

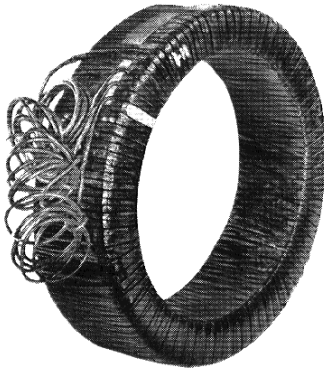


POWER CIRCUIT BREAKERS BUSHING-TYPE CURRENT TRANSFORMERS AND LINEAR COUPLER TRANSFORMERS

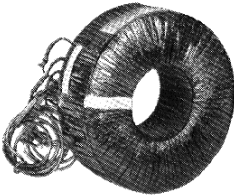
DESCRIPTIVE BULLETIN

33-356

FOR OUTDOOR OIL CIRCUIT BREAKERS



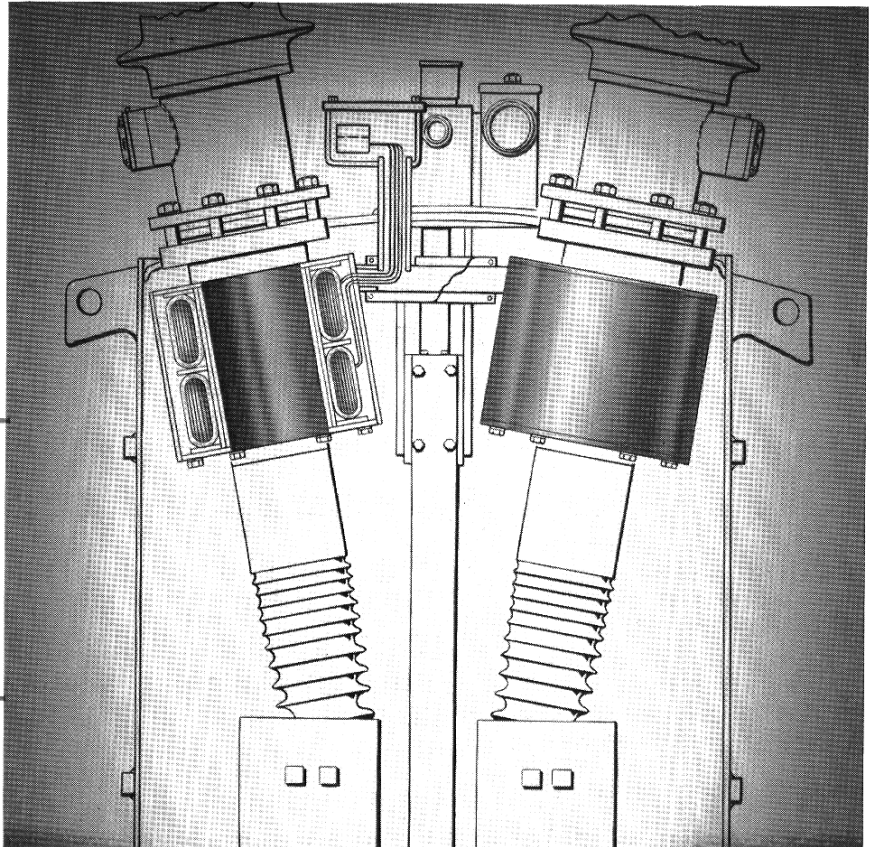
For 230/196 kv breaker



For 69 kv breaker



For 14.4 kv breaker



BUSHING-TYPE CURRENT TRANSFORMERS (TYPES BYM, BHB, BH AND BY) for use with outdoor oil circuit breakers have a secondary winding completely insulated and permanently assembled on a ring-type core, but have no primary winding or insulation for a primary winding. They are designed to fit over the circuit breaker bushing flanges, which are permanently grounded. Thus the circuit breaker bushing with its conductor or stud becomes the completely insulated single-turn primary winding of the bushing-type current transformer.

All breakers, except those with interrupting ratings of 250 mva or less, may be equipped with 2 transformers per bushing, or 12 transformers per three-pole breaker, having the described ratings and accuracy characteristics in accordance with NEMA standards SG4-3.09 and SG4-3.10, based on ASA standards C-57, Section 13. See tabulation on Page 4. Breakers rated 250 mva or less take a maximum of 6 transformers.

BUSHING-TYPE LINEAR COUPLER TRANSFORMERS (TYPE BLC) can be mounted in the same space as bushing-type current transformers when it is desired to provide high speed and sensitive bus differential protection through linear coupler bus differential protective relays.

BUSHING-TYPE CURRENT TRANSFORMER	CORE MATERIAL	RATIO	* PRIMARY APPLICATION
Type BYM	Hipersil®	Multi	Relaying
Type BHB	Hipersil®	Single	Metering
Type BH	Hipernik®	Single	Metering
Type BY	Hipersil®	Single	Metering

* The classification of multi-ratio transformers for relaying service and single-ratio transformers for metering service is a very general segregation. Depending on the specific conditions, any of the above types of transformers may be suitable for either or both relaying and metering applications.

WESTINGHOUSE SPECIAL FEATURES

- LOW-COST, CONVENIENT MEANS OF RELAYING AND METERING on conventional outdoor dead-tank oil circuit breakers.
- VACUUM-PRESSURE-IMPREGNATED to provide greater integrity of insulation.
- SPECIAL ALLOY CORES—Hipersil for relaying; Hipernik or Biased-Core Hipersil for metering.
- NEMA STANDARDS—NEMA Standard accuracy classifications met or exceeded, all NEMA Standard ratios provided.
- TWO STANDARD-SIZE TRANSFORMERS PER BUSHING 12 per breaker, available on all breakers except those rated 250 mva and below.
- LINEAR COUPLER TRANSFORMERS—Immune to a-c or d-c saturation for dependable bus differential relaying.

Application

Since these transformers have but a single-turn primary, the total ampere-turns available for supplying the secondary burden and the excitation current is equal to the primary current flowing. Hence, on the lower ratios of bushing-type current transformers more care in application is required than is necessary when applying wound-type current transformers, which usually have 1200 or more ampere-turns at normal rated primary current irrespective of the current ratio.

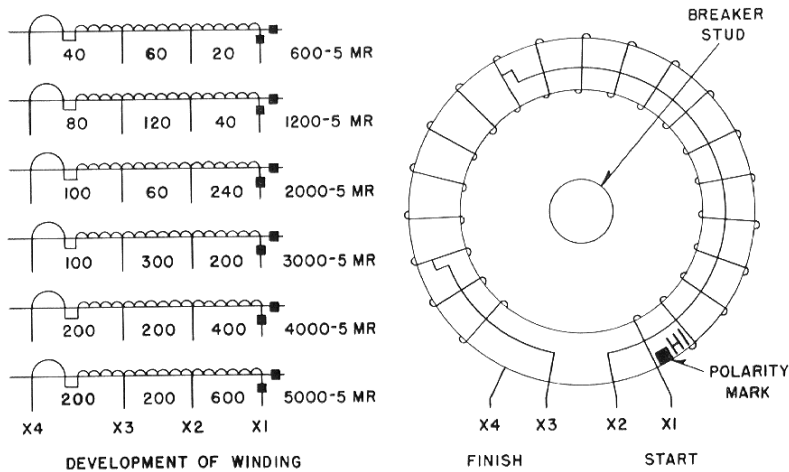
FOR RELAYING APPLICATIONS and general applications involving indicating instruments, standard multi-ratio bushing transformers having uncompensated, tapped, secondary windings are recommended. The wide choice of available ratios permits utilization of the most desirable ratio when installed, and provides a convenient means of future change in ratio if system or load conditions should warrant.

Nominal maximum primary current ratings are 600, 1200, 2000, 3000, 4000, and 5000 amperes, with a nominal secondary current rating of 5 amperes. See Fig. 1 on pages 2 and 3 for available tap ratios and secondary winding arrangements. The polarity and method of making the secondary leads are shown in Figs. 3 to 7.

FOR METERING APPLICATIONS—On the lower ratio transformers considerable improvement in accuracy over the range of primary currents encountered in metering are obtained by the use of special core materials and secondary winding compensation. For such applications, the single-ratio high-accuracy metering transformer is recommended. When necessary, double ratio metering transformers may be furnished at an increase in cost and at some reduction in accuracy. The over-current performance of the metering transformers is quite good, often approaching the accuracy of the standard relaying transformer for the same ratio.

Nominal primary current ratings are 300, 400, 600, 800, 1200, 1500, 2000, 3000, and 5000 amperes, with a nominal secondary rating of 5 amperes. The polarity and method of marking secondary leads are as shown in figures 3 to 7, except that there are only two secondary leads marked X1 and X2.

NEMA STANDARD RATIOS AND TAPS



■ Polarity mark adjacent to terminal X1 indicates that the end of the terminal bushing opposite the breaker contacts and terminal X1 have like polarity. With any combination of taps, the tap numerically nearest X1 has the same relative polarity as X1.

Figure 1—Connection chart for 600, 1200, 2000, 3000, 4000, and 5000 to 5 ampere multi-ratio bushing-type current transformers.

IDENTIFICATION OF TRANSFORMERS AND LEADS

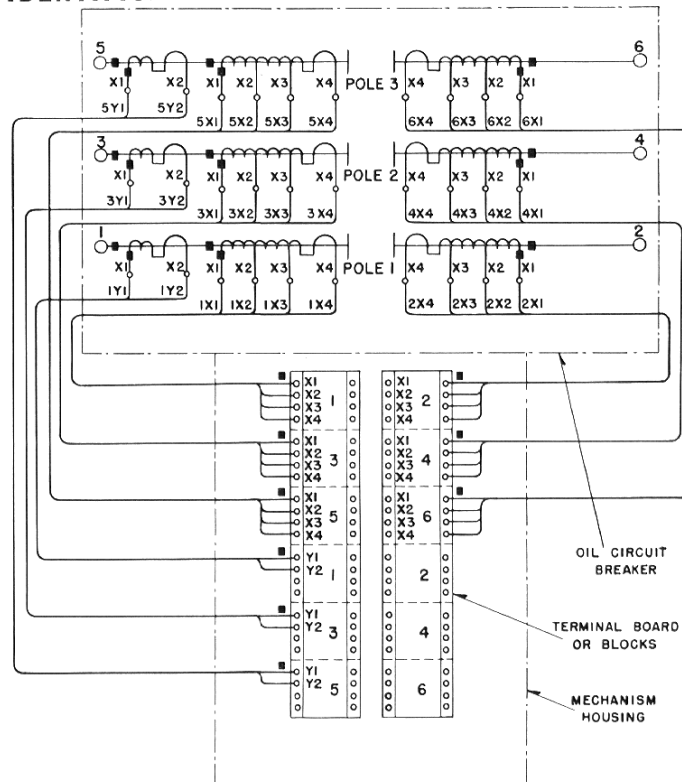
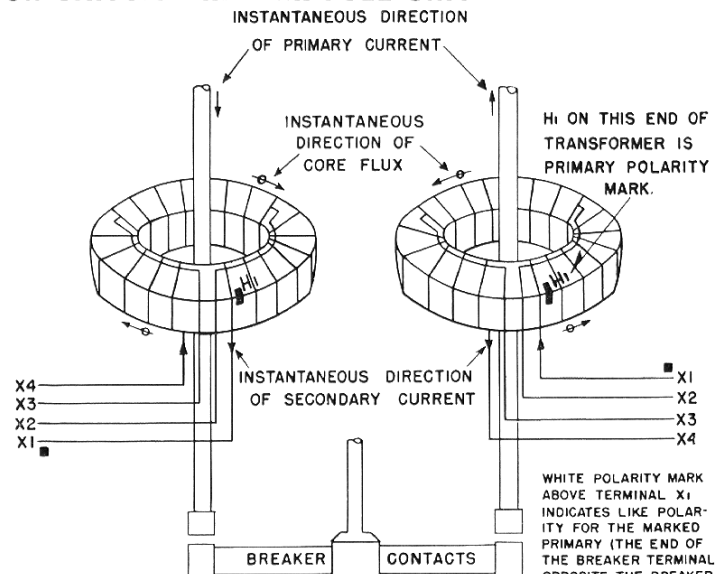


Figure 3—Standard method of identifying transformers and leads on multi-pole oil circuit breakers. Note: When one transformer per pole is used, transformers are located on bushings 1-3-5 unless otherwise specified.

BUSHING-TYPE CURRENT TRANSFORMERS

CURRENT RATIO	TURN RATIO	SECONDARY TAPS
600-AMPERE MULTI-RATIO		
100 to 5	20 to 1	X1-X2
200 to 5	40 to 1	X3-X4
300 to 5	60 to 1	X2-X3
400 to 5	80 to 1	X1-X3
600 to 5	120 to 1	X1-X4
1200-AMPERE MULTI-RATIO		
200 to 5	40 to 1	X1-X2
400 to 5	80 to 1	X3-X4
600 to 5	120 to 1	X2-X3
800 to 5	160 to 1	X1-X3
1200 to 5	240 to 1	X1-X4
2000-AMPERE MULTI-RATIO		
800 to 5	160 to 1	X2-X4
1200 to 5	240 to 1	X1-X2
1500 to 5	300 to 1	X1-X3
2000 to 5	400 to 1	X1-X4
3000-AMPERE MULTI-RATIO		
1500 to 5	300 to 1	X2-X3
2000 to 5	400 to 1	X2-X4
3000 to 5	600 to 1	X1-X4
4000-AMPERE MULTI-RATIO		
2000 to 5	400 to 1	X1-X2
3000 to 5	600 to 1	X1-X3
4000 to 5	800 to 1	X1-X4
5000-AMPERE MULTI-RATIO		
3000 to 5	600 to 1	X1-X2
4000 to 5	800 to 1	X1-X3
5000 to 5	1000 to 1	X1-X4

ARRANGEMENT OF TRANSFORMERS ON CIRCUIT BREAKER POLE UNIT



ACCURACY CHARACTERISTICS—

ACCURACY CLASSIFICATIONS

Outdoor Oil Circuit Breakers—Bushing-Type Current Transformers

OUTDOOR OIL CIRCUIT BREAKER RATING				TRANSFORMER ACCURACY CLASSIFICATION*		
KV	TYPE	MVA	AMPS†	RELAYING‡	#METERING	
					MINIMUM RATIO	ACCURACY
7.2	FO-22-A	50	600	10L50	400-5	0.6B-0.5
14.4	144G100	100	600	10L100	300-5	0.6B-0.5
	144G250	250	600	10L100	300-5	0.6B-0.5
	144G250	250	1200	10L200	300-5	0.6B-0.5
	144G1000	1000	1200	10L200	300-5	0.6B-0.5
	144G1000	1000	3000	10L400	1200-5	0.3B-0.5
	144G1500	1500	2000	10L400	800-5	0.3B-0.5
	144G1500	1500	4000	10L800	2000-5	0.3B-0.5
23	230G250	250	600	10L100	300-5	0.6B-0.5
	230G500	500	1200	10L200	300-5	0.6B-0.5
34.5	345G500	500	600	10L100	300-5	0.6B-0.5
	345G1000	1000	1200	10L200	300-5	0.6B-0.5
	345G1500	1500	1200	10L200	300-5	0.6B-0.5
	345G2500	2500	2000	10L400	800-5	0.3B-0.5
46	460G500	500	600	10L100	300-5	0.6B-0.5
	460G1500	1500	1200	10L200	300-5	0.6B-0.5
69	690G1000	1000	600	10L200	300-5	0.6B-0.5
	690G1500	1500	1200	10L400	300-5	0.6B-0.5
	690G2500	2500	1200	10L400	300-5	0.6B-0.5
	GM-5-A	2500	1200	10L400	300-5	0.6B-0.5
	GM-6	3500	2000	10L800	800-5	0.3B-0.5
	GM-6-A	3500	2000	10L800	800-5	0.3B-0.5
	690GMS000	5000	2000	10L800	800-5	0.3B-0.5
	GM-3	1500	800¶	10L800	300-5	0.6B-0.5
	GM-5	3500	1200	10L800	300-5	0.6B-0.5
	GM-6	5000	1200	10L800	300-5	0.6B-0.5
115	1150GM10000	10000	1600‡	10L800	600-5	0.3B-0.5
138	GM-4	3500	1200	10L800	300-5	0.6B-0.5
	GM-5	5000	1200	10L800	300-5	0.6B-0.5
	GM-7	10000	1600‡	10L800	600-5	0.3B-0.5
161	GM-5	5000	1200	10L800	300-5	0.6B-0.5
	GM-7	10000	1600‡	10L800	600-5	0.3B-0.5
	161GM15000	15000	1600‡	10L800	600-5	0.3B-0.5
230/196	2300-GW-5000	5000	1200	10L800	300-5	0.6B-0.5
	2300-GW-10000	10000	1600‡	10L800	600-5	0.3B-0.5
	2300-GW-15000	15000	1600‡	10L800	600-5	0.3B-0.5
287.5	2875-GW-15000	15000	1600‡	10L800	600-5	0.3B-0.5
330	3300-GW-25000	25000	1600‡	10L800	600-5	0.3B-0.5

* These values apply only to the transformers when used on circuits having 60-cycle frequency, and to those breakers rated at 250 mva and below, when only one transformer is installed on each bushing.

† The nominal primary current rating of the standard multi-ratio transformer corresponds to the listed continuous current ratings of the breakers unless otherwise noted.

‡ Accuracies listed meet the requirements of Paragraph 13-24.500 of ASA Standards C-57 as applied to the maximum secondary winding or ratio of the transformer.

* Accuracies listed meet the requirements of Paragraph 13-24.200 and 13-24.300 of ASA Standards C-57 as applied to the B-0.5 burden only. These transformers are single ratio, and minimum ratios on which the specified accuracy is obtainable are listed.

¶ The standard 1200-5 MR transformer normally applies to these 800 ampere oil circuit breakers, but 600-5MR with a 10L400 accuracy is available.

‡ The Standard 2000-5 MR transformer normally applies to these 1600-ampere oil circuit breakers, but a 1200-5 MR with a 10L800 accuracy is available.

NON-STANDARD TRANSFORMER ACCURACY CLASSIFICATION

The table of relaying and metering accuracies available on standard transformers for oil circuit breakers is in accordance with NEMA standards SG4-3.09 and SG4-3.10, which are based on section 13 of ASA Standards C-57. Since bushing transformers have several limitations, such as the single-turn primary and space limitations in apparatus, the table furnishes an excellent and needed guide as to the performance which may

be expected and economically obtained in standard apparatus. It is impractical to cover all possible specific applications such as accuracies on other than 60-cycle frequencies, ratios other than those listed, etc. Any relaying or metering applications not suitably covered here should be referred to Power Circuit Breaker Application Engineering Section, Switchgear Division, East Pittsburgh, for further information.

BUSHING-TYPE CURRENT TRANSFORMERS

RELAYING SERVICE ACCURACY CLASSIFICATION

The various accuracies listed apply to the maximum ratio of the corresponding multi-ratio transformers and are indicated by the classifications such as 10L50, 10L100, etc. The number preceding the letter L indicates the maximum per cent ratio error, in this case 10 per cent ratio error, at 20 times rated secondary current. The letter L designates a transformer having low internal impedance, of which bushing current transformers are an example, as compared to an H transformer, having high internal impedance, of which the usual wound primary current transformers are an example. The numbers following the letter such as 50, 100, etc., gives the voltage required across the terminals of one of the standard secondary burdens at 20 times rated secondary current. Since the nominal rated secondary current is 5 amperes, 20 times rated current is 100 amperes, and the ohms impedance of the secondary burden is given by dividing the burden voltages of 50, 100, 200, 400, and 800 by 100 giving the standard relaying burdens of 0.5, 1.0, 2.0, 4.0 and 8.0 ohms, respectively, as listed in Paragraph 13-21.100 of ASA Standards C-57.13.

For example, the standard relaying transformer for a type 690G1500, 1200-ampere, 69-kv breaker is a 1200-5 MR type

BYM transformer with a 10L400 accuracy classification. This transformer is one which on the 1200 to 5 ratio will not have a ratio error in excess of 10 per cent over a range of one to twenty times rated secondary current when energizing secondary burdens equal to or less than the standard B-4 burden, 4 ohms 50 per cent lagging power factor (See Fig. 8 for typical curves).

The last figure in this classification also has added significance in that on an open-circuit excitation test, approximately this voltage must be developed when the exciting current in amperes is equal to the per cent ratio error (10 amperes for these bushing current transformers, see Fig. 8 for curves). Although the classification is based only on the maximum ratio, it also gives some information as to the performance on lower ratios, since the excitation voltage varies directly with the ratio and the excitation current varies inversely as the ratio. This can be seen readily from the curves of Fig. 8. The curves of Fig. 9 may be calculated from the curves of Fig. 8 by means of the calculating method given in paragraph 13-94.560 of ASA Standards C-57, Section 13.

METERING SERVICE ACCURACY CLASSIFICATION

The accuracy classification for metering service is based on limits of "Transformer Correction Factor" (TCF); see Standard No. 13-24.200 and 13-24.300 of ASA Standards C-57.13. The TCF is that factor by which a wattmeter reading must be multiplied to correct for the ratio and phase angle errors of a current transformer, within specified limits of power factor of the circuit being metered. The various accuracy classes have definite limiting values for the TCF's at both 100 per cent and 10 per cent of rated primary current, and are designated by the maximum per cent error permitted by the limiting value of the TCF at 100 per cent rated primary current.

A definite relationship exists between the "Transformer Correction Factor" (TCF), the "Ratio Correction Factor" (RCF) and the "Phase Angle" (β) for power factors of the metered circuit between 1.0 and 0.6 lagging as given by the following expression:

$$\beta = 2600 (\text{RCF} - \text{TCF}) \text{ minutes.}$$

This results in a parallelogram describing the limits of the Phase Angle as a function of the Ratio Correction Factor for any given Transformer Correction Factor.

Since the secondary burden imposed on a current transformer has a material effect on its ratio and phase angle errors, the secondary burden must be inherently tied in with the accuracy classification. This is accomplished by having the first part of the metering classification denote the accuracy class and the second part denote one of the standard metering burdens.

Likewise, in the case of bushing current transformers, the accuracy is a function of the ratio, since the primary is limited to a single turn. Other things being the same, the higher the current ratio the lower the ratio and phase angle errors. For this reason the minimum ratio on which a given accuracy may be obtained from a standard high accuracy transformer is listed for each of the standard 600-ampere and 1200-ampere breakers.

For example, on the type 345G500, 600-ampere, 34.5-kv. breaker the 300/5 ratio is the lowest ratio on which a 0.6 B-0.5 accuracy rating may be obtained using a standard high accuracy transformer, i.e. at 100 per cent primary current the TCF will be between 0.994 and 1.006; the RCF will be between the same limits and the phase angle, β , will be between ± 31.2 minutes. The corresponding values at 10 per cent rated primary current are a TCF between 0.988 and 1.012, an RCF between 0.988 and 1.012, and β between ± 62.4 minutes. As indicated by the second part of the accuracy classification, B-0.5, the foregoing accuracy limits will be met when the transformer is energizing the standard B-0.5 burden equal to 12.5 volt-amperes at 90 per cent power factor lagging based on 5 amperes, 60 cycles. See Fig. 10 for typical metering performance curves.

It should be pointed out that on breakers of the higher current ratings, 2000 amperes and higher, the highest accuracy class in conjunction with the standard metering burden of B-0.5 has been assigned to the minimum ratio of transformer likely to be required in a circuit using such a breaker.

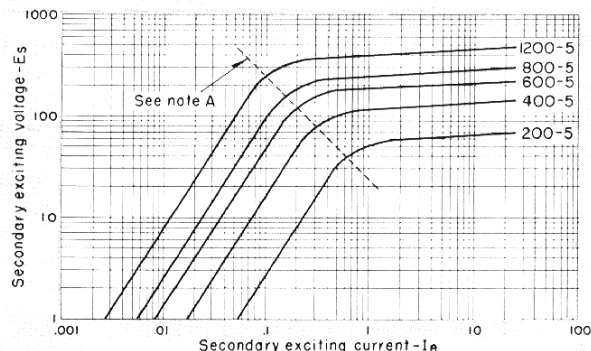


Figure 8—Typical excitation for a curve 60-cycle, 1200-5 MR, 10L400 transformer.

NOTE A—Above this line the voltage for a given exciting current for any unit will not be less than 95% of the curve value. Below this line the exciting current for a given voltage for any unit will not exceed the curve value by more than 25%.

CURRENT RATIO	TURN RATIO	SECONDARY RESISTANCE (OHMS)
1200-5	240-1	0.508
800-5	160-1	0.348
600-5	120-1	0.268
400-5	80-1	0.188
200-5	40-1	0.108

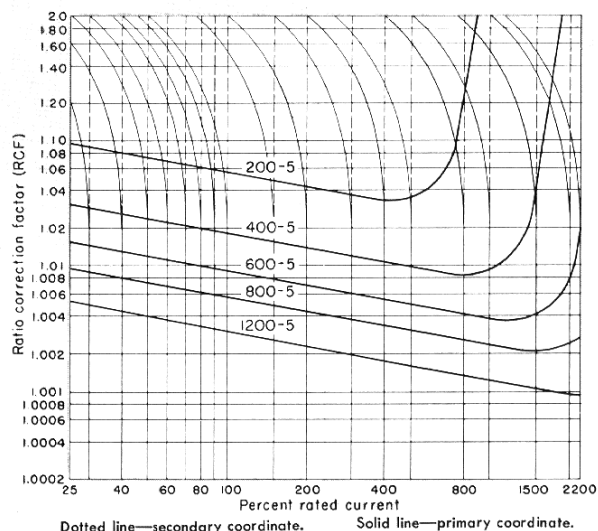


Figure 9—Typical ratio correction factor curves for a 60-cycle 1200-5MR, 10L400 transformer with a secondary burden of 2 ohms, 50 percent lagging power factor.

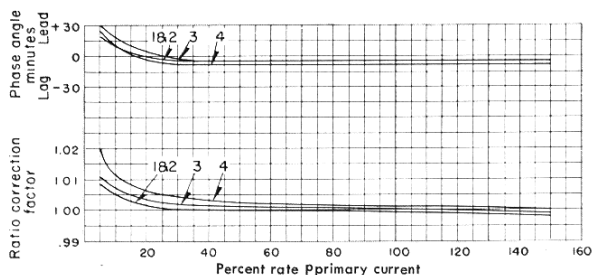


Figure 10—Typical ratio correction factor and phase angle curves.

Type BHB bushing current transformer, ratio 400-5, ASA Metering accuracy classification, 0.3B-0.5 at 60 cycles. Transformer compensated for standard ASA B-0.5 secondary burden.

CURVE NO.	SECONDARY BURDEN OHMS	POWER FACTOR %
1	0.1	90
2	0.2	90
3	0.5	90
4	1.0	50

PERFORMANCE DATA

Relaying Transformers

♦ **TYPICAL EXCITATION CURVES** for all standard ratios showing secondary volts vs secondary exciting amperes will be furnished on request. The curves will be extended to the equivalent of 25 amperes exciting current through the full secondary winding provided these values do not require an excitation voltage in excess of 1600 volts.

The approximate 75° C resistance of the secondary winding, including the two leads internal to the oil circuit breaker, is provided on the curves of Figure 8.

♦ **TYPICAL RATIO CORRECTION FACTOR CURVES** with a secondary burden of 2 ohms (50 VA) 50 percent lagging power factor, 60 cycles (the standard B2 burden), for each ratio over the range of 1/4 to 22 times rated primary current, provided the ratio correction factor does not exceed 2.0, will be furnished on request. Curves will be plotted as ratio correction factor vs. percent of rated primary current. These ratio correction factor curves are calculated from exciting current data.

Metering Transformers

♦ **TYPICAL RATIO CORRECTION FACTOR AND PHASE ANGLE CURVES** for the standard metering burdens of B-0.1, B-0.2, B-0.5, and B-1 from 5 to 150 percent of rated primary current, provided the transformer errors do not exceed those of accuracy class 1.2 of Paragraph 13-24.300 of ASA Standards C-57, will be furnished on request.

BUSHING-TYPE CURRENT TRANSFORMERS

COMMERCIAL TESTS AT FACTORY

1. All transformers are checked for proper nameplate and polarity markings.
2. All transformers are checked electrically to insure proper direction of windings to give correct polarity.
3. All transformers are given an induced potential test at 500 cycles by impressing a minimum of 2 times its 60 cycle, rated, relaying accuracy class voltage across the full secondary winding with the primary open-circuited.
4. All transformers for relaying service are given sufficient ratio tests to insure the proper number of turns; multi-ratio transformers are given sufficient ratio tests to insure the correctness of winding for each tap section. In addition, two excitation check points are taken on the secondary with the primary open-circuited to insure each transformer meets its specified relaying accuracy classifications.
5. All transformers for metering service are checked for ratio and phase angle at 10 and 100 percent rated primary current to insure that they meet their metering accuracy requirements.
6. After installation in the oil circuit breaker each transformer is given a one-minute potential test of 2500 volts between the shorted secondary winding including leads and ground. Also, each transformer is given polarity and ratio check tests to insure correct installation in the oil circuit breaker.

Ordering Information

The following information should be included on orders or inquiries for bushing-type current transformers:

1. Identification of type and rating of the circuit breaker on which the transformer is to be installed.
 - a. If installation is on a new breaker, this information should be on the breaker order.
 - b. If installation is on a breaker already installed, the breaker shop order (S.O.) should be given. Headquarters will advise if installation details such as cases, conduit, etc., are required.
2. State circuit frequency.
3. Give primary and secondary current ratings.
4. State applications.
 - a. For relaying service.*

* The items listed under this heading are not necessary if the relay application has been checked, and the standard multi-ratio transformer characteristics as listed for the particular breaker are satisfactory. However, it may not always be possible to furnish the transformer for old breakers in the field the same as listed for the equivalent modern breakers.

† When burdens and current ranges are not specified on the order,

- (1) Types or description of relays including burden if of other than Westinghouse manufacture.
- (2) Maximum and minimum phase and ground fault currents.
- (3) Other data such as diagrams or operational data pertaining to the apparatus or system to be protected which would be of value in checking the application.
- b. For metering service.†
 - (1) The total secondary burden including secondary lead in ohms at a specified power factor.
 - (2) Desired accuracy and maximum permissible transformer errors.
 - (3) Range of primary load currents and normal load current.

the metering transformers will be compensated for the Standard B-0.5 burden at rated current.

Always keep the burden as low as possible and the ratio as high as possible, remembering that for the same burden a 300-5 transformer will have a higher accuracy at 15-ampere primary current than a 150-5 ratio transformer at the same 15-ampere primary current.

BUSHING-TYPE LINEAR COUPLER TRANSFORMERS—See Page 8.

BUSHING-TYPE LINEAR COUPLER TRANSFORMERS

TYPE BLC

APPLICATION

The Type BLC linear coupler transformers are intended for use with linear coupler differential protective relays to provide dependable high speed, sensitive protection to station buses. These linear coupler transformers are "Air-Core" reactors having induced secondary voltages proportional to the primary current. Unlike current transformers, there is no saturation of magnetic circuit of the linear coupler transformer when it is subjected to heavy fault currents, even when the latter contains large d-c transient currents. This eliminates an ever-present problem which must receive consideration when using current transformers for bus differential protective relaying.

The differential circuit for linear coupler differential protection is formed by connecting the linear coupler transformer secondaries and linear coupler relays in series as shown in the accompanying schematic diagram (see Figure 11).

The simplicity and ease of application of linear coupler transformers and relays provide an outstanding method of station bus protection.

RATINGS

The standard linear coupler transformer is rated at 0.005 ohm mutual reactance at 60 cycles. This provides an open-circuit, secondary induced voltage of 5 volts per thousand amperes primary current.

The secondary self-impedances of linear coupler transformers vary with the size and specific design. Their values along with the number of circuits on the bus have a bearing on the sensitivity of the bus protection.

The variations in sizes of linear coupler transformers are dictated by the rating and design of the breakers in which they are to be installed. When ordering linear coupler transformers for breakers already installed, the breaker identification (S.O. number) or limiting dimensions for the linear coupler must be furnished.

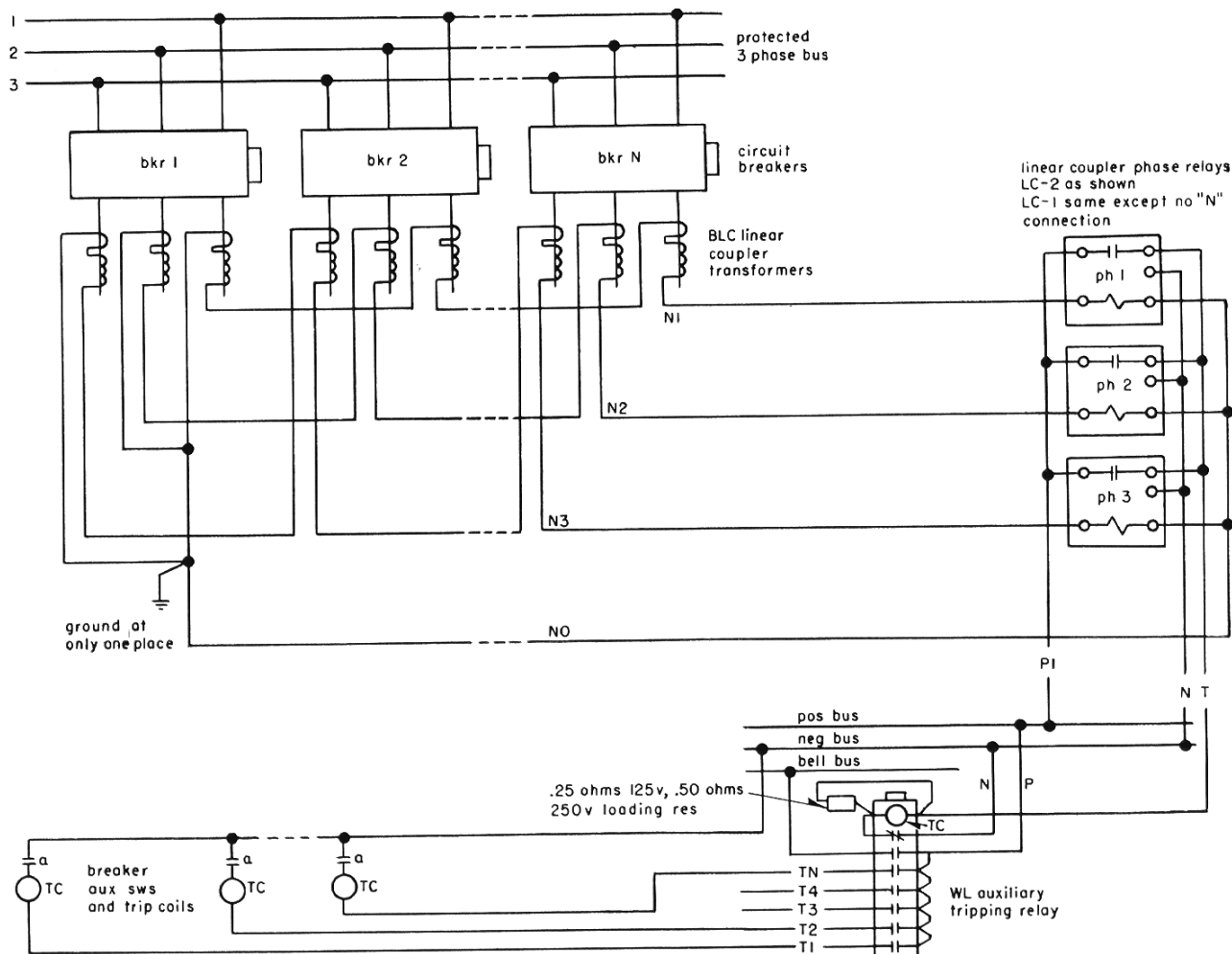


Figure 11—Typical schematic diagram of Linear Coupler Bus Differential Protection with Series Differential Loop using Phase Relays.

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