Westinghouse

Condenser Bushing Potential Device

Installation

Operation — Maintenance

INSTRUCTION BOOK

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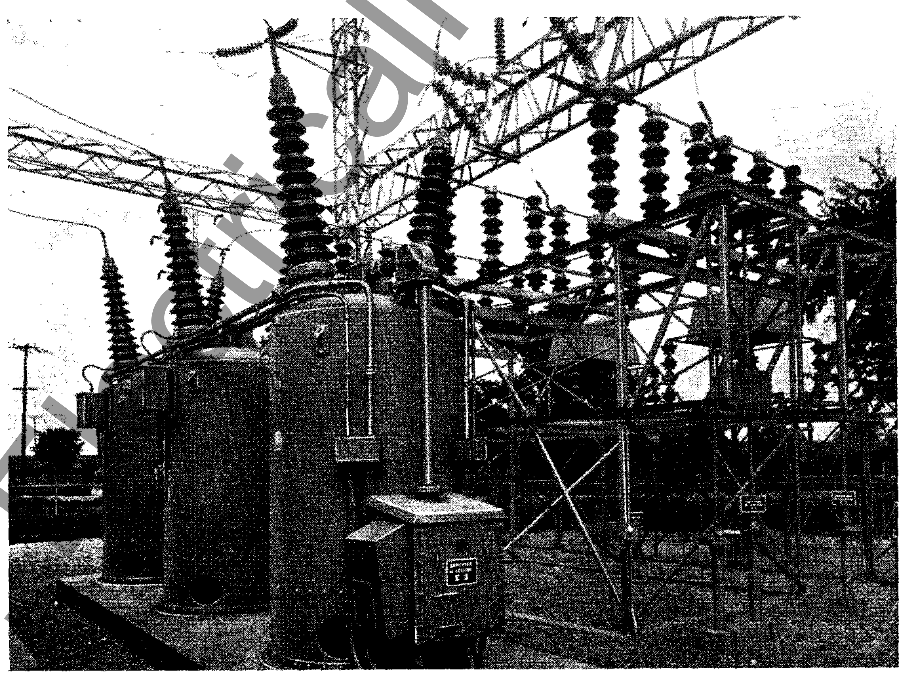


CONDENSER BUSHING POTENTIAL DEVICES MOUNTED ON A 154 KV. BREAKER FOR SYNCHRONIZING UNGROUNDED SYSTEMS

Westinghouse

Condenser Bushing Potential Device

DESCRIPTION AND THEORY

The Condenser Bushing Potential Device provides a means of obtaining a low voltage suitable for instrument and relay use, without using a high voltage potential transformer. The component parts of the device are mounted in a sheet steel protective housing and arrangement is provided for connecting to a tap near the ground band of a condenser bushing which may be the terminal of a circuit-breaker or of a power transformer, or may be mounted in a separate tank. The connection between the tap and housing is short and consists of a varnished cambric insulated lead covered cable. Fittings are provided on each end to afford easy installation.

The potential device makes use of the inherent potentiometer characteristics of the condenser bushing on high tension circuit-breakers and transformers. The condenser bushing itself consists of a conductor surrounded by alternate layers of insulating and conducting material. The conducting material may be considered as the plates of a condenser and the insulating material is, of course, the insulation between the various plates. The various conducting layers are accurately proportioned so that the voltage stresses are practically equal across each insulating layer. The bushing has a sufficient number of layers so that a comparatively low evenly distributed potential is obtained across each layer and from the voltage tap to ground. The condenser bushings with the voltage tap have been so designed that their well known advantages of mechanical ruggedness, great dielectric strength, high flashover value and long life are all retained.

This tap voltage is stepped down by a small potential transformer within the potential device and having suitable reactance and capacity in its secondary circuit to give a voltage of proper magnitude, usually 63.5 or 110 volts as desired, and of correct phase relation for the operation of switchboard instruments and relays.

The equipment within the housing consists of a low voltage potential transformer, an enclosed spark gap, a reactor and condensers. A ground switch is provided in the Type PB-2 device only. The normal position of the switch is open. When closed the tap connection to the bushing is grounded within the potential device housing.

The spark gap is a protective feature that functions when an overload has been placed on the secondary terminals of the device, thereby protecting the bushing. Likewise, the gap functions upon abnormal line conditions such as would be caused by lightning, switching, etc., thus protecting the instruments connected to the secondary of the device. The operation of the protective gap due to impulse surges caused by lightning, switching, etc., or excessive load is in no way detrimental to the long life of the bushing.

The transformer, reactor and condenser are all equipped with taps for the purpose of making accurate adjustment of the device. The ground connection of the primary of the transformer is made through the protective housing. All secondary leads from the transformer as well as leads from the reactor and condenser are brought to an adjusting panel mounted at the front and right hand side of the device. The potential transformer and reactor leads terminate on dial switches and the condenser leads on small knife switches so that adjustments may be quickly and easily made for any frequency or load within the range of the equipment. Three connections are provided at the bottom of the adjusting panel and an opening is provided in the bottom of the housing for leads to the instrument or relays which are to be actuated by the device. These leads may be handled and insulated in the same manner as the leads from the secondary of any standard potential transformer.

APPLICATION

There are essentially two bushing potential devices; namely the Type PB-1 and the Type PB-2. The distinguishing characteristics are the maximum permissible burden which may be imposed on the device and accuracy performance. The Type PB-1 device has the lower rating and accuracy. Whereas the PB-2 device operating at a higher tap voltage delivers greater output and is more accurate. These devices are not interchangeable physically and are designed to operate with bushings of different design.

The condenser bushing potential device is applicable for voltage indication, frequency indication, synchronizing and relay operation. The device may be applied to the standard bushings with voltage tap on circuit-breakers, power transformers or in separate tanks with the limitations in burden depending on primary voltage as given in Table I.

For larger volt-ampere burdens it is often the case that the power factor is relatively low, as in the average relay and in certain types of indicating instruments. In this case the effective volt ampere burden on the device may be reduced by paralleling a suitable condenser capacity installed within the device to improve the burden power factor. A discussion of the use and effect of this additional condenser is given under "Adjustments".

In case greater secondary burdens than those above are to be used, two potential devices per pole unit can be used in parallel per phase. When using this arrangement it is possible to carry a burden of double rating per phase. This will apply mostly to relay applications where it will be possible to open the paralleled secondaries when the breaker is in the open position. This arrangement is necessary because the Potential Device on the line side of the breaker would otherwise feed back into the device on the bus side.

One desirable application of this device is for synchronizing across a circuit-breaker using a potential device on both the line and bus sides of the breaker. On

TABLE 1

Bushing Class	Operating Voltage	BURDEN (63.5-110 VOLTS) PB-1	PB-2
92 kv.	88—92 kv.	8 watts**	15 watts*
115 kv.	110—115 kv.	15 watts	30 watts
138 kv.	132—138 kv.	20 watts	40 watts
161 kv.	154—161 kv.	27 watts	55 watts
196 kv.	187—196 kv.	50 watts	100 watts
230 kv.	220—230 kv.	60 watts	100 watts

*20 watts at 63.5 volts (only). **12 watts at 63.5 volts (only).

systems not solidly grounded and where there is possibility of neutral shift, phase to phase synchronizing should be used. This may be accomplished by connecting two devices in series (reversed open delta) on adjacent phases to indicate phase to phase voltage instead of the usual phase to ground voltage.

The potential device is adaptable to most relay protection schemes requiring a voltage source. It is inherently adapted to those schemes depending upon a voltage indication from phase to ground since the secondary voltage of the device is proportional to "phase to ground" voltage. The secondaries of three devices (three-phase installation) can be connected in star or delta to obtain potential for directional phase or ground relays. The potential device is energized continuously and a potential is always available for relay operation whenever a fault occurs.

INSPECTION

Upon receipt of the Condenser Bushing Potential Device, the first step is to make a thorough inspection to see that no parts appear to have been broken, bent or otherwise damaged during shipment. Particular attention should be paid to the condenser bushing voltage tap and to the plug connection. Any damage which has occurred should be taken care of by restoring the parts to the original condition or by obtaining replacement parts from the manufacturer. Claims for damage during shipment should be taken up at once with the transportation company.

The interior of the device should be inspected as to condition of wiring. In case there is any indication of the presence of moisture, the equipment should be thoroughly dried before putting into service with the condenser bushing.

INSTALLATION

The Condenser Bushing Potential Device is composed of two main parts, namely the condenser bushing and the potential device network contained within the protective housing. The condenser bushing is usually a part of the circuit-breaker or other high voltage apparatus and should be installed in accordance with instructions pertaining to the particular apparatus. The voltage tap on the bushing must extend outwards towards the potential device housing as shown in Figure 1, to permit proper assembly of the "lead-in" cable which is furnished with each housing. In case the bushing is mounted in a separate tank, it is only necessary to install the bushing in accordance with instruction Card No. (E.P.)I.C. 182 and I.T. 994 and fill the tank with Wemco "C" oil to the proper level as indicated by the gauge. Care must be taken to insure that all joints are made tight to prevent the entrance of moisture.

The potential device housing is equipped with two entrances for the primary and secondary circuits and with lugs for mounting on the circuit-breaker or transformer tank. When installing the housing (device contained within) as shown in Figures 2 and 3, care should be taken to insure that paint and other foreign material is cleaned from the lug surfaces which come into contact. These surfaces should then be given a coat of conducting paint to prevent rusting. Since the apparatus within the housing is grounded to the housing it is necessary that the device be grounded through the lug connection to the tank and the tank provided with a good ground.

The primary circuit as made by installation of the lead-in cable assembly shown in Figures 4a and 4b. The lead-in cable assembly consists of a high voltage varnished cambric insulated lead covered cable with suitable couplings, gaskets, and a porcelain plug. It is used to provide an electrical connection between the bushing voltage tap and the potential device. The lead-in cable assembly as shipped, is tested electrically and mechanically. Special pressure tests insure against the possible entrance of moisture in the completely assembled cable.

When the cable is first received, a careful inspection should be made to determine if the cable is in first class condition, undamaged in transit, and that no moisture is in evidence. If moisture is found, the cable assembly should be carefully dried in an oven of temperature not to exceed 85°C., before any attempt is made to place the cable in service.

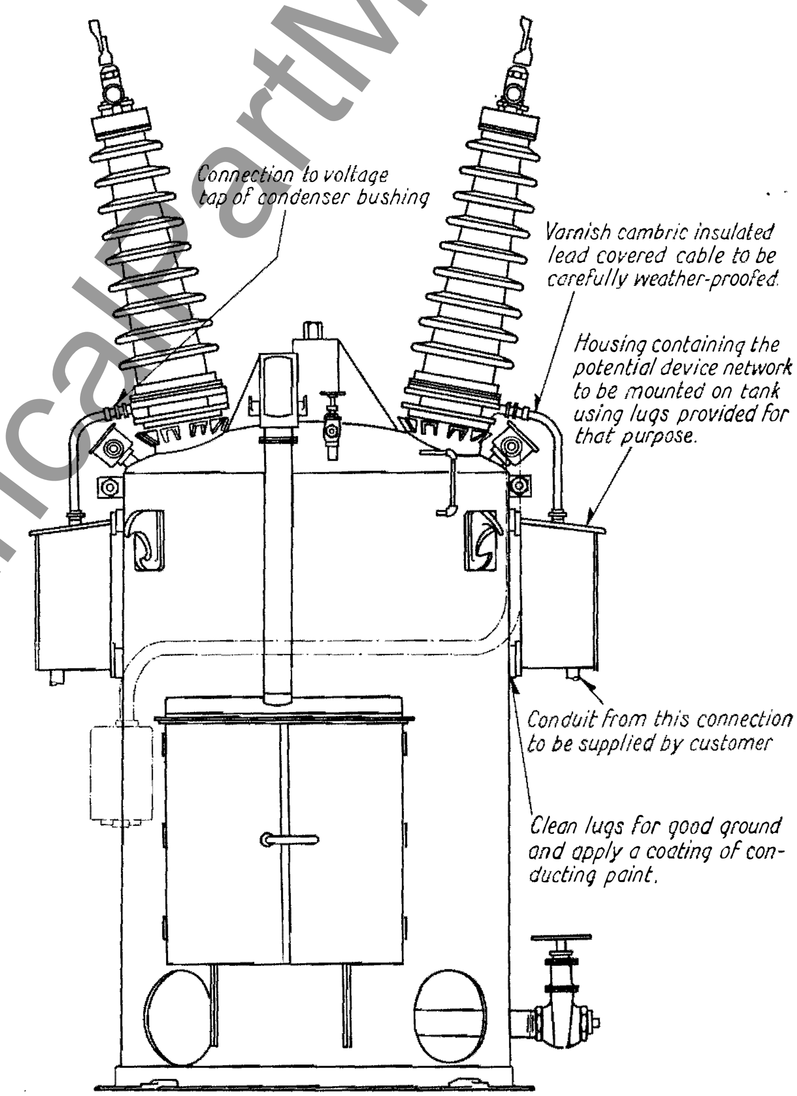


FIG. 1—CONDENSER BUSHING POTENTIAL DEVICE MOUNTED ON BREAKER TANK

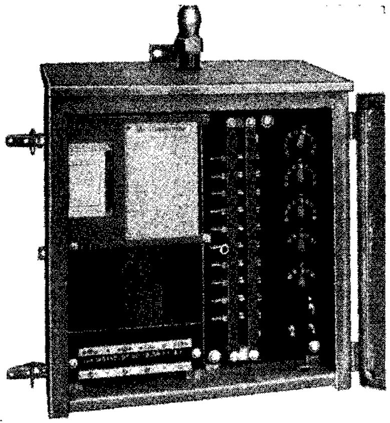


Fig. 2—Type PB-1

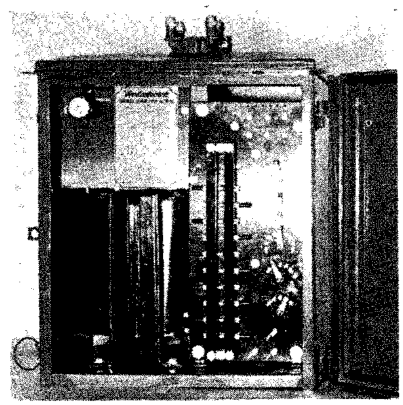


Fig. 3—Type PB-2

The voltage taps of all bushings should be filled with petrolatum (commercial vaseline) before being placed in service. Bushings equipped with a tap for the PB-1 device should have petrolatum forced into the chamber before installing the lead-in-cable. The petrolatum should be packed in the chamber in a manner that will prevent the possibility of any air pockets after assembly of the cable. Bushings equipped with a tap for the PB-2 device are provided with a filling plug, permitting the tap chamber to be filled with heated petrolatum in the liquid condition after the lead-in-cable is assembled in place. Sufficient time should be allowed in filling the chamber to prevent the formation of air pockets.

The installation of the lead-in-cable should be carried out in the following manner. The gasket supplied by the manufacturer for each coupling should be coated on both sides with a weather proofing shellac or varnish Apply a similar coating to all flanged surfaces and threads through which moisture may tend to pass. The housing end of the cable assembly should be assembled first and carefully tightened with a suitable wrench to insure a good tight weatherproof joint. The cable should then be carefully bent so that the bushing end of the cable may be inserted in the voltage tap of the bushing without interference. This coupling should then be tightened to insure a good tight weatherproof joint. The tap chamber of the bushing used with the PB-2 device should be filled with petrolatum as described above.

The entire cable assembly should be given a coat of weather-proof paint as a further protection against weather. The housing end of the cable should be connected to the transformer primary and the lightning arrester forming the T-connection as indicated on the wiring diagram. The connection from the primary of the transformer and of the lightning arrester to their respective points of grounding should be inspected to insure that same have not worked loose during transportation and field assembly.

ADJUSTMENT

Determination of Reference Potential–In making the proper adjustment of the condenser bushing potential device it is essential that a reference potential and a secondary burden be available. Due to the fact that both the magnitude and phase angle of the secondary voltage of the device is affected by the choice of settings, it is necessary to use a known reference as a basis. This reference should be a voltage in phase with the voltage across the condenser bushing to ground and of proportionate magnitude. ** It is usually most convenient to obtain this reference from potential transformers installed in a low voltage bus. Quite frequently the determination of the correct reference is complicated by the power apparatus between the high voltage system and the low voltage bus. For a particular example refer to Figure 5 where a 110 kv. system has been selected

**Suggest use of Reactive Component Compensator Style 423778 for obtaining voltage of correct magnitude and phase angle from the available bus potential transformers where necessary.

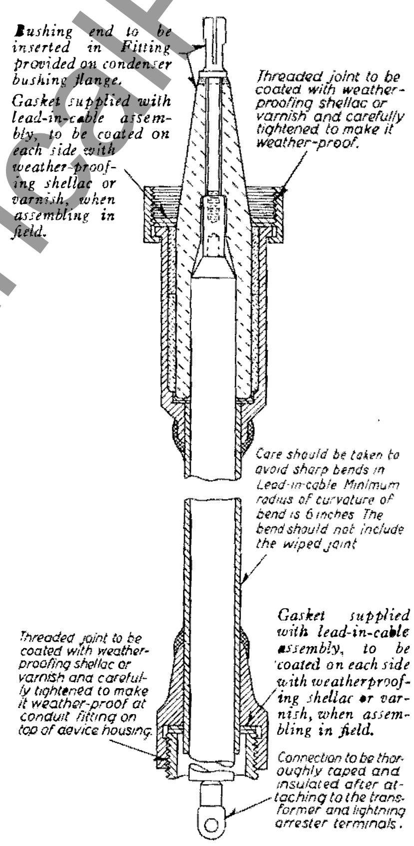


Fig. 4a—Lead in Cable Assembly (PB-1)

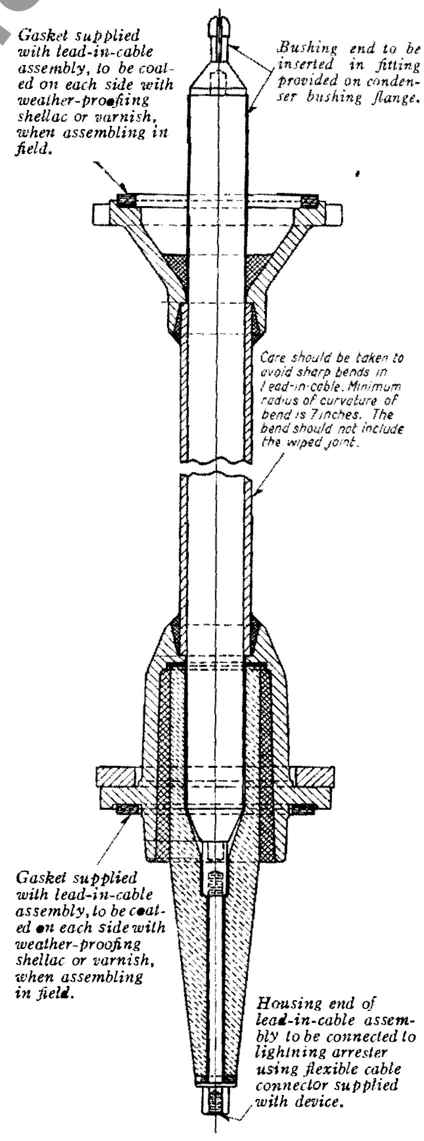


Fig. 4b—Lead in Cable Assembly (PB-2)

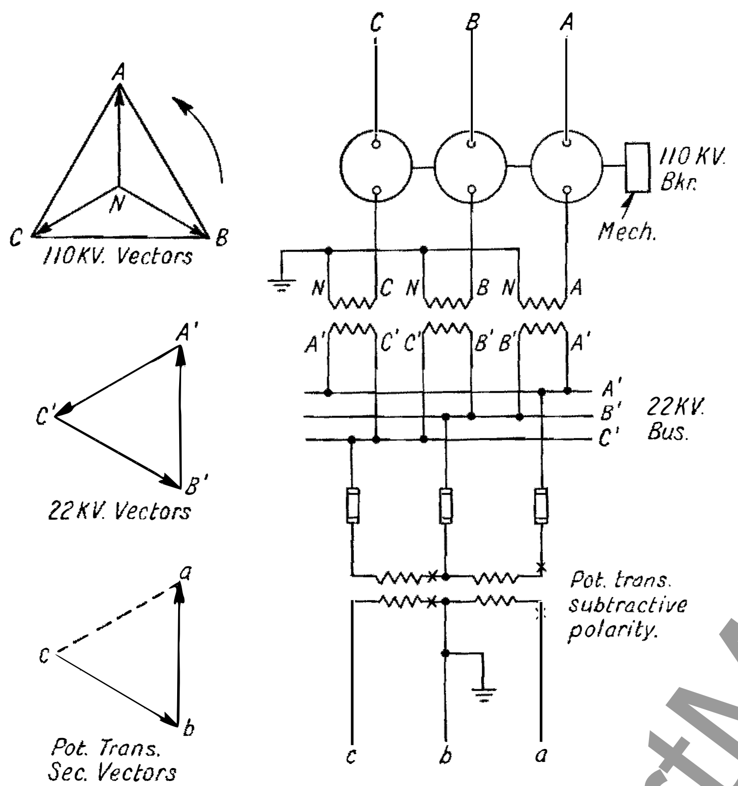


FIG. 5—VECTOR ANALYSIS FOR OBTAINING CORRECT REFERENCE POTENTIALS. PHASE ROTATION A, B, C.

with two potential transformers connected in open delta in the 22 kv., bus. An inspection of this diagram indicates that the voltages will have the following relation and the proper reference to be selected.

110 Kv. Voltage	Potential Transf. Sec (Reference)
A to N	a to b*
B to N	b to c
C to N	c to a

*By removing ground from tie point of pot. trans. secondary.

In making a similar analysis for a given installation, care must be exercised in the determination of the phase rotation of the system and of the relative polarity of the transforming apparatus.

To determine the magnitude of the potential device secondary voltage (across terminals S_1 S_2) a high resistance voltmeter (low burden) of not less than 20000 ohms at 110 volts should be used, to prevent the burden of the voltmeter affecting the secondary voltage. (Suggest Westinghouse Voltmeter Style No. 703872.) When it is impossible to obtain a voltmeter of low burden it will be necessary to include the burden of the meter in the dummy burden.

To determine the phase angle of the potential device secondary voltage relative to the "phase to ground" voltage of the system, it is recommended that a Westinghouse Phase Meter Style No. 408136A or a low burden two voltage element phase meter be used. The choice of instruments will depend on the particular application of the devices in question. If the devices are to be used for synchronizing it will probably be more convenient to use the synchronoscope as installed on the switchboard for determining phase angle. The phase meter is probably better adapted to adjusting the devices used for relaying on account of its accuracy and portability.

Regardless of the instrument used for phase indication, it will be necessary to energize one element from the known correct reference. When using the synchronoscope, potential transformer voltage can be applied to one side of the synchronoscope and the potential device voltage to the other. (Assuming of course that the primaries of each type of voltage apparatus are energized from same phase of the high voltage system and in synchronism.) This voltage must have approximately the same magnitude as the potential device secondary voltage. When the device is properly adjusted, the synchronoscope should indicate practically zero. When using the phase meter the current element should be energized from the potential transformer by connecting in series with sufficient resistance (or lamps) to limit the current to approximately two and one-half amperes in the secondary of the potential transformer and meter. In using this scheme care must be taken in avoiding overburden of the bus potential transformer. It is advisable to use the same reference phase for adjustment of devices on all three-phases and make allowance for angle between phases of the system (120°) when adjusting devices on the other two-phases. (Do not use voltage across open delta of the bus potential transformers to energize the current coil of the phase meter.) If a two voltage element phase meter is used, energize the lowest burden element from the potential device and the other from the potential transformer.

Determination of Adjusting Burden—It is often impossible to adjust the condenser bushing potential device with its associated meters and relays. This is due to the effect of the burdens of the measuring instruments used for adjusting and also to the distribution of secondary burden, when the devices are connected in star or delta, to supply potential to various relay and synchronizing schemes. If a device is to be adjusted to supply potential (phase to ground) to an individual instrument, for example, a synchronoscope or voltmeter, it will be more convenient to connect the secondary of the device to the instrument installed on the switchboard for use with the device. The device can be adjusted as later explained by using a high resistance voltmeter to obtain correct secondary voltage. If a voltmeter and synchronoscope are to be used interchangeably with one potential device it is advisable to adjust the device so that it supplies a voltage of correct magnitude when the voltmeter is connected and of correct phase angle when the synchronoscope is connected. (Should a "hot-line" indication be required, a neon lamp, ½ watt, 110 volt, can be connected to the secondary of the potential device continuously.)

A dummy burden is required to adjust the individual potential device when two or more devices are to be used in combination for a common burden. In most cases this burden should include the measuring instruments, particularly the phase meter. Several examples will be taken to illustrate the method of determining the dummy burden:

Example No. 1—Suppose it is assumed that three devices are to be installed on a three-phase 110 kv. breaker using system set-up as in Figure 5 to furnish potential for three directional CR relays using "90 degree" connection

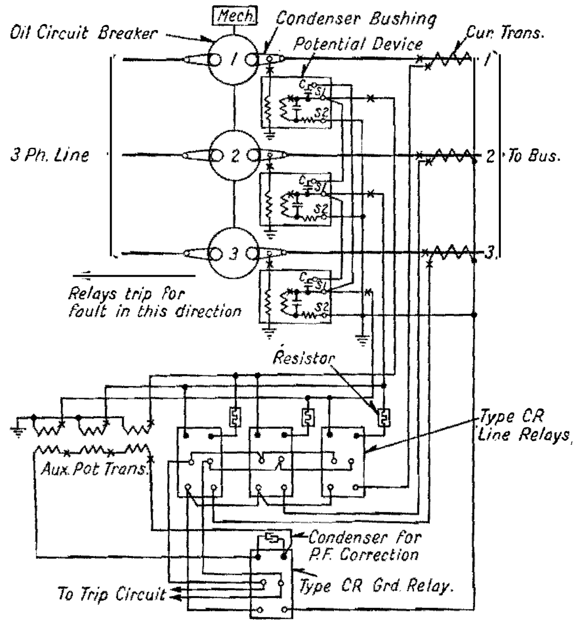
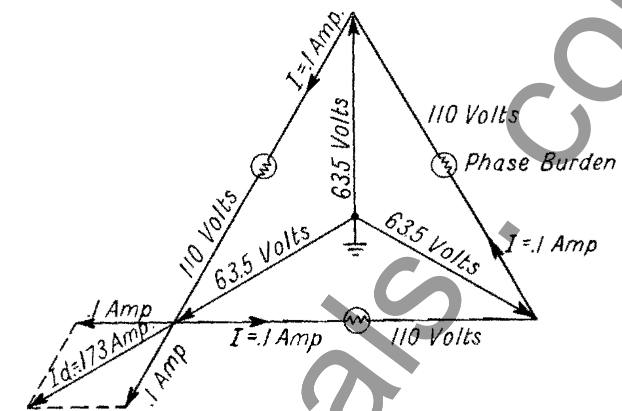


FIG. 6—CONDENSER BUSHING POTENTIAL DEVICE CONNECTIONS FOR GROUND AND LINE RELAYS, TYPE CR 90° CONNECTIONS



Assume A Phase Load Across Each Phase = 11 Volt-Amps., 100% P. F. At 110 Volts.

I (At 110 Volts) $= \frac{11}{110} = .1$ Amp.

From Left Hand Vectors of Current:

Id (Per Device) = 1.73 x I per phase = 1.73 x .1 = .173 Amp.

From Main Vector Diagram of Voltage:

$$\text{e Per Device} = \frac{\text{E Per Phase}}{1.73} = 63.5 \text{ Volts}$$

Burden Per Device = (e x Id) Per Device = 63.5 x .173 = 11 Volt-Amps., 100% P. F. at 63.5 Volts

Thus, Burden Per Device, Provided Phase Loading Is Equally Distributed, is the same Volt-Ampere Burden at 63.5 Volts as the Phase Burden is at 110 Volts.

FIG. 7—VECTOR DIAGRAM FOR DETERMINING DEVICE BURDEN FOR ANY GIVEN PHASE BURDEN

and equipped with external resistors. The devices will be connected in star on their secondaries as shown in Figure 6 and the relays connected in delta. The burden of the potential element of these relays is approximately 15.2 volt-amperes at 78 percent power factor on 110 volt circuit. Using the method shown in Figure 7 the burden per device is 15.2 volt-amperes at 78 percent power factor on basis of 63.5 volts. In order to obtain a better performance of each device it is desirable to compensate for the effect of the reactive component of the relay burden. A separate condenser installed within the device is for the purpose of correcting for reactive component of the secondary burden primarily to permit the use of larger burdens having a high reactive component. As indicated elsewhere in this publication the maximum burden of the PB-1 device for 110 kv. line voltage is 15 volt-amperes at 100% power factor on 110 volt basis. Thus to reduce the effective burden of the relays on each device in this example the calculation in Table II will determine the capacity of condenser to use in each device. This capacity may also be determined from the curve, Fig. 8.

This value of capacity should be obtained by combining the proper taps on the balance condenser in each potential device. These balance condensers are quite similar to the network condensers having the units connected in series with a tap brought out from each unit. The capacity of each unit is marked on the end of the case and on the panel. The proper capacity (2.08 in this example) should be obtained by parallel and series combinations on each condenser and finally connected across phases on the secondary of the potential device as shown in Figure 10. The effective burden on each device is 11.8 volt-amperes at 100% power factor. Each device should be adjusted for this burden which is made up as shown in Table III.

The adjusting burden is made up of the potential element of the phase meter, a condenser of 2.23 m.f. capacity and a resistor of 563 ohms resistance, all connected in parallel. The current element of the phase meter should be energized from the correct reference potential as described above and the device adjusted as later explained.

TABLE II

*Relay burden in volt-amperes (110 volts) (15.2 volt-amps. —78% P. F.)	11.8 + j 9.45
Minimum possible effective burden of relay in volt-amps. (Watt component)	11.8 + j 0
Reactive component in volt-amps. to be balanced by condenser (V. A.)	0 + j 9.45

$$\text{Balance Capacity} = \frac{\text{V.A.} \times 10^6}{\text{E} \times 2\,\pi \text{f}} = \frac{9.45 \times 10^6}{110^2 \times 377} = 2.08 \text{ micro-farads.}$$

*See Fig. 9.

TABLE III (Based on 63.5 Volts)

†Phase Meter burden in volt-amp. (5.75 volt-amp.—80.8% P.F.)**	4.65 + j 3.39
Paralleled condenser in volt-amps	0 — j 3.39
Paralleled resistor in volt-amps	7.15 + j 0
Adjusting burden in volt-amps	11.80 + j 0

$$\text{Paralleled resistance} = \frac{\text{E}^2}{\text{V.A.}} = \frac{63.5^2}{7.15} = 563 \text{ ohms.}$$

$$\text{Paralleled condenser} = \frac{\text{V. A.} \times 10^6}{\text{E}^2 \times 2\,\pi \text{f}} = \frac{3.39 \times 10^6}{63.5^2 \times 377} = 2.23 \text{ m. f.}$$

† Burden of potential coil of Phase Meter to be used should be measured accurately as the burden of different instruments vary somewhat.

** Phase meter burden can be eliminated if a low burden (less than one volt-amp.) phase meter is used.

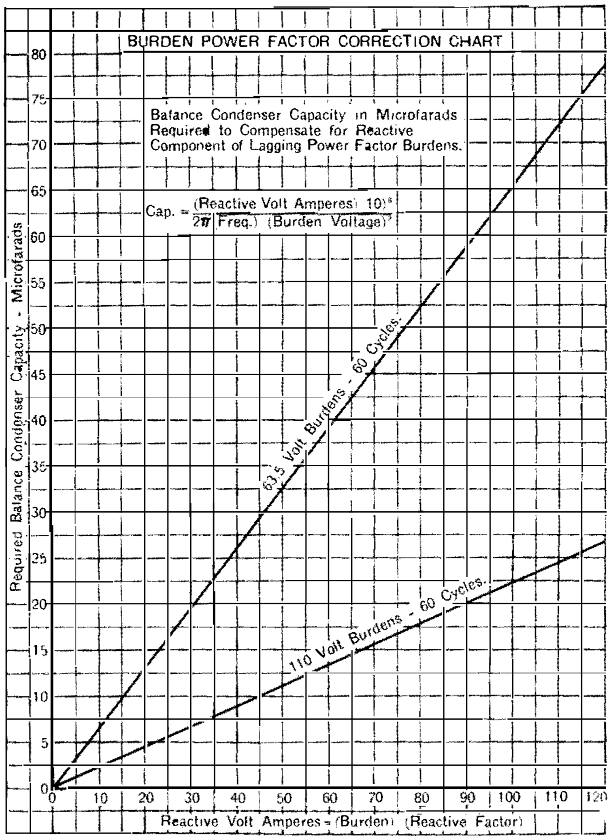


FIG. 8—BURDEN POWER FACTOR CORRECTION CHART

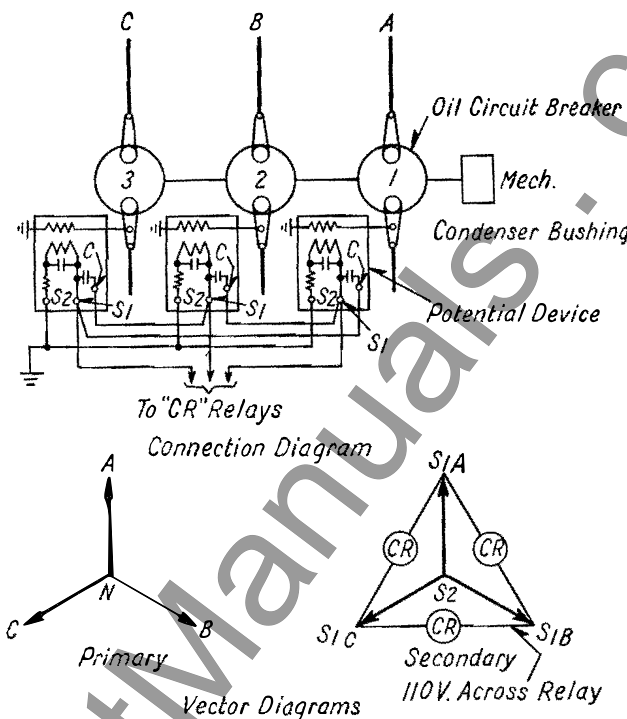
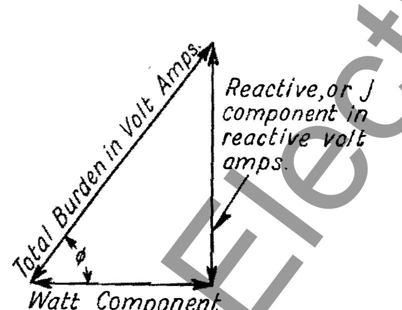


FIG. 10—THREE CONDENSER BUSHING POTENTIAL DEVICES CONNECTED IN STAR TO SUPPLY POTENTIAL FOR DIRECTIONAL PHASE PROTECTION

Example No. 2—Should it be required to adjust three devices to supply potential for CR relays using 30 degree connection (See Fig. 11) (without external resistor) a procedure similar to example number one is followed except the effective burden can be considerably reduced. See Table IV.

This does not indicate that it is necessary to balance with this amount of capacity to obtain proper functioning of the devices with the relays. It is an example however that apparently heavy burdens (low power factor) can be carried on the devices if the effective burden per device is reduced by power factor correction. The amount of condenser to use is governed by the permissible maximum burden of the device In correcting the effective burden to 100% power factor it is necessary to use an adjusting burden of 100% power factor which is usually much easier to make up than a burden at any other power factor.

If it is desirable to use a directional type CR ground relay with either of the above phase relay schemes, a residual delta voltage can be obtained by using an auxiliary star-delta three-phase transformer (Westinghouse Style No. 699869 all contained in one case). The CR ground relay should have four one microfarad condensers connected across the potential element to insure correct operation with the potential device.



Ø = Angle Depending on Power Factor of Burden.
Power Factor = Cosine Ø
Reactive Factor = Sine Ø
Watt Component = Power Factor x Total Burden.
Reactive Component = Reactive Factor x Total Burden.
For Relay Burden of 15.2 Volt-Amps. at 78% P.F.
Watt Component = .78 x 15.2 = 11.8 Watts.
Reactive Component—.62 x 15.2 = 9.45 Reactive Volt-Amps., Or Volt-Ampere Burden = 11.8 + j9.45.

FIG. 9—METHOD OF SEPARATING A BURDEN INTO ITS COMPONENTS

TABLE IV

Relay burden in volt-amps. (110 volts) (23.7 volt-amps.—15% P. F.)	3.56 + j 23.4
Minimum possible effective burden of relay in volt-amps. (watt component)	3.56 + j 0
Reactive component in volt-amps. to be balanced—by condenser (V. A.)	0 + j 23.4

$$\text{Balance capacity} = \frac{23.4 \times 10^6}{110^2 \times 377} = 5.12 \text{ m.f.}$$

TABLE V

$$\text{Burden imposed on each device} = 11.44 \times \frac{63.5}{110} = 6.62 \text{ volt-amps. at } 90\% \text{ P. F.}$$

Burden imposed on each device vectorally = 5.95 + j 2.88

Phase meter burden in volt-amps.	4.65 + j 3.39
Paralleled condenser in volt-amps.	0 — j 0.51
Paralleled resistance in volt-amps.	1.30 + j 0
Adjusting burden in volt-amps.	5.95 + j 2.88

$$\text{Paralleled resistance} = \frac{63.5^2}{1.30} = 3100 \text{ ohms.}$$

$$\text{Paralleled condenser} = \frac{.51 \times 10^6}{63.5^2 \times 377} = .335 \text{ m.f.}$$

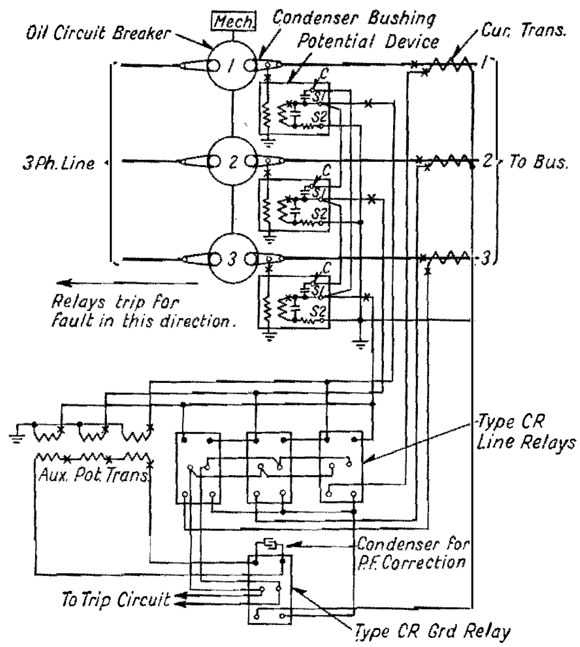


FIG. 11—CONDENSER BUSHING POTENTIAL DEVICE CONNECTIONS FOR GROUND AND LINE RELAYS TYPE CR 30° CONN.

The burden of this ground relay need not be considered in the adjustment of the devices.

It is sometimes desirable when using directional relay protection to check the angle between the voltage and current in the potential and current elements respectively. This check is described in detail in the instruction books covering the particular relay. One modification is necessary when using the potential device, however, in that the potential connections must be removed from one particular relay and the potential element of the phase meter inserted instead. In addition, the burden of the phase meter must be modified with condensers where possible to have the same burden as the potential element of the relay. For cases where the burden of the relay is less than the burden of the phase meter, the relays should be connected as used in service and the voltage across each potential element of the relay checked against a known reference voltage using the "null method" or using a low burden phase motor.

Example No. 3—Suppose it is assumed that two devices are to be installed on a three-phase 110 kv. breaker using a system set-up as in Figure 5 to furnish potential for a Type SI synchronoscope. The devices will be connected in series (reversed open delta) supplying a phase to phase voltage as shown in Figure 13. The standard Type SI synchronoscope has two elements, having burdens of 10.6 volt-amps. at 100% power factor and 11.44 volt-amps. at 90% power factor on the split phase element both on a 110 volt circuit. To adjust the two devices for the synchronoscope burden it is advisable to make an approximate adjustment on the individual device and make the final adjustment with the devices connected is reversed open delta to the synchronoscope. The adjusting burden is made up as shown in Table V.

The adjusting burden is made up of the potential element of the phasemeter, a condenser of .335 m.f. capacity and a resistor of 3100 ohms resistance all connected in parallel. The current element of the phase meter should be energized from the correct reference potential and the devices adjusted to approximately zero angle and 63.5 volts.

Connect the devices in reversed open delta to the synchronoscope mounted on the station switchboard. Energize the other side of the synchronoscope from the reference potential (correct phase and

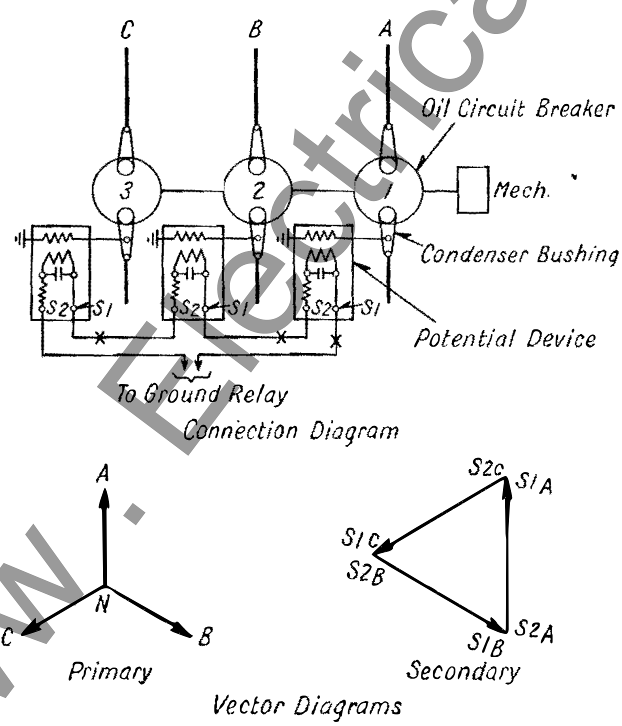


FIG. 12—THREE CONDENSER BUSHING POTENTIAL DEVICES CONNECTED IN DELTA TO SUPPLY RESIDUAL VOLTAGE FOR DIRECTIONAL GROUND POTENTIAL

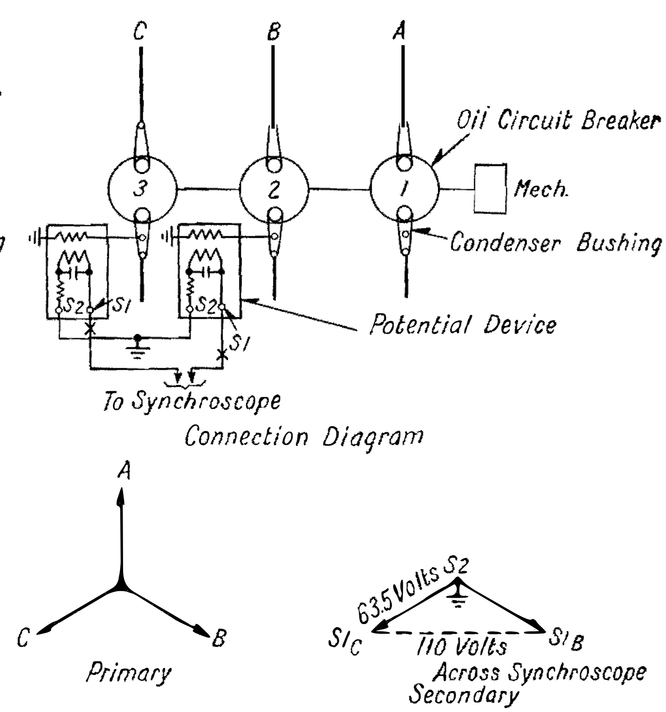


FIG. 13—TWO CONDENSER BUSHING POTENTIAL DEVICES CONNECTED TO SUPPLY POTENTIAL FOR PHASE TO PHASE SYNCHRONIZING

magnitude) and make any slight adjustment as may be required at the devices to bring the synchronoscope needle to zero. Both devices should be adjusted together. For a given shift in angle or voltage a portion of each should be corrected by making necessary adjustment on each device, and, not all on one device. This method of adjustment is suggested to prevent incorrect series operation of the devices. The regulation of a device is changed by changing its adjustment and it is quite easy to obtain settings whereby one device would tend to take all of the burden. This is prevented by making the initial approximate adjustment individually.

In general, regardless of the scheme used and total combined burden, it is necessary to determine the burden to which each device will be subjected at its desired normal operating voltage. When six devices are used per breaker to supply a common burden such as relays when the breaker is closed and some other burden such as a synchronoscope when the breaker is open, the same procedure is followed as in the above examples.

DEVICE ADJUSTMENTS

To facilitate the actual adjustment of the device, a complete understanding should be had of the connections and effect of variations of the network reactor, transformer and condenser.

The main reactor taps are connected to dial No. 1, so that rotating the movable selector switch from left to right increases the amount of reactance added to the circuit. This compensates for the phase shift caused by the capacity of the condenser bushing and the burden impedance. The vernier reactor is a small coil on the main reactor which may be connected additive or subtractive with respect to the main reactor by varying the selector switches on dials No. 2 and No. 3. When the numerical setting of dial switch No. 2 is larger than that of dial No. 3, the vernier is added to the main coil, and vice versa. The smaller vernier steps are between V_1 and V_5 while the relatively larger steps are between V_5 and V_9. This point should be kept in mind while making the final adjustments.

The transformer taps are connected to dials No. 4 and No. 5 in the following manner: (See diagram of device).

X_4-X_5-Lowest transformer voltage.

X_3-X_5-Intermediate

X_2-X_5-Intermediate

X_1-X_5-Normal transformer voltage

X_1-X_6-Intermediate

X_1-X_7-Intermediate

X_1-X_8-Highest transformer voltage.

The first contacts on dials No. 4 and No. 5 are marked "off" and provide a means of opening the secondary circuit when connections are being made to terminals "S_1" and "S_2" of the device. It is unnecessary to open the secondary circuit or to remove the voltage from the device while making adjustments as all the adjusting switches may be readily moved from one position to another while the device is energized. However, the selector switches on dials No. 1 to No. 5 should not bridge two adjacent contacts for any great length of time as this will give an unsatisfactory adjustment and may cause damage to the device.

The condensers are controlled by single pole double throw knife switches in such a way that the individual condenser units may be connected in series, parallel or series parallel as desired. From the wiring diagram it is evident that alternate switches thrown to the left and right place the various condenser units in parallel across the transformer secondary. A switch to the right and another to the left, with one or more openin between, places the units in series. The top switches control the larger units and the bottom switches control the smaller units of network condenser capacity.

It must be remembered that while the reactor predominately affects the phase error of the device, and the transformer and condenser affects the voltage, that the adjustment or variation of any one of the component parts must necessarily affect the magnitude and direction of the voltage and phase angle together. Assuming that the device is correctly mounted and connected to the bushing tap and that normal line-to-ground voltage is available for energizing the bushing, the following procedure should be noted.

1. Set the reactor selector switch dial No. 1 to R_5.
2. Set the vernier selectors, switches dial No. 2 and dial No 3 to V_1.
3. Set the transformer selector switch No. 4 to X_1.
4. Set the transformer selector switch dial No. 5 to X_5.
5. Close condenser knife switch B to left and switch C to the right.
6. Connect adjusting burden including phase meter or synchronoscope to S_1 S_2 on the panel of the device.
7. Connect a voltmeter having resistance not less than 20000 ohms on 150 volt scale to S_1 S_2.
8. Energize condenser bushing from high voltage system by closing breaker or line disconnects.
9. Energize current coil of phase meter or one element of synchrnoscope from the reference potential.
10. Connect reference potential to a voltmeter to determine its value at all times during the adjustment.
11. Note the voltage and phase angle errors as indicated by the meters using the initial dial and switch settings given in the preceding paragraphs. Both readings will probably be in error to start with. Vary the main reactor switch (Dial No. 1) left or right until the phase angle error is approximately zero as indicated by the phase indicator. Adjust the voltage by varying the condenser knife switches, remembering that the larger values of capacity are at the top and the smaller values at the bottom of the panel. Alternate switches to the right and left places the condenser units in parallel across the transformer secondary. Additional voltage and phase angle variation may be obtained by varying the transformer taps as previously indicated.

   When the voltage and phase angle readings are of approximately the desired values, the vernier reactor and smaller condenser units should be used to make the final close adjustments. Taps V1 to V5 of Dials No. 2 and No. 3 control the smaller steps of the vernier reactor while taps V5 to V9 control the larger steps.
12. In case the phase angle error is very great and difficulty is experienced in adjusting same, a re-check should be made to see that the voltage used for reference is approximately equal to the voltage desired from the potential device, is from the proper phase, and that the phase indicator polarity is correct. If the protective arrester functions, add additional condenser capacity to the circuit by means of the knife switches, or use a high voltage setting of the transformer. If satisfactory results cannot be obtained in this way, re-check the total volt-ampere burden on the device to make sure the rating of the device has not been exceeded.
13. When a desirable setting has been obtained measure the voltage across the mid point of dial No. 4

and 5 with a voltmeter having not less than 40000 ohms on the 300 volt scale. This voltage which is affected by various adjustments is the network condenser voltage and should not exceed 270 volts.

It is usually desirable to determine the tap voltage of the device as finally adjusted, and connected to the burden. This voltage can be calculated by multiplying the transformer secondary voltage with the transformer ratio. This ratio can be obtained from the transformer diagram furnished with each device. This voltage under normal operating conditions should not exceed 4300 volts with the PB-1 device and 8000 volts with the PB-2 device.

14. The PB-2 device can be adjusted to obtained modified performance. For instance the device can be adjusted to lower phase angle errors than shown on accompanying curves but at the sacrifice of ratio accuracy and vice versa. The best average performance for devices normally operating at rated line voltage is obtained with transformer ratios between 27/1 and 32/1.

15. When the devices are used in a three phase combination of any nature, care should be taken in adjusting the devices such that the same transformer taps are used on each device of a given 3 phase group. This precaution will tend to hold the internal impedance of each device at the same value.

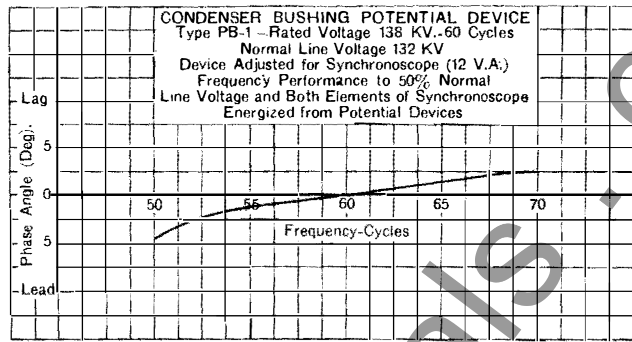


FIG. 14—APPROXIMATE PHASE ANGLE—FREQUENCY PERFORMANCE

16. If the above procedure is carefully observed the secondary voltage may be adjusted to approximately one and one-half percent of the desired value and phase angle to within 2 degrees for any burden within the normal rating of the device. After the adjustment is completed the locking bar should be fastened in place on the condenser knife switches and the final dial and switch settings recorded. The door of the housing should be closed and padlocked and no further attention need be given to the device.

PERFORMANCE

The performance of the condenser bushing potential device is dependent on the line frequency, line voltage and to some extent the amount of secondary burden. On referring to the performance curve (Figure 14) it is noted that the phase angle variation with frequency is quite small when using potential devices to energize both sides of the synchronoscope.

The typical performance characteristics may be noted from the curves shown in Figs. 15 to 18 on page 12. If the device should be loaded beyond its capacity the secondary voltage is decreased and the voltage across the last layer of the bushing is increased. Under a condition of sufficient over-burden the spark gap arrester will function and prevent the increased voltage from causing damage to the bushing.

RENEWAL PARTS

Since there are no parts in this device subject to wear there is practically no occasion to carry spare parts. However, in case the device is damaged and replacement parts are needed, it is necessary to give the name of the part and complete name plate marking which is located on the door of the device. It is advisable to carry several sets of spare lead-in cable gaskets, as these should be replaced whenever the connection to the bushing is opened.

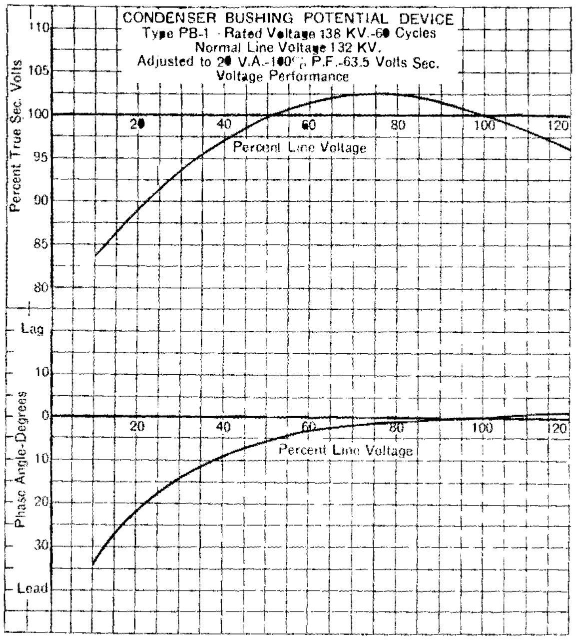


Fig. 15—Type PB-1 Typical Voltage Characteristics

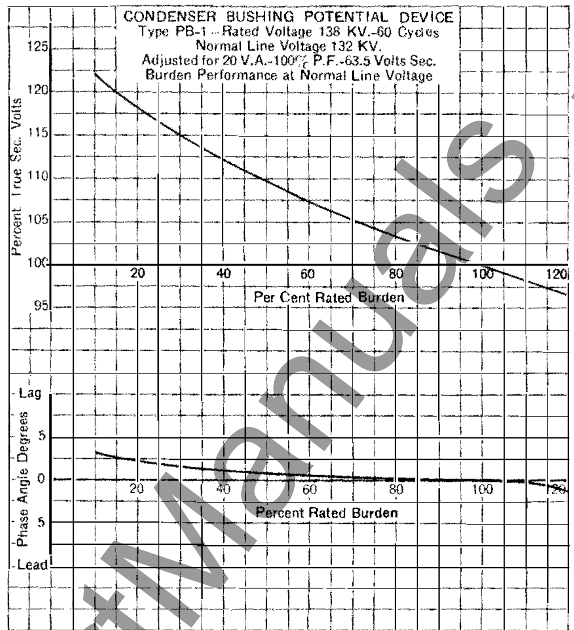


Fig. 16—Type PB-1 Typical Burden Characteristics

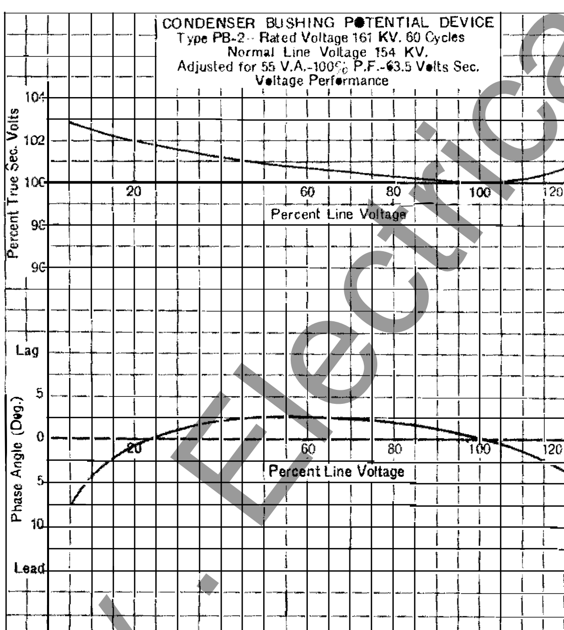


Fig. 17—Type PB-2 Typical Voltage Characteristics

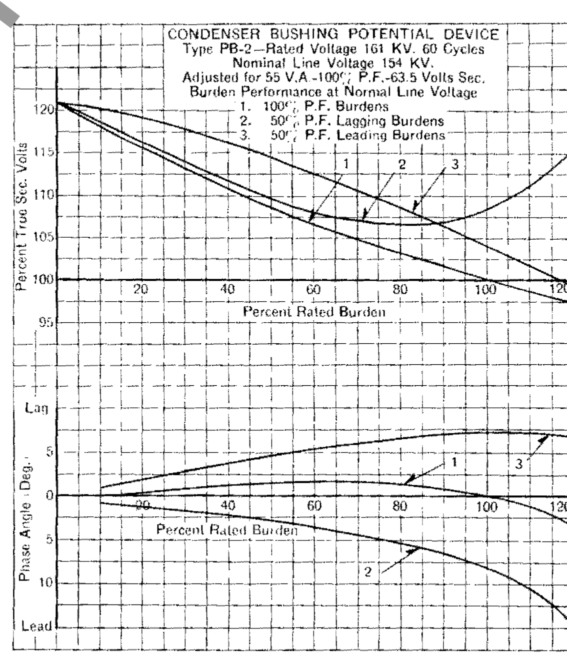


Fig. 18—Type PB-2 Typical Burden Characteristics

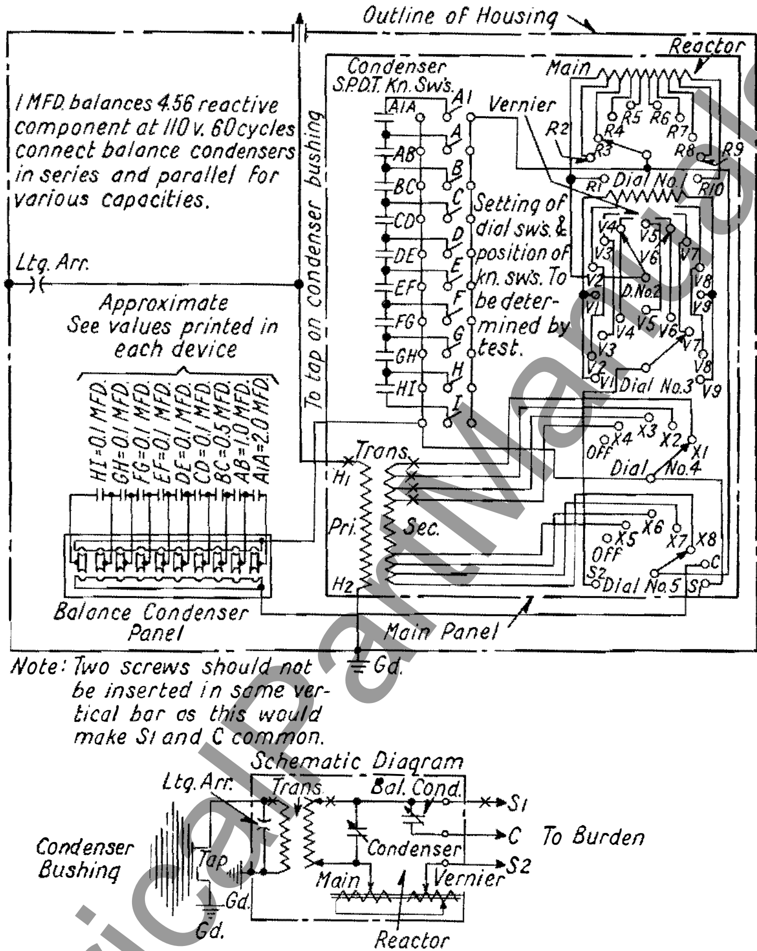


Fig. 19—Schematic and Wiring Diagram of Type PB-1 Bushing Potential Device

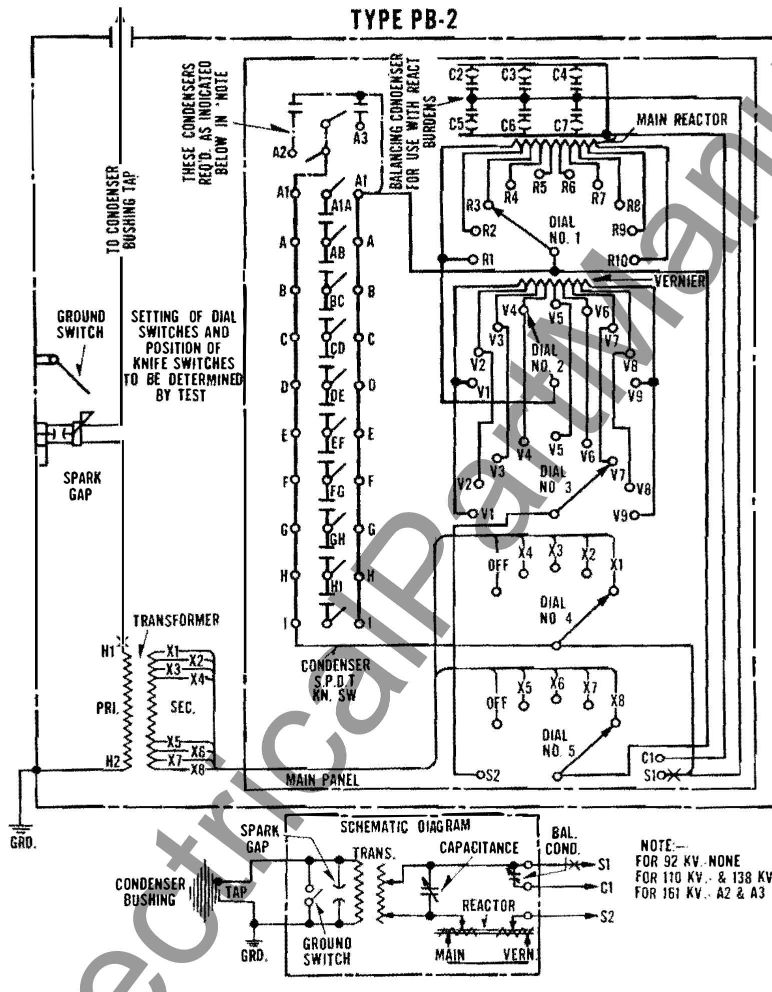


Fig. 20—Schematic and Wiring Diagram of the Type PB-2 Bushing Potential Device.

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January, 1937