IEEE Std C57.13.5™-2003

IEEE Standards

C57.13.5™

IEEE Trial-Use Standard of Performance and Test Requirements for Instrument Transformers of a Nominal System Voltage of 115 kV and Above

IEEE Power Engineering Society

Sponsored by the
Transformer Committee

IEEE

Published by
The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

1 August 2003

Print: SH95092
PDF: SS95092

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Sponsor

Transformer Committee
of the
IEEE Power Engineering Society

Approved 20 March 2003

IEEE-SA Standards Board

Abstract: This trial-use standard covers the test requirements, including test sequences, criteria, methods, and documentation for instrument transformers of 115 kV nominal system and above. It is to be used a supplement to IEEE Std C57.13™-1993. Besides the provision of up-to-date test requirements, the trial-use standard also provides test procedures that were not adequately covered in the previous standard.
Keywords: design tests, high voltage, instrument transformers, routine tests, special tests, test criteria, test method, test requirements, test sequence

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The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Print: ISBN 0-7381-3592-5 SH95092
PDF: ISBN 0-7381-3593-3 SS95092

Introduction

(This introduction is not part of IEEE Std C57.13.5-2003, IEEE Trial-Use Standard of Performance and Test Requirements for Instrument Transformers of a Nominal System Voltage of 115 kV and Above.)

The mission of Working Group PC57.13.5 is to develop a comprehensive set of performance and test requirements for instrument transformers of a nominal system voltage of 115 kV and above. The objective is to improve the performance and safety of the instrument transformers in response to the concern indicated in the publication EPRI Workshop on Failed High Voltage Instrument Transformers, held in September 1990.

This standard is also intended to introduce

a) New tests to reflect our present understanding of fast high-voltage transient induced on instrument transformers under the operation of system disconnect conditions.
b) New tests to verify the protection against internal arc, which has gradually been adopted by some utilities.

Suggestions for improvement gained in the use of this standard will be welcome. They should be sent to the IEEE Standards Department.

Publication of this trial-use standard for comment and criticism has been approved by the Institute of Electrical and Electronics Engineers. Trial-use standards are effective for 24 months from the date of publication. Comments for revision will be accepted for 18 months after publication. Suggestions for revision should be directed to the Secretary, IEEE-SA Standards Board, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, and should be received no later than 30 January 2005. It is expected that following the 24-month period, this trial-use standard, revised as necessary, shall be submitted to the IEEE-SA Standards Board for approval as a full-use standard.

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IEEE Trial-Use Standard of Performance and Test Requirements for Instrument Transformers of a Nominal System Voltage of 115 kV and Above

1. Overview

1.1 Scope

This trial-use standard applies to new single-phase instrument transformers of a nominal system voltage of 115 kV and above with capacitive insulation system for line-to-ground connection and for both indoor and outdoor application.

This trial-use standard is intended for use as a supplement to IEEE Std C57.13™-1993 and as a basis for performance and safety of equipment. It also describes test sequences, criteria, methods, and documentation for the test.

1.2 Purpose

The intended purpose of the trial-use standard is to supplement IEEE Std C57.13-1993 on the following:

a) Up-to-date requirements of performance characteristics and test for instrument transformers of a nominal system voltage of 115 kV and above,
b) Information related to test procedures, which have not been adequately covered in the present standard, and
c) Information related to the new test items.

2. References

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

CAN/CSA-C50052-99, Cast Aluminum Alloy Enclosures for Gas-Filled High-Voltage Switchgear and Controlgear.[1]

CAN/CSA-C50068-99, Wrought Steel Enclosures for Gas-Filled High-Voltage Switchgear and Controlgear.

CAN/CSA-C50064-99, Wrought Aluminum and Aluminum Alloy Enclosures for Gas-Filled High-Voltage Switchgear and Controlgear.

CAN/CSA-C50069-99, Welded Composite Enclosures of Cast and Wrought Aluminum Alloys for Gas-Filled High-Voltage Switchgear and Controlgear.

CAN/CSA-C1264-99, Ceramic Pressurized Hollow Insulators for High-Voltage Switchgear and Controlgear.

IEC 60270 (2000-12), High-Voltage Test Techniques—Partial Discharge Measurements.[2]

IEC 61181 (1993-06), Impregnated Insulation Materials—Application of Dissolved Gas Analysis (DGA) to Factory Tests on Electrical Equipment.

IEEE Std 4™-2001, IEEE Standard Techniques for High Voltage Testing.[3,4]

IEEE Std C57.12.90™-1999, Standard Test Code for Liquid-Immersed Distribution, Power and Regulating Transformers.

IEEE Std C57.13-1993, IEEE Standard Requirements for Instrument Transformers.

IEEE Std C57.19.01™-2000, IEEE Standard Performance Characteristics and Dimensions for Outdoor Apparatus Bushings.

IEEE C57.19.100™-1995 (Reaff 1997), IEEE Guide for Application of Power Apparatus Bushings.

IEEE Std C57.98™-1994, IEEE Guide for Transformer Impulse Tests.

IEEE Std C57.106™-2002, IEEE Guide for Acceptance and Maintenance of Insulating Oil in Equipment.

IEEE Std 693™-1997, IEEE Recommended Practices for Seismic Design of Substations.

NEMA Standards Publication No. 107-1987 (R 1993), Methods of Measurement of Radio Influence Voltage (RIV) of High Voltage Apparatus.[5]

1997 Uniform Building Code (Version 1.3).[6]

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[1]CSA publications are available from the Canadian Standards Association (Standards Sales), 178 Rexdale Blvd., Etobicoke, Ontario, Canada M9W 1R3 (http://www.csa.ca/).

[2]IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

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[4]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

[5]NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (http://global.ihs.com/).

[6]ICBO publications are available from the International Conference Board of Officials, 5360 Workman Mills Road, Whittier, CA 90601-2298, USA (http://www.icbo.org/).

3. Definitions

For the purposes of this standard, the following terms and definitions apply. IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition [B4],[7] should be referenced for terms not defined in this clause.

3.1 capacitive insulation system: An arrangement of internal insulation and electrodes to distribute both the alternating and impulse voltages along the bushing of the instrument transformer with capacitive dielectric layers and/or electrode(s) to achieve an improved coordination between the internal and external insulation for the purpose of increasing the overvoltage withstand capability.

3.2 internal arc protection class I: A special transformer design with a feature that, during an internal line-to-ground arc test with the arc taking place at a location, which is technically the most probable, the debris of the transformer will be confined to a circle, centered at the transformer. The diameter of this circle is equal to the sum of twice the length of the transformer and the diameter of the transformer.

3.3 internal arc protection class II: A special transformer design with a feature that, during an internal line-to-ground arc test with the arc taking place at a location, which is technically the most probable, will not fracture the insulator or housing of the transformer.

NOTE—The above definitions (3.2 and 3.3) regarding the classification of internal arc protection apply only to the test conditions specified in the standard. The instrument transformers may have different performance during an in-service internal arc fault. Refer to Annex D for more information regarding the interpretation of internal arc protection. The performance does not apply to any internal pressure relief device (e.g., rupture disc) provided with the transformer.

3.4 prescribed extinction voltage: The lowest required line-to-ground voltage for the transformer at which the partial discharge is determined if the reference intensity is 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.

NOTE—The reference partial discharge intensity for the transformers covered in this standard is 10 pC.

3.5 rated voltage factor: A multiplier applied to the rated (primary) voltage to derive the maximum voltage at which a transformer must comply with the relevant thermal requirements for a specified time and with the relevant accuracy requirements.

NOTE—Refer to Annex F for additional information.

4. General

For performance and safety, the instrument transformers shall comply with IEEE Std C57.13-1993, supplemented with the requirements provided in this clause. If any conflicts or inconsistencies exist between IEEE Std C57.13-1993 and this trial-use standard, the clauses in this standard shall take precedance.

4.1 Insulation requirements

4.1.1 Voltage ratings, dielectric test levels, and prescribed extinction voltages

The voltage ratings, dielectric test levels, and prescribed extinction voltages for instrument transformers are given in Table 1.

[7]The numbers in brackets correspond to those in the bibliography in Annex G.

NOTES

1—For nominal system voltages 230, 345, and 500 kV, good service experiences with instrument transformers of reduced insulation levels have been reported. The users should review their own records and decide accordingly. This trial-use standard recommends the use of the standard insulation voltage levels, which are of higher values for each system voltage.

2—The dielectric test levels and prescribed extinction voltages are applicable to instrument transformers used in grounded or effectively grounded neutral systems.

Table 1—Voltage ratings, dielectric test levels, and prescribed extinction voltages

Nominal system voltage (r.m.s.) (kV)	Maximum system voltage (r.m.s.) (kV)	Lightning impulse voltage (peak)		Switching impulse voltage (peak) (kV)	Power frequency withstand voltage[a] (r.m.s.)		Prescribed extinction voltage[b] (r.m.s.) (kV)
		Full wave (kV)	Chopped wave[c] (kV)		Dry (kV)	Wet (kV)	
115	123	550	630	—	230	230	123
138	145	650	750	—	275	275	145
161	170	750	860	—	325	325	170
230	245	950	1090	—	395	395	245
		1050	1210	—	460	460	
345	362	1175	1350	950	510	—	362
		1300	1500	975	575	—	
500	550	1550	1785	1175	680	—	550
		1800	2070	1300	830	—	
765	800	2100	2420	1550	975	—	800

[a] The duration for the power frequency voltage withstand test shall be in accordance with 4.1.8 for both dry and wet test conditions.
[b] The definition is provided in 3.3. The reference partial discharge intensity for the instrument transformers is 10 pC and shall be measured in accordance with IEC 60270 (2000-12).
[c] The minimum time to chopping shall be 3 μs.

4.1.2 Capacitance and dissipation factor requirements

The capacitance and dissipation factor of the transformer shall be measured at power frequency and at 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-immersed transformers:
   1) The dissipation factor shall be 0.5% maximum, and

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:[8]
   1) The dissipation factor shall be 0.15% maximum, and
   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%.

4.1.3 Creepage distance requirements

The ratio of minimum creepage distance on the external surface of the porcelain insulator to the nominal line-to-ground voltage shall be in accordance with IEEE Std C57.19.01-2000. The ratios for light and heavy pollution levels shall be 28 mm/kV and 44 mm/kV respectively. Table 2 provides minimum creepage distances as a function of nominal system voltage and level of pollution.

Table 2—Creepage distance

Nominal system voltage (r.m.s.) (kV)	Maximum system voltage (r.m.s.) (kV)	Minimum creepage distance (mm)	
		Light pollution	Heavy pollution
115	123	1 860	2 920
138	145	2 230	3 510
161	170	2 600	4 090
230	245	3 720	5 850
345	362	5 580	8 770
500	550	8 080	12 700
765	800	12 400	19 400

NOTES
1—The definitions of light and heavy pollution levels are given in IEEE Std C57.19.100-1995.
2—The creepage distance for composite insulator with silicone rubber sheds has not been established. This trial-use standard recommends the use of the same creepage distance as that for the porcelain insulator.

4.1.4 External radio influence voltage (RIV) requirements

The maximum external RIV of the instrument transformer shall be in accordance with Table 3 when the test voltage is applied to the primary terminal. The transformer shall be assembled as in service for the test. Any external electrodes, if not parts of the transformer, shall not be used for the test.

4.1.5 Routine partial discharge test

The partial discharge intensity measured at the voltage corresponding to the prescribed extinction voltage level as provided in Table 4 shall be less than or equal to the reference intensity of 10 pC. The measuring method shall be in accordance with IEC 60270 (2000-12).

[8]As the inherent capacitance of gas-filled instrument transformers is very low (in the range of 100–300 pF), the laboratory should take the necessary precautions to reduce the stray effects of the neighboring equipment on the capacitance measurement, and also the effects of the leakage current over the insulator surface on the dissipation factor measurement.

Table 3—RIV

Nominal system voltage (r.m.s.) (kV)	Maximum system voltage (r.m.s.) (kV)	Radio influence test voltage (r.m.s.) (kV)	Maximum radio influence voltage[a] (μV)
115	123	71	200
138	145	84	200
161	170	98	200
230	245	142	250
345	362	209	250
500	550	303	350
765	800	462	500

[a]The background noise level shall not be higher than half the maximum RIV.

The partial discharge test shall be carried out subsequent to the power frequency voltage withstand test as described in 7.7.[9]

Table 4—Routine partial discharge test voltage

Nominal system voltage (r.m.s.) (kV)	Maximum system voltage (r.m.s.) (kV)	Pre-stress voltage (r.m.s.) (kV)	Prescribed extinction voltage (r.m.s.) (kV)
115	123	185	123
138	145	220	145
161	170	260	170
230	245	315[a]	245
		370	
345	362	410[a]	300[b]
		460	
500	550	545[a]	435[b]
		665	
765	800	780	665[b]

[a]The values shown are for the reduced insulation levels in reference to Table 1.
[b]The standard recognizes the difficulties of partial discharge measurement at these voltage levels under the industrial environments with high noise level. The problem is aggravated if the test laboratories are undersized and world-class extra-high-voltage laboratories are required. Therefore, for the transformers of these voltage ratings, the prescribed extinction voltages are reduced to 1.5 times the rated voltages, which are considered still acceptable since the ground fault factor for a grounded or effectively grounded system does not exceed 1.4.

[9]An exception case is when the partial discharge test is repeated after the sealing test on transformers with air in contact with the oil during the sealing test.

The transformer shall withstand, for an appropriate duration in accordance with 4.1.8, the pre-stress voltage provided in Table 4 before the partial discharge is measured.Insulation resistance requirements

4.1.6 Insulation resistance requirements

The insulation resistances between individual winding and ground and between windings shall be measured at 1.0 kV (dc) or higher voltage. The values shall not be less than 200 MΩ.

4.1.7 Power frequency voltage withstand test

The power frequency withstand voltage shall be in accordance with the value provided in Table 1.

For current transformers, the voltage shall be applied to the primary winding.

For voltage transformers, the test voltage shall be either impressed between the primary and neutral terminals or induced from the secondary winding with the primary winding open-circuit. The neutral terminal shall be grounded during the test.

The voltage shall be maintained for 60 s. The time may be reduced in accordance with 4.1.8 if the frequency is higher than 120 Hz.

NOTE—This test can also be called induced voltage withstand test for voltage transformers.

4.1.8 Duration of power frequency voltage withstand test for test frequency higher than 120 Hz

If a test frequency of higher than 120 Hz is used for the power frequency voltage withstand test or for the pre-stress voltage for partial discharge measurement, the duration of the test may be reduced as given in the following expression:

$$Time(s) = \frac{7200}{Test\ Frequency(Hz)}$$

The duration shall not be less than 18 s and the test frequency shall not be greater than 400 Hz.

4.2 Mineral oil requirements

The mineral oil used for oil-immersed instrument transformers shall be processed from the naphthenic base crude oil or its equivalent.[10] It shall be in accordance with 2.1 of IEEE Std C57.106-2002. The characteristics of the new processed oil shall be in accordance with 2.2 and 2.3 of that standard.

For the extreme cold climate, the manufacturers and users have to agree on the mineral oil specification.

4.3 Requirements for accuracy and accuracy calibration systems

The accuracy performance shall be in accordance with the requirements of IEEE Std C57.13-1993.

All transformers with accuracy ratings of 0.3 or 0.6 shall be determined using calibration techniques and methods that shall give adequate results within 0.1% of the ratio and 3 minutes of phase angle. All

[10]A new insulating oil processed with the latest technology may be commercially available from the refinery. The user should check with the manufacturer for more information.

transformers with accuracy ratings of 1.2 shall be determined using calibration techniques and methods that shall give adequate results within 0.3% of the ratio and 6 minutes of phase angle.

The test burdens shall be in accordance with Tables 9 and 15 of IEEE Std C57.13-1993 for current transformers and voltage transformers respectively.

The equipment used for accuracy tests shall be traceable to the national standards. Records of accuracy verification for the calibration systems by an independent laboratory shall be regularly maintained.

NOTE—The maximum interval shall be five years for non-electronic equipment and two years for electronic devices, unless specified otherwise by the measuring equipment manufacturer.

4.4 Mechanical performance requirements

All instrument transformers shall comply with the mechanical performance requirements described in 4.4.1 and 4.4.2.

4.4.1 Sealing tests

All instrument transformers shall be sealed against leakage of insulating fluid for the normal service conditions stated in the IEEE Std C57.13-1993.

For oil-immersed transformers, the manufacturers shall review the sealing tests outlined in Table 5 and adopt the one most suitable for their transformers.

Table 5—Sealing test for oil-immersed instrument transformers

Test	**Average oil temperature** (°C)	**Internal pressure (kPa)**	**Time (h)**
(I)	50	35	24
(II)	50	103	12
(III)[a]	85	0	12
(IV)	25	35	60
(V)	25	103	24

[a]The standard recommends this procedure for transformers with oil expansion diaphragms or bellows. Other procedure as shown in the table, with application of pressure, e.g., by clamping the oil expansion diaphragms or bellows, instead of raising the average oil temperature of the transformer to 85 °C shall also be considered acceptable.

For gas-filled transformers, the construction of the tank shall be in accordance with the national standards on enclosures for gas-filled electrical equipment.[11] The manufacturer shall submit the certificate of the tank to the user for approval before the routine tests.

The maximum leakage-rates of the transformers designed for various ranges of ambient temperature shall be as follows:

[11]The Canadian standards are listed in Clause 2.

a) Average ambient temperature (20 °C): 0.5% / year
b) Low ambient temperature (T_L = –5, 10, –15, or –25 °C) 1.5% / year
c) Extra-low ambient temperature (T_L = –40 °C) 3.0% / year
d) Ultra-low ambient temperature (T_L = –50 °C) 6.0% / year

Where T_L is the lower limit of the ambient temperature range.

The manufacturer shall submit the routine sealing test procedure and acceptance criteria to the user for approval.

4.4.2 Mechanical strength of the transformer

All instrument transformers intended for pedestal mounting shall be capable of withstanding the non-simultaneous cantilever forces equivalent to those produced by winds of 160 km/h and the horizontal seismic force resulting from a zero-period acceleration[12] of 0.2 m/s^2.

All instrument transformers intended for suspension mounting shall be capable of withstanding a tension equal to 13 kN in addition to its own weight.

4.5 Thermal performance requirements

All instrument transformers shall not exceed the temperature rise limits given in Table 4 of IEEE Std C57.13-1993 when tested in accordance with 10.8 of this trial-use standard.

4.6 Ground shield requirements

All instrument transformers shall be provided with a ground shield between the primary winding and the secondary windings.

NOTE—The ground shield provides some degree of protection in the secondary circuit against an insulation failure between the primary and secondary windings.

4.7 Dissolved gas and water content requirements for new oil-immersed transformers

For new oil-immersed transformers, the maximum concentration of the dissolved gas and water content in the oil, after the test program, shall be in accordance with the values in Table 6.

The minimum sensitivity of a gas spectrum analyzer shall be in accordance with the last column of the table.

4.8 Endurance capability for fast high-voltage transient

All instrument transformers of a nominal system voltage of 345 kV and above shall be suitably designed to endure the fast high-voltage transient stress induced during the operation of the line disconnect switch located in its vicinity.

NOTE—To verify if the transformer design will comply with the requirement, the user should specify the endurance chopped-wave test (12.1).

[12]The acceleration value corresponds to the conventional 0.2g in seismic terminology.

Table 6—Dissolved gas and water content for new oil-immersed instrument transformers

Component		Maximum concentration (ppm)	Minimum sensitivity (ppm)
Hydrogen	H_2	15.0	3.0
Carbon monoxide	CO	40.0	5.0
Methane	CH_4	5.0	0.1
Ethane	C_2H_4	2.0	0.1
Ethylene	C_2H_6	3.0	0.1
Acetylene	C2H2	0.5[a]	0.1
Water	H_2O	10.0	3.0
NOTE—The values are in reference to Table A-1 of Annex A of IEC 61181 (1993-06) with the exception of the concentration for acetylene.			

[a]An acceptable transformer is indicated with the absence of acetylene. However, the trial-use standard has made allowances for residual acetylene present in the oil even after the oil processing.

4.9 Performance of internal arc protection

The transformer design with the safety features of limiting hazardous effects of an internal arc shall conform, during the test, with the requirements defined for their classes as provided in 3.1 and 3.2.

The special features of internal arc protection for instrument transformers shall be specified at the enquiry.

4.10 Identification of test sample in the type test report

For the purpose of traceability, the test sample used for the type tests shall be uniquely identified. Information related to the design and construction of the sample shall form part of the type test report.

4.11 Secondary short-circuit capability for voltage transformers

The voltage transformer shall be designed and constructed to have the following withstand capability:

a) With rated voltage maintained on the primary winding, each secondary winding including the tapped portion shall be capable of withstanding both the thermal and mechanical effects resulting from the secondary short circuit for duration of 1.0 s, and
b) The primary winding shall also be capable of withstanding both the thermal and mechanical effects resulting from the 1.0-s short circuit applied simultaneously to all secondary windings with rated voltage being maintained on the primary winding.

NOTE—Maximum temperature limits are given in 7.7 of IEEE Std C57.13-1993.

5. Test conditions

Unless specified otherwise for particular tests, the following test conditions shall apply:

a) The ambient temperature range for tests shall be from 0 °C through +40 °C with +20 °C as the reference temperature,
b) The transformer shall be in new, clean, and dry condition,
c) The transformer shall be mounted in a vertical position on the floor or on a structure, the height of which shall be no greater than that of the structure used in service, and
d) For gas-filled instrument transformers, the gas pressure shall be set, for all electrical tests, at the minimum rating value, which corresponds to the equivalent gas density at 20 °C for which the second alarm level is set.

6. Classification of tests

Tests listed in the trial-use standard are classified as routine type, and special tests, which are necessary to ensure that the design and construction of the transformer are adequate to comply with the requirements of IEEE Std C57.13-1993 and Clause 4 of this trial-use standard.[13]

6.1 Routine tests and test sequences

6.1.1 Routine tests applicable to instrument transformers

The manufacturer shall perform the following routine tests on each instrument transformer:

a) Verification of terminal markings and polarity (see 7.1)
b) Capacitance and dissipation factor test (before the dielectric tests) (see 7.2)
c) Applied voltage test on secondary windings (see 7.3)
d) Insulation resistance test on windings (see 7.4)
e) Lightning impulse voltage test on the primary winding (see 7.5)
f) Power frequency voltage withstand test (see 7.6)
g) Partial discharge test (see 7.7)
h) Dissolved gas and water content analysis tests for oil-immersed transformers (of a nominal system voltage of 345 kV and above) (see 7.8)
i) Sealing test (see 7.9)
j) Ground shield check (see 7.10)
k) Tests on mineral oil (see 7.11)

6.1.2 Routine tests applicable to current transformers

The manufacturer shall perform the following routine tests on each current transformer:

a) Inter-turn overvoltage test (see 8.1)
b) Accuracy test for metering rated current transformers (see 8.2)
c) Resistance measurement of relaying rated secondary windings (see 8.3)
d) Performance characteristics for relaying rated current transformers (see 8.4)

6.1.3 Routine tests applicable to voltage transformers

The manufacturer shall perform the following routine tests on each voltage transformer:
a) Applied voltage test on the neutral terminal (see 9.1)
b) Accuracy test (see 9.2)
c) Excitation characteristics with respect to rated voltage factor (see 9.3)
d) Resistance measurement of windings (see 9.4)

[13]For the purpose of reducing the routine test burden to the manufacturer, some tests are performed on the basis of selected samples.

6.1.4 Sequence of the routine tests

The routine tests shall be performed in the sequence as outlined in Figure 1 and Figure 2.[14]

For oil-immersed transformers, if air is in direct contact with the oil during the sealing test, a partial discharge test in accordance with 7.7 shall be repeated after the sealing test.

The tests on the mineral oil do not apply to gas-filled transformers.

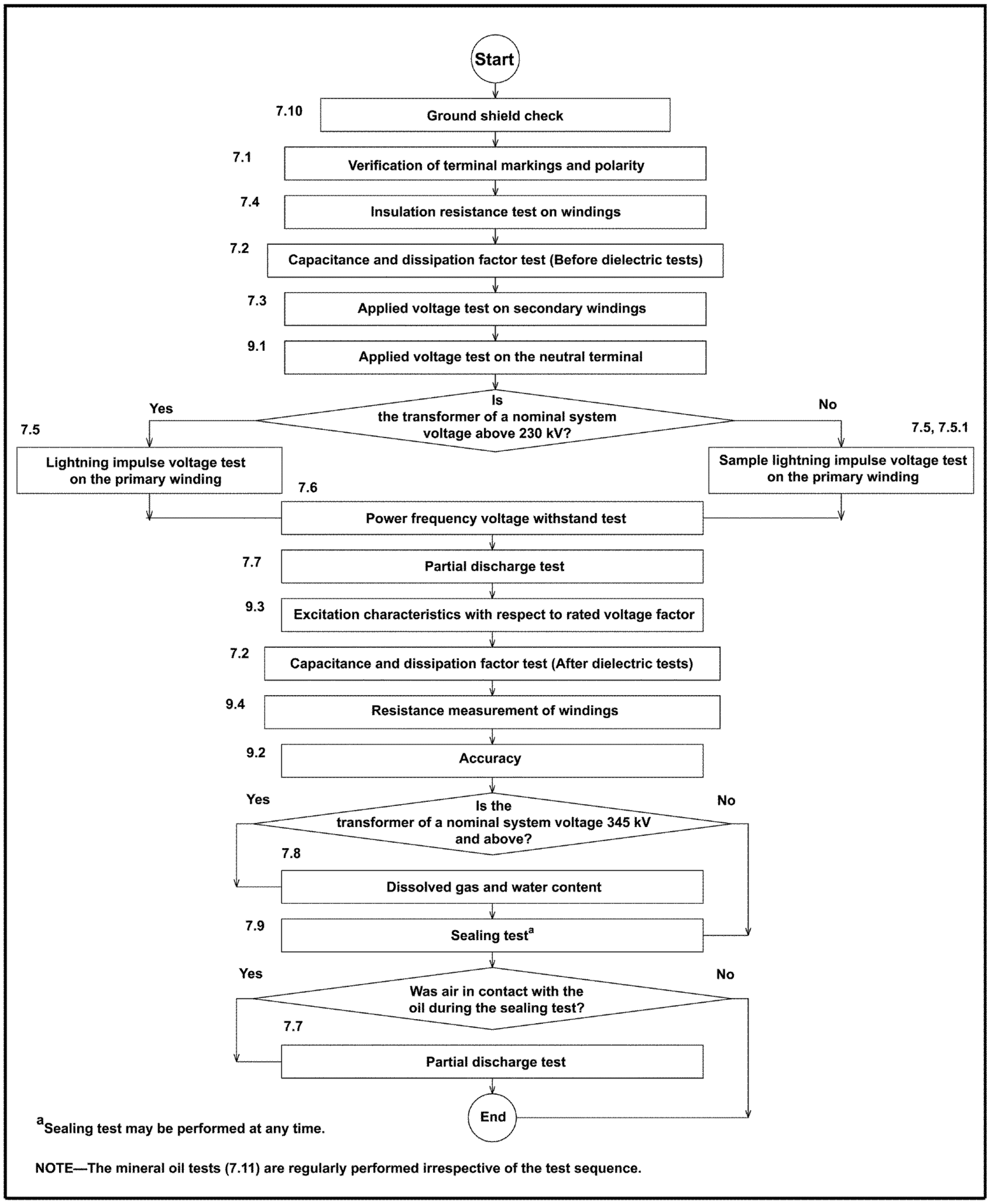


Figure 1—Flowchart of routine tests on current transformers

[14]The numbers next to the boxes are the pertinent clause references.

Figure 2—Flowchart of routine tests on current transformers

6.2 Type tests and test sequences

Type tests are intended to verify whether the characteristics and performance of the instrument transformer design comply with the requirements of IEEE Std C57.13-1993 and Clause 4 of this trial-use standard.

6.2.1 Type tests applicable to instrument transformers

The manufacturer shall perform the following type tests on each instrument transformer design:

a) Dissolved gas and water content analysis (see 10.1)
b) Mechanical test (see 10.2)
c) Lightning impulse voltage test on the primary winding (see 10.3)
d) Switching impulse voltage test on the primary winding—wet (see 10.4)
e) Radio influence voltage (RIV) test (see 10.5)
f) Power frequency voltage withstand test—wet (see 10.6)
g) Power frequency voltage withstand / partial discharge test—dry (see 10.7)
h) Temperature rise test (see 10.8)
i) Short-time mechanical and thermal rating test (see 10.9)
j) Accuracy performance test (see 10.10)
k) Creepage distance measurement (see 10.11)
l) Sealing system test for gas-filled instrument transformers (see 10.12)

6.2.2 Type test applicable to current transformers

The following type test shall be performed on each current transformer design:

Secondary open-circuit voltage withstand test (see 11.1).

6.2.3 Sequence of the type tests

The type tests shall be performed for each transformer design in the sequence as outlined in Figure 3 and Figure 4.[15]

6.2.4 Maximum number of samples used for the type tests

The type tests shall be preferably carried out on a single sample. For the convenience of scheduling, a second sample of the same design and construction shall be allowed. In order to meet the purpose of the dissolved gas analysis, the dielectric tests shall be performed on the same transformer.

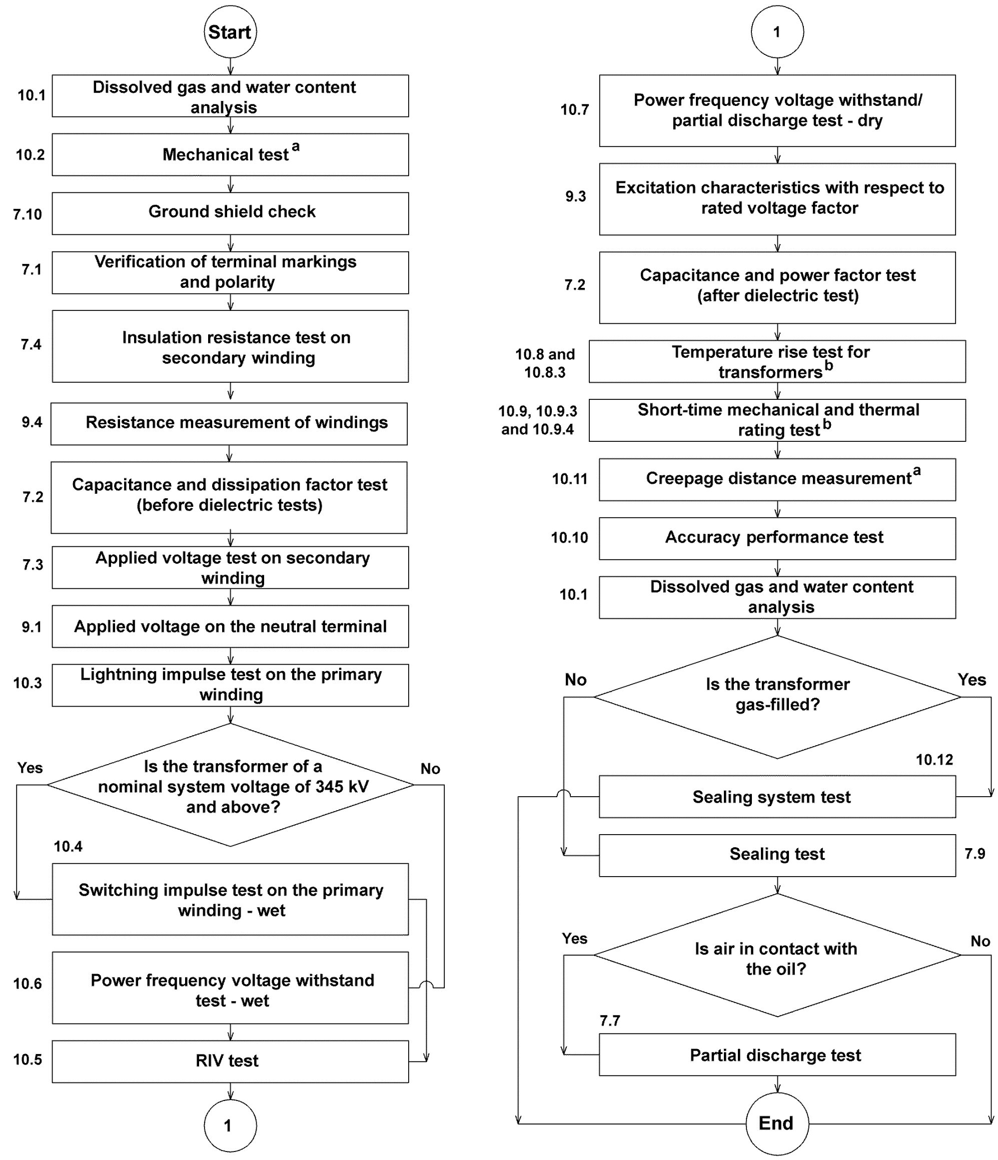
NOTE—The rationale behind the two samples is to increase the user's confidence on the design and consistency of manufacturing. At the same time, this facilitates the manufacturer to schedule the type tests.

6.3 Special tests

Special tests are intended to verify if the instrument transformers are adequately designed and constructed in order to:

a) Withstand abnormal or special service stresses induced by system operation or site conditions, or
b) Provide special features such as protection against internal arc.

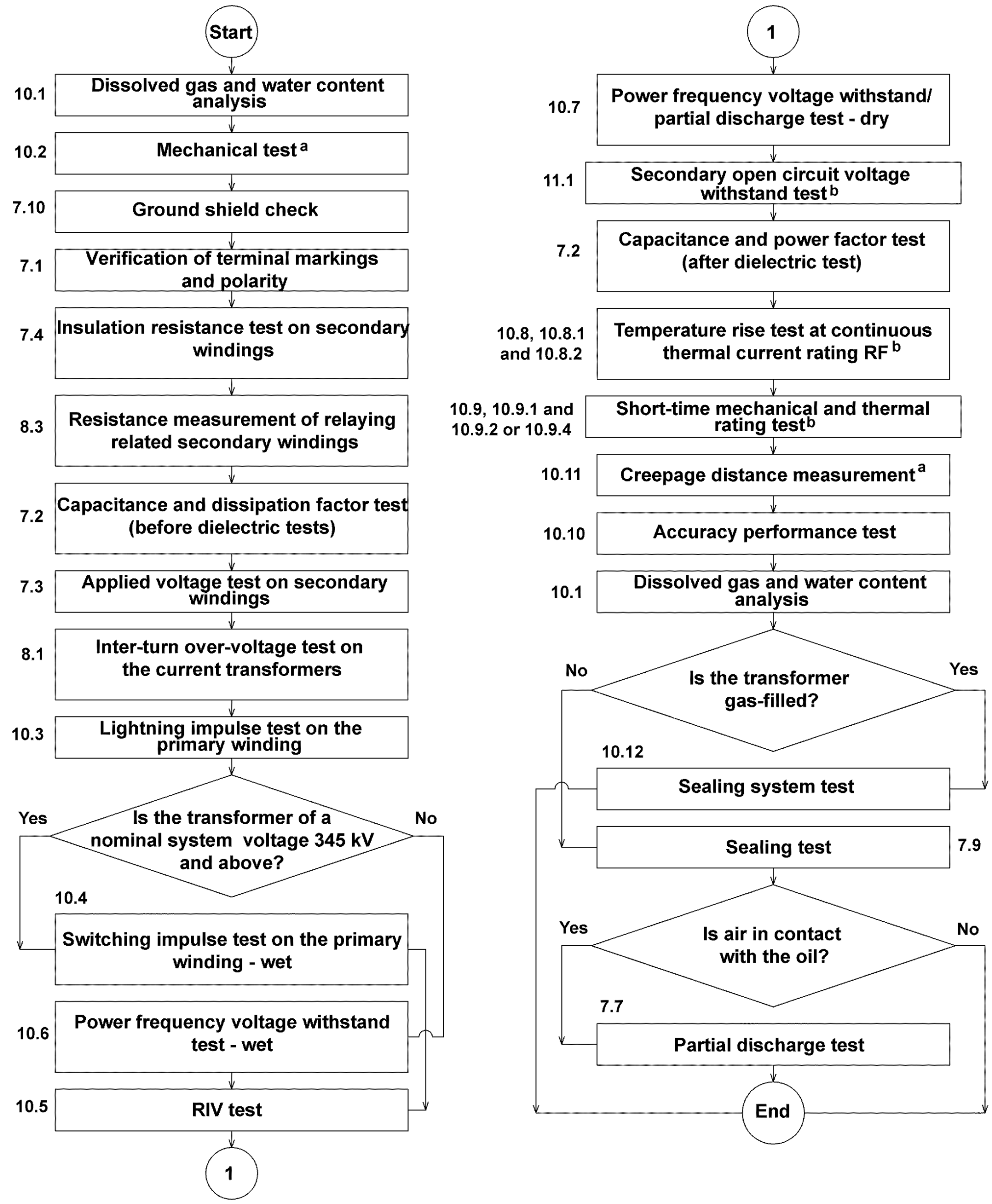
[15]See Footnote 14.



[a] The test may be performed at any time.

[b] The test may be performed at any time if the complete routine test program is performed after these tests.

Figure 3—Flowchart of type tests on voltage transformers



[a] The test may be performed at any time.

[b] The test may be performed at any time if the complete routine test program is performed after these tests.

Figure 4—Flowchart of type tests on current transformers

These tests are not mandatory and are performed only at the request of users, who should include the requirements of these tests in the specification at the time of enquiry.

The manufacturer has the option to perform the special test on a different sample that has not been subjected to any type test.

The following is the list of special tests:

1) Endurance chopped-wave test (see 12.1)
2) Internal arc test (see 12.2)
3) Seismic test (see 12.3)

7. Routine test procedures (applicable to instrument transformers)

7.1 Verification of terminal markings and polarity

The terminal markings and polarity shall be verified for all windings. The test shall be performed during the unit assembly and repeated as a part of the accuracy test.

The polarity check shall be performed in accordance with 8.4, IEEE Std C57.13-1993.

The terminal markings and polarity shall be in accordance with the nameplate and schematic.

7.2 Capacitance and dissipation factor test

The capacitance and dissipation factor shall be measured before and after the dielectric tests as indicated in the test sequences.

The test shall be performed at power frequency and at the following voltages:

a) 10 kV (r.m.s.)[16]
b) Maximum rated voltage

The temperature at which the measurements are taken shall be recorded.

The values of the capacitance and dissipation factor shall be in accordance with 4.1.2.

7.3 Applied voltage test on secondary windings

A voltage of 3 kV (r.m.s.) shall be applied to the secondary windings for 60 s.

The voltage shall be applied, while the other windings are grounded, between the winding under test and the ground.

The transformer shall be considered as having met the requirements if no disruptive discharge or collapse of voltage is observed.

[16]The measurement at 10 kV is optional as the values are useful as a reference for commissioning.

7.4 Insulation resistance test on windings

The insulation resistance of the individual winding to ground and between windings shall be measured at a voltage not less than 1.0 kV_{dc}.

The insulation resistance shall be in accordance with 4.1.6.

7.5 Lightning impulse voltage test on the primary winding

For transformers of a nominal system voltage of 230 kV and below, the lightning impulse voltage test shall be conducted as a sample test. The sample size for the test shall be determined in accordance with 7.5.1.

For transformers of a nominal system voltage above 230 kV, the test shall be performed as a routine test.

7.5.1 Determination of sample size

The user has the right to select the samples from the batch. The sample size shall be determined as follows:

a) The minimum number of samples subjected to the test shall be one for a batch of up to six units. The subsequent minimum number of samples for a batch size greater than six shall be the subsequent higher integer obtained when the batch size is divided by the integer 6.
b) If the sample fails to comply with the test requirements, two additional samples from the same batch shall be tested. If one of these two additional samples fails the test, then the entire batch of transformers shall be subjected to the test.

7.5.2 Test procedure and criteria

The routine lightning impulse test shall be the simplified version of the type test outlined in 10.3 with the following modifications:

a) The applied voltage wave shall be of negative polarity only, and
b) The test shall be carried out in the following sequence:
   1) One reduced wave with 50%–70% of the full wave value as provided in Table 1
   2) One full wave
   3) Two chopped waves of the value provided in Table 1 (applicable only to gas-filled transformers)
   4) Two full waves
   5) One reduced wave

The transformer shall be considered as having met the requirements if:

c) Neither external nor internal disruptive discharge is observed
d) No audible noise is noted from the transformer
e) No deviation is detected between the reduced wave and full wave oscillograms
f) No internal insulation failure is found with the capacitance and dissipation factor measurement

7.6 Power frequency voltage withstand test

The power frequency voltage withstand test shall be performed in accordance with 4.1.7 and 4.1.8.

The transformer shall be considered as having met the requirements if:

a) No external disruptive discharge or collapse of voltage is observed, and
b) No internal insulation failure is found with the capacitance and dissipation factor measurement.

7.7 Partial discharge test

The pre-stress voltage shall be in accordance with Table 4.

At the discretion of the manufacturer, the power frequency voltage withstand and partial discharge test may be performed in accordance with 10.7.

The partial discharge test shall be performed within 30 minutes after the power frequency voltage withstand test, either in the same laboratory or in a different laboratory, as follows:

Before the test, the setup shall be calibrated for partial discharge measurement of 10 pC.

If necessary, external electrodes may be used for the primary terminal and the ground of the transformer. The test method shall be in accordance with IEC 60270 (2000-12).

The pre-stress voltage shall be maintained in accordance with 4.1.8. Subsequently the test voltage shall be reduced to the level of the prescribed extinction voltage which shall then be maintained for 60 s.[17] The partial discharge intensity shall be measured during this time.

If the intensity exceeds the limit of 10 pC after the 60-s duration, the test may be extended, at the manufacturer's discretion, by up to 30 minutes at the prescribed extinction voltage level.

The test shall be terminated if the measured partial discharge intensity is less than or equal to 10 pC.

The transformer shall be considered as having met the requirements if the partial discharge intensity measured at the prescribed extinction voltage level is equal to or less than 10 pC.

7.8 Dissolved gas and water content analysis for oil-immersed transformers (of a nominal system voltage of 345 kV and above)

For oil-immersed transformers of a nominal system voltage of 345 kV and above, three days after the dielectric tests an oil sample shall be taken for dissolved gas and water content analysis.

The concentration of dissolved gas and water content shall be in accordance with the values provided in Table 6. The oil sampling point shall be indicated in the test report.

NOTES

1—This trial-use standard recommends carrying out a dissolved gas and water content analysis before the routine tests.

2—If the transformer is with a limited oil volume, the manufacturer should replenish the oil removed for the test before shipping the transformer.

7.9 Sealing test

The routine sealing test may be performed at any time at the convenience of the manufacturer.

[17]Partial discharge may be measured, at the manufacturer's discretion, as the test voltage is reduced from the pre-stress voltage level.

7.9.1 Sealing test for oil-immersed transformers

One of the tests outlined in Table 5 shall be carried out with all the fittings and accessories installed. Each sealed compartment shall be tested to the required internal pressure and at the average oil temperature indicated for the time interval in accordance with item a) in 4.4.1.

If the pressure is applied with air in direct contact with the insulating oil, the air shall be evacuated from the instrument transformer after the sealing test. A partial discharge test in accordance with 7.7 shall be repeated to verify that the residual air within the transformer has insignificant effect on the insulation system.

The transformer shall be considered as having withstood the test if there is:

a) No permanent deformation of the tank,
b) No sign of oil leakage, and
c) No significant pressure reduction (if applicable).

7.9.2 Sealing test for gas-filled transformers

The sealing test on gas-filled transformers shall be performed with a sniffing method at the normal ambient temperature with the transformer filled to the rated pressure (or density) corresponding to the normal ambient temperature.

The transformer shall be considered as having withstood the test if there is:

a) No permanent deformation of the tank, and
b) No gas leakage at a rate above the 20 °C limit as provided in item b) in 4.4.1.

NOTES

1—The sensitivity of the sniffer shall be adequate to detect a maximum leakage-rate of 0.5% / year.

2—If a leakage is detected, a test by the cumulative method as described in A.2 of Annex A shall be performed at normal ambient conditions. Alternatively, after reassembling the transformer with a new sealing system, the sniffing test shall be repeated.

7.10 Ground shield check

A three-terminal capacitance and dissipation factor measurement in the grounded specimen mode and at a voltage of 1.0 kV (r.m.s.) or lower shall be performed to determine:

a) The capacitance of the primary winding to the ground C_p
b) The capacitance of the secondary winding to the ground C_s, and
c) The capacitance between the primary and secondary winding C_{ps}

For a gas-filled transformer, the test may be performed at any setting of the gas pressure.

The presence of the ground shield shall be indicated if the measured capacitances are in accordance with the following expression:

$$1/C_{ps} = 1/C_p + 1/C_s$$

The transformer shall be considered as having met the requirements if the measured parameters are within 10% of the value determined with the above expression.

7.11 Tests on the mineral oil

The manufacturer of oil-immersed transformers shall regularly test the processed mineral oil for the dielectric strength and power factor at the room ambient temperature in accordance with Table 3 of IEEE Std C57.106-2002.[18]

8. Routine test procedures (applicable to current transformers)

8.1 Inter-turn overvoltage test

The test shall be performed in accordance with one of the following procedures. If there is no agreement between the manufacturer and user, the choice of the procedure shall be left to the manufacturer.

If secondary protective devices are provided, these devices shall be installed for the inter-turn overvoltage test.

Procedure A

With the secondary windings open-circuited (or connected to a high impedance device which reads the peak voltage), a substantially sinusoidal current shall be applied to the primary winding. The test current shall be increased until one of the following conditions is reached:

a) The r.m.s. value of the applied current is equal to the maximum primary current corresponding to the continuous thermal current rating factor (RF), or
b) The peak value of the secondary induced voltage is equal to:
    1) 280 V for metering rated current transformers, or
    2) 2.8 times the secondary terminal voltage rating for relaying rated current transformers

The test shall be maintained for 60 s.

Procedure B

With the primary winding open-circuited, a test voltage (at an elevated frequency not exceeding 400 Hz) shall be impressed to the terminals of each secondary winding. Both the test voltage and frequency shall be increased until one of the following conditions has been reached:

a) The peak value of the applied secondary test voltage is equal to:
    1) 280 V for metering rated current transformers, or
    2) 2.8 times the secondary terminal voltage rating for relaying rated current transformers

Or,

b) The r.m.s. value of the secondary current is equal to the continuous thermal current rating factor (RF)

The test duration shall be in accordance with 4.1.8.

At the frequency of 400 Hz, if the voltage achieved with the secondary current value corresponding to the continuous thermal current RF is lower than the value provided in a) above, then the voltage obtained shall be regarded as the test voltage.

The gas pressure of the gas-filled transformer may be at any setting equal to or less than the pressure given in Clause 5 for the test.

[18]The manufacturer is expected to test the quality of the processed oil before each oil filling.

The transformer shall be considered as having met the requirements if no external or internal disruptive discharge or collapse of voltage is observed, and, if provided, the secondary protective devices remain inoperative during the test.

8.2 Accuracy test for the metering rated current transformers

The test shall be performed in accordance with 6.11 and 8.1 of IEEE Std C57.13-1993.

The calibration of the test system provided in 4.3 shall apply.

The current transformer shall be demagnetized in accordance with 8.2 of IEEE Std C57.13-1993 before the accuracy test.

The gas pressure of the gas-filled transformer may be at any setting for the test.

The transformer shall be considered as having met the requirements if the performance is within the limits of the accuracy class.

8.3 Resistance measurement of relaying rated secondary windings

The resistance of relaying rated windings including tap portions shall be measured in accordance with 8.5 of IEEE Std C57.13-1993. The measured value shall be corrected to 75 °C.

The gas pressure of the gas-filled transformer may be at any setting for the test.

The resistance data obtained shall be compared with the design values to ensure proper construction.

8.4 Performance characteristics of relaying rated current transformers

The test comprises the following:

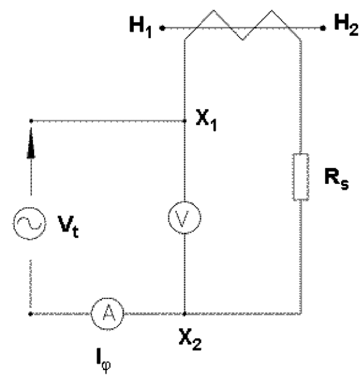
a) With the primary winding open-circuited as shown in Figure 5, a substantially sinusoidal voltage equal to the secondary terminal voltage rating, corrected with the additional voltage due to the winding resistance voltage drop, shall be applied to the full secondary winding.
The excitation current expressed as a percentage of the 20 times the rated secondary current shall be recorded.
b) The short-circuit impedance of the lowest tapped portion of the secondary winding shall be measured in accordance with item a) of 8.3.1.2 of IEEE Std C57.13-1993.
c) The turns-ratios of the secondary winding and the tapped portions to the primary winding shall be measured.

The gas pressure of the gas-filled transformer may be at any setting for the test.

The transformer shall be considered as having acceptable performance characteristics if:

1) The percent excitation current is not higher than 10%,
2) The short-circuit impedance is not higher than 1.05 times the resistance of the lowest tapped portion of the measured secondary winding,[19] and
3) The turns-ratios are in accordance with the marked ratios.

[19]Because the leakage reactance of an annular core current transformer with uniformly distributed windings is insignificant, the impedance of the winding is reduced to that of the winding resistance.



Assumption: Annular core with uniformly distributed secondary winding and the primary winding being in open circuit.

$V_t = V_s + 20 \times I_s \times R_s$ and

$$\text{Percent error ratio} = 100 \times \frac{I_\varphi}{20 \times I_s}$$

Where

V_t = applied voltage during the test in V
V_s = secondary voltage rating in V
I_φ = excitation current in A
I_s = rated secondary current in A
R_s = secondary winding resistance in Ω corrected to 75°C

Figure 5—Measurement of the ratio error for relaying rated current transformers

9. Routine test procedures (applicable to voltage transformers)

9.1 Applied voltage test on the neutral terminal

With the ground link temporarily removed from the neutral terminal of the transformer, a voltage of 19 kV (r.m.s.) shall be applied between the neutral terminal and the ground for 60 s.

The gas pressure of the gas-filled transformer may be at any setting equal to or less than the pressure given in Clause 5 for the test.

The transformer shall be considered as having met the requirements if no external and internal disruptive discharge or collapse of voltage is observed.

9.2 Accuracy test

The test shall be performed in accordance with 8.1 of IEEE Std C57.13-1993.

The calibration of the test system given in 4.3 shall apply.

The gas pressure of the gas-filled transformer may be at any setting for the test.

The transformer shall be considered as having met the requirements if the performance is within the limits of the accuracy class.

9.3 Excitation characteristics with respect to rated voltage factor

The excitation current of the voltage transformer shall be measured in accordance with 8.3.2 of IEEE Std C57.13-1993, with the voltage corresponding to the rated voltage factor applied to one of the windings and with the other windings open-circuited.

The impressed voltage shall be measured with both the r.m.s.-voltmeter and the average-voltmeter (but r.m.s. calibrated). The form factor, defined as:

$$k = \left(\frac{V_{rms}}{V_{avg}}\right)^2$$

where

V_{rms} = voltage measured with the r.m.s.-voltmeter, and
V_{avg} = voltage measured with the average-voltmeter.

The exciting current and the form factor shall be included in the routine test report.

The gas pressure of the gas-filled transformer may be at any setting equal to or less than the pressure given in Clause 5 for the test.

The measured excitation current shall be compared with the design value to ensure proper construction.

9.4 Resistance measurement of windings

The resistance of all the windings including tapped portions of the windings shall be measured in accordance with 8.5 of IEEE Std C57.13-1993. The measured values shall be corrected to 75 °C.

The gas pressure of the gas-filled transformer may be at any setting for the test.

The resistance data obtained shall be compared with the design values to ensure proper construction.

10. Type test procedures (applicable to instrument transformers)

10.1 Dissolved gas and water content analysis

For all oil-immersed transformer designs, the dissolved gas and water content analysis, in reference to Figure 3 and Figure 4, shall be performed:

a) At the commencement of the type test program,[20] and
b) At the reference point of the type test sequence.[21]

The transformer design is considered as having met the requirements if the last set of results is in accordance with Table 6.

[20]The analysis for oil sample taken before the type test program is not mandatory but highly recommended as this will ensure the test object is filled with oil that meets the limits for the analysis.

[21] If two samples are used for the type test program as described in 6.2.4, then the oil sample shall be taken 3 days after the completion of the last dielectric test in order to get a homogeneous dissolved gas content within the oil.

NOTE—If the transformer is with a limited oil volume, the manufacturer should replenish the oil removed for the test before shipping the transformer.

10.2 Mechanical test

10.2.1 Transformers for pedestal mounting

The instrument transformer shall be subjected to a greater of the cantilever forces in accordance with 4.4.2 for a period of 10 minutes.

The determination of the force due to the wind shall be in accordance with the latest edition of the Uniform Building Code. The determination of the force due to seismic load shall be based on zero-period acceleration of 0.2 m/s^2.

Successful completion shall be determined with the absence of permanent deformation of the transformer and the absence of oil or gas leakage during the test and within 2 h after the test.

10.2.2 Transformers for suspension mounting

The instrument transformer shall be suspended using the suspension hardware provided for this application. An additional tensile force of 13 kN shall be applied in the vertical axis to the transformer and maintained for 2 h.

Successful completion shall be determined with the absence of permanent deformation of the transformer and the absence of oil or gas leakage during the test and within 2 h after the test.

10.3 Lightning impulse voltage test on the primary winding

The test voltage shall be applied between the primary terminal and the ground terminal of the transformer. All the terminals of the secondary windings and the base frame shall be grounded during the test.

The wave-shape of the voltage shall be 1.2 μs x 50 μs. The test voltage shall be in accordance with Table 1.

The chopping device for the chopped voltage wave shall be set up as close to the transformer as possible in order to maximize the oscillatory voltage after the chopping (refer to 7.2.5 of IEEE Std 4-1995).

Both the voltage and the ground current oscillograms shall be taken.

The test shall begin with the negative polarity sequence and continue with the positive polarity sequence.

The negative polarity sequence comprises the following applications of voltage wave:

a) One reduced wave with 50%–70% of full wave value as provided Table 1,
b) One full wave,
c) Two chopped waves of the value provided in Table 1,
d) Fourteen full waves, and
e) One reduced wave.

The positive polarity sequence comprises the following applications of voltage wave:

1) One reduced wave with 50%–70% of full wave value as provided in Table 1,
2) Fifteen full waves, and
3) One reduced wave.

Several additional reduced waves may be applied, at the discretion of the manufacturer, before the test sequence with positive polarity.

The design shall be considered as having met the requirements if:

f) The number of external disruptive discharges is not more than two for the sequence of each polarity,
g) No deviation is detected between the reduced wave and full wave,
h) No deviation is detected between the two chopped waves before the instant of chopping,
i) No audible noise is noted from the transformer during the test,
j) No internal disruptive discharge is observed, and
k) No internal insulation failure is found with the capacitance and dissipation factor measurement.

10.4 Switching impulse voltage test on the primary winding—wet

The test shall be performed only on transformer designs of a nominal system voltage of 345 kV and above.

The voltage shall be applied between the primary terminal and the ground terminal of the transformer. All the terminals of the secondary windings and the base frame shall be grounded.

The preparation of the transformer and wetting procedure shall be in accordance with 14.2 of IEEE Std 4-1995. The precipitation conditions shall be as described under the "Standard test procedure" as outlined in Table 3 of the same standard.

The voltage waveshape shall be 250 μs ± 20% × 2 500 μs ± 60% (or [200–300] μs × [1000–4000] μs) standard wave-shape. The test voltage shall be in accordance with Table 1. The applied wave shall be at positive polarity only.

The test sequence shall consist of:

a) One reduced wave with 50%–70% of rated value provided in Table 1, and
b) Fifteen full waves.

The design shall be considered as having met the requirements if:

1) The number of external disruptive discharges is not more than two,
2) No deviation is detected between the reduced wave and full wave,
3) No audible noise is noted from the transformer during the test, and
4) No internal insulation failure is found with the capacitance and dissipation factor measurement.

10.5 External RIV test

The external RIV meter and the method used for the test shall be in accordance with the NEMA 107-1987.

The transformer shall be assembled with the primary terminals, connectors, and electrodes, if provided. The transformer shall be set up at a level above ground not greater than the height of the supporting structure used in service. Metallic pipes of approximately 2 m in length with sphere terminations, for the simulation of the bus or line connections in service, shall be assembled on each primary terminal.

The test circuit shall be calibrated for RIV measurement.

The test voltage, in accordance with Table 3, shall be applied to the primary terminal and the meter readings shall be corrected with the calibrated RIV factor to obtain the RIV level.

The transformer type shall be considered as having met the requirements if the RIV level is in accordance with Table 3.

10.6 Power frequency voltage withstand test—wet

The test shall be performed only on transformers of a nominal system voltage of 230 kV and below.

The test shall be performed as outlined in 4.1.7 and 4.1.8. The preparation of the transformer and wetting procedure shall be in accordance with 14.2 of IEEE Std 4-1995. The precipitation conditions shall be as described under the “Standard test procedure” as outlined in Table 3 of the same standard.

The design shall be considered as having met the requirements if:

a) No disruptive discharge or collapse of test voltage is observed during the test, and
b) No internal insulation failure is found with the capacitance and dissipation factor measurement.

10.7 Power frequency voltage withstand/partial discharge test—dry

The power frequency withstand voltage and prescribed extinction voltage shall be in accordance with Table 1.

Before the test, the setup shall be calibrated for the partial discharge measurement of 10 pC. The measuring method shall be in accordance with IEC 60270 (2000-12).

If necessary, external electrodes may be used for the primary terminals and the ground of the transformer.

As the test voltage is increased, the voltage at which the partial discharge intensity of 10 pC is detected shall be recorded. The test voltage shall then be increased until it reaches the power frequency withstand voltage level which shall be maintained for the duration in accordance with 4.1.8. Subsequently the test voltage shall be reduced to the prescribed extinction voltage level and then maintained for a duration of 60 s within which the partial discharge intensity shall be measured.[22]

If the partial discharge intensity exceeds the limit of 10 pC, the test may be extended, at the manufacturer’s discretion, by up to 10 minutes at the prescribed extinction voltage level.

The test shall be terminated if the measured partial discharge intensity has decreased to less than or equal to 10 pC.

The design shall be considered as having met the requirements if:

a) No external disruptive discharge or collapse of voltage is observed during the test,
b) The partial discharge intensity measured at the prescribed extinction voltage level is equal to or less than 10 pC, and
c) No internal insulation failure is found by the capacitance and dissipation factor measurement.

10.8 Temperature rise test

In order to carry out the proper test and calculations, before the test, all the possible onerous load conditions for the instrument transformer design shall be reviewed and identified in accordance with the following sub-

[22]The partial discharge intensity may be measured as the test voltage is reduced from the power frequency withstand voltage level.

clauses. The test shall be performed as described in 8.7 of IEEE Std C57.13-1993 with the additional requirements provided in A.1.

For gas-filled transformers, the gas pressure shall be at the minimum operating value. This corresponds to the equivalent gas density at 20 °C for which the second alarm level is set.

The design shall be considered as having met the requirements of 4.5 if the temperature rise is in accordance with Table 4 of IEEE Std C57.13-1993.

10.8.1 Temperature rise test for current transformers at the continuous thermal current rating RF

If a continuous thermal current RF greater than unity is specified, the temperature rise of the transformer shall be determined with either:

a) A temperature rise test at the maximum primary current, (i.e., *RF* × *rated primary current*), or
b) An alternative calculation procedure related to the application of over-current exponent *n*, if the temperature rise data obtained with an applied current *I* is available, as provided below.

With the exponent *n* conservatively assumed a value of 2 in the following expression:[23]

$$\theta_{load} = \theta \times \left(\frac{I_{load}}{I}\right)^n$$

Where θ_{load} = temperature rise with the maximum primary current I_{load}

The projected temperature rise, θ_{load}, at the maximum primary current shall be determined.

If the results exceed the allowable limits, a second temperature rise test, if possible, as provided in a), shall be performed. If the maximum primary current is beyond the test capability, the test with a primary current value as close to the maximum primary current as possible in order to accurately determine the over-current exponent *n* based on the temperature rises, shall be derived.[24]

10.8.2 Effects of the dielectric losses on temperature rise for current transformers

Before the temperature rise test, the dielectric losses of the transformer at the maximum rated voltage and the total secondary winding dc resistance losses shall be measured.

If the primary winding dc resistance loss is difficult to accurately measure, then, based on the test current, material, reference temperature, and physical dimensions of the primary conductor, the primary winding dc resistance loss shall be calculated.

If the dielectric losses are more than 20% of the total winding dc resistance losses, the test shall be conducted with the maximum rated voltage applied to the primary winding, which carries the rated current.[25]

[23] The second test is not required if the projected temperature rises with exponent n equal to 2 are below the limits.

[24] For an accurate determination of the exponent n, the primary current value should be preferably within 30% of the maximum primary current.

[25] It is acceptable to short circuit the primary winding and supply the required secondary current in order to have rated primary current flowing in the primary winding. This should be verified before the test with an appropriate measuring device. Alternatively, the rated primary current can be provided with a power supply insulated for the maximum rated voltage.

If the dielectric losses are equal to or less than 20% of total winding dc resistance losses, the test shall be performed at the rated current only. However, a correction due to the dielectric losses shall be applied to the temperature rise in accordance with the following expression:

$$\theta_r = \theta_m \times \left(1 + \frac{P_{diel}}{P_{I2R}}\right)$$

where

θ_m = temperature rise measured during the test,
θ_r = temperature rise corrected for the dielectric losses,
P_{diel} = dielectric losses at the maximum rated voltage,
P_{I2R} = total winding dc resistance losses corrected to 85 °C.

10.8.3 Temperature rise test for voltage transformers

The test with maximum accuracy burden shall be conducted at the rated primary voltage multiplied by a rated voltage factor of 1.1 or by any other rated voltage factor (greater than 1.1) if specified duration is longer than 2 h.

The transformer shall be loaded with the total accuracy burden (at any power factor convenient for the test) distributed among the secondary windings and tapped portions of them in a manner that has the worse thermal effect to the transformer.

If a thermal burden rating is specified, then a temperature rise test at the thermal burden rating shall be made at the rated primary voltage.

The distribution of the burden among the secondary windings depends on the specification. When a total thermal burden rating is specified for the transformer only, the burden shall be arranged in such a manner that imposes the worse thermal effect to the transformer. When a thermal burden is specified for simultaneous application to individual secondary windings, the transformer shall be tested accordingly.

The above two tests may be combined into a single test using the most onerous test conditions in terms of thermal effects as outlined above.

10.9 Short-time mechanical and thermal rating test

The test and calculation methods shall be in accordance with 8.6 of IEEE Std C57.13-1993 with the following modifications.

10.9.1 Short-time mechanical test for current transformers

The magnitude of the first asymmetrical current peak applied to the primary winding of the transformer shall be equal to or greater than 2.7 times the rated short-circuit current. The test shall be maintained for 100 ms or 6 cycles at 60 Hz.

This test may be combined with the short-time thermal rating test. In this case, the time for short-circuit current shall be 1.0 s.

10.9.2 Short-time thermal rating test for current transformers

The test shall be performed with the rated short-circuit current, or a current that provides an equivalent thermal effect, i.e., I^2t, applied to the transformer. If the "equivalent I^2t method" is used, the following conditions shall apply:

a) The minimum duration for rated short-time current is 1.0 s, and
b) The maximum duration is 5.0 s.

Instead of performing the test, calculations may be provided if the current densities for the primary and secondary windings and related current-carrying components are below the limits provided in 8.6 of IEEE Std C57.13-1993.[26] More information is provided in 10.9.4 of this standard.

10.9.3 Short-time mechanical and thermal rating test for voltage transformers

The test shall be made to prove compliance with 4.11.

The test shall preferably be performed at the rated frequency.[27] The applied voltage to the primary winding of the transformer shall be maintained at the rated value during the test.

For a transformer with a single secondary winding without a tapped portion, the test shall be performed with a short circuit applied to the secondary terminals.

For a transformer with different secondary winding arrangements, the short-circuit impedances of the secondary windings and their tapped portions shall be measured. A calculation based on the measured impedances shall be performed to determine which case(s) of secondary short circuit will provide the worse condition in terms of highest current amplitude and current density. The tests shall then be performed accordingly.

To produce the highest current amplitude and density in the primary winding, a simultaneous short circuit shall be applied to the terminals of all the secondary windings, including their tapped portions. The test may alternatively be performed with rated voltage maintained across the secondary winding during the test when short-circuiting the primary terminals.

Each test shall be maintained for 1.0 s.

Sufficient time, if necessary, shall be allowed for the transformer to cool down between tests.

Oscillograms of the applied voltage, secondary current, and the primary current shall be recorded during the test.

10.9.4 Short-time thermal rating calculations

The basis of the short-time thermal rating calculations shall be in accordance with 8.6.2 of IEEE Std C57.13-1993.

For current transformers, the determination of the stray conductor loss ratios shall be in accordance with 8.6.3 of the same standard.

[26]For example, the current densities of the secondary leads and connecting bar of the multi-turn primary and for the bushing(s) shall be determined in the calculations.

[27]Due to the test capability, a power frequency different from the rated frequency may be used (e.g., 50 Hz versus 60 Hz) with the test voltage appropriately adjusted for the impedance change of the test object. The same current amplitude as calculated for the rated frequency shall be obtained.

For voltage transformers, the calculation of the values for the secondary short-circuit current shall be in accordance with 8.6.4 of the same standard.

10.9.5 Criteria for the short-time mechanical and thermal rating test

The design shall be considered as having met the requirements if:

a) The inspection and examination after the test reveal no apparent physical damages that will impair the performance of the transformer,
b) The transformer, after the test, complies with all the routine test requirements and the accuracy performance remains unchanged, and
c) The calculated short-circuit current densities are in accordance with 8.6.2 of IEEE Std C57.13-1993.

10.10 Accuracy performance test

The test shall be similar to the routine accuracy test provided in 8.2 and 9.2 except that more measurements shall be taken to verify the accuracy performance for specified ranges of service conditions.

The design shall be considered as having met the requirements if the accuracy results are within the limits for the declared accuracy class.

10.11 Creepage distance measurement

The creepage distance of the insulator used for the transformer shall be measured as follows:

After the insulator or the transformer has been mounted on a horizontal plane, a vertical line of reference shall be established along the insulator.

The surface creepage distance between the top metallic flange (or electrode) and bottom flange (or ground electrode) along the reference line shall be determined with a non-stretchable gum tape.[28]

After the removal of the tape from the surface of the insulator, the length of the tape shall be measured.

The design shall be considered as having met the requirements if the creepage is in accordance with Table 2.

10.12 Sealing system test for gas-filled instrument transformers

The gas leakage-rate test shall be performed in accordance with A.2.

The transformer shall be considered as having met the requirements if:

a) The leakage-rates measured at normal room ambient temperature before and after the test do not exceed the permissible limit of 0.5%/year,
b) The leakage-rate measured at lowest extreme ambient temperature does not exceed the appropriate permissible limit, in reference to item b) in 4.4.1, depending on the reference temperature range,
c) The gas density switches installed on the instrument transformer do not give any alarm throughout the entire test sequence, and
d) The gas lost during the entire test sequence does not reach the alarm level of the density switches.

[28]Fiberglass gum tape with extremely low coefficient of elasticity is considered acceptable.

11. Type test procedure (applicable to current transformers)

11.1 Secondary open-circuit voltage withstand test

The test shall be performed at the rated frequency with the applied current equal to the rated value multiplied by the continuous thermal current RF. A substantially sinusoidal current waveform shall be maintained during the entire course of the test.[29]

All the secondary protective devices, if provided, shall be installed for the test.

One of following methods shall be used for the test:

a) Before the test starts, the secondary winding under test shall be short-circuited with either a switch or a circuit breaker. The test current shall be applied to the primary winding. After the current has reached the test value, the switch or circuit breaker across the secondary terminals shall be opened for 60 s, or
b) With the secondary winding under test open-circuit, a current of the test value shall be suddenly applied to the primary winding for 60 s.

The test shall be repeated for remaining secondary windings of the transformer.

The test current and secondary open-circuit voltage shall be recorded as part of the test report.

The design shall be considered as having successfully withstood the dielectric stresses produced by the test if:

1) No physical damage is noted that will impair the performance of the transformer,
2) In the case of designs with secondary voltage limiting devices, the arc shall be confined between the devices only during the test,[30] and
3) The current transformer complies with the routine test requirements.[31]

12. Special test procedures

12.1 Endurance chopped-wave test

The test is applicable for instrument transformers of a nominal system voltage of 345 kV and above.

The test shall be performed with the transformer at normal ambient temperature in accordance with IEEE Std 4-1995.

For all oil-immersed transformer designs, an oil sample shall be taken before the test and a minimum of three days after the test for the purpose of dissolved gas content comparison.

The voltage of the chopped wave shall be 80% of the rated lightning impulse voltage (full wave) provided in Table 1 and the polarity shall be negative only.

[29]The test is normally carried out in a high power laboratory because the apparent power required to maintain substantially sinusoidal current is higher than 20 MVA.
[30]Any damages to other parts of the secondary terminal cabinet are not acceptable.
[31]Any secondary protective device shall be replaced before the routine tests.

The test consists of 600 consecutive chopped waves. The time between consecutive applications shall be approximately 1.0 minute.

Details of the test are provided in A.3.

The design shall be considered as having met the requirements stated in 4.8 if:

a) The transformer withstands the power frequency voltage withstand test and the partial discharge test in accordance with 7.6 and 7.7,
b) For the oil-immersed transformer, there is no significant increase of dissolved gas contents compared with those before the test,[32] and
c) The inspection and autopsy of the complete internal insulation structure for the dismantled transformer reveal no trace of tracking or burnt marks.

12.2 Internal arc test

Before the test, the manufacturer shall submit the insulation design report to the user for review. The report shall include a description of the insulation system for the transformer. With the necessary calculations, drawings, and electric field studies, the manufacturer shall justify the location of the fuse element within the test sample. The dimensions and material of the ground shield lead shall form part of the report. The manufacturer shall also describe the strategy of limiting the hazardous effects in the event of an internal arc.

The test shall be performed to verify the design with the special features intended to limit the hazardous effects of an internal arc.

12.2.1 Requirement of the fuse element installation

The fuse element shall be installed at the location where the dielectric stress is the highest, and in the position, that is the least favorable for the controlled pressure relief.

12.2.2 Test conditions

The test shall be conducted under the following conditions:

a) The test current shall be the rated short-circuit current initiated as close as possible to the voltage zero crossing in order to obtain a fully asymmetrical current,
b) The tolerance on the angle of initiation of fault current shall be ±15°,
c) The frequency of the test current shall be between 48 and 62 Hz,
d) The test current shall be maintained at least for 0.2 s (12 cycles at 60 Hz),
e) The power source shall be capable of maintaining a sinusoidal current throughout the entire course of the test. It shall also be capable of obtaining, as a minimum, an asymmetrical peak current of 2.7 times the r.m.s. symmetrical current in the presence of the arc voltage, and
f) For the gas-filled transformer, the gas pressure shall be set at the maximum rating value.

The arc shall be initiated by means of a magnet copper wire 0.5 mm in diameter or 24 AWG.

The transformer shall be mounted on a pedestal at a minimum 300 mm high to simulate service conditions.

An enclosure with the same height as the pedestal shall be used to concentrically encircle the transformer during the test. The diameter of the enclosure shall be equal to the sum of the diameter or largest horizontal

[32]A significant increase of dissolved gas content is considered, with the exception of acetylene, as approximately twice the maximum acceptable limit shown in Table 6. There shall not be any increase of acetylene concentration level.

dimension of the transformer and twice the height of the transformer, with a minimum diameter of 1800 mm.

12.2.3 Test requirements

The design shall be considered as having successfully withstood the test if:

a) For transformer with internal arc protection class I, the debris of the fractured insulator, housings, and broken components of the transformer are confined within the prescribed enclosure. This requirement does not apply to the pressure relief device (e.g., rupture disc).
b) For transformers with internal arc protection class II, there is no fracture of the insulator or housings. This requirement does not apply to the pressure relief device (e.g., rupture disc).

NOTE—Unless it is specified otherwise, fire due to the burning oil is acceptable.

12.3 Seismic qualification

The transformer shall be qualified in accordance with IEEE Std 693-1997. The manufacturers shall review the pertinent clauses of the standard applicable to their design. Either a shake table test or seismic analysis on the transformer type shall be performed as required in the user's specification.

The design shall be considered as having met the requirements if the results of the shake table test or analysis are in accordance with the user's specification.

13. Identification of test sample in the type test report

The test sample for the type tests shall be identified in the test report to meet the objective of 4.10.

The manufacturer shall submit to the test laboratory:

a) A document package uniquely identifying the sample, and
b) A "Certificate of Sample Identification" stating that the submitted documents uniquely identify the sample with the assigned serial number

After checking the conformity of the sample to the submitted document package, the test laboratory shall include in the test report a copy of the Certificate of Sample Identification and a statement that the verification of the sample has been completed.

13.1 Document package related to transformer type

The manufacturer shall maintain the design and manufacturing records for the sample, which are identifiable in the document package.

13.1.1 Requirements of the document package

For the purpose of correlating the design and manufacturing records of the sample, the manufacturer shall submit, if applicable, but not limited to, the following documents to the test laboratory:

a) Data on type identification:
    1) Manufacturer's name
    2) Model type and ratings

   3) Serial number
   4) Factory work order number for the manufacturing of the sample
b) Drawings related to the transformer type:
   1) Outline drawing showing the dimensions, mass, and description
   2) Main nameplate and other rating plates
   3) Schematic diagram
   4) Drawing of the terminal cabinet showing the layout of the secondary terminals
   5) Drawing of the insulators
   6) Information on the pressure relief device
   7) Secondary protective devices on the secondary terminals
c) References to identify the following design documents and specifications:
   1) Winding specifications for different windings
   2) Engineering calculation report
   3) Core specifications
   4) Major insulation plan
   5) Bill of materials showing the first-level assemblies
   6) Cross-sectional view of the unit assembly
d) Information on the manufacturing of the sample:
   1) List of manufacturing procedures
   2) Quality records, i.e., inspection and test records

The document package shall bear a unique document reference number, which shall be included in the Certificate of Sample Identification.

Annex A

(normative)

Test code

A.1 Temperature rise test

Temperature rise tests shall be carried out in an area that is as free from drafts as practicable.

NOTE—In general, this condition is met when the air velocity does not exceed 0.5 m/s.

A.1.1 Measurement of the ambient and top tank cover temperatures

As a minimum, three thermometers or thermocouples shall be used for the measurement of the ambient temperature. They shall be distributed around the periphery of the transformer as described in 8.7.2 of the IEEE Std C57.13-1993 at a horizontal distance of approximately 1.0 m from the transformer. They shall be placed, in practice, in non-metallic containers filled with approximately one half-liter of oil.

For oil-immersed transformers, the temperature of the tank cover or the metallic bellows shall be measured with a thermocouple. A second thermocouple shall be used to determine the temperature of the external surface of the tank.

For gas-filled transformers, the temperature of the tank cover shall be measured with a thermocouple.

A.1.2 Measurement of the temperature rise

The temperature rise measurements shall be performed as described in 8.7.3 of IEEE Std C57.13-1993. The ultimate average temperature rise for the winding shall be determined with the resistance method. Other methods shall be permitted only if it is impracticable to use the resistance method.

A shutdown of five minutes or less is allowed for every four hours of the test in order to determine the progress of the test.

The transformer shall be considered in thermal equilibrium with the ambient air if the following conditions are met:

a) When the duration of the test is equal to or longer than five times the thermal time constant of the transformer,[33]
b) When all three consecutive sets of temperature rise readings (difference between the temperature of the tank cover and the average ambient temperature) taken, without shutdown, at intervals of no less than 30 minutes, show the change of temperature rise is equal to or less than 1 °C. When shutdowns are necessary for the determination of the temperature rises for the windings, the two consecutive sets of temperature rise readings shall not show a difference of more than 1 °C.

NOTE—A non-contact device (e.g., an infrared temperature measuring device) can be used for temperature measurements, provided it is calibrated for the emissivity of the tank cover.

[33]Before the test, the manufacturer shall estimate the thermal time constant of the test object. This estimation may be based on the results of the previous test on similar design or calculations. The thermal time constant can be accurately determined from the temperature rise curve obtained with several shutdowns during the course of the test.

A.1.3 Requirements of the bus connection for current transformers

The bus that connects to the primary terminals of the transformer shall extend not less than 1.0 m beyond the terminals. The temperature of the bus 1.0 m from the transformer, during the test, shall be within 5 °C of that of the terminals.

A.2 Sealing system test for gas-filled instrument transformers

The sealing system test shall be conducted on the transformer with the sealing system completely installed and filled with the same gas mixture as intended in service. The gas pressure shall be properly adjusted. The transformer shall be set up as in service with the possible exception of positioning because of the physical limitation of the environmental chamber.

A.2.1 Arrangements of the test setup

The transformer shall be installed in a relatively tight enclosure of a known volume (e.g., plastic tent) within the environmental chamber where the temperature can be controlled for the test range of temperatures, since only the cumulative leakage measurements are to be taken for the determination of leakage-rates. The enclosure shall be designed to allow for the physical dimension changes of the material due to the temperature variations.

Provisions for change of the gas content between tests within the enclosure shall be included. If for some reasons the gas content is too high, it is permissible to reset the gas content of the enclosure by purging and repeat the leakage-rate measurement.

The measuring equipment shall have the minimum accuracy of measuring a leakage-rate of 0.2% / year.

The equipment shall be calibrated before each series of tests by injecting a known quantity of gas mixture into the enclosure.

Fans may be installed in the enclosure in order to get a homogeneous mixture of gas. Extra heaters fitted into the enclosure may be necessary in order to fulfill the required rate of temperature rise of 10 °C/h.

The ambient temperature of the enclosure shall be measured with a minimum of three thermocouples located at approximately 300 mm from the transformer and equally distributed along the height of the transformer. For the lower ambient temperature limit, T_L, a tolerance of ±3 °C is acceptable.

A.2.2 Test procedure

The test shall be performed as follows:

a) The leakage-rate at ambient temperature 20 °C (±5 °C) shall be measured.
b) The ambient temperature of the enclosure shall be decreased to the appropriate lower limit of the ambient temperature, T_L (±3 °C), in accordance with the operating range of temperature for the transformer. An initial leakage-rate shall be taken at T_L (±3 °C).
c) The transformer shall be left at the lower ambient temperature limit, T_L (±3 °C), for a minimum period of 24 h throughout which the difference between the temperature at the top and at the bottom of the transformer shall be less than 5 °C.
d) A final leakage-rate shall be measured at T_L (±3 °C) at the end of the period.
e) The ambient temperature shall then be returned to the normal room ambient temperature at an average rate of 10 °C/h.

f) After the transformer has stabilized at the normal room ambient air temperature 20 °C (±5 °C), the leakage-rate shall be measured.

A.3 Endurance chopped-wave test

A.3.1 Sequence of the test program

The endurance chopped-wave test program shall be performed in the following sequence:

a) Before the test, an oil sample shall be taken from the transformer for dissolved gas content analysis, if the test object is an oil-immersed transformer.
b) As a minimum, 600 chopped-wave tests shall be applied to the transformer at a rate of approximately one impulse per minute.
c) At least 3 days after the test, an oil sample shall be taken from the transformer, if it is oil-immersed, for dissolved gas content analysis.
d) The transformer shall then be dismantled for autopsy.

A.3.2 Requirements of the applied wave

The applied voltage wave shall be a standard 1.2 μs x 50 μs impulse chopped close to the peak. The chopping time, i.e., the time interval from the chopping instant to the zero crossing of the applied voltage, shall be equal to or less than 0.32 μs. A longer chopping time is acceptable providing that the chopping device is located at a distance equal to or less than the total height of the transformer, and that no additional resistance is introduced in series between the transformer and the chopping device as described in 7.2.5 of IEEE Std 4-1995. The voltage shall be measured and recorded in accordance with Clause 7 of IEEE Std 4-1995.

A.3.3 Chopping device

The applied voltage shall be chopped with a suitable device. Because a shorter chopping time than normal is critical for the test, a chopping device made of multiple series of connected sphere gaps shall preferably be used to the rod gap.

A.3.4 Current transformer connections

The impulse voltage shall be applied to the primary winding with all secondary windings short-circuited and grounded through a current sensor for the measurement of the ground current.

A.3.5 Voltage transformer connections

The test voltage shall be applied to the primary terminal, while the neutral terminal shall be grounded through a current sensor. The secondary winding terminals shall be short-circuited and grounded through a separate current sensor for the measurement of the ground current.

A.3.6 Measurement of voltage and current

For each application of the wave, the peak voltage shall be measured with a peak voltmeter. After a series of fifty consecutive tests, oscillograms of the voltage and current(s) shall be taken and compared with earlier tests.

A.3.7 Detection of failure

Any unexplained deviation between the reduced and any full chopped wave detected with the comparison of the two voltage oscillograms up to the time of voltage wave chopping is an indication of a failure or probable change of conditions in the circuit external to the transformer or triggering of protective devices.

Any unusual noise detected within the transformer at the instant of applying the impulse is an indication of a failure.

For the above cases, an investigation should be conducted to determine the causes of the problem.

Any induced voltage recorded in the measuring system during the first 1 or 2 μs shall be disregarded. Due to the difficulties in interpretation, the deviation between the reduced and any full chopped wave after the voltage wave chopping shall be disregarded.

A similar diagnostic procedure shall apply to the oscillograms for the ground current.

Annex B

(informative)

Dielectric tests performed at an altitude of 1000 m or less for instrument transformers designed for installation at altitudes greater than 1000 m

Because of reduced air density, a table of dielectric strength correction factors for altitudes greater than 1000 m is provided in Table 1 of IEEE Std C57.13-1993.

Ideally, in order to verify that the transformers are appropriately designed and manufactured, the voltages to be applied for the dielectric tests, if conducted at an altitude of 1000 m or less, should be in accordance with those in Table 1 of this trial-use standard adjusted with the correction factor for the altitude corresponding to the site.

Such a method necessitates oversizing the internal insulation because of the test level increase. For some designs, this can be accomplished without a substantial cost increase, but for some other designs of instrument transformers, e.g., voltage transformers, this may lead to a significant cost increase.[34]

The insulation withstand capability of high-voltage instrument transformers is a complex matter. In order to have the optimum voltage withstand capability (mainly during wet conditions) for a given insulator, the co-ordination between the external and internal insulation needs to be properly implemented.

Several solutions to this problem are outlined in the list below (which, by no means, is complete):

a) The user may consider specifying that the transformers be dielectric tested to the voltage levels with the appropriate altitude correction factor.
b) The user may consider specifying that the prototype be dielectric tested in a laboratory located at the required operating altitude or higher with the rated test voltages, and the remaining transformers be dielectric tested with the rated insulation levels without considering the altitude correction factor.
c) The user may consider specifying that the manufacturer use an external insulation (or hollow insulator) with proven performance that meets or exceeds the corrected insulation levels, and to submit a report comparing the existing and new internal insulation plans showing the layout of the grading electrodes or rings. A low voltage test should also be agreed upon between the user and manufacturer to verify that the internal insulation is correctly implemented for the transformers.[35] The routine dielectric tests should be performed at the rated voltage levels without the altitude correction.

The choice of one of these solutions may lead to significant additional costs and the matter should be fully discussed and agreed upon between the user and the manufacturer.

The purpose of this annex is:

1) To outline the complexity of the underlying problem, and
2) To encourage discussion whereby a better solution will surface

[34]Under normal conditions, a voltage transformer of nominal system voltage of 245 kV is a single coil design. However, with over-dimensioned insulation, it can be a cascade coil design, which requires much more materials and labor than single coil design.

[35]The low voltage test is for checking voltage distribution along the bushing tube. During the test, the voltages at the grading electrodes or rings can be determined using the capacitive coupling (or pickup) method. It may be one of the two tests suggested below:

I) An applied voltage test at power frequency of a suitable level, which will not likely cause insulation damage

II) A transient voltage test with the use of a recurrent surge generator

Annex C

(informative)

Dielectric tests, oil sampling, and other related measurements in the field

It is recognized that the dielectric tests impose a severe stress on the insulation. If applied frequently, the dielectric test may cause irreparable damage to the transformer. Consultation with the manufacturer regarding the appropriate field dielectric tests is a good measure against undue field problems. Extreme caution shall be exercised during the test.

The standard recommends, in general, that:

a) Field tests of insulation shall not be in excess of 75% of the factory test voltages.
b) DC voltage tests, except the insulation resistance or Megger test, are not recommended for high-voltage instrument transformers.
c) Read the instruction manual provided with the transformers.
d) For gas-filled transformers, after the final gas filling to the proper pressure, a dew-point reading should be taken and recorded.
e) When in doubt, consult with the factory before proceeding with the test.
f) Oil sampling should be performed on very rare occasions, as the quantity of oil in instrument transformers is very limited. It is always a good practice to check with the manufacturer before any oil sampling. This is important because, in addition to the limited volume, special devices and techniques may be necessary to prevent air or moisture ingress into the inside of the transformer. If oil samples are frequently taken, the users are at risk of major insulation failure due to the seriously depleted oil level inside the transformer.

Annex D

(informative)

Internal arc protection for instrument transformers

The working group responsible for the development of this document clarifies its position on the issues of internal arc protection as follows:

a) Since insulation performance is probabilistic in nature, the "technically most probable" fault location conveys no further implication than its literal meaning. Henceforth any internal arc protection scheme is no assurance that the transformers will perform as expected under an internal arc situation.

b) The purpose of including these definitions and tests is

   1) To reflect what some users want at present,

   2) To encourage discussion, whereby a better version will evolve, and

   3) To induce awareness rather than to provide a sense of security, as the idea of internal arc protection is relatively new within the industry.

Annex E

(normative)

Validity of type test reports and guidance for reviewing the design comparison report for the modified design

E.1 Validity of type test reports

The type test report shall remain valid as long as there is no change in the design with respect to the materials, parts, and manufacturing procedures. If there are changes made to the design, the manufacturer shall submit a report comparing the qualified with the modified design to the user. The manufacturer shall provide the user access to the relevant documents for assessing the effects of the design changes to the type test report. The user has the option to request the type test program to be repeated in parts or in its entirety if the user does not accept the submitted document.

E.1.1 Content of the comparison report

The comparison report shall provide the description and data of the materials and components used for both the type tested design and the modified transformer. A comparison of the performance under both test and operating conditions shall be made to demonstrate the favorable effects of the design change. The report shall also recommend appropriate action necessary to qualify the modified design.

E.1.2 Time of notification

The manufacturer shall notify the user when the comparison report will be available at the time he submits the contract documents for approval.

E.1.3 Confidentiality of information

The information provided by the manufacturer shall not be revealed to the third party without the written consent of the manufacturer.

E.2 Guidance of reviewing the comparison report

For reviewing the comparison report on design change, the following is a typical list of critical design parameters. It should be noted the list is by no means complete and varies from one case to another. It should be considered as a reference list.

a) Dielectric test data:
   1) Same or lower test voltage levels
   2) Same dimensions, type, and profile of the insulator
   3) Same dimensions and contour of the primary electrode
   4) Same primary winding
   5) Same internal voltage grading system

6) Same shape and dimensions of the metallic core housing containing the secondary windings. For example, the dielectric tests may be applicable if the secondary windings are located within the same housing for current transformers with different transformation ratios or accuracy classes
7) Same or higher supporting structure
8) Same manufacturing processes

b) Thermal characteristics:
1) Same or lower test current
2) Similar rated frequency: If the test frequency is different (e.g., 50 Hz versus 60 Hz) the results have to be carefully analyzed. It is generally accepted that a test performed at 50 Hz covers the performance of a 60 Hz apparatus provided that the temperature rise values recorded during the test at 50 Hz do not exceed 95% of the temperature rise limit.
3) Same or lower current density in the primary winding
4) Same or lower current density in the secondary windings
5) Same or lower I^2R losses in the primary winding
6) Same or lower I^2R losses in the secondary windings
7) Same or lower dielectric losses
8) Same or lower core losses with the rated secondary loads
9) Same or lower ratio “total losses / insulating fluid volume”
10) Same or lower ratio “total losses / external thermal dissipating surface,” the thermal dissipating surface being the metallic surfaces (top head and bottom tank)
11) Same manufacturing processes

c) Short-circuit performance data:
1) Same or lower test current
2) Same or lower current density in the primary winding
3) Same or lower current density in the secondary windings
4) Same or lower I^2t requirement in the primary winding
5) Same or lower I^2t requirements in the secondary windings
6) For current transformers, same primary conductor length, shape, and material
7) Same mechanical construction (mechanical stiffeners, insulating material shape, and dimensions)
8) Same manufacturing processes

d) Secondary open-circuit withstand capability:
1) Same or lower saturation curve (saturation voltage)
2) Same insulation material used on the conductors used for secondary windings
3) Same or lower voltage between turns and/or layers of the secondary windings
4) Same insulation system used on the conductors for secondary winding as used for the connection between the terminal box and windings
5) Same secondary winding bushings
6) Same voltage limiting devices

Annex F

(informative)

Rated voltage factor

The term is defined in 3.5 of this standard and used in both 9.3 and 10.8.3 to ensure that the transformers are appropriately tested. A set of proposed values for the rated voltage factor is provided in Table F.1 for reference only.

Table F.1—Proposed values of rated voltage factors

Rated voltage factor	Rated time
1.1	Continuous
1.5	30 s
1.9	30 s

Annex G

(informative)

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