



IEEE Standard Requirements for Instrument Transformers

IEEE Power Engineering Society

Sponsored by the
Transformers Committee



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(Revision of
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IEEE Standard Requirements for Instrument Transformers

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Transformers Committee
of the
IEEE Power Engineering Society

Approved 27 March 2008
IEEE-SA Standards Board

Abstract: Electrical, dimensional, and mechanical characteristics are covered, taking into consideration certain safety features, for current and inductively coupled voltage transformers of types generally used in the measurement of electricity and the control of equipment associated with the generation, transmission, and distribution of alternating current. The aim is to provide a basis for performance and interchangeability of equipment covered and to assist in the proper selection of such equipment. Safety precautions are also addressed. Accuracy classes for metering service are provided. The test code covers measurement and calculation of ratio and phase angle, demagnetization, impedance and excitation measurements, polarity determination, resistance measurements, short-time characteristics, temperature rise tests, dielectric tests, and measurement of open-circuit voltage of current transformers.

Keywords: accuracy, current transformer, instrument transformer, primary winding, rated secondary voltage, routine tests, secondary winding, type tests, voltage transformer

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Introduction

This introduction is not part of IEEE Std C57.13-2008, IEEE Standard Requirements for Instrument Transformers.

This standard was prepared by the Instrument Transformer Subcommittee of the Transformers Committee of the IEEE Power Engineering Society. The purpose of this standard is to cover the electrical, dimensional, and mechanical characteristics and to take into consideration certain safety features, for current and inductively coupled voltage transformers.

The changes in this revision of this standard are to the rated voltage rating of voltage transformers to eliminate the confusion caused by the specification of the primary voltage and the system voltage for line to ground transformers. An addition of partial discharge testing was added to the test section.

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1. Overview

1.1 Scope

This standard is intended for use as a basis for performance and interchangeability of equipment covered, and to assist in the proper selection of such equipment. Safety [precautions are also addressed](#).

This standard covers certain electrical, dimensional, and mechanical characteristics, and takes into consideration certain safety features of current and inductively coupled voltage transformers of types generally used in the measurement of electricity and the control of equipment associated with the generation, transmission, and distribution of alternating current.

1.2 Purpose

The purpose of this standard is to provide the performance requirements for electrical system and test interchangeability of current and inductively coupled voltage transformers. These transformers are for both indoor and outdoor application.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

~~This standard shall be used in conjunction with the following publications. When the following publications are superseded by an approved revision, the revision shall apply.~~

ANSI C37.06, [American National Standard for Switchgear—AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis—Preferred Ratings and Related Required Capabilities.](#)¹

[IEEE Std 4™, IEEE Standard Techniques for High-Voltage Testing.](#)

IEEE Std C37.04™, IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.^{2, 3}

IEEE Std C37.09™, IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Basis.

IEEE Std C57.12.00™, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.

~~¹ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.~~

~~²IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.~~

IEEE Std C57.12.90™, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers ~~and IEEE Guide for Short Circuit Testing of Distribution and Power Transformers~~

~~IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing (ANSI).~~

IEEE Std C57.19.00™, IEEE Standard General Requirements and Test Procedure for Outdoor Apparatus Bushings

~~. IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).~~

[IEEE Std C57.13.6™, IEEE Standard for High-Accuracy Instrument Transformers.](#)

NEMA SG 4, Alternating-Current High-Voltage Circuit Breakers.⁴

3. Definitions

[For the purposes of this document, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms* \[B30\]⁵ should be referenced for terms not defined in this clause.](#)

~~All definitions, except as specifically covered in this standard, shall be in accordance with IEEE Std 100-1992.~~
4

~~**3.1 bar-type current transformer:** One that has a fixed and straight single primary winding turn passing through the magnetic circuit. The primary winding and secondary winding(s) are insulated from each other and from the core(s) and are assembled as an integral structure.~~

~~**3.2 basic lightning impulse insulation level (BIL):** A specific insulation level expressed in kilovolts of the crest value of a standard lightning impulse.~~

~~**3.3 burden of an instrument transformer:** That property of the circuit connected to the secondary winding that determines the active and reactive power at the secondary terminals.~~

~~NOTE — The burden is expressed either as total ohms impedance with the effective resistance and reactance components, or as the total voltamperes and power factor at the specified value of current or voltage, and frequency.~~

~~**3.4 bushing-type current transformer:** One that has an annular core and a secondary winding insulated from and permanently assembled on the core but has no primary winding and no insulation for a primary winding. This type of current transformer is for use with a fully insulated conductor as the primary winding. A bushing-type current transformer usually is used in equipment where the primary conductor is a component part of other apparatus.~~

~~**3.5 cascade-type voltage transformer:** A voltage transformer that has an insulated neutral or grounded neutral terminal and that has the primary winding subdivided into two or more (usually equal) series-connected sections, mounted on one or more magnetic cores, and that has the secondary winding located about the core at the neutral end of the primary winding. The sections of the primary winding are coupled by “coupling windings.” The cores, if more than one, are insulated from each other and connected to definite voltage levels along the primary winding.~~

~~**3.6 continuous thermal current rating factor (RF):** The number by which the rated primary current of a current transformer is multiplied to obtain the maximum primary current that can be carried continuously without exceeding the limiting temperature rise from 30 °C average ambient air temperature. The RF of tapped secondary or multi-ratio transformers applies to the highest ratio, unless otherwise stated. (When current transformers are incorporated internally as parts of larger transformers or power circuit breakers, they shall meet allowable average winding and hot spot temperature limits under the specific conditions and requirements of the larger apparatus.)~~

~~**3.7 current transformer (CT):** An instrument transformer intended to have its primary winding connected in series with the conductor carrying the current to be measured or controlled.~~

~~**3.8 double-secondary current transformer:** One that has two secondary windings each on a separate magnetic circuit with both magnetic circuits excited by the same primary winding.~~

~~**3.9 double-secondary voltage transformer:** One that has two secondary windings on the same magnetic circuit with the secondary winding insulated from each other.~~

³NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street NW, Washington, DC 20037, USA.

⁴Information on references can be found in clause 2.

~~**3.10 excitation losses for an instrument transformer:** The power (usually expressed in watts) required to excite the transformer at its primary terminals.~~

~~NOTE — Excitation losses include core, dielectric, and winding losses due to the excitation current.~~

~~**3.11 fused-type voltage transformer:** One that is provided with means for mounting one or more fuses as integral parts of the transformer in series with the primary winding.~~

~~**3.12 grounded-neutral terminal-type voltage transformer:** One that has the neutral end of the primary winding connected to the case or mounting base in a manner not intended to facilitate disconnection.~~

~~**3.1 indoor voltage (or voltage) transformer:** One that, because of its construction, must be protected from the weather.~~

~~**3.14 instrument transformer:** One that is intended to reproduce in its secondary circuit, in a definite and known proportion, the current or voltage of its primary circuit with the phase relations substantially preserved.~~

~~**3.15 insulated-neutral terminal-type voltage transformer:** One that has the neutral end of the primary winding insulated from the case or base and connected to a terminal that provides insulation for a lower voltage than~~

required for the line terminal. (The neutral may be connected to the case or mounting base in a manner intended to facilitate temporary disconnection for dielectric testing.)

3.16 leakage flux: Any magnetic flux, produced by current in an instrument transformer winding, which does not link all turns of all windings.

3.17 low remanence current transformer: One with a remanence not exceeding 10% of maximum flux.

3.18 marked ratio: The ratio of the rated primary value to the rated secondary value as stated on the nameplate.

3.19 multiple secondary current transformer: One that has three or more secondary windings, each on a separate magnetic circuit, with all magnetic circuits excited by the same primary winding.

3.20 multi-ratio current transformer: One with three or more ratios obtained by the use of taps on the secondary winding.

3.21 nominal ratio: See: marked ratio

3.22 outdoor current (or voltage) transformer: One of weather-resistant construction, suitable for service without additional protection from the weather.

3.23 percent ratio correction: The difference between the ratio correction factor and unity, expressed in percent [(RCF - 1) × 100] See: ratio correction factor

3.24 phase angle of an instrument transformer (PA): The phase displacement, in minutes or radians, between the primary and secondary values. The phase angle of a current transformer is designated by the Greek letter beta (β) and is positive when the current leaving the identified secondary terminal leads the current entering the identified primary terminal. The phase angle of a voltage transformer is designated by the Greek letter gamma (γ) and is positive when the secondary voltage from the identified to the unidentified terminal leads the corresponding primary voltage.

3.25 phase angle correction factor (PACF): The ratio of the true power factor to the measured power factor. It is a function of both the phase angles of the instrument transformers and the power factor of the primary circuit being measured.

NOTE — The phase angle correction factor corrects for the phase displacement of the secondary current or voltage, or both, due to the instrument transformer phase angle(s).

For a current transformer, the phase angle correction factor: $PACF = \cos(\phi_2 \mp \beta) / \cos(\phi_2)$

For a voltage transformer, the phase angle correction factor: $PACF = \cos(\phi_2 - \gamma) / \cos(\phi_2)$

When both voltage and current transformers are used, the combined phase angle correction: $PACF = \cos(\phi_2 \mp \beta) / \cos(\phi_2)$

ϕ_2 is the apparent power factor angle of the circuit being measured.

3.26 polarity: The relative instantaneous directions of the currents entering the primary terminals and leaving the secondary terminals during most of each half cycle.

NOTE — Primary and secondary terminals are said to have the same polarity when, at a given instant during most of each half cycle, current enters the primary terminal and leaves the secondary terminal in the same direction as though there was a continuous circuit between the two terminals.

3.27 primary winding: The winding intended for connection to the circuit to be measured or controlled.

3.28 rated current: The primary current upon which the performance specifications are based.

3.29 rated secondary current: The rated current divided by the marked ratio.

3.30 rated secondary voltage: The rated voltage divided by the marked ratio.

3.31 rated voltage: The primary voltage upon which the performance specifications of a voltage transformer are based.

~~**3.32 ratio correction factor (RCF):** The ratio of the true ratio to the marked ratio. The primary current or voltage is equal to the secondary current or voltage multiplied by the marked ratio times the ratio correction factor.~~

~~**3.33 secondary winding:** The winding intended for connection to the measuring, protection, or control devices.~~

~~**3.34 series parallel primary current transformer:** One that has two insulated primary windings that are intended for connection in series or parallel to provide different rated currents.~~

~~**3.35 tapped secondary current or voltage transformer:** One with two ratios obtained by use of a tap on the secondary winding.~~

~~**3.36 thermal burden rating of a voltage transformer:** The voltampere output that the voltage transformer will provide continuously at rated secondary voltage without exceeding the specified temperature limits.~~

~~**3.37 three wire type current transformer:** One that has two insulated primary windings and one secondary winding and is for use on a three wire, single phase service.~~

~~NOTE — The primary windings and the secondary winding are permanently assembled on the core as an integral structure. The secondary current is proportional to the phasor sum of the primary currents.~~

~~**3.38 transformer correction factor (TCF):** The ratio of the true watts or watthours to the measured secondary watts or watthours, divided by the marked ratio.~~

~~NOTE — The transformer correction factor for a current or voltage transformer is the ratio correction factor multiplied by the phase angle correction factor for a specified primary circuit power factor.~~

~~The true primary watts or watthours are equal to the watts or watthours measured, multiplied by the transformer correction factor and the marked ratio.~~

~~The true primary watts or watthours, when measured using both current and voltage transformers, are equal to the current transformer ratio correction factor multiplied by the voltage transformer ratio correction factor multiplied by the marked ratios of the current and voltage transformers multiplied by the observed watts or watthours. It is usually sufficiently accurate to calculate true watts or watthours as equal to the product of the two transformer correction factors multiplied by the marked ratios multiplied by the observed watts or watthours.~~

~~**3.39 true ratio:** The ratio of the root mean square (rms) primary voltage or current to the rms secondary voltage or current under specified conditions.~~

~~**3.40 turns ratio of a current transformer:** The ratio of the secondary winding turns to the primary winding turns.~~

~~**3.41 turns ratio of a voltage transformer:** The ratio of the primary winding turns to the secondary winding turns.~~

~~**3.42 voltage transformer (VT):** An instrument transformer intended to have its primary winding connected in shunt with the voltage to be measured or controlled.~~

~~**3.43 window type current transformer:** One that has a secondary winding insulated from and permanently assembled on the core, but has no primary winding as an integral part of the structure. Primary insulation is provided in the window, through which one turn of the line conductor can be passed to provide the primary winding.~~

~~**3.44 wound type current transformer:** One that has a primary winding consisting of one or more turns mechanically encircling the core or cores. The primary winding(s) and secondary winding(s) are insulated from each other and from the core(s) and are assembled as an integral structure.~~

3.2 split-core current transformer: One that has a secondary winding insulated from and permanently assembled on the core but has no primary winding as an integral part of the structure. This type of core can be opened or separated such that it can be placed over a primary conductor and reattached and secured. It shall have a minimum insulation for the 2.5 kV applied test, and it may or may not be fully rated for the primary voltage. This type is primarily used as a temporary or permanent installation where it is not practical to break the primary conductor.

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⁵The numbers in brackets correspond to those of the bibliography in Annex A.

4. General requirements

4.1 Service conditions

4.1.1 Usual temperature and altitude service conditions

Instrument transformers conforming to this standard shall be suitable for operation at their thermal ratings, provided that the altitude does not exceed 1000 m.

4.1.1.1 30 °C average ambient temperature

If the transformers are air cooled, the ambient temperature of the cooling air does not exceed 40 °C and the average ambient temperature of the cooling air for any 24-h period does not exceed 30 °C.⁶

The minimum ambient air temperature is –30 °C.

4.1.1.2 55 °C average ambient temperature

Instrument transformers may also be given ratings for operation in 55 °C average ambient temperature, with maximum ambient air temperature not exceeding 65°C.

4.1.2 Unusual temperature and altitude service conditions

Instrument transformers may be applied at higher altitudes or higher ambient temperatures than specified in 4.1.1, but the performance may be affected and special consideration should be given to these applications (see 4.4).

4.1.3 Other conditions that may affect design and application

Where unusual conditions other than those discussed in 4.1.1 or 4.1.2 exist, they should be brought to the attention of those responsible for the design and application of instrument transformers. Examples of these conditions are as follows:

- a) Damaging fumes or vapors, excessive or abrasive dust, explosive mixtures of dust or gases, steam, salt spray, excessive moisture or dripping water, etc.
- b) Abnormal vibrations, shocks, or tilting
- c) Ambient temperatures above 55 °C or below –30 °C
- d) Unusual transportation or storage conditions

⁶It is recommended that the average temperature of the cooling air be calculated by averaging 24 consecutive hourly readings. When the outdoor air is the cooling medium, the average of the maximum and minimum daily temperature may be used. The value that is obtained in this manner is usually higher than the true daily average by not more than 1/2 °C.

- e) Unusual space limitations or restricted ventilation
- f) Unusual duty, frequency of operation, difficulty of maintenance, poor wave form, unbalanced voltage, special insulation requirements, etc.
- g) Applications in switchgear assemblies, including metal enclosed bus
- h) Applications with high-voltage power circuit breakers
- i) Applications with power transformers
- j) Applications with outdoor bushings

4.2 Effect of air density on flashover voltage

The effect of decreased air density is to decrease the flashover voltage for a given flashover distance. See IEEE Std 4⁷ for use of a correction factor with sphere gaps.

The dielectric strength of air decreases as altitude increases. Dielectric strength that depends on air should be multiplied by the proper altitude correction factor to obtain the dielectric strength at the required altitude (see Table 1⁸).

Table 1—Dielectric strength correction factors for altitudes greater than 1000 m

Altitude meters	Altitude correction factor for dielectric strength
1000	1.00
1200	0.98
1500	0.95
1800	0.92
2100	0.89
2400	0.86
2700	0.83
3000	0.80
3600	0.75
4200	0.70
4500	0.67
NOTE—An altitude of 4500 m is considered a maximum for instrument transformers conforming to this standard.	

4.3 Frequency

Instrument transformers shall be designed and rated for operation at a frequency of 60 Hz.

⁷Information on references can be found in Clause 2.

⁸Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

4.4 Effect of altitude on temperature rise and effect of ambient temperature on permissible loading

4.4.1 Loading of current transformers at less than rated current at high altitudes

Current transformers may be operated at altitudes greater than 1000 m without exceeding established temperature limits provided the current is reduced below rated (or below rated times continuous thermal current rating factor) by 0.3% for each 100 m that the altitude exceeds 1000 m.

4.4.2 Operation of current transformers at other than 30 °C ambient temperature

Current transformers designed for 55 °C temperature rise above 30 °C average ambient air temperature may be loaded in accordance with the curves shown in Figure 1 for any given average cooling air temperature and continuous thermal current rating factor. The percent of rated primary current that can be carried continuously

without causing established temperature limits to be exceeded is given by the curves. For example, a transformer with a continuous thermal current rating factor (RF) of 2.0 at 30 °C ambient temperature can be used at approximately 150% of rated current at an ambient temperature of 55 °C.

4.4.3 Loading of voltage transformers at higher altitudes or higher ambient temperatures

For safety reasons, voltage transformers can be operated at higher altitudes or higher ambient temperatures only after consultation with the manufacturer, because a large percentage of the temperature rise may be due to iron loss, which varies widely with design.

4.5 Basic impulse insulation levels, dielectric tests, and outdoor instrument transformer creepage distance and wet tests

An instrument transformer shall be assigned a basic impulse insulation level (BIL) to indicate the factory dielectric tests that the transformer is capable of withstanding.

With the following exceptions, basic impulse insulation voltages, applied voltage test voltages for primary winding insulation, and creepage distances and wet tests for outdoor instrument transformers are listed in Table 2 and Table 3:

- a) Applied voltage tests for primary winding insulation are not required on grounded-neutral-terminal-type voltage transformers.
- b) For insulated-neutral-terminal-type voltage transformers, the applied voltage test for primary winding insulation shall be 19 kV on outdoor types with BILs greater than 110 kV. On indoor types, and on outdoor types with BILs of 110 kV or less, the test shall be 10 kV.

- c) There is no BIL requirement on the neutral terminal of grounded-neutral- or insulated-neutral- terminal-type voltage transformers.
- d) The applied voltage test for secondary winding insulation and between multiple secondary windings shall be 2.5 kV.
- e) The applied voltage test for autotransformers for use in the secondary circuits of instrument transformers shall be 2.5 kV.
- f) The applied voltage test for the primary insulation of auxiliary instrument transformers (for use in the secondary circuits of instrument transformers) shall be 2.5 kV.
- g) The applied voltage test between primary windings of three-wire-type current transformers with 10 kV BIL shall be 4 kV.

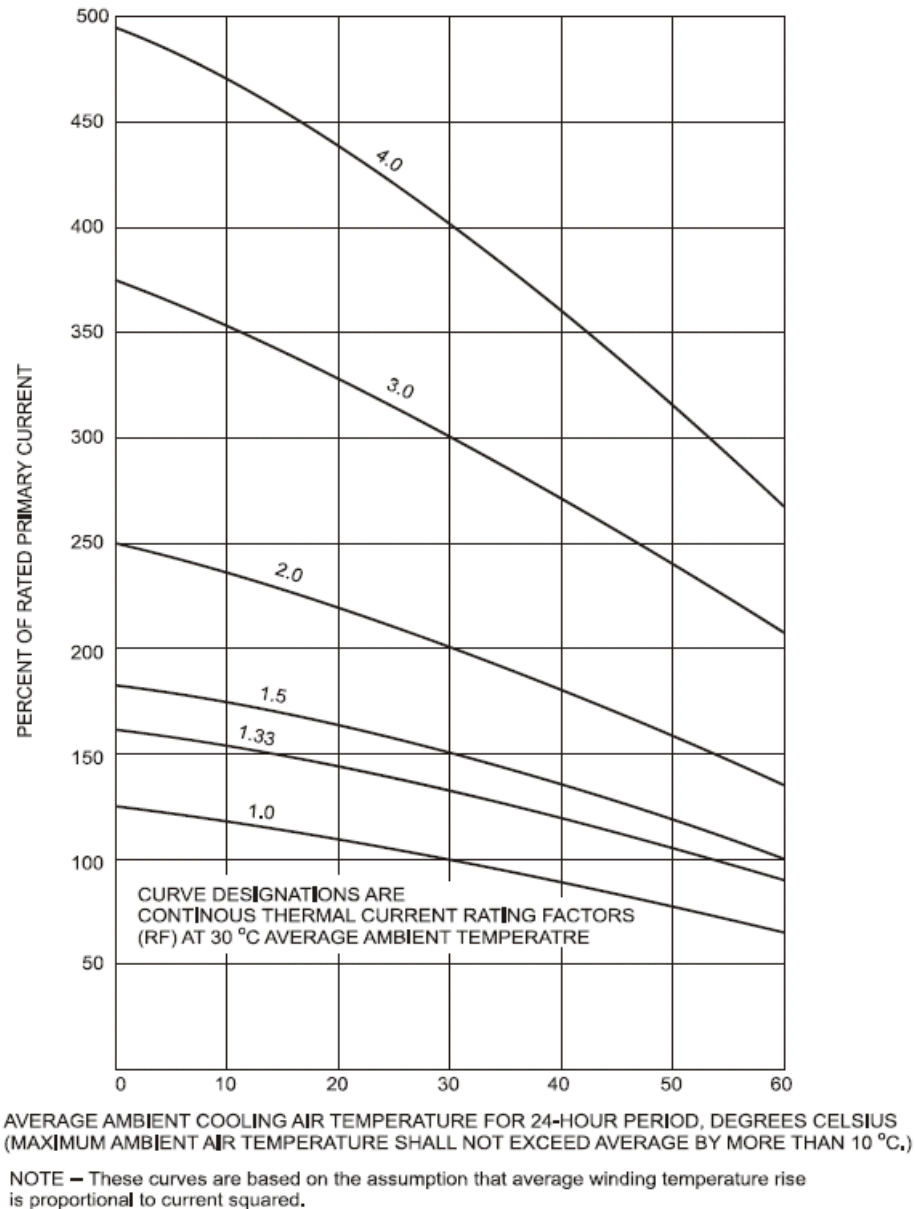


Figure 1 –55 °C rise current transformer basic loading characteristics (in air)

See Table 2 –Basic impulse insulation levels and dielectric tests^a

Maximum system voltage (kV)	Nominal system voltage (kV)	BIL and full-wave crest (kV) ^b	Chopped wave minimum time to crest flashover (kV) and (us)	Power frequency applied voltage test (kV rms)	Wet 60 Hz 10 s withstand (kV rms) ^c	Minimum creepage distance for Light Pollution (mm) and (in)
0.66	0.6	10	12 –	4	–	---
1.20	1.20	30	36 1.50	10	6 ^d	--
2.75	2.4	45	54 1.50	15	13 ^d	--
5.60	5.0	60	69 1.50	19	20 ^d	--
9.52	8.7	75	88 1.60	26	24 ^d	--
15.5	15	95	110 1.80	34	30 ^d	--
15.5	15	110	130 2.00	34	34	279 11
25.5	25	125	145 2.25	40	36 ^d	381 15
25.5	25	150	175 3.00	50	50	432 17
36.5	34.5	200	230 3.00	70	70	660 26
48.3	46	250	290 3.00	95	95	890 35
72.5	69	350	400 3.00	140	140	1220 48
123	115	450	520 3.00	185	185	1680 66
123	115	550	630 3.00	230	230	2010 79
145	138	650	750 3.00	275	275	2340 92
170	161	750	865 3.00	325	315	2900 114
245	230	900	1035 3.00	395	350	3560 140
245	230	1050	1210 3.00	460	445	4320 170
362	345	1300	1500 3.00	575		5210 205
550	500	1675	1925 3.00	750		8080 318
550	500	1800	2070 3.00	800		8080 318
800	765	2050	2360 3.00	920		11200 442

^a See 8.8.2 for User tests.

^b The selection of the lower BIL for a given nominal voltage, or for a marked ratio in Table 10 through Table 14, also reduces other requirements as tabulated above. The acceptability of these reduces requirements should be evaluated for a specific instrument transformer design and application.

^c For test procedures, see IEEE Std C57.19.00.

^d These values are requirements for distribution transformer bushings that are in IEEE Std C57.12.00.

~~See table 3 for current transformers with the same dielectric test requirements as power circuit breakers. See clause 8. for test methods.~~

Table 3—Basic impulse insulation levels and dielectric tests for current transformers with the same dielectric test requirements as outdoor power circuit breakers^a

Low frequency (kV, rms)			Impulse test 1.2 × 50 μ s wave (kV, crest) ^b					Minimum creep distance
Rated maximum	1 min dry	10 s wet	Full-wave withstand	Interrupter full wave	Chopped Wave, Time to Chop 2 μ s withstand	Chopped Wave, Time to Chop 3 μ s withstand	Switching impulse insulation level	(mm) and (in)
123	260	230	550B ^c	412	710	632	Not required	1780 70
145	310	275	650B ^c	488	838	748	Not required	2130 84
170	365	315	750B ^c	552	968	862	Not required	2490 93
245	425	350	900B ^c	675	1160	1040	Not required	3560 140
362	555	Not required	1300B ^c	975	1680	1500	825	5310 209
550	860	Not required	1800B ^c	1350	2320	2070	1175	8080 318
800	960	Not required	2050B ^c	1540	2640	2360	1425	11200 442

^aSee IEEE Std C37.09 for impulse and applied potential test procedures.

^bNo flashovers are permitted on current transformers.

^cThe letter “B” values are established by ANSI C37.06 for current transformers that have the same requirements as power circuit breakers.

4.6 Temperature rise

The limits of observable temperature rise in instrument transformers when tested in accordance with their ratings shall be as given in Table 4, and the transformers shall be designed so that the hottest-spot winding temperature rise above ambient will not exceed the values given in Table 4.

Table 4—Limits of temperature rise^a

Type of instrument transformer	30 °C ambient		55 °C ambient	
	Average winding temperature rise determined by resistance method (°C)	Hottest-spot winding temperature rise (°C) ^b	Average winding temperature rise determined by resistance method (°C)	Hottest-spot winding temperature rise (°C)
55 °C rise	55 ^c	65	30	40
65 °C rise	65 ^c	80	40	55
80 °C rise dry-type	80	110	55	85

^aTemperature rise of current transformers that are a part of high-voltage power circuit breakers or power transformers shall be in accord with IEEE Std C37.04 or IEEE Std C57.12.00, respectively.

^bTemperature rise of other metallic parts shall not exceed these values.

^cTemperature rise at the top of the oil in sealed transformers shall not exceed these values.

4.7 Tests

4.7.1 Instrument transformer test

These are the routine, type, and other tests that are necessary to assure that the design and construction of the transformer are adequate to meet the specified requirements. The method of making tests shall be as described in Clause 8, except as otherwise required in Table 3, or by equivalent alternative methods.

4.7.2 Routine tests

Each instrument transformer shall receive the following routine tests at the factory. These tests shall be made on the instrument transformer after complete assembly, where feasible. [The sequence of test shall be as follows:](#)

- a) Applied voltage dielectric tests between windings and between windings and ground (with the exception there is no primary insulation test for bushing type, split-core, or any current transformer designed with incomplete insulation for the primary conductor)
- b) Induced voltage tests
- c) Partial discharge tests
- d) Accuracy tests
- e) Polarity test

4.7.3 Type tests (design tests)

Type tests shall be performed on at least one transformer of each design group that may have a different characteristic in the specific test. Transformers subjected to type tests shall withstand the applicable routine tests before and after the type tests. It is not necessary to conduct more than one type test on the same unit.

Type tests for voltage transformers shall include:

- a) Impulse (BIL) test
- b) Wet 60 Hz 10 s withstand test
- c) Short-time mechanical withstand test
- d) Temperature rise test to verify the thermal burden rating factor
- e) Accuracy test to verify quoted accuracy ratings

Type tests for current transformers shall include:

- 1) Impulse (BIL) test
- 2) Wet 60 Hz 10 s withstand test
- 3) Short-time mechanical current rating test
- 4) Temperature rise test to verify the thermal ~~burden~~current rating factor
- 5) Accuracy test to verify quoted accuracy ratings under normal temperature service conditions
- 6) Switching impulse test, if applicable (see Table 3)
- 7) Open-circuit secondary voltage withstand

4.7.4 Other tests

Other tests are additional tests made for application information, for provision of specific data requested by users, for verification of type capability, and so on. Examples of other tests are as follows:

- a) Special accuracy tests
- b) Open-circuit secondary voltage magnitude or withstand capability on current transformers
- c) Voltage transformer capabilities in respect to 125%, 140%, and 173% overvoltage characteristics required
- d) Radio influence voltage test (RIV)
- e) ~~Partial discharge test~~

4.8 Construction

4.8.1 Polarity and terminal marking

The relative instantaneous polarity of terminals or leads shall be clearly indicated by permanent markings that cannot easily be obliterated.

When the polarity is indicated by letters, the letter “H” shall be used to distinguish the leads or terminals connected to the primary winding and the letter “X” (also “Y” and “Z,” etc., if multiple secondary windings are provided) shall be used to distinguish the leads or terminals connected to the secondary winding. In addition, each lead shall be numbered, for example, H₁, H₂, X₁, and X₂. If more than three secondary windings are provided, they shall be identified as X, Y, Z, and W for four secondary windings; X, Y, Z, W, and V for five secondary windings; X, Y, Z, U, W, and V for six secondary windings, and so on. H₁ and X₁ (also Y₁ and Z₁, etc., if provided) shall be of the same polarity.

When multiple primary windings are provided, the leads or terminals shall be designated by the letter “H” together with consecutive pairs of numbers (H_1 , H_2 , H_3 , H_4 , etc.). The odd-numbered leads or terminals shall be of the same polarity.

When taps or leads are provided on the secondary winding(s), the leads or terminals shall be lettered as required above and numbered X_1 , X_2 , X_3 , etc., or Y_1 , Y_2 , Y_3 , etc., with the lowest and highest numbers indicating the full winding and the intermediate numbers indicating the taps in their relative order. When X_1 is not in use, the lower number of the two leads in use shall be the polarity lead. [In the case of dual primary ratios that are obtained by secondary taps, the \$X_3\$ or \$Y_3\$ terminal shall be common to both taps.](#)

4.8.2 Symbols

Instrument transformer symbols are given in Table 5.

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 <i>Example:</i> Voltage transformers with one primary winding and one secondary winding 14 400:120 V Ratio 120:1	Ratio between primary and secondary amperes <i>Example:</i> Current transformer with one primary winding and one secondary winding Current ratio 100:5 A
x (multiplication sign)	Voltage ratings or ratios of transformer with a primary or secondary winding having two or more coils for series or parallel connection <i>Example:</i> 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 <i>Example:</i> 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 <i>Example:</i> 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 <i>Example:</i> 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 primary current is rated current in only one primary winding.) a) Transformer with two or more primary windings designed to be used individually <i>Example:</i> 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 <i>Example:</i> 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 <i>Example:</i> Current transformer for three-wire single-phase Current ratio 100 & 100:5 A

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 the 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 a different power factor is not necessarily the same as at the specified standard burden.

5.2 Expression of Transformer Correction Factor at 0.6 power factor (lagging) of metered load

It can be shown⁹ that a TCF at 0.6 power factor (lagging) of the metered load is as follows:

- a) For voltage transformers

$$\text{TCF} = \text{RCF} + \gamma/2600$$

- b) For current transformers

$$\text{TCF} = \text{RCF} - \beta/2600$$

where

RCF is the ratio correction factor

γ , β is the 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 ^b	Voltage transformers (at 90% to 110% rated voltage)		Current transformers			
			At 100% rated current ^a		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

^aFor current transformers, the 100% rated current limit also applies to the current corresponding to the continuous thermal current rating factor.

^bFor the 0.15 metering accuracy class, see IEEE Std C57.13.6.

5.4 Limiting values of Ratio Correction Factor 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 values¹⁰ of the angles derived from the expression in 5.2 are given as follows:

a) For voltage transformers

⁹ This is true of errors within the range of the standard metering accuracy classes.

¹⁰ This is true of errors within the range of the standard metering accuracy classes.

$$\gamma = 2600 (\text{TCF} - \text{RCF})$$

b) For current transformers

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

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 transformers and in Figure 3 for voltage transformers.

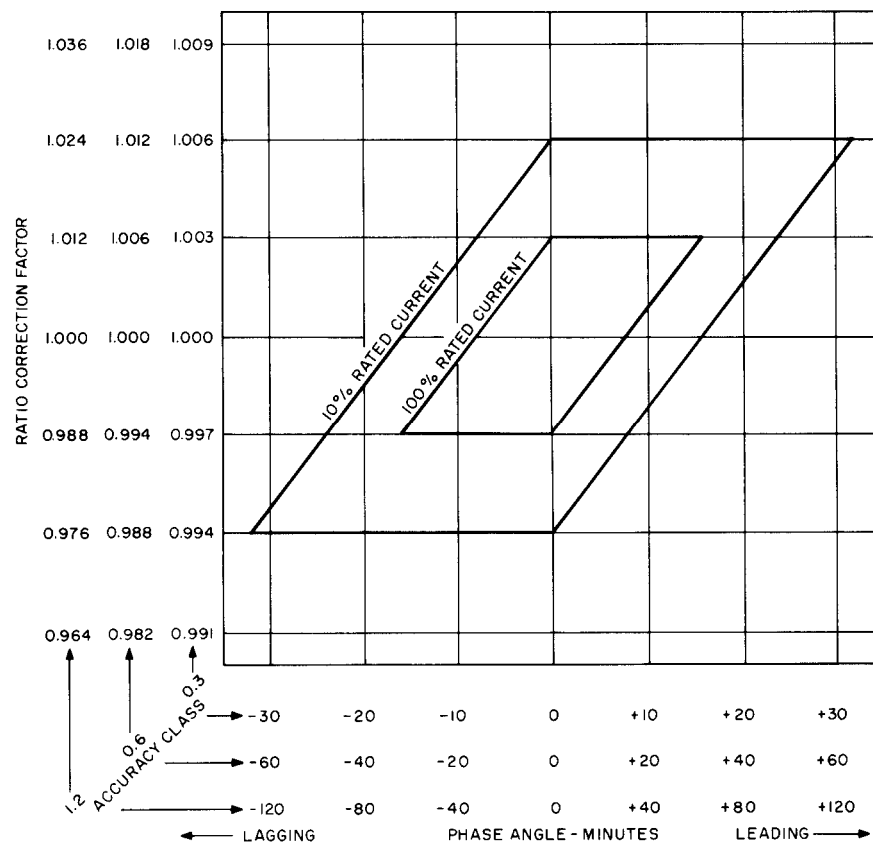


Figure 2— Limits of accuracy classes for current transformers for metering

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