



Bushing Potential Device

TYPE KA-108

INTRODUCTION

Power systems need a low voltage equivalent of the system line voltage for relaying or measuring purposes. The most common method to obtain this is to use a potential transformer. Potential transformers are very accurate, but are expensive, both for purchase and installation. They take considerable space in a sub station and require a mounting platform several feet above ground. High voltage bushings are common in substations as part of power transformers and circuit breakers. HV bushings form a capacitance divider as a natural consequence of the construction. So there is a voltage signal available which is proportional to the system voltage at every bushing above 115kV fitted with a voltage tap.

The Potential Device connects to the Voltage Tap (Capacitance Tap) on the HV bushing and provides:

- 1) Another capacitance in parallel to the bushing C2 to reduce the voltage to a preferred value (between 3 and 7.5kV),
- 2) A stepdown transformer to step this voltage down to 115 / 66.4 - volts, and
- 3) An adjustable inductive reactance used to correct the output voltage phase angle to be inline with the system voltage.

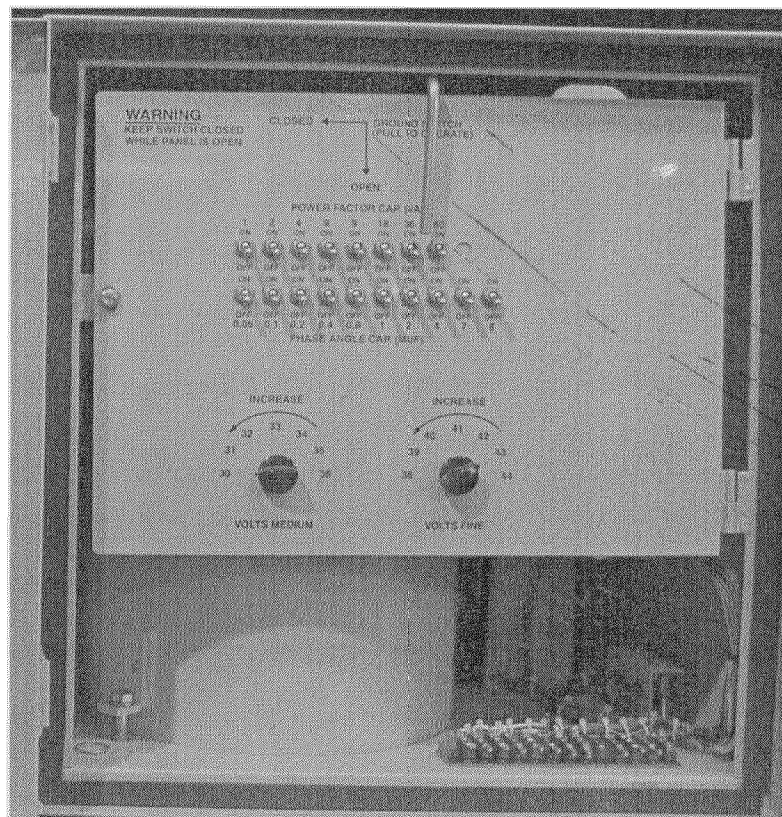


Fig. 1 Type KA-108 potential device with door open showing the adjustment panel.
Ground switch handle at top interlocks with panel when switch is "OPEN"

These instructions do not purport to cover all details or variations in equipment or to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered efficiently for the purchaser's purposes, the matter should be referred to the General Electric Company

The potential device (Figs. 1 and 2) will deliver an economic signal for relays, synchroscopes, voltmeters, and other instruments. Since the accuracy of the device is limited, it is not recommended for metering for revenue applications. The potential device is energized from the capacitance tap of a condenser bushing, circuit breaker or a current transformer.

The potential device is designated Class A in accordance with NEMA SG 4 - 1990. When properly adjusted to suit a particular bushing, the device will furnish two independent potentials of 115 and 66.4 volts each. The voltages are in phase with, and have a fixed ratio to the line-to-ground voltage of the bushing.

Ratio and phase angle vary slightly with changes in line voltage, burden and frequency, but remain within the limits permitted by the Standard NEMA SG 4-1990 Sections 3.8.4.1 (Voltage Regulation), 3.8.4.2 (Burden Regulation) and 3.8.5 (Adjustment).

RECEIVING, HANDLING AND STORING

Examine the equipment as soon as it is received for any damage that might have been sustained in shipment. If injury or rough handling is evident, file a damage claim with the Transportation Company immediately and notify the nearest General Electric Sales Office promptly.

Carefully inspect all porcelain parts for damage. Check all lead connections to make sure they are in place and that terminal connections are tight. Operate the grounding switch to see that it is in good working condition.

Lifting lugs are provided on the sides of the housing for vertical lifting. If the device and accessories cannot be installed soon after their arrival, store them in a clean dry place. After continued storage, inspect for moisture on all internal parts. Be sure all parts are thoroughly dry before installing and using the device.

DESCRIPTION

The bushing potential device contains a high-reactance transformer, adjusting equipment, an auxiliary capacitor, a ground switch, a protective gap, and a separately powered space heater. These parts are contained in a weatherproof steel housing.

The high-reactance step-down transformer is contained in an oil-filled tank having a 1-inch (25.4-mm) air cushion above the oil. The high-voltage bushing connects to the primary coil. Secondary leads are brought out through a low-voltage feed-through and connected to taps on the power tap switch (Volts Coarse) mounted to the transformer cover. Fig. 3 shows a typical Connection Diagram.

The adjustment equipment consists essentially of an adjustment transformer, phase-angle capacitors, and power-factor capacitors. Rotary and toggle switches on the front of the panel control them. The hinged panel can be opened to provide access to the interior of the housing for making primary connections and coarse voltage adjustment via the power tap switch.

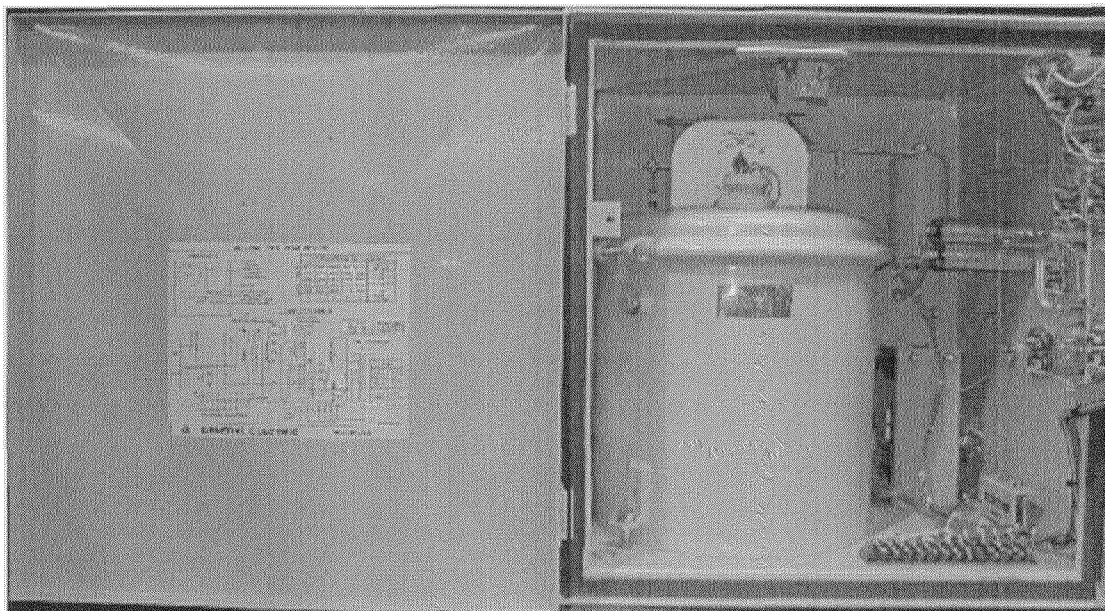


Fig. 2 Interior view of potential device with panel swung open.
Ground switch "CLOSED" at top rear

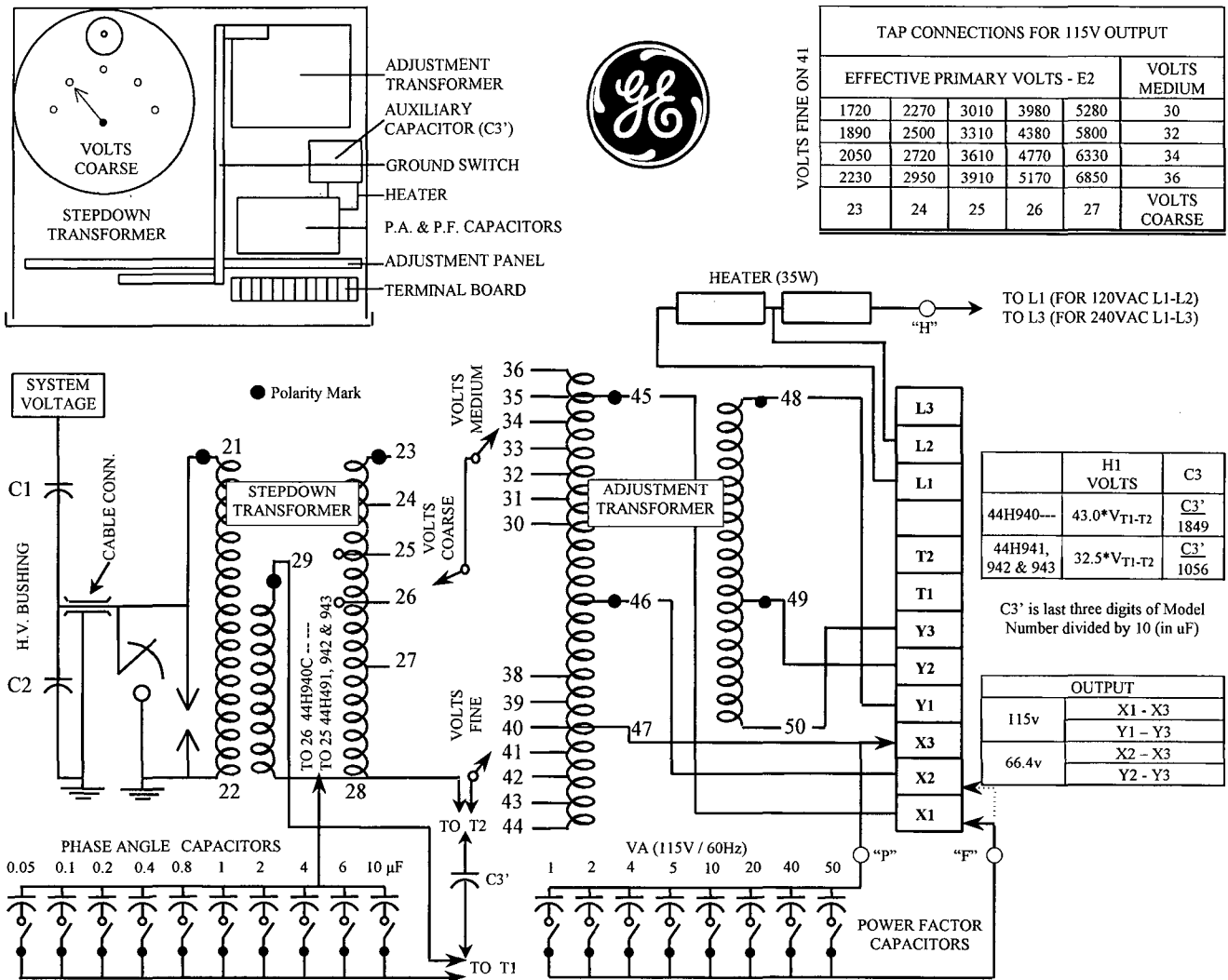


Fig. 3 Connection Diagram

Fine and medium tap switches (located on the panel) finish the selection of the over-all ratio. Rated total watt output can be distributed in any combination between the X and Y windings.

Toggle switches in the phase-angle section are identified by capacitance values and in the power-factor section by capacitive volt-amperes at 115 volts and 60 hertz. In 50-hertz applications, these power-factor values must be multiplied by 50/60.

A clearly marked terminal board at the bottom of the housing serves to facilitate customer connections.

CAUTION - Terminals L1, L2 and L3, as well as the heater remain energized even when the ground switch is "closed."

The auxiliary capacitor supplements the tap-to-ground capacitance of the bushing, as required for voltage ratio and reactance match. Devices for General Electric Type F or OF bushings operate without the capacitor.

Use the grounding switch to remove the high-voltage input. The operating handle extends over the front of the panel, so that the panel cannot be opened before closing the ground switch. Pull the handle forward to latch it into position.

CAUTION - WHEN WORKING INSIDE THE HOUSING, USE A STICK AND BRAID TO PERMANENTLY GROUND THE HIGH-VOLTAGE SECTION.

The protective gap at the H1 bushing protects the primary circuit from over-voltages greater than twice normal (15kV). The proper spacing (5/8-inch or 16 mm) is set at the factory.

A space heater is provided to keep the compartment dry. It requires a separate power supply of 38 watts, 120 or 240 volts. The "H" lead of the heater must be connected to L1 or L3 as shown on the Connection Diagram.

CONSTANT-BURDEN CAPACITY

The potential device output capacity is not limited to the rated burden watts listed in NEMA SG 4 Table 3-4. When the application permits, substantially higher burdens can be connected to the unit. In such a case, the unit will still conform to NEMA Standard SG 4 for Class A operation, except the burden regulation may exceed 12 percent (NEMA SG 4 Section 3.8.4.2). This is of no consequence when burdens are constant, or vary only slightly. The increased output is termed "constant-burden capacity".

The tabulation Fig. 5 shows that the constant-burden capacity is a function of line voltage and the capacitances of the high-voltage bushing. For example: at 79.7 kV, the device output can be raised from 35 watts rated to 55 watts for bushing capacitance C_1 equal or greater than 475 pf.

GE Bushing Potential Device	
NO. _____	CAT. 44H94 TYPE KA-108
<input type="checkbox"/> 60 HERTZ	<input type="checkbox"/> 50 HERTZ
<input type="checkbox"/> $\sqrt{3}$ LINE TO GROUND KV	BURDEN <input type="text"/> WATTS
SECONDARY VOLTAGE <input type="checkbox"/> 115/66.4 VOLTS <input type="checkbox"/> 110/63.5 VOLTS	
CLASS A BUSHING C_1 <input type="text"/> pF C_2 <input type="text"/> pF	
"Use with Type A normally grounded bushing taps only as defined by IEEE 57.19.01"	
32B443052P02	WEIGHT 350 lbs
CAUTION! BEFORE INSTALLING OR OPERATING READ INSTRUCTION GEI-95192	
MADE IN U.S.A.	

Fig. 4 Typical nameplate

INSTALLATION

CAUTION - THE HIGH-VOLTAGE BUSHING MUST BE DE-ENERGIZED BEFORE CONNECTING THE POTENTIAL DEVICE.

Installation dimensions are shown in Fig. 7.

Note: The cable is ordered separate from the potential device. See GEI-79087 for cable connection instructions.

Bushing Voltage Tap configurations vary between manufacturers. GE Bushing Potential Device Cables at the bushing end conform to IEEE C57.19.01 Type A: Normally Grounded (See Fig 6). With proper cable adapters (provided by others) the GE Potential Device can be operated with bushing with other tap configurations. GE Potential Devices require 3 to 7.5 kV at the input terminals; the bushing must be able to operate with this voltage-to-ground at the Voltage Tap.

CONSTANT BURDEN CAPACITY					
MAXIMUM OUTPUT WATTS FOR FIXED BURDENS					
LINE-TO- GROUND VOLTAGE	NEMA TABLE 3-4 RATED WATTS	C1 MIN TO ACHIEVE RATED WATTS	BUSHING CAPITANCES		
			C1 pf		
			400	475	575
			WATTS		
66400	25	375	30	40	50
79700	35	375	40	55	75
93000	45	375	55	75	100
133000	80	350	100	145	200

Fig. 5 Constant-burden capacity

CONNECTIONS TO BUSHING

1. Remove the plug from the tap chamber of the bushing. Save the oil from the chamber for future use. Insure that the tap chamber and cable end are free of contamination.
2. Partially disassemble the cable hardware to permit visual contact engagement between the cable and the bushing tap. Avoid turning the contacts on each other, to prevent chip formation. Tighten securely the two O-ring seals.
3. Refill the chamber with the saved or new compound. Leave a 1/4-inch (6 mm) air cushion for expansion if the compound temperature is 25C. If the compound is heated to 130°C, omit the air cushion. The latter method is preferable for inclined tap chambers.
4. To bolt the cable to either wall of the cabinet, open the knockout and install the gasket, which is stored in the housing.

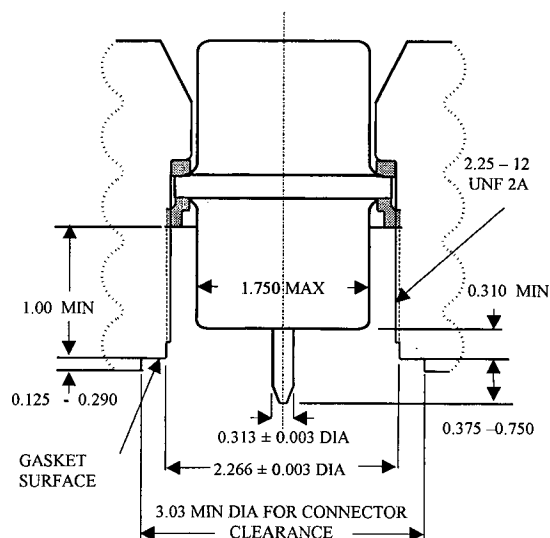


Fig. 6 Bushing Voltage Tap
IEEE C57.19.01 Type A: Normally Grounded

Best operating conditions are usually obtained when the total burden connected to the potential device has unity power-factor or is somewhat leading. Lagging power-factor burdens cause the primary voltage of the main transformer to be increased above normal. A power-factor capacitor is provided to correct lagging burdens back to unity power-factor so that the above condition does not exist.

ADJUSTMENT PROCEDURE

All switches and tap connections for making ratio, phase angle and burden power-factor adjustments are located on the panel (except Volts Coarse is on the cover of the stepdown transformer).

It is recommended that the potential device grounding switch be closed when making or changing tap connections and adjustments. The output terminals should not be short-circuited since the protective gap will arc over continuously and subject the primary circuit to abnormally high-voltage stresses.

The following procedure may be employed for adjusting the potential device to operate a given load from a given bushing.

BURDEN POWER-FACTOR ADJUSTMENT

Note—Non-linear burden impedance must be avoided since the characteristics of the device may be affected. Iron core relays should be operated at less than half the saturation density, to insure linear impedance.

Refer to the Connection Diagram and connect the power-factor capacitor in parallel with the instrument burden. Note that the capacitors can be connected to X1-X3, X2-X3, Y1-Y3, or Y2-Y3.

When part of the burden is connected "WYE" (phase to neutral) and part "DELTA" (phase to phase), connect the power-factor capacitor so that it is in parallel with the part of the burden containing the major inductance. For "DELTA" burdens, lead "F" can be joined to an outgoing conduit wire by using a blank section on the terminal board.

The burden power-factor can be corrected to unity by any of three methods. The third method is more accurate because it matches the actual capacitances of the power-factor capacitor to the actual inductance values of the burden. The first two methods rely only on nominal values.

I. If a suitable power source and meters are available, the total instrument load can be accurately measured and segregated into its watt and reactive volt-ampere components by the following formulas:

$$\sqrt{(VA)^2 - (W)^2} = \text{Reactive Volt-Amperes}$$

also

$$VA \times \sqrt{1 - \frac{(\%PF)^2}{(100)^2}} = \text{Reactive Volt-Amperes}$$

and

$$VA \times \frac{\%PF}{100} = \text{Watts}$$

If the reactive volt-ampere component is inductive (lagging) as usual, select power-factor capacitors for an equivalent value of capacitive volt-amperes plus seven capacitive volt-amperes extra.

In cases where the reactive volt-ampere component of the burden is already capacitive (leading), select power-factor capacitors as required, so that the total leading value will be seven volt-amperes.

II. When it is impractical to make actual measurements, as described above, an approximate adjustment of the burden power-factor can be made as follows:

Obtain rated burden of instruments being used from catalogs, handbooks or data sheets that apply. These values are usually given in terms of volt-amperes and power-factor and may be segregated into watt and reactive volt-ampere components as shown above.

Add up the watt and reactive volt-ampere components of all instruments connected to the device and apply power-factor correction in the same manner as above.

III. Place an ammeter with a 1- or 2-amp scale between X1 (or X2) and the burden. Remove the "F" lead and connect it to the burden side of the ammeter. Read the voltage across X1-X3. Now adjust the power-factor capacitors until the burden impedance (Volts/Amps) becomes a maximum. Add about 7 VA additional correction.

It may be necessary to readjust slightly the ratio and phase angle of the device if the power-factor capacitor settings are changed from those originally determined.

RATIO AND PHASE ANGLE ADJUSTMENT

The device should be connected to its particular bushing and burden, which was corrected to a slightly leading power factor.

This section assumes that a reference voltage as a standard of comparison for the potential device voltage is available. If not, adjustments may be made as described under "Adjustment By Calculation." Accuracy of adjustment depends on the reliability of a reference voltage being in-phase with, and in a known ratio to, the bushing line-to-ground potential. Since ratio and phase angle adjustments affect each other, make both alternately.

The reference voltage may be produced by:

1. Another potential device.
2. Potential transformer.
3. Low-voltage winding of a step-up transformer.
4. Network energized by (3), with components to simulate impedance voltage drops from the transformer low-voltage winding to location of potential device.

The reference voltage may be compared to the potential device voltage by use of:

- (a) High impedance voltmeters (Vacuum tube VM, Flux VM, etc.).
- (b) Phase-angle meter.
- (c) Ratio and phase-angle test set.
- (d) Oscilloscope.

A reference voltage source and means to compare the reference voltage with the potential device output is combined in one set of equipment in the Reference Potential Set of the Doble Engineering Company.

Selecting a combination of winding taps that will equalize the output and reference voltages makes ratio adjustments. The rotary tap switch (on top of the stepdown transformer) serves as the coarse voltage adjustment from the step-down transformer. Manipulating the "medium" and "fine" tap switches (located on the adjustment panel) can further refine the ratio adjustment.

NOTE—When changing the coarse tap adjustment, close the ground switch and open the panel.

RATIO - FINE ON TAP 41	TAP CONNECTIONS FOR 115 V OUTPUT					
	EFFECTIVE PRIMARY VOLTS - E2					RATIO MEDIUM
	1720	2270	3010	3980	5280	30
	1890	2500	3310	4380	5800	32
	2050	2720	3610	4770	6330	34
	2230	2950	3910	5170	6850	36
	23	24	25	26	27	RATIO COARSE

Fig. 8 Table for selecting preliminary tap settings

Preliminary positions of the "coarse" and "medium" switch are determined from the tabulation on the Connection Diagram (also Fig 8). Calculate voltage E2 (refer to "Adjustment By Calculation"). Enter table at nearest E2 and select the corresponding tap for "coarse" and "medium" ratios. Example: When E2 equals 2500 volts, use ratio coarse tap No. 24 and ratio medium tap No. 32 as a preliminary adjustment.

The phase angle is adjusted to equal that of the reference by connecting a phase-angle meter between the potential device output and the reference voltage. Manipulation of the phase-angle capacitance control is described under "Principle of Adjustment."

The switch positions will have to be varied as alternate phase angle and ratio adjustments are made, however the coarse tap position does not ordinarily require a change.

A high degree of accuracy is obtained when a ratio and phase angle test set is available to balance the burden voltage against a reference

If a phase-angle meter is not available, a voltmeter can be used. See Fig. 9. Connect potential device terminal X3 to the grounded side of the reference voltage. Connect a voltmeter (VM-2) between X1 and the reference voltage. As the phase angle reduces to zero, this difference voltage becomes a minimum. Voltmeters with progressively smaller voltage ranges should be used in order to permit a minimum reading of approximately 1-volt.

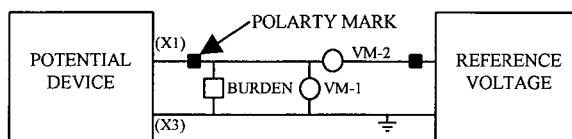


Fig. 9 Adjustment connections using voltmeter VM-1 for ratio and voltmeter VM-2 for phase-angle.

Oscilloscopes also facilitate accurate calibrations. If one voltage deflects the vertical sweep and the other the horizontal sweep, the scope serves for phasing-in mainly, although it cannot distinguish between zero and 180 degrees phase angle. (Connections shown in Fig. 10). The beam will describe an ellipse. As the ellipse reduces to a single line, both voltages assume equal or opposite phase. The opposite phase possibility is eliminated by ascertaining that the difference voltage between references and burden voltage is zero. The correct ratio is obtained with the aid of a high impedance voltmeter across the burden.

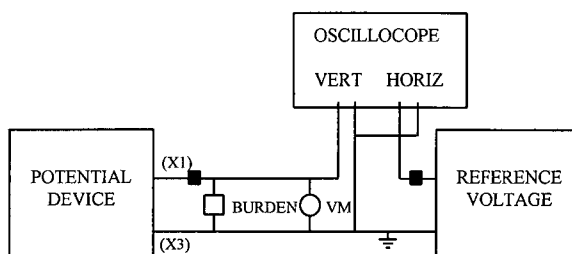


Fig. 10 Adjustment connections using a voltmeter for ratio and the for oscilloscope phase-angle

The oscilloscope can be connected to serve as a ratio and a phase-angle detector, thus eliminating a separate voltmeter. See Fig. 11. The burden voltage deflects the vertical sweep while the difference voltage (burden minus reference) is impressed on the horizontal sweep. As zero phase angle is approached, the initial ellipse will reduce to a single inclined line. This indicates equal phase. The inclined line will assume vertical direction, as the ratio tends to equal the reference ratio.

In both cases, the final single trace may show ripples which result from a difference in harmonics of the two compared voltages.

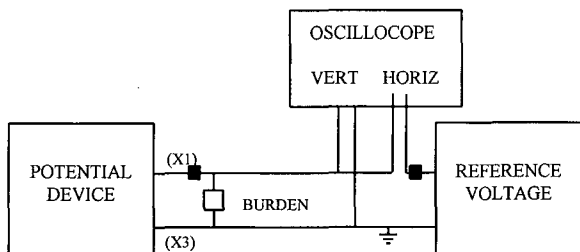


Fig. 11 Adjustment connections using the oscilloscope for ratio and phase-angle adjustments

Adjustment by Calculation

This method yields fairly accurate adjustments, if the potential device secondary voltage cannot be compared easily with a known value.

I. Ratio

Determine E2 from:
$$E2 = \frac{E1C1}{K(C1+C2+C3)}$$

where

E1 = Line-to-Ground volts of bushing

$$K = 1 + 0.1 \times \frac{WB}{WR}$$

WB - Burdens watts

WR - Rated watts from Fig. 5

C₁ = Capacitance (pf) from conductor to capacitance tap. Obtain from bushing nameplate.

C₂ = Capacitance (pf) from tap to ground. Obtain from bushing nameplate. If C₂ is given, C₂ = C₂ - C₁

C₃ = Auxiliary capacitance.

For models with "G" or "A" in 7th place, obtain C₃ from label on capacitor connected to main transformer primary.

For models with "B" or "C" in 7th place, the three digits following the "B" or "C" in model number divided by 10, is C₃' in μf. See Fig. 3 Connection Diagram.

$$C_3 = C_3' / 1849 - 44H940 \text{ series}$$

$$C_3' / 1056 - 44H941, 2, 3 \text{ series}$$

For example, assume model 44H940C120

$$C_3' = 120 / 10 = 12\mu f$$

$$C_3 = 12\mu f / 1849 = 6490 \text{ pf}$$

Enter the table on the Connection Diagram (or Fig. 8) at a value nearest to E2. Select corresponding positions of the "coarse" and "medium" ratio taps.

II. Phase Angle

Determine the capacitive impedance of bushing and auxiliary capacitor from:

$$X_C = \frac{10^{12}}{\omega (C_1 + C_2 + C_3)} \text{ ohms}$$

Where $\omega = 377$ for frequency of 60 hertz,

and C₁, C₂, and C₃ as previously defined.

The required potential device inductive impedance is then

$$X_L = X_C \text{ ohms}$$

Since X_L is adjusted by varying the phase-angle capacitance, determine the amount of phase-angle capacitance from one of the impedance scales shown in Fig. 12. Select the applicable impedance nomograph by referring to the catalog number on the device nameplate.

Refinement of Settings

The burden has been corrected to a slightly leading power factor as described under "Burden Power Factor Adjustment." Do not alter these settings. Place a high resistance voltmeter across the terminals to which the burden is connected. The potential device ground switch should be closed when changing ratio and phase-angle settings. A record of voltmeter readings, ratio and phase-angle settings kept during adjustment will be of value in arriving at the final settings.

Proceed as follows:

Change the phase-angle switches by small positive or negative increments (0.4 to 1.0 pF) to find a resonant peak in the output voltage. Use smaller steps (0.1 pF) near the peak. Now adjust the ratio settings by small steps (Volts Fine Taps) to reach the desired voltage level, such as 115V. For each ratio step, search again for the resonant peak with fine steps in the phase-angle capacitance. The actual capacitances will vary slightly from the switch markings. Also, the ratio controls will affect phase angle and conversely the phase angle affects the ratio.

The final settings are likely to differ somewhat from those determined by calculation.

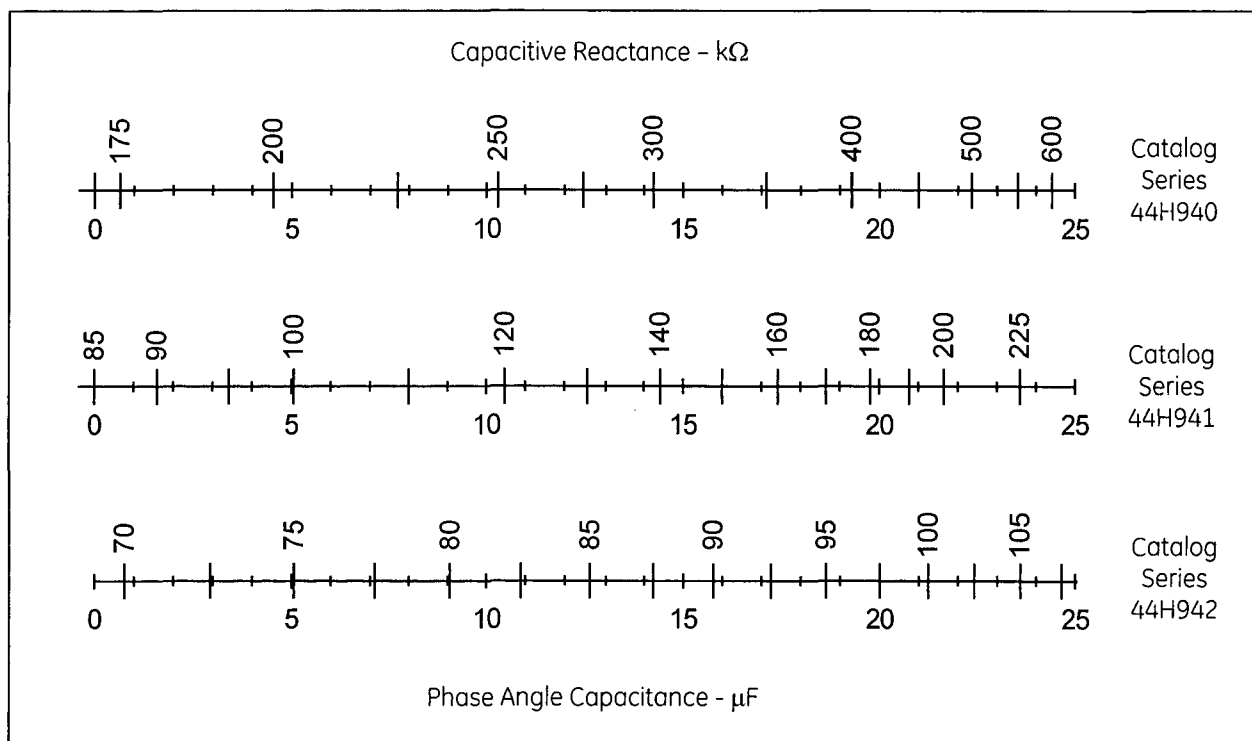


Fig. 12 Reactance ohms vs. phase angle capacitance

Field Adjustment By Nomograph

The nomograph (see **APPENDIX**) presents a simplified method of finding the switch settings; thus replacing the calculations given in the foregoing section. This is valuable not only in actual field calibration, but also when considering moving the device to another bushing, or even to a different circuit voltage.

In applying the graph, determine capacitances C_1 , C_2 , C_3 as described in section "Adjustment By Calculation."

HOW TO USE NOMOGRAPHS:

Select appropriate nomograph by matching the first 6 digits of the model number with the graph.

Plot the sum $C_1 + C_2 + C_3 + \text{cable capacitance}$ on "Total Capacitance" Scale, the required phase angle capacitance is read from the "Phase Angle Capacitance" Scale. Ratio settings are found by drawing a line from the above-mentioned sum, through C_1 on " C_1 " Scale to intersect the "Reference" line. Then from this point on the reference line through the "line-to-line voltage" Scale to the "Coarse and Medium Taps" Scale from which Volts Coarse and Volts Medium tap positions can be determined.

**EXAMPLE:**

For the example shown in **APPENDIX A** for a 230kV system: $C_1 = 350\text{pf}$, $C_2 = 7950\text{pf}$, 20ft cable = 980pf , and for model 44H940C120, $C_3 = 6490\text{pf}$ (see "Adjustment by Calculation" to determine C_3 from model number); thus Total Capacitance is 9350pf . From "Phase Angle Capacitance" Scale, phase angle capacitance is determined to be $13 \mu\text{f}$. Ratio tap positions become 27 and 30. Refer back to "Refinement of Settings" to finish calibration.

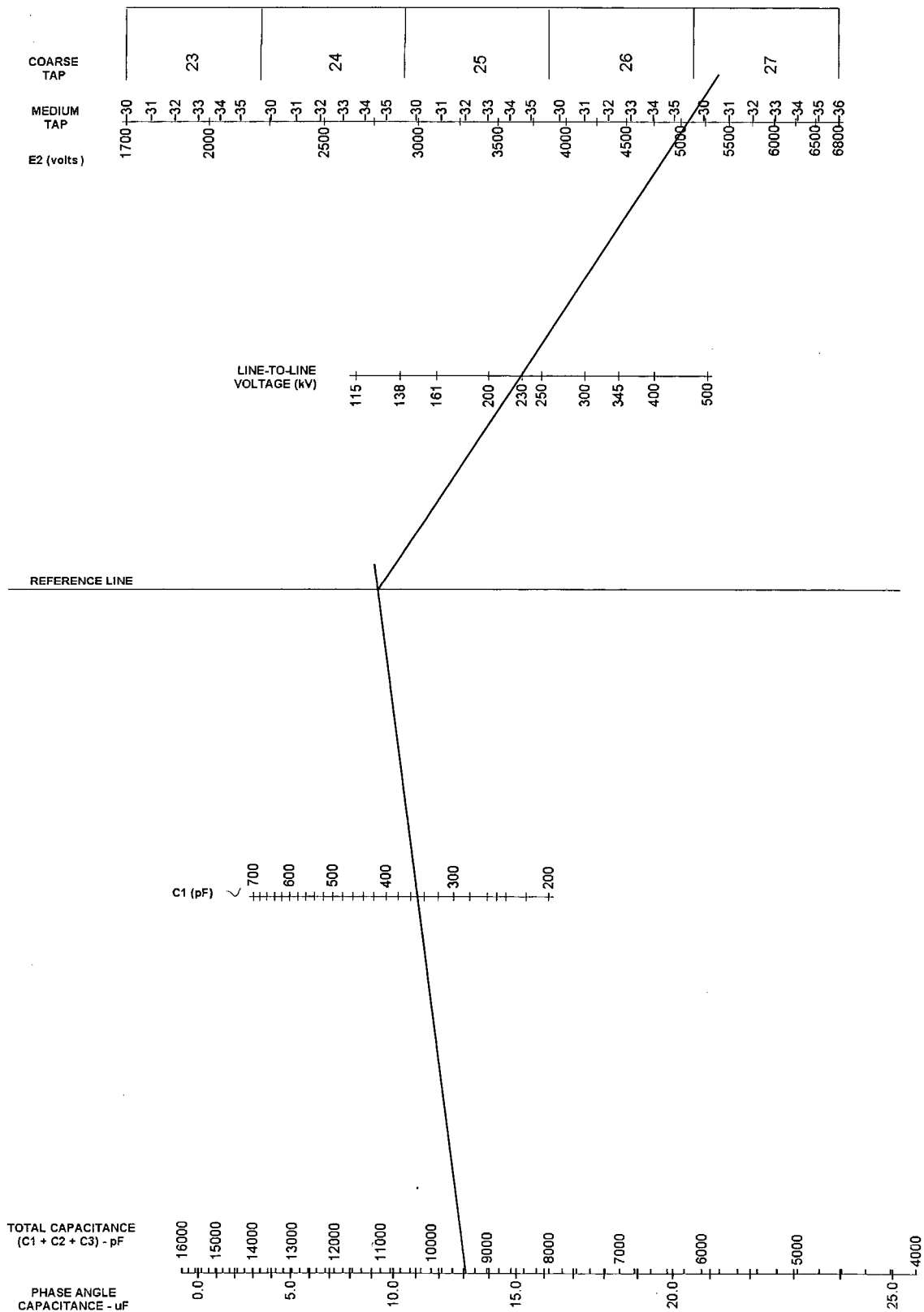
RENEWAL PARTS

Place orders for renewal parts with the nearest General Electric Sales Office. Specify the quantity required and give the catalog or part numbers of the required parts. If these numbers are not obtainable, describe the parts in detail. Always give the serial number and the complete nameplate rating of the equipment.

GE Parts Super Center

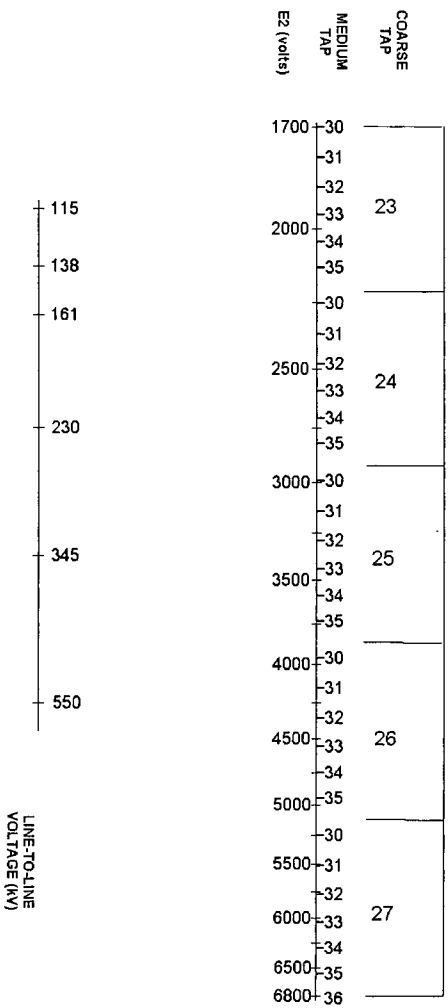
APPENDIX A

RATIO & PHASE ANGLE NOMOGRAPH (44H940 SERIES)

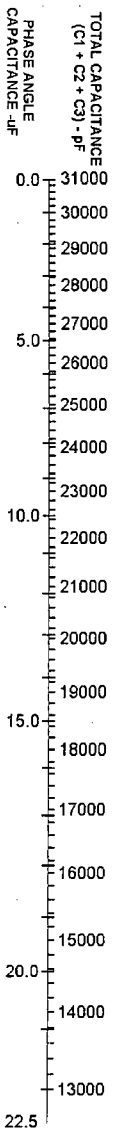
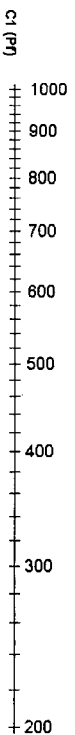


APPENDIX B

RATIO & PHASE ANGLE NOMOGRAPH (44H941 SERIES)

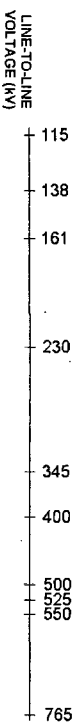
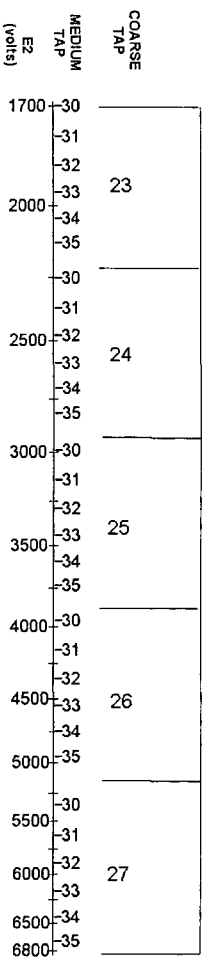


REFERENCE LINE



APPENDIX C

RATIO & PHASE ANGLE NOMOGRAPH (44H942 SERIES)



REFERENCE LINE

