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BRITISH STANDARD

BS 7626 : 1993

Specification for

Current transformers

(Implementation of CENELEC HD 553 S1)

UDC 621.314.6

BSI STANDARDS

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Power Electrical Engineering Standards Policy Committee (PEL/-) to Technical Committee PEL/59, upon which the following bodies were represented:

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National foreword

This British Standard has been prepared under the direction of the Power Electrical Engineering Standards Policy Committee. It implements Harmonization Document HD 553 S1 : 1992, published by the European Committee for Electrotechnical Standardization (CENELEC) which was derived from IEC 185 : 1987 plus Amendment No. 1 (1990), published by the International Electrotechnical Commission (IEC).

The CENELEC common modifications have been implemented at the appropriate places in the text and are indicated by a side line in the margin. Parts of the original IEC text that have been modified by CENELEC have been quoted in national annex NA.

This British Standard supersedes BS 3938 : 1973 which is declared obsolescent.

Products may continue to be manufactured to BS 3938 : 1973 until 1 June 1998.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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English version

Current transformers

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Transformateurs de courant
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Stromwandler
(IEC 185 : 1987, modifiziert)

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Up-to-date lists and bibliographical references concerning national implementation may be obtained on application to the Central Secretariat or to any CENELEC member.

This Harmonization Document exists in three official versions (English, French, German).

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

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Foreword

The CENELEC 53rd Technical Board decided the issue of a primary questionnaire on IEC Publication 185 : 1987. Based on the comments received from National Committees, 56 BT set up a task force (BTTF 56-3) to prepare the common modifications. These modifications were discussed on 1988-11-24 and the voting procedure was started on 1990-02-08.

The vote had a positive result for EEC Committees but, taking into account some negative votes received, 65 BT committed BTTF 56-3 to prepare a final text with some improvements, basically of an editorial nature, before ratification. BTTF 56-3 finalized the text on 1990-10-23 for submission to 66 BT, which accepted it for submission to a second vote.

The text of this draft was approved by CENELEC as HD 553 S1 on 24 March 1992.

The following dates have been fixed:

- latest date of announcement of the HD at national level (doa) 1992-12-01
- latest date of publication of a harmonized national standard (dop) 1993-06-01
- latest date of withdrawal of conflicting national standards (dow) 1993-06-01

For products which have complied with the relevant national standard before 1993-06-01, as shown by the manufacturer or by a certification body, this previous standard may continue to apply for production until 1998-06-01.

Annexes designated 'normative' are part of the body of the standard. In this standard, annex ZA (cross references) is normative and annex ZB (B-deviations) is informative.

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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 class –25 outdoor type transformers	–25 °C
— minimum, for class –40 outdoor type transformers	–40 °C

In extreme cases, for outdoor transformers, lower minimum ambient temperatures (i.e. –50 °C) may be required.

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 (U_m) 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.)

Note. — When a current transformer is a part of another equipment (i.e. switchgear), a rated time other than 1 s may be specified.

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 Table IIA.

*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
100	380	150
100	450	185
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 IIB

deleted

TABLE IIC

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 II E

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 II D).

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).

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.

10.2.3 *Chopped lightning impulse*

If additionally specified, the primary windings shall also be capable of withstanding chopped lightning-impulse voltages as per Clause 20.

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^2t) 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 IIA, IIB and IIC, 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 $U_m \geqslant 300$ 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 IIC, 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 $U_m \geqslant 300$ 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 $U_m \geqslant 300$ kV*

The power frequency test for windings having $U_m \geqslant 300$ 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 II D, 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 II E, 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 current at a frequency between 40 Hz and 60 Hz (in accordance with IEC Publication 60) and of r.m.s. value equal to the rated primary current (or rated extended current when applicable) shall be applied for 1 min to the primary winding. If the voltage produced at the secondary terminals has a peak value greater than the prescribed test voltage, the applied current shall be reduced accordingly.

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 no greater than ten 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).

When the test frequency exceeds twice the rated frequency, the duration of the test may be reduced from 1 min as below:

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

with a minimum of 15 s.

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 115% chopped impulses
- —fourteen 100% full impulses

b) Windings having $U_m \geq 300$ kV
- —one 100% full impulse
- —two 115% chopped impulses
- —two 100% full impulses

Other test voltage values may be agreed upon between purchaser and manufacturer.

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.

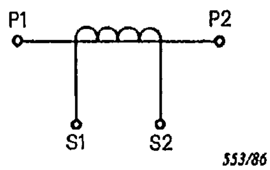
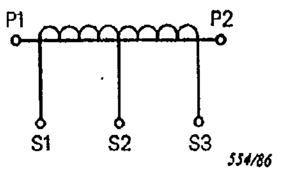
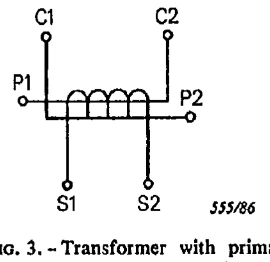
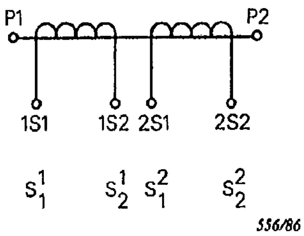
22.1 *Method of marking*

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.)

Other terminal markings may be used when specified in national standards.

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, 15VA, Class 0.5; 2S, 30VA, 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.

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 insulation in 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.

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 5	3 5	3 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%:

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

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.

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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.

A.6. 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}:

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.

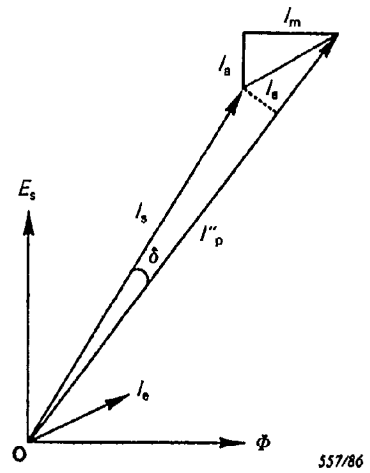

FIGURE A1

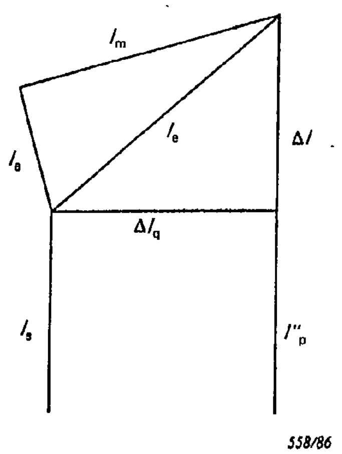

FIGURE A2

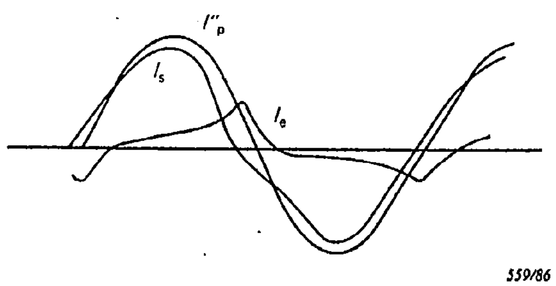

FIGURE A3

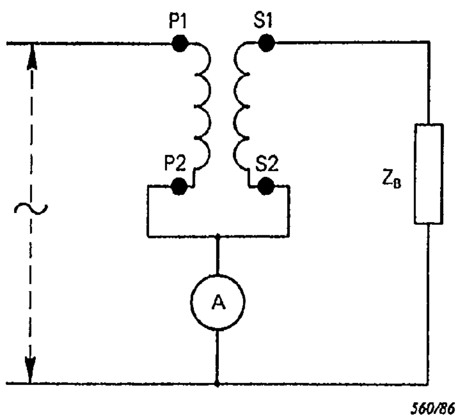

FIGURE A4

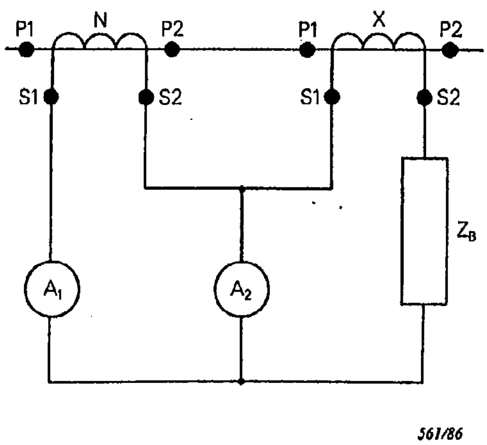

FIGURE A5

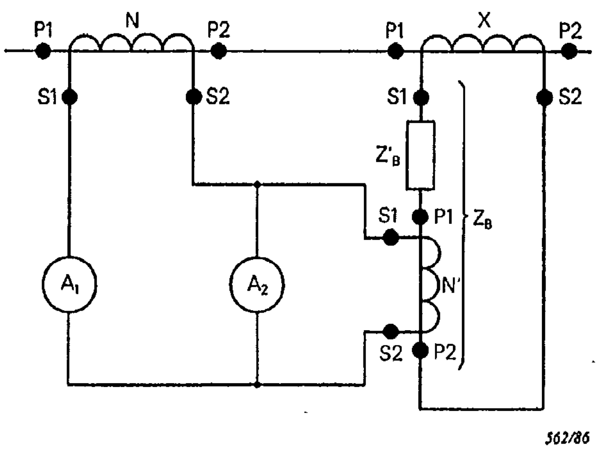

FIGURE A6

ANNEX ZA (normative)

OTHER INTERNATIONAL PUBLICATIONS QUOTED IN THIS STANDARD WITH THE REFERENCES OF THE RELEVANT EUROPEAN PUBLICATIONS

When the international publication has been modified by CENELEC common modifications, indicated by (mod), the relevant EN/HD applies.

IEC Publication	Date	Title	EN/HD	Date
28	1925	International standard of resistance for copper	—	—
38, mod	1983	IEC Standard voltages†	HD 472 S1	1989
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	Series	Insulation co-ordination	HD 540	Series
85	1984	Thermal evaluation and classification of electrical insulation	HD 566 S1	1990
507	1975	Artificial pollution tests on high-voltage insulators to be used on a.c. systems (Report)	—	—

† The title of HD 472 S1 is: Nominal voltages for low voltages public electricity supply systems.
* IEC 60-1 : 1989 was harmonized as HD 588 S1 : 1991.

ANNEX ZB (informative)

B-deviations

B-deviation: National deviation from an HD due to particular technical requirements, permitted for a specified transitional period.

Clause	Deviation	Latest date for removal
	SWEDEN	1997-03-31
2	Add a new subclause: 2.5 *Mechanical strength* The manufacturer shall state the highest permissible force which may be applied to a primary terminal in a direction along its axis and in an arbitrary direction in a plane perpendicular to the terminal axis.	
10.3 – 10.5	The secondary winding insulation shall be capable of withstanding 4 kV instead of 3 kV. The inter-turn insulation of the windings shall be capable of withstanding 6 kV peak across the complete secondary winding instead of 4,5 kV.	
27	For classes 0,1 to 0,5 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 1 VA to 100 % of the rated burden provided rated output is not higher than 20 VA.	
41	The rating plate shall contain the constants needed for calculation of the accuracy limit factor.	

National annex NA (informative)

Original IEC text amended by CENELEC common modifications

2. Service conditions

2.1 has been replaced. It read as follows.

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

3. Definitions

In 3.16, the title has been changed. It read as follows.

3.16 *Highest voltage for equipment*

10. Insulation requirements

In 10.1.1, last line, 'Tables IIA or IIB' has been replaced by 'Table IIA'.

Table IIA has been modified. It was as follows.

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
	40	10
7.2	40	20
	60	20
12	60	28
	75	28
17.5	75	38
	95	38
24	95	50
	125	50
36	145	70
	170	70
52	250	95
72.5	325	140
123	450	185
145	550	230
170	650	275
	750	325
245	850	360
	950	395
	1 050	460

Table IIB has been deleted. It was as follows.

TABLE IIB

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

The note to Table IIE has been moved to 10.2.2.

10.2.3 has been replaced. It read as follows.

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.

19. Test of interturn insulation

The text of Procedure A has been replaced. It read as follows.

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.

The second paragraph of Procedure B has been replaced. It read as follows.

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).

20. Chopped lightning-impulse test on primary windings

Items a) and b) have been modified. They read as follows.

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

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

National annex NB (informative)

Cross-references

Publication referred to	Corresponding British Standard
IEC 44-4 : 1980	BS 6184 : 1981 *Method for measuring partial discharges in instrument transformers*
IEC 50(321) : 1986	BS 4727 *Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms* Part 2 : Group 16 : 1991 *Instrument transformers*
IEC 60-1 : 1990	BS 923 *Guide on high-voltage testing techniques* Part 1 : 1990 *General*
	BS 5622 *Guide for insulation co-ordination*
IEC 71-1 : 1976	Part 1 : 1979 *Terms, definitions, principles and rules*
IEC 71-2 : 1976	Part 2 : 1979 *Application guide*
IEC 85 : 1984	BS 2757 : 1986 *Method for determining the thermal classification of electrical insulation*

BSI BS*7626 93 ■ 1624669 0338783 029 ■

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