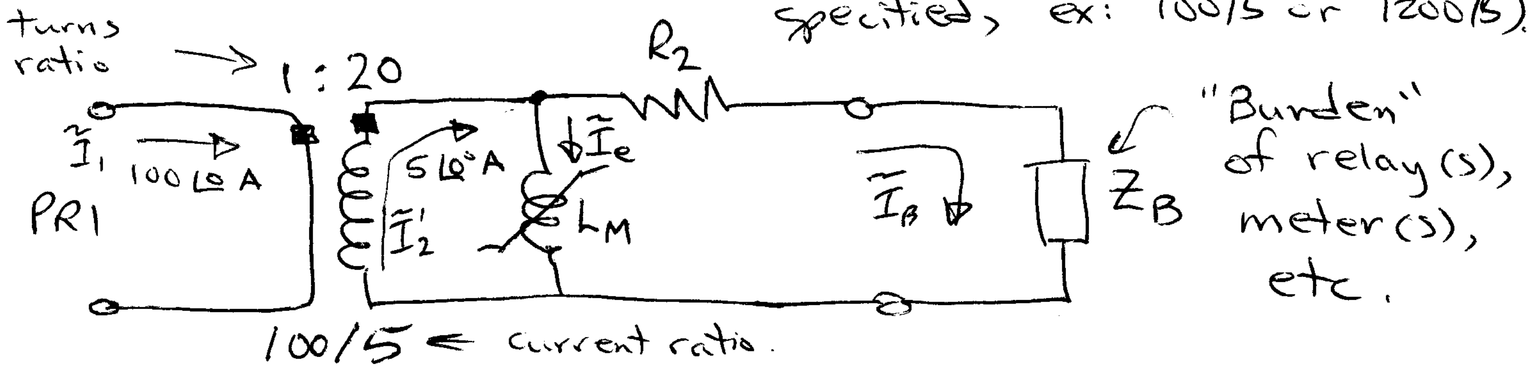
Current Transformers (Current ratio is always specified, ex: 100/5 or 1200/5)



Note: X_L in pri & sec often neglected, as is R_c (core loss).

"H" and "L" ratings given in book are obsolete. (OLD ASA STANDARDS).

ANSI:
- "T" – performance of CT must be measured. (Not seen very often).
- "C" – performance can be calculated. (This type is most usual).

ex: 10C800: $|\tilde{I}_B|$ is within ±10% of $|\tilde{I}_2'|$ for a secondary current of 20× rated. ("Rated" is almost always 5A) The corresponding burden voltage for this CT is 800V ⇒ Burden must be 8Ω.

Standard burden designations:

C100 →	B-1 :	1.0 ∠60° Ω	PF = 0.5 lag
C200 →	B-2 :	2.0 ∠60° Ω	
C400 →	B-4 :	4.0 ∠60° Ω	
C800 →	B-8 :	8.0 ∠60° Ω	

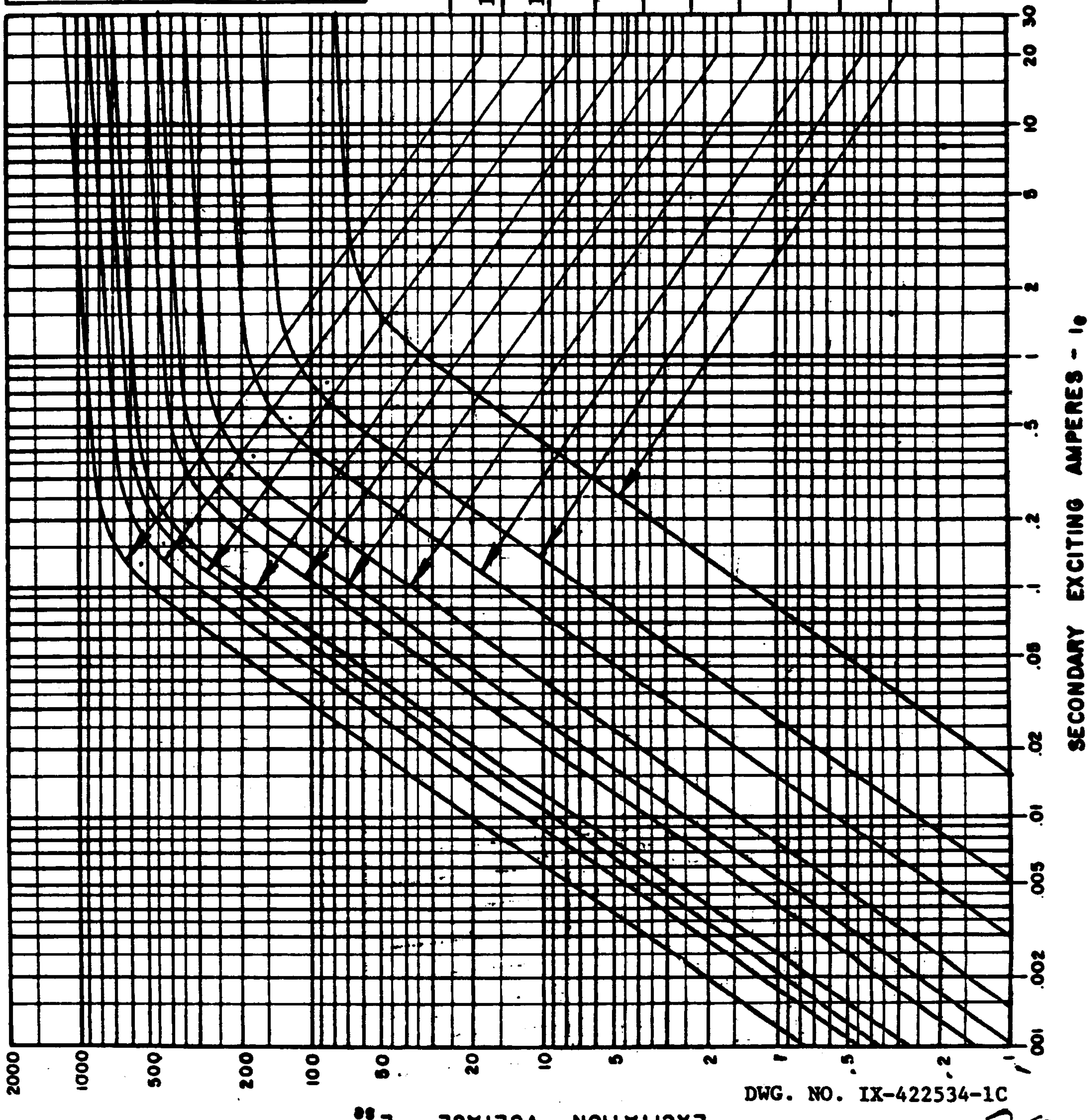
McGRAW-EDISON
POWER SYSTEMS GROUP

BTCT EXCITING CURRENT CURVES

TYPE OE - 1200
DWG. NO. A-422534
OCB TYPE -
FREQUENCY 60 CYCLES
MAXIMUM RATIO 1200/5
TOTAL SEC. TURNS 240
SEC. RES. .0027 OHMS/TURN AT 75°C
ASA ACCURACY 10C800

MARKED RATIO	SEC. TURNS	SEC. TAPS
100/5	20	X_2-X_3
200/5	40	X_1-X_2
300/5	60	X_1-X_3
400/5	80	X_4-X_5
500/5	100	X_3-X_4
600/5	120	X_2-X_4
800/5	160	X_1-X_4
900/5	180	X_3-X_5
1000/5	200	X_2-X_5
1200/5	240	X_1-X_5

DESERET GENERATION & TRANSMISSION Order C-06...-5 To be used on H_1, H_2, H_3 H.V. Bushings.



DWG. NO. IX-422534-1C

REF-
LF-6

20

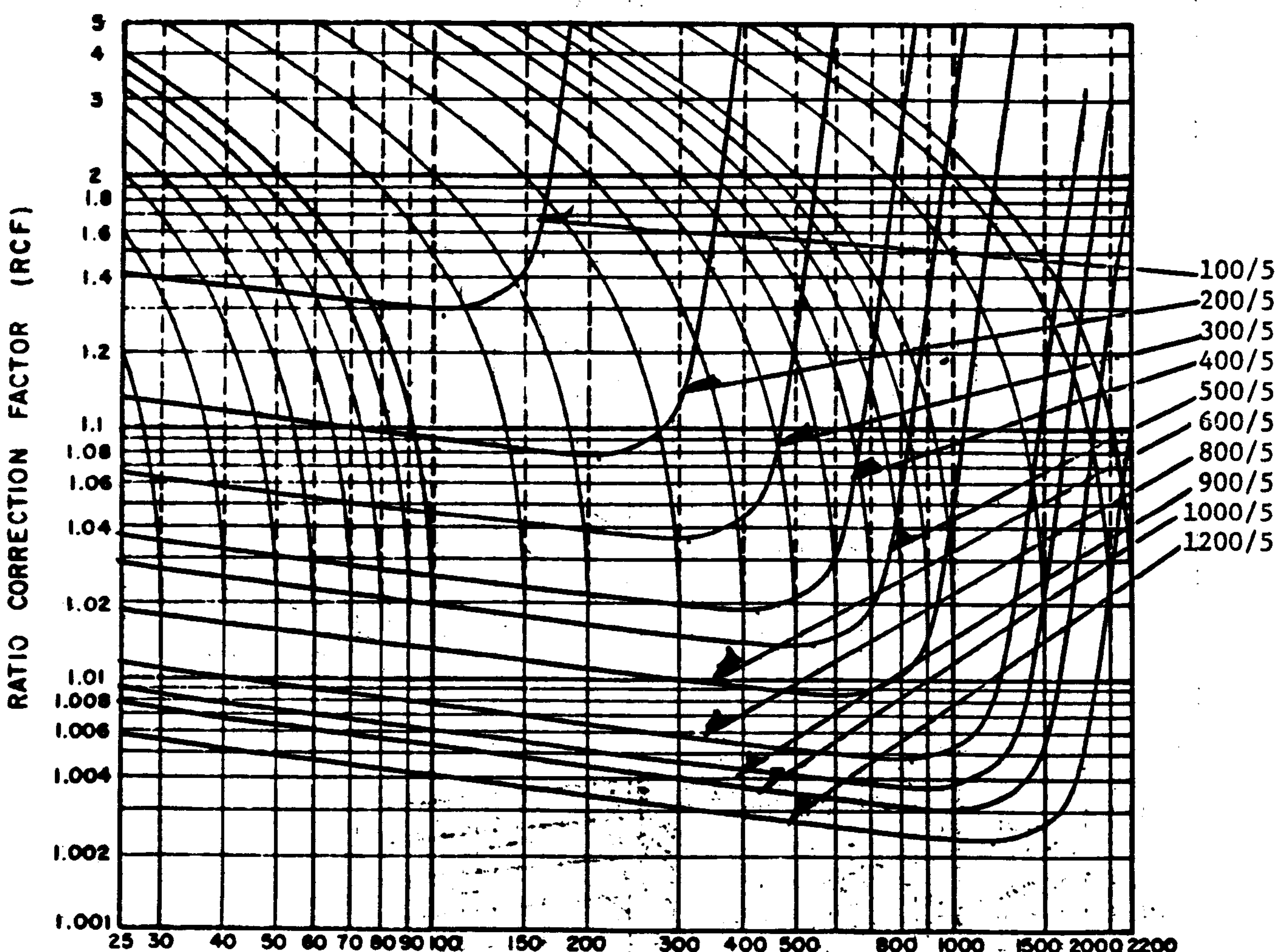
McGRAW-EDISON
POWER SYSTEMS GROUP

BTCT RATIO CORRECTION FACTOR CURVES

ASA STANDARD B- 8(8 OHMS, 50 PERCENT PF LAG) SEC BURDEN

MARKED RATIO	SEC. TURNS	SEC. TAPS
100/5	20	X_2-X_3
200/5	40	X_1-X_2
300/5	60	X_1-X_3
400/5	80	X_4-X_5
500/5	100	X_3-X_4
600/5	120	X_2-X_4
800/5	160	X_1-X_4
900/5	180	X_3-X_5
1000/5	200	X_2-X_5
1200/5	240	X_1-X_5

TYPE OE- 1200
DWG. NO. A-422534
OCB TYPE-
FREQUENCY 60 CYCLES
MAXIMUM RATIO 1200/5
TOTAL SEC. TURNS 240
SEC. RES. .0027 OHMS/TURN AT 75°C
ASA ACCURACY 10C800



PERCENT RATED CURRENT DWG. NO. RCF-422534-8C

DOTTED LINE - SECONDARY COORDINATE SOLID LINE - PRIMARY COORDINATE

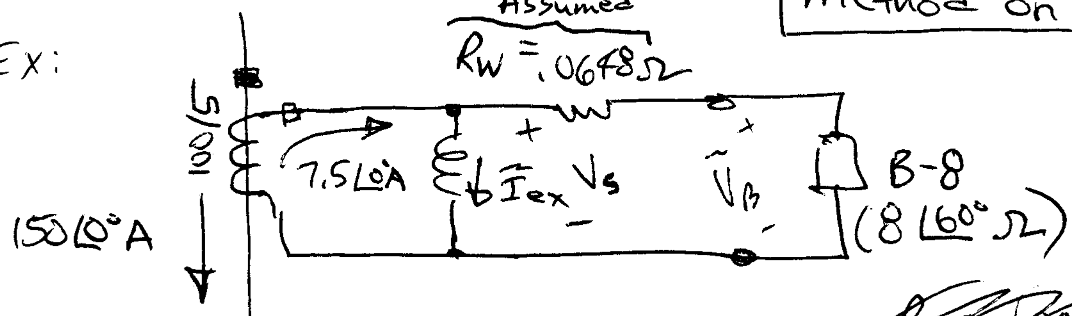
DESERET GENERATION & TRANSMISSION Order C-06- 5 To be used on H_1, H_2, H_3 H.V. Bushings.

REF -
LF - 7

It is very important to determine CT ratio error for anticipated fault conditions, or even for load conditions.

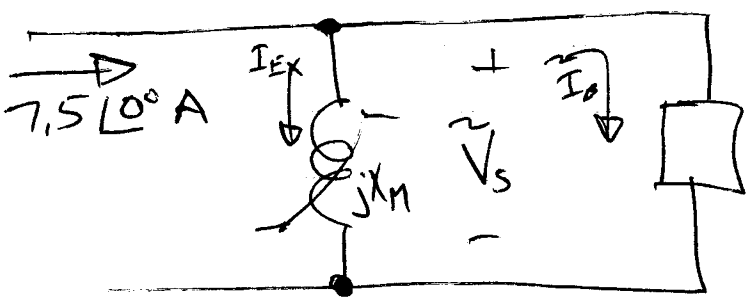
Do NOT use book's (Glover's) method on pp. 413-416!

Ex:



$\tilde{I}_s' = 7.5\angle 0°$ A

$\tilde{I}_{ex}$ must be determined iteratively from exciting current curves (see attached).



$Z_{TOT} = 8\angle 60° + .0648$
$= 8.033\angle 59.6°$

Iterating, Assume $I_{EX} = 0$ $\quad V_s = 7.5\,(Z_{TOT}) = 60.24\angle 59.6°$

From curve, 60V ⇒ $I_{EX} \cong 2.1$ A ⇒ $\tilde{I}_B \cong 7.5 - 2.1 = 5.4$ A

@ 5.4A, $V_s = 43.4$V ⇒ $I_{EX} \cong 1.3$A ⇒ $I_B \cong 7.5 - 1.3 = 6.2$ A

@ 6.2A, $V_s = 49.8$V ⇒ $I_{EX} \cong 1.5$A ⇒ $I_B \cong 7.5 - 1.5 = 6.0$ A

@ 6.0 A, $V_s = 48.2$V ⇒ $I_{EX} \cong 1.4$A ⇒ $I_B \cong 7.5 - 1.4 = 6.1$ A

Check: $$\tilde{I}_B = 7.5\angle 0° \left(\frac{j\overbrace{\frac{48.2}{1.4}}^{X_M}}{8.033\angle 59.6° + j\frac{48.2}{1.4}} \right) = 6.213\angle +5.6° \text{ A}$$

Note: Assumption that $\tilde{I}_{EX}$ has same angle as $\tilde{I}_B$ leads to error.

Continuing iteration,

$$\tilde{V}_s = (6.213\angle 5.6^\circ)(8.033\angle 59.6^\circ) = 49.9\angle 65.21^\circ \text{ V}$$

$$\Rightarrow \tilde{I}_{EX} = 1.5\angle 65.21-90^\circ = 1.5\angle -24.79^\circ \text{ A}$$

$$\tilde{I}_B = 7.5\angle 0^\circ - 1.5\angle -24.79^\circ = 6.17\angle 5.85^\circ \text{ A}$$

$$\tilde{V}_s = (6.17\angle 5.85^\circ)(8.033\angle 59.6^\circ) = 49.56\angle 65.45^\circ \text{ V}$$

$$\Rightarrow \tilde{I}_{EX} = 1.5\angle 65.45-90^\circ = 1.5\angle -24.45^\circ \text{ A}$$

$$\tilde{I}_B = 7.5\angle 0^\circ - 1.5\angle -24.45^\circ = \boxed{6.18\angle 5.78^\circ \text{ A}}$$

At this point, convergence is obtained. Main limit of accuracy is E_s vs I_{EX} curve.

Ratio Error = ~~[illegible]~~ $= \dfrac{I_{EX}}{I_2'} = \dfrac{1.5}{7.5} = \underline{\underline{20\%}}$

Angle Error = $\underline{\underline{+5.78^\circ}}$

In this example, effect was exaggerated by using B-8 burden with 100/5 tap (full ratio is 1200/5).

Homework: Probs: (11.1) (Assume ideal CT & VT)

(11.H1): Using handouts for 1200/5 MR CT, show that rating is only 10C400 when the 600/5 ratio is used, with B-4 burden.

Table 8—Current transformer ratings, multi-ratio type

Current ratings (A)		Secondary taps	Current ratings (A)		Secondary taps
	600:5			3000:5	
50:5		X2 – X3	300:5		X3 – X4
100:5		X1 – X2	500:5		X4 – X5
150:5		X1 – X3	800:5		X3 – X5
200:5		X4 – X5	1000:5		X1 – X2
250:5		X3 – X4	1200:5		X2 – X3
300:5		X2 – X4	1500:5		X2 – X4
400:5		X1 – X4	2000:5		X2 – X5
450:5		X3 – X5	2200:5		X1 – X3
500:5		X2 – X5	2500:5		X1 – X4
600:5		X1 – X5	3000:5		X1 – X5
	1200:5			4000:5	
100:5		X2 – X3	500:5		X1 – X2
200:5		X1 – X2	1000:5		X3 – X4
300:5		X1 – X3	1500:5		X2 – X3
400:5		X4 – X5	2000:5		X1 – X3
500:5		X3 – X4	2500:5		X2 – X4
600:5		X2 – X4	3000:5		X1 – X4
800:5		X1 – X4	3500:5		X2 – X5
900:5		X3 – X5	4000:5		X1 – X5
1000:5		X2 – X5			
1200:5		X1 – X5			
	2000:5			5000:5	
300:5		X3 – X4	500:5		X2 – X3
400:5		X1 – X2	1000:5		X4 – X5
500:5		X4 – X5	1500:5		X1 – X2
800:5		X2 – X3	2000:5		X3 – X4
1100:5		X2 – X4	2500:5		X2 – X4
1200:5		X1 – X3	3000:5		X3 – X5
1500:5		X1 – X4	3500:5		X2 – X5
1600:5		X2 – X5	4000:5		X1 – X4
2000:5		X1 – X5	5000:5		X1 – X5

Table 9—Standard burdens for current transformers with 5 A secondary windings*

Burdens	Burden designation†	Resistance (Ω)	Inductance (mH)	Impedance (Ω)	Voltamperes (at 5 A)	Power factor
Metering burdens	B-0.1	0.09	0.116	0.1	2.5	0.9
	B-0.2	0.18	0.232	0.2	5.0	0.9
	B-0.5	0.45	0.580	0.5	12.5	0.9
	B-0.9	0.81	1.040	0.9	22.5	0.9
	B-1.8	1.62	2.080	1.8	45.0	0.9
Relaying burdens	B-1	0.50	2.300	1.0	25.0	0.5
	B-2	1.00	4.600	2.0	50.0	0.5
	B-4	2.00	9.200	4.0	100.0	0.5
	B-8	4.00	18.400	8.0	200.0	0.5

*If a current transformer secondary winding is rated at other than 5 A, ohmic burdens for specification and rating shall be derived by multiplying the resistance and inductance of the table $[5/(\text{ampere rating})]^2$, the VA at rated current, the power factor, and the burden designation remaining the same.
†These standard burden designations have no significance at frequencies other than 60 Hz.

6.3.1 Tapped-secondary or multiple-ratio current transformer accuracy rating

The metering accuracy rating applies to the full secondary winding, unless otherwise specified.

6.4 Accuracy ratings for relaying

A current transformer for relaying shall be given an accuracy rating according to 6.4.1.

6.4.1 Basis for relaying accuracy ratings

For relaying accuracy ratings, the ratio correction shall not exceed 10%. Relaying accuracy ratings shall be designated by a classification and a secondary terminal voltage rating as follows:

a) *C, K, or T, classification.* C or K classification covers current transformers in which the leakage flux in the core of the transformer does not have an appreciable effect on the ratio or ratios within the limits of current and burden outlined in this subclause, so that the ratio can be calculated in accordance with 8.1.10. Current transformers with K classification shall have a knee-point voltage (see 6.10.2) at least 70% of the secondary terminal voltage rating.

   T classification covers current transformers in which the leakage flux in the core of the transformer has an appreciable effect on the ratio within the limits specified in item b.

   An appreciable effect is defined as a 1% difference between the values of actual ratio correction and the ratio correction calculated in accordance with 8.1.10.

b) *Secondary terminal voltage rating.* This is the voltage the transformer will deliver to a standard burden at 20 times rated secondary current without exceeding 10% ratio correction. Furthermore, the ratio correction shall be limited to 10% at any current from 1 to 20 times rated secondary current at the standard burden or any lower standard burden used for secondary terminal voltage ratings. For example, on a current transformer with 5 A rated secondary current, relay accuracy rating C100 means that the ratio can be calculated and that the ratio correction will not exceed 10% at any current from 1 to 20 times rated secondary current with a standard 1.0 ohm burden (1.0 Ω × 5 A × 20 × rated secondary current = 100 V).

Secondary terminal voltage ratings are based on a rated secondary current of 5 A (100 A at 20 times rated) and standard burdens. The voltage ratings and their associated burdens are as follows:

Secondary terminal voltage	Standard burden (see table 9)
10	B-0.1
20	B-0.2
50	B-0.5
100	B-1
200	B-2
400	B-4
800	B-8

If a current transformer secondary winding is rated at other than 5 A, appropriate voltage rating values shall be derived by multiplying the standard voltage rating values by 5/(amperes rating). For such transformers, the burden will be derived as in table 11 and the secondary terminal voltage rating will be the resulting value at 20 times rated secondary current. For example, if the rated secondary current is 1 A, the burden corresponding to B-2.0 will be 2.0 × 25, or 50 Ω (at 0.5 power factor); and the corresponding secondary terminal voltage rating will be 50 × 20 × 1 = 1000 V. In this example, the relay accuracy rating would be C1000, K1000, or T1000 as applicable.

6.4.2 Tapped-secondary or multi-ratio current transformer

The relay accuracy class applies only to the full winding, unless otherwise specified. If transformers have C or K classification on the full winding, all tapped sections shall be arranged so that the ratio can be calculated in accordance with 8.1.10 [see 6.4.1 item a)].

6.5 Continuous thermal current rating factors based on 30 °C average ambient air temperature

The thermal current rating factors shall be 1.0, 1.33, 1.5, 2.0, 3.0, or 4.0.

6.6 Short-time current ratings

The short-time thermal current and short-time mechanical capabilities are not independent.

6.6.1 Short-time mechanical current rating

The short-time mechanical current rating shall be the rms value of the ac component of a displaced (asymmetrical) primary current wave that the transformer is capable of withstanding with the secondary winding short-circuited. "Capable of withstanding" shall be interpreted to mean that if subjected to this duty, the current transformer shall show no damage and shall be capable of meeting the other applicable requirements of this standard.

6.6.2 Short-time thermal current rating

The 1 s thermal current rating of a current transformer is the rms symmetrical primary current that can be carried for 1 s with the secondary winding short-circuited without exceeding in any winding the limiting temperature. The temperature of a conductor in the windings of a current transformer shall be determined from calculation using methods specified in 8.6.2.

The limiting temperature shall be 250 °C for copper conductor, or 200 °C for EC aluminum conductor. A maximum temperature of 250 °C shall be allowed for aluminum alloys that have resistance to annealing properties at 250 °C equivalent to EC aluminum at 200 °C, or for applications of EC aluminum where the characteristics of the fully annealed material satisfy the mechanical requirements.

If the 1 s rating is not dependent on core saturation (see 8.6.3), the short-time thermal current rating for any time up to 5 s may be determined from the 1 s rating by dividing the current for 1 s by the square root of the specified number of seconds. For example, the 3 s thermal current rating is equal to the 1 s current rating divided by the square root of 3, or 58% of the one second rating. This calculation includes the assumption that the primary current is symmetrical during the time interval.

6.6.3 Short-time and continuous current ratings of window-type or bushing-type current transformers

Such current transformers, in which the primary conductor is not an integral part of the current transformers, shall be rated in terms of primary current, even though the short-time mechanical and thermal limitations and the continuous thermal limitations are those of the secondary winding only. Such ratings specified for current transformers of this construction should not be considered to be applicable to the conductor used for the primary winding of these transformers, as such conductor may be a component of other apparatus or bus work having different limitations.

6.7 Secondary winding induced voltages

6.7.1 Operation with secondary circuit open

Current transformers should never be operated with the secondary circuit open because hazardous crest voltages may result. Transformers conforming to this standard shall be capable of operating under emergency conditions for 1 min with rated primary current times the rating factor with the secondary circuit open if the open-circuit voltage does not exceed 3500 V crest.

6.7.2 Induced voltage test

(Not required for window-type or bar-type 10 kV BIL current transformers rated 600 A and below and having no relay accuracy rating.)

The one minute test voltage applied to the secondary terminals with the primary winding open shall be twice the relay rated voltage given in 6.4.1, item b), but not under 200 V.

Transformers with no relay voltage classification shall be tested at 200 V. If a frequency higher than 60 Hz is necessary to avoid excessive exciting current, see 8.8.4 for reduced time of application. If the voltage cannot be induced sinusoidally even at 400 Hz without core saturation, no test is required.

6.8 Nameplates

Nameplates shall include, as a minimum, the following:

a) Manufacturer's name or trademark
b) Manufacturer's type
c) Manufacturer's serial number (SER)
d) Rated primary and secondary current
e) Nominal system voltage (NSV) or maximum system voltage (MSV) (None for bushing CTs)
f) Basic impulse insulation level (BIL kV) (None for bushing CTs)
g) Rated frequency (Hz)
h) Continuous thermal current rating factor (RF)
i) Accuracy rating
   1) Metering accuracy class at a specified standard burdens: as a minimum, the burdens at which the transformer is rated 0.3 accuracy class
   2) Relaying accuracy rating on transformers intended primarily for relaying applications

NOTE—See IEEE Std C37.04-1979 and NEMA SG 4-1975 for nameplate requirements in high-voltage circuit breakers.

6.9 Terminals

Primary terminals of wound-type and bar-type current transformers shall be suitable for use with either aluminum or copper conductors. Secondary terminals and voltage terminals, where provided, shall be suitable for use with copper conductors.

6.10 Application data

The following characteristic data suitable for portraying or calculating performance shall be made available.

6.10.1 Data for metering applications

These data shall consist of the following:

a) Typical ratio correction factor and phase angle curves, for the standard burdens for which metering accuracy ratings are assigned, plotted over the range of current from 0.1 times rated current to the maximum continuous thermal current rating. These curves shall be plotted on rectangular coordinate paper and need not be drawn where the errors exceed the limits of the 1.2 accuracy class.
b) Short-time mechanical and short-time thermal current ratings, as defined in 6.6.1 and 6.6.2 respectively.

6.10.2 Data for relaying applications

These data shall consist of the following:

a) Relaying accuracy rating, as defined in 6.4
b) Short-time mechanical and short-time thermal current ratings, as defined in 6.6.1 and 6.6.2, respectively.
c) Resistance of the secondary winding between the secondary terminals at a specified temperature given in such a way that the value for each published ratio may be determined.
d) For C or K class transformers, typical excitation curves on log-log coordinate paper, with square decades, plotted between excitation current and induced secondary voltage for each published ratio, extending from 1% of the relay accuracy rating secondary terminal voltage to a voltage that will cause an excitation current of five times rated secondary current.
   Curves shall also show the knee of the curve. For current transformers with nongapped cores, the knee is defined as the point where the tangent is at 45 degrees to the abscissa. For current transformers with gapped cores, the knee is defined as the point where the tangent is at 30 degrees to the abscissa. For current transformers conforming to this standard, it shall be possible to draw the above tangents to the excitation curves. The maximum tolerance of excitation values above and below the knee shall be as shown (see figure 4), for both gapped and nongapped cores.
   NOTE—The 45 degree and the 30 degree tangents were established from experience using conventional magnetic materials. The significance of these tangent points will be dependent on the magnetic material in use.
e) For T class transformers, typical overcurrent ratio curves on rectangular coordinate paper plotted between primary and secondary current over the range from 1 to 22 times rated primary current for all the standard burdens[8] up to the standard burden which causes a ratio correction of 50% (see figure 5).

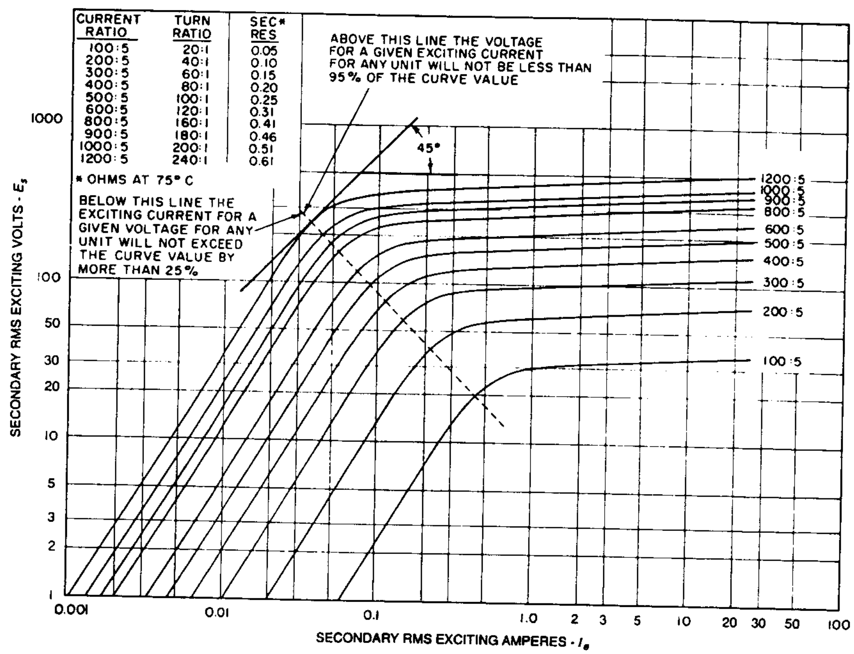


Figure 4—Typical excitation curves for multi-ratio C or K class current transformers with nongapped cores

[8] Except B = 0.9 and 1.8.

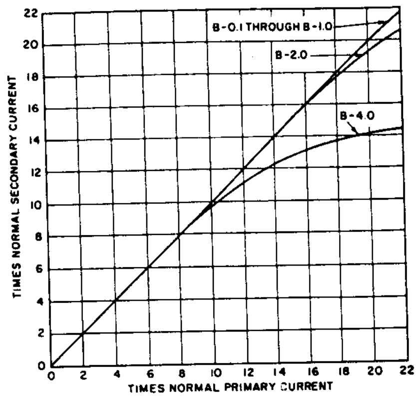


Figure 5—Typical overcurrent ratio curve

6.11 Routine accuracy tests

Tests for current transformers with metering accuracy ratings shall be made on each transformer, and shall consist of measurement of ratio and phase angle at 100% and at 10% of rated current, when energized at rated frequency. The burden shall be the maximum standard burden for which the transformer is rated at its best accuracy class.

Routine accuracy tests for current transformers with only a relaying accuracy rating shall be made on each transformer and shall consist of a turns ratio check and a measurement of exciting current at the voltage at which the typical excitation curve (see figure 4) has a 45 degree tangent (for nongapped cores) or a 30 degree tangent (for gapped cores). The exciting current shall not exceed 125% of the typical curve value.

7. Voltage transformers

7.1 Terms in which ratings shall be expressed

The ratings of a voltage transformer shall include:

a) Basic impulse insulation level in terms of full-wave test voltage (see tables 10–14 and figures 6a–6h)
b) Rated primary voltage and ratio (see tables 10–14 and figures 6a–6h)
c) Frequency (in Hertz)
d) Accuracy ratings (see 5.3)
e) Thermal burden rating (see 7.4)

NOTE—In tables 10 through 13 voltage transformers connected line-to-ground on an ungrounded system cannot be considered grounding transformers and shall not be operated with the secondary windings in closed delta because excessive currents may flow in the delta.

Table 10—Ratings and characteristics of group 1* voltage transformers

Rated voltage (V)	Marked ratio	Basic impulse insulation level (kV crest)
120 / 208Y	1:1	10
240 / 416Y	2:1	10
300 / 520Y	2.5:1	10
120 / 208Y	1:1	30
240 / 416Y	2:1	30
300 / 520Y	2.5:1	30
480 / 832Y	4:1	30
600 / 1040Y	5:1	30
2400 / 4160Y	20:1	60
4200 / 7270Y	35:1	75
4800 / 8320Y	40:1	75
7200 / 12 470Y	60:1	110 or 95
8400 for 14 400Y	70:1	110 or 95
12 000 / 20 750Y	100:1	150 or 125
14 400 / 24 940Y	120:1	150 or 125

*Group 1 voltage transformers are for application with 100% of rated primary voltage across the primary winding when connected line-to-line or line-to-ground. (For typical connections, see figures 6a and 6b.) Group 1 voltage transformers shall be capable of operations at 125% of rated voltage on an emergency basis (this capability does not preclude the possibility of ferroresonance), provided the burden, in voltamperes at rated voltage, does not exceed 64% of the thermal burden rating, without exceeding the following average winding temperatures: 105 °C for 55 °C rise types, 115 °C for 65 °C rise types, and 130 °C for 80 °C rise types. This will result in reduction of life expectancy.

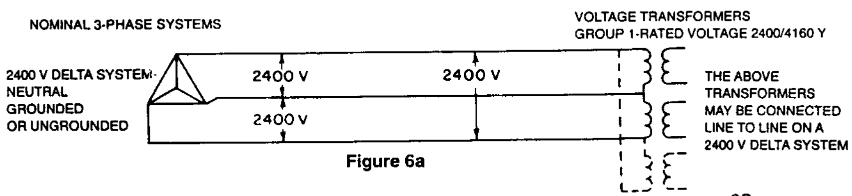


Figure 6a

OR

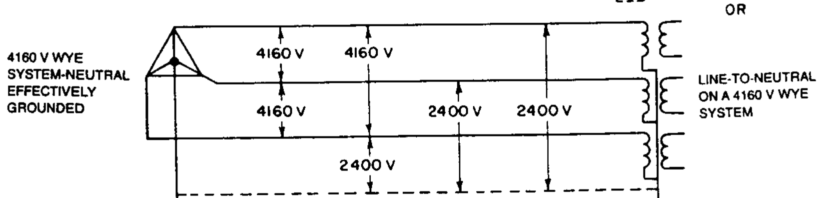


Figure 6b

Figures 6a and 6b—Typical primary connections

Table 11—Ratings and characteristics of group 2* voltage transformers

Rated voltage (V)	Marked ratio	Basic impulse insulation level (kV crest)
120	1:1	10
240	2:1	10
300	2.5:1	10
480	4:1	10
600	5:1	10
2400	20:1	45
4800	40:1	60
7200	60:1	75
12 000	100:1	110 or 95
14 000	120:1	110 or 95
24 000	200:1	150 or 125
34 500	300:1	200 or 150
46 000	400:1	250
69 000	600:1	350

*Group 2 voltage transformers are primarily for line-to-line services, and may be applied line-to-ground or line-to-neutral at a winding voltage equal to the primary voltage rating divided by the square root of 3. (For typical connections see figures 6c and 6d.) Note that the thermal burden capability will be reduced at this voltage.

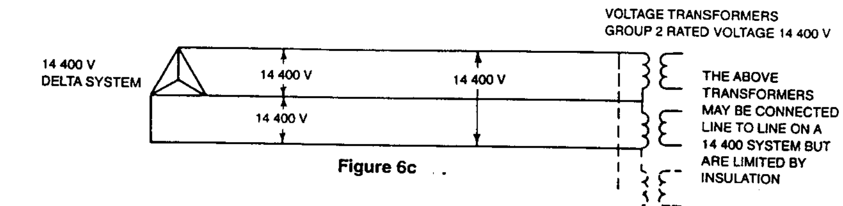


Figure 6c

TO

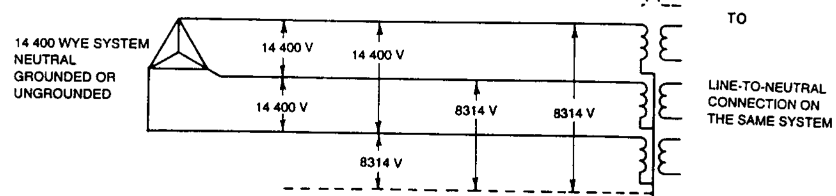


Figure 6d

Figures 6c and 6d—Typical primary connections

Table 12—Ratings and characteristics of group 3* outdoor voltage transformers

Rated voltage (V)	Marked ratio	Basic impulse insulation level (kV crest)
24 940 Grd Y/14 400	120/200 & 120/200:1	150 or 125
34 500 Grd Y/20 125	175/300 &175/300:1	200
46 000 Grd Y/27 600	240/400 & 240/400:1	250
69 000 Grd Y/40 250	350/600 & 350/600:1	350
115 000 Grd Y/69 000	600/1000 & 600/1000:1	550 or 450
138 000 Grd Y/80 500	700/1200 &700/1200:1	650 or 550
161 000 Grd Y/92 000	800/1400 & 800/1400:1	750 or 650
230 000 Grd Y/138 000	1200/2000 & 1200/2000:1	1050 or 900
345 000 Grd Y/207 000	1800/3000 & 1800/3000:1	1300 or 1175
500 000 Grd Y/287 500	2500/4500 & 2500/4500:1	1800 or 1675
750 000 Grd Y/431 250	3750/6250 & 3750/6250:1	2050

*Group 3 voltage transformers are for line-to-ground connection only and have two secondary windings. They may be insulated-neutral or grounded-neutral terminal type. Ratings through 161 000 Grd Y/92 000 shall be capable of the square root of 3 times rated voltage (this capability does not preclude the possibility of ferroresonance) for 1 min without exceeding 175 °C temperature rise for copper conductor or 125 °C rise for EC aluminum. Ratings 230 000 Grd Y/138 000 and above shall be capable of operation at 140% of rated voltage with the same limitation of time and temperature. (For typical connections, see figure 6e.) Group 3 transformers shall be capable of continuous operation at 110% of rated voltages, provided the burden in voltamperes at this voltage does not exceed the thermal burden rating.

NOTE—The double voltage ratio is usually achieved by a tap in the secondary winding. In such cases the nonpolarity terminal of the winding shall be the common terminal.

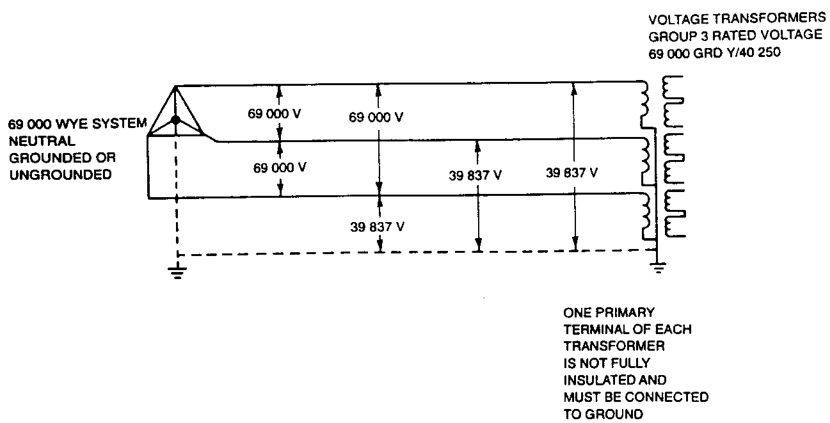


Figure 6e—Typical primary connections

Table 13—Ratings and characteristics of group 4* indoor voltage transformers

Group	Rated voltage (V)	Marked ratio	Basic impulse insulation level (kV crest)
Group 4A: For operations at approximately 100% of rated voltage (see figure 6b)	4160 Grd Y/2400	20:1	60
	7200 Grd Y/4200	35:1	75
	8320 Grd Y/4800	40:1	75
	12 470 Grd Y/7200	60:1	110 or 95
	14 400 Grd Y/8400	70:1	110 or 95
Group 4B: For operation at approximately 58% of rated voltage (see figure 6d)	4160 Grd Y/2400	35:1	60
	4800 Grd Y/4800	40:1	60
	7200 Grd Y/7200	60:1	75
	12 000 Grd Y/12 000	100:1	110 or 95
	14 400 Grd Y/14 400	120:1	110 or 95

*Group 4 voltage transformers are for line-to-ground connection only. They may be insulated-neutral or grounded-neutral terminal type. (For typical connections of Group 4A, see figure 6f. For typical connections of Group 4B, see figure 6g.) Group 4 transformers shall be capable of continuous operation at 110% of rated voltages, provided the burden in voltamperes at this voltage does not exceed the thermal burden rating. Group 4A voltage transformers shall be capable of operation at 125% of rated voltage on an emergency basis (this capability does not preclude the possibility of ferroresonance), provided the burden, in voltamperes at rated voltage, does not exceed 64% of the thermal burden rating, without exceeding the following average winding temperatures: 105°C for 55°C rise types, 115 °C for 65 °C rise types and 130 °C for 80 °C rise types. (This will result in a reduction of normal life expectancy.)

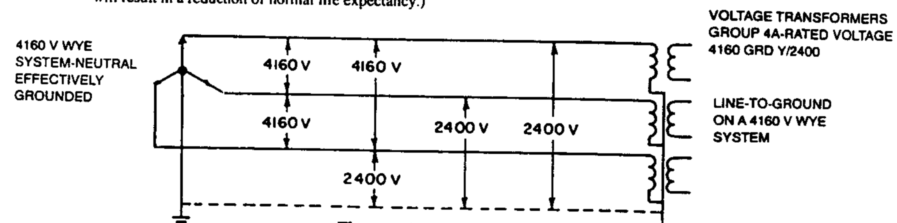


Figure 6f

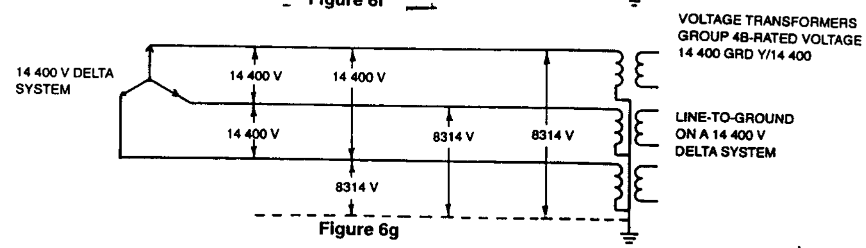


Figure 6g

Figures 6f and 6g—Typical primary connections

Table 14—Ratings and characteristics of group 5[*] indoor voltage transformers

Rated voltage (V)	Marked ratio	Basic impulse insulation level (kV crest)
12 470 Grd Y/7200	60:1	110
14 000 Grd Y/8400	70:1	110
20 780 Grd Y/12 000	100:1	150 or 125
24 940 Grd Y/14 400	120:1	150 or 125
34 500 Grd Y/20 125	175:1	200 or 150

[*]Group 5 voltage transformers are for line-to-ground connection only, and are for use outdoors on grounded systems. They may be insulated-neutral or grounded-neutral terminal type. They shall be capable of operation at 140% of rated voltage for 1 min without exceeding 175 °C temperature rise for copper conductor or 125 °C rise for EC aluminum conductor. (This will result in a reduction of normal life expectancy.) Group 5 voltage transformers shall be capable of continuous operation at 110% of rated voltage, provided the burden, in voltamperes at this voltage, does not exceed the thermal burden rating. This capability does not preclude the possibility of ferroresonance.

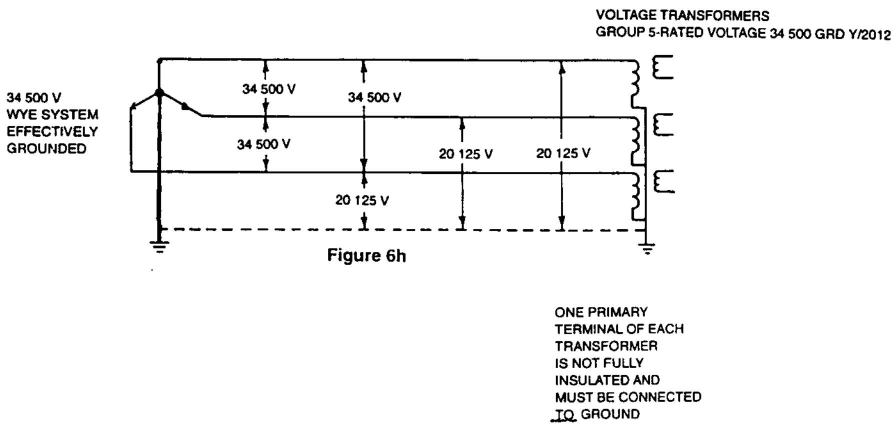


Figure 6h

Figure 6h—Typical primary connections

7.2 Standard burdens

Standard burdens for voltage transformers for rating purposes are shown in table 15.

Table 15—Standard burdens for voltage transformers

Characteristics on standard burdens[*]			Characteristics on 120 V basis			Characteristics on 69.3 V basis		
Designation	*VA*	*Power factor*	*Resistance (Ω)*	*Inductance*	*Impedance (Ω)*	*Resistance (Ω)*	*Inductance*	*Impedance (Ω)*
W	12.5	0.10	115.2	3.0400	1152	38.4	1.0100	384
X	25.0	0.70	403.2	1.0900	576	134.4	0.3640	192
M	35.0	0.20	82.3	1.0700	411	27.4	0.3560	137
Y	75.0	0.85	163.2	0.2680	192	54.4	0.0894	64
Z	200.0	0.85	61.2	0.1010	72	20.4	0.0335	24
ZZ	400.0	0.85	30.6	0.0503	36	10.2	0.0168	12

[*]These burden designations have no significance except at 60 Hz.

NOTE—For rated secondary voltages from 108 Vthrough 132 V or from 62.4 V through 76.2 V, the standard burdens for accuracy tests within ±10% of rated voltage are defined by the characteristic burden impedances at 120 V or 69.3 V respectively. For other rated secondary voltages, the standard burdens for accuracy tests withing ±10% of rated voltage are defined by the characteristic burden voltamperes and power factor. The characteristic voltamperes apply at rated secondary voltage and appropriate impedances are required. When transformers with rated secondary volts from 108 V through 132 V are tested at secondary voltages within ±10% of 1/2 times rated voltage, the standard burdens for accuracy test are defined by the characteristic burdens impedances at 69.3 V. When transformers with other rated secondary volts are to be tested at secondary voltages within ±10% of 1/13 times rated voltage, the standard burdens for accuracy test are defined by the characteristic burden voltamperes and power factor. The characteristic voltamperes apply at 1/13 times rated voltage, for a given standard burden, the burden impedances are lower and the changes in accuracy resulting from burden current are greater than at rated voltage.

7.3 Accuracy ratings

7.3.1 Assignment of accuracy ratings

A voltage transformer shall be assigned an accuracy rating for each of the standard burdens for which it is rated. For example, an accuracy rating might be 0.3W and X, 0.6Y, 1.2Z.

7.3.2 Accuracy classification for voltage transformers with two secondary windings or tapped-secondary windings

The burden on any two secondary terminals affects the accuracy on all other terminals. The burden stated in the accuracy ratings is the total burden on the transformer. The accuracy class shall apply with the burden divided between the secondary outputs in any manner.

7.4 Thermal burden ratings

The thermal burden rating of a voltage transformer shall be specified in terms of the maximum burden in voltamperes that the transformer can carry at rated secondary voltage without exceeding the temperature rise given in table 4.

If no thermal burden in voltamperes rating is given, the thermal burden rating in voltamperes shall be the same as the maximum standard burden for which an accuracy rating is given.

Each winding, including the primary winding, of a multiple-secondary transformer shall be given a thermal burden rating. If only one thermal burden rating is specified, it shall be applicable to any distribution of secondary voltamperes, including the use of taps.

7.5 Nameplates

Voltage transformers shall be provided with nameplates that shall include, as a minimum, the following information (see table 5):

a) Manufacturer's name or trademark
b) Manufacturer's type
c) Manufacturer's serial number (SER), numerals only
d) Rated voltage (PRI)
e) Ratio or ratios
f) Basic impulse insulation level (BIL kV)
g) Rated frequency (in Hertz)
h) Thermal burden rating or ratings at ambient temperature or temperatures, in voltamperes in degrees Celsius
i) Accuracy rating: maximum standard burden at which the accuracy rating is 0.3 class, as a minimum.

7.6 Terminals

Primary terminals shall be electrically and mechanically suitable for use with either copper or aluminum conductors. Secondary terminals shall be electrically and mechanically suitable for use with copper conductors.

7.7 Short-circuit capability

Voltage transformers shall be capable of withstanding for 1 s the mechanical and thermal stresses resulting from a short circuit on the secondary terminals with full voltage maintained on the primary terminals. "Capable of withstanding" shall be interpreted to mean that, if subjected to this duty, the voltage transformer shall show no damage and shall be capable of meeting the other applicable requirements of this standard. The temperature of the conductors in the windings of voltage transformers under short-circuit conditions shall be determined from calculations using the methods specified in 8.6.4. The limiting temperature shall be 250 °C for copper conductors, or 200 °C for EC aluminum conductors. A maximum temperature of 250 °C shall be allowed for aluminum alloys that have resistance to annealing properties at 250 °C equivalent to EC aluminum at 200 °C, or for applications of EC aluminum where the characteristics of the fully annealed material satisfy the mechanical requirements.

7.8 Application data

Characteristic data shall be made available by the manufacturer as follows:

a) Typical ratio correction factor and phase angle curves for rated primary voltage (and, when specified, for rated primary voltage divided by the square root of 3), plotted for the standard burdens from 0 VA to the voltamperes of the burden, and also plotted for unity power factor burden from 0 VA to the voltamperes of the largest standard burden plotted. Ratio correction factor and phase angle data for other burdens may be calculated by methods outlined in clause 8.

b) Accuracy ratings for all standard burdens up to and including the maximum standard burden rating of the transformer.

7.9 Induced voltage test

The test voltage shall be as follows:

a) For transformers with two fully insulated primary terminals, the test voltage shall be twice the rated voltage of the windings.
b) For insulated-neutral or grounded-neutral terminal type transformers, the test voltage shall be equal to the applied voltage test kilovolts specified in table 2 for the BIL. (If the routine factory applied voltage test on insulated-neutral terminal type transformers is made at the applied voltage test kilovolts specified in table 2 for the BIL, then the induced voltage test shall be at twice the rated voltage of the windings.)

7.10 Routine accuracy tests

These tests shall be made on each transformer and shall consist of ratio and phase angle tests at 100% of rated primary voltage at rated frequency with zero burden, and with the maximum standard burden for which the transformer is rated at its best accuracy class.

Table 5—Instrument transformer symbols

Symbol	Voltage transformers	Current transformers
: (colon)	Ratio expression, only to show ratio between primary and secondary voltages or between primary and tertiary voltages *Example:* Voltage transformers with one primary winding and one secondary winding 14 400:120 V Ratio 120:1	Ratio between primary and secondary amperes *Example:* Current transformer with one primary winding and one secondary winding Current ratio 100:5 A
× (multiplication sign)	Voltage ratings or ratios of transformer with a primary or secondary winding having two or more coils for series or parallel connection *Example:* Voltage transformer with primary winding in two coils for series or parallel connection for two ratings 2400 × 4800 V Ratio 20 × 40:1	Current ratings of transformer with a primary or secondary winding having two or more coils for series or parallel connection *Example:* Current transformer with two primary windings in two coils for series or parallel connection for two ratios Current ratio 100 × 200:5 A
// (double slant line)	(Not used)	Ampere ratings of separate secondary windings each having an independent core *Example:* Current transformer with two separate secondary windings and two cores Current ratio 100:5//5 A
& (ampersand)	Voltage ratings or ratios of separate secondary windings on one core *Example:* Voltage transformer for connection line-to-ground, with one primary winding and two secondary windings 14 400:120 & 72 V Ratio 120 & 200:1	Ampere ratings of separate primary windings on one core (When all primary current ratings are the same, the transformer shall produce rated secondary current when each primary winding carries rated current and the primary currents are in phase. When all primary currents are not the same, the transformer shall produce rated secondary current when the only primary current is rated current in only one primary winding.) a) Transformer with two or more primary windings designed to be used individually *Example:* Current transformer with two primary windings Current ratio 100 & 600:5 A b) Totalizing transformer with two or more primary windings that can be used simultaneously and connected in different circuits *Example:* Totalizing current transformer with three primary windings Current ratio 5 & 5 & 5:5 A c) Transformer for three-wire single-phase circuit with two separate primary windings Example: Current transformer for three-wire single-phase circuit Current ratio 100 & 100:5 A

Table 5—Instrument transformer symbols (*Continued*)

Symbol	Voltage transformers	Current transformers
/ (single slant line)	Two or more primary or secondary voltage ratings obtained by taps in the secondary winding. *Example:* Voltage transformer with taps in the secondary winding for additional primary voltage ratings 8400/12 000/14 400 V Ratio 70/100/120:1 *Example:* Voltage transformer with a tap in the secondary winding for additional secondary voltage ratings 14 000 V Ratio 120/200:1	Different primary current ratings obtained by taps in the secondary winding *Example:* Current transformer with taps in the secondary winding for additional ratios Current ratio 300/400/600:5 A
E	Designation of primary voltage ratings *Example:* Voltage transformer with E-rated voltage for connection on an E voltage system 14 000 (E)	(Not used directly)
(E/E_1Y)	*Example:* Voltage transformer with E-rated voltage that is suitable for connection on an E voltage system or for Y connection on an E_1 voltage system 2400/4160Y (E/E_1Y)	
(E_1GrdY/E)	*Example:* Voltage transformer with E-rated voltage with reduced insulation at neutral end, for line-to-ground connection on an E_1 voltage system 12 470GrdY/7200 (E_1GrdY/E)	

5. Accuracy classes for metering

5.1 Basis for accuracy classes

Accuracy classes for revenue metering are based on the requirement that the transformer correction factor (TCF) of the voltage transformer or of the current transformer shall be within specified limits when the power factor (lagging) of the metered load has any value from 0.6 to 1.0, under specified conditions as follows:

a) For current transformers, at the specified standard burden (see 6.2 for standard burdens) at 10% and at 100% of rated primary current (also at the current corresponding to the rating factor (RF) if it is greater than 1.0). The accuracy class at a lower standard burden is not necessarily the same as at the specified standard burden.
b) For voltage transformers, for any burden in voltamperes from zero to the specified standard burden, at the specified standard burden power factor (see 7.2 for standard burdens) and at any voltage from 90% to 110% of the rated voltage. The accuracy class at a lower standard burden of different power factor is not necessarily the same as at the specified standard burden.

5.2 Expression of TCF at 0.6 power factor (lagging) of metered load

It can be shown[6] that a TCF at 0.6 power factor (lagging) of the metered load is:

a) For voltage transformers
$TCF = RCF + \gamma/2600$
b) For current transformers,
$TCF = RCF - \beta/2600$

where

RCF = ratio correction factor
γ, β = phase angle in minutes, for voltage transformers and current transformers respectively

5.3 Standard accuracy classes

The limits of transformer correction factor in standard accuracy classes shall be as shown in table 6.

Table 6—Standard accuracy class for metering service and corresponding limits of transformer correction factor [0.6 to 1.0 power factor (lagging) of metered load]

Metering accuracy class	Voltage transformers (at 90% to 100% rated voltage)		Current transformers			
			*At 100% rated current**		*At 10% rated current*	
	Minimum	*Maximum*	*Minimum*	*Maximum*	*Minimum*	*Maximum*
0.3	0.997	1.003	0.997	1.003	0.994	1.006
0.6	0.994	1.006	0.994	1.006	0.988	1.012
1.2	0.988	1.012	0.988	1.012	0.976	1.024

*For current transformers the 100% rated current limit also applies to the current corresponding to the continuous thermal current rating factor.

[6]This is true for errors within the range of the standard metering accuracy classes.

5.4 Limiting values of RCF and phase angle for standard accuracy classes

The limiting values of RCF are the same as those for TCF (see 5.2). For any known value of RCF for a given transformer the limiting values[7] of the angles derived from the expression in 5.2 are given by:

a) For voltage transformers,
$\gamma = 2600\ (TCF - RCF)$

b) For current transformers,
$\beta = 2600\ (RCF - TCF)$

in which TCF is taken as the maximum and minimum values, given in table 6, for the specified accuracy class.

These relations are shown graphically in figure 2 for current and in figure 3 for voltage transformers.

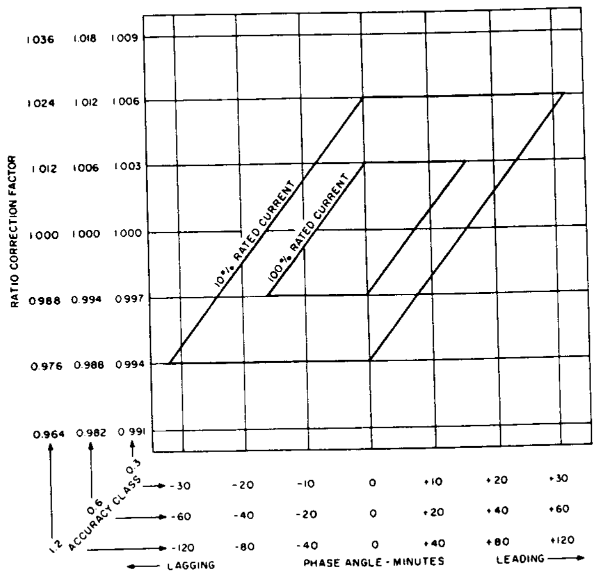


Figure 2—Limits of accuracy classes for current transformers for metering

NOTE—The accuracy requirements for 100% rated current also apply at the continuous thermal current rating of the transformer.

[7]This is true of errors within the range of the standard metering accuracy classes.

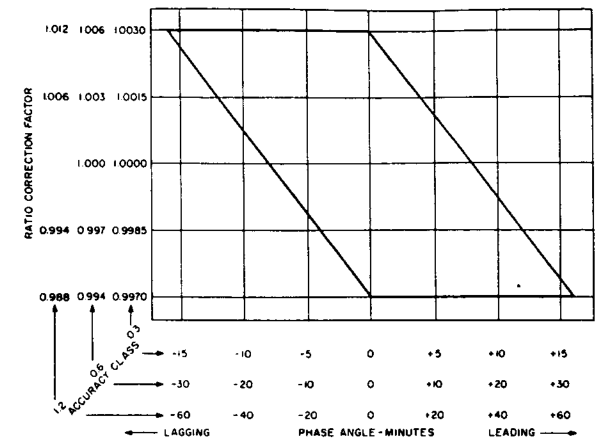


Figure 3—Limits of accuracy classes for voltage transformers for metering

NOTE—The transformer characteristics shall lie within the limits of the parallelogram for all voltages between 90% to 110% of rated voltage.