

IEEE Standard Requirements for Instrument Transformers

IEEE Power and Energy Society

Sponsored by the
Transformers Committee

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IEEE Standard Requirements for Instrument Transformers

Sponsor

Transformers Committee
of the
IEEE Power and Energy Society

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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, IEEE C57.13™, 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™-2016, IEEE Standard Requirements for Instrument Transformers.

This standard was prepared by the Instrument Transformer Subcommittee of the Transformers Committee of the IEEE Power and Energy 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 IEEE Std C57.13 include revised partial discharge requirements, the addition of Annex B, covering bushing current transformers and two classes of instrument transformer requirements have been introduced. In addition, this standard has been reorganized to make it more understandable. The accuracy requirements from IEEE Std C57.13.6™ have also been incorporated into the standard.¹

¹ Information on references can be found in Clause 2.

Contents

1. Overview	11
1.1 Scope	11
1.2 Purpose	11
2. Normative references	12
3. Definitions	12
4. General requirements	13
4.1 Service conditions	13
4.2 Effect of air density on flashover voltage	14
4.3 Frequency	15
4.4 Effect of altitude on temperature rise and effect of ambient temperature on permissible loading	15
4.5 Basic impulse insulation levels, dielectric tests, and outdoor instrument transformer creepage distance and wet test	16
4.6 Temperature rise	19
4.7 Capacitance and dissipation factor requirements	20
4.8 Classification of tests	20
4.9 Construction	22
5. Accuracy classes for metering	25
5.1 Basis for accuracy classes	25
5.2 Expression of transformer correction factor at 0.6 power factor (lagging) of metered load	26
5.3 Standard accuracy classes	26
5.4 Limiting values of ratio correction factor and phase angle for standard accuracy classes	27
6. Current transformers	30
6.1 Terms in which ratings shall be expressed	30
6.2 Standard burdens	30
6.3 Accuracy ratings for metering	30
6.4 Accuracy ratings for relaying	32
6.5 Continuous thermal current rating factors based on 30 °C average ambient air temperature	34
6.6 Short-time current ratings	34
6.7 Secondary winding-induced voltages	35
6.8 Nameplates	36
6.9 Terminals	36
6.10 Application data	36
6.11 Routine accuracy tests	39
7. Voltage transformers	40
7.1 Terms in which ratings shall be expressed	40
7.2 Standard burdens	44
7.3 Accuracy ratings	45
7.4 Thermal burden ratings	45
7.5 Nameplates	46
7.6 Terminals	46
7.7 Short-circuit capability	46
7.8 Application data	47
7.9 Induced voltage test	47
7.10 Routine accuracy tests	47

8. Test procedures applicable to instrument transformers	47
8.1 Ratio and phase angle measurement and calculations	48
8.2 Impedance, excitation, and composite error measurements	49
8.3 Polarity	52
8.4 Resistance measurements	53
8.5 Dielectric tests	55
8.6 Partial discharge measurement	57
9. Test procedures applicable to current transformers	59
9.1 Ratio and phase angle measurement and calculations	59
9.2 Demagnetization	63
9.3 Impedance measurements	64
9.4 Polarity	65
10. Test procedures applicable to voltage transformers	66
10.1 Ratio and phase angle measurement and calculations	66
10.2 Impedance measurements	68
10.3 Polarity	69
11. Type test procedures applicable to instrument transformers	70
11.1 Short-time characteristics	70
11.2 Temperature rise tests	72
11.3 Impulse tests	75
11.4 Partial discharge measurement	77
11.5 Wet voltage withstand tests	78
11.6 Ground shield check—72kV class and above	79
12. Type test procedures applicable to current transformers	79
12.1 Short-time thermal rating of current transformers	79
12.2 Current transformer temperature rise tests	80
12.3 Inter-turn overvoltage test	80
13. Type test procedures applicable to voltage transformers	81
13.1 Short-circuit thermal capability of voltage transformers	81
13.2 Voltage transformer temperature rise tests	82
Annex A (informative) Bibliography	83
Annex B (normative) Bushing-type current transformer (BCT) and special purpose window type current transformers	86
B.1 Introduction	86
B.2 Scope	86
B.3 General requirements	86
B.4 Continuous thermal ratings	88
B.5 Short-time ratings	90
B.6 Dielectric consideration	90
B.7 Construction	90
B.8 Routine tests	92
B.9 Type tests	93
B.10 Installation	93
B.11 Field tests	94
B.12 Bushing linear coupler (BLC)	94

IEEE Standard Requirements for Instrument Transformers

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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.

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.

This standard covers the requirements for Class 1 instrument transformers. For instrument transformers of a nominal system voltage of 115 kV and above if Class 2 is required refer to IEEE Std C57.13.5TM.¹

¹ Information on references can be found in Clause 2.

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.

IEC 60270, High-voltage test techniques—Partial discharge measurements.²

IEC 61869-2, Instrument Transformers—Part 2: Additional Requirements for Current Transformers.

IEEE Std 4™, IEEE Standard for High-Voltage Testing Techniques.^{3, 4}

IEEE Std 693™, IEEE Recommended Practice for Seismic Design of Substations.

IEEE Std C37.04™, IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers.

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.

IEEE Std C57.12.90™, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.

IEEE Std C57.13.5™, IEEE Standard of Performance and Test Requirements for Instrument Transformers of a Nominal System Voltage of 115 kV and Above.

IEEE Std C57.13.6™, IEEE Standard for High-Accuracy Instrument Transformers.

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

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁵

class 1 instrument transformer: An instrument transformer that is constructed and tested in accordance with this standard.

class 2 instrument transformer: An instrument transformer that is constructed and tested in accordance with IEEE Std C57.13.5™.

gapped core: A core where the magnetic core has an intentional gap filled with non-magnetic material.

² IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch/>). IEC publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

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⁵ *IEEE Standards Dictionary Online* subscription is available at: <http://ieeexplore.ieee.org/xpls/dictionary.jsp>.

indoor voltage transformer: One that, because of its construction, shall be protected from the weather.

prescribed extinction voltage: The minimum voltage at which the reference partial discharge intensity shall be met when the voltage applied to the transformer is gradually decreased without interruption from the power frequency withstand voltage or pre-stress voltage value during the partial discharge test.

partial discharge inception voltage: The lowest voltage at which partial discharges exceeding a specified level are observed under specified conditions when the voltage applied to the test object is gradually increased from a lower value.

4. General requirements

4.1 Service conditions

4.1.1 Unusual 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.

The minimum ambient air temperature is $-30\text{ }^{\circ}\text{C}$ for outdoor applications and $-5\text{ }^{\circ}\text{C}$ for indoor applications.

4.1.1.1 $30\text{ }^{\circ}\text{C}$ average ambient temperature

If the transformers are air cooled, the ambient temperature of the cooling air does not exceed $40\text{ }^{\circ}\text{C}$ and the average ambient temperature of the cooling air for any 24-hour period does not exceed $30\text{ }^{\circ}\text{C}$.⁶

4.1.1.2 $55\text{ }^{\circ}\text{C}$ average ambient temperature

Instrument transformers may also be given ratings for operation in $55\text{ }^{\circ}\text{C}$ average ambient temperature, with maximum ambient air temperature not exceeding $65\text{ }^{\circ}\text{C}$.

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 4.2 and 4.4).

NOTE—For applications involving bushing-type current transformers, see Annex B.⁷

⁶ It 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 $1/2\text{ }^{\circ}\text{C}$.

⁷ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

4.1.3 Other conditions that may affect design and application

Where 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.
- 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.*
- k) For altitudes below sea level or buried underground.*
- l) Seismic conditions: For seismic qualification methods refer to IEEE Std 693.

*For applications involving bushing-type current transformers, see Annex B.

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 4 for use of a correction factor.

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 1). For an altitude exceeding 3000 m, caution should be exercised.

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

Altitude (m)	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 ^a	0.67
NOTE 1—Intermediate values may be obtained by interpolation. NOTE 2—This table considers the effect of decreased air density due to decreased air pressure.	

^aAn 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.

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.

Refer to Annex B for use of bushing-type current transformers in ambient temperatures of 90 °C in hot oil.

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

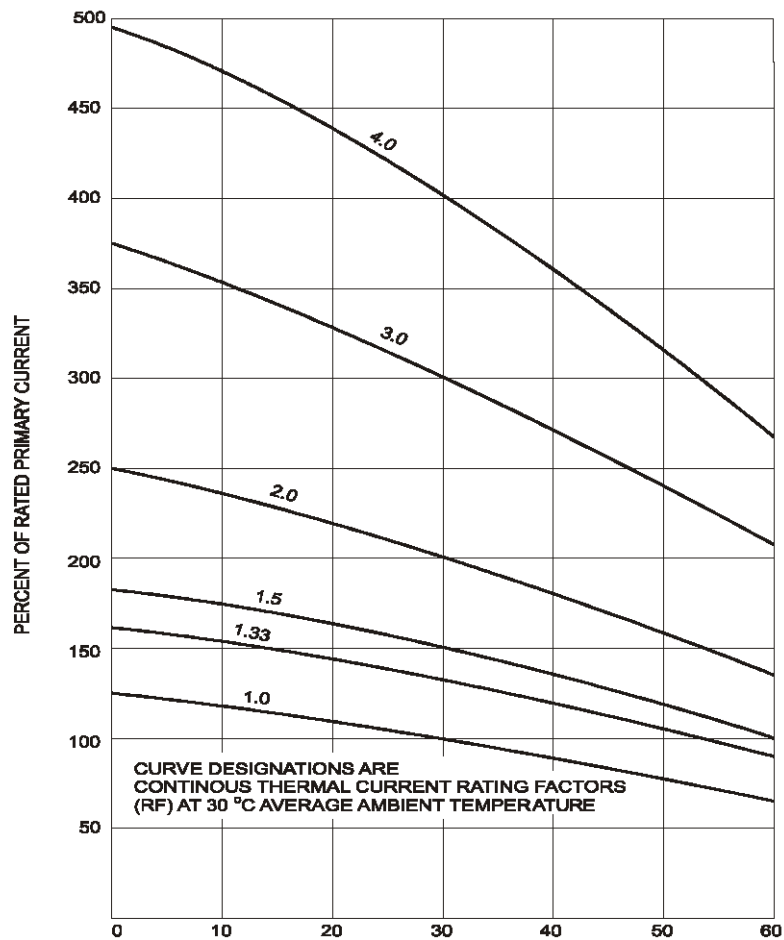
For safety reasons, voltage transformers can be operated at higher altitudes or higher ambient temperatures only after consultation with the manufacturer, because a large percentage of the temperature rise may be due to iron loss, which varies widely with design.

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

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 voltage 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.



NOTE 1—Average ambient cooling air temperature for 24-hour period degrees Celsius (maximum ambient air temperature does not exceed average by more than 10 °C).

NOTE 2—These curves are based on the assumption that average winding temperature rise is proportional to current squared.

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

Table 2—Basic impulse insulation levels and dielectric tests^{a, f}

Nominal system voltage (kV, rms)	Maximum system voltage (kV, rms)	Lightning impulse voltage (BIL) ^b (kV, peak)		Switching impulse voltage (kV, peak)	Power frequency withstand voltage (kV, rms)	
		Full Wave	Chopped ^f Wave		Dry	Wet ^c
0.6	0.66	10 ^e	12 ^e	—	4 ^e	—
1.2	1.20	30	36	—	10	6 ^d
2.4	2.75	45	54	—	15	13 ^d
5.0	5.60	60	69	—	19	20 ^d
8.7	9.52	75	88	—	26	24 ^d
15	15.5	95	110	—	34	30 ^d
		110	130	—	34	34 ^d
25	25.5	125	145	—	40	36 ^d
		150	175	—	50	50
34.5	36.5	200	230	—	70	70
46	48.3	250	290	—	95	95
69	72.5	350	400	—	140	140
115	123	450	520	—	185	185
		550	630	—	230	230
138	145	650	750	—	275	275
161	170	750	865	—	325	315
230	245	900	1035	—	395	350
		1050	1210	—	460	445
345	362	1175	1350	950	510	—
		1300	1500	975	575	—
500	550	1550	1785	1175	680	—
		1800	2070	1300	830	—
765	800	2100	2420	1550	975	—

^a See 8.5.2 for User tests.

^b The selection of the lower BIL for a given nominal voltage, or for a marked ratio in Figure 14, Table 15, Figure 16, Table 17, and Figure 18 also reduces other requirements as tabulated above. The acceptability of these reduced 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.

^e For current transformers with no primary insulation, such as bushing-type, there are no BIL, chopped or applied voltage requirements.

^f The minimum time to chopping shall be 3 μ s.

Table 3—Creepage distances for porcelain insulators

Nominal system voltage (kV, rms)	Maximum system voltage (kV, rms)	Minimum Creepage Distance (mm)	
		Light Pollution	Heavy Pollution
15	15.5	240	380
25	25.5	405	635
34.5	36.5	560	875
46	48.3	745	1 170
69	72.5	1 115	1 750
115	123	1 860	2 920
138	145	2 235	3 510
161	170	2 605	4 090
230	245	3 720	5 845
345	362	5 580	8 765
500	550	8 085	12 705
765	800	12 370	19 435

NOTE 1—The definitions of light and heavy pollution levels are provided in IEEE Std C57.19.100-2012.
NOTE 2—The creepage distance for composite insulator with silicone rubber sheds has not been established. This standard recommends the use of the same creepage distance as that for the porcelain insulator.

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

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) ^b
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

^a Temperature 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 (refer also to Annex B for BCTs).

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

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

Terminals for use in air shall be designed so that their maximum operating temperature when tested with their ratings do not exceed the values provided in Table 5.

Table 5—Maximum operating temperature of power terminals intended for bolted connection in air

Performance	Bare copper or aluminum terminals (°C)	Tin-plated terminals (°C)	Silver-plated terminals (°C)
Maximum operating temperature	90	105	115
Maximum operating temperature for use in metal enclosed switchgear ^a	70	105	105

^a Refer to IEEE Std C37.20.1, IEEE Std C37.20.2 and IEEE Std C37.20.3.

4.7 Capacitance and dissipation factor requirements

The capacitance and dissipation factor of the transformer shall be measured at power frequency at the following test voltages:

- 10 kV
- Maximum rated voltage

The test shall be performed before and after the dielectric tests. The increase of capacitance measured after compared with that measured before the dielectric tests shall be less than the value produced by the breakdown of one capacitive element.

The dissipation factor shall be in accordance with the following requirements:

- a) For oil-filled transformers
 - 1) The dissipation factor shall be 0.5% maximum at a reference ambient temperature of 20°C.
 - 2) The absolute increase of the dissipation factor value measured after compared with the value measured before the dielectric tests shall be less than 0.1%.
- b) For gas-filled transformers
 - 1) The dissipation factor shall be 0.15% maximum at a reference ambient temperature of 20°C.
 - 2) The absolute increase of the dissipation factor value measured after compared with the value measured before the dielectric tests shall be less than 0.03%.
- c) For transformers with a rated voltage less than 10 kV, for dry type molded transformers without capacitive graded insulation or for bushing current transformers these capacitance and dissipation factor requirements do not apply.

4.8 Classification of tests

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 through Clause 13, or by equivalent alternative methods. Many references are available as sources for the material in the preceding clauses. Those references referred to specifically are listed by number in Annex A. Other references, which may be of general utility to the user of these clauses, or of the complete standard, are also included in Annex A. Routine and type tests are in Table 6.

4.8.1 Test requirements

Test requirements for current transformers and voltage transformers are summarized in Table 6.

Table 6—Test requirements

Measurement or test	Current transformers		Voltage transformers	
	Reference subclause	Test classification	Reference subclause	Test classification
Capacitance and dissipation factor	4.7	R ^d	4.7	R ^d
Applied voltage	4.5d), 4.5e), 4.5f), and 8.5.3	R	4.5a), 4.5b), 4.5c), 4.5d), 4.5e), 4.5f), and 8.5.3	R
Partial discharge	8.6 R and 11.4 T	R/T	8.6 R and 11.4 T	R/T
Induced voltage	6.7.2 and 8.5.4	R	7.9 and 8.5.4	R
Inter-turn overvoltage	12.3	T ^a	—	
Polarity	8.3 and 9.4	R	8.3 and 10.3	R
Accuracy	Figure 7, 8.1, and 9.1	R	7.10, 8.1, and 10.1	R
Excitation	Figure 7 and 8.2.3	R	8.2.3	T
Composite error	8.2.3.1	R ^b	—	
Resistance	8.4	R ^c	8.4	T
Impedance	8.2 and 9.3	T	8.2 and 10.2	T
Short-time thermal rating	11.1 and 12.1	T	11.1 and 13.1	T
Temperature rise	11.2 and 12.2	T	11.2 and 13.2	T
Impulse tests	11.3	T	11.3	T
Wet voltage withstand tests – for outdoor instrument transformers	11.5	T	11.5	T
Ground shield check	11.6	T	11.6	T

R – Routine test

T – Type test (design test)

^a May be used as routine test in lieu of induced test when secondary voltage exceeds 1200 V.

^b May be used as routine test for verifying compliance to meet relaying class at rated current.

^c Required for relay class CTs. This is not required for metering only CTs.

^d Required for oil-filled and gas-filled instrument transformers.

4.8.2 Special tests for gas-filled instrument transformers

These tests are to be performed subject to agreement between the producer and the user. Procedures for the following tests can be found in IEEE Std C57.13.5:

- a) Sealing system test
- b) Internal arc test

4.8.3 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, but not limited to the following:

- a) Special accuracy tests
- b) Voltage transformer capabilities in respect to 125%, 140%, and 173% overvoltage characteristics
- c) Radio influence voltage test (RIV)
- d) Thermal-cycle tests
- e) Seismic evaluations/tests
- f) Mechanical loading

4.9 Construction

4.9.1 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, W, V, and U 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 (H1, H2, H3, H4, 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 X1, X2, X3, etc., or Y1, Y2, Y3, etc., with the lowest and highest numbers indicating the full winding and the intermediate numbers indicating the taps in their relative order. When X1 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 X3 or Y3 terminal shall be common to both taps.

4.9.2 Ground shield requirements

For 72 kV class instrument transformers and above a ground shield shall be provided between the primary and secondary windings.

4.9.3 Symbols

Instrument transformer symbols are given in Table 7.

Table 7—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 transformer 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
× (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. 2 400 × 4 800 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
& (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 120:1 & 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

Table 7—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. <i>Example:</i> Voltage transformer with taps in the secondary winding for additional primary voltage ratings 8 400/12 000/14 400 V Ratio 70/100/120:1 <i>Example:</i> 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 <i>Example:</i> Current transformer with taps in the secondary winding for additional ratios Current ratio 300/400/600:5 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 600:5//5
E / (E/E1Y) / (E/E,GrdY) (Designation of primary voltage ratings)	<i>Example:</i> Voltage transformer with E-rated voltage for connection on an E voltage system 14 000 (E) <i>Example:</i> Voltage transformer with E-rated voltage that is suitable for connection on an E voltage system or for Y connection on an E1 voltage system 2 400/4 160Y (E/E1Y) <i>Example:</i> Voltage transformer with E-rated voltage with reduced insulation at neutral end, for line-to-ground connection on an E1 voltage system 7 200/12 470GrdY (E/E, GrdY)	(Not used directly)

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:

- For current transformers, at the specified standard burden (see 6.2 for standard burdens) at 10% or 5% (see Table 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 shown that a TCF at 0.6 power factor (lagging) of the metered load is as follows⁸:

- a) For voltage transformers

$$\text{TCF} = \text{RCF} + \frac{\gamma}{2600} \quad (1)$$

- b) For current transformers

$$\text{TCF} = \text{RCF} - \frac{\beta}{2600} \quad (2)$$

where

RCF is the ratio correction factor derived from $1 - (\pm \text{Ratio Error}/100)$. Note that for transformers having negative ratio error the RCF will be greater than unity.

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 8.

⁸ This is true of errors within the range of the standard metering accuracy classes.

Table 8—Standard accuracy class for metering service and corresponding limits of transformer correction factor and ratio correction factor [0.6 to 1.0 power factor (lagging) of metered load]^c

Metering accuracy class	Voltage transformers (at 90% to 110% rated voltage)		Current transformers					
	Minimum	Maximum	At 100% rated current ^a		At 10% rated current		At 5% rated current	
			Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
0.15S ^b	—	—	0.9985	1.0015	—	—	0.9985	1.0015
0.15 ^b	0.9985	1.0015	0.9985	1.0015	—	—	0.9970	1.0030
0.15N	—	—	0.9985	1.0015	0.9970	1.0030	—	—
0.3S	—	—	0.9970	1.0030	—	—	0.9970	1.0030
0.3	0.9970	1.0030	0.9970	1.0030	0.9940	1.0060	—	—
0.6	0.9940	1.0060	0.9940	1.0060	0.9880	1.0120	—	—
1.2	0.9880	1.0120	0.9880	1.0120	0.9760	1.0240	—	—

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

^b Previously defined in IEEE Std C57.13.6.

^c Other accuracy requirements may be specified and should be included on the nameplate.

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 values of the angles derived from the expression in 5.2 are given as shown in Equation (3) and Equation (4).⁹

- a) For voltage transformers

$$\gamma = 2600 \times (\text{TCF} - \text{RCF}) \quad (3)$$

- b) For current transformers

$$\beta = 2600 \times (\text{RCF} - \text{TCF}) \quad (4)$$

in which TCF is taken as the maximum and minimum values, given in Table 8, for the specified accuracy class.

These relations are shown graphically in Figure 2, Figure 3, and Figure 4 for current transformers, and Figure 5 for voltage transformers.

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

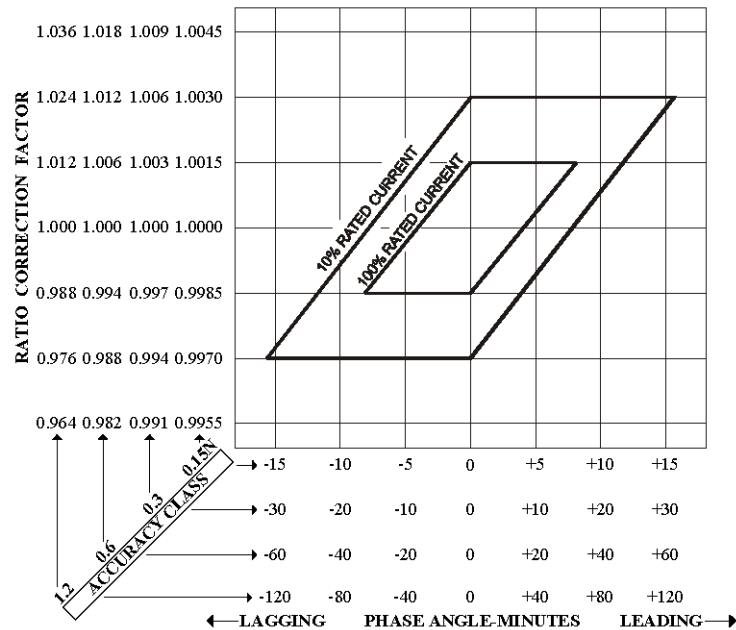


Figure 2—Limits for accuracy classes for current transformers for metering

In Figure 2, the accuracy requirements for 100% rated current also apply at the continuous thermal current rating of the transformer.

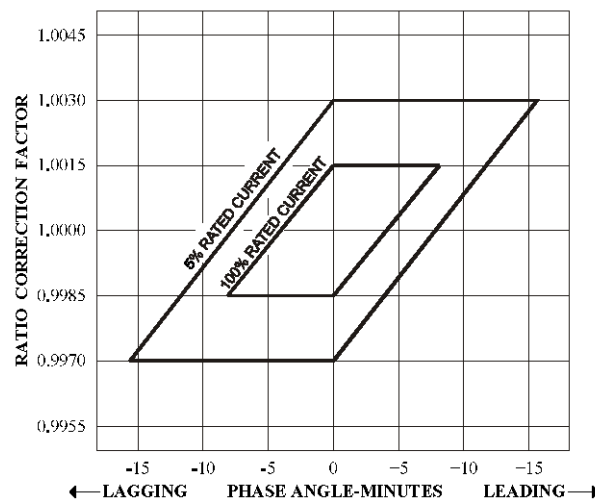


Figure 3—Limits for 0.15 accuracy class for current transformers for metering

In Figure 3, the transformer characteristics shall lie within the stated limits of the parallelogram at 5% and 100% of rated current. For current transformers, the 100% rated current limits also applies to the current corresponding to the continuous thermal current rating factor, if it is greater than 1.0.