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INTERNATIONAL ELECTROTECHNICAL COMMISSION

CURRENT TRANSFORMERS

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by IEC Technical Committee No. 38: Instrument Transformers.

This second edition replaces the first edition of IEC Publication 185 (1966) as well as Amendments No. 1 (1977), No. 2 (1980) and No. 3 (1982).

The text of this standard is based also on the following documents:

Six Months' Rule	Report on Voting	Two Months' Procedure	Report on Voting
38(CO)68	38(CO)70	38(CO)72	38(CO)75

Further information can be found in the relevant Reports on Voting indicated in the table above.

The following IEC publications are quoted in this standard:

Publications Nos. 28 (1925): International Standard of Resistance for Copper.
38 (1983): IEC Standard Voltages.
44-4 (1980): Instrument Transformers, Part 4: Measurement of Partial Discharges.
50(321) (1986): International Electrotechnical Vocabulary (IEV), Chapter 321: Instrument Transformers.
60-1 (1973): High-voltage Test Techniques, Part 1: General Definitions and Test Requirements.
71: Insulation Co-ordination.
85 (1984): Thermal Evaluation and Classification of Electrical Insulation.
507 (1975) (Report): Artificial Pollution Tests on High-voltage Insulators to be Used on A.C. Systems.

CURRENT TRANSFORMERS

CHAPTER I: GENERAL REQUIREMENTS APPLICABLE TO ALL CURRENT TRANSFORMERS

SECTION ONE – GENERAL

1. Scope

This standard applies to newly manufactured current transformers for use with electrical measuring instruments and electrical protective devices at frequencies from 15 Hz to 100 Hz.

Although the requirements relate basically to transformers with separate windings they are also applicable, where appropriate, to auto-transformers.

2. Service conditions

Unless otherwise specified, current transformers shall be suitable for use under the following service conditions:

Note. – The manufacturer should be informed if the conditions, including the conditions under which transformers are to be transported, differ from those specified.

2.1 *Ambient air temperatures*

Maximum	40 °C
Daily mean, not exceeding	30 °C
Minimum, for indoor type transformers	−5 °C
Minimum, for outdoor type transformers	−25 °C

2.2 *Altitude*

Up to 1000 m (3 300 ft) above sea level.

2.3 *Atmospheric conditions*

Atmospheres which are not heavily polluted.

2.4 *System earthing*

1) Isolated neutral system (see definition Sub-clause 3.18).

2) Resonant earthed system (see definition Sub-clause 3.19).

3) Earthed neutral system (see definition Sub-clause 3.21):
   a) Effectively earthed neutral system.
   b) Non-effectively earthed neutral system.

3. Definitions

For the purposes of this standard, the following definitions shall apply.

Some of the definitions agree with or are similar to those of IEC Publication 50(321): International Electrotechnical Vocabulary (IEV), Chapter 321: Instrument Transformers. These are indicated by the relevant IEV reference numbers in brackets.

3.1 *Instrument transformer*

A transformer intended to supply measuring instruments, meters, relays and other similar apparatus (321-01-01 modified).

3.2 *Current transformer*

An instrument transformer in which the secondary current, in normal conditions of use, is substantially proportional to the primary current and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections (321-02-01).

3.3 *Primary winding*

The winding through which flows the current to be transformed.

3.4 *Secondary winding*

The winding which supplies the current circuits of measuring instruments, meters, relays or similar apparatus.

3.5 *Secondary circuit*

The external circuit supplied by the secondary winding of a transformer.

3.6 *Rated primary current*

The value of the primary current on which the performance of the transformer is based (321-01-11 modified).

3.7 *Rated secondary current*

The value of the secondary current on which the performance of the transformer is based (321-01-15 modified).

3.8 *Actual transformation ratio*

The ratio of the actual primary current to the actual secondary current (321-01-17 modified).

3.9 *Rated transformation ratio*

The ratio of the rated primary current to the rated secondary current (321-01-19 modified).

3.10 *Current error (ratio error)*

The error which a transformer introduces into the measurement of a current and which arises from the fact that the actual transformation ratio is not equal to the rated transformation ratio (321-01-21 modified).

The current error expressed in per cent is given by the formula:

$$\text{Current error \%} = \frac{(K_n I_s - I_p) \times 100}{I_p}$$

where K_n is the rated transformation ratio, I_p is the actual primary current and I_s the actual secondary current when I_p is flowing, under the conditions of measurement.

3.11 *Phase displacement*

The difference in phase between the primary and secondary current vectors, the direction of the vectors being so chosen that the angle is zero for a perfect transformer (321-01-23 modified).

The phase displacement is said to be positive when the secondary current vector *leads* the primary current vector. It is usually expressed in minutes or centiradians.

Note. – This definition is strictly correct for sinusoidal currents only.

3.12 *Accuracy class*

A designation assigned to a current transformer the errors of which remain within specified limits under prescribed conditions of use.

3.13 *Burden*

The impedance of the secondary circuit in ohms and power-factor.

The burden is usually expressed as the apparent power in voltamperes absorbed at a specified power-factor and at the rated secondary current.

3.14 *Rated burden*

The value of the burden on which the accuracy requirements of this specification are based.

3.15 *Rated output*

The value of the apparent power (in voltamperes at a specified power-factor) which the transformer is intended to supply to the secondary circuit at the rated secondary current and with rated burden connected to it.

3.16 *Highest voltage for equipment*

The highest r.m.s. phase-to-phase voltage for which a transformer is designed in respect of its insulation.

3.17 *Rated insulation level*

The combination of voltage values which characterizes the insulation of a transformer with regard to its capability to withstand dielectric stresses.

3.18 *Isolated neutral system*

A system which has no intentional connection to earth except through indicating, measuring or protective devices of very high impedance.

3.19 *Resonant earthed system (a system earthed through an arc-suppression coil)*

A system earthed through a reactor, the reactance being of such value that during a single line-to-earth fault, the power-frequency inductive current passed by this reactor essentially neutralizes the power-frequency capacitive component of the earth-fault current.

Note. – With resonant earthing of a system, the current in the fault is limited to such an extent that an arcing fault in air would be self-extinguishing.

3.20 *Earthing factor*

At a selected location in a three-phase system (generally the point of installation of an equipment), for a given system layout, is the ratio, expressed as a percentage, of the highest r.m.s. line-to-earth power-frequency voltage on a sound phase at the selected location during a fault to earth affecting one or more phases, to the line-to-line r.m.s. power-frequency voltage which would be obtained at the selected location with the fault removed.

3.21 *Earthed neutral system*

A system in which the neutral is connected to earth, either solidly, or through a resistance or reactance of low enough value to reduce materially transient oscillations and to give a current sufficient for selective earth fault protection:

a) A system with *effectively-earthed* neutral at a given location is a system characterized by an earthing factor at this point which does not exceed 80%.

Note. – This condition is obtained in general when, for all system configurations, the ratio of zero-sequence reactance to positive-sequence reactance is less than 3 and the ratio of zero-sequence resistance to positive-sequence reactance is less than one.

b) A system with *non-effectively earthed* neutral at a given location is a system characterized by an earthing factor at this point that may exceed 80%.

3.22 *Exposed installation*

An installation in which the apparatus is subject to overvoltages of atmospheric origin.

Note. – Such installations are usually connected to overhead transmission lines, either directly, or through a short length of cable.

3.23 *Non-exposed installation*

An installation in which the apparatus is not subject to overvoltages of atmospheric origin.

Note. – Such installations are usually connected to cable networks.

3.24 *Rated frequency*

The value of the frequency on which the requirements of this standard are based.

3.25 *Rated short-time thermal current (I_{th})*

The r.m.s. value of the primary current which a transformer will withstand for one second without suffering harmful effects, the secondary winding being short-circuited.

3.26 *Rated dynamic current (I_{dyn})*

The peak value of the primary current which a transformer will withstand, without being damaged electrically or mechanically by the resulting electromagnetic forces, the secondary winding being short-circuited.

3.27 *Rated continuous thermal current*

The value of the current which can be permitted to flow continuously in the primary winding, the secondary winding being connected to the rated burden, without the temperature rise exceeding the values specified.

SECTION TWO – RATING AND PERFORMANCE REQUIREMENTS APPLICABLE TO ALL CURRENT TRANSFORMERS

4. Standard values of rated primary current

4.1 *Single-ratio transformers*

The standard values of rated primary currents are:

<u>10</u> – 12.5 – <u>15</u> – <u>20</u> – 25 – <u>30</u> – 40 – <u>50</u> – 60 – <u>75</u> amperes,

and their decimal multiples or fractions.

The preferred values are those underlined.

4.2 *Multi-ratio transformers*

The standard values given in Sub-clause 4.1 refer to the lowest values of rated primary current.

5. Standard values of rated secondary current

The standard values of rated secondary current are 1 A, 2 A and 5 A, but the preferred value is 5 A.

Note. – For transformers intended for delta-connected groups these ratings divided by $\sqrt{3}$ are also standard values.

6. Rated continuous thermal current

Unless otherwise specified, the rated continuous thermal current shall be the rated primary current. (See Clause 28.)

7. Standard values of rated output

The standard values of rated output up to 30 VA are:

2.5 – 5.0 – 10 – 15 and 30 VA.

Values above 30 VA may be selected to suit the application.

Note. – For a given transformer, provided one of the values of rated output is standard and associated with a standard accuracy class, the declaration of other rated outputs, which may be non-standard values, but associated with other standard accuracy classes, is not precluded.

8. Short-time current ratings

Current transformers supplied with a fixed primary winding or conductor shall comply with the requirements of Sub-clauses 8.1 and 8.2 below.

8.1 *Thermal rating*

A rated short-time thermal current (I_{th}) shall be assigned to the transformer. (See definition Sub-clause 3.25.)

8.2 *Dynamic rating*

The value of the rated dynamic current (I_{dyn}) shall normally be 2.5 times the rated short-time thermal current (I_{th}) and it shall be indicated on the rating plate when it is different from this value. (See definition Sub-clause 3.26.)

9. Limits of temperature rise

The temperature rise of a current transformer when carrying a primary current equal to the rated continuous thermal current, with a unity power-factor burden corresponding to the rated output, shall not exceed the appropriate value given in Table I. These values are based on the service conditions given in Clause 2.

- If ambient temperatures in excess of the values given in Sub-clause 2.1 are specified, the permissible temperature rise in Table I shall be reduced by an amount equal to the excess ambient temperature.
- If a transformer is specified for service at an altitude in excess of 1 000 m and tested at an altitude below 1 000 m, the limits of temperature rise given in Table I shall be reduced by the following amounts for each 100 m that the altitude at the operating site exceeds 1 000 m:

a) Oil immersed transformers 0.4%

b) Dry-type transformers 0.5%

The temperature rise of the windings is limited by the lowest class of insulation either of the winding itself or of the surrounding medium in which it is embedded. The maximum temperature rises of the insulation classes are as given in Table I.

TABLE I

Limits of temperature rise of windings

Class of insulation (in accordance with IEC Publication 85*)	Maximum temperature rise (K)
All classes immersed in oil	60
All classes immersed in oil and hermetically sealed	65
All classes immersed in bituminous compound	50
Classes not immersed in oil or bituminous compound:	
Y	45
A	60
E	75
B	85
F	110
H	135

Note. – With some products (e.g. resin) the manufacturer should specify the relevant insulation class.

When the transformer is fitted with a conservator tank, has an inert gas above the oil, or is hermetically sealed, the temperature rise of the oil at the top of the tank or housing shall not exceed 55 K.

When the transformer is not so fitted or arranged, the temperature rise of the oil at the top of the tank or housing shall not exceed 50 K.

The temperature rise measured on the external surface of the core and other metallic parts where in contact with, or adjacent to, insulation shall not exceed the appropriate value in Table I.

10. Insulation requirements

10.1 *Rated insulation levels, primary windings*

The choice of the insulation level for transformers having highest voltage for equipment greater than or equal to 3.6 kV shall be made in accordance with IEC Publication 71: Insulation Co-ordination. For transformers having highest voltage for equipment less than 3.6 kV, the insulation level is determined by the rated short-duration power-frequency withstand voltage.

10.1.1 For windings having highest voltage for equipment in the range 3.6 kV $\leq U_m <$ 300 kV, the rated insulation level, defined by the rated lightning-impulse and short-duration power-frequency withstand voltages, shall be one of those given in Tables II A and II B.

* IEC Publication 85: Thermal Evaluation and Classification of Electrical Insulation.

10.1.2 For windings having highest voltage for equipment $U_m \geqslant 300$ kV, the rated insulation level, defined by the rated switching and lightning impulse withstand voltages, shall be one of those given in Table II C.

Note. – In this voltage range, it is considered that switching impulse should have priority in the selection of insulation level.

10.2 *Other requirements for primary winding insulation*

10.2.1 *Power-frequency withstand voltage*

Windings having highest voltage for equipment $U_m \geqslant 300$ kV shall also be capable of withstanding the specified power-frequency test. Two alternative methods are specified in this standard for windings in this category. The methods are based on different requirements regarding the test voltages and the test procedures.

Method I: The winding shall withstand the power-frequency short-duration withstand voltage corresponding to the selected rated lightning-impulse voltage as given in Table II D.

Method II: The winding shall withstand a power-frequency test of longer duration at a voltage level lower than the short-duration test combined with a partial discharge test requirement. The test voltages, related to the highest voltage for equipment U_m, are given in Table II E.

Method I shall be used unless otherwise specified.

The use of Method II requires special agreement between manufacturer and purchaser.

Note. – The Method II test may be preceded by a lightning-impulse test in order to complete the dielectric routine tests of the primary winding.

If Method I is adopted, the lightning-impulse test is to be considered a type test.

Table II A

Rated insulation levels for transformer primary windings having highest voltage for equipment less than 300 kV

Highest voltage for equipment U_m (r.m.s.)	Rated lightning-impulse withstand voltage (peak)	Rated power-frequency short-duration withstand voltage (r.m.s.)
kV	kV	kV
0.72		3
1.2		6
3.6	20	10
3.6	40	10
7.2	40	20
7.2	60	20
12	60	28
12	75	28
17.5	75	38
17.5	95	38
24	95	50
24	125	50
36	145	70
36	170	70
52	250	95
72.5	325	140
123	450	185
123	550	230
145	550	230
145	650	275
170	650	275
170	750	325
245	850	360
245	950	395
245	1 050	460

Table II B

Rated insulation levels for transformer primary windings having highest voltage for equipment less than 52 kV

Based on practice in the United States of America and some other countries

Highest voltage for equipment U_m (r.m.s.)	Rated lightning-impulse withstand voltage (peak) Power system ≤500 kVA	>500 kVA	Rated power-frequency short-duration withstand voltage (r.m.s.)
kV	kV	kV	kV
4.40	60	75	19
13.20 13.97 14.52	95	110	34
26.4	150		50
36.5	200		70

Table II C

Rated insulation levels for transformer primary windings having highest voltage for equipment greater than or equal to 300 kV

Highest voltage for equipment U_m (r.m.s.)	Rated switching-impulse withstand voltage (peak)	Rated lightning-impulse withstand voltage (peak)
kV	kV	kV
300	750	950
	850	1 050
362	850	1 050
	950	1 175
420	950	1 175
	1 050	1 300
	1 050	1 425
525	1 050	1 425
	1 175	1 550
765	1 300	1 800
	1 425	2 100
	1 550	2 400

Note. – As the test voltage for U_m = 765 kV has not as yet been finally settled, some interchange between switching and lightning impulse test levels may become necessary.

TABLE IID

Method I: Power-frequency withstand voltages for transformer primary windings having highest voltage for equipment greater than or equal to 300 kV

Rated lightning-impulse withstand voltage (peak)	Power-frequency short-duration withstand voltage (r.m.s.)
kV	kV
950	395
1 050	460
1 175	510
1 300	570
1 425	630
1 550	680
1 800	790
2 100	880
2 400	975

TABLE IIE

Method II: Power-frequency test voltages for transformer primary windings having highest voltage for equipment greater than or equal to 300 kV

Highest voltage for equipment U_m (r.m.s.)	Power-frequency prestress voltage 10 s (r.m.s.)	Partial discharge test voltage 5 min (r.m.s.)
kV	kV	kV
300	395	225
362	460	270
420	510	315
525	630	395
765	790/880*	575

*To be determined by the rated lightning-impulse withstand voltage (see Table IID).

Note. – The specified values of the voltages are provisional and may be changed in the light of experience and of revision of IEC Publication 44-4: Instrument Transformers, Part 4: Measurement of Partial Discharges.

Other voltage levels may be used due to network conditions and require special agreement between manufacturer and purchaser.

10.2.2 *Partial discharges*

The permissible magnitude of partial discharges and the requirements for their measurement are given in IEC Publication 44-4 which is applicable to all current transformers except transformers having $U_m \geqslant 300$ kV specified in accordance with Method II (see Sub-clause 17.3).

10.2.3 *Chopped lightning impulse*

If additionally specified, the primary windings shall also be capable of withstanding chopped lightning-impulse voltages having the same peak value as the full lightning-impulse voltages.

10.2.4 *Measurement of dielectric dissipation factor*

If additionally specified, the dielectric dissipation factor (tan δ) shall be measured. The measurement is applicable only to transformers with liquid-immersed primary winding insulation having $U_m \geqslant 72.5$ kV. The permissible value of the dielectric dissipation factor measured at a voltage not exceeding $U_m/\sqrt{3}$ shall also be subjected to additional specification.

Notes 1. – The dielectric dissipation factor is dependent on both voltage and temperature.

2. – Measurements of the dielectric dissipation factor at low voltage (e.g. 2.5 kV to 10 kV) may be used as a reference value when determining whether the insulation is deteriorating in service.

10.3 *Between-section insulation requirements*

For primary and secondary windings divided into two or more sections, the between-section insulation shall be capable of withstanding a rated power-frequency short-duration withstand voltage of 3 kV (r.m.s.) for 1 min.

10.4 *Insulation requirements for secondary windings*

The secondary winding insulation shall be capable of withstanding a rated power-frequency short-duration withstand voltage of 3 kV (r.m.s.) for 1 min.

10.5 *Interturn insulation requirements*

The interturn insulation of the windings shall be capable of withstanding for 1 min an interturn overvoltage of 4.5 kV peak across the complete secondary winding.

For some types of transformers, lower values can be accepted in accordance with the test procedure given in Clause 19.

10.6 *Creepage distance*

For outdoor insulation sensitive to pollution, the required minimum creepage distance measured on the insulation surface is given in Table III. In addition, the ratio between the total minimum creepage distance and the arcing distance should generally not exceed 3.5 : 1.

TABLE III

Pollution level	Minimum nominal specific creepage distance between phase and earth (mm/phase-to-phase kV)
I Light	16
II Medium	20
III Heavy	25
IV Very heavy	31

Notes 1. – The definition of the various pollution classes is still under consideration.

It is recognized that the performance of surface insulation is greatly affected by insulator shape.

2. – Artificial pollution tests, described in IEC Publication 507 (Report): Artificial Pollution Tests on High-voltage Insulators to be Used on A.C. Systems, are not included in this standard. More experience is needed before a test requirement based on this report can be issued.

10.7 *Altitude*

The disruptive discharge of external insulation depends on the prevailing atmospheric conditions. In order to ensure that the withstand voltages of the external insulation of a current transformer intended for operation at altitudes exceeding 1 000 m above sea level are sufficient, the arcing distance normally has to be increased.

For general guidance, the rated withstand voltage on which the arcing distance is based should be increased by 1% for each 100 m in excess of 1 000 m above sea level.

SECTION THREE – TESTS – GENERAL

11. Classification of tests

The tests specified in this standard are classified as type tests, routine tests and special tests.

Type test

A test made on a transformer of each type to demonstrate that all transformers made to the same specification comply with the requirements not covered by routine tests.

Note. – A type test may also be considered valid if it is made on a transformer which has minor deviations. Such deviations should be subject to agreement between manufacturer and purchaser.

Routine test

A test to which each individual transformer is subjected.

Special test

A test other than a type test or a routine test, agreed on by manufacturer and purchaser.

11.1 *Type tests*

The following tests are type tests; for details, reference should be made to the relevant clauses:

a) Short-time current test(s) (Clause 12).

b) Temperature-rise test (Clause 13).

c) Lightning-impulse test (Clause 14).

d) Switching-impulse test (Clause 14).

e) Wet tests for outdoor type transformers (Clause 15).

f) Determination of errors (Clauses 29, 31 and 39).

The dielectric type tests should all be carried out on the same transformer, unless otherwise specified.

After transformers have been subjected to the dielectric type tests of Sub-clause 11.1, they shall be subjected to all the routine tests of Sub-clause 11.2.

11.2 *Routine tests*

The following tests are routine tests; for details, reference should be made to the relevant clauses:

a) Verification of terminal marking (Clause 16).

b) Power-frequency withstand test on secondary windings (Clause 18).

c) Power-frequency withstand test between sections (Clause 18).

d) Interturn overvoltage test (Clause 19).

e) Power-frequency withstand test on primary winding (Clause 17).

f) Partial discharge measurement (Clause 17).

g) Determination of errors (Clauses 30 and 40).

Apart from the fact that determination of errors of Item *g)* shall be performed after the tests of Items *b), c)* and *d),* the order or possible combination of the other tests is not standardized.

Repeat power-frequency tests on primary windings should be performed at 80% of the specified test voltage, except when Method II has been adopted.

11.3 *Special tests*

The following tests are special tests; for details, reference should be made to the relevant clauses:

a) Chopped lightning-impulse test (Clause 20).

b) Measurement of the dielectric dissipation factor (Clause 21).

SECTION FOUR – TYPE TESTS

12. Short-time current tests

For the thermal short-time current I_{th} test, the transformer shall initially be at a temperature between 17 °C and 27 °C.

This test shall be made with the secondary winding(s) short-circuited and at a current I for a time t, such that $(I^2 t)$ is not less than $(I_{th})^2$ and provided t has a value between 0.5 s and 5 s.

The dynamic test shall be made with the secondary winding(s) short-circuited and with a primary current the peak value of which is not less than the rated dynamic current (I_{dyn}) for at least one peak.

The dynamic test may be combined with the thermal test above provided the first major peak current of that test is not less than the rated dynamic current (I_{dyn}).

The transformer shall be deemed to have passed these tests if, after cooling to ambient temperature (between 10 °C and 30 °C), it satisfies the following requirements:

a) it is not visibly damaged;

b) its errors after demagnetization do not differ from those recorded before the tests by more than half the limits of error appropriate to its accuracy class;

c) it withstands the dielectric tests specified in Clauses 17, 18 and 19 but with the test voltages or currents reduced to 90% of those given;

d) on examination, the insulation next to the surface of the conductor does not show significant deterioration (e.g. carbonization).

The examination *d)* is not required if the current density in the primary winding, corresponding to the rated short-time thermal current, does not exceed 160 A/mm² where the winding is of copper of conductivity not less than 97% of the value given in IEC Publication 28: International Standard of Resistance for Copper.

Note. – Experience has shown that in service the requirements for thermal rating are generally fulfilled in the case of Class A insulation provided that the current density in the primary winding, corresponding to the rated short-time current, does not exceed 180 A/mm², where the winding is of copper of conductivity not less than 97% of the value given in IEC Publication 28. Consequently, compliance with this requirement may take the place of tests, if agreed between manufacturer and purchaser.

13. Temperature-rise test

A test shall be made to prove compliance with the requirements of Clause 9. For the purpose of this test, current transformers shall be deemed to have attained a steady temperature when the rate of temperature rise does not exceed 1 K per hour.

The test-site ambient temperature shall be between 10 °C and 30 °C.

For the test, the transformers shall be mounted in a manner representative of the mounting in service.

The temperature rise of windings shall, when practicable, be measured by the increase in resistance method, but for windings of very low resistance thermocouples may be employed.

The temperature rise of parts other than windings may be measured by thermometers or thermocouples.

14. Impulse tests on primary windings

14.1 *General*

The impulse tests shall be performed in accordance with IEC Publication 60: High-Voltage Test Techniques.

The test voltage shall be applied between the terminals of the primary winding (connected together) and earth. The frame, case (if any), core (if intended to be earthed) and all terminals of the secondary winding(s) shall be connected to earth.

The impulse tests generally consist of voltage applications at reference and rated voltage levels. The reference impulse voltage shall be between 50% and 75% of the rated impulse withstand voltage. The peak value and the waveshape of the impulse voltages shall be recorded.

Evidence of insulation failure due to the test may be given by variation in the waveshape at both reference and rated withstand voltage.

Improvements in failure detection may be obtained by the recording of earth current(s), as a complement to the voltage records.

14.2 *Lightning-impulse test*

The test voltages shall have the appropriate values given in Tables II A, II B and II C, depending on the highest voltage for equipment and the specified insulation level.

14.2.1 *Windings having $U_m < 300$ kV*

The test shall be performed with both positive and negative polarities. Fifteen consecutive impulses of each polarity, not corrected for atmospheric conditions, shall be applied.

The transformer passes the test if for each polarity:

- no disruptive discharge occurs in the non-self-restoring internal insulation,
- no flashovers occur along the non-self-restoring external insulation,
- no more than two flashovers occur across the self-restoring external insulation,
- no other evidence of insulation failure is detected (e.g. variations in the waveshape of the recorded quantities).

Note. – The application of 15 positive and 15 negative impulses is specified for testing the external insulation. If other tests are agreed between manufacturer and purchaser to check the external insulation, the number of lightning impulses may be reduced to three of each polarity, not corrected for atmospheric conditions.

14.2.2 *Windings having $U_m \geq 300$ kV*

The test shall be performed with both positive and negative polarities. Three consecutive impulses of each polarity, not corrected for atmospheric conditions, shall be applied.

The transformer passes the test if:

- no disruptive discharge occurs,
- no other evidence of insulation failure is detected (e.g. variations in the waveshape of the recorded quantities).

14.3 *Switching-impulse test*

The test voltages shall have the appropriate values given in Table II C, depending on the highest voltage for equipment and the specified insulation level.

The test shall be performed with both positive and negative polarities. Fifteen consecutive impulses of each polarity corrected for atmospheric conditions shall be applied.

Outdoor-type transformers shall be subjected to wet test. Dry test is not required.

The transformer passes the test if for each polarity:

- no disruptive discharge occurs in the non-self-restoring internal insulation,
- no flashover occurs along the non-self restoring external insulation,
- no more than two flashovers occur across the self-restoring external insulation,
- no other evidence of insulation failure is detected (i.e. variations in the waveshape of the recorded quantities).

15. Wet test for outdoor type transformers

In order to verify the performance of the external insulation, outdoor type transformers shall be subjected to wet tests.

The wetting procedure shall be in accordance with Sub-clause 8.1 of IEC Publication 60-1, High-voltage Test Techniques, Part 1: General Definitions and Test Requirements.

15.1 *Windings having $U_m < 300$ kV*

The test shall be performed in accordance with Sub-clause 17.2, with power-frequency voltage corrected for atmospheric conditions.

15.2 *Windings having $U_m \geq 300$ kV*

The test shall be performed with switching impulse voltage in accordance with Sub-clause 14.3.

SECTION FIVE – ROUTINE TESTS

16. Verification of terminal markings

It shall be verified that the terminal markings are correct (see Clause 22).

17. Power-frequency tests on primary windings and measurement of partial discharges

17.1 *General*

The power-frequency tests shall be performed in accordance with IEC Publication 60.

The test voltage shall be applied between the terminals of the primary winding (connected together) and earth. The frame, case (if any), core (if intended to be earthed) and all terminals of the secondary winding(s) shall be connected to earth.

The measurement of partial discharges shall be performed in accordance with IEC Publication 44-4.

The minimum measurable magnitude due to disturbances or the measuring sensitivity of the adopted circuit shall in general be lower than half the permissible magnitude specified.

17.2 *Windings having $U_m < 300$ kV*

The test voltages for windings having $U_m < 300$ kV shall have the appropriate values given in Tables II A and II B, depending on the highest voltage for equipment. The test shall be performed for 1 min in accordance with Sub-clause 17.1.

17.3 *Windings having $U_m \geq 300$ kV*

The power frequency test for windings having $U_m \geq 300$ kV shall be carried out in accordance with one of the methods indicated as Method I and Method II in the following sub-clauses.

Method I should be used unless otherwise specified.

The use of Method II shall be subject to agreement between manufacturer and purchaser.

17.3.1 *Method I*

The test voltages shall have the appropriate values given in Table IID, depending on the rated lightning-impulse withstand voltage. The test shall be performed for 1 min in accordance with Sub-clause 17.1.

17.3.2 *Method II*

The test voltages shall have the appropriate values given in Table IIE, depending on the highest voltage for equipment. The Method II test procedure shall consist of a short-time application for 10 s at the power-frequency prestress voltage. This prestress voltage is then reduced to the partial discharge test voltage without interruption and maintained at this level for 5 min.

The maximum permissible partial discharge magnitude measured during the final minute at the specified partial discharge test voltage shall be 10 pC.

18. Power-frequency tests between sections of primary and secondary windings and on secondary windings

The test voltage shall have the appropriate values given in Sub-clauses 10.3 and 10.4. The test voltage shall be applied for 1 min in turn between the terminals of each secondary winding or section of winding and earth. The frame, case (if any), core (if intended to be earthed) and the terminals of all other windings or sections shall be connected together and to earth.

19. Test of interturn insulation

The interturn overvoltage test to meet the requirements of Sub-clause 10.5 shall be performed in accordance with one of the test procedures given below.

Procedure A

With the secondary winding open-circuited (or connected to a high impedance device which reads peak voltage), a substantially sinusoidal alternating current at a frequency between 40 Hz and 62 Hz (in accordance with IEC Publication 60) and of r.m.s. value less than or equal to the rated primary current (or rated extended current when applicable) shall be applied for 1 min to the primary winding, sufficient to produce a voltage at the secondary terminals having a peak value equal to the prescribed test voltage.

Procedure B

With the primary winding open-circuited, the prescribed test voltage (at some suitable frequency) shall be applied for 1 min to the secondary terminals providing that the r.m.s. value of the secondary current does not exceed the rated secondary current (or rated extended current when applicable).

The value of the test frequency shall be not greater than five times the rated frequency; at this frequency value, the prescribed test voltage may be the value obtained at the rated secondary current (extended range current when applicable).

SECTION SIX - SPECIAL TESTS

20. Chopped lightning-impulse test on primary windings

The test shall be carried out with negative polarity only and combined with the negative polarity full lightning-impulse test in the manner described below.

The standard lightning impulse shall be chopped after 2 to 5 µs. The chopping circuit shall be so arranged that the amount of overswing to opposite polarity of the recorded impulse shall be limited to approximately 30% of the chopped impulse. The sequence of the impulse applications shall be as follows:

a) Windings having $U_m < 300$ kV
- one 100% full impulse
- two 100% chopped impulses
- fourteen 100% full impulses

b) Windings having $U_m \geq 300$ kV
- one 100% full impulse
- two 100% chopped impulses
- two 100% full impulses

Differences in impulse shape of full wave application before and after the chopped impulses are indication of an internal fault.

Flashovers during chopped impulses along self-restoring external insulation should be disregarded in the evaluation of the behaviour of external insulation.

21. Measurement of dielectric dissipation factor

The measurement of the dielectric dissipation factor (tan δ) shall be made after the power-frequency test on the primary windings. The ambient temperature and the temperature of the equipment under test shall be between 10 °C and 30 °C.

The measurement of the dielectric dissipation factor shall be made by means of a Schering Bridge or other equivalent method.

The test voltage shall be applied to the short-circuited primary winding terminals. Generally the short-circuited secondary winding(s), any screen and the isolated metal casing shall be connected to the measuring bridge. If the transformer has a special device (terminal) suitable for the measurement, the other terminals shall be short-circuited and connected to the earthed or the screened metal casing.

SECTION SEVEN – MARKING

22. Terminal markings – General rules

The terminal markings shall identify:

a) the primary and secondary windings;

b) the winding sections, if any;

c) the relative polarities of windings and winding sections;

d) the intermediate tappings, if any.

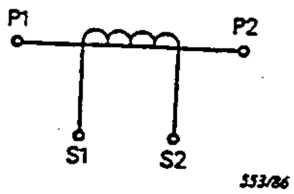
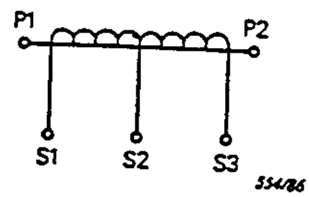
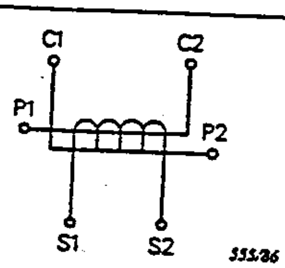
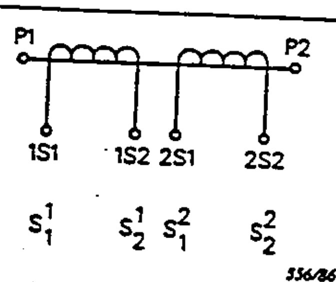
22.1 *Method of marking*

The terminals shall be marked clearly and indelibly either on their surface or in their immediate vicinity.

The marking shall consist of letters followed, or preceded where necessary, by numbers. The letters shall be in block capitals.

22.2 *Markings to be used*

The markings of current transformer terminals shall be as indicated in the following table:

Primary terminals Secondary terminals	 FIG. 1. – Single ratio transformer.	 FIG. 2. – Transformer with an intermediate tapping on secondary winding.
Primary terminals Secondary terminals	 FIG. 3. – Transformer with primary winding in 2 sections intended for connections either in series or in parallel.	 FIG. 4. – Transformer with 2 secondary windings; each with its own magnetic core. (Two alternative markings for the secondary terminals.)

22.3 *Indication of relative polarities*

All the terminals marked P 1, S 1 and C 1 shall have the same polarity at the same instant.

23. Rating plate markings

All current transformers shall carry at least the following markings:

a) the manufacturer's name or other mark by which he may be readily identified;

b) a serial number or a type designation, preferably both;

c) the rated primary and secondary current, i.e.:

$$K_n = I_{pn}/I_{sn} \text{ A (e.g. } K_n = 100/5 \text{ A);}$$

d) the rated frequency (e.g. 50 Hz);

e) the rated output and the corresponding accuracy class, together with additional information specified in later parts of these recommendations (see Clause 32);

Note. – Where appropriate the category of secondary winding should be marked (e.g. 1S, 15 VA, Class 0.5; 2S, 30 VA, Class 1).

f) the highest voltage for equipment (e.g. 1.2 kV or 145 kV);

g) the rated insulation level (e.g. 6/ – kV* or 275/650 kV).

Notes 1. – The two Items *f)* and *g)* may be combined into one marking (e.g. 1.2/6/ – kV* or 145/275/650 kV).

*2. – A dash indicates absence of an impulse voltage level.

All information shall be marked in an indelible manner on the current transformer itself or on a rating plate securely attached to the transformer.

In addition, the following information shall be marked whenever space is available:

h) the rated short-time thermal current (I_{th}) and the rated dynamic current if it differs from 2.5 times the rated short-time thermal current (e.g. 13 kA or 13/40 kA);

i) the class of insulation, if different from class A;

Note. – If several classes of insulating material are used, the one which limits the temperature rise of the windings should be indicated.

k) on transformers with two secondary windings, the use of each winding and its corresponding terminals.

CHAPTER II: ADDITIONAL REQUIREMENTS FOR MEASURING CURRENT TRANSFORMERS

SECTION EIGHT – GENERAL

24. Scope

Chapter II covers the requirements and tests, in addition to those in Chapter I, that are necessary for current transformers for use with electrical measuring instruments.

25. Definitions

25.1 *Measuring current transformer*

A current transformer intended to supply indicating instruments, integrating meters and similar apparatus.

25.2 *Composite error*

Under steady-state conditions, the r.m.s. value of the difference between:

a) the instantaneous values of the primary current, and

b) the instantaneous values of the actual secondary current multiplied by the rated transformation ratio,

the positive signs of the primary and secondary currents corresponding to the convention for terminal markings.

The composite error ε_c is generally expressed as a percentage of the r.m.s. values of the primary current according to the formula:

$$\varepsilon_c = \frac{100}{I_p} \sqrt{\frac{1}{T} \int_0^T (K_n i_s - i_p)^2 \, dt}$$

where:

K_n = rated transformation ratio

I_p = r.m.s. value of the primary current

i_p = instantaneous value of the primary current

i_s = instantaneous value of the secondary current

T = duration of one cycle

25.3 *Rated instrument limit primary current (IPL)*

The value of the minimum primary current at which the composite error of the measuring current transformer is equal to or greater than 10%, the secondary burden being equal to the rated burden.

Note. – The composite error should be greater than 10%, in order to protect the apparatus supplied by the instrument transformer against the high currents produced in the event of system fault.

25.4 *Instrument security factor (FS)*

The ratio of rated instrument limit primary current to the rated primary current.

Note. – In the event of system fault currents flowing through the primary winding of a current transformer, the safety of the apparatus supplied by the transformer is greatest when the value of the rated instrument security factor (FS) is small.

25.5 *Secondary limiting e.m.f.*

The product of the instrument security factor FS, the rated secondary current and the vectorial sum of the rated burden and the impedance of the secondary winding.

Notes 1. – The method by which the secondary limiting e.m.f. is calculated will give a higher value than the real one. It was chosen in order to apply the same test method as in Sub-clause 34.5 and Clause 39 for protective current transformers.

Other methods may be used by agreement between manufacturer and purchaser.

2. – For calculating the secondary limiting e.m.f., the secondary winding resistance should be corrected to a temperature of 75 °C.

25.6 *Exciting current*

The r.m.s. value of the current taken by the secondary winding of a current transformer, when a sinusoidal voltage of rated frequency is applied to the secondary terminals, the primary and any other windings being open-circuited.

SECTION NINE – ACCURACY REQUIREMENTS

26. Accuracy class designation

For measuring current transformers, the accuracy class is designated by the highest permissible percentage current error at rated current prescribed for the accuracy class concerned.

26.1 *Standard accuracy classes*

The standard accuracy classes for measuring current transformers are:

0.1 – 0.2 – 0.5 – 1 – 3 – 5.

27. Limits of current error and phase displacement

For Classes 0.1 – 0.2 – 0.5 and 1, the current error and phase displacement at rated frequency shall not exceed the values given in Table IV when the secondary burden is any value from 25% to 100% of the rated burden.

For Classes 0.2 S and 0.5 S, the current error and phase displacement of current transformers for special applications (in particular in connection with special electricity meters which measure correctly at a current between 50 mA and 6 A, that is between 1% and 120% of the rated current 5 A) at rated frequency shall not exceed the values given in Table IV A when the secondary burden is any value from 25% to 100% of the rated burden. These classes shall mainly be used for the ratios 25/5, 50/5 and 100/5 and their decimal multiples and only for the rated secondary current 5 A.

For Class 3 and Class 5, the current error at rated frequency shall not exceed the values given in Table V when the secondary burden is any value from 50% to 100% of the rated burden.

The secondary burden used for test purposes shall have a power-factor of 0.8 lagging except that when the burden is less than 5 VA, a power-factor of 1.0 shall be used. In no case shall the test burden be less than 1 VA.

TABLE IV

Limits of error

Accuracy class	± Percentage current (ratio) error at percentage of rated current shown below				± Phase displacement at percentage of rated current shown below							
					Minutes				Centiradians			
	5	20	100	120	5	20	100	120	5	20	100	120
0.1	0.4	0.2	0.1	0.1	15	8	5	5	0.45	0.24	0.15	0.15
0.2	0.75	0.35	0.2	0.2	30	15	10	10	0.9	0.45	0.3	0.3
0.5	1.5	0.75	0.5	0.5	90	45	30	30	2.7	1.35	0.9	0.9
1.0	3.0	1.5	1.0	1.0	180	90	60	60	5.4	2.7	1.8	1.8

TABLE IV A

Limits of error for current transformers for special applications
This table is applicable only to transformers having a rated secondary current of 5 A

Accuracy class	± Percentage current (ratio) error at percentage of rated current shown below					± Phase displacement at percentage of rated current shown below									
						Minutes					Centiradians				
	1	5	20	100	120	1	5	20	100	120	1	5	20	100	120
0.2S	0.75	0.35	0.2	0.2	0.2	30	15	10	10	10	0.9	0.45	0.3	0.3	0.3
0.5S	1.5	0.75	0.5	0.5	0.5	90	45	30	30	30	2.7	1.35	0.9	0.9	0.9

TABLE V

Limits of error

Class	± Percentage current (ratio) error at percentage of rated current shown below	
	50	120
3	3	3
5	5	5

Limits of phase displacement are not specified for Class 3 and Class 5.

28. Extended current rating

Current transformers of accuracy Classes 0.1 to 1 may be marked as having an extended current rating provided they comply with the following two requirements:

a) The rated continuous thermal current shall be the rated extended primary current expressed as a percentage of the rated primary current.

b) The limits of current error and phase displacement prescribed for 120% of rated primary current in Table IV shall be retained up to the rated extended primary current.

Standard values of rated extended primary current are 120%, 150% and 200% of the rated primary current.

SECTION TEN – TESTS FOR ACCURACY

29. Type tests

Type tests to prove compliance with Clause 27 shall, in the case of transformers of Classes 0.1 to 1, be made at each value of current given in Table IV at 25% and at 100% of rated burden (subject to 1 VA minimum).

Transformers having extended current ratings greater than 120% shall be tested at the rated extended primary current instead of at 120% of rated current.

Transformers of Class 3 and Class 5 shall be tested for compliance with the two values of current given in Table V at 50% and at 100% of rated burden (subject to 1 VA minimum).

30. Routine tests

The routine test for accuracy is in principle the same as the type test in Clause 29, but routine tests at a reduced number of currents and/or burdens are permissible provided it has been shown by type tests on a similar transformer that such a reduced number of tests is sufficient to prove compliance with Clause 27.

31. Instrument security current

A type test may be performed using the following indirect test:

With the primary winding open-circuited, the secondary winding is energized at rated frequency by a substantially sinusoidal voltage having an r.m.s. value equal to the secondary limiting e.m.f.

The resulting excitation current (I_{exc}), expressed as a percentage of the rated secondary current (I_{sn}) multiplied by the instrument security factor FS, shall be equal to or exceed the rated value of the composite error of 10%:

$$\frac{I_{exc}}{I_{sn}\,FS} \cdot 100 \geqslant 10\%$$

If this result of measurement should be called into question, a controlling measurement shall be performed with the direct test (see Appendix A), the result of which is then mandatory.

Note. - The great advantage of the indirect test is that high currents are not necessary (for instance 30 000 A at a primary rated current 3 000 A and an instrument security factor 10) and also no burdens which must be constructed for 50 A. The effect of the return primary conductors is not physically effective at the indirect test. Under service conditions the effect can only enlarge the composite error, which is desirable for the safety of the apparatus supplied by the measuring transformer.

SECTION ELEVEN - MARKING

32. Marking of the rating plate of a measuring current transformer

The rating plate shall carry the appropriate information in accordance with Clause 23.

The accuracy class and instrument security factor shall be indicated following the indication of corresponding rated output (e.g. 15 VA Class 0.5 FS 10).

Current transformers having an extended current rating (Clause 28) shall have this rating indicated immediately following the class designation (e.g. 15 VA Class 0.5 ext. 150%).

Note. - The rating plate may contain information concerning several combinations of output and accuracy class the transformer can satisfy (e.g. 15 VA Class 0.5–30 VA Class 1) and in this case non-standard values of output may be used (e.g. 15 VA Class 1–7 VA Class 0.5) in accordance with note to Clause 7.

CHAPTER III: ADDITIONAL REQUIREMENTS FOR PROTECTIVE CURRENT TRANSFORMERS

SECTION TWELVE - GENERAL

33. Scope

Chapter III covers the requirements and tests, in addition to those in Chapter I, that are necessary for current transformers for use with electrical protective relays, and in particular for the forms of protection in which the prime requirement is the maintenance of accuracy up to several times the rated current.

For certain protective systems where the current transformer characteristics are dependent on the overall design of the protective equipment (for example high-speed balanced systems and earth-fault protection in resonant earthed networks), additional requirements may be necessary.

Current transformers intended for both measurement and protection shall comply with all the chapters of this standard.

34. Definitions

34.1 *Protective current transformer*

A current transformer intended to supply protective relays.

34.2 *Composite error**

Under steady-state conditions, the r.m.s. value of the difference between:

a) the instantaneous values of the primary current and

b) the instantaneous values of the actual secondary current multiplied by the rated transformation ratio,

the positive signs of the primary and secondary currents corresponding to the convention for terminal markings.

The composite error is generally expressed as a percentage of the r.m.s. values of the primary current according to the mathematical expression:

$$\varepsilon_c = \frac{100}{I_p}\sqrt{\frac{1}{T}\int_0^T (K_n i_s - i_p)^2 \, dt}$$

where:
K_n = the rated transformation ratio
I_p = the r.m.s. value of the primary current
i_p = the instantaneous value of the primary current
i_s = the instantaneous value of the secondary current
T = the duration of one cycle

*See Appendix A.

34.3 *Rated accuracy limit primary current*

The value of primary current up to which the transformer will comply with the requirements for composite error.

34.4 *Accuracy limit factor*

The ratio of the rated accuracy limit primary current to the rated primary current.

34.5 *Secondary limiting e.m.f.*

The product of the accuracy limit factor, the rated secondary current and the vectorial sum of the rated burden and the impedance of the secondary winding.

34.6 *Exciting current*

The r.m.s. value of the current taken by the secondary winding of a current transformer when sinusoidal voltage of rated frequency is applied to the secondary terminals, the primary and any other windings being open-circuited.

SECTION THIRTEEN – ACCURACY REQUIREMENTS

35. Standard accuracy limit factors

The standard accuracy limit factors are:

5 – 10 – 15 – 20 – 30.

36. Accuracy classes

36.1 *Accuracy class designation*

For protective current transformers, the accuracy class is designed by the highest permissible percentage composite error at the rated accuracy limit primary current prescribed for the accuracy class concerned, followed by the letter "P" (meaning protection).

36.2. *Standard accuracy classes*

The standard accuracy classes for protective current transformers are:

5 P and 10 P.

37. Limits of error

At rated frequency and with rated burden connected, the current error, phase displacement and composite error shall not exceed the values given in Table VI.

For testing purposes when determining current error and phase displacement, the burden shall have a power-factor of 0.8 inductive except that, where the burden is less than 5 VA, a power-factor of 1.0 is permissible.

For the determination of composite error, the burden shall have a power-factor of between 0.8 inductive and unity at the discretion of the manufacturer.

TABLE VI

Limits of error

Accuracy class	Current error at rated primary current %	Phase displacement at rated primary current		Composite error at rated accuracy limit primary current %
		minutes	centiradians	
5 P	± 1	± 60	± 1.8	5
10 P	± 3	—	—	10

SECTION FOURTEEN – TESTS FOR ACCURACY

38. Type and routine tests for current error and phase displacement

Tests shall be made at rated primary current to prove compliance with Clause 37 in respect of current error and phase displacement.

39. Type tests for composite error

a) Compliance with the limits of composite error given in Table VI shall be demonstrated by a direct test in which a substantially sinusoidal current equal to the rated accuracy limit primary current is passed through the primary winding with the secondary winding connected to a burden of magnitude equal to the rated burden but having, at the discretion of the manufacturer, a power-factor between 0.8 inductive and unity (see Appendix A).

The test may be carried out on a transformer similar to the one being supplied except that reduced insulation may be used provided that the same geometrical arrangement is retained.

Note. – Where very high primary currents and single bar-primary winding current transformers are concerned, the distance between the return primary conductor and the current transformer should be taken into account from the point of view of reproducing service conditions.

b) For current transformers having substantially continuous ring cores, uniformly distributed secondary windings and having either a centrally located primary conductor(s) or a uniformly distributed primary winding, the direct test may be replaced by the following indirect test provided that the effect of the return primary conductor(s) is negligible.

With the primary winding open-circuited, the secondary winding is energized at rated frequency by a substantially sinusoidal voltage having an r.m.s. value equal to the secondary limiting e.m.f.

The resulting exciting current, expressed as a percentage of the rated secondary current multiplied by the accuracy limit factor, shall not exceed the limit of composite error given in Table VI.

Notes 1. – In calculating the secondary limiting e.m.f., the secondary winding impedance should be assumed to be equal to the secondary winding resistance measured at room temperature and corrected to 75 °C.

2. – In determining the composite error by the indirect method, a possible difference between turns ratio and rated transformation ratio need not be taken into account.

40. Routine tests for composite error

For all transformers qualifying under Item *b)* of Clause 39, the routine test is the same as the type test.

For other transformers, the indirect test of measuring the exciting current may be used, but a correction factor shall be applied to the results, the factor being obtained from a comparison between the results of direct and indirect tests applied to a transformer of the same type as the one under consideration (see Note 2), the accuracy limit factor and the conditions of loading being the same.

In such cases, certificates of test should be held available by the manufacturer.

Notes 1. – The correction factor is equal to the ratio of the composite error obtained by the direct method and the exciting current expressed as a percentage of the rated secondary current multiplied by the accuracy limit factor, as determined by the indirect method specified in Item *a)* of Clause 39.

2\. – The expression "transformer of the same type" implies that the ampere turns are the same irrespective of ratio and that the geometrical arrangements, magnetic materials and the secondary windings are identical.

SECTION FIFTEEN - MARKING

41. Marking of the rating plate of a protective current transformer

The rating plate shall carry the appropriate information in accordance with Clause 23. The rated accuracy limit factor shall be indicated following the corresponding output and accuracy class (e.g. 30 VA Class 5 P 10).

Note. – A current transformer satisfying the requirements of several combinations of output and accuracy class and accuracy limit factor may be marked according to all of them.

e.g.:	(15 VA Class 0.5)	or	(15 VA Class 0.5)
	(30 VA Class 1)		(15 VA Class 1, ext. 150%)
	(30 VA Class 5 P 10)		(15 VA Class 5 P 20)

APPENDIX A

PROTECTIVE CURRENT TRANSFORMERS

A1. Vector diagram

If consideration is given to a current transformer which is assumed to contain only linear electric and magnetic components in itself and in its burden, then, under the further assumption of sinusoidal primary current, all the currents, voltages and fluxes will be sinusoidal and the performance can be illustrated by a vector diagram such as Figure A1, page 74.

In Figure A1, I_s represents the secondary current. It flows through the impedance of the secondary winding and the burden which determines the magnitude and direction of the necessary induced voltage E_s and of the flux ϕ which is perpendicular to the voltage vector. This flux is maintained by the exciting current I_e, having a magnetizing component I_m parallel to the flux, and a loss (or active) component I_a parallel to the voltage. The vector sum of the secondary current I_s and the exciting current I_e is the vector I''_p representing the primary current divided by the turns ratio (number of secondary turns to number of primary turns).

Thus, for a current transformer with turns ratio equal to the rated transformation ratio, the difference in the lengths of the vectors I_s and I''_p, related to the length of I''_p, is the current error according to the definition of Sub-clause 3.10, and the angular difference δ is the phase displacement according to Sub-clause 3.11.

A2. Turns correction

When the turns ratio is different from (usually less than) the rated transformation ratio, the current transformer is said to have turns correction. Thus, in evaluating the performance, it is necessary to distinguish between I''_p, the primary current divided by the turns ratio, and I'_p, the primary current divided by the rated transformation ratio. Absence of turns correction means $I'_p = I''_p$. If turns correction is present, I'_p is different from I''_p, and since I''_p is used in the vector diagram and I'_p is used for the determination of the current error, it will be seen that turns correction has an influence on the current error (and may be used deliberately for that purpose). However, the vectors I'_p and I''_p have the same direction, so turns correction has no influence on phase displacement.

It will also be apparent that the influence of turns correction on composite error is less than its influence on current error.

A3. The error triangle

In Figure A2, page 74, the upper part of Figure A1 is re-drawn to a larger scale and under the further assumption that the phase displacement is so small that for practical purposes the two vectors I_s and I''_p can be considered to be parallel. Assuming again that there is no turns correction, it will be seen by projecting I_e to I_p that with a good approximation the in-phase component (ΔI) of I_e can be used instead of the arithmetic difference between I''_p and I_s to obtain the current error and, similarly, the quadrature component (ΔI_q) of I_e can be used to express the phase displacement.

It will further be seen that under the given assumptions the exciting current I_e divided by I''_p is equal to the composite error according to Sub-clause 34.2.

Thus, for a current transformer without turns correction and under conditions where a vector representation is justifiable, the current error, phase displacement and composite error form a right-angled triangle.

In this triangle, the hypotenuse representing the composite error is dependent on the magnitude of the total burden impedance consisting of burden and secondary winding, while the division between current error and phase displacement depends on the power factors of the total burden impedance and of the exciting current. Zero phase displacement will result when these two power factors are equal, i.e. when I_s and I_e are in phase.

A4. Composite error

The most important application, however, of the concept of composite error is under conditions where a vector representation cannot be justified because non-linear conditions introduce higher harmonics in the exciting current and in the secondary current (see Figure A3, page 74).

It is for this reason that the composite error is defined as in Sub-clause 34.2 and not in the far simpler way as the vector sum of current error and phase displacement as shown in Figure A2, page 74.

Thus, in the general case, the composite error also represents the deviations from the ideal current transformer that are caused by the presence in the secondary winding of higher harmonics which do not exist in the primary. (The primary current is always considered sinusoidal for the purpose of this standard.)

A5. Direct test for composite error

Figure A4, page 74, shows a current transformer having a turns ratio of 1/1. It is connected to a source of primary (sinusoidal) current, a secondary burden with linear characteristics and to an ammeter in such a manner that both the primary and secondary currents pass through the ammeter but in opposite directions. In this manner, the resultant current through the ammeter will be equal to the exciting current under the prevailing conditions of sinusoidal primary current, and the r.m.s. value of that current related to the r.m.s. value of the primary current is the composite error according to Sub-clause 34.2.

Figure A4, therefore represents the basic circuit for the direct measurement of composite error.

Figure A5, page 74, represents the basic circuit for the direct measurement of composite error for current transformers having rated transformation ratios differing from unity. It shows two current transformers of the same rated transformation ratio. The current transformer marked (N) is assumed to have negligible composite error under the prevailing conditions (minimum burden), while the current transformer under test and marked (X) is connected to its rated burden. They are both fed from the same source of primary sinusoidal current, and an ammeter is connected to measure the difference between the two secondary currents. Under these conditions, the r.m.s. value of the current in the ammeter A_2 related to the r.m.s. value of the current in ammeter A_1 is the composite error of transformer (X), the relation being expressed as a percentage.

With this method, it is necessary that the composite error of transformer (N) is truly negligible under the conditions of use. It is not sufficient that transformer (N) has a known composite error since, because of the highly complicated nature of composite error (distorted waveform), any composite error of the reference transformer (N) cannot be used to correct the test results.

A6. Alternative method for the direct measurement of composite error

Alternative means may be used for the measurement of composite error and one method is shown in Figure A6, page 74.

Whilst the method shown in Figure A5 requires a "special" reference transformer (N) of the same rated transformation ratio as the transformer (X) and having negligible composite error at the accuracy limit primary current, the method shown in Figure A6, page 74, enables standard reference current transformers (N) and (N′) to be used at or about their rated primary currents. It is still essential, however, for these reference transformers to have negligible composite errors but the requirement is easier to satisfy.

In Figure A6, (X) is the transformer under test, (N) is a standard reference transformer with a rated primary current of the same order of magnitude as the rated accuracy limit primary current of transformer (X) (the current at which the test is to be made), and (N′) is a standard reference transformer having a rated primary current of the order of magnitude of the secondary current corresponding to the rated accuracy limit primary current of transformer (X). It should be noted that the transformer (N′) constitutes a part of the burden Z_B of transformer (X) and must therefore be taken into account in determining the value of the burden Z'_B. A_1 and A_2 are two ammeters and care must be taken that A_2 measures the difference between the secondary currents of transformers (N) and (N′).

If the rated transformation ratio of transformer (N) is K_n, of transformer (X) is K_{nx} and of transformer (N′) is K'_n, the ratio K_n must equal the product of K'_n and K_{nx}:

$$\text{i.e. } K_n = K'_n \cdot K_{nx}.$$

Under these conditions, the r.m.s. value of the current in ammeter A_2, related to the current in ammeter A_1, is the composite error of transformer (X), the relation being expressed as a percentage.

Note. - When using the methods shown in Figures A5 and A6, care should be taken to use a low impedance instrument for A_2 since the voltage across this ammeter (divided by the ratio of transformer (N′) in the case of Figure A6) constitutes part of the burden voltage of transformer (X) and tends to reduce the burden on this transformer. Similarly, this ammeter voltage increases the burden on transformer (N).

A7. Use of composite error

The numeric value of the composite error will never be less than the vector sum of the current error and the phase displacement (the latter being expressed in centiradians).

Consequently, the composite error always indicates the highest possible value of current error or phase displacement.

The current error is of particular interest in the operation of overcurrent relays, and the phase displacement in the operation of phase sensitive relays (e.g. directional relays).

In the case of differential relays, it is the combination of the composite errors of the current transformers involved which must be considered.

An additional advantage of a limitation of composite error is the resulting limitation of the harmonic content of the secondary current which is necessary for the correct operation of certain types of relays.

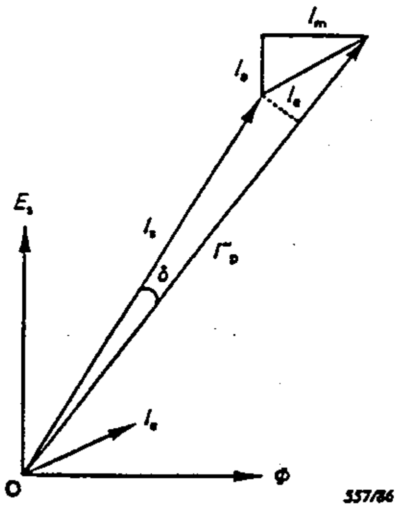


FIGURE A1

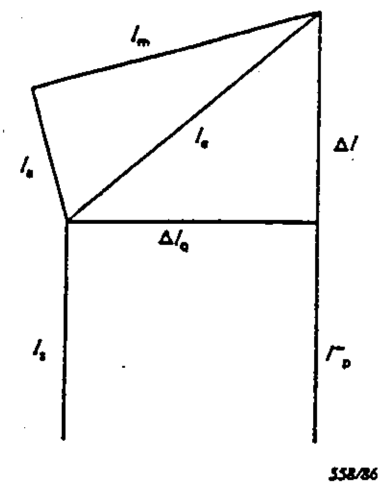


FIGURE A2

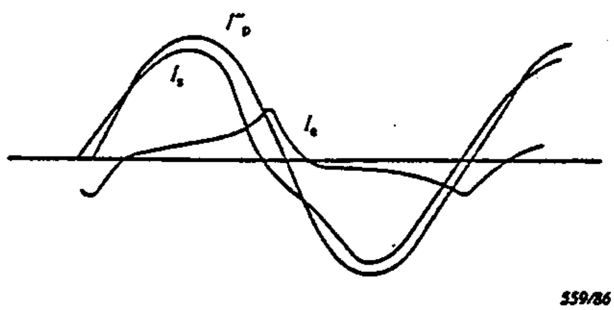


FIGURE A3

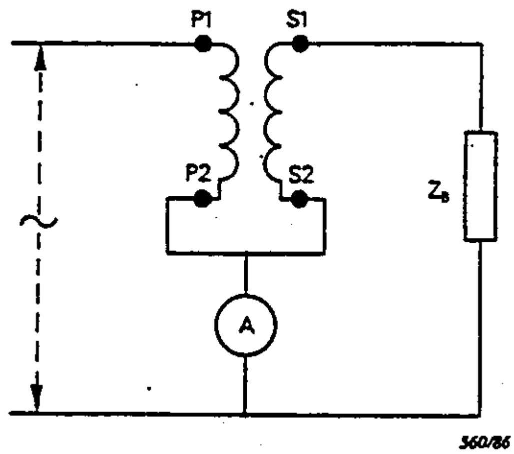


FIGURE A4

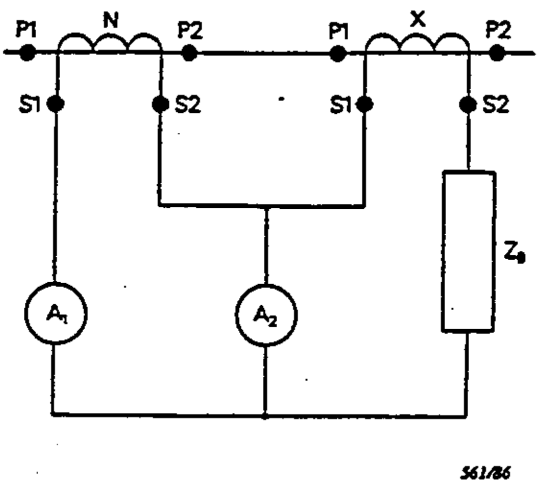


FIGURE A5

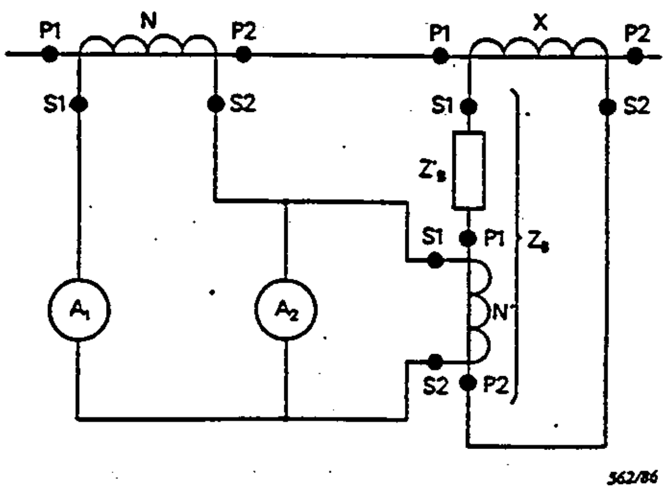


FIGURE A6

Publications de la CEI préparées par le Comité d'Etudes n° 38

44: – Transformateurs de mesure.

44-3 (1980)	Troisième partie: Transformateurs combinés.
44-4 (1980)	Quatrième partie: Mesure des décharges partielles.
185 (1987)	Transformateurs de courant.
186 (1987)	Transformateurs de tension.

IEC Publications prepared by Technical Committee No. 38

44: – Instrument transformers.

44-3 (1980)	Part 3: Combined transformers.
44-4 (1980)	Part 4: Measurement of partial discharges.
185 (1987)	Current transformers.
186 (1987)	Voltage transformers.

NORME INTERNATIONALE
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185

1987

AMENDEMENT 1
AMENDMENT 1

1990-07

Amendement 1

Transformateurs de courant

Amendment 1

Current transformers

Bureau Central de la Commission Electrotechnique Internationale 3, rue de Varembé Genève, Suisse

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

CODE PRIX
PRICE CODE B

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For price, see current catalogue

PREFACE

This amendment has been prepared by IEC Technical Committee No. 38: Instrument transformers.

The text of this amendment is based on the following documents:

Six Months' Rule	Report on Voting
38(CO)82	38(CO)85

Full information on the voting for the approval of this amendment can be found in the Voting Report indicated in the above table.

Page 53

27. Limits of current error and phase displacement

Add the following note at the end of this clause:

Note.- In general the prescribed limits of current error and phase displacement are valid for any given position of an external conductor spaced at a distance in air not less than that required for insulationin air at the highest voltage for equipment (U_m).

Special conditions of application, including lower ranges of operation voltages associated with high current values, should be a matter of separate agreement between manufacturer and purchaser.

Publications de la CEI préparées par le Comité d'Etudes n° 38

44: —	Transformateurs de mesure.
44-3 (1980)	Troisième partie: Transformateurs combinés.
44-4 (1980)	Quatrième partie: Mesure des décharges partielles.
44-6 (1992)	Partie 6: Prescriptions concernant les transformateurs de courant pour protection pour la réponse en régime transitoire.
185 (1987)	Transformateurs de courant. Modification n° 1 (1990).
186 (1987)	Transformateurs de tension. Modification n° 1 (1988).

IEC publications prepared by Technical Committee No. 38

44: —	Instrument transformers.
44-3 (1980)	Part 3: Combined transformers.
44-4 (1980)	Part 4: Measurement of partial discharges.
44-6 (1992)	Requirements for protective current transformers for transient performance.
185 (1987)	Current transformers. Amendment No. 1 (1990).
186 (1987)	Voltage transformers. Amendment No. 1 (1988).

NORME INTERNATIONALE
INTERNATIONAL STANDARD

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IEC
185

1987

AMENDEMENT 2
AMENDMENT 2

1995-08

Amendement 2

Transformateurs de courant

Amendment 2

Current transformers

Bureau Central de la Commission Electrotechnique Internationale 3, rue de Varembé Genève, Suisse

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

CODE PRIX
PRICE CODE R

Pour prix, voir catalogue en vigueur
For price, see current catalogue

FOREWORD

This amendment has been prepared by IEC technical committee 38: Instrument transformers.

The text of this amendment is based on the following documents:

DIS	Report on voting
38/147/DIS	38/156/RVD

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

Page 3

CONTENTS

Replace the titles of clauses 14, 17, 18, 20 and 21 by the following new titles:

14 Impulse tests on primary winding

17 Power frequency withstand tests on primary windings and partial discharge measurement

18 Power frequency withstand tests between sections of primary and secondary windings and on secondary windings

20 Chopped impulse test on primary winding

21 Measurement of capacitance and dielectric dissipation factor

Add the title of the new clause 21 bis, Mechanical tests

Add the title of the new annex B as follows:

Annex B – Multiple chopped impulse test ....

Page 7

Insert, in the existing list of IEC publications, the titles of the following standards:

IEC 71-1: 1993, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 270: 1981, *Partial discharge measurements*

IEC 567: 1992, *Guide for the sampling of gases and of oil from oil-filled electrical equipment and for the analysis of free and dissolved gases*

IEC 599: 1978, *Interpretation of the analysis of gases in transformers and other oil-filled electrical equipment in service*

IEC 815: 1986, *Guide for the selection of insulators in respect of polluted conditions*

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10 Insulation requirements

Replace existing subclauses 10.1 to 10.6 by the following:

These requirements apply to all types of current transformer insulation. For gas insulated current transformers supplementary requirements may be necessary (under consideration).

10.1 *Rated insulation levels for primary windings*

The rated insulation level of a primary winding of a current transformer shall be based on its highest voltage for equipment U_m.

For a current transformer without primary winding and without primary insulation of its own, the value U_m = 0,72 kV is assumed.

10.1.1 For windings having U_m = 0,72 kV or 1,2 kV, the rated insulation level is determined by the rated power frequency withstand voltage, according to table 2A.

10.1.2 For windings having U_m = 3,6 kV or higher, but less than 300 kV, the rated insulation level is determined by the rated lightning impulse and power frequency withstand voltages and shall be chosen in accordance with table 2A.

For the choice between the alternative levels for the same value of U_m see IEC 71.

10.1.3 For windings having U_m greater than or equal to 300 kV the rated insulation level is determined by the rated switching and lightning impulse withstand voltages and shall be chosen in accordance with table 2B.

For the choice between the alternative levels for the same value of U_m see IEC 71.

Table 2A – Rated insulation levels for transformer primary windings having highest voltage for equipment U_m < 300 kV

Highest voltage for equipment U_m (r.m.s.) kV	Rated power frequency withstand voltage (r.m.s.) kV	Rated lightning impulse withstand voltage (peak) kV
0,72	3	–
1,2	6	–
3,6	10	20 40
7,2	20	40 60
12	28	60 75
17,5	38	75 95
24	50	95 125
36	70	145 170
52	95	250
72,5	140	325
100	185	450
123	185	450
	230	550
145	230	550
	275	650
170	275	650
	325	750
245	395	950
	460	1 050

NOTE – For exposed installations, it is recommended to choose the highest insulation levels.

Table 2B – Rated insulation levels for transformer primary windings having highest voltage for equipment $U_m \geq 300$ kV

Highest voltage for equipment U_m (r.m.s.) kV	Rated switching impulse withstand voltage (peak) kV	Rated lightning impulse withstand voltage (peak) kV
300	750	950
	850	1 050
362	850	1 050
	950	1 175
420	1 050	1 300
	1 050	1 425
525	1 050	1 425
	1 175	1 550
765	1 425	1 950
	1 550	2 100

NOTES

1 For exposed installation it is recommended to choose the highest insulation levels.

2 As the test voltage levels for U_m = 765 kV have not as yet been finally settled, some interchange between switching and lightning impulse test levels may become necessary.

10.2 *Other requirements for primary winding insulation*

10.2.1 *Power frequency withstand voltage*

Windings having highest voltage for equipment $U_m \geq 300$ kV shall withstand the power frequency withstand voltage corresponding to the selected lightning impulse withstand voltage according to table 2C.

10.2.2 *Partial discharges*

Partial discharge requirements are applicable to current transformers having U_m not less than 7,2 kV.

The partial discharge level shall not exceed the limits specified in table 2D, at the partial discharge test voltage specified in the same table, after a prestressing performed according to the procedures of 17.2.

Table 2C – Power frequency withstand voltages for transformer primary windings having highest voltage for equipment $U_m \geq 300$ kV

Rated lightning impulse withstand voltage (peak) kV	Rated power frequency withstand voltage (r.m.s.) kV
950	395
1 050	460
1 175	510
1 300	570
1 425	630
1 550	680
1 950	880
2 100	975

Table 2D – Partial discharge test voltages and permissible levels

Type of earthing of the system	PD test voltage (r.m.s.) kV	Permissible PD level pC	
		Type of insulation	
		Immersed in liquid	Solid
Earthed neutral system (earthing factor ≤ 1,5)	U_m	10	50
	$1,2\ U_m/\sqrt{3}$	5	20
Isolated or non-effectively earthed neutral system (earthing factor > 1,5)	$1,2\ U_m$	10	50
	$1,2\ U_m/\sqrt{3}$	5	20

NOTES

1 If the neutral system is not defined, the values given for isolated or non-effectively earthed systems are valid.

2 The permissible PD level is also valid for frequencies different from rated frequency.

10.2.3 *Chopped lightning impulse*

If additionally specified, the primary winding shall also be capable of withstanding a chopped lightning impulse voltage having a peak value of 115 % of the full lightning impulse voltage.

NOTE – Lower values of test voltage may be agreed between manufacturer and purchaser.

10.2.4 *Capacitance and dielectric dissipation factor*

These requirements apply only to transformers with liquid immersed primary winding insulation having $U_m \geq 72,5$ kV.

The values of capacitance and dielectric dissipation factor (tan δ) shall be referred to the rated frequency and to a voltage level in the range from 10 kV to $U_m/\sqrt{3}$.

NOTES

1 The purpose is to check the uniformity of the production. Limits for the permissible variations may be the subject of an agreement between manufacturer and purchaser.

2 The dielectric dissipation factor is dependent on the insulation design and on both voltage and temperature. Its value at $U_m/\sqrt{3}$ and ambient temperature normally does not exceed 0,005.

10.2.5 *Multiple chopped impulses*

If additionally agreed, the primary winding of oil-immersed CTs having $U_m \geq 300$ kV shall be capable of withstanding multiple chopped impulses for checking the behaviour to high-frequency stresses expected in operation.

As there is not enough experience to propose a definitive test programme and acceptance criteria, in this standard only some information is given in annex B on possible test procedure. The proof that the design is adequate is left to the manufacturer.

NOTE – The design should be particularly examined with respect to internal shields and connections carrying transient currents.

10.3 *Between section insulation requirements*

For primary and secondary windings divided in two or more sections, the rated power frequency withstand voltage of the insulation between sections shall be 3 kV (r.m.s.)

10.4 *Insulation requirements for secondary windings*

The rated power frequency withstand voltage for secondary windings insulation shall be 3 kV (r.m.s.).

10.5 *Interturn insulation requirements*

The rated withstand voltage for interturn insulation shall be 4,5 kV peak. For some types of transformers, lower values can be accepted in accordance with the test procedure given in clause 19.

NOTE – Due to the test procedure, the waveshape may be highly distorted.

10.6 *Creepage distance*

10.6.1 *Pollution and creepage distance*

For outdoor current transformers with ceramic insulator susceptible to contamination, the creepage distances for given pollution levels are given in table 3.

Table 3 – Creepage distances for given pollution levels

Pollution level		Minimum nominal specific creepage distance mm/kV 1) 2)	Creepage distance / Arcing distance
I	Light	16	≤ 3,5
II	Medium	20	
III	Heavy	25	≤ 4,0
IV	Very heavy	31	

1) Ratio of the leakage distance between phase and earth over the r.m.s. phase-to-phase value of the highest voltage for the equipment (see IEC 71-1).

2) For other information and manufacturing tolerances on the creepage distance see IEC 815.

NOTES

1 It is recognized that the performance of surface insulation is greatly affected by insulator shape.

2 In very lightly polluted areas, specific nominal creepage distances lower than 16 mm/kV can be used depending on service experience. 12 mm/kV seems to be a lower limit.

3 In cases of exceptional pollution severity, a specific nominal creepage distance of 31 mm/kV may not be adequate. Depending on service experience and/or on laboratory test results, a higher value of specific creepage distance can be used, but in some cases the practicability of washing may have to be considered.

Page 33

Add the following new subclause:

10.8 *Mechanical requirements*

These requirements apply only to current transformers having a highest voltage for equipment of 72,5 kV and above.

In table 7 guidance is given on the static loads that current that current transformers shall be capable of withstanding. The figures include loads due to wind and ice.

The specified test loads are intended to be applied in any direction to the primary terminals.

Table 7 – Static withstand test loads

Highest voltage for equipment U_m kV	Static withstand load F_R N	
	Load class I	Load class II
72,5 to 100	1 250	2 500
123 to 170	2 000	3 000
245 to 362	2 500	4 000
≥ 420	4 000	6 000

NOTES

1 The sum of the loads acting in routinely operating conditions should not exceed 50 % of the specified withstand test load.

2 Current transformers should withstand rarely occurring extreme dynamic loads (e.g. short-circuits) not exceeding 1,4 times the static withstand test load.

3 For some applications it may be necessary to establish the resistance to rotation of the primary terminals. The moment to be applied during test shall be agreed between manufacturer and purchaser.

Page 33

11 Classification of tests

Replace the subclauses 11.1, 11.2 and 11.3 by the following:

11.1 *Type tests*

The following tests are type tests; for details reference should be made to the relevant clauses:

a) Short-time current test	clause 12
b) Temperature rise test	clause 13
c) Lightning impulse test	14.2
d) Switching impulse test	14.3
e) Wet test for outdoor type transformers	clause 15
f) Determination of errors	clauses 29, 31 and 39

All the dielectric type tests should be carried out on the same transformer, unless otherwise specified.

After transformers have been subjected to the dielectric type tests of 11.1, they shall be subjected to all the routine tests of 11.2.

Evidence of insulation failure due to the test may be given by variation in the waveshape at both reference and rated withstand voltage.

Improvements in failure detection may be obtained by recording of the current(s) to earth as a complement to the voltage record.

14.2 *Lightning impulse test*

The test voltage shall have the appropriate value, given in tables 2A or 2B depending on the highest voltage for equipment and the specified insulation level.

14.2.1 *Windings having U_m < 300 kV*

The test shall be performed with both positive and negative polarities. Fifteen consecutive impulses of each polarity, not corrected for atmospheric conditions, shall be applied.

The transformer passes the test if for each polarity:

- no disruptive discharge occurs in the non-self-restoring internal insulation;
- no flashovers occur along the non-self-restoring external insulation;
- no more than two flashovers occur across the self-restoring external insulation;
- no other evidence of insulation failure is detected (e.g. variations in the waveshape of the recorded quantities).

NOTE – The application of 15 positive and 15 negative impulses is specified for testing the external insulation. If other tests are agreed between manufacturer and purchaser to check the external insulation, the number of lightning impulses may be reduced to three of each polarity, not corrected for atmospheric conditions.

14.2.2 *Windings having $U_m \geq$ 300 kV*

The test shall be performed with both positive and negative polarities. Three consecutive impulses of each polarity, not corrected for atmospheric conditions, shall be applied.

The transformer passes the test if:

- no disruptive discharge occurs;
- no other evidence of insulation failure is detected (e.g. variations in the waveshape of the recorded quantities).

14.3 *Switching impulse test*

The test voltage shall have the appropriate value, given in table 2B, depending on the highest voltage for equipment and the specified insulation level.

The test shall be performed with positive polarity. Fifteen consecutive impulses, corrected for atmospheric conditions, shall be applied.

For outdoor-type transformers the test shall be performed under wet conditions (see clause 15).

The transformer passes the test if:

- no disruptive discharge occurs in the non-self-restoring internal insulation;
- no flashovers occur along the non-self-restoring external insulation;
- no more than two flashovers occur across the self-restoring external insulation;
- no other evidence of insulation failure is detected (e.g. variations in the waveshape of the recorded quantities).

NOTE – Impulses with flashover to the walls or ceilings of the laboratory should be disregarded.

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15 Wet test for outdoor type transformers

Replace the existing text of this clause by the following:

The wetting procedure shall be in accordance with IEC 60-1.

For windings having U_m < 300 kV, the test shall be performed with power frequency voltage of the appropriate value given in table 2A depending on the highest voltage for equipment applying corrections for atmospheric conditions.

For windings having $U_m \geq 300$ kV, the test shall be performed with switching impulse voltage of positive polarity of the appropriate value given in table 2B, depending on the highest voltage for equipment and the rated insulation level.

17 Power frequency tests on primary windings and measurement of partial discharges

Replace the title and text of this clause by the following:

17 Power frequency withstand tests on primary windings and partial discharge measurement

17.1 *Power frequency test*

The power frequency withstand test shall be performed in accordance with IEC 60-1.

The test voltage shall have the appropriate value given in tables 2A or 2C depending on the highest voltage for equipment. The duration shall be 60 s.

The test voltage shall be applied between the short-circuited primary winding and earth. The short-circuited secondary winding(s), the frame, case (if any) and core (if there is a special earth terminal) shall be connected to earth.

17.2 *Partial discharges measurement*

17.2.1 *Test circuit and instrumentation*

The test circuit and the instrumentation used shall be in accordance with IEC 270. Some examples of test circuits are shown in figures 1 to 3.

The instrument used shall measure the apparent charge *q* expressed in picocoulomb (pC). Its calibration shall be performed in the test circuit (see an example in figure 4).

A wide-band instrument shall have a bandwidth of at least 100 kHz with an upper cut-off frequency not exceeding 1,2 MHz. Narrow-band instruments shall have their resonance frequency in the range 0,15 to 2 MHz. Preferred values should be in the range from 0,5 to 2 MHz but, if feasible, the measurement should be performed at the frequency which gives the highest sensitivity.

The sensitivity shall allow the detection of a partial discharge level of 5 pC.

NOTES

1 The noise should be sufficiently lower than the sensitivity. Pulses that are known to be caused by external disturbances may be disregarded.

2 For the suppression of external noise, the balanced test circuit (figure 3) is appropriate.

3 When electronic signal processing and recovery are used to reduce the background noise, this should be demonstrated by varying its parameters such that it allows the detection of repeatedly occurring pulses.

17.2.2 *Partial discharge test procedure*

After a prestressing performed according to procedure A or B, the partial discharge test voltages specified in table 2D are reached and the corresponding partial discharge levels are measured in a time within 30 s.

The measured partial discharge shall not exceed the limits specified in table 2D.

Procedure A:

The partial discharge test voltages are reached while decreasing the voltage after the power frequency withstand test.

Procedure B:

The partial discharge test is performed after the power frequency withstand test. The applied voltage is raised to 80 % of the power frequency withstand voltage, maintained for not less than 60 s, then reduced without interruption to the specified partial discharge test voltages.

If not otherwise specified, the choice of the procedure is left to the manufacturer. The test method used shall be indicated in the test report.

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18 Power frequency tests between sections of primary and secondary windings and on secondary windings

Replace the title and text of this clause by the following:

18 Power frequency withstand tests between sections of primary and secondary windings and on secondary windings

The test voltage, with the appropriate value given in 10.3 and 10.4 respectively, shall be applied for 60 s in turn between the short-circuited terminals of each winding section or each secondary winding and earth.

The frame, case (if any), core (if there is a special earth terminal) and the terminals of all the other windings or sections shall be connected together and to earth.

19 Test of interturn insulation

Replace the title and text of this clause by the following:

19 Interturn overvoltage test

The interturn overvoltage test shall be performed in accordance to one of the following procedures.

If not otherwise agreed, the choice of the procedure is left to the manufacturer.

Procedure A:

With the secondary windings open-circuited (or connected to a high impedance device which reads peak voltage), a substantially sinusoidal current at a frequency between 40 Hz and 60 Hz (in accordance with IEC 60-1) and of r.m.s. value equal to the rated primary current (or rated extended primary current when applicable) shall be applied for 60 s to the primary winding.

The applied current shall be limited if the test voltage of 4,5 kV peak is obtained before reaching the rated current (or extended rated current).

Procedure B:

With the primary winding open-circuited, the prescribed test voltage (at some suitable frequency) shall be applied for 60 s to the terminals of each secondary winding, providing that the r.m.s. value of the secondary current does not exceed the rated secondary current (or rated extended current).

The value of the test frequency shall be not greater than 400 Hz.

At this frequency, if the voltage value achieved at the rated secondary current (or rated extended current) is lower than 4,5 kV peak, the obtained voltage is to be regarded as the test voltage.

When the frequency exceeds twice the rated frequency, the duration of the test may be reduced from 60 s as below:

$$\text{duration of test (in s)} = \frac{\text{twice the rated frequency}}{\text{test frequency}} \times 60$$

with a minimum of 15 s.

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20 Chopped lightning-impulse test on primary windings

Replace the title and text of this clause by the following:

20 Chopped impulse test on primary winding

The test shall be carried out with negative polarity only and combined with the negative polarity lightning impulse test in the manner described below.

The voltage shall be a standard lightning impulse, chopped between 2 µs and 5 µs. The chopping circuit shall be so arranged that the amplitude of overswing of opposite polarity of the actual test impulse shall be limited to approximately 30 % of the peak value. The test voltage of the full impulses shall have the appropriate value, given in tables 2A or 2B, depending on the highest voltage for equipment and the specified insulation level.

The chopped impulse test voltage shall be in accordance with 10.2.3.

The sequence of impulse applications shall be as follows:

a) for windings having $U_m < 300$ kV:
   - one full impulse;
   - two chopped impulses;
   - fourteen full impulses.

b) for windings having $U_m \geq 300$ kV:
   - one full impulse;
   - two chopped impulses;
   - two full impulses.

Differences in wave shape of full wave applications before and after the chopped impulses are an indication of an internal fault.

Flashovers during chopped impulses along self-restoring external insulation shall be disregarded in the evaluation of the behaviour of the insulation.

21 Measurement of dielectric dissipation factor

Replace the title and text of this clause by the following:

21 Measurement of capacitance and dielectric dissipation factor

The measurement of capacitance and dielectric dissipation factor shall be made after the power frequency withstand test on the primary windings.

The test voltage shall be applied between the short-circuited primary winding terminals and earth. Generally the short-circuited secondary winding(s), any screen and the insulated metal casing shall be connected to the measuring bridge. If the current transformer has a special device (terminal) suitable for this measurement, the other low-voltage terminals shall be short-circuited and connected together with the metal casing to the earth or the screen of the measuring bridge.

NOTE – In some cases, it is necessary to connect the earth to other points of the bridge.

The test shall be performed with the current transformer at ambient temperature whose value shall be recorded.

Add the following new clause after clause 21:

21 bis Mechanical tests

The tests are carried out to demostrate that a current transformer is capable of complying with the requirements specified in 10.8.

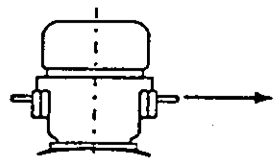
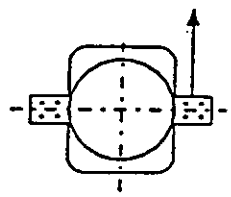
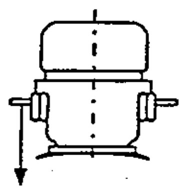
The current transformer shall be completely assembled, installed in vertical position with the frame rigidly fixed.

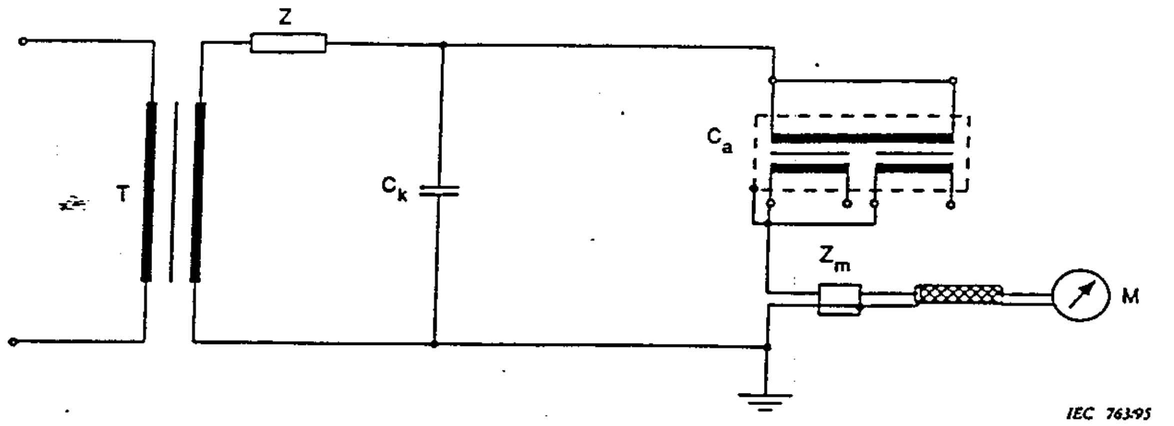
Liquid-immersed current transformers shall be filled with the specified insulation medium and submitted to the operating pressure.

The test loads shall be applied for 60 s for each of the conditions indicated in table 8.

The current transformer shall be considered to have passed the test if there is no evidence of damage (deformation, rupture or leakage).

Table 8 – Modalities of application of test loads to be applied to the primary terminals

Horizontal to each terminal	
	
Vertical to each terminal	
NOTE – The test load shall be applied to the centre of the terminal.	



T is the test transformer

C_a is the instrument transformer to be tested

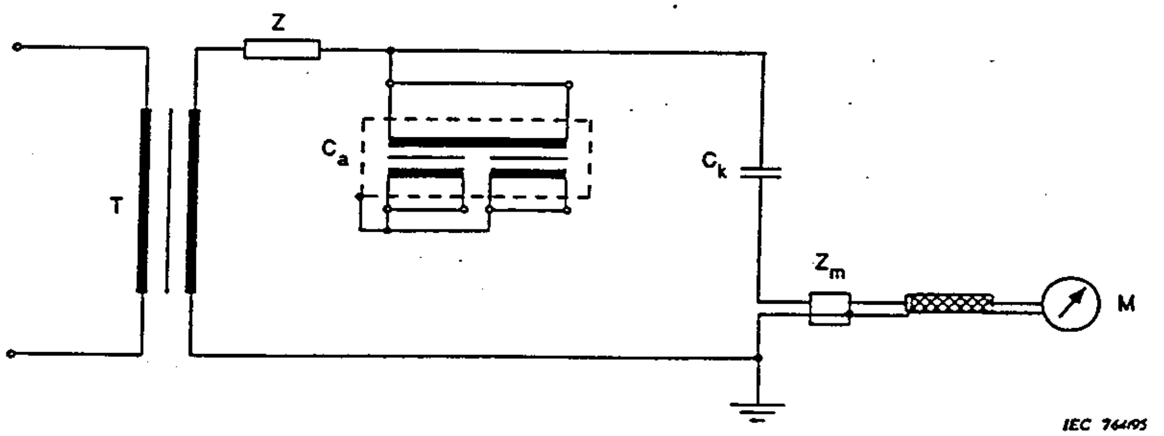
C_k is the coupling capacitor

M is the PD measuring instrument

Z_m is the measuring impedance

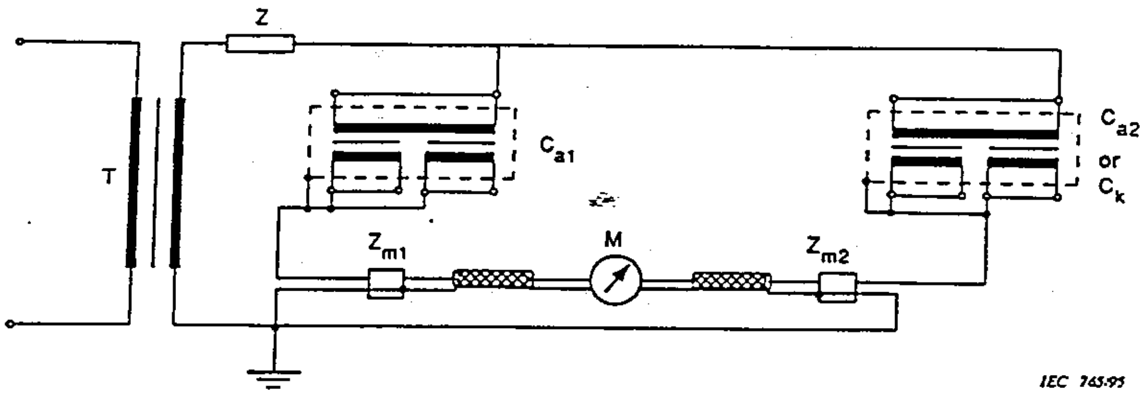
Z is the filter (not present if C_k is the capacitance of the test transformer)

Figure 1 – Test circuit for partial discharge measurement



Symbols as in figure 1

Figure 2 – Alternative test circuit for partial discharge measurement



T is the test transformer

C_{a1} is the instrument transformer under test

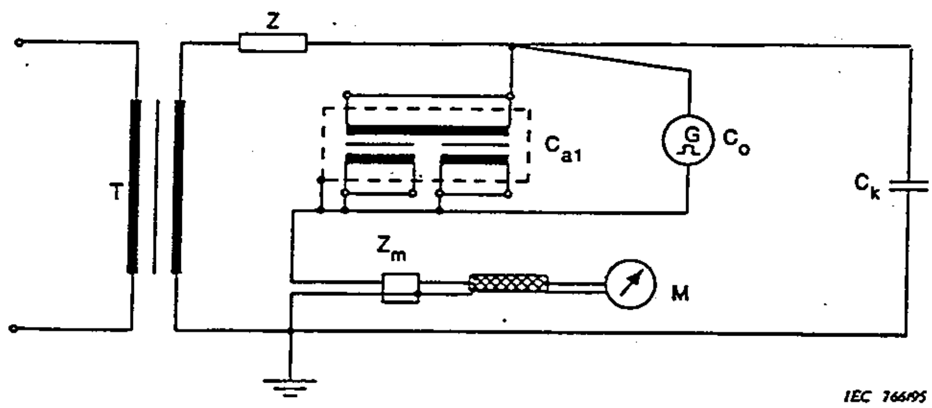
C_{a2} is the auxiliary PD free object (or C_k coupling capacitor)

M is the PD measuring instrument

Z_{m1} and Z_{m2} are the measuring impedances

Z is the filter

Figure 3 – Example of balanced test circuit for partial discharge measurement



Symbols as in figure 1

G is the impulse generator with capacitance C_0

Figure 4 – Example of calibration circuit for partial discharge measurement

Annex B
(informative)

Multiple chopped impulse test

The test shall be performed with impulses of negative polarity chopped near the crest.

The virtual duration of voltage collapse, measured according to IEC 60-1, shall be about 0,5 µs. The circuit shall be so arranged that the overswing to opposite polarity of the recorded impulse shall be of the order of 50 % of the peak value.

The voltage peak value should be about 60 % of the rated lightning impulse withstand voltage.

At least 100 impulses are necessary to put failures in evidence. They shall be applied at the rate of about one impulse per minute.

Before the test and three days after the test the analysis of the gas dissolved in the oil of the transformer shall be carried out.

The criteria for evaluating the result should be based on the amount and composition of the gases produced (ratio of the quantities of significant gases) but no figures can presently be given. Relatively large amounts of H_2 and C_2H_2 are an indication of fault.

Oil sampling procedure may be the one given in IEC 567.

Analysis procedure and basis for fault diagnosis may be based on IEC 599.

Publications de la CEI préparées par le Comité d'Etudes n° 38

44: — Transformateurs de mesure.

44-3 (1980)	Troisième partie: Transformateurs combinés.
44-4 (1980)	Quatrième partie: Mesure des décharges partielles.
44-6 (1992)	Partie 6: Prescriptions concernant les transformateurs de courant pour protection pour la réponse en régime transitoire.
185 (1987)	Transformateurs de courant. Modification n° 1 (1990). Amendement 2 (1995).
186 (1987)	Transformateurs de tension. Modification n° 1 (1988). Amendement 2 (1995).

IEC publications prepared by Technical Committee No. 38

44: — Instrument transformers.

44-3 (1980)	Part 3: Combined transformers.
44-4 (1980)	Part 4: Measurement of partial discharges.
44-6 (1992)	Requirements for protective current transformers for transient performance.
185 (1987)	Current transformers. Amendment No. 1 (1990). Amendment 2 (1995).
186 (1987)	Voltage transformers. Amendment No. 1 (1988). Amendment 2 (1995).