

INSTRUCTIONS

For Application and Installation

INTRODUCTION

CAUTION: The equipment covered by this publication must be selected for a specific application and it must be installed, operated, and maintained by qualified persons who are thoroughly trained and who understand any hazards that may be involved. This publication is written only for such qualified persons and is not intended to be a substitute for adequate training and experience in safety procedures for this type of equipment.

S&C 30-Volt-Ampere Potential Devices are applicable for intermediate-tap-point-to-ground connection on grounded, wye-connected shunt capacitor banks, and for line-to-ground connection in all other applications. For neutral-to-ground connection on ungrounded, wye-connected shunt capacitor banks and reactors, S&C 15-Volt-Ampere Potential Devices are to be used. Refer to S&C Instruction Sheet 581-510.

Application and Performance

S&C 30-Volt-Ampere Potential Devices are resistance-type voltage-sensing units. Their output of 30 volts-amperes at 120 volts (accommodating inductive burdens up to 60 va) makes them suitable for a wide range of single-phase and three-phase applications, from 23 kv through 138 kv—including relaying, monitoring, and nonrevenue metering. And because potential devices are accurate to within 1½%, they are suitable for virtually any protection scheme. Although designed for outdoor use, they may be used indoors or in metal-enclosed switchgear.

The S&C 30-Volt-Ampere Potential Device is a constant-current-output device, like a current transformer. Its output current is directly proportional to the voltage applied to its line terminal. Furthermore, with a fixed burden connected across its output terminals, the

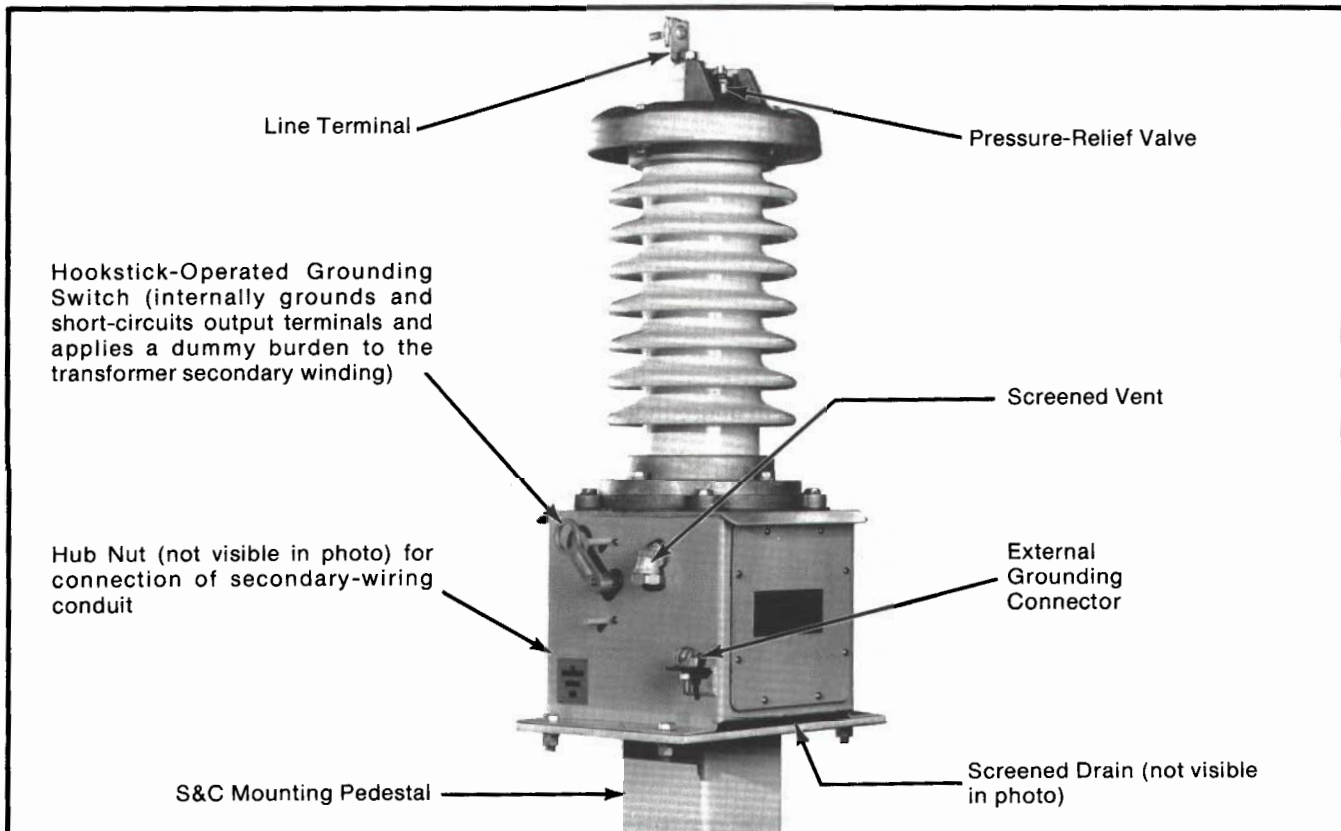


Figure 1. S&C 30-Volt-Ampere Potential Device, Catalog Number 81473R6-D, rated 23 kv.

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device produces an output voltage that is directly proportional to the voltage applied to its line terminal. Specifically, the output voltage is nominally 120 volts rms when a 480-ohm resistive burden is connected across the output terminals and line-to-ground voltage corresponding to rated system voltage is applied to the line terminal.* Hence, an S&C 30-Volt-Ampere Potential Device may be used for any appropriate application

* The voltage ratio of the potential device (with the 480-ohm rated burden connected to the output of the device) is equal to the device's nominal system voltage rating/ $120\sqrt{3}$.

requiring a voltage source, provided the burden is fixed and does not exceed the output rating of the potential device. However, larger inductive burdens (e.g., as high as 60 volt-amperes at 60° lagging phase angle) may be easily accommodated by connecting a suitable shunt capacitor across the burden for power-factor correction. Also, an adjustable phase-relation between input and output voltage may be readily achieved by connecting suitable power-factor correction elements across the burden.

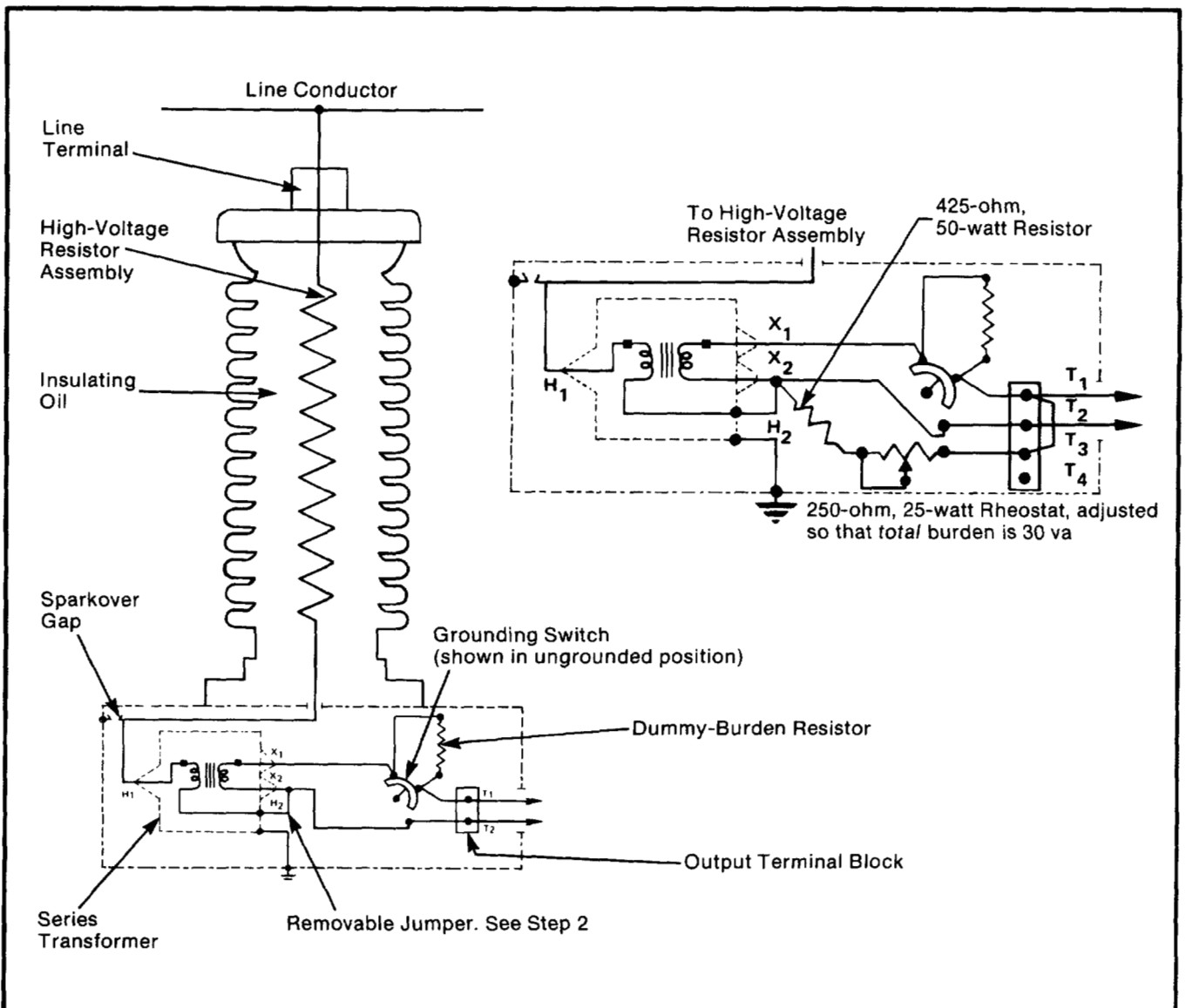


Figure 2. S&C 30-Volt-Ampere Potential Device schematic. The inset illustrates the circuit adaptation provided for the optional factory-adjusted calibration device, catalog number suffix "-T."



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S&C 30-Volt-Ampere Potential Devices are rated like single-bushing voltage transformers in terms of system line-to-line voltage, but are connected line-to-ground.†

Unlike capacitor-coupled devices, S&C 30-Volt-Ampere Potential Devices do not possess resonant characteristics and are immune to ferroresonance. Their limited frequency response makes them ideal for service at locations where high-frequency transients might otherwise cause spurious relay operations. Furthermore, unlike voltage transformers, S&C 30-Volt-Ampere Potential Devices do not saturate when subjected to switching overvoltages.

Although special consideration to lightning exposure is unnecessary, it is desirable, as with voltage transformers and other electrical apparatus, to provide surge arresters if the prevalence of lightning warrants.

Construction

S&C 30-Volt-Ampere Potential Devices utilize a high-voltage resistor assembly immersed in insulating oil and sealed in a wet-process porcelain bushing. See Figure 1. A measured amount of air is left above the oil level to permit expansion and contraction of the oil volume with temperature changes; a pressure-relief valve is incorporated in the cover of the potential device to prevent excessive pressure buildup during normal operation under high-ambient-temperature conditions. Since the pressure-relief valve opens only if the internal pressure reaches a level of 9 to 11 psig, and then only momentarily, the resistor assembly is essentially sealed so that moisture contamination and sludging tendencies are virtually eliminated.

The resistor assembly is comprised of a large number of high-precision thick-metal-film resistors connected in series. Resistance values have been selected so that the current flow through the high-voltage resistor assembly is approximately 4 milliamperes. The individual resistors have a temperature coefficient of less than 0.01% per degree C, over a temperature range of -55°C to $+175^{\circ}\text{C}$, assuring an exceptionally high degree of temperature stability.

† S&C Potential Devices are rated for application on grounded systems, but application to ungrounded systems may be made through the use of specially applied or specially modified potential devices. A standard potential device applied on an ungrounded system must have a system voltage rating at least equal to the system voltage multiplied by $\sqrt{3}$, and the burden impedance must not exceed the normal 480-ohm value (so that the high-voltage resistor assembly will not overheat and the output will not exceed 120 volts in the event of an accidental ground on the system). When a standard potential device is applied as described, the nominal output is typically reduced to a maximum of 60 volts and 7.5 volt-amperes (48 volts and 4.8 volt-amperes for 46-kv ungrounded systems). Specially modified potential devices can be provided for ungrounded-system application with nominal output of 70 volts and 10 volt-amperes.

The top cover of the device, to which the resistor assembly is internally connected, is provided with (if specified at time of ordering) either a parallel-groove type connector for use with wire conductors, or a vertical-pad line terminal with standard four-hole drilling for use with bus or pad-terminal connectors. At the base of the device, a stud connected to the resistor assembly is brought through an O-ring sealed Cypoxy™‡ insulator plate into the base enclosure, where connection is made to the primary side of the series transformer, and to a sparkover gap which limits high voltages which might appear at the transformer primary due to line surges or an inadvertent open secondary circuit. The sparkover gap is factory-set at 0.305 inches, to spark over at approximately 13 kv to 14 kv.

The series transformer is of the single-primary-bushing type, oil filled and solder sealed. The neutral end of the primary winding is permanently connected to the transformer case, which is grounded. The secondary winding is completely isolated and has a low-frequency withstand to ground of 2.5 kv for one minute. A removable jumper is furnished, connected from the X2 secondary winding terminal to ground. (The jumper may be removed if single-point grounding at another location is desired.) This transformer is essentially a current transformer in that its primary current is that of the potential-device resistor and is independent of the secondary burden. It has a turns ratio of 63 to 1 and is *nominally* rated at 30-volt-amperes.

The primary of the transformer (connected in series with the potential-device resistor) is energized in direct proportion to the line-to-ground voltage, but like any current transformer, *a closed secondary must be maintained whenever current is flowing in the primary*. If the secondary circuit is open, all of the primary current is used for magnetizing the core and the resulting high flux densities, limited only by saturation of the core, will induce high voltages which may cause permanent insulation damage to the transformer.

To allow removal of the connected burden without open-circuiting the transformer secondary winding, a hookstick-operated grounding switch is provided in the base of the potential device. The switch, when placed in the "ground" position, short-circuits and grounds the potential-device output terminals and at the same time connects an internal dummy-burden resistor across the secondary winding of the transformer. See Figure 2.

Note that the grounding switch short-circuits and grounds the *external* burden only. The transformer will

‡ Cypoxy is the S&C trademark for S&C's cycloaliphatic epoxy resin system.



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remain energized until the high-voltage connection to the potential device is removed or de-energized.

A weathertight hub nut is provided for the secondary-winding conduit connection.

The transformer has been designed for a secondary voltage of 120 volts, a voltage which should be held approximately constant by adjustment of the burden applied. The secondary voltage, for all practical purposes, is in phase with the line-to-ground primary voltage for a purely resistive burden, and will vary in phase angle exactly as the phase angle of the burden imposed.

The secondary current is approximately 63 times the primary current. Although the nominal secondary output is 30 volt-amperes when the potential device is energized at rated voltage, a reduced but still usable volt-ampere

output is available when the potential device is energized at less than rated voltage. See Figure 3.

Operation of the transformer with a connected burden of less than its available volt-ampere output, as shown in Figure 3, should be avoided to prevent the secondary voltage from exceeding its 120-volt design value.

When furnished for use in conjunction with an S&C Automatic Control Device—Type GP, or with the unbalance compensation module option of S&C Automatic Control Devices—Types UP or UPR, these potential devices are equipped with a factory-adjusted calibration device (contained within the base of the potential device). Inclusion of the calibration device is signified by the addition of the suffix “-T” to the potential-device catalog number. See inset, Figure 2.

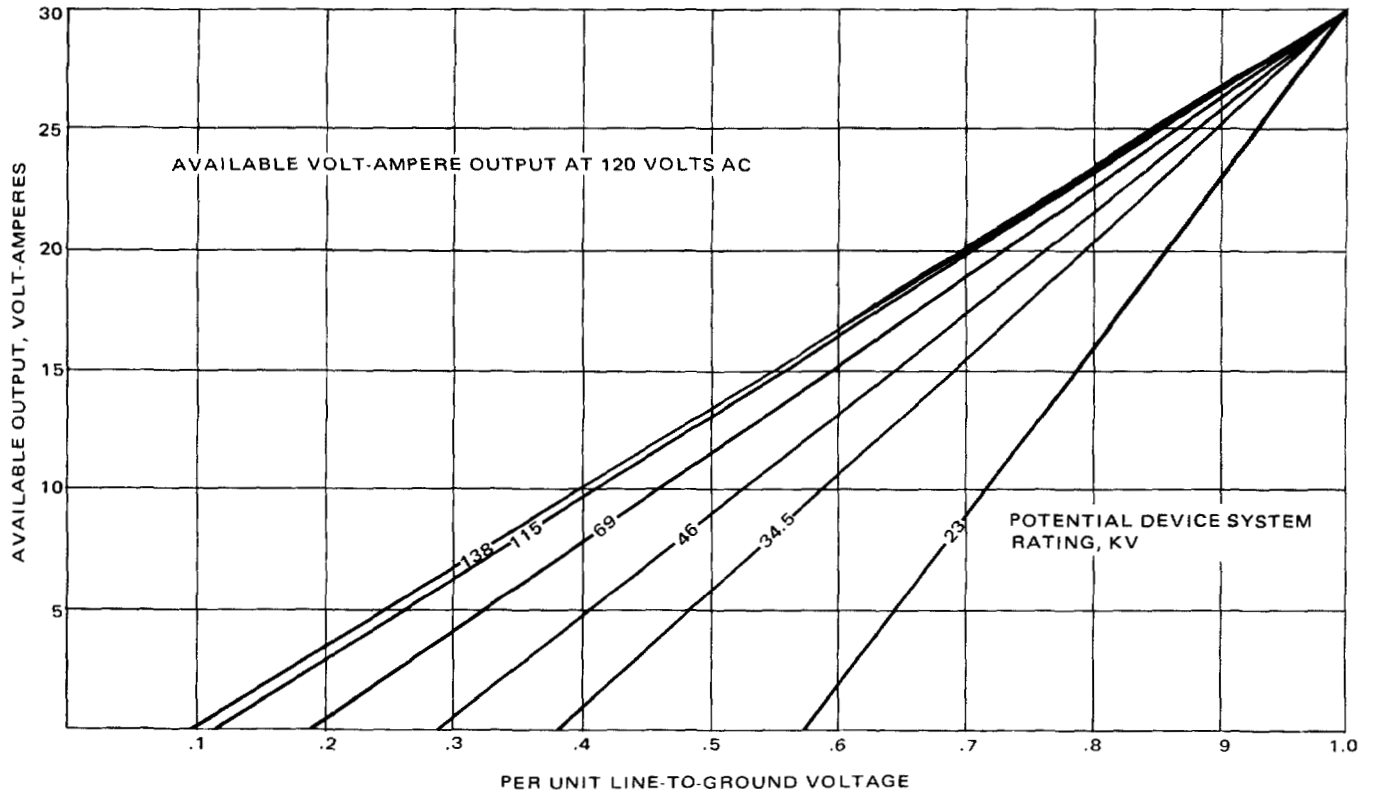


Figure 3.



BURDEN ADJUSTMENTS

Adjusting a Unity-Power-Factor Burden to Maintain 120-Volt Output

If the volt-amperes of the connected burden are less than the volt-amperes of available output and the burden is of unity power factor, a resistance with a volt-ampere burden equal to their arithmetical difference should be paralleled with the original burden to keep the secondary at 120 volts.

For example, with a 19 volt-ampere unity-power-factor (resistive) burden, and 30 volt-amperes available, a resistance is required equal to

$$\frac{(E_s)^2}{\text{VA available} - \text{VA connected}} \quad \text{or} \quad \frac{(120)^2}{30 - 19} = 1310 \text{ ohms}$$

For practical purposes, a 1500-ohm, 50-watt adjustable wire-wound resistor would be chosen, and adjustment made until 120 volts is indicated across the burden. The voltmeter used for the measurement should have a minimum input impedance of 5000 ohms per volt to avoid appreciable additional loading.

For an alternate method of determining the ohmic rating of the burden-adjusting resistor, refer to Figure 5.

Adjusting the Burden When Power Factor Is Other Than Unity

When burdens of less than the available output and of other than unity power factor are involved, the resistive burden which must be added to maintain the secondary at 120 volts may be determined vectorially as shown in Figure 4.

Here, the 30-volt-ampere output is scaled in watts and vars (volt-amperes reactive). Watts are scaled on the X-axis and the vars on the Y-axis. The arc CD is the locus of the transformer burden at power factors from unity to zero. Continuing with the foregoing example, if it is desired, in addition to the 19-va unity-power-factor burden, to add a 7.5-va burden of, say, 0.27 power factor, the watts and vars components must first be determined as follows:

$$0.27 \times 7.5 = 2.0 \text{ watts}$$

and

$$\sqrt{(7.5)^2 - (2.0)^2} = 7.2 \text{ vars}$$

Adding the 19 watts of the original resistive or unity-power-factor burden vectorially, a total burden of 21-j7.2 va is indicated, and plotted as OA in Figure 4.

AB, which scales about 8 watts, is the additional resistance burden which must be paralleled with the useful burden to make up the total 30 va as indicated by OB. The resistance required is calculated as:

$$R = \frac{(120)^2}{8} = 1800 \text{ ohms}$$

Here, a standard 2000-ohm, 50-watt adjustable wire-wound resistor would be chosen and adjusted to obtain 120 volts across the secondary burden.

Inasmuch as the ohmic value of the required resistor as determined in the preceding example is obviously dependent upon the user's application, it cannot readily be furnished as part of the potential-device assembly. However, suitable resistors, such as the Ohmite "Divid-ohm" adjustable wire-wound type, are usually available from local sources.

With a burden of high reactive (inductive) volt-ampere content, the useful output of the transformer may be increased by shunting the burden with a capacitor which will draw reactive (capacitive) volt-amperes equal to the reactive (inductive) volt-amperes of the burden. For example, a burden of 50 volt-amperes at 60 degrees lagging power-factor angle becomes a unity-power-factor burden of only 25 volt-amperes after the addition of an 8-microfarad capacitor for power-factor correction. To make up the balance of the required total 30 volt-amperes, a 2880-ohm resistor would also have to be connected across the burden.

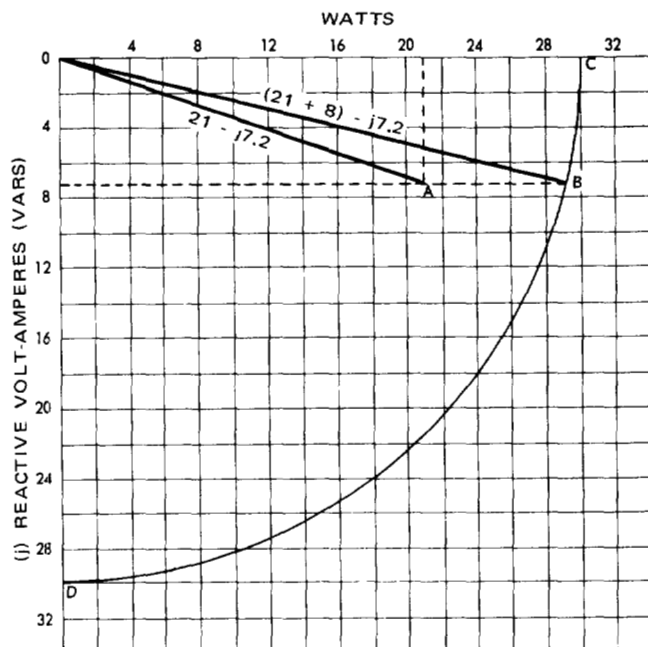


Figure 4.

BURDEN ADJUSTMENTS

For an alternate method of determining the ohmic rating of the burden-adjusting resistor, refer to Figure 5.

Application Notes

The burden-adjusting resistor may be connected directly across the instrument terminals.

If two or more independent burdens are involved, a make-before-break switch or a "shorting" contact, similar to that of an ammeter switch, should be employed

for switching to avoid a momentary open circuit during the transfer operation.

Although the S&C Potential Device is normally applied on grounded systems, application on ungrounded systems is possible through the use of specially modified or applied potential devices. In such cases the continuous available output will be less than 30 volt-amperes (see footnote "†" on page 3).

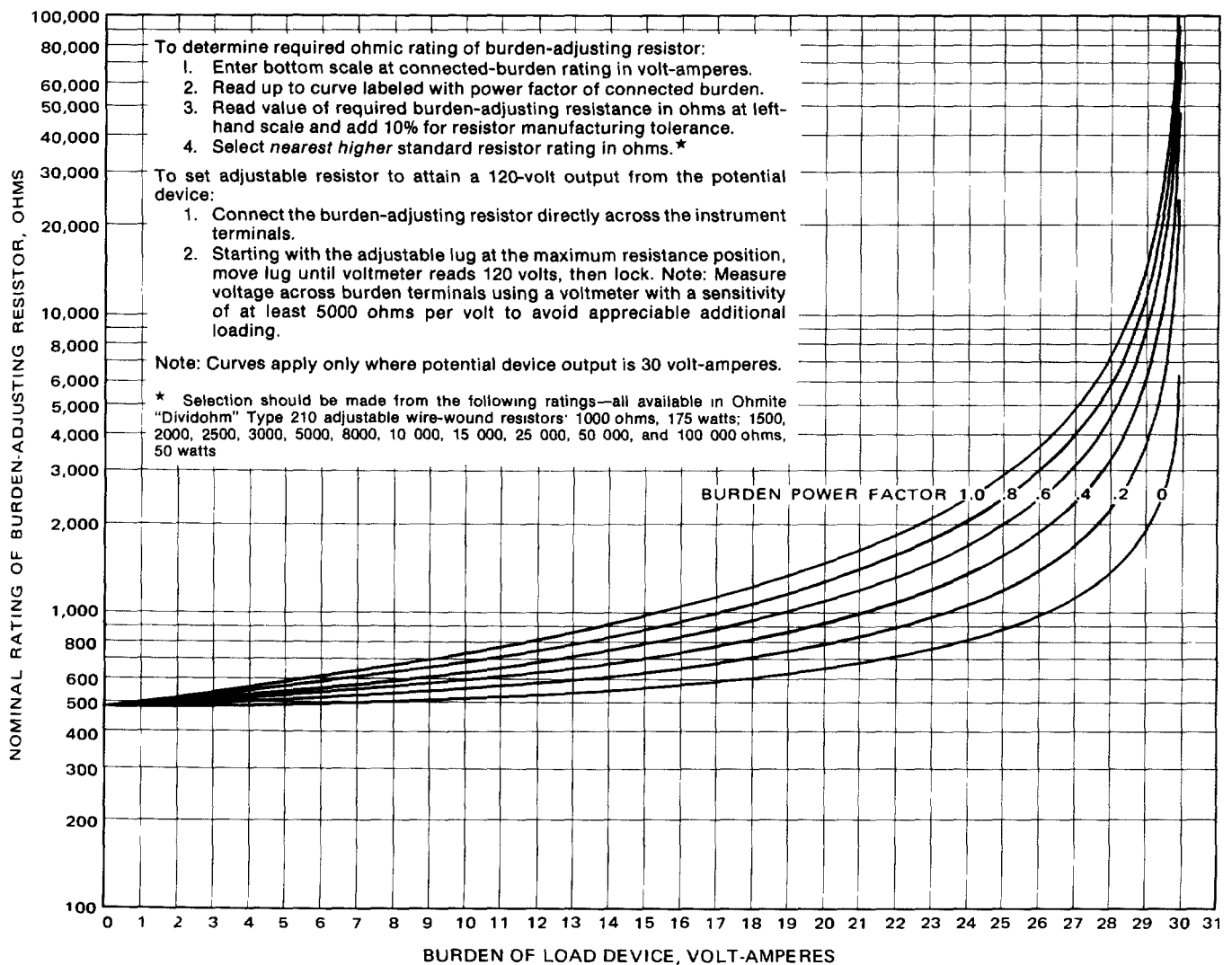


Figure 5.



MEASUREMENT OF LINE-TO-GROUND VOLTAGE

Measuring Line-to-Ground Voltage (E_{l-g}) Using a Resistive (Unity-Power-Factor) Burden

When the burden consists purely of resistance, E_p is in phase with $I_p R_{pde}$ (see Figure 6) and may be added arithmetically. Adjust the burden resistance and read I_s when E_s is adjusted to 120 volts. I_p then equals $I_s/63$ and the voltage across the potential-device resistor element is determined by $I_p R_{pde}$. This value added to the E_p of 8000 volts ($120 \times$ the effective voltage ratio of 66.7) indicates the line-to-ground voltage (E_{l-g}). For example: If the secondary milliamperes (I_s) are read as 189 when E_s is adjusted to 120 volts, then the primary current I_p is determined by $189/63$ or 3 ma. Multiplying this value by the R_{pde} of, say, 8.1 megohms (stamped on the potential-device nameplate), a voltage of 24,300 volts ($0.003 \times 8.1 \times 10^6$) is obtained which, when added to the E_p of 8000 volts (66.7×120), indicates a line-to-ground voltage (E_{l-g}) of 32,300 volts.

This may be expressed by the formula:

$$E_{l-g} = \frac{I_s}{63} R_{pde} + 66.7 E_s \quad \text{or} \quad \frac{I_s R_{pde} + 4200 E_s}{63}$$

Note: Values obtained by this method of measurement are accurate to $\pm 4\%$.

Vector Relation of Transformer-Primary Voltage (E_p) with Line-to-Ground Voltage (E_{l-g})

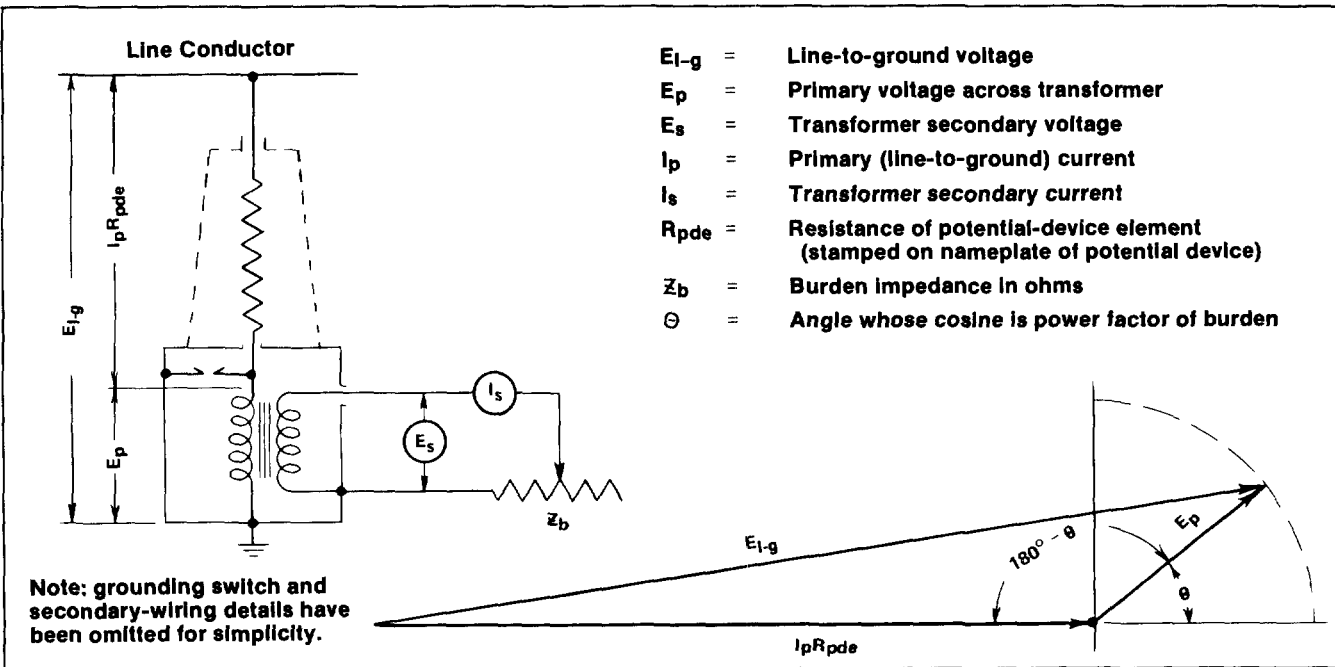


Figure 6.

Measuring Line-to-Ground Voltage (E_{l-g}) with a Burden Having Other Than Unity Power Factor

With a burden whose power factor is the cosine of Θ , the line-to-ground voltage (E_{l-g}) may be determined by application of the cosine formula in which two sides of a triangle and the included angle are known. (See Figure 6.)

$$E_{l-g}^2 = (I_p R_{pde})^2 + E_p^2 - 2(I_p R_{pde} E_p) \cos(180^\circ - \Theta)$$

or

$$E_{l-g} = \sqrt{(I_p R_{pde})^2 + E_p^2 - 2(I_p R_{pde} E_p) \cos(180^\circ - \Theta)}$$

As with the unity-power-factor method, the primary current is determined by adjusting the burden for a secondary voltage of 120 volts and dividing the secondary current (I_s) thus indicated by 63. The voltage across the potential-device resistor element is again the product of I_p and R_{pde} and, as before, the voltage across the transformer primary (E_p) is 66.7 times 120, or 8000 volts.

EFFECT OF BURDEN VARIATION ON SECONDARY VOLTAGE

The variation of secondary voltage (E_s) with applied burden for a constant primary current (I_p) is illustrated by the curve of Figure 7. It is intended to show the characteristics of the secondary voltage with variable loading rather than to provide specific values for direct application. It should also be pointed out that under actual conditions the 4-ma primary current (I_p) would not remain a strict constant, as assumed in Figure 7. The variation in secondary voltage (E_s) when translated to the primary affects the component of the line-to-ground voltage (E_{l-g}) impressed across the potential-device resistor element. For example, if the secondary terminals were shorted completely, there would be zero voltage across both the primary and secondary of the transformer, with the result that the entire line-to-ground voltage (E_{l-g})—less the negligible ohmic drop across the transformer primary—would appear across the potential-device resistor element, and I_p would increase as follows:

$$I_p = \frac{E_{l-g} - 66.7E_s}{R_{pde}} \quad \text{or} \quad \frac{E_{l-g} - 0}{R_{pde}}$$

Inasmuch as the watts, or heat, which must be dissipated by the resistor element increases as the square of I_p , the secondary terminals should not be left in a shorted condition for more than five minutes.

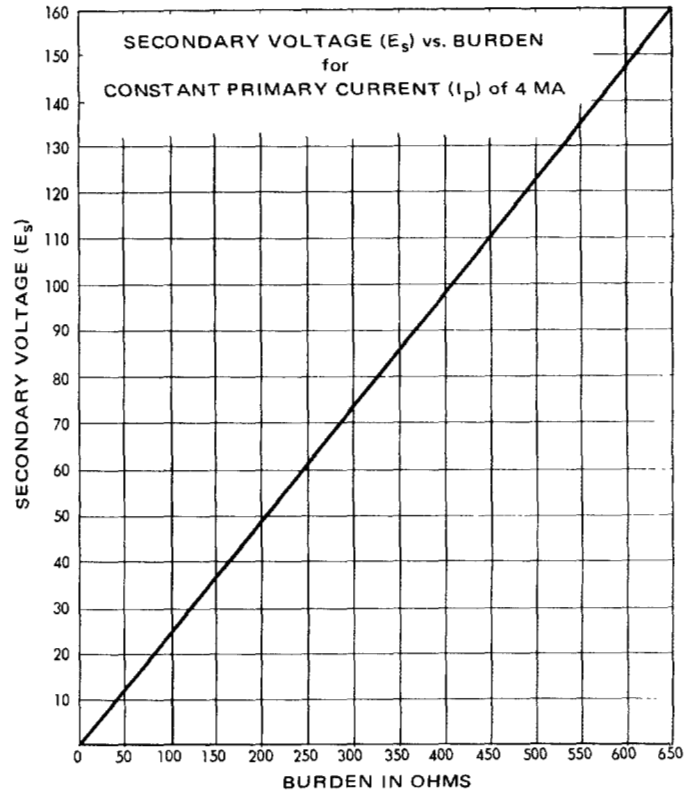


Figure 7.

INSTALLATION

Step 1

Mount the potential device on the S&C Mounting Pedestal (if furnished) or other suitable structure. *Note:* The potential device is intended for vertical mounting only.

Step 2

Remove the potential-device base cover nearest the conduit hub nut. Install one-inch conduit between the potential device and the S&C Automatic Control Device or other equipment.

Make up the connections in accordance with the wiring diagram furnished with the automatic control device.

If single-point grounding at another location is desired, remove the jumper connected between the potential-device transformer secondary bushing and the transformer case, and connect Terminal T2 to the selected grounding point.

Replace the potential-device base cover.

Step 3

Refer to the "Burden Adjustments" section on page 5 and connect the appropriate burden to the potential device to obtain an output voltage of 120 volts rms.

Step 4

Make sure the line to which the potential device is to be connected has been completely disconnected from all sources of power and properly grounded. Then make the connection to the line terminal of the potential device.

Step 5

Remove the temporary grounds.

Step 6

Refer to the instruction sheet furnished with the S&C Automatic Control Device, as appropriate, and proceed as directed therein.

