



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

IEEE Power and Energy Society

Developed by the
Transformers Committee

IEEE Std C57.13.5™-2019
(Revision of IEEE Std C57.13.5-2009)



STANDARDS

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

Sponsored by the

Transformers Committee
of the
IEEE Power and Energy Society

Approved 7 November 2019

IEEE SA Standards Board

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Abstract: 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 are discussed in this standard. This standard is intended for use as a supplement to IEEE Std C57.13™-2016 and as a basis for performance and safety of equipment. Test sequences, criteria, methods, and documentation for the test are also described.

Keywords: design test, high-voltage, IEEE C57.13.5™, instrument transformers, routine tests, special tests, test criteria, test method, test requirements, test sequence

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Introduction

This introduction is not part of IEEE Std C57.13.5-2019, IEEE Standard for Performance and Test Requirements for Instrument Transformers of a Nominal System Voltage of 115 kV and Above.

The mission of C57.13.5™ Test Requirements for Instrument Transformers of a Nominal System Voltage of 115 kV and Above Working Group 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.

The first edition was published in 2003. The second edition was published in 2009.

The main changes introduced in this revision are:

- Update of references
- New definitions have been added for gas-filled instrument transformers
- Wind speed has been decreased from 160 km/h to 40 m/s (144 km/h)
- Partial discharge levels (type test vs routine test) have been combined in a single table
- Requirements of for density monitoring for gas-filled instrument transformers have been added
- Pressure routine and type tests have been added for enclosures used on gas-filled instrument transformers
- Addition of a rated arc proof current
- Reference to R10 series has been added for the arc proof current
- Additional identification for current transformers having an anti-remanence gap in the magnetic circuit
- Addition of a remanence factor test
- RIV performance have been restricted to rated voltages equal to or higher than 245 kV
- RIV test levels have been adjusted to $I_1 U_m / \sqrt{3}$
- Allowable gas leakage rates at low temperature have been reduced
- Maximum acetylene concentration has been decreased to non-detectable
- Ambient air temperature range during testing has been clarified
- Cumulative test methodology is now prescribed instead of sniffing for gas leakage measurement
- Correction of the equation in the assumption for [Figure 5](#) for the accuracy and excitation current measurements
- Clarifications added to the short-time mechanical test for current transformers and voltage transformers
- Clarifications added for the internal arc test
- Clarification added for the electrical endurance test
- Revision of the temperature rise test methodology
- Additional requirements regarding the number of reduced lightning impulse
- Clarifications have been added regarding chopped lightning impulse tests
- Addition of an [Annex D](#) regarding gas tightness measurement

Contents

1. Overview.....	11
1.1 Scope.....	11
1.2 Purpose.....	11
1.3 Word usage.....	11
2. Normative references	12
3. Definitions.....	12
4. General.....	14
4.1 Insulation requirements	14
4.2 Mineral oil requirements	18
4.3 Requirements for accuracy and accuracy calibration systems	18
4.4 Mechanical performance requirements	18
4.5 Thermal performance requirements.....	20
4.6 Ground shield requirements	20
4.7 Dissolved gas and water content requirements for new oil-immersed transformers	20
4.8 Endurance capability for fast high voltage transient	21
4.9 Performance of internal arc protection	21
4.10 Identification of test sample in the type test report.....	21
4.11 Secondary short-circuit capability for voltage transformers	21
4.12 Relaying current transformers having an anti-remanence gap	22
4.13 Gas filling pressure and gas monitoring for gas-filled instrument transformers.....	22
5. Test conditions.....	22
6. Classification of tests.....	23
6.1 Routine tests and test sequences	23
6.2 Type tests and test sequences	26
6.3 Special tests	29
7. Routine test procedures (applicable to instrument transformers)	29
7.1 Verification of terminal markings and polarity	29
7.2 Capacitance and dissipation factor test	29
7.3 Applied voltage test on secondary windings.....	29
7.4 Insulation resistance test on windings.....	30
7.5 Lightning impulse voltage test on the primary winding	30
7.6 Power frequency voltage withstand test	31
7.7 Partial discharge test.....	31
7.8 Dissolved gas and water content analysis for oil-immersed transformers (of a nominal system voltage of 345 kV and above)	32
7.9 Sealing test	32
7.10 Ground shield check	32
7.11 Tests on the mineral oil	33
7.12 Inspection and routine pressure test for enclosure of gas-filled instrument transformers.....	33
8. Routine test procedures (applicable to current transformers)	33
8.1 Inter-turn over-voltage test	33
8.2 Accuracy test for the metering rated current transformers	34
8.3 Resistance measurement of relaying rated secondary windings	34
8.4 Performance characteristics of relaying current transformers	35
9. Routine test procedures (applicable to voltage transformers).....	36

9.1 Applied voltage test on the neutral terminal.....	36
9.2 Accuracy test	36
9.3 Excitation characteristics with respect to rated voltage factor	36
9.4 Resistance measurement of windings.....	37
10. Type test procedures (applicable to instrument transformers)	37
10.1 Dissolved gas and water content analysis	37
10.2 Mechanical test.....	37
10.3 Lightning impulse voltage test on the primary winding.....	38
10.4 Switching impulse voltage test on the primary winding – wet.....	39
10.5 External radio influence voltage (RIV) test	40
10.6 Power frequency voltage withstand test – wet	40
10.7 Power frequency voltage withstand/partial discharge test - dry.....	40
10.8 Temperature rise test.....	41
10.9 Short-time mechanical and thermal rating test.....	43
10.10 Accuracy performance test	44
10.11 Creepage distance measurement.....	44
10.12 Leakage test at low temperature for gas-filled instrument transformers	45
10.13 Burst test on enclosure for gas-filled instrument transformers.....	45
11. Type test procedure (applicable to current transformers).....	45
11.1 Secondary open-circuit voltage withstand test.....	45
12. Special test procedures	46
12.1 Endurance chopped wave test.....	46
12.2 Internal arc test	47
12.3 Seismic qualification	48
13. Identification of test sample in the type test report.....	48
13.1 Document package related to transformer type	49
Annex A (normative) Test code	50
Annex B (normative) Validity of type test reports and guidance for reviewing the design comparison report for the modified design	54
Annex C (normative) Current transformers used for the detection of unbalance current of capacitor banks ..	56
Annex D (normative) Gas tightness	67
Annex E (informative) Dielectric tests performed at an altitude of 1000 m or less for instrument transformers designed for installation at altitudes greater than 1000 m	72
Annex F (informative) Dielectric tests, oil sampling, and other related measurements in the field	73
Annex G (informative) Internal arc protection for instrument transformers.....	74
Annex H (informative) Rated voltage factor	75
Annex I (informative) Current transformers having transient performance requirements.....	76
Annex J (informative) Electrical endurance test, explanatory note	77
Annex K (informative) Bibliography	78

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

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1. Overview

1.1 Scope

This standard is intended for use as a supplement to IEEE Std C57.13™-2016 ^{8¹} and as a basis for performance and safety of equipment.¹ It also describes test sequences, criteria, methods, and documentation for tests. This standard applies to 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.

1.2 Purpose

The purpose of this standard is to supplement the IEEE Std C57.13-2016 ~~2008~~, with specific requirements to 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~~ applications.

¹Information on ~~reference~~ [references](#) can be found in Clause 2.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (shall equals is required to).^{2, 3}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (should equals is recommended that).

The word *may* is used to indicate a course of action permissible within the limits of the standard (may equals is permitted to).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (can equals is able to).

2. Normative references

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

ASCE 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures.⁴

ASTM D1275-~~06~~, Standard Test Method for Corrosive Sulfur in Electrical Insulating Liquids.⁵ ~~Oil.~~²

²The use of the word *must* is deprecated and shall not be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

³The use of *will* is deprecated and shall not be used when stating mandatory requirements, *will* is only used in statements of fact.

⁴ASCE publications are available from the American Society of Civil Engineers (<http://www.asce.org>).

⁵²ASTM publications are available from the American Society for Testing and Materials ~~ASTM Customer Services, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428-2959 USA,~~ (<http://www.astm.org>).

IEC 60270:~~2000~~, High-Voltage Test Techniques—Partial discharge measurements.^{6 3}

[IEC 61869-2:2012, Instrument Transformers—Part 2: Additional Requirements for Current Transformers.](#)

IEEE Std C57.13TM-~~2016~~ ~~2008~~, IEEE Standard Requirements for Instrument Transformers.^{7 8}

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

IEEE Std C57.106TM-~~2015~~ ~~2006~~, IEEE Guide for Acceptance and Maintenance of Insulating [Mineral Oil](#) in Equipment.

IEEE Std C62.11TM ~~2005~~, IEEE Standard for Metal-Oxide Surge Arresters for AC Power circuits (>1 kV).

IEEE Std 4TM-~~2013~~ ~~1995~~, IEEE Standard ~~Techniques~~ for High-Voltage Testing [Techniques](#).⁴

IEEE Std 693TM ~~2005~~, IEEE Recommended Practices for Seismic Design [of](#) ~~for~~ Substations.

NEMA ~~Standards Publication No-107-1987~~, Methods of Measurement of Radio Influence Voltage (RIV) of High Voltage Apparatus.^{9 5}

^{6 3} IEC publications are available from the ~~Sales Department of the~~ International Electrotechnical Commission, ~~Case Postale 131, 3 rue de Varembe, CH 1211, Geneve 20, Switzerland/Suisse,~~ (<https://www.iec.ch>) [and the American National Standards Institute](#) (<https://www.ansi.org/>).

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^{9 5} NEMA publications are available from the ~~Sales Department,~~ National Electrical Manufacturers Association, ~~1300 North 17th Street, Suite 1847, Rosslyn, VA, 22209, USA,~~ (<http://www.nema.org/>).

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary* ~~Online: Glossary of Terms & Definitions~~ should be consulted ~~referenced~~ for terms not defined in this clause.^{10 6}

alarm pressure (or density) for gas-filled instrument transformers: Pressure (Pa), referred to the standard atmospheric air conditions of +20 °C and 101.3 kPa (or density), which may be expressed in relative or absolute terms, at which a monitoring signal is provided.

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.

class I instrument transformer: An instrument transformer that is constructed and tested in accordance with IEEE Std C57.13-2016.

class II instrument transformer: An instrument transformer rated 115 kV and above, with capacitive insulation, and which is constructed and tested in accordance with IEEE Std C57.13.5 supplemented with requirements of IEEE Std C57.13-2016.

design pressure (of a pressurized gas enclosure): Pressure used to determine the thickness of an enclosure. It is, at least, the upper limit of the gas pressure reached within the enclosure when the instrument transformer is subjected to the maximum ambient air temperature increased by the gas temperature rise due to the flow of rated current and the losses caused by the rated voltage.

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 height of the transformer and the diameter of the transformer.

^{10 6} ~~The IEEE Standards Dictionary~~ ~~Online: Glossary of Terms & Definitions~~ is available at: <http://dictionary.ieee.org/>.

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 ~~Internal arc protection class I and Internal arc protection Class II~~ regarding the classification of internal arc protection apply only to the test conditions specified in this standard. The instrument transformers may have different performance during an in-service internal arc fault. Refer to Annex [G 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 [and protective cover, if applicable](#)) provided with the [transformer](#).¹¹ ~~transformers.~~⁷

[minimum functional pressure \(or density\) for gas-filled instrument transformers:](#) Pressure (Pa), referred to the standard atmospheric air conditions of +20 °C and 101.3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of the instrument transformer are maintained.

prescribed extinction voltage: The lowest line-to-ground voltage required for the transformer at which the partial discharge is determined to exist if the reference [level](#) ~~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. The reference partial discharge [level](#) ~~intensity~~ for the transformers covered in this standard is 10 pC.

[rated arc proof current:](#) Maximum current for which the internal arc classification applies.

[rated filling pressure \(or density\) for gas-filled instrument transformers:](#) Pressure (in Pa), referred to the standard atmospheric air conditions of +20 °C and 101.3 kPa (or density), which may be expressed in relative or absolute terms, to which the instrument transformer is filled before being put into service.

¹¹ ⁷ Notes in text, tables, and figures [of a standard](#) are given for information only and do not contain requirements needed to implement this standard.

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 [H](#) ~~F~~ for additional information.

terminals: Conductive element belonging to the instrument transformer provided for connecting that instrument transformer to one or more external conductors. Terminals are normally connected to one or more conductors by means of connectors, [which](#) ~~that~~ are generally not considered to be part of the instrument transformer itself.

thermal current rating factor: A multiplier applied to the rated primary and secondary current to derive the maximum current that can be carried continuously without exceeding either the limiting temperature rises or the accuracy class limitation.

4. General

For ~~the~~ performance and safety, [class 2](#) ~~the~~ instrument transformers shall comply with IEEE Std C57.13-[2016](#) ~~2008~~, supplemented with the requirements provided in this clause. If any conflicts or inconsistencies exist between IEEE Std C57.13-[2016](#) ~~2008~~ and this standard, the clauses in this standard shall take precedence.

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.

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

NOTE 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 and dielectric test levels

Nominal system voltage (rms) (line-to-line) (kV)	Maximum system voltage (rms) (line-to-line) (kV)	Lightning impulse voltage (peak) (kV)		Switching impulse voltage (peak) (kV)	Power frequency withstand voltage ^b (rms) (line-to-ground) (kV)	
		Full wave	Chopped wave ^a		Dry	Wet
115	123	550	630	—	230	230
138	145	650	750	—	275	275
161	170	750	865	—	325	325
230	245	900	1035	—	395	395
		1050	1210	—	460	460
345	362	1175	1350	950	510	—
		1300	1500	975	575	—
500	550	1550	1785	1175	680	—
		1800	2070	1300	830	—
765	800	2100	2420	1550	975	—

(New)

^aThe minimum time to chopping shall be 3 μ s.

^bThe duration for the power frequency voltage withstand test shall be in accordance with 4.1.8 for both dry and wet test conditions.

4.1.2 Capacitance and dissipation factor requirements

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

- 10 kV_(rms)^{12 8}
- Maximum rated voltage

The test shall be performed before and after the dielectric tests. The increase of capacitance measured after [dielectric tests](#) 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 [and solid-insulation](#) transformers:
 - 1) The dissipation factor shall be 0.5% maximum at a reference ambient temperature of 20 °C.
 - 2) The absolute increase of the dissipation factor value measured after [dielectric tests into](#) ~~compared with~~ the value measured before the dielectric tests shall be less than 0.1%.
- b) For gas-filled transformers^{13 9}
 - 1) The dissipation factor shall be 0.15% maximum at a reference ambient temperature of 20 °C.
 - 2) The absolute increase of the dissipation factor value measured after [dielectric tests to](#) ~~compared with~~ the value measured before the dielectric tests shall be less than 0.03%.

^{12 8} The measurement at 10 kV is optional as the values are useful as a reference for commissioning.

^{13 9} As the inherent capacitance of gas-filled instrument transformers is very low (in the range of 100 pF to 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.

4.1.3 Creepage distance requirements

The following minimum creep values shown in Table 2 are based on the voltage across the insulating distance. For the instrument transformers rated 115 kV and above, the voltage shall be the nominal line-to-ground kV rating. These values may need to be adjusted for factors such as shape, number of sheds, and bushing inclination.

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 distances as a function of nominal phase-to-ground
system voltage distance**

Contamination	Creep distance
Light	28 mm/kV
Medium	35 mm/kV
Heavy	44 mm/kV
Extra heavy	54 mm/kV or greater

(New)

Nominal system voltage (rms) kV	Maximum system voltage (rms) kV	Minimum creepage distance mm	
		(Light pollution)	(Heavy pollution)
115	121	1860	2920
138	145	2235	3510
161	169	2605	4090
230	242	3720	5845
345	362	5580	8765
500	550	8085	12 705
765	800	12 370	19 435

(Deleted)

~~NOTE 1—~~The definitions of [contamination](#) ~~light and heavy pollution~~ levels are provided in IEEE C57.19.100™ [B16].¹⁴ ~~Std C57.19.00™ 1995 [B17]. For medium and extra heavy pollution levels, additional information regarding creepage distances can also be found in IEEE Std C57.100™ 1995.~~

~~NOTE 2—~~The creepage distance for composite insulator with silicone rubber sheds has not been established. This standard recommends the use of the same creepage distance as that for the porcelain insulator.

[Table 3 provides examples of creepage distances as a function of nominal system voltage and level of contamination.](#)

[Table 3—Examples of creepage distances](#)

Nominal system voltage (rms) (kV)	Maximum system voltage (rms) (kV)	Minimum creepage distance (mm)	
		Light contamination	Heavy contamination
115	123	1860	2920
138	145	2235	3510
161	170	2605	4090
230	245	3720	5845
345	362	5580	8765
500	550	8085	12 705
765	800	12 370	19 435

[\(New\)](#)

[NOTE—For medium and extra heavy contamination levels, additional information regarding creepage distances can also be found in IEEE C57.19.100 \[B16\].](#)

4.1.4 External radio influence voltage (RIV) requirements

The maximum external ~~radio influence voltage (RIV)~~ of the instrument transformer shall be in accordance with Table ~~4 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](#) ~~part~~ of the transformer, shall not be used for the test.

¹⁴[The numbers in brackets correspond to those of the bibliography in Annex K.](#)

Table ~~4 3~~—External ~~radio influence voltage (RIV)~~

Nominal system voltage (line-to-line) (rms) (kV)	Maximum system voltage (line-to-line) (rms) (kV)	Radio influence test voltage (line-to-ground) (rms) (kV)	Maximum radio influence voltage (μ V) ^a
230	245	156	250
345	362	230	250
500	550	349	350
765	800	508	500

(New)

Nominal system voltage (line-to-line) (rms) kV	Maximum system voltage (line-to-line) (rms) kV	Radio influence test voltage (line-to-ground) (rms) kV	Maximum radio influence voltage ¹⁰ μ V
115	121	71	200
138	145	84	200
161	169	98	200
230	242	142	250
345	362	209	250
500	550	303	350
765	800	462	500

(Deleted)

^{a 40} The background noise level shall not be higher than half the maximum [radio influence voltage \(RIV\)](#).

4.1.5 ~~Routine~~ partial discharge test

The partial discharge [level intensity](#) measured at the voltage corresponding to the prescribed extinction voltage level as provided in Table ~~5 4~~ shall be less than or equal to the reference [level intensity](#) of 10 pC. The measuring method shall be in accordance with IEC 60270:~~2000~~.

The partial discharge test shall be carried out subsequent¹⁴ to the power frequency voltage withstand test as described in 7.7 (routine test) or in 10.7 (type test).¹⁵

The transformer shall withstand, for an appropriate duration in accordance with 4.1.8, the pre-stress voltage provided in Table 5 4 before the partial discharge is measured.

Table 5— ~~Routine~~ Partial discharge test voltages ~~tests voltage~~

Nominal system voltage (rms) (line-to-line) (kV)	Maximum system voltage (rms) (line-to-line) (kV)	Type test levels		Routine test levels	
		Pre-stress voltage (rms) (line-to-ground) (kV)	Prescribed extinction voltage (rms) (line-to-ground) (kV)	Pre-stress voltage (rms) (line-to-ground) (kV)	Prescribed extinction voltage (rms) (line-to-ground) (kV)
115	123	230	123	185	123
138	145	275	145	220	145
161	170	325	170	260	170
230	245	395 ^a	245	315 ^a	245
		460		370	
345	362	510 ^a	362	410 ^a	300 ^b
		575		460	
500	550	680 ^a	550	545 ^a	435 ^b
		830		665	
765	800	975	800	780	665 ^b

(New)

^aThe values shown are for the reduced insulation levels in reference to Table 1.

^bThe standard recognizes the difficulties of partial discharge measurement at these voltage levels in the industrial environments with high level of background noise. The problem is aggravated if the test laboratories are undersized. Sometimes extra-high-voltage test services with specialized capabilities are required. For the transformers of these voltage ratings, therefore, the prescribed extinction voltages are reduced to 1.5 times the nominal system voltages in order to allow the test to be performed in manufacturers' laboratories. The reduced voltage levels are considered still acceptable since the ground fault factor for a system with a grounded or effectively grounded neutral does not exceed 1.4.

¹⁵ ¹⁴ An exception case is under the situation of repeating the partial discharge test after the sealing test during which dry air is in contact with the oil of the transformer.

Nominal system voltage (rms) (line-to-line) kV	Maximum system voltage (rms) (line-to-line) kV	Pre-stress voltage (rms) (line-to-ground) kV	Prescribed extinction voltage (rms) (line-to-ground) kV
115	121	185	121
138	145	220	145
161	169	260	169
230	242	315 ^a	242
		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 in the industrial environments with high level of background noise. The problem is aggravated if the test laboratories are undersized. Sometimes extra-high-voltage test services with specialized capabilities are required. For the transformers of these voltage ratings, therefore, the prescribed extinction voltages are reduced to 1.5 times the rated voltages in order to allow the test to be performed in manufacturers' laboratories. The reduced voltage levels are considered still acceptable since the ground fault factor for a system with a grounded or effectively grounded neutral does not exceed 1.4.			

(Deleted)

4.1.6 Insulation resistance requirements

The insulation resistances between individual winding and ground and between windings shall be measured at a voltage not less than 1.0 kV (dc). 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 the 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 shown~~ in Equation (1):

$$Time(s) = \frac{7200}{TestFrequency(Hz)} \quad (1)$$

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.^{16 12} It shall be in accordance with ~~4.2 of~~ IEEE Std C57.106^{TM-2015-2006}. The characteristics of the new processed oil shall be in accordance with 4.1, 4.1.1, 4.1.2, ~~3~~ and 4.1.3 ~~4 of that standard IEEE Std C57.106-2006~~.

In addition, it shall be demonstrated the oil is non-corrosive in accordance with the extended ASTM D1275 Method B test.

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

^{16 12} 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.

4.3 Requirements for accuracy and accuracy calibration systems

Requirement for accuracy measuring systems and accuracy system calibration shall comply with 8.1.1 of IEEE Std C57.13-2016.

~~The accuracy performance shall be in accordance with the requirements of IEEE Std C57.13-2008.~~

~~Accuracy performance for all transformers shall be determined using calibration techniques and methods having an inherent accuracy of at least 4 times better than the maximum guaranteed accuracy for the ratio and ± 2 minutes for phase angle.~~

~~The test burdens shall be in accordance with Table 9 and Table 15 of IEEE Std C57.13-2008 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 calibration interval shall be five years for non-electronic equipment and one year for electronic devices, unless specified otherwise by the measuring equipment manufacturer.

4.4 Mechanical performance requirements

All instrument transformers shall comply with the following 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 IEEE Std C57.13-2016 ~~2008~~.

4.4.1.1 Oil-immersed instrument transformers

The manufacturers shall review the typical examples of sealing tests outlined in Table 6-5 and adopt the one most suitable for their transformers. Other test methods could also be fully acceptable.

Table 6-5—Typical examples of 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

(New)

Test	Average oil temperature °C	Internal pressure kPa	Time h
(I)	50	35	24
(II)	50	103	12
(III) ¹³	85	0	12
(IV)	25	35	60
(V)	25	103	24

(Deleted)

^a ~~13~~ standard recommends this procedure for transformers equipped with oil expansion diaphragms or bellows. Other procedures, as shown in the table 5, with application of pressure, for example, ~~(e.g.,~~ by clamping the oil expansion diaphragms or bellows instead of raising the average oil temperature of the transformer to 85 °C, should also be considered acceptable~~).~~

4.4.1.2 Gas-filled instrument transformers

The construction of the tank shall be in accordance with the national standards¹⁴ on enclosures for gas-filled electrical equipment.¹⁷ The manufacturer shall submit the certificate of the tank to the user for approval before the routine tests.

The tightness characteristic of a gas-filled instrument transformer shall be consistent with a minimum maintenance and inspection philosophy.

The tightness of closed pressure systems for gas is specified by the relative leakage rate F_{rel} of the gas-filled instrument transformer.

Standardized value in ambient temperature prevailing in factories (10 °C to 40 °C) is 0.5% per year, for SF₆ and SF₆-N₂ mixtures.

Lower leakage rates can be specified according to national regulations and regional practice. An increased leakage rate at extreme temperatures is acceptable, provided that this rate resets to a value not higher than the maximum permissible value at normal ambient air temperature prevailing in factories. The increased temporary leakage rate shall not exceed the following values (where T_L is the lower limit of the ambient temperature range):

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

~~a) For average ambient temperature (20 °C): 0.5%/year~~

a) For low ambient temperature ($T_L = -5, -10, -15, -25$ and -40 °C): 1.5%/year

~~c) For extra low ambient temperature ($T_L = -40$ °C): 3.0%/year~~

b) For ultra-low ambient temperature ($T_L = -50$ °C): 3 6.0%/year

¹⁷ ¹⁴ Additional informative documentation (Canadian and European Standards) about pressure vessels used in electrical equipment not containing corrosive gas such as oxygen and/or water are listed in Annex K ~~J~~.

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 following non-simultaneous mechanical stresses:

- a) Static terminal loads according to load values shown in Table Z.6
- b) Winds of 40 m/s. The determination of the force due to the wind shall be in accordance with ASCE 7. 160 km/h

NOTE—Wind speed higher than 40 m/s may be specified.

- c) Resulting mechanical stresses produced by an ice coating of 20 mm.
- d) For Horizontal seismic force resulting from a zero-period acceleration of 0.1 g as defined as low-qualification, see level in IEEE Std 693™, 2005

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

Table Z.6—Static terminal loads

Maximum system voltage (kV)	Static terminal load (N)	
	Voltage transformers	Current transformers
≤ 170	1000	2000
245 to 362	1250	2500
≥ 550	1500	4000

NOTE 1—The sum of loads acting in routinely operating conditions should not exceed 50% of the specified terminal load.

NOTE 2—In ~~some sum~~ applications, instrument transformers with through current terminals⁷ should withstand rarely occurring extreme dynamic load conditions such as short-circuits not exceeding 1.4 times the static terminal load.

NOTE 3—For some applications, it may be necessary to establish the resistance to rotation of the primary terminals. The moment to be applied during tests has to be agreed between the manufacturer and purchaser.

4.5 Thermal performance requirements

The limits of observable temperature rise in instrument transformers when tested in accordance with their ratings shall be as given in Table 4 ~~and Table 5~~ of IEEE Std C57.13-~~2016~~ 2008.

[For use at altitudes higher than 1000 m, see 4.4. of IEEE Std C57.13-2016.](#)

~~Terminals for use in air shall be designed so that their maximum operating temperature when tested with their ratings do not exceed the values provided in Table 7.~~

~~**Table 7—Maximum operating temperature of power terminals intended for bolted connection in air**~~

~~Performance~~	~~Bare copper or bare aluminum terminals~~	~~Tin-plated terminals~~	~~Silver-plated terminals~~
~~Maximum operating temperature (°C)~~	~~90~~	~~105~~	~~115~~

~~(Deleted)~~

4.6 Ground shield requirements

The 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 8.

The minimum sensitivity of gas spectrum analyzer shall be in accordance with the last column of [the table 8](#).

Table 8—Dissolved gas and water content for new oil-immersed instrument transformers

Component	Maximum concentration (p.p.m.)	Minimum sensitivity (p.p.m.)
Hydrogen (H ₂)	15.0	2.0
Carbon monoxide (CO)	40.0	5.0
Carbon Dioxide (CO ₂)	200.0	10.0
Methane (CH ₄)	5.0	0.1
Ethylene (C ₂ H ₄)	2.0	0.1
Ethane (C ₂ H ₆)	3.0	0.1
Acetylene (C ₂ H ₂)	Not detectable	0.1
Water (H ₂ O)	10.0	3.0

(New)

Component	Maximum Concentration (p.p.m.)	Minimum Sensitivity (p.p.m.)
Hydrogen H ₂	15.0	3.0
Carbon monoxide CO	40.0	5.0
Methane CH ₄	5.0	0.1
Ethane C ₂ H ₆	2.0	0.1
Ethylene C ₂ H ₄	3.0	0.1
Acetylene C ₂ H ₂	0.5 ¹⁵	0.1
Water H ₂ O	10.0	3.0

(Deleted)

~~NOTE—The values are in reference to Table A-1 of Annex A of IEC 61181: 2007 [B16] with the exception of the concentration for acetylene.~~

~~¹⁵—An acceptable transformer is indicated with the absence of acetylene. However, this standard has made allowances for the residual acetylene present in the oil even after the oil processing.~~

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 [withstand](#) ~~endure~~ the fast high voltage transient stress induced during the operation of the line disconnect switch located in its vicinity. For more information see Annex [I](#).

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

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 Clause 3.

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

[The classification applies at a current level not exceeding the rated arc proof current. For example, the rated arc proof current for a current transformer is a current equal to or lower than its rated short-time current.](#)

[The arc proof current shall be selected from the R10 series. The R10 series comprises the numbers 1 – 1.25 – 1.6 – 2 – 2.5 – 3.15 – 4 – 5 – 6.3 – 8 and their products by \$10^n\$ \(where \$n = 3\$ to 5 for the scope of this standard\).](#)

[The rated arc proof current shall be indicated on the nameplate.](#)

[NOTE—A lower value than the rated short-circuit current \(for current transformers\) may be appropriate when the user's calculation indicates that the rated short-time current is higher than actual short-circuit current.](#)

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 capabilities:

- 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 s, ~~and~~
- b) The primary winding shall also be capable of withstanding both the thermal and mechanical effects resulting from the 1 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-[2016](#) ~~2008~~.

4.12 Relaying current transformers having an anti-remanence gap

Some protection relaying schemes require an anti-remanence gap in the magnetic circuit in order to reduce the core remanence to a value close to zero. Normally, such an anti-remanence gap is decreasing the core remanence to a value less than 10% of the saturation flux.

Presence of an anti-remanence gap shall be indicated on the nameplate. An “R” letter shall be added within the relaying class, for example, CR400.

4.13 Gas filling pressure and gas monitoring for gas-filled instrument transformers

The gas pressure (or density) shall be assigned by the manufacturer. The pressure (or density) of gas is referred to atmospheric conditions of 20 °C at which the gas-filled instrument transformer is filled before being put into service.

In addition to the filling level, the following values have to be assigned by the manufacturer:

— Alarm pressure (or density)

— Minimum functional pressure (or density)

Gas-insulated instrument transformers shall be equipped with a gas density monitoring device. This device shall comprise at least two monitoring contacts, one set to the assigned alarm pressure level and one set to the assigned minimum functional pressure. Additional contacts may be required by the user. For digital gas density monitoring devices, other specific requirements may be applicable.

5. Test conditions

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

- a) The ambient temperature range for tests should generally ~~shall~~ be from 10 ~~0~~ °C through +40 °C with +20 °C as the reference temperature. Some tests may sometimes be performed in outdoor conditions such as the short-circuit and internal arc test.
- b) The transformer shall be ~~in new~~ and in a ~~clean~~ dry condition ~~conditions~~
- 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.
- d) For gas-filled instrument transformers, the gas pressure shall be set, for all electrical tests, unless otherwise stated, at the minimum functional value, which corresponds to the equivalent gas density at 20 °C for which the second alarm level is set.

6. Classification of tests ~~test~~

Tests listed in this standard are classified as routine, ¹⁸ ~~16~~ type, and special tests, which are necessary to verify ~~ensure~~ that the design and construction of the transformer are adequate to comply with the requirements of ~~Clause 4 and~~ IEEE Std C57.13-2016 and Clause 4 of this standard ~~2008~~.

¹⁸ ~~16~~ For reducing the routine test burden to the manufacturer, some tests are performed based on selected samples.

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 and after 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)
- [l\) Inspection and routine pressure test on enclosures for gas-filled instrument transformers \(see 7.12\)](#)

6.1.2 Additional routine tests ~~Routine test~~ applicable to current transformers

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

- a) Inter-turn over-voltage 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 Additional routine tests ~~Routine test~~ applicable to voltage transformers

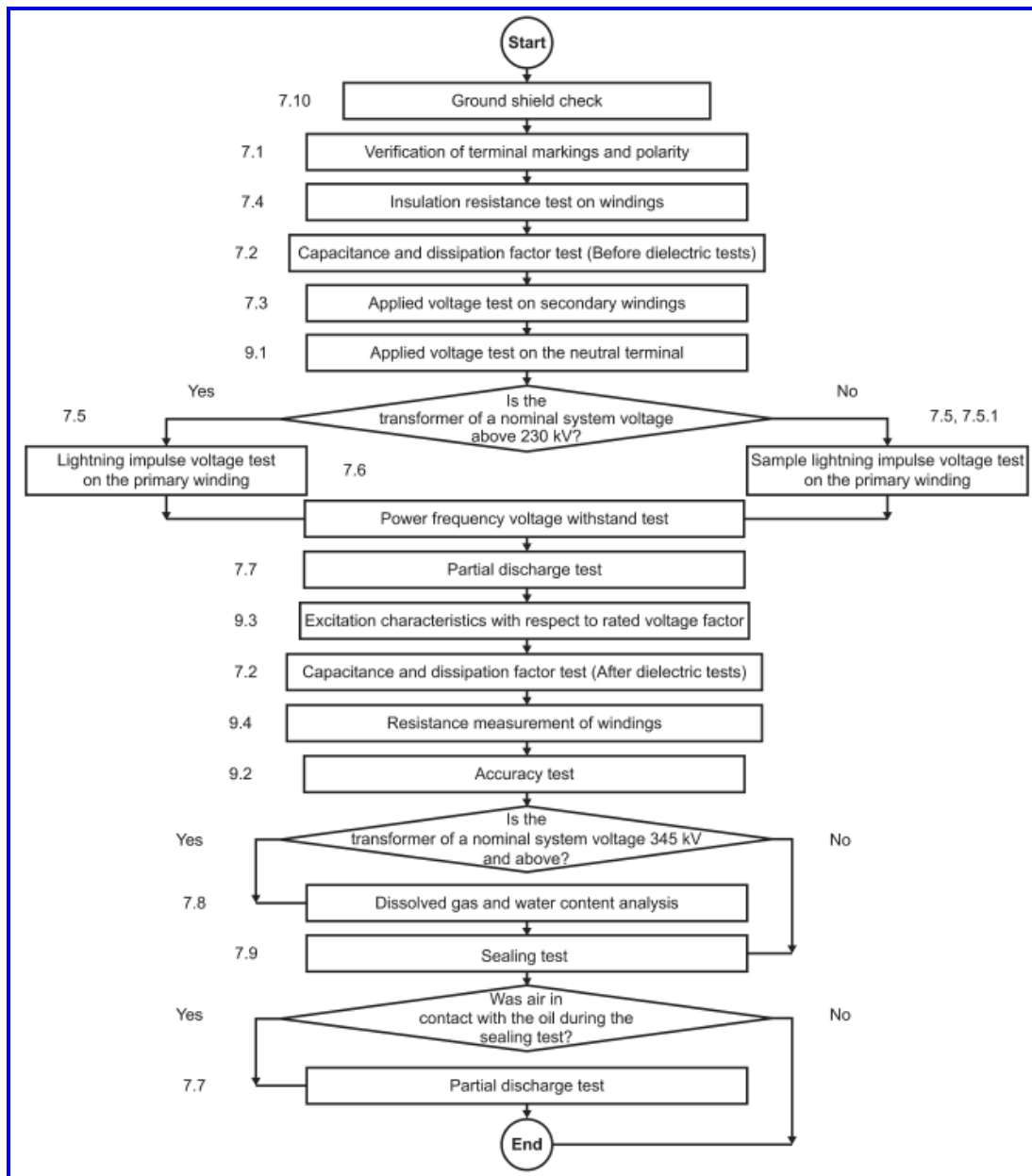
The manufacturer shall perform the following routine tests on each voltage transformer:

- 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)

6.1.4 Sequence of the routine tests

The routine tests should ~~test shall~~ be performed following ~~in~~ the recommended sequence as outlined in Figure 1 and Figure 2.¹⁹

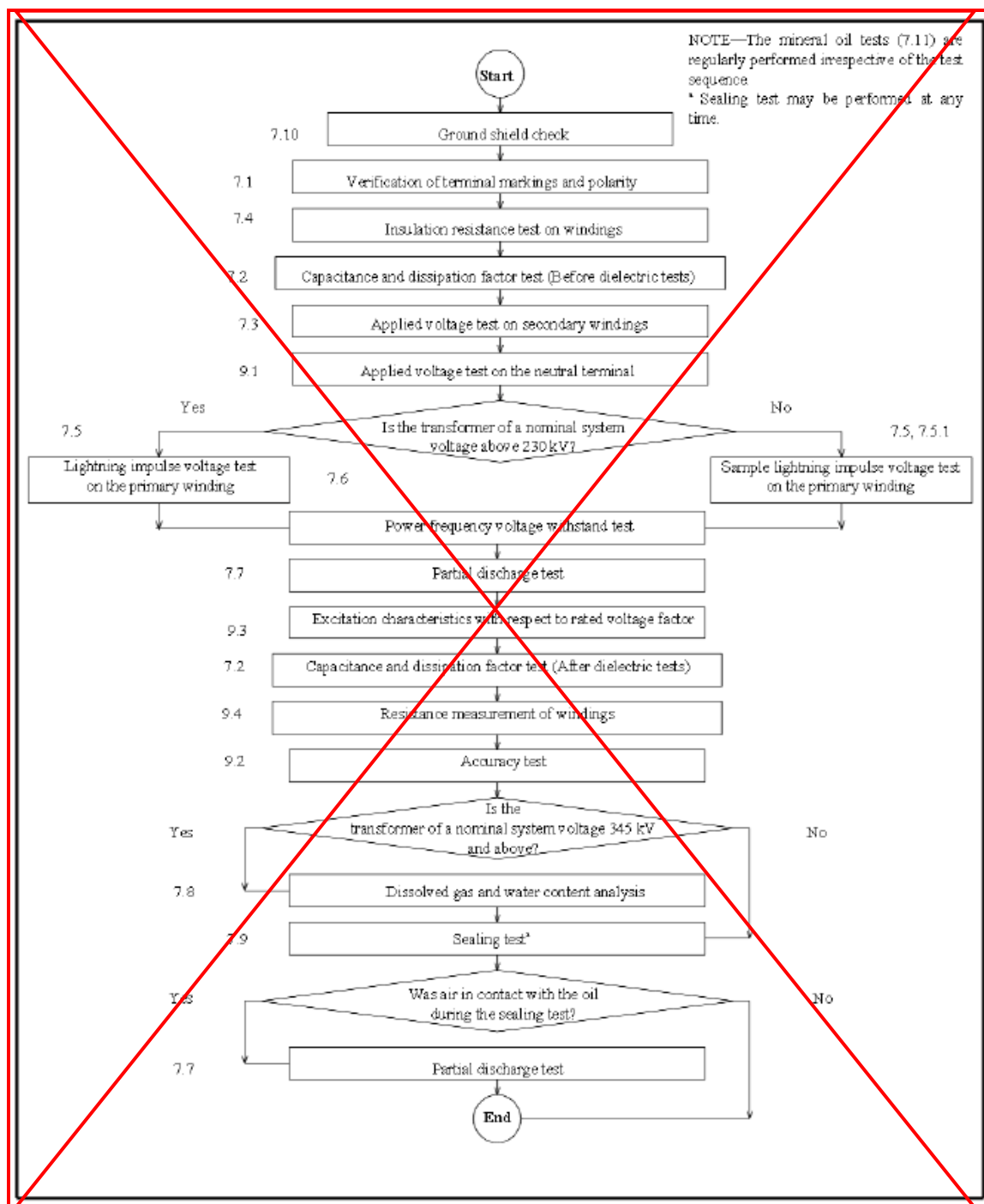
¹⁹ ~~17~~ The numbers next to the boxes are the pertinent clause references.



(New)

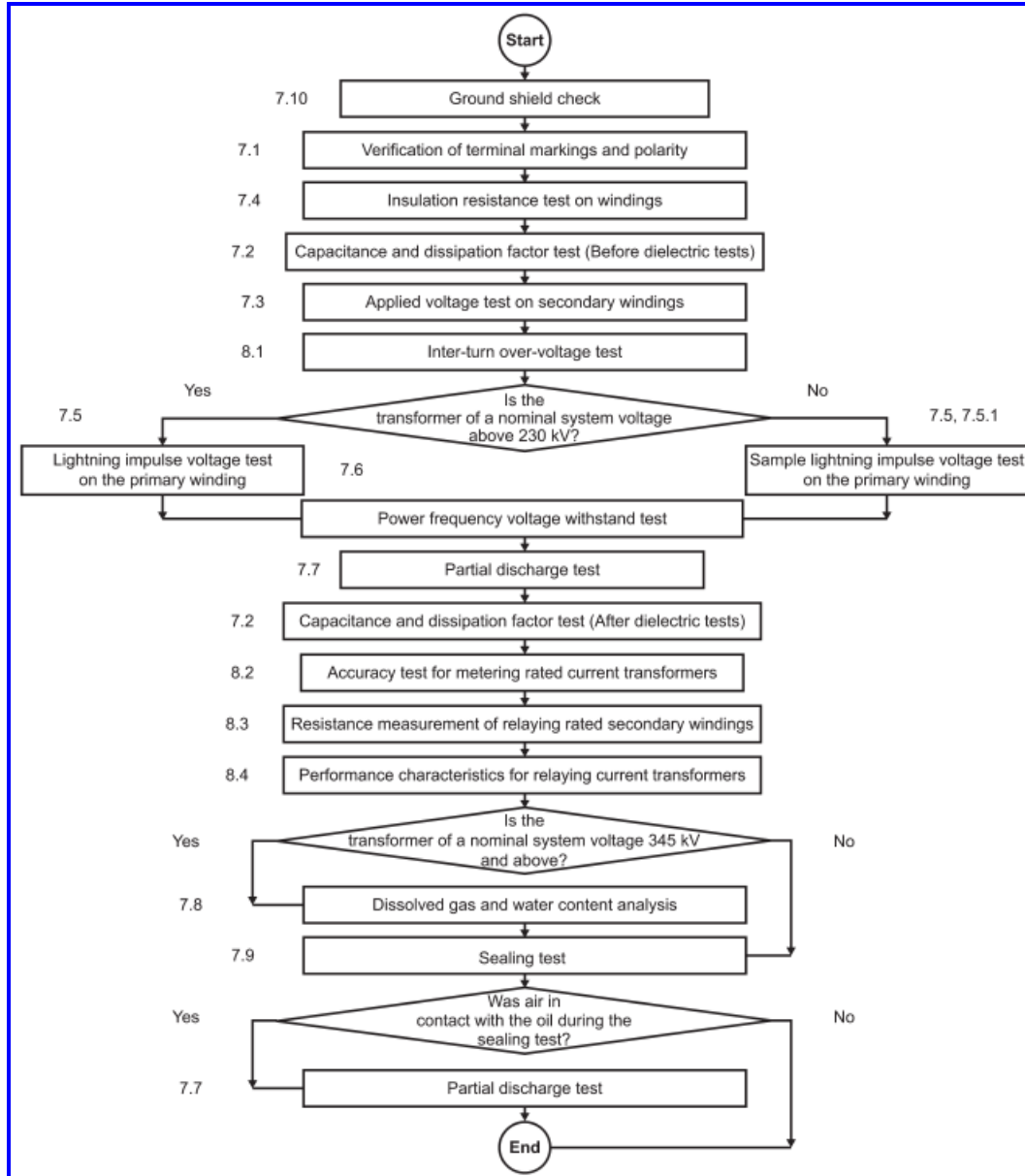
NOTE 1—The mineral oil tests (7.11) are regularly performed irrespective of the test sequence.

NOTE 2—Sealing test may be performed at any time.



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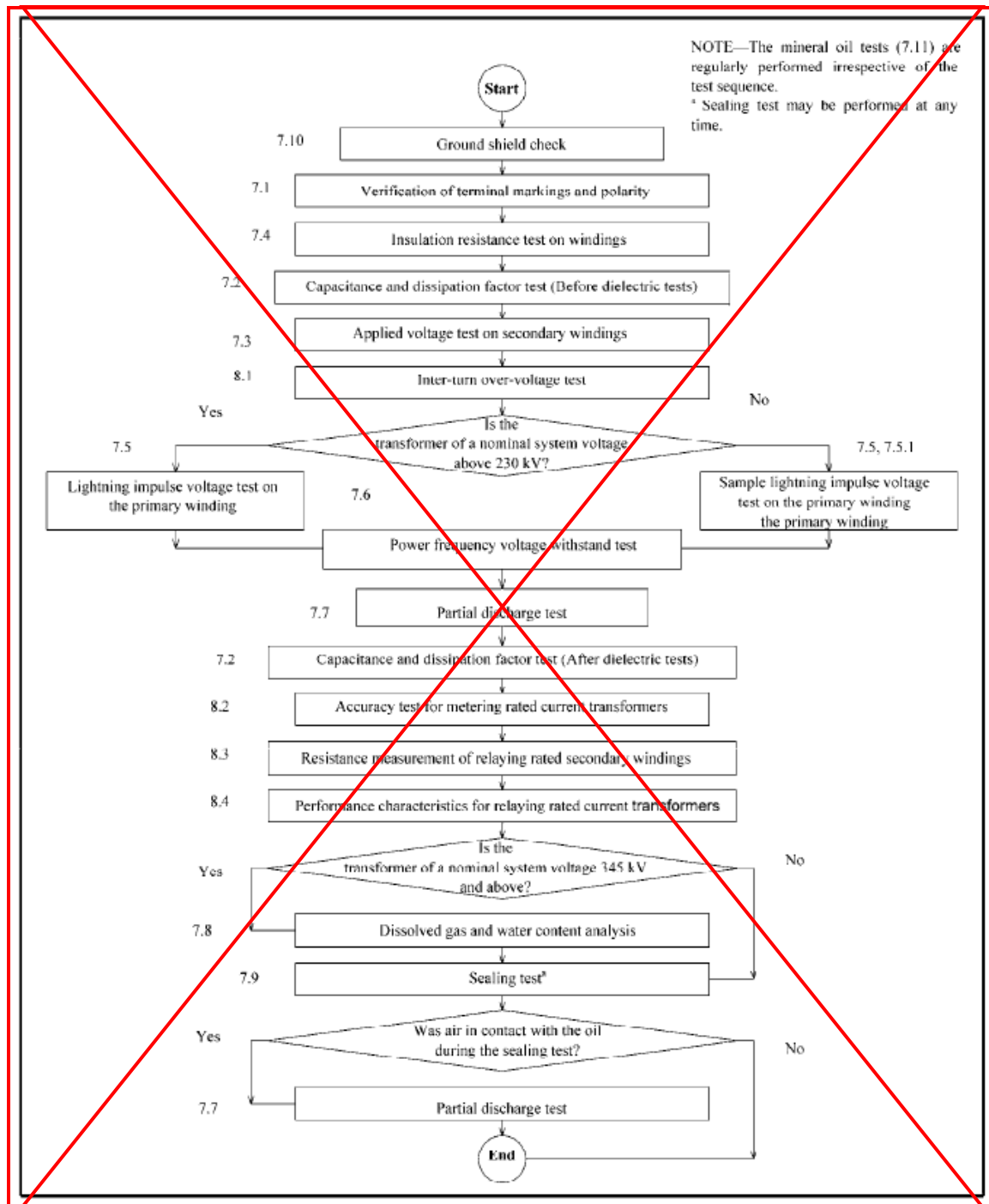
Figure 1—Flowchart of routine tests on voltage transformers¹⁷



(New)

NOTE1—The mineral oil tests (7.11) are regularly performed irrespective of the test sequence.

NOTE 2—Sealing test may be performed at any time.



(Deleted)

Figure 2—Flowchart of routine ~~tests~~ tests on current transformers

For oil-immersed transformers, if dry air or nitrogen is in 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.

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 ~~Clause 4 and IEEE Std C57.13-2016 and Clause 4 of this standard 2008.~~

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 (10.9)
- j) Accuracy performance test (~~see~~-10.10)
- k) Creepage distance measurement (~~see~~-10.11)

- l) [Leakage](#) ~~Sealing system~~ test [at low temperature](#) for gas-filled instrument transformers (~~see~~ 10.12)

m) [Burst test on enclosure for gas-filled instrument transformers \(10.13\)](#)

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 [should](#) ~~shall~~ be performed for each transformer design [following](#) ~~in~~ the [recommended](#) sequence as outlined in Figure 3 and Figure 4.^{[20](#)}

²⁰[The numbers next to the boxes are the pertinent clause references.](#)