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Transformateurs de tension

Voltage transformers

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

VOLTAGE 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.

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4) The IEC has not laid down any procedure concerning marking as an indication of approval and has no responsibility when an item of equipment is declared to comply with one of its recommendations.

PREFACE

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

This second edition replaces the first edition of IEC Publication 186(1969) as well as Supplements A (1970) and B (1981) and Amendments No. 1 (1978) and No. 2 (1980).

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)69	38(CO)71	38(CO)73	38(CO)76

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): Instruments Transformers, Part 4: Measurement of Partial Discharges.
50(321) (1986): International Electrotechnical Vocabulary (IEV), Chapter 321: Instrument Transformers.

60: High-Voltage Test Techniques.
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.
358 (1971): Coupling Capacitors and Capacitor Dividers.
507 (1975): Artificial Pollution Tests on High-Voltage Insulators to be Used on A.C. Systems.

VOLTAGE TRANSFORMERS

CHAPTER I: GENERAL REQUIREMENTS APPLICABLE TO ALL VOLTAGE TRANSFORMERS

SECTION ONE – GENERAL

1. Scope

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

The general requirements of this chapter apply to all voltage transformers, but, for certain types, for example capacitor voltage transformers, the requirements are subject to the modifications stated in the appropriate chapter.

Although the requirements relate basically to transformers with separate windings, they are also applicable, where appropriate, to auto-transformers. The standard does not apply to transformers for use in laboratories.

Note. – Requirements specific to three-phase voltage transformers are not included in this standard but, so far as they are relevant, the requirements in Chapter I apply to these transformers and a few references to them are included in Chapter I (e.g. see Sub-clauses 4.4 and 5.1, Clause 6 and Section Eight).

2. General requirements

All the transformers shall be suitable for measuring purposes, but, in addition, certain types may be suitable for protection purposes. Transformers for the dual purpose of measurement and protection shall comply with Chapters I, II, III and IV of this standard.

3. Service conditions

Unless otherwise specified, this standard is valid for the following service conditions.

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

3.1 *Ambient air temperature*

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

3.2 *Altitude*

Up to 1 000 m (3 300 ft) above sea level.

3.3 *Atmospheric conditions*

Atmospheres which are not heavily polluted.

3.4 *System earthing*

1) Isolated neutral system (see Sub-clause 4.20).

2) Resonant earthed system (see Sub-clause 4.21).

3) Earthed neutral system (see Sub-clause 4.23):

a) effectively earthed neutral system;

b) non-effectively earthed neutral system.

4. Definitions

For the purpose 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 number in brackets.

4.1 *Instrument transformer*

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

4.2 *Voltage transformer*

An instrument transformer in which the secondary voltage, in normal conditions of use, is substantially proportional to the primary voltage and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections (321-03-01).

4.3 *Unearthed voltage transformer*

A voltage transformer which has all parts of its primary winding, including terminals, insulated from earth to a level corresponding to its rated insulation level.

4.4 *Earthed voltage transformer*

A single-phase voltage transformer which is intended to have one end of its primary winding directly earthed or a three-phase voltage transformer which is intended to have the star-point of its primary winding directly earthed.

4.5 *Primary winding*

The winding to which the voltage to be transformed is applied.

4.6 *Secondary winding*

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

4.7 *Secondary circuit*

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

4.8 *Rated primary voltage*

The value of the primary voltage which appears in the designation of the transformer and on which its performance is based (321-01-12 modified).

4.9 *Rated secondary voltage*

The value of the secondary voltage which appears in the designation of the transformer and on which its performance is based (321-01-16 modified).

4.10 *Actual transformation ratio*

The ratio of the actual primary voltage to the actual secondary voltage (321-01-18 modified).

4.11 *Rated transformation ratio*

The ratio of the rated primary voltage to the rated secondary voltage (321-01-20 modified).

4.12 *Voltage error (ratio error)*

The error which a transformer introduces into the measurement of a voltage and which arises when the actual transformation ratio is not equal to the rated transformation ratio (321-01-22 modified).

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

$$\text{voltage error \%} = \frac{k_n U_s - U_p}{U_p} \times 100$$

where:

k_n is the rated transformation ratio

U_p is the actual primary voltage

U_s is the actual secondary voltage when U_p is applied under the conditions of measurement

4.13 *Phase displacement*

The difference in phase between the primary voltage and the secondary voltage 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 voltage vector leads the primary voltage vector. It is usually expressed in minutes or centiradians.

Note. — This definition is strictly correct for sinusoidal voltages only.

4.14 *Accuracy class*

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

4.15 *Burden*

The admittance of the secondary circuit expressed in siemens and power factor (lagging or leading).

Note. — The burden is usually expressed as the apparent power in voltamperes, absorbed at a specified power factor and at the rated secondary voltage.

4.16 *Rated burden*

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

4.17 *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 voltage and with rated burden connected to it (321-01-27 modified).

4.18 *Highest voltage for equipment*

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

4.19 *Rated insulation level*

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

4.20 *Isolated neutral system*

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

4.21 *A 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 phase-to-earth fault, the power-frequency inductive current passed by this reactor substantially neutralizes the power-frequency capacitance component of the earth-fault current.

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

4.22 *Factor of earthing*

The factor of earthing at a selected location of a three-phase system (generally, the point of installation of 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 fault-free phase at the selected location during a fault to earth (affecting one or more phases at any point) to the line-to-line r.m.s. power-frequency voltage which would be obtained at the selected location with the fault removed.

4.23 *An 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 transient oscillations and to give a current sufficient for selective earth fault protection.

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

Note. — This condition is obtained approximately when, for all system configurations, the ratio of zero-sequence reactance to the positive-sequence reactance is less than 3 and the ratio of zero-sequence resistance to positive-sequence reactance is less than 1.

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

4.24 *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.

4.25 *Non-exposed installation*

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

Note. — Such installations are usually connected to underground cable networks.

4.26 *Rated frequency*

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

4.27 *Rated voltage factor*

The multiplying factor to be applied to the rated primary voltage to determine the maximum voltage at which a transformer must comply with the relevant thermal requirements for a specified time and with the relevant accuracy requirements.

SECTION TWO — RATING AND PERFORMANCE REQUIREMENTS APPLICABLE TO ALL VOLTAGE TRANSFORMERS

5. Standard values of rated voltages

5.1 *Rated primary voltages*

The standard values of rated primary voltage of three-phase transformers and of single-phase transformers for use in a single-phase system or between lines in a three-phase system shall be one of the values of nominal system voltage designated as being usual values in IEC Publication 38: IEC Standard Voltages. The standard values of rated primary voltage of a single-phase transformer connected between one line of a three-phase system and earth or between a system neutral point and earth shall be $1/\sqrt{3}$ times one of the values of nominal system voltage.

Note. — The performance of a voltage transformer as a measuring or protection transformer is based on the rated primary voltage, whereas the rated insulation level is based on one of the highest voltages for equipment of IEC Publication 38.

5.2 *Rated secondary voltages*

The rated secondary voltage shall be chosen according to the practice at the location where the transformer is to be used. The values given below are considered standard values for single-phase transformers in single-phase systems or connected line-to-line in three-phase systems and for three-phase transformers:

a) Based on the current practice of a group of European countries:

100 V and 110 V;

200 V for extended secondary circuits.

b) Based on the current practice in the United States and Canada:

120 V for distribution systems;
115 V for transmission systems;
230 V for extended secondary circuits.

For single-phase transformers intended to be used phase-to-earth in three-phase systems where the rated primary voltage is a number divided by $\sqrt{3}$, the rated secondary voltage shall be one of the fore-mentioned values divided by $\sqrt{3}$, thus retaining the value of the rated transformation ratio.

Notes 1. — The rated secondary voltage for windings intended to produce a residual secondary voltage is under consideration.

2\. — Whenever possible, the rated transformation ratio should be of a simple value. If one of the following values: 10 - 12 - 15 - 20 - 25 - 30 - 40 - 50 - 60 - 80 and their decimal multiples is used for the rated transformation ratio together with one of the rated secondary voltages of this sub-clause, the majority of the standard values of nominal system voltage of IEC Publication 38 will be covered.

6. Standard values of rated output

The standard values of rated output at a power factor of 0.8 lagging, expressed in volt-amperes, are:

<u>10</u>, 15, <u>25</u>, 30, <u>50</u>, 75, <u>100</u>, 150, <u>200</u>, 300, 400, <u>500</u> VA.

The values underlined are preferred values. The rated output of a three-phase transformer shall be the rated output per phase.

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.

7. Standard values of rated voltage factor

The voltage factor is determined by the maximum operating voltage which, in turn, is dependent on the system and the voltage transformer primary winding earthing conditions.

The standard voltage factors appropriate to the different earthing conditions are given in Table I below, together with the permissible duration of maximum operating voltage (i.e. rated time).

TABLE I

Standard values of rated voltage factors

Rated voltage factor	Rated time	Method of connecting the primary winding and system earthing conditions
1.2	Continuous	Between phases in any network Between transformer star-point and earth in any network
1.2	Continuous	Between phase and earth in an effectively earthed neutral system (Sub-clause 4.23 *a)*)
1.5	30 s	
1.2	Continuous	Between phase and earth in a non-effectively earthed neutral system (Sub-clause 4.23 *b)*) with automatic earth fault tripping
1.9	30 s	
1.2	Continuous	Between phase and earth in an isolated neutral system without automatic earth fault tripping (Sub-clause 4.20) or in a resonant earthed system (Sub-clause 4.21) without automatic earth fault tripping
1.9	8 h	
Note. — Reduced rated times are permissible by agreement between manufacturer and user.		

8. Limits of temperature rise

Unless otherwise specified below, the temperature rise of a voltage transformer at the specified voltage, at rated frequency and at rated burden, or at the highest rated burden if there are several rated burdens, at any power factor between 0.8 lagging and unity, shall not exceed the appropriate value given in Table II.

The voltage to be applied to the transformer shall be in accordance with Item *a)*, *b)* or *c)* below, as appropriate:

a) *All voltage transformers irrespective of voltage factor and time rating* shall be tested at 1.2 times the rated primary voltage. The test shall be continued until the temperature of the transformer has reached a steady state.

b) *Transformers having a voltage factor of 1.5 for 30 s or 1.9 for 30 s* shall be tested at their respective voltage factor for 30 s starting after the application of 1.2 times rated voltage for a time sufficient to reach stable thermal conditions; the temperature rise shall not exceed by more than 10 K the value specified in Table II.

Alternatively, such transformers may be tested at their respective voltage factor for 30 s starting from the cold condition; the winding temperature rise shall not exceed 10 K.

Note. — This test may be omitted if it can be shown by other means that the transformer is satisfactory under these conditions.

c) Transformers having a voltage factor of 1.9 for 8 h shall be tested at 1.9 times the rated voltage for 8 h starting after the application of 1.2 times rated voltage for a time sufficient to reach stable thermal conditions; the temperature rise shall not exceed by more than 10 K the values specified in Table II.

The values in Table II are based on the service conditions given in Clause 3.

If ambient temperatures in excess of the values given in Sub-clause 3.1 are specified, the permissible temperature rise in Table II 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 II 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 II.

TABLE II

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. — For some materials (e.g. resin) the manufacturer should specify the relevant insulation class.

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

When the transformer is fitted with a conservator tank or 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 II.

9. Insulation requirements

9.1 *Rated insulation levels, primary windings*

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

9.1.1 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 power-frequency short-duration withstand voltages, shall be one of those given in Tables IIIA or IIIB.

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

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

9.2 *Other requirements for primary winding insulation*

9.2.1 *Power-frequency withstand voltage*

Windings having highest voltage for equipment $U_m \geq 300$ kV shall also be capable of withstanding the specified power-frequency test. There are two alternative methods specified in this standard for windings in this category. These 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 IIID.

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, depending on the highest voltage for equipment U_m, are given in Table IIIE.

Method I shall be used unless otherwise specified.

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

Note. — 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 should be considered a type test.

TABLE IIIA

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

Highest voltage for equipment U_m (r.m.s.)	Rated lightning-impulse withstand voltage (peak)	Rated power-frequency short-duration withstand (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
	850	360
245	950	395
	1 050	460

TABLE IIIB

Rated insulation levels for transformer primary windings having highest voltage for equipment below 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		Rated power-frequency short-duration withstand voltage (r.m.s)
	≤ 500 kVA	> 500 kVA	
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 IIIC

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 IIID

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 IIIE

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 pre-stress 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 IIID).

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: Instruments 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.

9.2.2 *Power-frequency withstand voltage for earthed terminal*

The terminal of the primary winding intended to be earthed shall, when insulated from the case or frame, be capable of withstanding a rated power-frequency short-duration withstand voltage of 3 kV r.m.s. for 1 min.

9.2.3 *Partial discharges*

The permissible magnitude of partial discharges and the requirements for their measurement are given in IEC Publication 44-4. That standard is applicable to all voltage transformers except transformers having $U_m \geqslant 300$ kV and requiring adoption of Method II (see Sub-clause 16.3).

9.2.4 *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 voltage.

9.3 *Between-section insulation requirements*

For 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.

9.4 *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.

9.5 *Creepage distance*

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

TABLE IV

Pollution level	Minimum nominal specific creepage distance between phase and ground (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.

9.6 *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 voltage 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.

9bis. **Short-circuit withstand capability**

The voltage transformer shall be designed and constructed to withstand without damage, when energized at rated voltage, the mechanical and thermal effects of an external short-circuit for the duration of 1 s.

SECTION THREE — TESTS — GENERAL

10. **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.

10.1 *Type tests*

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

a) Temperature-rise test (Clause 11)

b) Lightning-impulse test (Clause 13)

c) Switching-impulse test (Clause 13)

d) Wet test for outdoor type transformers (Clause 14)

e) Determination of errors (Clauses 26 and 35)

f) Short-circuit withstand capability test (Clause 12)

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

After transformers have been subjected to the dielectric type tests of Sub-clause 10.1, they shall be subjected to all routine tests of Sub-clause 10.2.

10.2 *Routine tests*

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

a) Verification of terminal markings (Clause 15).

b) Power-frequency withstand test on secondary winding (Clause 17).

c) Power-frequency withstand test between sections (Clause 17).

d) Power-frequency withstand test on primary windings (Clause 16).

e) Partial discharge measurement (Clause 16).

f) Determination of errors (Clauses 26.1 and 36).

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

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

10.3 *Special tests*

The following test is a special test. For details, reference should be made to the relevant clause:

a) Chopped lightning-impulse test (Clause 18)

SECTION FOUR – TYPE TESTS

11. **Temperature-rise test**

A test shall be made to prove compliance considered with Clause 8. For the purpose of this test, voltage transformers shall be considered to have attained a steady-state 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.

When there is more than one secondary winding, the test shall be made with the appropriate rated burden connected to each secondary winding, unless otherwise agreed between manufacturer and purchaser.

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

The temperature rise of the windings shall be measured by the increase in resistance method.

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

12. Short-circuit withstand capability test

This test shall be made to prove compliance with Sub-clause 9.7.

For this test, the transformer shall initially be at a temperature between 10 °C and 30 °C.

The voltage transformer shall be energized from the primary side and the short-circuit applied between the secondary terminals.

One short-circuit shall be applied for the duration of 1 s.

Note. — This requirement applies also where fuses are an integral part of the transformer.

During the short-circuit, the r.m.s. value of the applied voltage at the transformer terminals shall be not less than the rated voltage.

In the case of transformers provided with more than one secondary winding, or section, or with tappings, the test connection shall be agreed between manufacturer and purchaser.

Note. — For inductive type transformers, the test may be carried out by energizing the secondary winding and applying the short-circuit between the primary terminals.

The transformer shall be deemed to have passed this test if, after cooling to ambient temperature, it satisfies the following requirements:

a) it is not visibly damaged;

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

c) it withstands the dielectric tests specified in Clauses 16 and 17, but with the test voltage reduced to 90% of those given;

d) on examination, the insulation next to the surface of both the primary and the secondary windings does not show significant deterioration (e.g. carbonization).

The examination *d)* is not required if the current density in the winding does not exceed 160 A/mm^2 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. The current density is to be based on the measured symmetrical r.m.s. short-circuit current in the secondary winding (divided by the rated transformation ratio in the case of the primary).

13. Impulse tests on primary winding

13.1 *General*

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

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 wave-shape of the impulse voltages shall be recorded.

Evidence of insulation failure in the test may be given by variation in the recorded quantity(ies) at both reference and rated withstand voltage.

13.2 *Lightning-impulse test*

The test voltage shall have the appropriate values given in Tables IIIA, IIIB or IIIC, depending on the highest voltage for equipment and the specified insulation level. The test voltage shall be applied between each line terminal of the primary winding and earth. The earthed terminal of the primary winding or the non-tested line terminal in the case of an unearthed voltage transformer, the frame, case (if any) and core (if intended to be earthed) shall be earthed during the test.

In order to improve the failure detection, an additional quantity shall be recorded.

At the manufacturer's discretion, the earth connection may be made through a suitable current recording device. The secondary terminals may be connected together and earthed or may be connected to a suitable device for recording the voltage wave appearing across the secondary winding(s) during the test.

13.2.1 *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 has passed 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 (i.e. variations in the wave-shape of the recorded quantities).

For unearthed voltage transformers, approximately half the number of impulses shall be applied to each line terminal in turn with the other line terminal connected to earth.

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 should be reduced to three of each polarity, not corrected for atmospheric conditions.

13.2.2 *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 has passed the test if:

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

13.3 *Switching-impulse test*

The test voltages shall have the appropriate values given in Table IIIC, depending on the highest voltage for equipment and the specified insulation level. The test ~~voltage~~ shall be applied between the line terminal of the primary winding and earth. The earth terminal of the primary winding, one terminal of the secondary winding(s), the frame, case (if any) and core (if intended to be earthed) shall be connected to earth.

At the manufacturer's discretion, the earth connection may be made through a suitable current recording device. The non-earthed secondary terminals may be left open or connected to a high impedance device for recording the voltage wave appearing across the secondary windings(s) during the test.

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

Note. — To counteract the effect of core saturation, it is permissible, between consecutive impulses, to modify the magnetic status of the core by a suitable procedure.

Outdoor type transformers shall be subjected to wet tests. Dry tests are not required.

The transformer has passed the test if for each polarity:

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

14. 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.

14.1 *Windings having $U_m < 300$ kV*

The test shall be performed in accordance with Sub-clauses 16.1 and 16.2 with power-frequency voltage corrected for atmospheric conditions.

14.2 *Windings having $U_m \geqslant 300$ kV*

The test shall be performed with switching-impulse voltage in accordance with Sub-clause 13.3.

SECTION FIVE — ROUTINE TESTS

15. Verification of terminal markings

It shall be verified that the terminal markings are correct (see Clause 21).

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

16.1 *General*

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

For separate source withstand tests, the duration shall be 1 min.

For induced overvoltage withstand tests, the frequency of the test voltage may be increased above the rated value to prevent saturation of the core. The duration of the test shall be 1 min.

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

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

with a minimum of 15 s.

When Method II has been adopted, see Sub-clause 16.3.2.

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.

16.2 *Windings having $U_m < 300$ kV*

The test voltages for windings having $U_m < 300$ kV shall have the appropriate values given in Tables IIIA or IIIB, depending on the highest voltage for equipment.

When there is a considerable difference between the specified highest voltage for equipment U_m and the specified rated primary voltage, the induced voltage shall be limited to five times the rated primary voltage.

16.2.1 *Unearthed voltage transformers*

Unearthed voltage transformers shall be submitted to the following tests:

a) Separate source withstand voltage test

The test voltage shall be applied for 1 min between earth and all the terminals of the primary winding(s) connected together. The frame, case (if any), core (if intended to be earthed) and all terminals of the secondary winding(s) shall be connected together and to earth.

b) Induced overvoltage withstand test

At the manufacturer's discretion, the test shall be made by exciting the secondary winding with a voltage of sufficient magnitude to induce the specified test voltage in the primary winding, or by exciting the primary winding directly at the specified test voltage.

The test voltage shall be measured at the high voltage side in each case. The frame, case (if any), core (if intended to be earthed), one terminal of each secondary winding and one terminal of the primary winding shall be connected together and to earth.

Note. — The test may be performed by test voltage applications to each line terminal for half the required time with a minimum of 15 s for each terminal.

16.2.2 *Earthed voltage transformers*

Earthed voltage transformers shall be submitted to the following tests:

a) Separate source withstand voltage test, when applicable

The test voltage shall have the appropriate value given in Sub-clause 9.2.2 and shall be applied for 1 min between the terminal of the primary winding intended to be earthed and earth. The frame, case (if any), core (if intended to be earthed) and all terminals of the secondary winding(s) shall be connected together and to earth.

b) Induced overvoltage withstand test

The test shall be performed as specified in Sub-clause 16.2.1. The terminal of the primary winding(s) intended to be earthed in service shall be earthed during the test.

16.3 *Windings having $U_m \geqslant 300$ kV*

The transformer shall be submitted to the following tests:

a) Separate source withstand voltage test, when applicable

The test voltages shall have the appropriate values given in Sub-clause 9.2.2 and the test shall be performed as specified in Sub-clause 16.2.2.

b) Induced overvoltage withstand test

The induced overvoltage withstand 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 paragraphs. The transformer under test shall be connected and the voltage measured as specified in Sub-clause 16.2.2. Method I should be used unless otherwise specified. The use of Method II shall be subject to agreement between manufacturer and purchaser.

16.3.1 *Method I*

The test voltages shall have the appropriate values given in Table IIID, depending on the rated lightning-impulse withstand voltage. The duration of the test shall be in accordance with Sub-clause 16.1.

16.3.2 *Method II*

The test voltages shall have the appropriate values given in Table IIIE, depending on the highest voltage for equipment. Independent of the test frequency, the Method II test procedure shall consist of a short-time application of 10 s at the power-frequency pre-stress voltage. This pre-stress 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.

17. **Power-frequency tests between sections and on secondary windings**

The test voltage shall have the appropriate values given in Sub-clauses 9.3 and 9.4 respectively. The test voltage shall be applied for 1 min in turn between the terminals of each secondary winding or section 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.

SECTION SIX – SPECIAL TESTS

18. **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 microseconds. The chopping circuit shall be so arranged that the amount of overswing to opposite polarity of the recorded impulse shall be limited to the order of 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 $U_m \geqslant 300$ kV

- one 100% full impulse
- two 100% chopped impulses
- two 100% full impulses

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

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

SECTION SEVEN – MARKING

19. Rating plate markings

All voltage 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 voltage (e.g. 66/0.11 kV);

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

e) rated output and the corresponding accuracy class (e.g. 50 VA, Class 1.0);

Note. – When two separate secondary windings are provided, the marking should indicate the output range of each secondary winding in VA, the corresponding accuracy class and the rated voltage of each winding.

f) highest system voltage (e.g. 72.5 kV);

g) rated insulation level (e.g. 140/325 kV).

Note. – The two Items *f)* and *g)* may be combined into one marking (e.g. 72.5/140/325 kV).

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

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

h) rated voltage factor and corresponding rated time;

i) 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.

j) on transformers with more than one secondary winding, the use of each winding and its corresponding terminals.

SECTION EIGHT – TERMINAL MARKINGS

20. General

These markings are applicable to single-phase voltage transformers, and also to sets of single-phase voltage transformers assembled as one unit and connected as a three-phase voltage transformer, or to a three-phase voltage transformer having a common core for the three phases.

21. Markings

21.1 *Terminal markings*

Markings shall be in accordance with Figures 1 to 10, pages 76 to 78 as appropriate.

Capital letters A, B, C and N denote the primary-winding terminals and the lower-case letters a, b, c and n denote the corresponding secondary-winding terminals.

The letters A, B and C denote fully insulated terminals and the letter N denotes a terminal intended to be earthed and the insulation of which is less than that of the other terminal(s).

Letters da and dn denote the terminals of windings intended to supply a residual voltage.

21.2 *Relative polarity*

Terminals having corresponding capital and lower-case markings shall have the same polarity at the same instant.

CHAPTER II: ADDITIONAL REQUIREMENTS FOR SINGLE-PHASE MEASURING VOLTAGE TRANSFORMERS

SECTION NINE – GENERAL

22. Scope

Chapter II contains requirements and tests, in addition to those in Chapter I, that are necessary for single-phase measuring voltage transformers.

23. Definitions

23.1 *Measuring voltage transformer*

A voltage transformer intended to supply indicating instruments, intergrating meters and similar apparatus.

SECTION TEN – ACCURACY REQUIREMENTS

24. Accuracy class designation

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

24.1 *Standard accuracy classes*

The standard accuracy classes for single-phase measuring voltage transformers are:

0.1 – 0.2 – 0.5 – 1.0 – 3.0

25. Limits of voltage error and phase displacement

The voltage error and phase displacement at rated frequency shall not exceed the values given in Table IV at any voltage between 80% and 120% of rated voltage and with burdens of between 25% and 100% of rated burden at a power factor of 0.8 lagging.

The errors shall be determined at the terminals of the transformer and shall include the effects of any fuses or resistors as an integral part of the transformer.

TABLE V

Limits of voltage error and phase displacement

Class	Percentage voltage (ratio) error ±	Phase displacement ±	
		Minutes	Centiradians
0.1	0.1	5	0.15
0.2	0.2	10	0.3
0.5	0.5	20	0.6
1.0	1.0	40	1.2
3.0	3.0	Not specified	Not specified

Note. — When ordering transformers having two separate secondary windings, because of their interdependence, the user should specify two output ranges, one for each winding, the upper limit of each output range corresponding to a standard rated output value. Each winding should fulfil its respective accuracy requirements within its ouput range, whilst at the same time the other winding has an output of any value from zero up to 100% of the upper limit of the output range specified for the other winding. In proving compliance with this requirement, it is sufficient to test at extreme values only. If no specification of output ranges is supplied, these ranges are deemed to be from 25% to 100% of the rated output for each winding.

If one of the windings is loaded only occasionally for short periods, its effect upon the other winding may be neglected.

SECTION ELEVEN — TESTS FOR ACCURACY

26. Type tests

To prove compliance with Clause 25, type tests shall be made at 80%, 100% and 120% of rated voltage, at rated frequency and at 25% and 100% of rated burden.

26a. Routine tests

The routine tests for accuracy are in principle the same as the type tests in Clause 26, but routine tests at a reduced number of voltages 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 25.

SECTION TWELVE — MARKING

27. Marking of the rating plate of a measuring voltage transformer

The rating plate shall carry the appropriate information in accordance with Clause 19.

The accuracy class shall be indicated following the indications of the corresponding rated output (e.g. 100 VA, Class 0.5).

Note. — The rating-plate may contain information concerning several combinations of output and accuracy class that the transformer can satisfy.

CHAPTER III: ADDITIONAL REQUIREMENTS FOR SINGLE-PHASE PROTECTIVE VOLTAGE TRANSFORMERS

SECTION THIRTEEN – GENERAL

28. **Scope**

Chapter III covers the requirements and tests, in addition to those in Chapters I and II, that are necessary for single-phase protective voltage transformers.

The requirements of Chapter III apply particularly to transformers which are required to have sufficient accuracy to operate protective systems at voltages that occur under fault conditions.

29. **Definitions**

29.1 *Protective voltage transformer*

A voltage transformer intended to provide a supply to electrical protective relays.

29.2 *Residual voltage winding*

The winding of a single-phase voltage transformer intended, in a set of three single-phase transformers, for connection in broken delta for the purpose of producing a residual voltage under earth-fault conditions.

SECTION FOURTEEN – ACCURACY REQUIREMENTS

30. **Accuracy class designation**

All voltage transformers intended for protective purposes, with the exception of residual voltage windings, shall be assigned a measuring accuracy class in accordance with Clauses 24 and 25. In addition, they shall be assigned one of the accuracy classes specified in Sub-clause 30.1.

The accuracy class for a protective voltage transformer is designated by the highest permissible percentage voltage error prescribed for the accuracy class concerned, from 5% of rated voltage to a voltage corresponding to the rated voltage factor (see Sub-clause 4.27). This expression is followed by the letter "P".

30.1 *Standard accuracy classes*

The standard accuracy classes for protective voltage transformers are "3P" and "6P", and the same limits of voltage error and phase displacement will normally apply at both 5% of rated voltage and at the voltage corresponding to the rated voltage factor. At 2% of rated voltage, the error limits will be twice as high as those at 5% of rated voltage.

Where transformers have different error limits at 5% of rated voltage and at the upper voltage limit (i.e. the voltage corresponding to rated voltage factor 1.2, 1.5 or 1.9), agreement should be made between manufacturer and user.

31. **Limits of voltage error and phase displacement**

The voltage error and phase displacement at rated frequency shall not exceed the values in Table VI at 5% rated voltage and at rated voltage multiplied by the rated voltage factor (1.2, 1.5 or 1.9) with burdens of between 25% and 100% of rated burden at a power factor of 0.8 lagging.

At 2% of rated voltage, the limits of error and phase displacement with burdens of between 25% and 100% of rated burden at a power factor of 0.8 lagging will be twice as high as those given in Table VI.

TABLE VI

Limits of voltage error and phase displacement

Class	Percentage voltage (ratio) error + or –	Phase displacement + or –	
		Minutes	Centiradians
3 P	3.0	120	3.5
6 P	6.0	240	7.0

Note. — When ordering transformers having two separate secondary windings, because of their interdependence, the user should specify two output ranges, one for each winding, the upper limit of each output range corresponding to a standard rated output value. Each winding should fulfil its respective accuracy requirements within its output range, whilst at the same time the other winding has an output of any value from zero up to 100% of the upper limit of its output range. In proving compliance with this requirement, it is sufficient to test at extreme values only. If no specification of output ranges is supplied, these ranges are deemed to be from 25% to 100% of the rated output for each winding.

SECTION FIFTEEN – REQUIREMENTS FOR SECONDARY WINDINGS INTENDED TO PRODUCE A RESIDUAL VOLTAGE

32. **Rated secondary voltages**

Rated secondary voltages of windings intended to be connected in broken delta with similar windings to produce a residual voltage are given in Table VII.

TABLE VII

Rated secondary voltages

Preferred values		Alternative (non-preferred) values
V		V
100	110	200
$\frac{100}{\sqrt{3}}$	$\frac{110}{\sqrt{3}}$	$\frac{200}{\sqrt{3}}$
$\frac{100}{3}$	$\frac{110}{3}$	$\frac{200}{3}$

Note. — Where system conditions are such that the preferred values of rated secondary voltages would produce a residual voltage that is too low, the non-preferred values may be used, but attention is drawn to the need to take precautions for purposes of safety.

33. **Rated output**

The rated output of windings intended to be connected in broken delta with similar windings to produce a residual voltage shall be specified in voltamperes and the value shall be chosen from the values specified in Clause 6.

Note. — For a given admittance of the secondary circuit, the power delivered by this winding under the conditions specified in this clause will normally differ from the power that it may deliver in the event of a fault when associated with two other similar windings in a three-phase system.

34. **Accuracy class**

The accuracy class for a residual voltage winding shall be as defined in Sub-clause 30.1 and in Clause 31.

SECTION SIXTEEN — TESTS FOR ACCURACY

35. **Type tests**

To prove compliance with Clause 31, type tests shall be made at 2%, 5% and at 100% of rated voltage and at rated voltage multiplied by the rated voltage factor, at 25% and at 100% of rated burden at a power-factor of 0.8 lagging.

36. **Routine tests**

The routine tests for accuracy are in principle the same as the type tests in Clause 35, but routine tests at a reduced number of voltages 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 31.

SECTION SEVENTEEN — MARKING

37. **Marking of the rating plate of a protective voltage transformer**

The rating plate shall carry the appropriate information in accordance with Clause 19.

The accuracy class shall be indicated after the corresponding rated output.

An example of a typical rating plate is given in Figure 11, page 79.

CHAPTER IV: ADDITIONAL REQUIREMENTS FOR CAPACITOR VOLTAGE TRANSFORMERS

SECTION EIGHTEEN – GENERAL

38. Scope

Chapter IV covers the requirements and tests, in addition to those in Chapters I, II and III, that are necessary for capacitor voltage transformers intended to be connected between line and earth, comprising essentially a capacitor divider and an electromagnetic unit interconnected as shown diagrammatically in Figure A1 of Appendix A.

Chapter IV does not apply to capacitor voltage transformers in which the capacitance of the high-voltage capacitor is such that outputs of 10 VA cannot be obtained, although some of the clauses may apply to such devices.

39. General requirements

Unless otherwise stated in this chapter, all capacitor voltage transformers shall comply with the relevant requirements in Chapters I, II and III. In addition, the capacitor(s) shall comply with the requirements of the IEC Publication 358: Coupling Capacitors and Capacitor Dividers.

40. Definitions

For the purpose of this chapter, the following definitions apply:

40.1 *Capacitor voltage transformer*

A voltage transformer comprising a capacitor divider unit and an electromagnetic unit so designed and interconnected that the secondary voltage of the electromagnetic unit is substantially proportional to and in phase with the primary voltage applied to the capacitor divider unit.

40.2 *Voltage divider*

A device comprising resistors, capacitors or inductors by means of which it is possible to obtain between two points a voltage proportional to the voltage to be measured (20-30-160).

40.2.1 *Capacitor (voltage) divider*

A voltage divider comprising only capacitors.

40.2.2 *High-voltage (or line) terminal*

Terminal to be connected to the power line.

40.2.3 *Low-voltage terminal*

Terminal to be connected to the carrier-frequency transmission circuit or to the earth terminal.

Note. — The high-voltage and low-voltage terminals are the primary terminals.

40.2.4 *Intermediate (voltage) terminal*

Terminal to be connected to an intermediate circuit, such as the electromagnetic unit of a capacitor voltage transformer.

40.3 *High-voltage capacitor (C_1)*

Capacitor connected between the high-voltage and intermediate voltage terminals.

40.4 *Intermediate-voltage capacitor (C_2)*

Capacitor connected between the intermediate-voltage terminal and the low-voltage or the earth terminal.

40.5 *Electromagnetic unit*

The component of a capacitor voltage transformer, connected between the intermediate terminal and the earth terminal of the capacitor divider (or possibly directly connected to earth when a carrier-frequency coupling device is used) which supplies the secondary voltage.

Note. — An electromagnetic unit essentially comprises a transformer to reduce the intermediate voltage to the required value of secondary voltage, and an inductive reactance, approximately equal, at rated frequency to the capacitive reactance of the two parts of the divider connected in parallel ($C_1 + C_2$). The inductive reactance may be incorporated wholly or partially in the transformer.

40.6 *Intermediate voltage*

The voltage to earth at the intermediate voltage terminal of the capacitor divider unit when primary voltage is applied between the primary and earth terminals.

40.7 *Voltage ratio (of a capacitor divider)*

Ratio between the sum of the capacitances of the high-voltage and intermediate voltage capacitors and the capacitance of the high-voltage capacitor:

$$\frac{C_1 + C_2}{C_1}$$

Notes 1. — C_1 and C_2 include the stray capacitances, which are generally negligible.

2\. — This ratio corresponds also to the ratio of the primary voltage to the open-circuit intermediate voltage.

40.8 *Open-circuit intermediate voltage*

Voltage across the intermediate voltage capacitor when a voltage is applied between the high-voltage and low-voltage terminals, no impedance being connected in parallel with the intermediate voltage capacitor.

Note. — This voltage is equal to the applied voltage (primary voltage) divided by the voltage ratio.

40.9 *Rated open-circuit intermediate voltage*

Voltage across the intermediate voltage capacitor when the rated voltage is applied between the high-voltage and low-voltage terminals and both the high-voltage and the intermediate-voltage capacitors have the capacitance values for which they have been designed.

40.10 *Reference range of frequency*

The range of frequency values within which a capacitor voltage transformer complies with the relevant accuracy requirements.

40.11 *Reference range of temperature*

The range of ambient temperature values within which a capacitor voltage transformer complies with the relevant accuracy requirements (see Note 2 of Clause 44).

40.12 *Protective device*

A device incorporated in a capacitor voltage transformer for the purpose of limiting over-voltages which may appear across one or more of its components and/or to prevent sustained ferro-resonance.

Note. — The device may include a spark gap and may be located in several different ways according to its nature.

40.13 *Carrier-frequency coupling device*

A circuit element intended to permit the injection of carrier frequency and which is connected between the earth terminal of a capacitor divider unit and earth, having an impedance which is insignificant at power frequency, but appreciable at the carrier frequency.

SECTION NINETEEN — RATING AND PERFORMANCE REQUIREMENTS

41. Standard reference range of frequency

The standard reference range of frequency shall be from 99% to 101% of the rated frequency for accuracy classes for measurement, and from 96% to 102% for accuracy classes for protection.

42. Standard values of rated output

The standard values of rated output are those specified in Clause 6.

Note. — Attention is drawn to the fact that the load taken by a resistor or reactor permanently connected to the secondary terminals and forming an integral part of the electromagnetic unit is not considered to be part of the rated output.

SECTION TWENTY — ACCURACY REQUIREMENTS

43. Standard accuracy classes

The standard accuracy classes for capacitor voltage transformers are:

- for measurement: 0.2; 0.5; 1.0; 3.0;
- for protection: 3P and 6P.

(See also Chapters II and III.)

44. Limits of voltage error and phase displacement

The voltage error and phase displacement shall not exceed the values given in Clauses 25 and 31 for the appropriate accuracy class, under the conditions specified therein, and also for any value of temperature and frequency within the reference ranges (see Sub-clause 3.1 and Clause 41 above).

Notes 1. — For capacitor voltage transformers with electromagnetic units having two separate secondary windings, reference should be made to the note to Clause 25 or Clause 31.

2. — Whatever the ambient temperature may be within its reference range, it is necessary for the test to be carried out in steady temperature conditions.

SECTION TWENTY-ONE — EFFECTS OF TRANSIENTS

45. Ferro-resonance

a) When a capacitor voltage transformer, supplied at 120% of rated voltage and with a substantially zero burden, has its secondary terminals short-circuited and the short circuit suddenly removed, the peak of the secondary voltage shall revert to a value which does not differ from its normal value by more than 10% after ten cycles of rated frequency.

b) When a capacitor voltage transformer, supplied at a voltage corresponding to its rated voltage factor and with a substantially zero burden, has its secondary terminals short-circuited and the short circuit suddenly removed, ferro-resonance shall not be sustained for more than 2 s.

46. Transient response

Following a short circuit of the supply between the high-voltage terminal and the low-voltage terminal connected to earth, the secondary output voltage of a capacitor voltage transformer shall decay, within one cycle of rated frequency, to a value of less than 10% of the peak value before short circuit.

Note. — The influence of the transient response on the behaviour of the network protection is a very complex matter and it is not possible to give values valid for all cases. The influence on the relay is not only dependent on the amplitude, but also on the frequency of the transient. The given value permits correct behaviour of the usual, electromechanical protection relay for usual line length and short-circuit currents. For high speed relay (e.g. solid state relay) or very short lines, or low short-circuit current, the transient response should be part of an agreement between user and manufacturer of the network protection relay and the capacitor voltage transformer.

SECTION TWENTY-TWO — COUPLING DEVICE

47. Carrier-frequency coupling device

When a carrier-frequency coupling device is connected by the manufacturer into the earth lead of the intermediate-voltage capacitor, the accuracy of the capacitor voltage transformer shall remain within the specified class.

SECTION TWENTY-THREE — TESTS

48. General

The type and routine tests on capacitor voltage transformers are essentially the same as those specified in Chapters I, II and III, with the exceptions given below. Type tests shall be made in accordance with Clauses 49, 50, 51, 52 and 53, and routine tests in accordance with Clauses 54 and 55.

The tests specified in Clauses 51, 52, 53 and 55 are direct tests on the capacitor voltage transformer (Figure A1, Appendix A) or tests on the equivalent circuit (Figure A2, Appendix A) as specified under the various clauses.

The main condition allowing tests on the equivalent circuit is given in Appendix B.

All tests shall be performed with the actual electromagnetic unit and not with a model. On the contrary, a specially made equivalent capacitance with the capacitance value of $C_1 + C_2$ may be used in the place of the capacitor divider.

The circuit used for each test shall be indicated on the test report.

Note. — The capacitors should be tested in accordance with IEC Publication 358, as far as possible, taking into account any other duty that the capacitors may have to perform in addition to their operation as the voltage divider of the capacitor voltage transformer.

SECTION TWENTY-FOUR – TYPE TESTS

49. Temperature-rise test

A temperature-rise test shall be made in accordance with Clause 11 and may be performed on the electromagnetic unit alone.

50. Impulse test

An impulse test shall be performed, preferably on a complete capacitor voltage transformer, in accordance with Clause 13 but using a 1.2 to 5/40 to 60 μs impulse, or the capacitor voltage divider may be tested in accordance with IEC Publication 358, and the electromagnetic unit given a separate impulse test, in accordance with the specification of Clause 13, deviating only by the value of test voltage which shall be reduced in accordance with the voltage ratio of the capacitor divider unit.

Note. – If a protective gap across the electromagnetic unit is incorporated, it should be prevented from functioning during the tests. Any protective gap across the carrier-current coupling device should be short-circuited during the tests.

51. Ferro-resonance tests

The following tests shall be made on a complete capacitor voltage transformer – or on the equivalent circuit, provided that the relation given in Appendix B are fulfilled – to prove compliance with Clause 45.

The tests shall be made by short-circuiting the secondary terminals for at least 0.1 s, the short circuit being opened by a protective device (e.g. fuse, circuit-breaker, etc.) chosen for this purpose by agreement between manufacturer and user. If no agreement has been made, the choice is left to the manufacturer. The burden of the capacitor voltage transformer after the short circuit has cleared shall be only that imposed by the recording equipment and shall not exceed 5 VA. The voltage of the power source (at the high-voltage terminal), the secondary voltage and the short-circuit current during the test shall be recorded. Oscillograms shall be part of the test report.

During the short circuit, the voltage of the power source shall not differ by more than 10% from the voltage before short circuit and it shall remain substantially sinusoidal. The voltage drop over the short-circuit loop (contact resistance of the closed contactor included), measured directly at the secondary terminals of the capacitor voltage transformer, shall be less than 10% of the voltage at the same terminals before the short circuit.

a) The test shall be made a minimum of thirty times at 120% of rated primary voltage.

b) The test shall be repeated ten times at a primary voltage corresponding to the appropriate voltage factor.

Notes 1. – If it is known that a saturable burden will be used in service, agreement should be made between user and manufacturer regarding the tests to be made at or near that burden.

2\. – In order to ensure that the voltage of the power source does not differ, during the short circuit, by more than 10% from the voltage before short circuit, the short-circuit impedance of the supply circuit should be low. If the test is performed on a complete capacitor voltage transformer, this condition is generally fulfilled because of the relatively high current of the capacitor divider. On the contrary, should the equivalent circuit be employed, a much lower impedance source than that which would be suitable for accuracy measurement only is necessary.

52. Transient response test

The test to prove compliance with Clause 46 shall be made on a complete capacitor voltage transformer – or on the equivalent circuit, provided that the relation given in Appendix B are fulfilled – by short-circuiting the high-voltage and earthed low-voltage terminals while the capacitor voltage transformer is operating at rated primary voltage at 25% and 100% of rated burden. The burden shall be one of the two following possibilities:

a) series burden composed of a pure resistance and an inductive reactance connected in series;

b) series-parallel burden composed of two impedances connected in parallel, one impedance being a pure resistance and the other one having a power factor of 0.5.

The circuit diagrams and the values of the components of both burdens are given in Appendix C.

If no agreement has been made, the choice between the burdens of Item *a)* or *b)* is left to the manufacturer.

The collapse of the secondary voltage shall be recorded on an oscillograph. Oscillograms shall be part of the test report.

The test shall be made either ten times at random, or twice at the peak of the primary voltage and twice at the zero passage of primary voltage. In the last case, the phase angle of the primary voltage shall not differ from more than ± 20° of the peak and zero passage.

53. **Tests for accuracy**

The tests shall be made at rated frequency, at room temperature and at both extreme temperatures on a complete capacitor voltage transformer or on the equivalent circuit for class 1 and above. For classes 0.5 and 0.2, the use of the equivalent circuit, or a calculation of the influence of temperature shall be agreed upon between user and manufacturer.

Note. — Tests at extreme temperatures on a complete capacitor voltage transformer are more severe than tests on the equivalent circuit or than a calculation of the temperature influence, but are very difficult to perform and expensive. Tests on a complete capacitor voltage transformer also give the best possible indication concerning the measuring errors which may appear in service because of the changes in ambient temperature.

If the equivalent circuit is used, two measurements under identical conditions of voltage, burden, frequency and temperature — within the standard reference range — have to be carried out once on the complete apparatus and once with the equivalent circuit.

The difference between the results of these two measurements must not exceed 50% of the accuracy class (for instance 0.25% and 10 min for accuracy class 0.5) and must, of course, be taken into account in determining the errors of the complete capacitor voltage transformer at the limits of temperature and frequency.

Provided the temperature characteristics of the capacitor divider are known over the reference range of temperature, the errors at extreme values of temperature may be determined by calculations based on the measured results at one temperature and the temperature coefficient of the capacitor divider. Alternatively, a measurement at room temperature only may be performed on the equivalent circuit if the equivalent capacitance — e.g. a capacitor made especially for this purpose — is adapted to the capacitance values corresponding to the temperature extreme values, taking into account the temperature coefficient of the actual capacitor divider.

Tests at a constant value of temperature shall be made at the extreme values of frequency.

The actual values of test frequency and test temperature shall be part of the test report.

Notes 1. — Measurement of the capacitance and of the temperature coefficient of the capacitors is part of the requirements of IEC Publication 358.

2. — The tests show the influence of burden, voltage and frequency as well as of temperature on the equivalent capacitance $C_1 + C_2$. Attention should be paid to the fact that the temperature effect on the inductive reactance and on the winding resistances of the electromagnetic unit can be determined only if the actual electromagnetic unit is subjected to the extreme temperatures. As a supplementary indication concerning changes in the capacitor divider ratio caused by temperature, it is recommended to measure the voltage errors and phase displacements before and immediately after — or during — the temperature-rise test of Clause 49 performed as a direct test on the capacitor voltage transformer. In this case, the measurement as well as the temperature-rise test cannot be performed on the equivalent circuit or on the electromagnetic unit alone.

3. — Present-day service experience has shown that capacitor voltage transformers may be used satisfactorily in the accuracy class 0.5. Unfortunately it is at present not possible to recommend tests resulting in satisfactory conclusions concerning the amount of influence of sudden changes in temperature, of particular weather conditions, of stray capacitances and of leakage currents on the voltage errors and phase displacements. These influences can be evaluated only by theoretical considerations.

SECTION TWENTY-FIVE — ROUTINE TESTS

54. Power-frequency tests

54.1 *Capacitor voltage divider*

Tests on the capacitor voltage divider shall be made in accordance with IEC Publication 358.

54.2 *Low-voltage terminal of the capacitor voltage divider*

Capacitor dividers with a low-voltage terminal shall be subjected for 1 min to a test voltage between the low-voltage and earth terminals.

The test voltage shall be an a.c. voltage of 10 kV (r.m.s. value).

If the low-voltage terminal is not exposed to the weather or if a carrier-frequency coupling device with overvoltage protection is part of the capacitor voltage transformer, a lower value of test voltage (e.g. 4 kV) may be agreed upon between manufacturer and user.

54.3 *Electromagnetic unit*

For this test, the electromagnetic unit may be disconnected from the capacitor divider.

The test voltage may be either applied between the intermediate-voltage terminal and earth or, alternatively, induced from the secondary winding. In either case, it shall have a value equal to the test voltage for the whole of the capacitor voltage divider, divided by its voltage ratio.

The frequency may be increased to prevent excessive magnetizing current and the test shall be applied for a time in accordance with Sub-clause 16.1.

Note. — If a protective gap across the electromagnetic unit is incorporated, it should be prevented from functioning during the tests. Any protective gap across the carrier current coupling device should be short-circuited during the tests.

55. Tests for accuracy

Tests for accuracy shall be made on the complete capacitor voltage transformer or on the equivalent circuit at one value of frequency within the standard reference range of frequency and at one value of temperature within the standard reference range of temperature.

The actual values of test frequency and test temperature shall be part of the test report.

Note. — Tests on the equivalent circuit are generally less accurate than tests on the complete circuit.

Routine tests at a reduced number of voltages and/or burdens are permissible provided it has been shown by type test on a similar capacitor voltage transformer that such a reduced number of tests is sufficient to prove compliance with the accuracy requirements.

Tests on the equivalent circuit can be performed if:

a) the type test according to Clause 53 has shown that the difference between the measured values on the complete circuit and the equivalent circuit is smaller than 20% of the accuracy class, for example smaller than 0.2% and 8 min for accuracy class 1;

b) the inaccuracy in the determination of the capacitor divider ratio, for example by measurement of each capacitance separately (capacitances of each unit and of the intermediate-voltage capacitor C_2, is smaller than 20% of the accuracy class, for example smaller than 0.2% for accuracy class 1;

c) the type test according to Clause 53 has shown that the limits of error of the accuracy class will not be surpassed as a combined effect of the burden, frequency, temperature and inaccuracy mentioned under Items *a)* and *b)*.

For more details concerning the use of the equivalent circuit, see Appendix D.

SECTION TWENTY-SIX — MARKING

56. Marking of the rating plate of a capacitor voltage transformer

The capacitor voltage transformer (or the electromagnetic unit, if separate) shall carry the following additional information on the rating plate:

a) the words "capacitor voltage transformer" or a similar reference;

b) rated capacitance between high-voltage and low-voltage terminals:

c) identification numbers of the capacitor units belonging to the capacitor voltage transformer (in the case where the capacitor stack is composed of more than one unit);

d) only in the cases where an intermediate terminal is still accessible when the capacitor voltage transformer is completely assembled:

$$C_N = \frac{C_1 \times C_2}{C_1 + C_2}$$

— rated open-circuit intermediate voltage, in volts or kilovolts;

— the measured voltage ratio.

An example of a typical rating plate is given in Figure 11, page 79.

The capacitor divider unit shall carry markings in accordance with IEC Publication 358.

Note. — The above-mentioned information may be indicated on two rating plates, one for the magnetic part and one for the capacitive part.

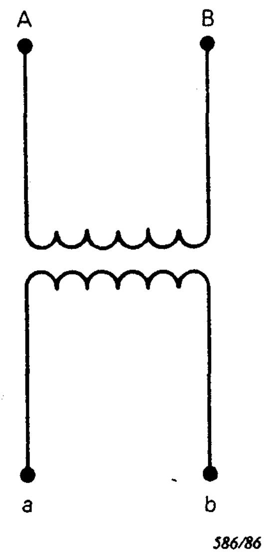


FIG. 1. — Transformateur monophasé avec bornes primaires totalement isolées et un seul circuit secondaire.
Single-phase transformer with fully insulated terminals and a single secondary.

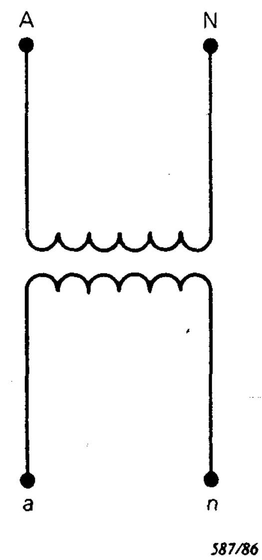


FIG. 2. — Transformateur monophasé avec une borne primaire neutre à isolement réduit et un seul circuit secondaire.
Single-phase transformer with a neutral primary terminal with reduced insulation and a single secondary.

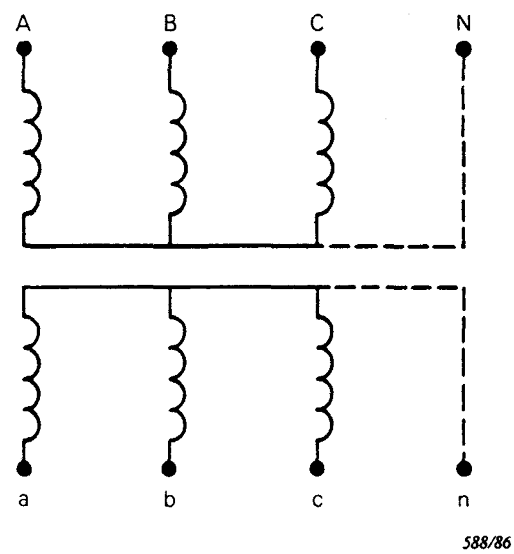


FIG. 3. — Ensemble triphasé avec un seul circuit secondaire.
Three-phase assembly with a single secondary.

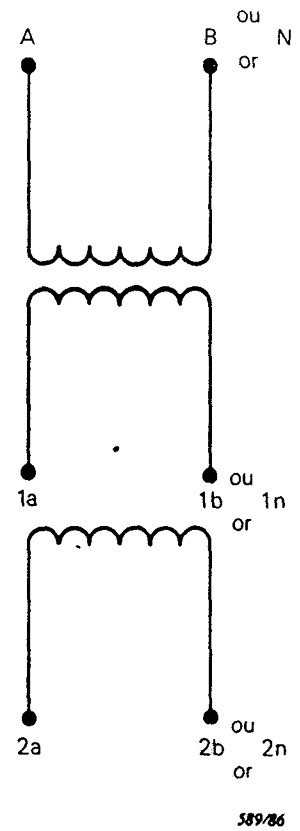


FIG. 4. — Transformateur monophasé avec deux circuits secondaires.
Single-phase transformer with two secondaries.

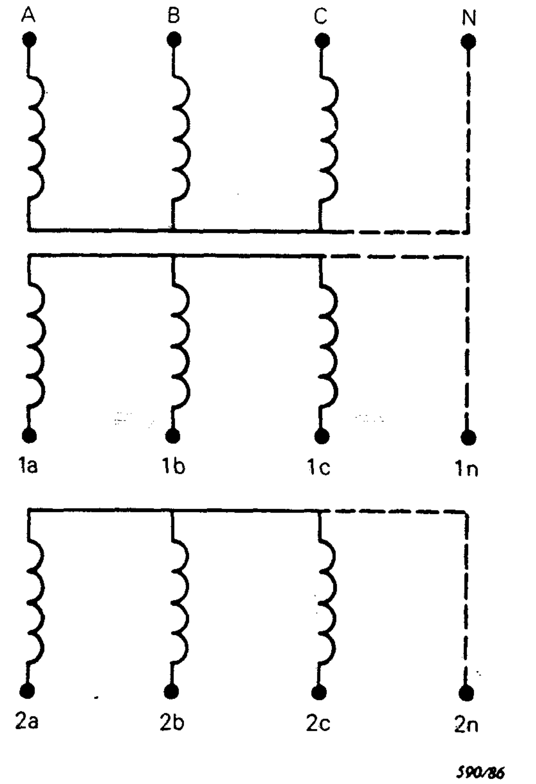


FIG. 5. — Ensemble triphasé avec deux circuits secondaires.
Three-phase assembly with two secondaries.

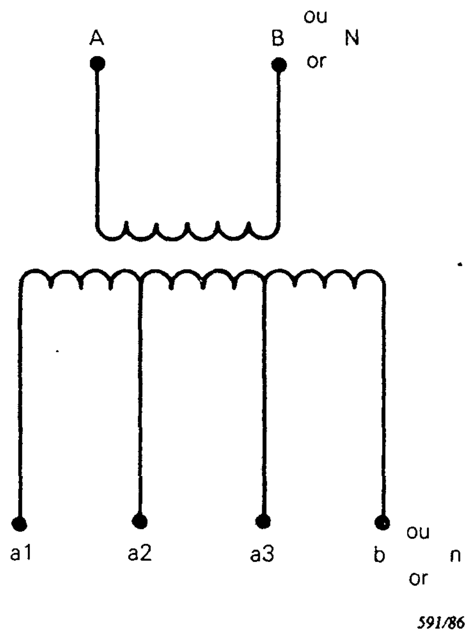


FIG. 6. — Transformateur monophasé avec un circuit secondaire à prises multiples.
Single-phase transformer with one multi-tap secondary.

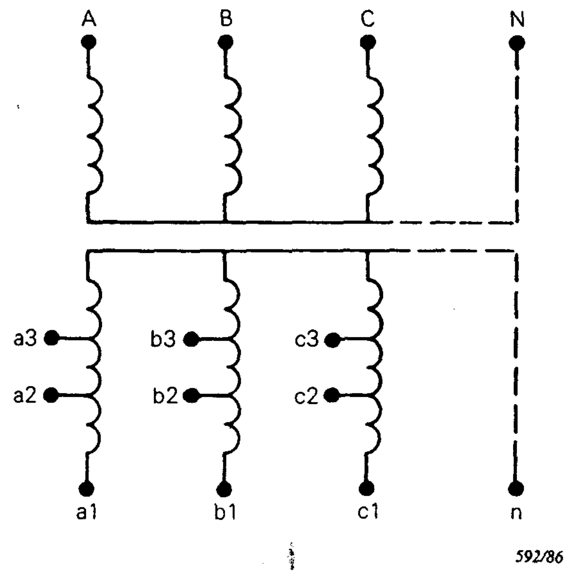


FIG. 7. — Ensemble triphasé avec un circuit secondaire à prises multiples.
Three-phase assembly with one multi-tap secondary.

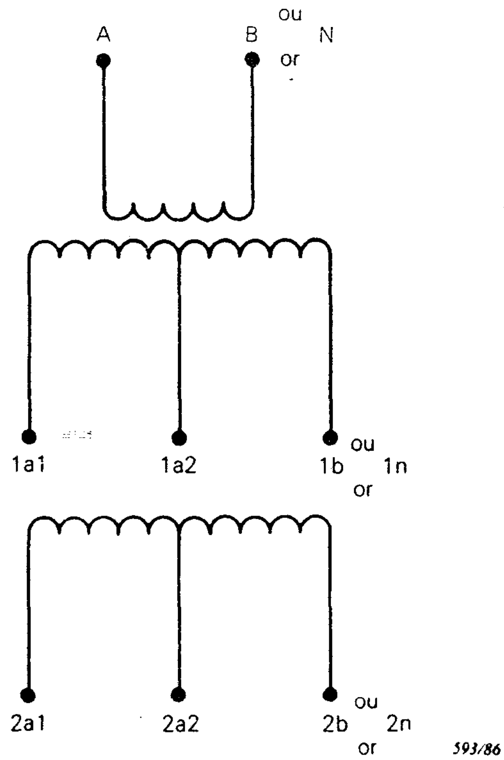


FIG. 8. — Transformateur monophasé avec deux circuits secondaires à prises multiples.
Single-phase transformer with two multi-tap secondaries.

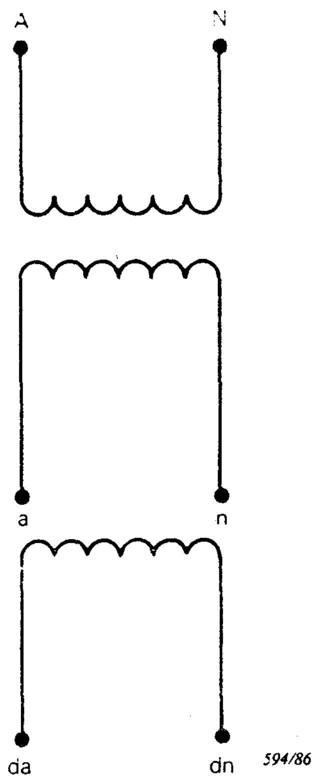


FIG. 9. — Transformateur monophasé avec un enroulement de tension résiduelle.
Single-phase transformer with one residual voltage winding.

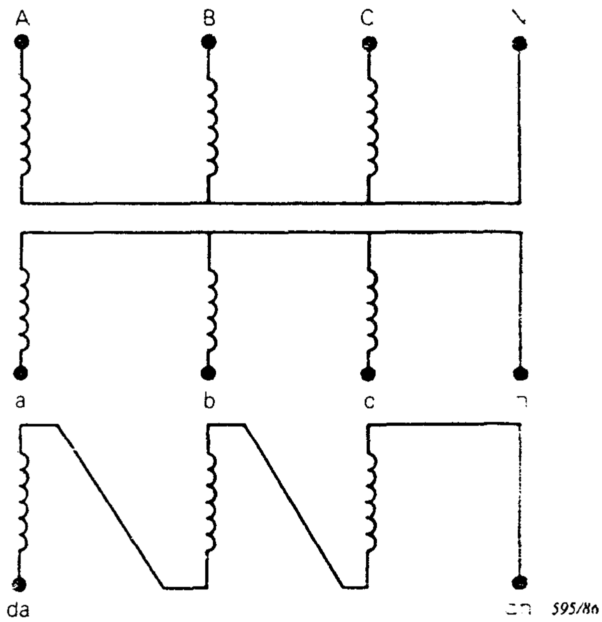


FIG. 10. — Transformateur triphasé avec enroulement de tension résiduelle.
Three-phase transformer with one residual voltage winding.

<table>
<tr><td colspan="2">Transformateur de tension ou transformateur condensateur de tension
Voltage transformer or capacitor voltage transformer</td><td colspan="4">A — N 220 000 : $\sqrt{3}$ V</td></tr>
<tr><td colspan="2">Constructeur
Manufacturer</td><td colspan="2">1a — 1n</td><td>(2a — 2n)</td><td>da — dn</td></tr>
<tr><td colspan="2">N°/No. 67/ ....</td><td colspan="2">110 : $\sqrt{3}$</td><td></td><td>110 : 3</td></tr>
<tr><td>Type</td><td>50 Hz</td><td>VA : 25</td><td>50</td><td></td><td>25</td></tr>
<tr><td>245/460/1 050 kV</td><td>1,9 U_n 30 s</td><td>Cl : 0,5</td><td>3P</td><td></td><td>6P</td></tr>
<tr><td colspan="2">* C_1 .... µF
N° de série:
Serial No.: ....</td><td colspan="4">* C_2 .... µF
N° de série:
Serial No.: ....</td></tr>
</table>

* Uniquement pour les transformateurs condensateurs de tension.
For capacitor voltage transformers only.

FIG. 11. — Exemple type de plaque signalétique.
Example of a typical rating plate.

ANNEXE A

SCHÉMA TYPE ET SCHÉMA DU CIRCUIT ÉQUIVALENT D'UN TRANSFORMATEUR CONDENSATEUR DE TENSION

APPENDIX A

TYPICAL AND EQUIVALENT DIAGRAMS FOR A CAPACITOR VOLTAGE TRANSFORMER

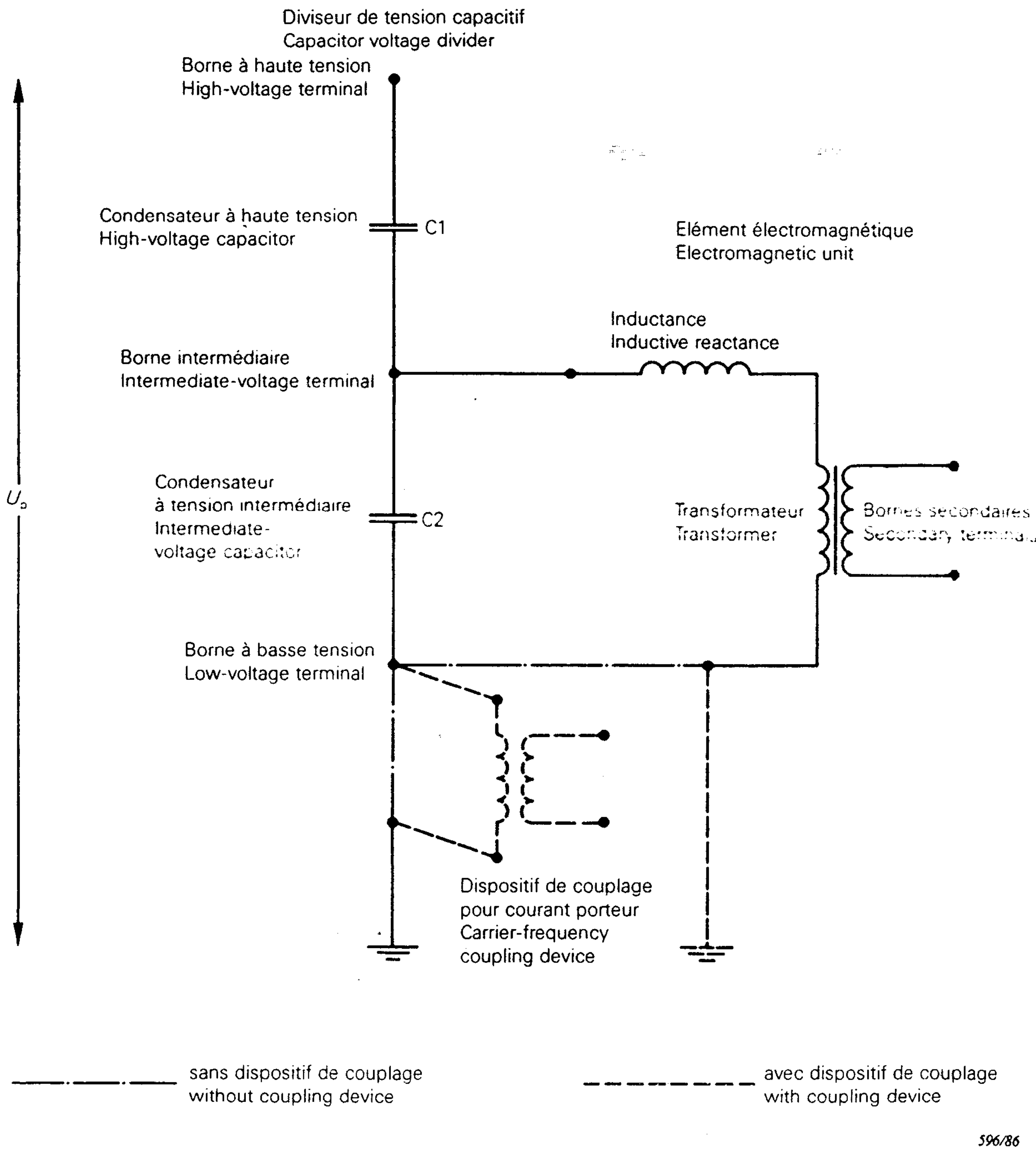


FIG. A1. — Schéma type d'un transformateur condensateur de tension.
Typical diagram for a capacitor voltage transformer.

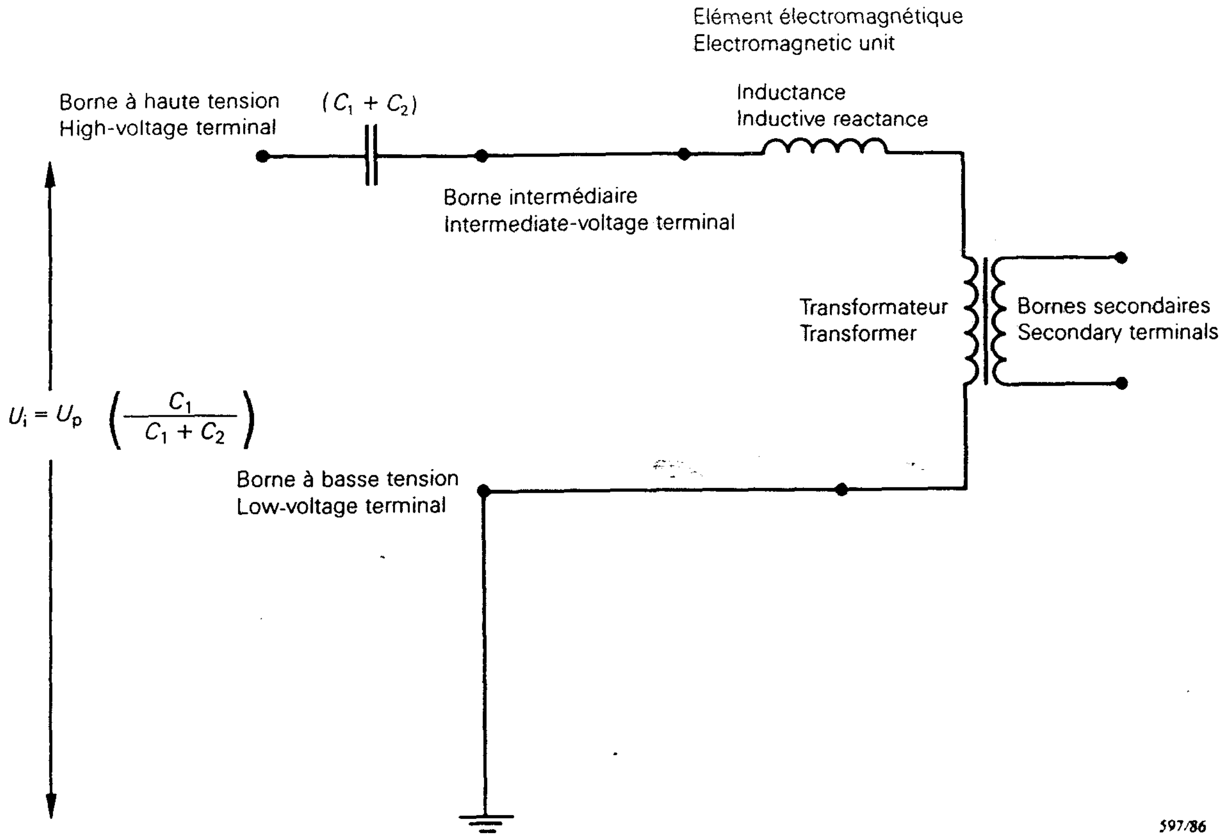


FIG. A2. — Schéma du circuit équivalent d'un transformateur condensateur de tension.
Diagram of equivalent circuit for a capacitor voltage transformer.

APPENDIX B

MAIN CONDITION ALLOWING TESTS ON THE EQUIVALENT CIRCUIT

The main condition allowing tests on the equivalent circuit according to Figure A2, Appendix A, is that the relations:

$$L_1 \times C_1 = L_2 \times C_2$$

and

$$R_1 \times C_1 = R_2 \times C_2$$

are fulfilled for the capacitor dividers.

In these relations, C_1, L_1 and R_1 are, respectively, the capacitance, the series inductance and the series loss resistance of the high-voltage capacitor C_1. C_2, L_2 and R_2 are the corresponding values of the intermediate voltage capacitor C_2.

These relations involve the necessity that the capacitors C_1 and C_2 of the divider are of the same construction and have values of the dielectric dissipation factor which do not differ from each other by more than $3 \cdot 10^{-4}$.

The relations regarding the series inductances has no practical influence on most capacitor dividers having a natural frequency of 100 kHz or more.

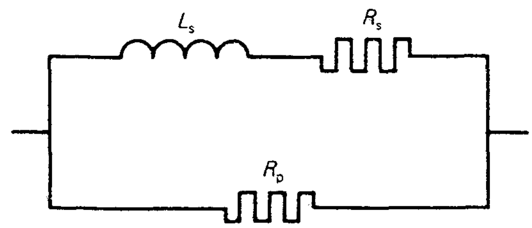
If an additional resistance is connected in series with one of the capacitors C_1 or C_2, tests on the equivalent circuit do not give results truly representative of direct tests and, in this case, the equivalent circuit should be used with precaution.

APPENDIX C

BURDENS FOR THE TRANSIENT RESPONSE TEST

The circuit diagrams of the two possible burdens are given in Figure C1 and the corresponding values of their components in Table CI.

a) Series burden 598/86



b) Series-parallel burden 599/86

FIG. C1. – Circuit diagram of the burden for the transient response test.

TABLE CI

Impedance values of the pure series and of the series-parallel burden for the transient response test

	Burden *a)* (pure series)		Burden *b)* (series-parallel)		
	R	ωL	R_p	R_s	ωL_s
100% of S_n	0.8 $\|Z_n\|$	0.6 $\|Z_n\|$	2.2 $\|Z_n\|$	0.72 $\|Z_n\|$	1.25 $\|Z_n\|$
25% of S_n	3.2 $\|Z_n\|$	2.4 $\|Z_n\|$	8.8 $\|Z_n\|$	2.88 $\|Z_n\|$	5 $\|Z_n\|$

where:
S_n = rated burden in voltamperes
U_n = secondary voltage in volts, such that

$$Z_n = \frac{U_n^2}{S_n}, \; |Z_n| \text{ in ohms}$$

Notes 1. – The total burden given by these values has a power factor of 0.8.

2. – The inductive reactance should be a linear one, e.g. air-core type. The series resistance is composed of the equivalent series resistance of the inductive reactance (resistance of the winding plus equivalent series resistance of the iron losses) and of a separate resistance.

3. – The error of the burden should be less than ± 5% for Z_n and smaller than ± 0.03 for the power factor.

APPENDIX D

USE OF THE EQUIVALENT CIRCUIT FOR THE ROUTINE TESTS FOR ACCURACY

In the present state of technology, the equivalent circuit may be used for the routine tests for accuracy without difficulties up to class 1. For higher accuracy classes, the equivalent circuit may be used after agreement between manufacturer and user.

The error introduced by the equivalent circuit test is a cumulative effect of the following factors:

a) Determination of the capacitor divider ratio (main cause of error), the errors being particularly caused by:

— inaccuracy of the measurement, for example of each capacitance separately;

— influence of stray capacitances.

Note. — This influence may be reduced provided that capacitance values of C_1 and C_2 are measured on an erected capacitor divider and not on each capacitor unit separately.

b) Determination of the equivalent capacitance, as the sum of the measured capacitance of C_1 and C_2 and of the specially made equivalent capacitance, if used.

Notes 1. — Present-day technology for capacitance measurement gives such accuracy for the equivalent capacitance that it will add only small errors (about 1 min).

2. — The use of an actual capacitor divider in the equivalent circuit may introduce errors due to the stray capacitance because of the supplementary connexions.

c) Differences between the tangent of the loss angles of the capacitances C_1 and C_2 and the specially made equivalent capacitance, if used.

Note. — A difference of the tangent of the loss angles of the capacitances C_1 and C_2 of less than $3 \cdot 10^{-4}$ has negligible influence.

d) Variation of the capacitances and of the dielectric dissipation factors in C_1 and C_2 due to voltage changes, especially because the voltage across the equivalent capacitance is much smaller than the normal voltages across C_2 and especially C_1.

Note. — A specially made equivalent capacitance connected in the equivalent circuit operates within a small voltage range and has only small variations of capacitance and losses due to the applied voltage. These variations have therefore negligible influence on the measured errors of the capacitor voltage transformer. The equivalent capacitance should always be exactly adjusted to the measured value of C_1 and C_2 in order to avoid the introduction of new errors according to Item *b)* above.

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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[redacted]

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Modification / Amendment

n° 1 / No. 1

Décembre 1988 / December 1988

à la / to

Publication 186
1987

Transformateurs de tension

Voltage transformers

สำนักงานมาตรฐานผลิตภัณฑ์อุตสาหกรรม

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

16 ก.ย. 2534

MIC

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)77	38(CO)79

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

Page 13

4. **Definitions**

On page 15, replace the existing text of Sub-clause 4.17 by the following:

4.17 *Output*

4.17.1 *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 voltage and with rated burden connected to it (321-01-27 modified).

4.17.2 *Thermal limiting output*

The value of the apparent power referred to rated voltage which can be taken from a secondary winding, at rated primary voltage applied, without exceeding the limits of temperature rise of Clause 8.

Notes *1.-* In this condition the limits of error may be exceeded.

2.- In the case of more than one secondary winding, the thermal limiting output is to be given separately.

3.- The simultaneous use of more than one secondary winding is not admitted unless there is an agreement between manufacturer and purchaser.

Page 21

8. Limits of temperature rise

After the first paragraph of Item a), add the following:

If a thermal limiting output is specified, the transformer shall be tested at rated primary voltage, at a burden corresponding to the thermal limiting output at a unity power factor without loading the residual voltage winding.

If a thermal limiting output is specified for one or more secondary windings, the transformer shall be tested separately with each of these windings connected, one at a time, to a burden corresponding to the relevant thermal limiting output at a unity power factor.

Page 35

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11. Temperature-rise test

Add the following sentence to the second paragraph:

The residual voltage winding shall be loaded in accordance with Sub-clause 35.1 or Clause 8.

Page 51

25. Limits of voltage error and phase displacement

On page 53, replace the last sentence of the note by the following:

If one of the windings is loaded only occasionally for short periods or only used as a residual voltage winding, its effect upon other windings may be neglected.

Page 55

29. Definitions

Replace the existing text of Sub-clause 29.2 by the following:

29.2 *Residual voltage winding*

The winding of a single-phase voltage transformer intended, in a set of three single-phase transformers, for connection in broken delta for the purpose of:

a) producing a residual voltage under earth-fault conditions;

b) damping of relaxation oscillations (ferro-resonances).

Page 59

33. Rated output

Replace the existing text of this clause by the following:

33. Output

33.1 *Rated output*

The rated output of windings intended to be connected in broken delta with similar windings to produce a residual voltage shall be specified in voltamperes and the value shall be chosen from the values specified in Clause 6.

33.2 *Rated thermal limiting output*

The rated thermal limiting output of the residual voltage winding shall be specified in voltamperes; the value shall be 15, <u>25</u>, <u>50</u>, 75, <u>100</u> VA and their decimal multiples, related to the rated secondary voltage with unity power factor. The values underlined should be preferred.

Note.- Since the residual voltage windings are connected in a broken delta, these windings are only loaded under fault conditions.

Deviating from the definition in Sub-clause 4.17.2, the rated thermal output of the residual voltage winding should be referred to a duration of 8 h.

34. Accuracy class

Replace the existing text of this clause by the following:

The accuracy class for a residual voltage winding shall be 6P as defined in Sub-clause 30.1 and Clause 31.

Notes 1.- If a residual voltage winding is used for special purposes, another standard accuracy class in accordance with Sub-clauses 24.1 and 30.1 and Clauses 25 and 31 can be agreed between manufacturer and purchaser.

2.- If the residual voltage winding is used only for damping purposes, an accuracy class designation is not mandatory.

SECTION SIXTEEN - TEXTS FOR ACCURACY

Replace the existing section by the following:

SECTION SIXTEEN - ADDITIONAL TESTS FOR SINGLE-PHASE PROTECTIVE VOLTAGE TRANSFORMERS

35. Type tests

35.1 *Temperature rise test*

If one of the secondary windings is used as a residual voltage winding, a test shall be made in accordance with Clause 11, starting with the test in accordance with Clause 8*a)* at 1.2 times the rated primary voltage and directly followed by the test in accordance with Clause 8*c)*.

During the preconditioning test with 1.2 times the rated primary voltage, the residual voltage winding is unloaded. During the test, at 1.9 times the rated primary voltage for 8 h, the residual voltage winding shall be loaded with the burden corresponding to the rated thermal limiting output (see Sub-clause 33.2), while the other windings are loaded with the rated burden.

If for other secondary windings a thermal limiting output is specified, an additional test shall be made in accordance with Item *a)* of Clause 8 at rated primary voltage without loading the residual voltage winding.

Note.- The voltage measurement has to be performed on the primary winding, as the actual secondary voltage may be appreciably smaller than the rated secondary voltage multiplied by the voltage factor.

35.2 *Tests for accuracy*

To prove compliance with Clause 31, type tests shall be made at 2%, 5% and 100% rated voltage and at rated voltage multiplied by the rated voltage factor: at 25% and 100% of rated burden at a power factor of 0.8 lagging.

When the transformer has several secondary windings, they are to be loaded as stated in the note to Clause 31.

A residual voltage winding is unloaded during the tests with voltages up to 100% rated voltage and loaded with rated burden during the test with a voltage equal to rated voltage multiplied by the rated voltage factor.

36. Routine tests

36.1 *Tests for accuracy*

The routine tests for accuracy are in principle the same as the type tests in Clause 35, but routine tests at a reduced number of voltages 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 31.

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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
38/148/DIS	38/157/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

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CONTENTS

Replace the titles of clauses 16, 17 and 18 by the following new titles:

Add the titles of new clauses 9 ter, 18 bis and 18 ter as follows:

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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 (second edition)*

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

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9 Insulation requirements

Replace existing subclauses 9.1 to 9.5 by the following:

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

9.1 *Rated insulation levels for primary windings*

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

9.1.1 For windings having U_m = 0,72 or 1,2 kV, the rated insulation level is determined by the rated power-frequency withstand voltage, according to table 3A.

9.1.2 For windings having U_m = 3,6 kV and greater 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 3A.

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

9.1.3 For windings having $U_m \geq$ 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 3B.

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

Table 3A – 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 3B – 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.

Table 3C – 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

9.2 *Other requirements for primary winding insulation*

9.2.1 *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 3C.

9.2.2 *Power frequency withstand voltage for the earthed terminal*

The terminal of the primary winding intended to be earthed shall, when insulated from the case or frame, be capable of withstanding the rated power frequency short-duration withstand voltage of 3 kV (r.m.s.).

9.2.3 *Partial discharges*

Partial discharges requirements are applicable to inductive voltage transformers having U_m greater than or equal to 7,2 kV.

The partial discharge level shall not exceed the limits specified in table 3D, at the partial discharge test voltage specified in the same table, after a prestressing performed according to the procedures of 16.4.

9.2.4 *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.

Table 3D – Partial discharge test voltages and permissible levels

Type of earthing of the system	Connections of the primary winding	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)	Phase-to-earth	U_m	10	50
		$1,2\ U_m/\sqrt{3}$	5	20
	Phase-to-phase	$1,2\ U_m$	5	20
Isolated or non-effectively earthed neutral system (earthing factor > 1,5)	Phase-to-earth	$1,2\ U_m$	10	50
		$1,2\ U_m/\sqrt{3}$	5	20
	Phase-to-phase	$1,2\ U_m$	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.

3 When the rated voltage of a voltage transformer is considerably lower than its declared highest system voltage U_m, lower prestress voltages and measuring voltages may be agreed between manufacturer and purchaser.

9.2.5 *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 at the rated frequency and at a voltage level in the range from 10 kV to $U_m/\sqrt{3}$.

NOTES

1 The purpose is to check the uniformity of 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.

3 For some types of voltage transformer designs the interpretation of the results may be difficult to assess.

9.3 *Between-section insulation requirements*

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

9.4 *Insulation requirements for secondary windings*

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

9.5 *Requirements for the external insulation*

9.5.1 *Pollution*

For outdoor inductive voltage transformers, with ceramic insulator, susceptible to contamination, the creepage distances for given pollution levels are given in table 4.

Table 4 – Creepage distances for given pollution levels

Pollution level		Minimum nominal specific creepage distance mm/kV [1) 2)]	$\frac{\text{Creepage distance}}{\text{Arcing distance}}$
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 case 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.

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Add the following new clause after 9 bis:

9 ter **Mechanical requirements**

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

In table 8 guidance is given on the static loads that inductive voltage transformers shall be capable 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 8 – Static withstand test loads

Highest voltage for equipment U_m kV	Static withstand test load F_R N		
	Voltage transformers with:		
	voltage terminals	through current terminals	
		Load class I	Load class II
72,5 to 100	500	1 250	2 500
123 to 170	1 000	2 000	3 000
245 to 362	1 250	2 500	4 000
≥ 420	1 500	4 000	5 000

NOTES

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

2 In some applications voltage transformers with through current terminals 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.

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10 Classification of tests

Replace, on page 35, the texts of subclauses 10.1, 10.2 and 10.3 by the following:

10.1 *Type tests*

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

a) Temperature rise test	clause 11
b) Lightning impulse test	13.2
c) Switching impulse test	13.3
d) Wet test for outdoor-type transformers	clause 14
e) Determination of errors	clauses 26 and 35
f) Short-circuit withstand capability test	clause 12

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

After transformers have been subjected to the dielectric type tests of 10.1, they shall be subjected to all routine tests of 10.2.

10.2 *Routine tests*

The following tests apply to each individual transformer:

a) Verification of terminal markings	clause 15
b) Power frequency withstand test on secondary winding	clause 17
c) Power frequency withstand test between sections	clause 17
d) Power frequency withstand test on primary windings	clause 16
e) Partial discharge measurement	16.4
f) Determination of errors	26.1 and clause 36

The order of the tests is not standardized but determination of errors shall be performed after the other tests.

Repeated power frequency tests on primary windings shall be performed at 80 % of the specified test voltage.

10.3 *Special tests*

The following tests shall be performed upon agreement between manufacturer and purchaser:

a)	Chopped impulse test on primary winding	clause 18
b)	Measurement of capacitance and dielectric dissipation factor	clause 18 bis
c)	Mechanical tests	clause 18 ter

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13 Impulse test on primary winding

Replace the text of this clause by the following:

13.1 *General*

The impulse test shall be performed in accordance with IEC 60-1.

The test voltage shall be applied between each line terminal of the primary winding and earth. The earthed terminal of the primary winding or the non-tested line terminal in the case of an unearthed voltage transformer, at least one terminal of each secondary winding, the frame, case (if any) and core (if intended to be earthed) shall be earthed during the test.

The impulse tests generally consist of voltage application 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 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.

For failure detection the record of current(s) to earth or of voltages appearing across the secondary winding(s), shall be performed in addition to the voltage record.

NOTE – The earth connections may be made through suitable current recording devices.

13.2 *Lightning impulse test*

The test voltage shall have the appropriate value, given in tables 3A or 3B depending on the highest voltage for equipment and the specified insulation level.

13.2.1 *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).

For unearthed voltage transformers, approximately half the number of impulses shall be applied to each line terminal in turn with the other line terminal connected to earth.

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.

13.2.2 *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).

13.3 *Switching impulse test*

The test voltage shall have the appropriate value, given in table 3B, 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 14).

NOTE – To counteract the effect of core saturation, it is permitted, between consecutive impulses, to modify the magnetic conditions of the core by a suitable procedure.

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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14 Wet test for outdoor type transformers

Replace the 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 3A 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 3B, depending on the highest voltage for equipment and the rated insulation level.

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

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

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

16.1 *General*

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

For separate source withstand tests the duration shall be 60 s.

For the induced voltage withstand test, the frequency of the test voltage may be increased above the rated value to prevent saturation of the core. The duration of the test shall be 60 s. If, however, the test 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.

16.2 *Windings having U_m < 300 kV*

The test voltages for windings having U_m < 300 kV shall have the appropriate values given in table 3A depending on the highest voltage for equipment.

When there is a considerable difference between the specified highest voltage for equipment (U_m) and the specified rated primary voltage, the induced voltage shall be limited to five times the rated primary voltage.

16.2.1 *Unearthed voltage transformers*

Unearthed voltage transformers shall be submitted to the following tests:

a) *Separate source withstand voltage test*

The test voltage shall be applied between earth and all primary winding terminals connected together. The frame, case (if any), core (if there is a special earth terminal) and all secondary winding terminals shall be connected together and to earth.

b) *Induced voltage withstand test*

At the manufacturer's discretion, the test shall be made by exciting the secondary winding with a voltage of sufficient magnitude to induce the specified test voltage in the primary winding, or by exciting the primary winding directly at the specified test voltage.

The test voltage shall be measured at the high voltage side in each case. The frame, case (if any), core (if intended to be earthed) and one terminal of each secondary winding and the other terminal of the primary winding shall be connected together and to earth.

The test should be performed by test voltage applications to each line terminal for half the required time, with a minimum of 15 s for each terminal.

16.2.2 *Earthed voltage transformers*

Earthed voltage transformers shall be submitted to the following tests:

a) *Separate source withstand voltage test, when applicable*

The test voltage shall have the appropriate value given in 9.2.2 between the primary voltage terminal intended to be earthed and earth.

The frame, case (if any), core (if intended to earthed) and all secondary voltage terminals shall be connected together and to earth.

b) *Induced voltage withstand test*

The test shall be performed as specified in 16.2.1. The primary voltage terminal intended to be earthed in service shall be earthed during the test.

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

The transformers shall be submitted to the following tests:

a) *Separate source withstand voltage test, when applicable*

The test voltage shall have the appropriate value given in 9.2.2 and the test shall be performed as specified in 16.2.2.

b) *Induced voltage withstand test*

The test voltage shall have the appropriate value given in table 3C, depending on the rated lightning impulse withstand voltage. The test shall be performed as specified in 16.2.2.

16.4 *Partial discharge measurement*

16.4.1 *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 12 to 14.

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 15).

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 MHz to 2 MHz. Preferred values should be in the range from 0,5 MHz and 2 MHz but, if feasible, the measurement should be performed at the frequency which gives the highest sensitivity.

The sensitivity shall allow to detect a partial discharge level of 5 pC.

NOTES

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

2 For the suppression of external noise, the balanced test circuit is appropriate (figure 14). The use of a coupling capacitor to balance the circuit may be inadequate for the elimination of external interference.

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

16.4.2 *Test procedure for earthed voltage transformers*

After a prestressing performed according to procedure A or B, the partial discharge test voltages specified in table 3D are reached and the corresponding partial discharge level is measured in a time within 30 s.

The measured partial discharge levels shall not exceed the limits specified in table 3D.

Procedure A

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

Procedure B

The partial discharge test is performed after the induced voltage withstand test. The applied voltage is raised to 80 % of the induced 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 procedure is left to the manufacturer. The test method used shall be indicated in the test report.

16.4.3 *Test procedure for unearthed voltage transformers*

The test circuit for unearthed voltage transformers shall be the same as for earthed voltage transformers but two tests shall be performed by applying the voltages alternately to each of the high voltage terminals with the other high voltage terminal connected to a low voltage terminal, frame and case (if any) (see figures 12 to 14).

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17 Power frequency tests between sections and on secondary windings

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

17 Power frequency withstand tests between sections and on secondary windings

The test voltage, with the appropriate value given in 9.3 and 9.4 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 (intended to be earthed) and the terminals of all the other windings or sections shall be connected together and to earth.

18 Chopped lightning-impulse test on primary windings

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

18 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 as defined in IEC 60-1, chopped between 2 μs and 5 μs. The chopping circuit shall be so arranged that the amount of overswing of opposite polarity of the recorded 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 3A or 3B depending on the highest voltage for equipment and the specified insulation level.

The chopped impulse test voltage shall be in accordance with 9.2.4.

The sequence of impulse applications shall be as following:

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

   For unearthed voltage transformers, two chopped impulses and approximately half the number of full impulses shall be applied to each terminal.

b) *for windings having* U_m *≥ 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.

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Add the following new clauses 18 bis and 18 ter:

18 bis **Measurement of capacitance and dielectric dissipation factor**

The test shall be carried out in accordance with 9.2.5, after the power frequency withstand test on the primary windings.

The test circuit shall be agreed between manufacturer and purchaser, the bridge method being preferred.

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

18 ter **Mechanical tests**

The tests are carried out to demonstrate than an inductive voltage transformer is capable of complying with the requirements specified in clause 9 ter.

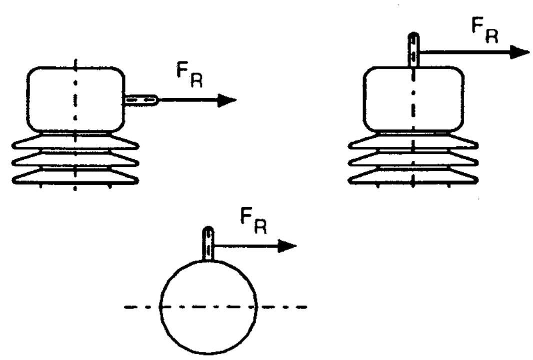
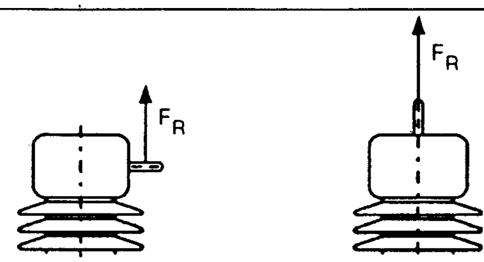
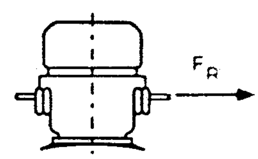
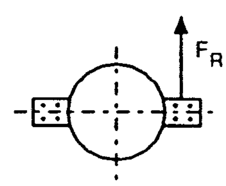
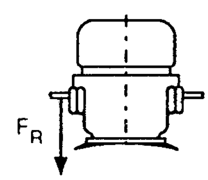
The voltage transformer shall be completely assembled, installed in vertical position with the frame rigidly fixed.

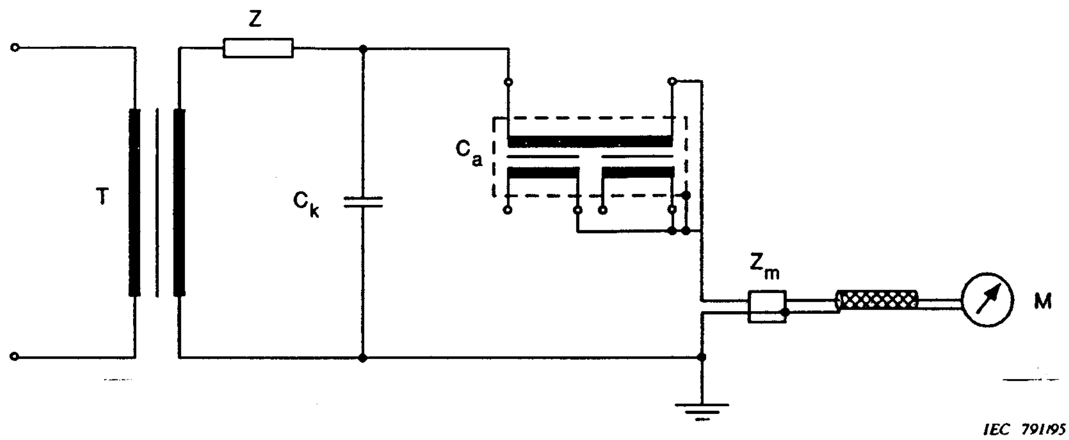
Liquid-immersed voltage transformers shall be filled with the specified insulation medium and submitted to the operating pressure.

The test loads shall be applied for 60 s for each of the conditions indicated in table 9.

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

Table 9 – Modalities of application of the test loads to be applied to the line primary terminals

Type of voltage transformer	Modality of application	
With voltage terminal	Horizontal	
	Vertical	
With through current 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

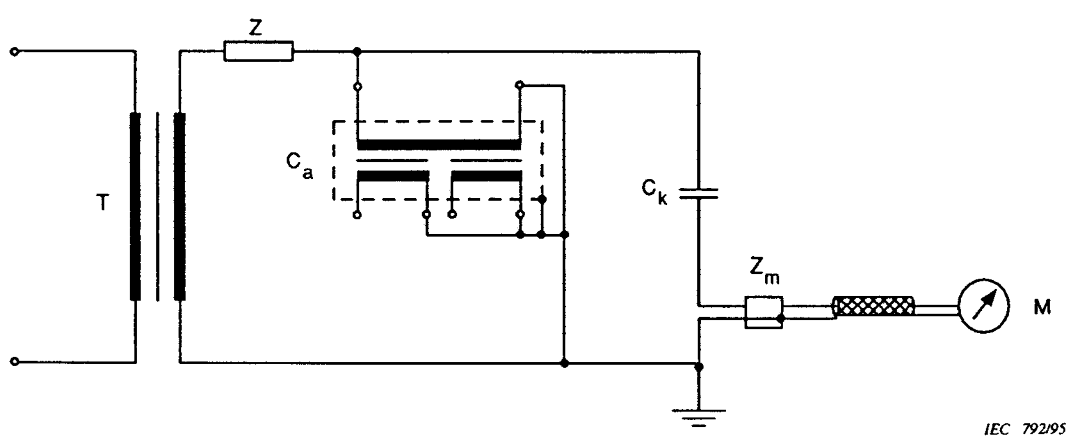
C_k is the coupling capacitor

M is the PD measuring instrument

Z_m is the measuring impedance

Z is the filter

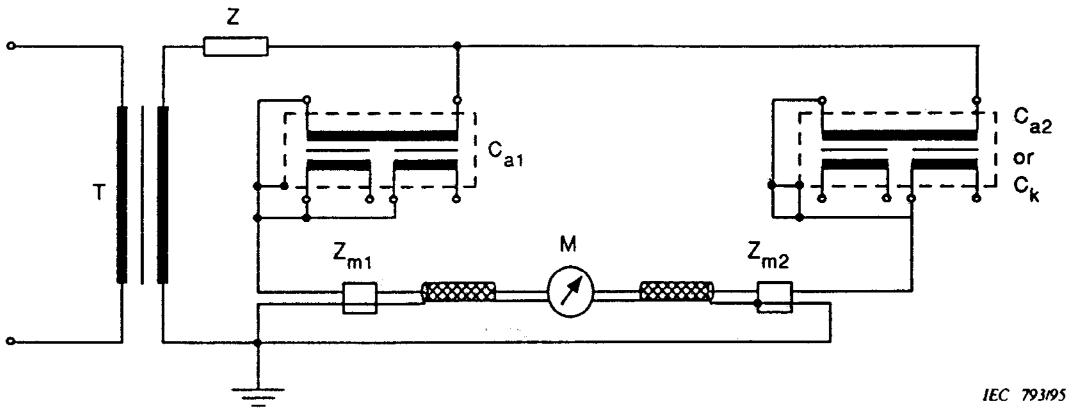
Figure 12 – Test circuit for partial discharge measurement



Symbols as in figure 12

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

Figure 13 – Alternative test circuit for partial discharge measurement



T is the test transformer

C_{a1} is the instrument transformer under test

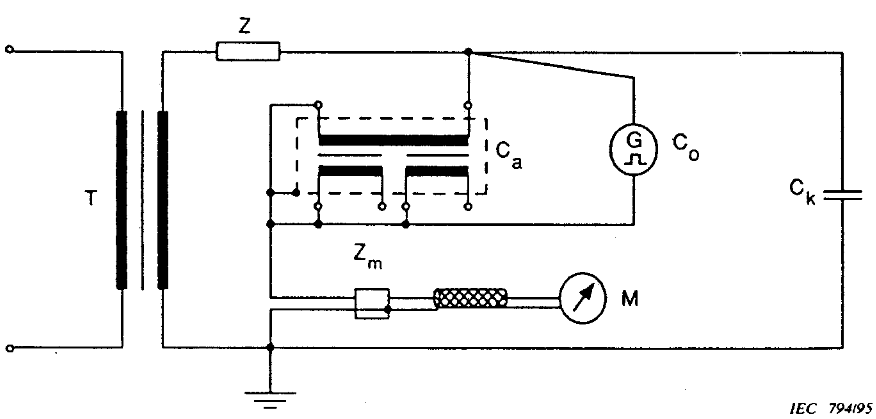
C_{a2} is the auxiliary PD free object (or C_k = coupling capacitor)

M is the PD measuring instrument

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

Z is the filter

Figure 14 – Example of balanced test circuit for partial discharge measurement



Symbols as in figure 12

G is the impulse generator with capacitance C_0

Figure 15 – Example of calibration circuit for partial discharge measurement

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).