

The PCR is also listed by UL as meeting:

- The requirements of a DC isolating/AC coupling device suitable for the isolation of objectionable DC current from cathodically protected systems to ground as defined in the 2005 edition

of the NFPA 70 Article 250.6(E).

- An over-voltage protective device, having been tested to the applicable requirements of ANSI C62.11.

Listings specific to hazardous locations are summarized as follows:

The PCR is listed by Underwriters Laboratories (UL) for use in hazardous locations in accordance with NFPA 70 (U.S. National Electric Code), Articles 500-505 for Class I, Division 2, Groups A, B, C, and D. The applicable UL standard to which the PCR is listed is UL 1604 which deals with non-sparking products to meet Class I, Division 2 requirements. The PCR is also C-UL listed to the above classifications per Canadian code C22.2 No. 213-M1987.

For Zone 2 use, the PCR has been given a Type Examination by a Notified Body (UL/Demko) for compliance to ATEX directive 94/9/EC using EN50021. The device is marked II 3 G EEx nA II T5.

Solid-State Design

The PCR is built with proven solid-state components which have an instantaneous response with respect to voltage, thereby initiating voltage clamping immediately when the voltage attempts to exceed the blocking level selected.

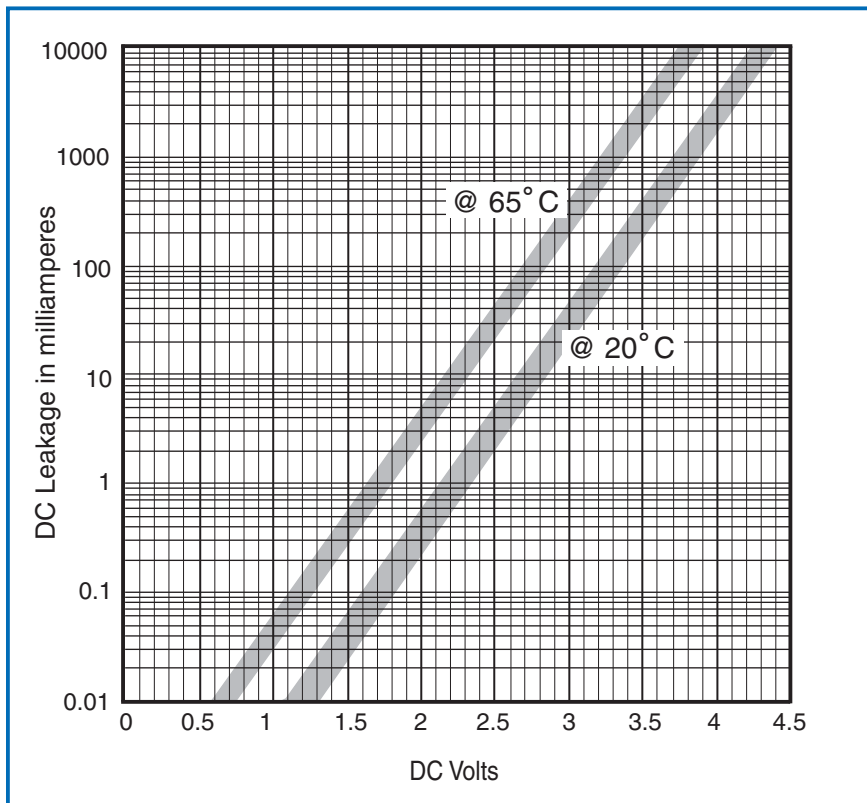
Fail-Safe

An important safety feature for the PCR is that if subject to AC fault current or lightning surge current in excess of rating such that failure occurs, failure will occur in the shorted mode. In the shorted mode, the unit can carry greater than rated fault current or lightning surge current and still provide an effective grounding (or conducting) path.

Enclosure

The PCR enclosure is made of a light gray fiberglass-reinforced polyester material suitable for outdoor non-submersible applications and is rated NEMA 4X (comparable to IP 66). Optionally, the PCR can be supplied as a submersible device with the same dimensions rated

FIGURE 3 DC Voltage vs. DC Leakage Current (Standard Asymmetrical PCR with -3V / +1V Blocking Voltage)



NEMA 6P (comparable to IP68). The PCR enclosure is not "explosion-proof" because this is not a requirement for a Class Division 2 listing.

Mounting

The PCR is made to mount on a flat surface (e.g., a rectangular wood treated post) with two 3/8" (≈10mm) diameter bolts furnished by user; however, a number of optional mounting methods and accessories are available for specific applications.

For insulated joint application, various bus bar mounting arrangements can be furnished as an option. This maximizes joint protection by minimizing lead length, and provides physical support for the PCR.

For AC mitigation and similar applications, the PCR can be mounted inside of an enclosed pedestal which is partially buried in the earth. See Figure 6.

Packaged Weight / Unit

Approximately 12 to 20 pounds (5.5 to 9.1 kg) depending on model selected, exclusive of packaging.

Polarity / Electrical Connection

Polarity marks (+) and (-) are provided above the lead connection points to aid in proper installation. Connect the (-) to the structure with CP and the (+) to the grounded, or more positive, system. Connections are normally made with leads to two-hole terminal pads which already contain 1/2" stainless steel bolts, nuts and washers (unless an alternate connection method is selected). Leads and compression connectors are normally user furnished.

Terminals, pre-connected to adapter plates, are also available to facilitate mounting across insulated joints or to similar bolted connection points.

Size

Refer to the following figures for dimensional data for each model. Figures 7A-7D.

Ambient Temperature

-45° C to +65° C

Number of Operations

Virtually unlimited under maximum ratings, provided the operations are not immediately repetitive.

Energy Requirements:

None. The devices are totally passive.

Moden Number Structure

For Class 1, Div. 2, Zone 2 and Non-hazardous locations

Model # = PCR-A/B-C-D-E

Select desired value for "A." Model positions "B" through "E" are options to be specified only if required. (Any accessories must be ordered separately by model number.)

A: Fault Current

Symmetrical AC-RMS fault current rating at 30 cycles in kA .

(See previous rating table for capability at 1, 3, and 10 cycles.)

60 Hz	50 Hz
3.7KA	3.5KA
5.0KA	5KA
10KA	9KA
15KA	14KA

Examples:

PCR-10KA (60Hz)
PCR-3.5KA (50Hz)

B: Steady-State Current

Optional higher AC current rating.

If the standard 45 ampere rating at 50/60 Hz is acceptable, then omit "B."

(The standard rating is sufficient for most applications.) If a higher steady-state rating is required, insert **"/80A"** to specify an 80 ampere rating at 50/60 Hz .

Example:

PCR-10KA (Standard rating)
PCR-10KA/80A (Optional Rating)

C: Asymmetrical vs. symmetrical voltage blocking

The standard PCR has asymmetrical voltage blocking characteristics. It blocks the flow of DC current from -3.0 volts to +1.0 volt. Omit "C" if the standard asymmetrical blocking is acceptable (suitable for most applications). If it is desired to have a PCR that has symmetrical voltage blocking, from -2.0 volts to +2.0 volts, then specify **"S"** in this model position.

Example:

PCR-3.7KA (Asymmetrical blocking)
PCR-3.7KA-S (Symmetrical blocking)

D: Terminals

Two-hole spade terminals are standard, but compact connectors and 4 hole NEMA terminals are available. See photos on the following page (4 hole terminals not shown). Compact connectors are recommended where necessary to insulate the connections to the PCR after installation (for example, with a user furnished heat-shrink sleeve). Add **"CC"** to the end of any model number only if compact connectors are required, or **"4H"** for 4 hole terminals.

Examples:

PCR-10KA (Standard connector)
PCR-10KA-CC (Compact connector)
PCR-15KA-4H (4 hole terminal)

E: Options

Any factory authorized option may be added to the end of the catalog number. Select **"-CS2"** to obtain a PCR with a NEMA 6P envi-

ronmental rating for submersion.

Example:

PCR-3.7KA-CS2.

Accessories

If desired, order separately as follows:

Weld Tab Mounting Option

For certain insulated joint applications, the Weld Tab Mounting option is desirable where welding to the flange is permitted (user determined) because this minimizes lead length and maximizes over-voltage protection due to lightning. This option is limited to the following PCR models: PCR-3.5KA, PCR-3.7KA, PCR-5KA, PCR-9KA, and PCR-10KA. (If this option is desired for any other model, contact DEI.)

See Figure 5 for Weld Tab Mounting details. Standard PCR terminals are required with the WTM option.

The channel bracket, normally furnished with a PCR will be omitted as it is not used when this option is provided.

Pedestal Mounting Options

A light green 36" fiberglass pedestal is available for enclosing the PCR and all cable connections. When the PCR is used in applications where both cable lead connections come from below ground level (e.g., AC voltage mitigation applications) or where it is desired to provide a second level of protection around the standard PCR enclosure, the Pedestal Mounting Option can be ordered as an accessory. All mounting

The PCR with Standard Connectors



hardware required to mount the PCR in the pedestal will be packaged with the PCR. The channel bracket, normally furnished with a PCR, will be omitted.

See Figure 6 for Pedestal details. The height of the standard pedestal is 36". To order, specify **Pedestal-36"** plus the desired PCR model.

Example:

Pedestal-36

Lead/Connector Options

It is suggested that users furnish their own leads and connectors required to attach to the PCR terminals; however DEI will furnish one lead size, suitable for any fault current rating, when specified. The standard lead is insulated, extra flexible, 2/0 AWG copper cable.

All leads are provided with a compression terminal on one end ready for attaching to the PCR terminal pad. The following lead options are available.

Note: Two leads required per PCR.

Lead # = L - T

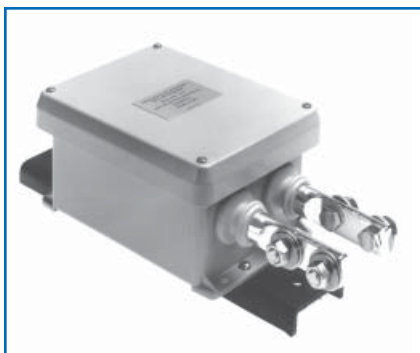
L = desired lead length in inches or mm. Specify length and units of measurement.

T = Specify BT3/8-10 for a bolted terminal which is attached with a 3/8" or 10 mm bolt, or NT for No Terminal.

Examples:

Lead # = 10"-BT3/8-10

The PCR with Compact Connectors



Lead # =300mm-BT3/8-10

Lead # = 12"-NT

If Leads and Adapter Plates (described in the next section) are purchased, specify NT above because the required terminals are furnished with the Adapter Plates.

Bolted terminals are furnished instead of compression connectors so that a compression tool is not required for field installation. Bolted terminals also enable a user to cut the lead to the shortest allowable length and install it with readily available tools in the field.

Lead Adapter Plate Option

If the PCR leads are to be bolted to their connecting points in the field, such as across an insulated joint, a 1/8" (3.2 mm) thick, nickel plated copper adapter plate can be furnished to simplify making this connection. The adapter plate has a factory-assembled bolted-type cable lead connector that accepts 2/0 to 4/0 AWG (70 to 120 mm²) conductor with a mounting hole size specified by the user. Reference Figure 4 for Adapter Plate details.

If Adapter Plates are desired, specify model **AP- "D"** where **"D"** is the bolt diameter in inches or mm. The resulting hole diameter in the adaptor plate will allow sufficient clearance for the outer diameter of the insulating sleeve over the flange bolts. Ideally, the insulating sleeve over the bolt, and the bolt to which the adapter plates are attached, should be 1/4" (6.4 mm) longer than the other sleeves/bolts to account for the thickness of two adapter plates. Most manufacturers of insulated joint kits can provide one different length bolt and insulating sleeve in an insulation kit upon request.

Pipe Mounting Options

Any PCR model can be furnished with a stainless steel backplate and U-bolts suitable for mounting to a user-furnished 2" pipe (outer diameter 2.375" or 60.3 mm). To order, specify part

number PM2.

A complete Pipe Mounting Kit includes the above items plus a 2" diameter pipe, 48" (1219 mm) long, a 4-bolt threaded pipe flange base suitable for mounting to a field fabricated concrete foundation, and four 5/8" x 12" (\approx 16 mm x 305 mm) galvanized anchor bolts, each with two nuts. Complete Pipe Mounting Kits can be ordered with any PCR model by specifying model PMK2-48.

FIGURE 4 Adapter Plates

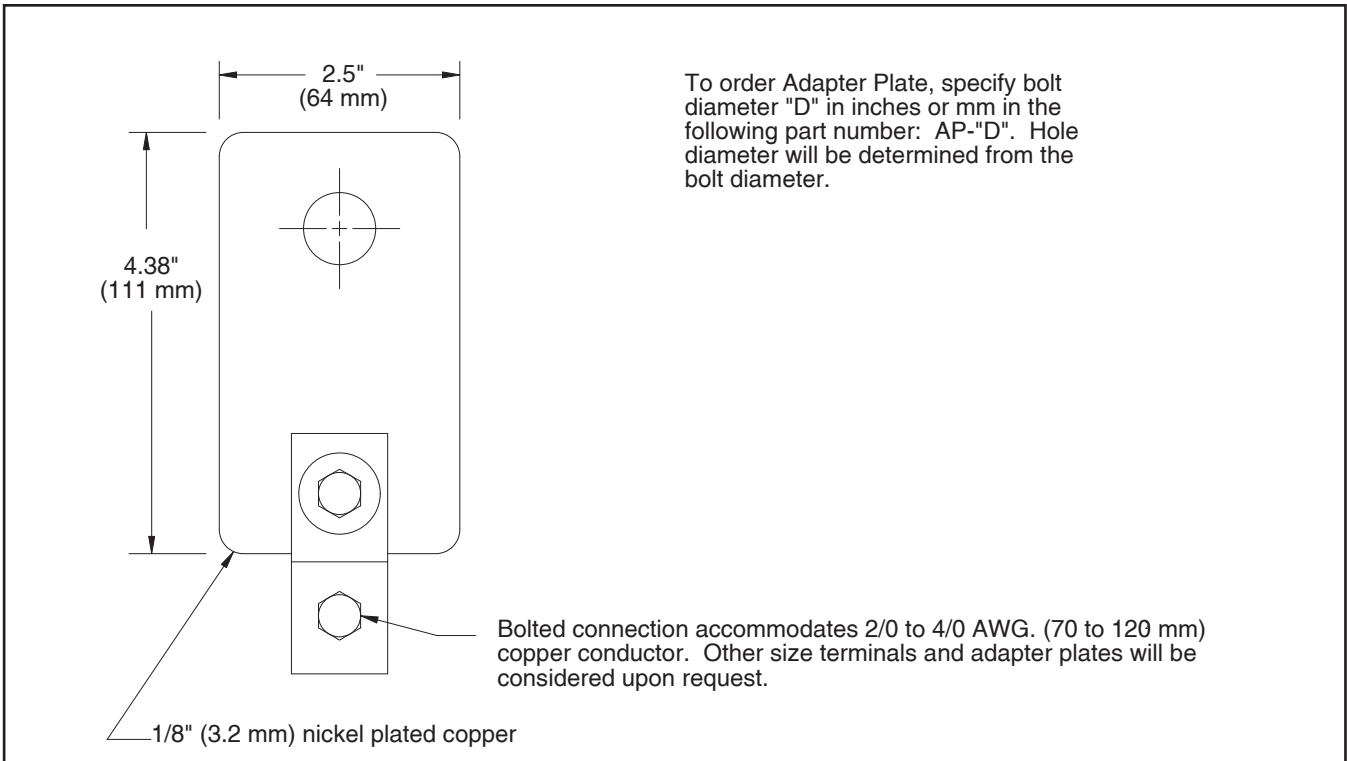
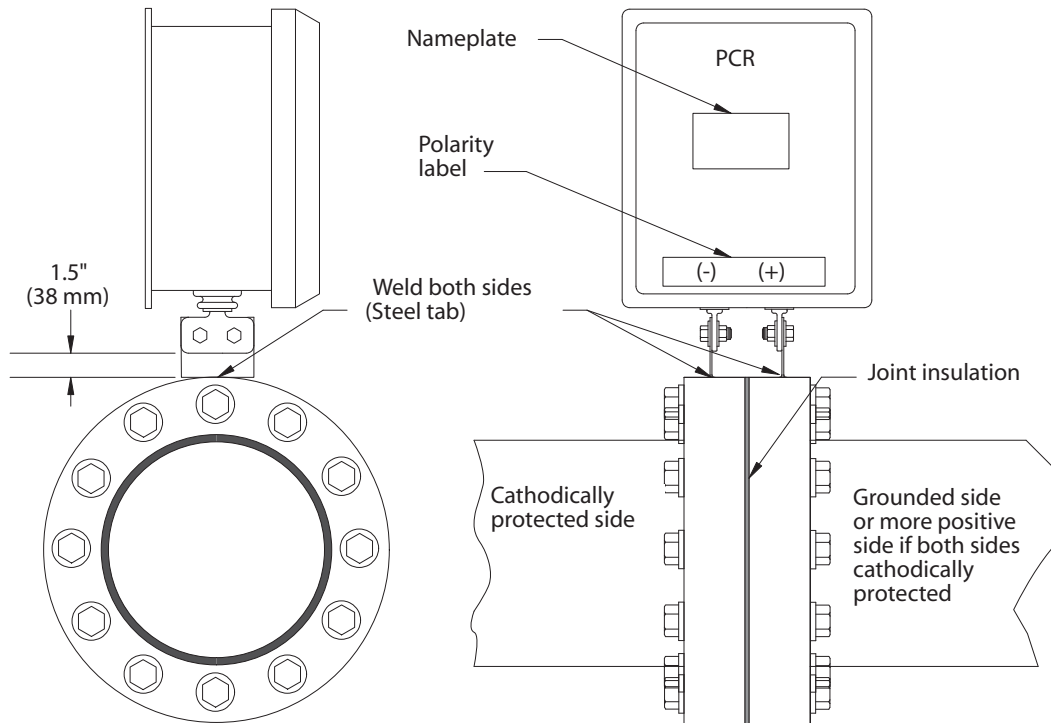


FIGURE 5 Weld Tab Mounted PCR



User to determine if welding to the flange is acceptable.

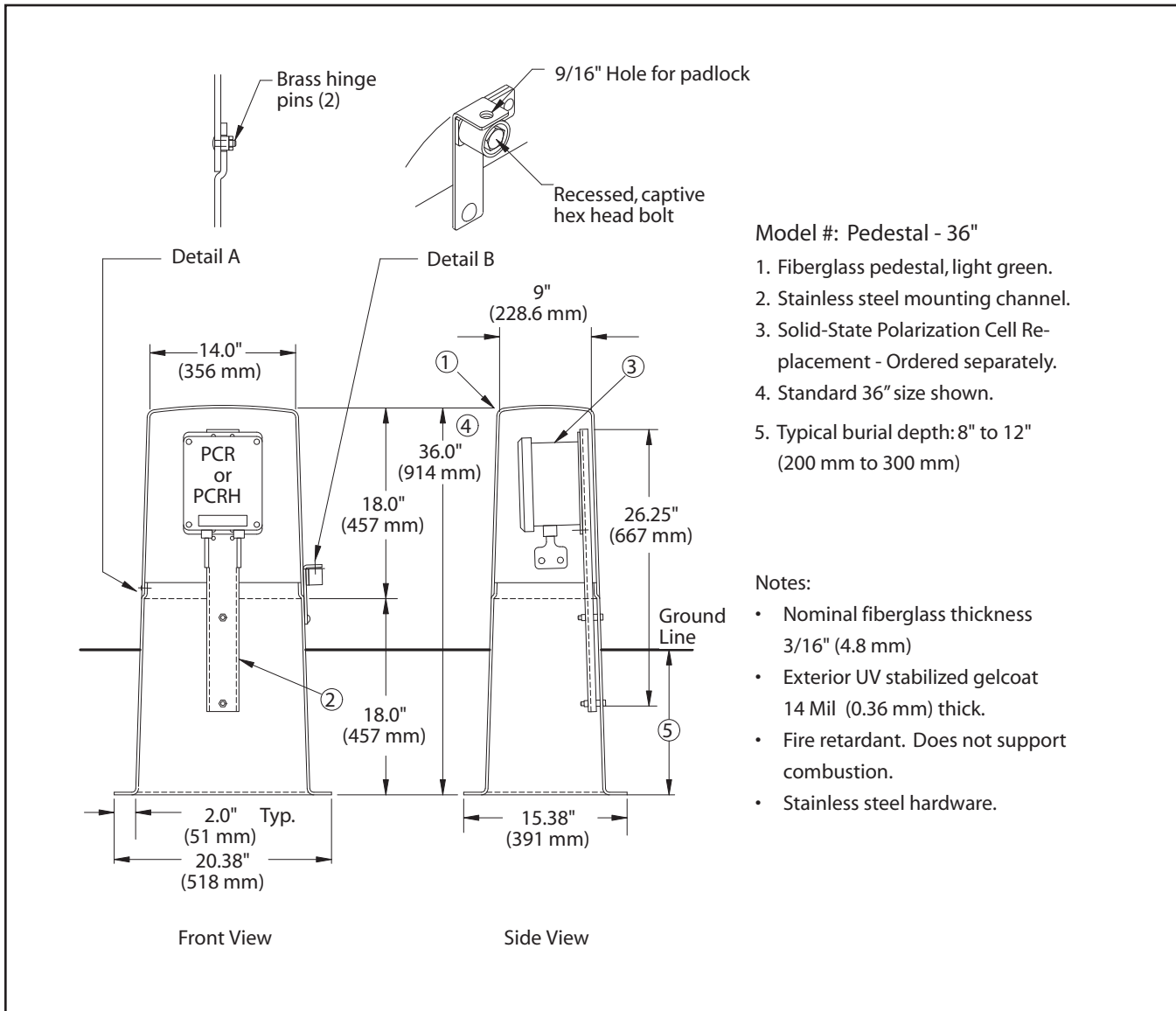
Applies to Models:

PCR-3.7KA, PCR-5KA and PCR-10KA @ 60 Hz

PCR-3.5KA, PCR-5KA and PCR-9KA @ 50 Hz

(Not applicable to PCRH Models.)

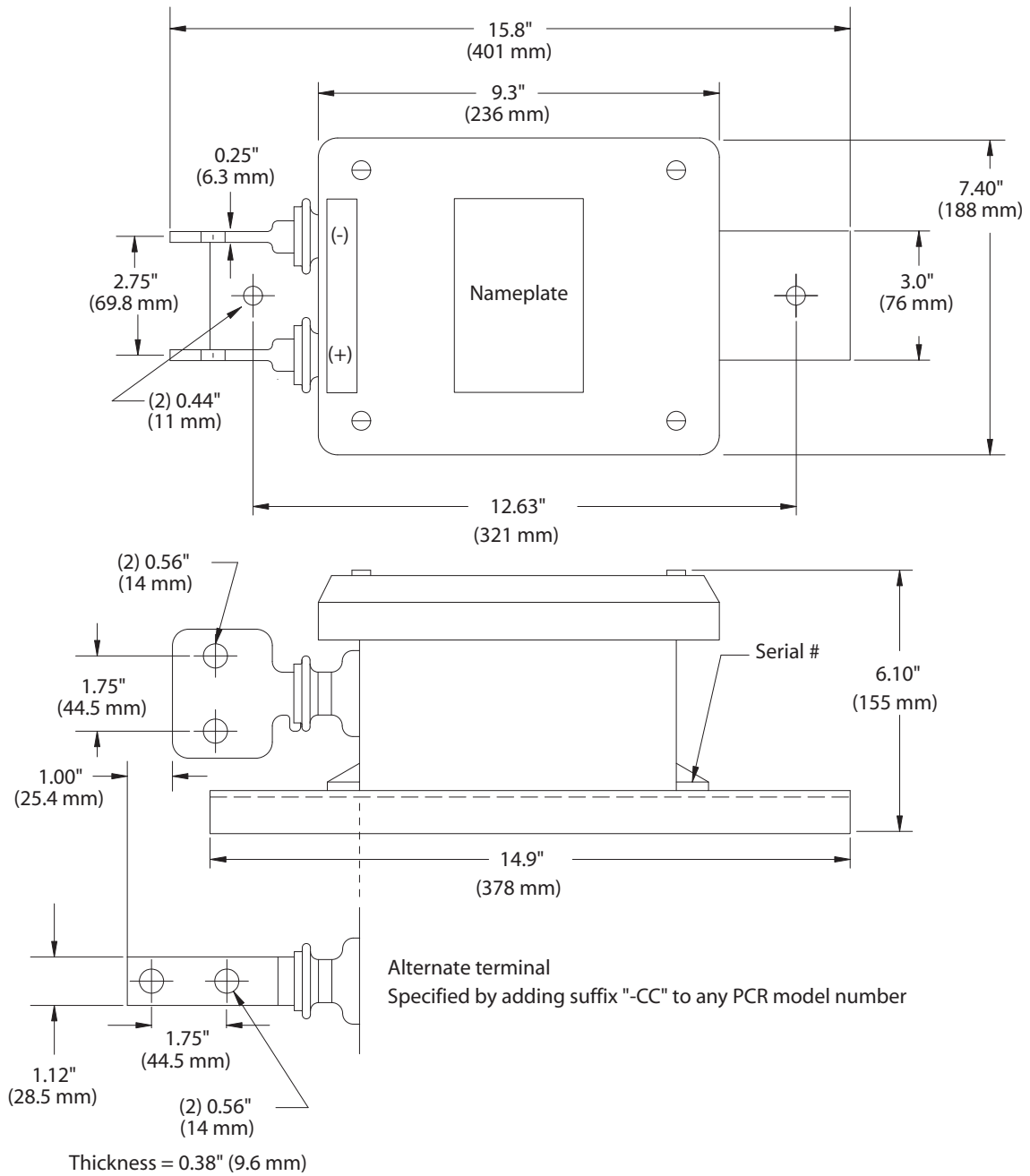
FIGURE 6 Pedestal Mounted PCR



- Model #: Pedestal - 36"
1. Fiberglass pedestal, light green.
 2. Stainless steel mounting channel.
 3. Solid-State Polarization Cell Replacement - Ordered separately.
 4. Standard 36" size shown.
 5. Typical burial depth: 8" to 12" (200 mm to 300 mm)

- Notes:
- Nominal fiberglass thickness 3/16" (4.8 mm)
 - Exterior UV stabilized gelcoat 14 Mil (0.36 mm) thick.
 - Fire retardant. Does not support combustion.
 - Stainless steel hardware.

FIGURE 7A PCR Outline Dimensions



Applies To Models:

PCR-3.7KA PCR-5KA & PCR-10KA @ 60 Hz

PCR-3.5KA, PCR-5KA & PCR-9KA @ 50 Hz

FIGURE 7B PCR Outline Dimensions

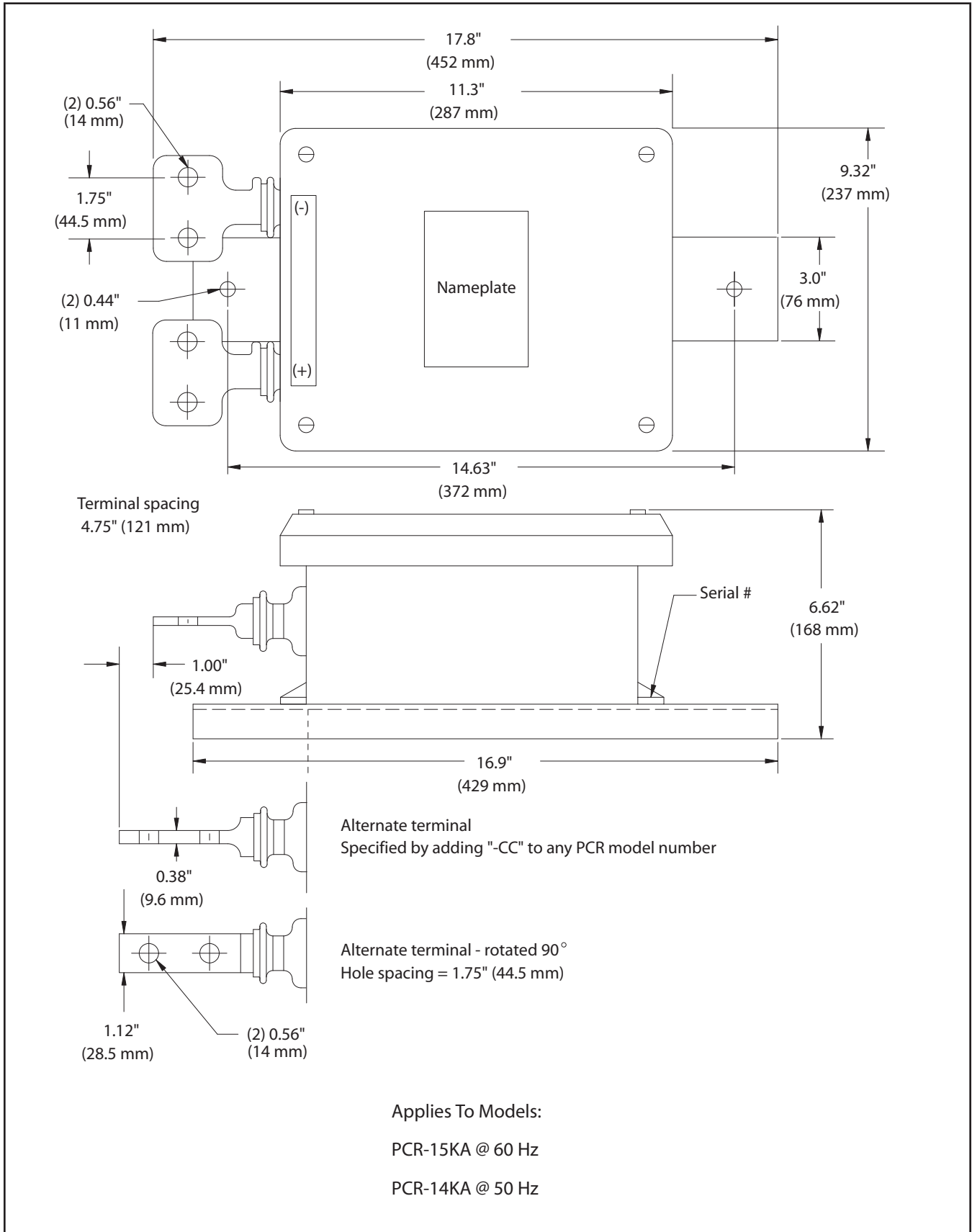
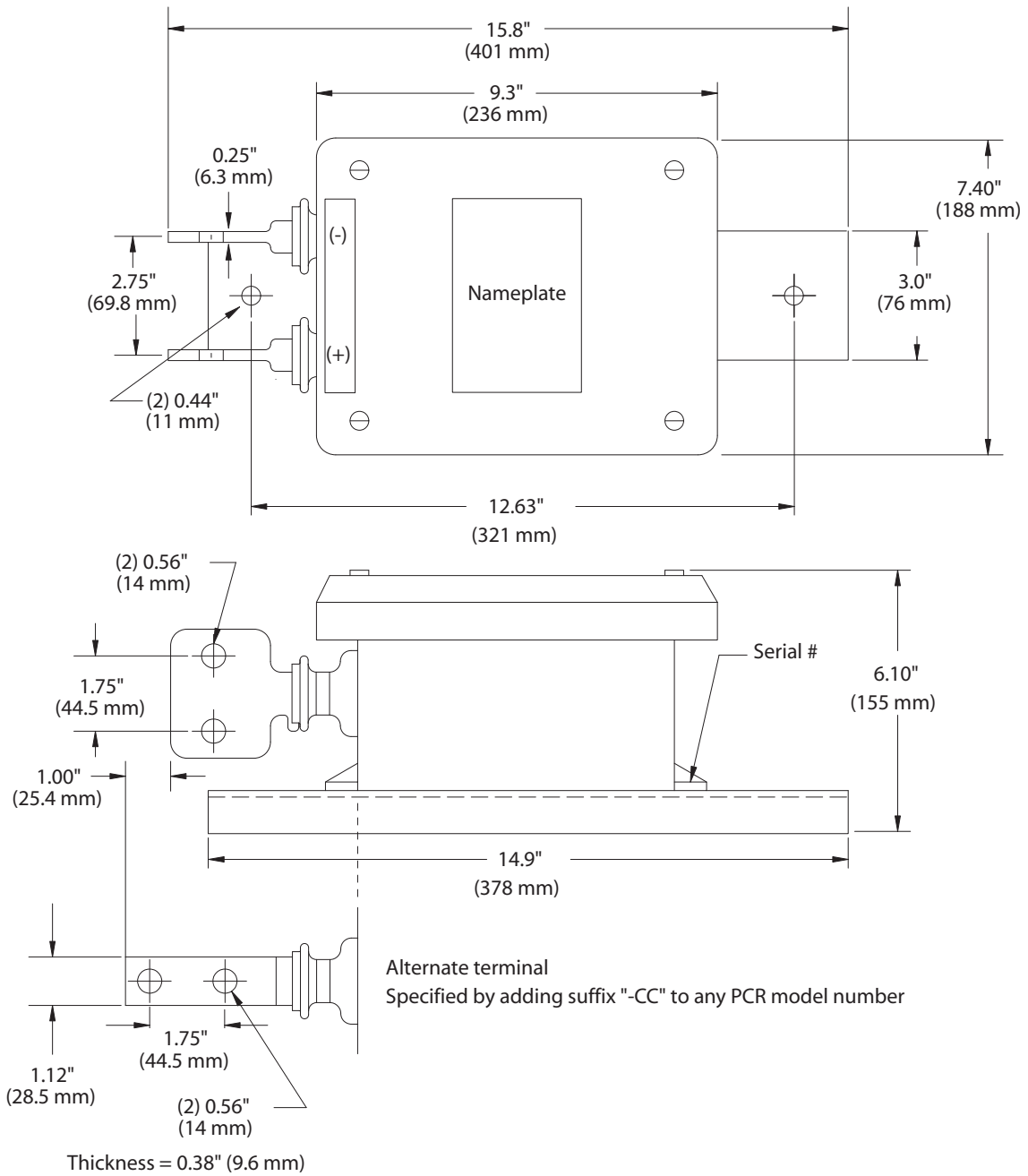


FIGURE 7C PCR Outline Dimensions

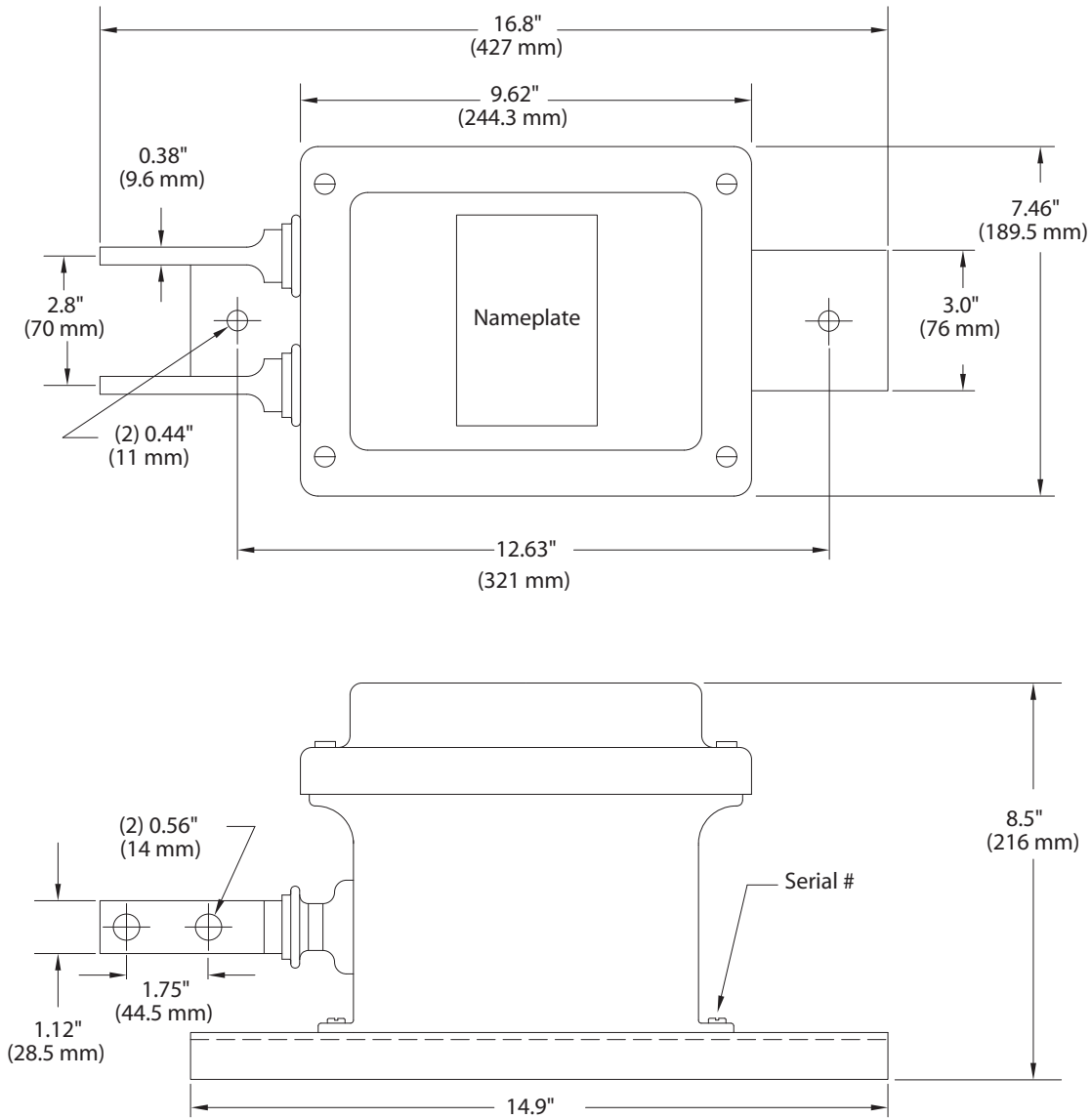


Applies To Models:

PCR-3.7KA PCR-5KA & PCR-10KA @ 60 Hz

PCR-3.5KA, PCR-5KA & PCR-9KA @ 50 Hz

FIGURE 7D PCR Outline Dimensions



Applies To Models:

PCR-3.7KA/80A, PCR-5KA/80A and PCR-10KA/80A @ 60 Hz

PCR-3.5KA/80A, PCR-5KA/80A and PCR-9KA/80A @ 50 Hz

See notes in Figure 7C regarding alternate enclosure.