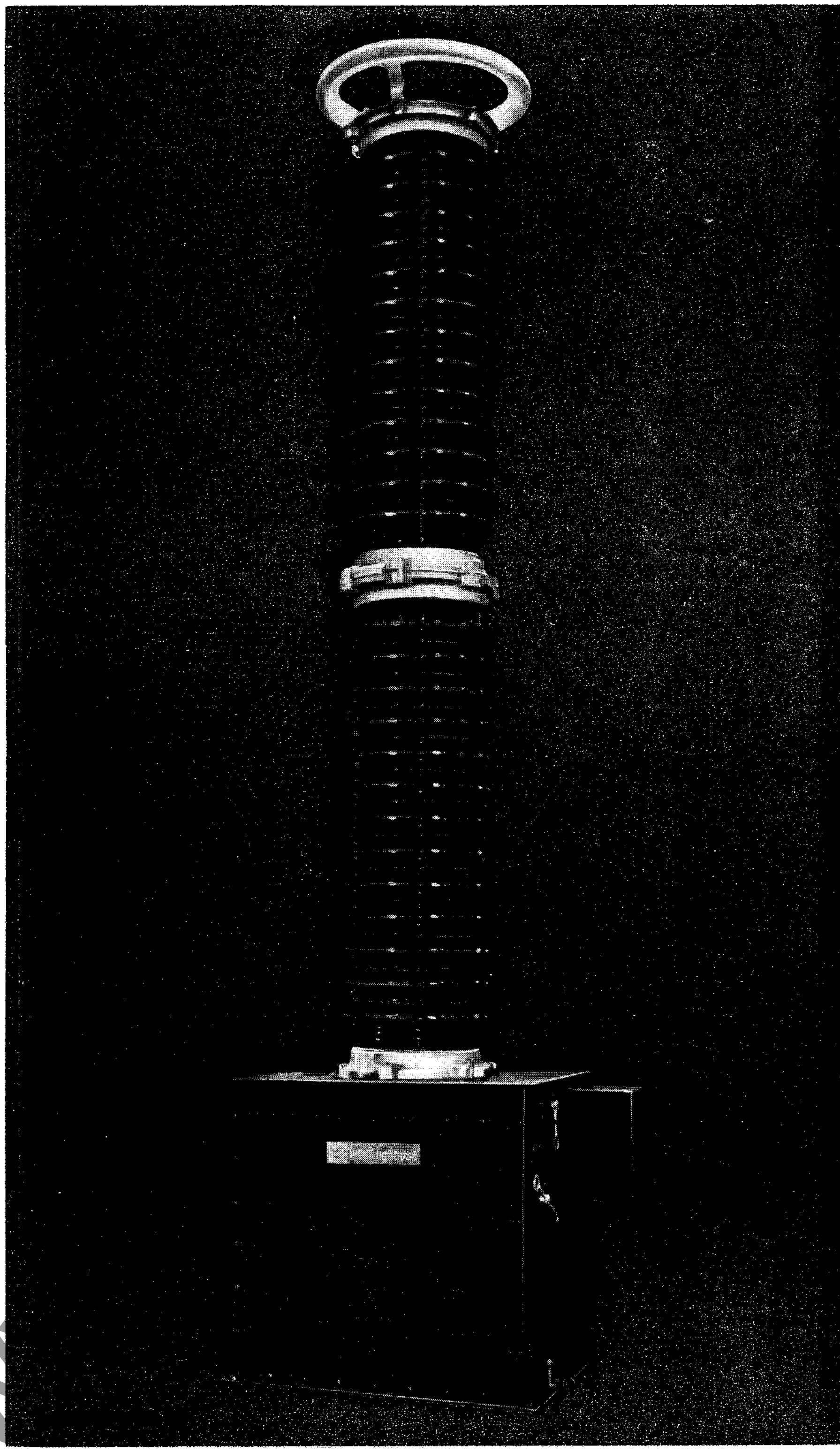
Westinghouse

# Potential Devices for Revenue Metering
Type PCM

# Coupling Capacitors
Type PC-6



Like many advancements in electrical equipment design, economic considerations first prompted a study of the use of a highly refined capacitive potential device for supplying a secondary voltage for revenue power metering. As transmission voltages moved up to 345 and 500 kv, the expanding differential in insulation costs between a wound type potential transformer and a capacitive voltage divider demanded that this new application be seriously examined. After nearly two years of design work, development and testing, it was proved that the capacitive device was, indeed, capable of achieving the required accuracy performance, dependent only on using the proper design parameters in the potential device circuitry. Basically, the Westinghouse type PCM metering accuracy potential device involves no new design concepts nor untried materials. The PCM design merely represents a refinement of the standard potential device circuitry employed for many years to give secondary voltages for purposes of relaying, telemetering, supervisory control, and voltage indication.

As general acceptance of the PCM device as a reliable source of metering potential continues to increase, the PCM promises to find new applications on systems rated lower than the EHV range. This is particularly true where the carrier function is also required, since this can easily be incorporated into the PCM device, whereas a separate coupling capacitor would be required if potential transformers were used for metering. The PCM device is available in voltage ratings from 115 kv to 700 kv. The base cabinet and the circuit components contained therein are identical regardless of voltage rating. To increase voltage ratings above 115 kv, additional coupling capacitor units are merely stacked in series to achieve the desired rating. This modular construction has the advantage of ease in handling, shipping and installation, and minimum risk in breakage.

The type PC-6 coupling capacitor is an extra high capacitance unit which does not contain the PCM potential device circuitry.

January, 1967
New Information
E, D, C/2003/DB

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## Application

(See photo on page 12)

The PCM device is applied mainly where inter-ties between two utilities require revenue power metering at HV or EHV levels. The PCM employs an extremely accurate version of the basic capacitive divider network, using a 20 kv tap voltage to drive a tunable, circuit consisting of the tap capacitance, an oil-filled transformer-reactor combination having very fine adjustment taps, and a ferroresonant suppression device. Potential for revenue metering which meets ASA standard 0.3 accuracy class requirements is available on each of two independent secondary windings, tapped to obtain the ASA standard ratio (such as 1200/2000 to 1 for 230 kv). A third winding is available for connection in broken delta with the two potential devices on adjacent phases when residual voltage is desired for polarization of ground relays.

The PCM is designed to stay within the 0.3 parallelogram of a Farber diagram (Figure 1) for all standard burdens ranging from 0 to 400 volt-amperes, which includes W, X, Y, Z, and ZZ burdens. The following table summarizes these burdens as defined in Instrument Transformer standards, ASA C57.13. *No change in internal connections* nor recalibration is necessary regardless of how actual burdens are varied within this range. Also included is the accuracy class of each secondary winding.

Further versatility is provided since the zero volt-ampere point can be shifted downward, outside the .3 parallelogram to meet known burden requirements; e.g., a range of 200 va to 600 va could easily be provided. (See Figure 2 on page 6).

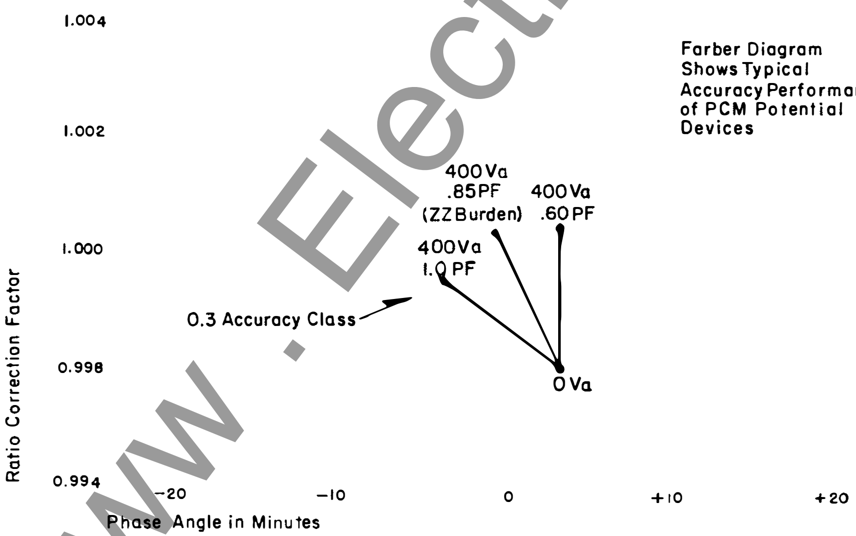
All PCM devices are factory tuned, calibrated and tested to assure compliance with .3 accuracy class requirements. A ratio and phase angle bridge, recognized by the National Bureau of Standards, is used in conjunction with a gas-filled high voltage capacitor to calibrate the PCM devices. The bridge is capable of measuring errors of ±.01% in ratio and ± 1.0 minute in phase angle.

Unlike old types of potential devices, no further tuning in the field is necessary, during or after installation, regardless of the actual burden to be connected to the device.

### Accuracy Performance

| Standard Burden Designation | Secondary Volt-Amperes | Power Factor of Std. Burden | Accuracy Class | |
|---|---|---|---|---|
| | | | $X_1$-$X_2$-$X_3$ or $Y_1$-$Y_2$-$Y_2$ Windings | $W_1$-$W_2$-$W_3$ Winding① |
| W | 12.5 | 0.10 | .3 | 1.2 |
| X | 25 | 0.70 | .3 | 1.2 |
| Y | 75 | 0.85 | .3 | . . . |
| Z | 200 | 0.85 | .3 | . . . |
| ZZ | 400 | 0.85 | .3 | . . . |

① The maximum permissible burden of the "W" winding (used for zero-sequence voltage) is 50 va.




Farber Diagram Shows Typical Accuracy Performance of PCM Potential Devices

Figure 1

## Construction

Coupling units used in PCM potential devices and PC-6 carrier coupling capacitors are of the extra-high capacitance type. The microfarad value is about three times that of the "high-capacitance" PC-5 type and almost nine times that of the "low capacitance" PC-4 type. The unit consists of a wet-process porcelain cylinder fitted with end castings.

Cork neoprene gaskets coated with a resilient adhesive provide a reliable seal against moisture. This cylinder contains a large number of individual wound-type capacitor sections connected in series. Operating voltage stress on these sections is extremely low, insuring the very high reliability required of a potential device or coupling capacitor.

After the capacitor sections are assembled into a series stack, the stack is subjected to a vacuum-heat cycling process designed, not only to remove all free moisture, but also to break down and remove any low molecular weight impurities from the kraft paper.

The lower coupling unit in a stack is always equipped with a tap bushing, which provides the 20 kv capacitor necessary to operate the potential device circuit of the PCM. When a PC-6 coupling capacitor only is ordered, this tap is still provided to allow for future addition of a potential device circuit.

Note that the tap capacitance is contained in the same housing as the stack capacitance. This provides for a constant ratio between stack capacitance and tap capacitance, regardless of temperature changes. This arrangement contributes greatly to the ability of the PCM to meet .3 accuracy class requirements.

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**Coupling Capacitors**
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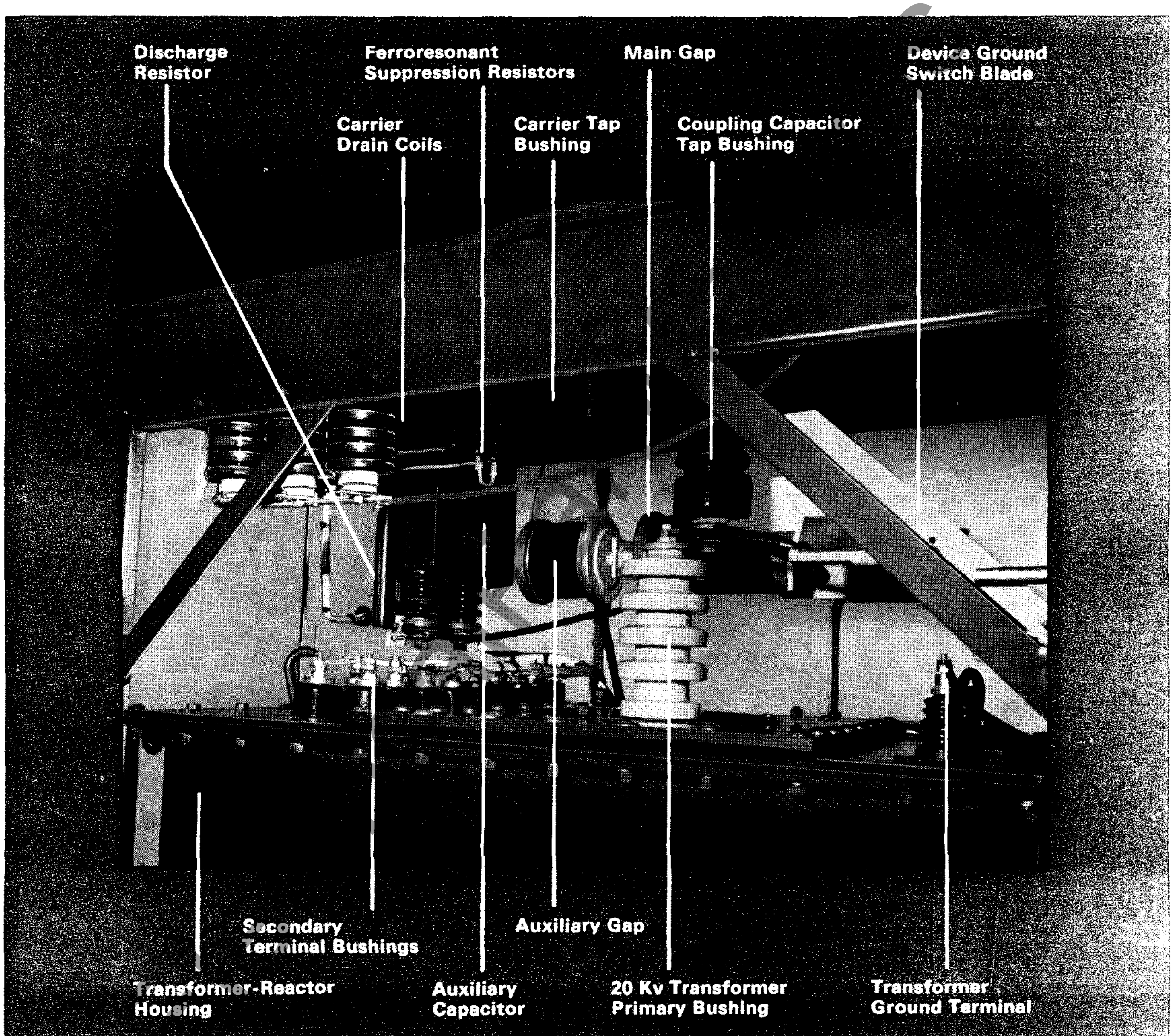

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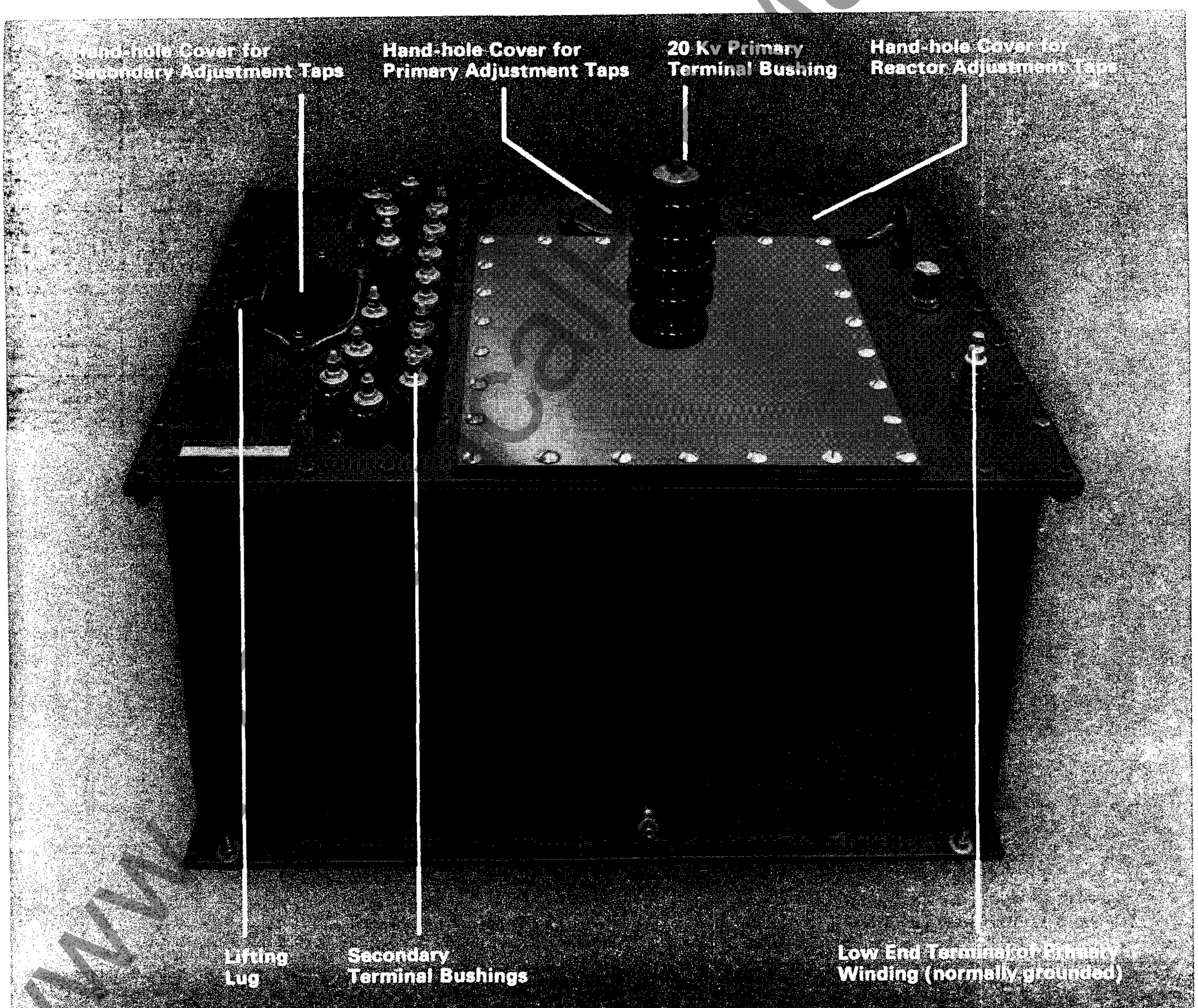
### Transformer-Reactor

A specially designed, extremely accurate oil filled potential transformer operates from the 20 kv source provided by the capacitive voltage divider. Three secondary windings, designated X, Y, and W, are each tapped for approximately 115/67 volts. (The actual voltage is determined by the ASA standard ratio for each rating.) Both the primary and secondary windings are equipped with very fine adjustment taps to allow pinpoint accuracy in obtaining the ASA standard ratio of transformation.

An integrally mounted reactor in series with the primary winding of the potential transformer, is also equipped with fine taps to allow exact tuning of the inductive reactance with the capacitive reactance of the coupling capacitors. This tuning is completed at the factory. The L/R ratio, or "Q", of the reactor circuit is very high, thus providing a very low-loss circuit which in turn contributes to accuracy performance.

Thermal burden rating of the transformer is 1000 va, capable of being taken from either of the taps on each of the main secondary windings (X and Y).



### Ferroresonant Suppressor

Since any circuit containing capacitance and iron core inductances is subject to possible ferroresonant oscillations due to saturation, it is necessary to incorporate an effective means of damping these oscillations before they can cause false operations of relays and/or damage to the transformer. The cause of ferroresonance in a capacitive potential device could be a switching surge on the transmission line, removal of a secondary short in the burden connected to the device, or simply opening the grounding switch of the potential device. Any of these conditions or others which present a sudden change in voltage or frequency can shock the circuit into oscillation.

To prevent occurrence of this problem in the PCM device, a tuned filter circuit is employed to insert a dummy load of several hundred watts which effectively damps oscillations before they reach significant magnitudes. Under normal conditions, the suppressor draws only about two volt-amperes burden.

### Terminal Block

An easily accessible terminal block is provided in the side compartment. Here connections can be made for X, Y and W windings and for the heater. The main door of the potential device housing need not be removed.

### Carrier Accessories (Optional)

When the dual function of carrier coupling is desired, the PCM can be equipped with carrier drain coil, gap, and grounding switch, and a carrier lead-in bushing or conduit connector. No loss of accuracy in the potential device is experienced since the PCM is calibrated with the carrier circuitry connected.

### Heater

A heater, center tapped for either 115 or 230 volts, is provided to prevent condensation of moisture inside the cabinet. The heater should be energized from a separate source if available, so that the 400 va burden capability of the PCM device is not reduced.

### Tap for Transient Recorder (Optional)

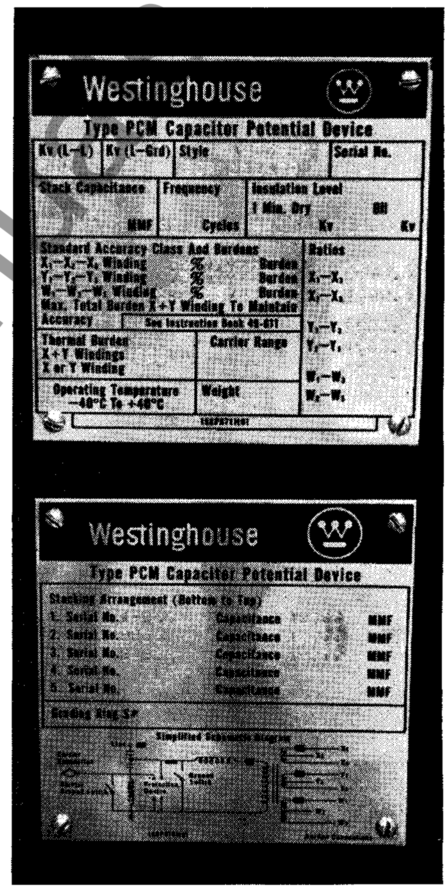
A low voltage tap capacitor can be inserted between the low potential bushing on the coupling capacitor and ground. An oscilloscope or other recording device can be connected across this capacitor to observe the nature of transient phenomena occuring on the transmission line.

### Protective Gaps
### (See Schematic Diagram, Page 9)

The "main gap" is set to fire at approximately 40 kv (twice the normal tap voltage). An auxiliary capacitor with its own protective gap and discharge resistor, are then inserted in series with the arcing gap, thus holding the resultant voltage to half the spark-over value, or about 20 kv, the normal operating voltage. This prevents the secondary voltage (115 volt) from dropping to zero momentarily, which could falsely actuate a relay. Another gap is placed across the carrier choke coil to prevent surge damage.

### Nameplate Data

Coupling capacitor stacking information and other pertinent data (as shown in photo) are provided on two cabinet-mounted nameplates. In addition, each coupling capacitor unit carries its own nameplate with its own identifying serial number.




**Typical Nameplate Data**

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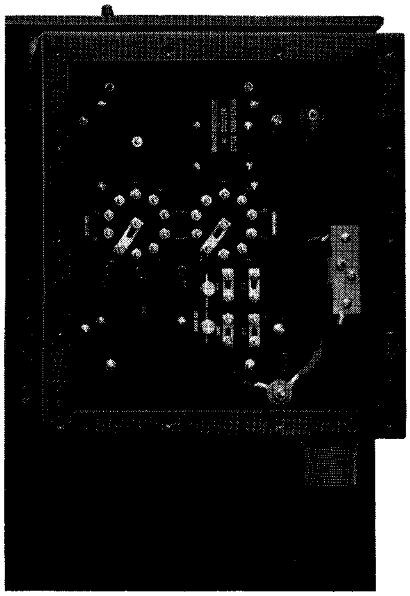
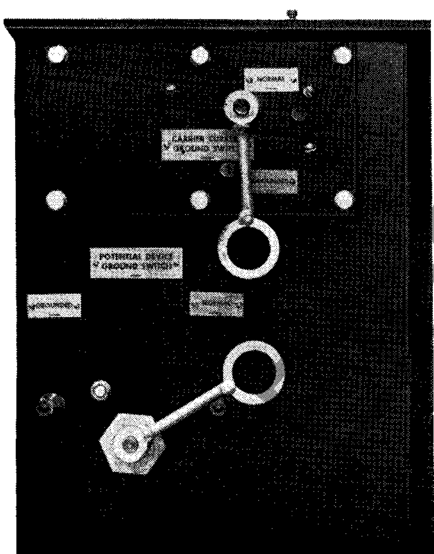
### Hi-Coupler Wide Band Filter (Optional)



The 100 watt, 40 to 200 kc Hi-Coupler filter can be added to a side compartment on the main cabinet for easy accessibility.

### Potential Ground Switch



An externally hookstick-operated ground switch is provided to ground the 20 kv tap voltage if maintenance should be required, in the cabinet without de-energizing the device. The contact is easily visible when the bolted door of the cabinet is removed.

## Flexibility of the PCM device

The standard PCM device is guaranteed to hold the .3 accuracy class for all burdens from 0 to 400 va having any power factors from .6 to 1.0. However, if the characteristics of a burden are known before the device is calibrated at the factory, the PCM can be calibrated to that burden, resulting in accuracy performance much better than .3 per cent.

Also, if it is known that the actual burden will be outside of the ASA standard ZZ burden classification (that is, more than 400 va, and/or less than .6 power factor), the PCM device can be specially adjusted using the extra-fine tuning taps on the reactor and transformer primary. For large burdens, the end result is to move the zero va point outside the .3 parallelogram and provide a range of 200 va-600 va burden. (See Figure 2). Or, in the case of a low power factor burden, the device can be inductively detuned which has the end result of rotating the accuracy line to the left, making it appear like a burden with a much higher power factor. (See Figure 3). Burdens with power factors less than those defined by ASA standards, are very possible and even probable at inter-ties where double metering installations exist.

Also, deliberate capacitive detuning is possible, which greatly reduces ratio errors while increasing phase angle errors only slightly. (See Figure 3). Here, the line is seen to be rotated to the right and shortened.

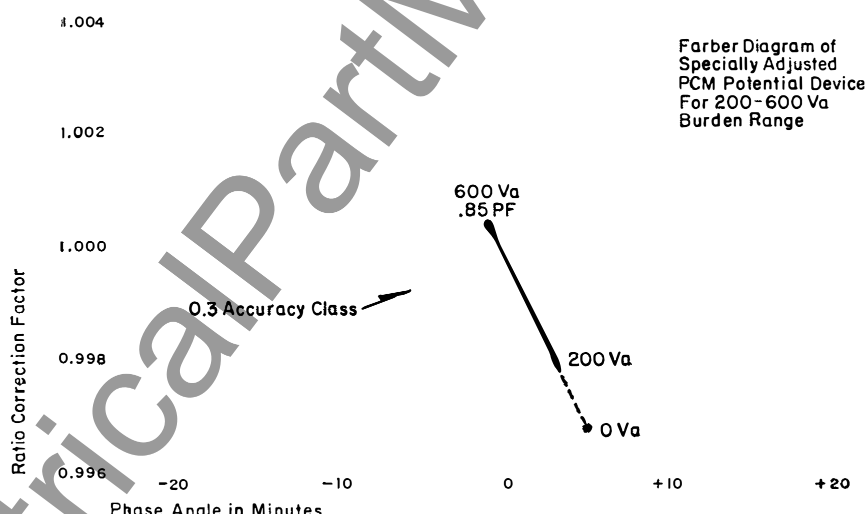



Figure 2

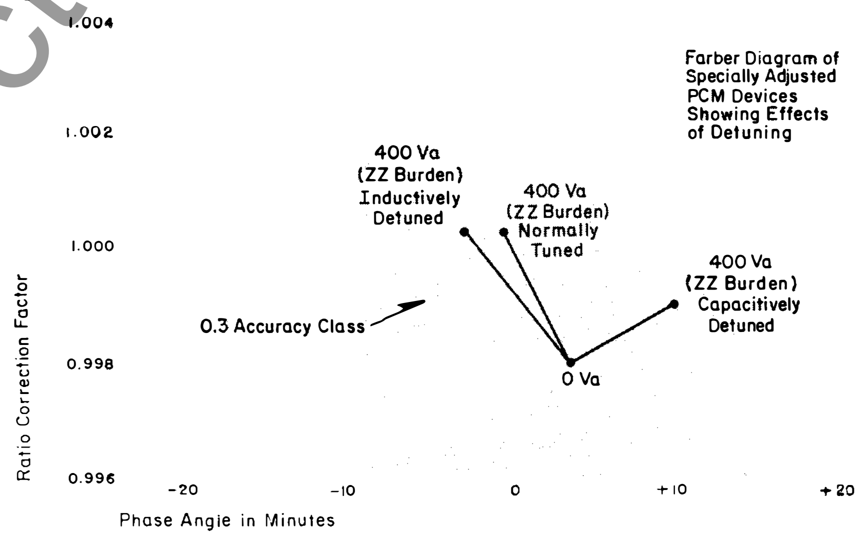



Figure 3

# Potential Devices for Revenue Metering
Type PCM

# Coupling Capacitors
Type PC-6

## Design Tests

Design tests performed on the PCM potential device far exceed those given in NEMA standards publication SG 11-1955, paragraphs 3.08 and 4.08. Design testing has included accuracy measurements under severe conditions of contamination, voltage variation, rainfall and deluge (to simulate hot-washing), and, of course, for varying magnitudes of burdens and burden power factors. Complete description of these tests, the methods employed, pertinent calculations and graphical test results are given in IEEE transactions paper 31 TP 65-670, entitled, "A New Metering Accuracy Capacitance Potential Device." Copies are available from Westinghouse, Distribution Apparatus Division, Bloomington, Indiana.

In addition, radio influence tests and full voltage dielectric tests at 500 kv, including wet and dry switches surge tests and BIL tests, have been performed at the Westinghouse EHV laboratory in Trafford, Pennsylvania. These meet and exceed those tests described in SG 11-1955, paragraph 3.07 for coupling capacitors and conform to the values given in the table of electrical and mechanical characteristics.

## Production Tests

Routine, production tests include those specified in NEMA publication SG 11-1955, paragraphs 3.06 for coupling capacitor units and 4.07 for potential device circuits.

For coupling capacitor units, prorated tests are performed on units rated from 69 kv to 167 kv (or maximum line to ground ratings of 42 kv to 100 kv). These tests include capacitance measurement, low-frequency dry withstand test, repeated capacitance measurement, and radio influence test for internal corona. For potential device circuits, tests include measurements of (1) resistance, (2) ratio, (3) phase angle, (4) polarity, (5) dielectric strength, (6) capacitance, and (7) protective gap settings. A brief description of each of these tests is as follows:

**(1) Resistance** – The PCM devices designed to be a very low-loss circuit for good accuracy performance. Loss in the complete potential device is approximately 300 watts including the coupling capacitor.

**(2) Ratio** – Each PCM device is calibrated to comply with ASA standard ratios of transformation within .3 accuracy, according to Instrument Transformer Standards, ASA C57.13.

**(3) Phase Angle** – Calibration as to phase angle meets the .3 accuracy class requirements of C57.13.

**(4) Polarity** – The 20 kv potential transformer is connected and tested for subtractive polarity, in compliance with generally accepted practice on instrument transformers.

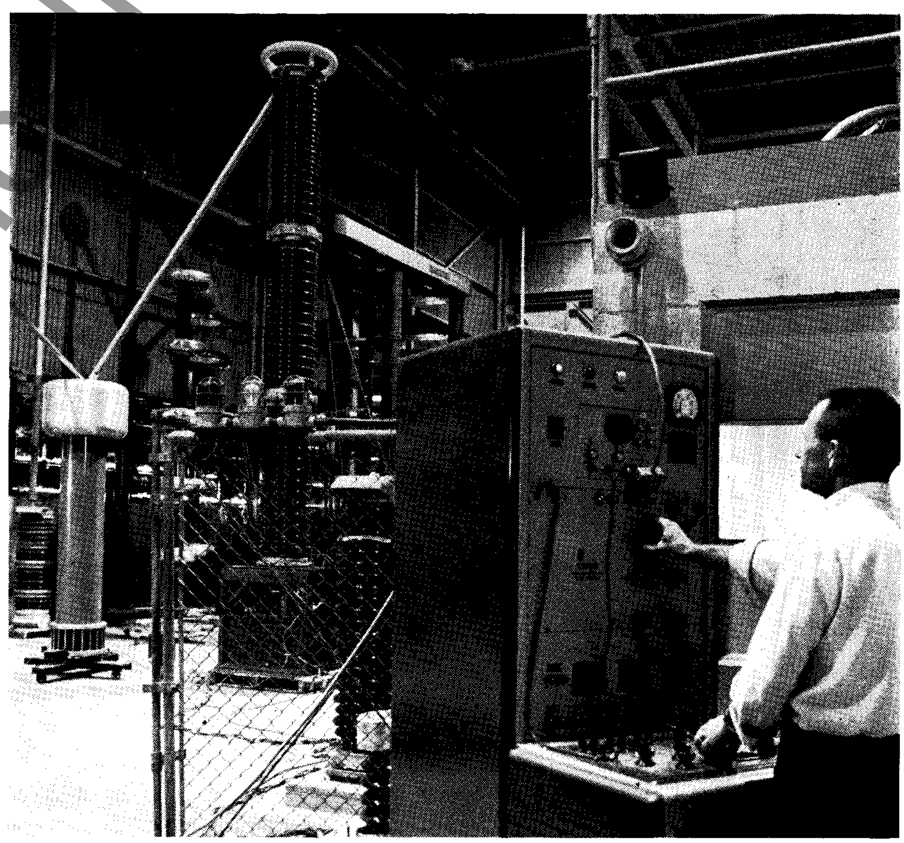
**(5) Dielectric**

(a) The 20 kv potential transformer and the complete capacitor are subjected to a one-minute, low-frequency test voltage of 4 times the operating tap voltage, or 80 kv rms.

(b) The secondary windings of the potential transformer and the ferroresonant suppression circuit are subjected to a one-minute, 2500 volt test to ground.

**(6) Capacitance** – The microfarad value of the tap capacitance is measured and recorded on the nameplate of the PCM device.

**(7) Protective Gaps** – The sparkover values of all protective gaps are tested to insure coordination with the insulation requirements of the components they are to protect.



**500 kv PCM device during calibration. At left is the compressed gas 500 kv standard capacitor which forms a part of a precision voltage divider network. The test console at right contains the divider tap capacitor, an instrument transformer type of ratio and phase angle bridge, ASA standard W, X, Y, Z and ZZ burdens and direct-reading scales for ratio and phase angle voltage errors. This calibration equipment is certified by the U. S. National Bureau of Standards through reciprocal agreements with the German National Bureau of Standards.**

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## Fusing

Westinghouse makes no firm recommendation concerning fusing the secondary of the PCM device. Permanent secondary faults, if allowed to persist, will damage the 20 kv transformer-reactor coils.

Where protective relaying and revenue metering are involved, local practice will dictate whether fuses are to be used or not.

If a fuse is considered desirable, 20 ampere KAW Buss Limitron fuses are recommended. Following is the time-current characteristic curve of this fuse and the rated, thermal and short circuit currents of both the 67 volt and 115 volt windings.

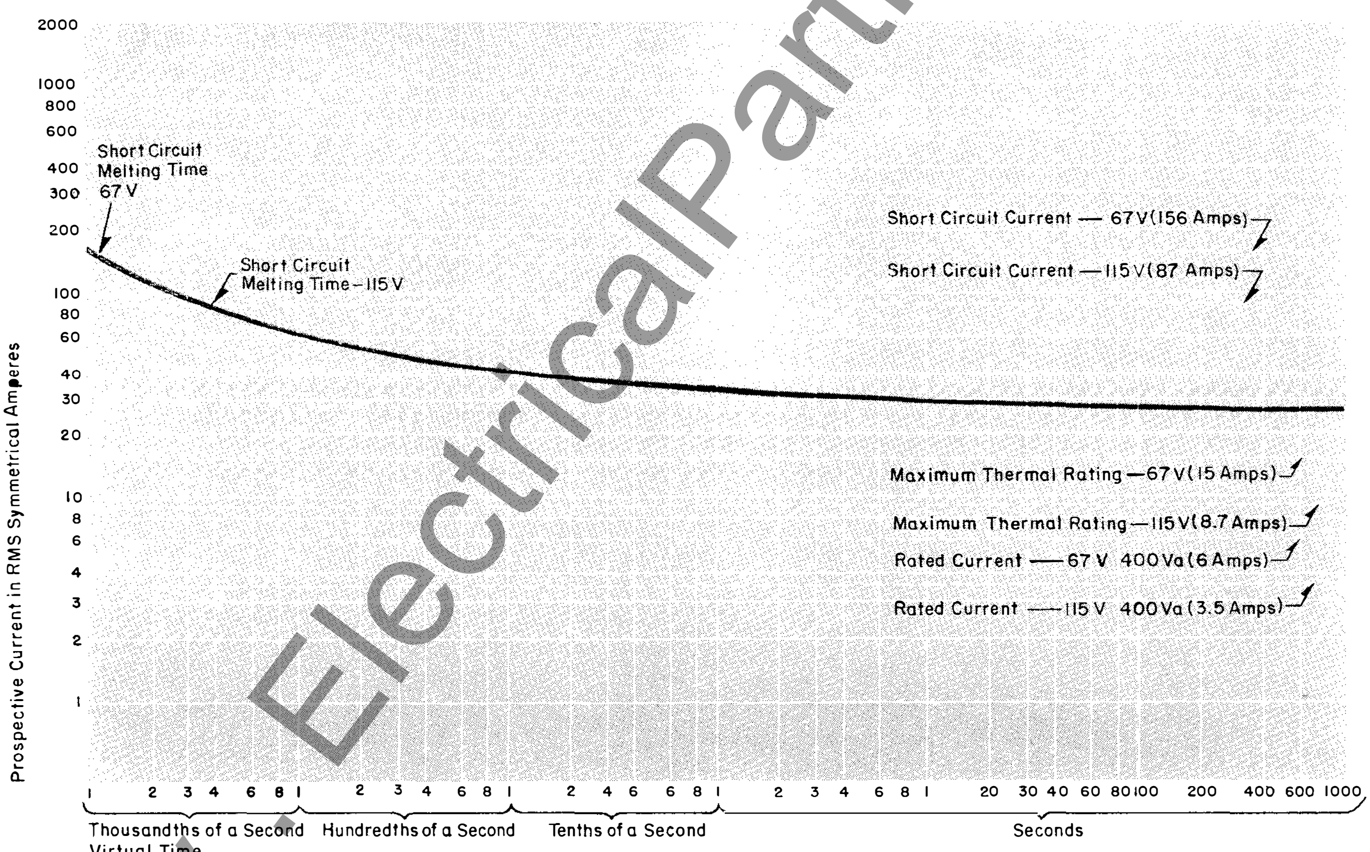
## Electrical and Mechanical Characteristics – Types PC-6 and PCM

| Nominal System Kv (Line to Line) | PCM Voltage Ratio Kv Line to Ground to: | | Nominal Capacitance Microfarads | Low Frequency Test (Rms Kv) | | Basic Insulation Level (BIL)① Kv Crest | Minimum Creep Distance, Inches |
|---|---|---|---|---|---|---|---|
| | 115 Volt Secondary | 67 Volt Secondary | | 1 Min. Dry | 10 Sec. Wet | | |
| **115** | 600/1 | 1000/1 | .0174 | 265 | 230 | 550 | 84 |
| **138** | 700/1 | 1200/1 | .0145 | 320 | 275 | 650 | 95 |
| **161** | 800/1 | 1400/1 | .0123 | 370 | 315 | 750 | 116 |
| **230** | 1200/1 | 2000/1 | .0087 | 525 | 445 | 1050 | 168 |
| **288** | 1500/1 | 2500/1 | .0070 | 655 | 555 | 1300 | 200 |
| **345** | 1800/1 | 3000/1 | .0058 | 785 | 665 | 1550 | 252 |
| **500** | 2500/1 | 4500/1 | .0040 | 1050 | 880 | 1800 | 350 |
| **700** | 3500/1 | 6100/1 | .0029 | .... | ... | .... | 478 |

① Also termed impulse withstand test using 1½ x 40 microsecond waveshape.

### PCM Potential Device Recommended Fusing – 1000 Va Thermal Rating

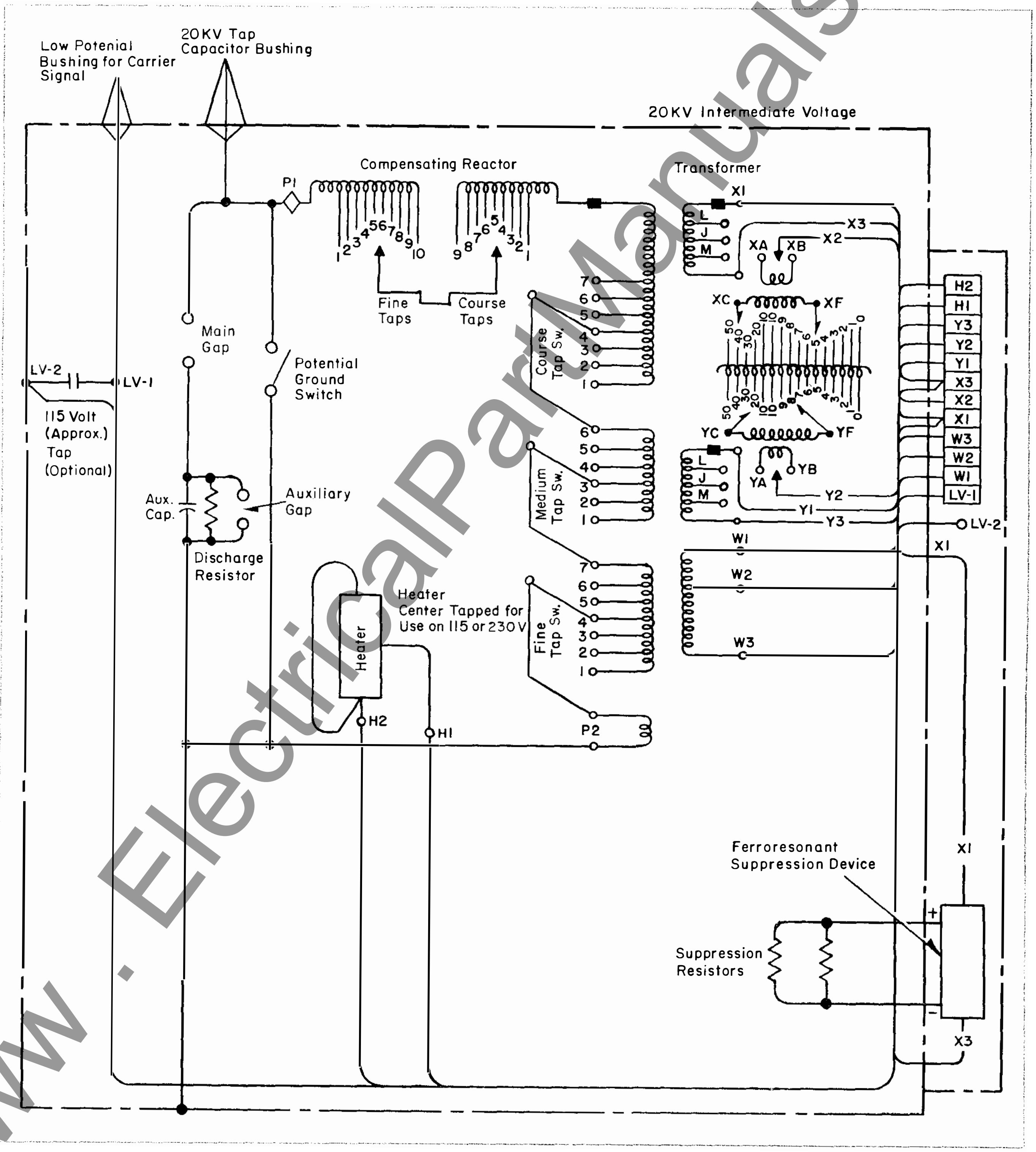
Average melting time-current characteristic curve using KAW Buss Limitron fuses, 20 ampere rating.



## Potential Devices for Revenue Metering
Type PCM

## Coupling Capacitors
Type PC-6

**Schematic Diagram – PCM Device**



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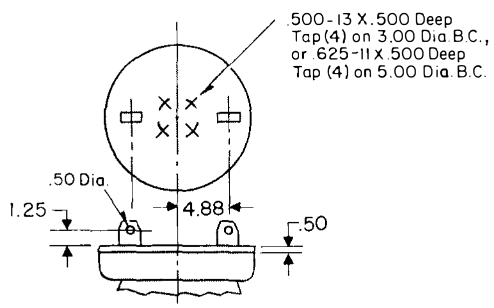
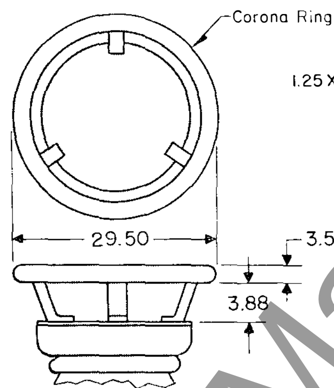
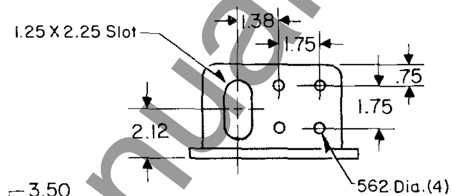
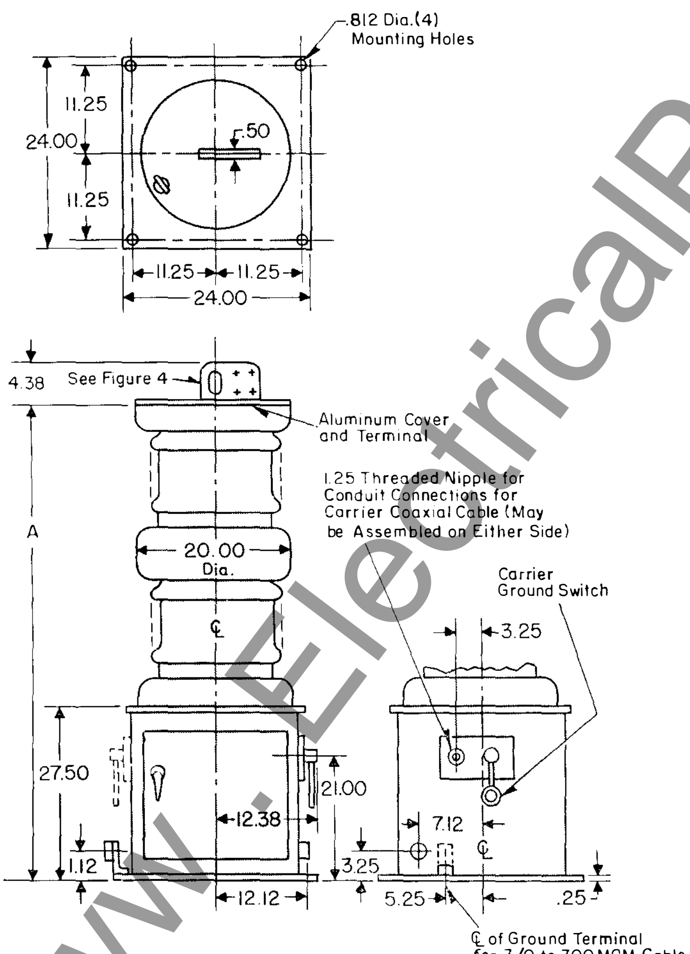
## Stacking Information, Weights and Dimensions

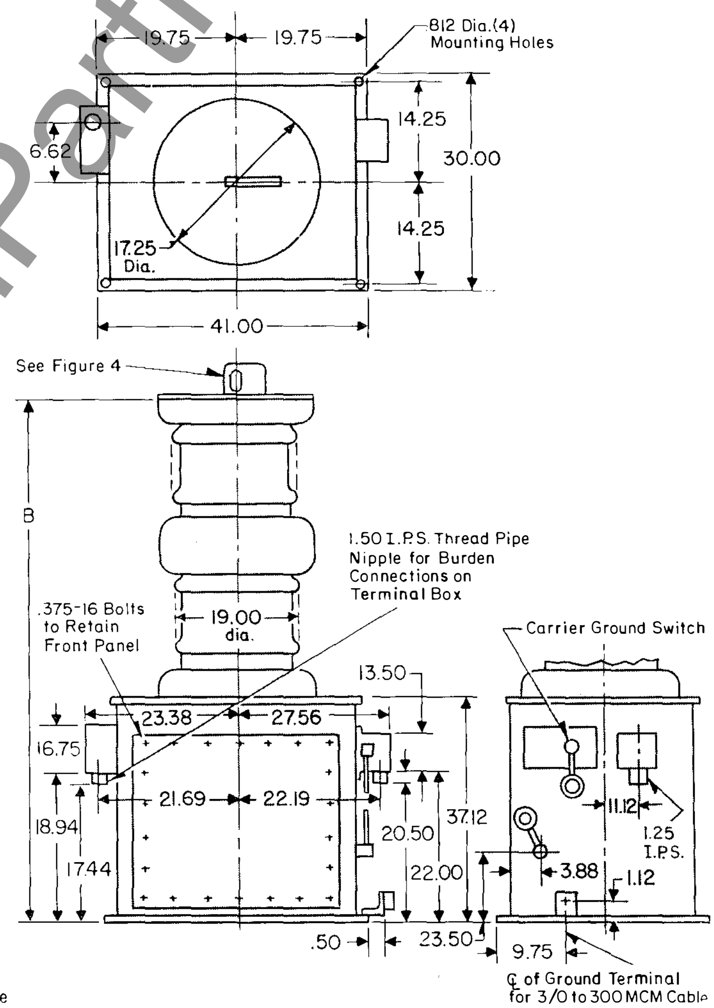



Type PC-6




Type PCM

# Potential Devices for Revenue Metering
Type PCM

# Coupling Capacitors
Type PC-6

## Stacking Information, Weights and Dimensions

| Coupling Units | | | | | Device Rating (Nominal System Kv) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position | Style Number | | Kv | Lbs. | | | | | | | | |
| | Brown Porcelain | Sky Gray Porcelain | | | 115 | 138 | 161 | 230 | 288 | 345 | 500 | 700 |
| Upper ① | 792C488A06 | 793C147A06 | 115 | 615 | | | | 1 | 1 | 2 | | |
| | 792C488A08 | 793C147A08 | 138 | 690 | | | | | | | | 4 |
| | 792C488A11 | 793C147A11 | 167 | 800 | | | | | | | 2 | |
| Lower ① | 792C488A04 | 793C147A07 | 115 | 615 | 1 | | | 1 | | 1 | | |
| | 792C488A05 | 793C147A09 | 138 | 690 | | 1 | | | | | | 1 |
| | 792C488A06 | 793C147A10 | 161 | 800 | | | 1 | | | | | |
| | 792C488A07 | 793C147A12 | 167 | 800 | | | | | 1 | | 1 | |
| Dimension A, Type PC-6, Inches | | | | | 74½ | 80¼ | 89¼ | 121½ | 136¼ | 168½ | 212¾ | 291¼ |
| Dimension B, Type PCM, Inches | | | | | 84⅛ | 89⅞ | 98⅞ | 131⅛ | 145⅞ | 178⅛ | 222⅜ | 300⅞ |
| Net Weight, Type PC-6, Pounds | | | | | 850 | 925 | 1035 | 1465 | 1650 | 2080 | 2635 | 3685 |
| Net Weight, Type PCM, Pounds | | | | | 2115 | 2180 | 2300 | 2730 | 2915 | 3345 | 3900 | 4960 |

① A "lower" unit is one which is mounted directly on top of the base cabinet. An "upper" unit is any unit mounted above the lower unit.

# Potential Devices for Revenue Metering
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# Coupling Capacitors
Type PC-6

500 kv installation of metering accuracy PCM potential devices at the Ray Braswell EHV substation of the Mississippi Power and Light Company.



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