

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Insulators for overhead lines with a nominal voltage above 1000 V –
Part 1: Ceramic or glass insulator units for a.c. systems – Definitions, test
methods and acceptance criteria**

**Isolateurs pour lignes aériennes de tension nominale supérieure à 1 000 V –
Partie 1: Éléments d'isolateurs en matière céramique ou en verre pour systèmes
à courant alternatif – Définitions, méthodes d'essai et critères d'acceptation**



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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.080.10, 29.240.20

ISBN 978-2-8322-7128-5

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**INSULATORS FOR OVERHEAD LINES
WITH A NOMINAL VOLTAGE ABOVE 1 000 V –****Part 1: Ceramic or glass insulator units for AC systems –
Definitions, test methods and acceptance criteria**

FOREWORD

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IEC 60383 has been prepared by IEC technical committee 36: Insulators. It is an International Standard.

This fifth edition cancels and replaces the fourth edition published in 1993. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) The complete document has been revised and updated. The layout of the document has been changed in order to increase readability;
- b) RIV test has been added (Clause 14);
- c) Impulse puncture test in air has been added (15.2);
- d) Residual strength test has been added (Clause 21);

- e) Zinc sleeve test has been added (Clause 28);
- f) Impact test has been added (Clause 30);
- g) Annex C, coatings on ceramic and glass insulators has been added;
- h) Annex D, impact test has been added.

The text of this International Standard is based on the following documents:

Draft	Report on voting
36/564/FDIS	36/571/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60383 series, published under the general title *Insulators for overhead lines with a nominal voltage above 1 000 V*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
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- amended.

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INTRODUCTION

This part of IEC 60383 deals with four different types of insulators:

- Pin insulators
- Line post insulators
- String insulator units
- Insulators for overhead electric traction lines

Certain clauses of this document contain general requirements and other clauses contain specific tests relevant to each of the above-mentioned insulators.

INSULATORS FOR OVERHEAD LINES WITH A NOMINAL VOLTAGE ABOVE 1 000 V –

Part 1: Ceramic or glass insulator units for AC systems – Definitions, test methods and acceptance criteria

1 Scope

This part of IEC 60383 applies to insulators of ceramic material or glass for use on AC overhead power lines and overhead traction lines with a nominal voltage greater than 1 000 V and a frequency not greater than 100 Hz. It also applies to insulators for use on DC overhead electric traction lines.

This document applies to string insulator units, rigid overhead line insulators and to insulators of similar design when used in substations.

It does not apply to insulators forming parts of electrical apparatus or to parts used in their construction or to post insulators which are covered by IEC 60168, *Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1 000 V*.

Tests on insulator strings and insulator sets (for example, wet switching impulse voltage) are dealt with in IEC 60383-2.

The object of this document is:

- to define the terms used
- to define insulator characteristics and to prescribe the conditions under which the specified values of these characteristics shall be verified
- to prescribe test methods
- to prescribe acceptance criteria.

This document does not include requirements dealing with the choice of insulators for specific operating conditions.

Specific requirements on the use of coatings on ceramic or glass insulators are described in the informative Annex C.

Numerical values for insulator characteristics are specified in IEC 60305, IEC 60433 and IEC 60720.

NOTE A guide for the choice of insulators under polluted conditions has been published, see IEC 60815-1 and -2.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60120, *Ball and socket couplings of string insulator units – Dimensions*

IEC 60305, *Insulators for overhead lines with a nominal voltage above 1000 V – Ceramic or glass insulator units for AC systems – Characteristics of insulator units of the cap and pin type*

IEC 60372, *Locking devices for ball and socket couplings of string insulator units – Dimensions and tests*

IEC 60433, *Insulators for overhead lines with a nominal voltage above 1000 V – Ceramic insulators for AC systems – Characteristics of insulator units of the long rod type*

IEC 60437, *Radio interference test on high-voltage insulators*

IEC 60471, *Clevis and tongue couplings of string insulator units – Dimensions*

IEC 61211, *Insulators of ceramic material or glass for overhead lines with a nominal voltage greater than 1 000 V – Impulse puncture testing in air*

ISO 1459:1973, *Metallic coatings – Protection against corrosion by hot dip galvanizing – Guiding principles*

ISO 1460, *Metallic coatings – Hot dip galvanized coatings on ferrous metals – Determination of the mass per unit area – Gravimetric method*

ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test Methods*

ISO 1463, *Metal and oxide coatings – Measurement of coating thickness – Microscopical method*

ISO 2064, *Metallic and other non-organic coatings – Definitions and conventions concerning the measurement of thickness*

ISO 2178:2016, *Non-magnetic coatings on magnetic substrates – Measurement of coating thickness – Magnetic method*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

insulator string

one or more string insulator units coupled together and intended to give flexible support to conductors and stressed mainly in tension

3.2

rigid insulator

insulator intended to give rigid support to an overhead line conductor and to be stressed mainly by bending and compressive loads

3.3**long rod insulator**

rigid insulator intended to be subjected to tensile loads, comprising an insulating part having an approximately circular cylindrical shank, with or without sheds, and external or internal fixing devices attached to each end

3.4**cap and pin insulator**

insulator comprising an insulating part usually having the form of a disk or bell, with or without ribs on its surface, and end fittings consisting of an outside cap and an inside pin attached axially

3.5**pin insulator**

rigid insulator consisting of an insulating component intended to be mounted rigidly on a supporting structure by means of a pin passing up inside the insulating component which consists of one or more pieces of insulating material permanently connected together

Note 1 to entry: The pin can have two basic shapes. With one shape, the insulating component is fixed to the end of the pin and does not allow contact of the insulating component with the supporting structure. With the other shape, the insulating component is fixed by means of the pin in contact with the supporting structure either directly or with a plate in between, the plate being either a separate washer or part of the pin (sometimes referred to as a pin post insulator).

3.6**line post insulator**

rigid insulator intended to be subjected to cantilever, tensile and compressive loads, constructed with one or more insulating materials and assembled on a metal base that is intended to be mounted rigidly on a supporting structure

3.7**traction insulator**

insulator or insulator set intended to give flexible or rigid support for overhead electric traction lines. All types of overhead line insulators may be used for this purpose.

3.8**annealed glass**

glass which has been treated to eliminate internal stresses

3.9**toughened glass**

glass in which pre-stresses have been created in order to improve its mechanical characteristics

3.10**lot**

group of insulators offered for acceptance from the same manufacturer, of the same design and manufactured under presumed similar conditions of production

Note 1 to entry: One or more lots may be offered together for acceptance; the lot(s) offered may consist of the whole, or part, of the quantity ordered.

3.11**flashover (of an insulator)**

disruptive discharge external to the insulator, and over its surface, connecting those parts which normally have the operating voltage between them

3.12**impulse withstand voltage**

highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified conditions

3.13

power frequency withstand voltage

RMS value of sinusoidal power frequency voltage that the insulation of the given equipment can withstand during tests made under specified conditions and for a specified duration

3.14

electromechanical failing load

maximum load reached when a string insulator unit is tested under the prescribed conditions of the test

3.15

mechanical failing load

maximum load reached when an insulator is tested under the prescribed conditions of test

3.16

specified mechanical failing load, SFL

mechanical load that causes the loss of mechanical characteristics of any part of an insulator, when tested according to the relevant standard

Note 1 to entry: SFL can also be used for specified electromechanical failing load.

3.17

puncture (of an insulator)

disruptive discharge passing through the solid insulating material of the insulator which produces a permanent loss of dielectric strength

3.18

creepage distance

shortest distance or the sum of the shortest distances along the surface on an insulator between two conductive parts which normally have the operating voltage between them

Note 1 to entry: The surface of cement or of any other non-insulating jointing material is not considered as forming part of the creepage distance.

Note 2 to entry: If a high resistance coating is applied to parts of the insulating part of an insulator, such parts are considered to be effective insulating surfaces and the distance over them is included in the creepage distance.

Note 3 to entry: Insulators with grooves e.g. pin insulators, the creepage measurements shall start at the centre of the side groove.

3.19

minimum creepage distance

defined minimum allowed creepage distance which cannot be subject to a specified negative tolerance

3.20

nominal creepage distance

value of the creepage distance which can also be subject to a specified positive or negative tolerance

3.21

minimum nominal creepage distance

defined minimum allowed creepage distance which can also be subject to a specified negative tolerance

Note 1 to entry: Minimum nominal creepage distance is a definition that normally applies to cap and pin insulators.

3.22**displacements****axial displacement**

maximum positional variation, parallel to the insulator axis, of a definite point on the circumference of the considered insulator during one complete revolution around the insulator axis

radial displacement

maximum positional variation, perpendicular to the insulator axis, of a definite point on the circumference of the considered insulator during one complete revolution around the insulator axis

angular displacement

angular deviation around the insulator axis between corresponding planes of the two coupling pieces

3.23**short standard string**

string used to verify characteristics of a unit which are significant only to an insulator string

<for cap and pin units> insulator string of 5 insulator units

<for long rod insulator units> insulator string between 1 m and 2 m in length for long rod insulator units intended to be assembled in a string

Note 1 to entry: For long rod insulators less than 1 m long intended to be used as a string, the unit itself is considered as a short standard string.

Note 2 to entry: The definition short standard string is different to the definition of short string in IEC 61467.

Note 3 to entry: For systems with insulator string with less than 5 insulators, must be considered the string with the real number of insulators.

3.24**specified characteristic**

<domain> numeric value of a voltage or of a mechanical load or any other characteristic specified in an IEC international standard

<domain> numeric value of any such characteristic agreed between the purchaser and the manufacturer

4 Classification, types of insulators and insulating materials**4.1 Insulator classes**

Insulators for overhead lines are divided into two classes according to their design:

Class A: an insulator or string insulator unit in which the length of the shortest puncture path through solid insulating material is at least equal to half the arcing distance. An example of a class A insulator is a long rod insulator with external fittings.

Class B: an insulator or string insulator unit in which the length of the shortest puncture path through solid insulating material is less than half the arcing distance. An example of a class B insulator is a cap and pin insulator.

4.2 Insulator types

For the purposes of this part of IEC 60383, overhead line insulators are divided into the four following types:

- pin insulators
- line post insulators
- string insulator units, divided into two sub-types:
 - cap and pin insulators
 - long rod insulators
- insulators for overhead electric traction lines.

NOTE Insulators for overhead traction lines are normally insulators of one of the first three types above, with or without special adaptations of the metal fittings, designed for use on overhead electric traction lines.

4.3 Insulating materials

The insulating materials of overhead line insulators covered by this part are:

- ceramic material, porcelain
- annealed glass, being glass in which the mechanical stresses have been relaxed by thermal treatment
- toughened glass, being glass in which controlled mechanical stresses have been induced by thermal treatment.

NOTE 1 Further information on the definition and classification of ceramic and glass insulating materials can be found in IEC 60672-1 and IEC 60672-3.

NOTE 2 The term "ceramic material" is used in this part to refer to porcelain materials and, contrary to North American practice, does not include glass.

5 Identification of insulators

Each insulator shall be marked, either on the insulating component or on a metal part, with the name or trademark of the manufacturer and the year of manufacture. In addition, each string insulator unit shall be marked with the specified electromechanical or mechanical failing load whichever is applicable. These markings shall be legible and indelible.

The designations included in IEC 60305, IEC 60433 and IEC 60720 may be used.

6 Classification of tests

6.1 Type tests

Type tests are intended to verify the main characteristics of an insulator which depend mainly on its design. They are usually carried out on a small number of insulators and only once for a new design or manufacturing process of insulator and then subsequently repeated only when the design, material (described on the manufacture's drawings) or manufacturing process is changed. When the change affects only certain characteristics, only the test(s) relevant to these characteristics need to be repeated. Moreover, it is not necessary to perform the electrical and mechanical type tests on a new design of insulator if a valid test certificate is available on an insulator of equivalent design and same manufacturing process. The meaning of equivalent design is given in the relevant clauses when applicable. The results of type tests are certified either by test certificates accepted by the purchaser or by test certificates confirmed by a qualified organization.

For dimensional and mechanical tests (electromechanical failing load test, mechanical failing load test, thermal-mechanical performance test, residual strength test and impact test), the certificate shall be valid for ten years from the date of issue. There is no time limit for the validity of certificates for electrical type tests (dry lightning impulse withstand voltage, wet power frequency withstand voltage, RIV test, puncture withstand test, impulse puncture test in air).

Within the above limits, the type test certificates remain valid while there is no significant disparity between the results of the type tests and subsequent corresponding sample tests. A method for comparing type and sample test results is given in Annex A.

Type tests shall be carried out only on insulators from a lot which meets the requirements of all the relevant routine tests.

6.2 Sample tests

Sample tests are carried out to verify the characteristics of an insulator which can vary with the manufacturing process and the quality of the component materials of the insulator. Sample tests are used as acceptance tests on a sample of insulators taken at random from a lot which has met the requirements of the relevant routine tests.

NOTE The acceptance coefficients and sample sizes used in this part of IEC 60383 for the statistical evaluation of results by variables have been chosen to reproduce as closely as possible the operating characteristic (OC) curves of the method by attributes used in former editions of IEC 60383 for usual lot sizes. For other lot sizes, the OC curves will be different. Further information on the statistical evaluation of test results and calculation of OC curves can be found in ISO 2859-2017, ISO 2859/1-1999, ISO 2859/2-1985: Sampling procedures and tables for inspection by attributes and ISO 3951-2013: Sampling procedures for inspection by variables.

6.3 Routine tests

Routine tests are intended to eliminate defective units and are carried out during the manufacturing process. Routine tests are carried out on every insulator.

NOTE When, in certain cases, the type, sample and routine tests are carried out as a whole on a new design of insulator, they are referred to as "prototype tests". Some tests are repeated during type, sample and routine tests and could thereby be omitted. Which tests to be omitted are upon agreement.

7 Cross-reference tables for tests to be performed

7.1 Pin insulators

The following tests are applicable to pin insulators. Certain tests are applicable only to certain classes of insulator or materials. To determine the tests which are applicable to pin insulators, reference should be made to the cross-reference table (Table 1).

The numbers on the first line in each square represent the quantity of insulators to be submitted to each test; the codes E1 and E2 correspond to the references given to the samples in 8.2. The second line in each square (figures in italics) indicates the clauses and/or subclauses which are applicable to the insulator and test in question.

The applicable type tests are to be performed once only for a given insulator (see 6.1 for more details). No comparison of type and sample test results can be satisfactorily made for the mechanical failing load test on pin insulators.

The applicable sample tests are performed on the samples E1 or E2 as indicated in the cross-reference table. The sizes of these samples shall be determined in accordance with 8.2. The sample tests shall be performed in the order indicated below; however, it is possible to carry out the tests which apply only to sample E1 (or E2) before those which apply to the other sample, after having carried out those tests which apply to both samples.

The applicable routine tests shall be performed on every insulator.

Mounting arrangements specific to pin insulators are given in Clause 32.

With reference to 6.1, an electrically equivalent insulator unit is a type made in the same factory, with the same materials, and by the same process and has, in addition, the following characteristics:

- nominal arcing distance is the same or larger
- nominal creepage distance is the same or larger
- shed profile is the same.

With reference to 6.1, a mechanically equivalent insulator unit is a type made in the same factory, with the same materials, by the same process, and having the same strength class, and the same design of connection between insulating components and metal parts.

Table 1 – Cross-reference table for pin insulators

Insulator type		Pin insulators					
Material		Ceramic material		Annealed glass		Toughened glass	
Class		A	B	A	B	A	B
TYPE TESTS	Verification of the dimensions	5	5	5	5	5	5
		← 17 →					
	Dry lightning impulse withstand voltage	3	3	3	3	3	3
		← 12, 32.1, 32.2, 37 →					
	Wet power frequency withstand voltage	3	3	3	3	3	3
		← 13, 32.1, 32.2, 37 →					
	RIV test	5	5	5	5	5	5
		← 14 →					
	Puncture withstand test ¹⁾	N/A	5	N/A	5	N/A	5
		← 15 →					
	Mechanical failing load test	5	5	5	5	5	5
		← 19.1, 19.3, 32.3 →					
SAMPLE TESTS	Verification of dimensions	E2	E2	E2	E2	E2	E2
		← 17 →					
	Temperature cycle test	E1&E2	E1&E2	E1&E2	E1&E2	N/A	N/A
		← 24.1 →		← 24.2 →		N/A	N/A
	Mechanical failing load test	E1	E1	E1	E1	E1	E1
		← 19.1, 19.3, 32.3 →					
	Thermal shock test	N/A	N/A	N/A	N/A	E2	E2
		N/A	N/A	N/A	N/A	← 25 →	
	Puncture withstand test ¹⁾	N/A	E2	N/A	E2	N/A	E2
		N/A	15	N/A	15	N/A	15
ROUTINE TESTS	Routine visual inspection	All	All	All	All	All	All
		← 29 →					
	Routine electrical test	N/A	All	N/A	All	N/A	N/A
		N/A	16	N/A	16	N/A	N/A

Key

N/A: Not Applicable

¹⁾ Type of puncture withstand test shall be used upon agreement between manufacturer and purchaser.

²⁾ When applicable.

7.2 Line post insulators

The following tests are applicable to line post insulators. Certain tests are applicable only to certain classes of insulators or materials. To determine the tests which are applicable to line post insulators, refer to the following cross-reference table (Table 2).

The numbers on the first line in each square represent the quantity of insulators to be submitted to each test; the codes E1 and E2 correspond to the references given to the samples in 8.2. The second line in each square (figures in *italics*) indicates the clauses and/or subclauses which are applicable to the insulator and test in question.

The applicable type tests are to be performed once only for a given insulator (see 6.1 for more details).

The applicable sample tests are performed on the samples E1 or E2 as indicated in the cross-reference table. The sizes of these samples shall be determined in accordance with 8.2. The sample tests shall be performed in the order indicated in Table 2; however, it is possible to carry out the tests which apply only to sample E1 (or E2) before those which apply to the other sample, after having carried out those tests which apply to both samples.

The applicable routine tests shall be performed on every insulator.

Mounting arrangements specific to line post insulators are given in Clause 34.

With reference to 6.1, an electrically equivalent insulator unit is a type made in the same factory, with the same materials, and by the same process and has, in addition, the following characteristics:

- nominal arcing distance is the same or larger
- nominal creepage distance is the same or larger
- shed profile is the same.

With reference to 6.1, a mechanically equivalent insulator unit is a type made in the same factory, with the same materials, by the same process, and having the same strength class, and the same design of connection between insulating components and metal parts.

Table 2 – Cross-reference table for line post insulators

Insulator type		Line post insulators					
Material		Ceramic material		Annealed glass		Toughened glass	
Height ¹⁾		H ≤ 600	H > 600	H ≤ 600	H > 600	H ≤ 600	H > 600
Class		A ²⁾	A	A ²⁾	A	A ²⁾	A
TYPE TESTS	Verification of the dimensions	5	5	5	5	5	5
		← 17 →					
	Dry lightning impulse withstand voltage	3	1	3	1	3	1
		← 12, 34.1, 34.2, 37 →					
	Wet power frequency withstand voltage	3	1	3	1	3	1
		← 13, 34.1, 34.2, 37 →					
SAMPLE TESTS	RIV test	3	1	3	1	3	1
		← 14 →					
	Mechanical failing load test	5	5	5	5	5	5
		← 19.1, 19.4, 33.1, 34.3 →					
	Verification of dimensions	E2	E2	E2	E2	E2	E2
		← 17 →					
ROUTINE TESTS	Temperature cycle test	E1&E2	E1&E2	E1&E2	E1&E2	N/A	N/A
		← 24.1 →		← 24.2 →		N/A	N/A
	Mechanical failing load test	E1	E1	E1	E1	E1	E1
		← 19.1, 19.4, 33.2, 34.3 →					
	Thermal shock test	N/A	N/A	N/A	N/A	E2	E2
		N/A	N/A	N/A	N/A	← 25 →	
ROUTINE TESTS	Porosity test	E1	E1	N/A	N/A	N/A	N/A
		← 26 →		N/A	N/A	N/A	N/A
	Galvanizing test	E2	E2	E2	E2	E2	E2
		← 27 →					
	Routine visual inspection	All	All	All	All	All	All
		← 29 →					
ROUTINE TESTS	Routine mechanical test	N/A	All	N/A	All	N/A	All
		N/A	31.1	N/A	31.1	N/A	31.1
Key N/A: Not Applicable 1) H is the nominal overall height in millimetres (see IEC 60720). 2) Class B line post insulators shall be submitted to the tests applicable to class B pin insulators (see Table 1).							

7.3 String insulator units

7.3.1 General

The following tests are applicable to string insulator units. Certain tests are applicable only to certain classes of insulators or materials. To determine the tests which are applicable to string insulator units, refer to the following cross-reference table (Table 3). The numbers on the first line in each square represent the quantity of insulators to be submitted to each test; the codes E1, E2 and E3 correspond to the references given to the samples in 8.2. The second line in each square (figures in *italics*) indicates the clauses and/or subclauses which are applicable to the insulator and test in question.

The applicable type tests, as indicated in the cross-reference table below, are to be performed once only for a given insulator or insulator of equivalent design (see 6.1 and 7.3.2 for more details).

The applicable sample tests are to be performed on the samples E1, E2 or E3 as indicated in the cross-reference table. The sizes of these samples shall be determined in accordance with 8.2. The sample tests shall be performed in the order indicated below; however it is possible to carry out the tests which apply only to sample E1 (or E2) before those which apply to the other sample after having carried out those tests which apply to both samples.

The applicable routine tests shall be performed on every insulator supplied. Mounting arrangements specific to string insulator units are given in Clause 36.

7.3.2 Specified type tests on string insulator units

7.3.2.1 Electrical type tests on string insulator units

The electrical type tests which are performed on a short standard string are intended to give a comparison of performance, on a standard basis, of different string insulator units, taking into account the effect of the presence of adjacent units.

NOTE The specified performance and test results obtained on short standard strings cannot necessarily be extended on a linear basis to longer strings. However, if the withstand voltage test is made on two short strings of different lengths (e.g. 1 m and 2 m), then the results can be linearly interpolated to provide information on the performance of strings whose lengths lie between the two lengths tested.

With reference to 6.1, an electrically equivalent insulator unit is a type made in the same factory, with the same materials, and by the same process and has, in addition, the following characteristics:

- for long rod insulators:
 - nominal core diameter is the same or smaller
 - nominal shed spacing is the same within $\pm 5\%$
 - shed projection is the same within $\pm 5\%$
 - shed profile is the same
 - nominal creepage distance is equal or greater
 - nominal arcing distance is equal or greater
- for cap and pin insulators:
 - shed profile is the same
 - nominal arcing distance is equal or greater
 - diameter of the insulating part is the same or greater within $+5\%$
 - the nominal spacing is the same within $\pm 5\%$
 - nominal creepage distance is the equal or greater

7.3.2.2 Mechanical type tests

With reference to 6.1, a mechanically equivalent insulator unit is a type made in the same factory, with the same materials, by the same process, and having the same strength class, the same coupling size and the same design of connection between insulating components and metal parts. In addition it has the following characteristics:

- for long rod insulators:
 - nominal core diameter is the same
- for cap and pin insulators:
 - nominal diameter is the same or smaller.

Table 3 – Cross-reference table for string insulator units – cap and pin

Material		Ceramic material	Toughened glass
Class		B	B
TYPE TESTS	Verification of the dimensions	10	10
		← 17 →	
	Dry lightning impulse withstand voltage	1SS ¹⁾	1SS ¹⁾
		← 12, 36, 37 →	
	Wet power frequency withstand voltage	1SS ¹⁾	1SS ¹⁾
		← 13, 36, 37 →	
	RIV test	3	3
		← 14 →	
	Impulse puncture test in air	10	10
		← 15.2 →	
	Electromechanical failing load test	5+5 ⁶⁾	N/A
		18, 35.1	N/A
	Mechanical failing load test	N/A	5+5 ⁶⁾
		N/A	19.2, 19.4, 35.1
SAMPLE TESTS	Thermal-mechanical performance test	10	10
		← 20, 35.1 →	
	Residual strength test	25	25
		← 21, 24.1 →	
	Zinc sleeve test ³⁾	3	3
		← 28.2 →	
	Impact test ⁸⁾	3	3
		← 30 →	
	Verification of dimensions ²⁾	E1, E2	E1, E2
		← 17 →	
	Verification of displacements	E1, E2	E1, E2
		← 22 →	
	Verification of the locking system ³⁾	E2	E2
		← 23 →	
	Galvanizing test	E2	E2
		← 27 →	
	Temperature cycle test	E1&E2	N/A
		← 24.1 →	N/A
	RIV test ⁴⁾	E3	E3
		← 14 →	
	Puncture withstand test ⁵⁾	E3	E3
		← 15 →	
	Electromechanical failing load test	E1 ⁷⁾	N/A
		18, 35.2	N/A
	Mechanical failing load test	N/A	E1 ⁷⁾
		N/A	19.2, 19.4, 35.2
	Thermal shock test	N/A	E2
		N/A	25
	Porosity test	E1	N/A
		26	N/A
	Zinc sleeve test ³⁾	Half of E1	Half of E1
		← 28.3 →	

Material		Ceramic material	Toughened glass
Class		B	B
ROUTINE TESTS	Routine visual inspection	All	All
		← 29 →	
	Routine mechanical test	All	All
		← 31.2 →	
	Routine electrical test	All	N/A
	Routine thermal shock test	N/A	All
N/A		25.2	

Key
N/A: Not Applicable

1) 1SS = Test to be carried out on one short standard string.

2) E1 and E2 for coupling gauging, other dimensions E2 only. See Clause 17.

3) When applicable.

4) Introduced as sample test as it can show variation in quality. The test can be omitted based on agreement between manufacturer and purchaser if RIV is not an issue in field.

5) Preferred test for transmission line insulators is "Impulse puncture test in air" unless Power frequency withstand test in oil with stable and reproducible resistivity is available.

6) 5 samples are chosen from samples submitted to impulse puncture test in air – see 15.2.

7) Part of the samples are chosen from samples submitted to impulse puncture test in air (E3/2) – see 15.2 (if impulse puncture test in air is selected).

8) Applies to standard and antifog profiles (there is limited experience of testing other profiles).

For IEC designation U40B and U40BP, RIV test and impulse puncture test in air are not applicable.

Table 4 – Cross-reference table for string insulator units – long rod

Material		Ceramic material	
Class		A	B
TYPE TESTS	Verification of the dimensions	5	10
		← 16 →	
	Dry lightning impulse withstand voltage	1 or SS ¹⁾	1 or SS ¹⁾
		← 12, 36, 37 →	
	Wet power frequency withstand voltage	1 or SS ¹⁾	1 or SS ¹⁾
		← 13, 36, 37 →	
	Impulse puncture test in air	N/A	5
		← 15.2 →	
	RIV test	N/A	3
		← 14 →	
	Electromechanical failing load test	N/A	5
		N/A	18, 35.1
SAMPLE TESTS	Verification of dimensions ²⁾	E1, E2	E1, E2
		← 17 →	
	Verification of displacements	E1, E2	E1, E2
		← 22 →	
	Verification of the locking system ³⁾	E2	E2
		← 23 →	
	Temperature cycle test	E1&E2	E1&E2
		← 24.1 →	
	Electromechanical failing load test	N/A	E1
		N/A	18, 35.2
	Mechanical failing load test	E1	N/A
		19.2, 19.4, 35.2	N/A
	RIV test ⁴⁾	N/A	E3
		← 14 →	
	Puncture withstand test ⁵⁾	N/A	E3
		N/A	15
	Porosity test	E1	E1
		← 26 →	
	Galvanizing test	E2	E2
		← 27 →	

Material		Ceramic material	
Class		A	B
ROUTINE TESTS	Routine visual inspection	All	All
		← 29.2 →	
	Routine mechanical test	All	All
		← 31.2 →	
	Routine electrical test	N/A	All
N/A		16	

Key

N/A: Not Applicable

1) 1 or SS = Test to be carried out either on one insulator or on one short standard string.

2) E1 and E2 for coupling gauging, other dimensions E2 only. See Clause 17.

3) When applicable.

4) Introduced as sample test as it can show variation in quality. The test can be omitted based on agreement between manufacturer and purchaser if RIV is not an issue in field.

5) Preferred test for transmission line insulators is "Impulse puncture test in air" unless Power frequency withstand test in oil with stable and reproducible resistivity is available.

7.4 Insulators for overhead electric traction lines

There is no cross-reference table for insulators for overhead electric traction lines, as these insulators are usually of one of the other three types indicated. The tests applicable to this corresponding type of insulator shall be performed together with the combined bending/tensile test, when applicable.

Mounting arrangements specific to insulators for overhead electric traction lines are given in Clause 37.

In addition to the tests normally required, a bending and tensile test may be necessary for insulators which are submitted to such forces in service. The performance of this test shall be subject to agreement between the purchaser and the manufacturer at the time of ordering. In the same way, the test procedure, mounting arrangements and acceptance criteria shall also be agreed between manufacturer and purchaser. RIV tests on insulators for traction lines can be omitted based upon agreement between manufacturer and purchaser.

8 Procedures for type and sample tests

8.1 Insulator selection for type tests

The quantity of insulators to be tested for each test, as indicated in the cross-reference table, shall be taken from a lot of insulators which meets the requirements of all the relevant routine tests.

NOTE This selection is normally carried out by the manufacturer.

8.2 Sampling rules and procedures for sample tests

For the sample tests, three groups are used, E1, E2 and E3. The sizes of these samples are indicated in Table 5. When more than 10 000 insulators are concerned, they shall be divided into an optimum number of equal lots comprising between 2 000 and 10 000 insulators. The

results of the tests shall be evaluated separately for each lot. For $N \leq 300$ the number of samples is set to zero.

Table 5 – Sample sizes for sample tests

Lot size (N)	Sample size		
	E1	E2	E3
$N \leq 300$	0		
$300 < N \leq 2\,000$	4	3	3
$2\,000 < N \leq 5\,000$	8	4	4
$5\,000 < N \leq 10\,000$	12	6	6

The insulators shall be selected at random from the lot. The purchaser has the right to make the selection.

The samples shall be subjected to the applicable sample tests shown in the respective cross-reference table. In the case of failure of the sample to satisfy a test, the relevant re-test procedure (see 8.3) shall be applied.

Insulators which have been submitted to sample tests which may affect their mechanical and/or electrical characteristics shall not be used in service.

8.3 Re-test procedure for sample tests

When specified in the acceptance criteria, the following re-test procedure applies for sample tests.

If only one insulator or metal part fails to comply with the sample tests, a new sample equal to twice the quantity originally submitted to that test shall be subjected to re-testing. The re-testing shall comprise the test in which failure occurred, preceded by those tests which may be considered as having influenced the results of the original test.

If two or more insulators or metal parts fail to comply with any of the sample tests, or if any failure occurs during the re-testing, the complete lot is considered as not complying with this part and shall be withdrawn by the manufacturer.

Provided the cause of the failure can be clearly identified, the manufacturer may sort the lot to eliminate all the insulators with this defect. (In the case of a lot that has been divided into smaller lots and if one of the smaller lots does not comply, the investigation may be extended to the other lots). The sorted lot(s) or part thereof may then be re-submitted for testing. The number then selected shall be three times the first quantity chosen for the tests. The re-testing shall comprise the test in which failure occurred preceded by those tests which may be considered as having influenced the results of the original test. If any insulator fails during this re-testing, the complete lot is considered as not complying with this part.

9 General requirements for electrical tests

Outlined below are the test procedures and requirements for electrical testing of the different types of insulators which fall within the scope of this part of IEC 60383. The lists of tests, mounting arrangements and acceptance constants are given in relevant clauses for each type of insulator.

- The lightning impulse voltage and power-frequency voltage test procedures shall be in accordance with IEC 60060-1.

- Lightning impulse voltages shall be expressed by their prospective peak values and power-frequency voltages shall be expressed as peak values divided by $\sqrt{2}$.
- When the natural atmospheric conditions at the time of the test differ from the standard values (see IEC 60060-1), it is necessary to apply correction factors in accordance with IEC 60060-1.
- The insulators shall be clean and dry before starting high-voltage tests.
- Special precautions shall be taken to avoid condensation on the surface of the insulators, especially when the relative humidity is high. For example, the insulator shall be maintained at the ambient temperature of the test location for sufficient time for thermal equilibrium to be reached before the test starts.
Except by agreement between the purchaser and the manufacturer, dry tests shall not be made if the relative humidity exceeds 85 %.
- The time intervals between consecutive applications of the voltage shall be sufficient to minimize effects from the previous application of voltage in flashover or withstand tests.

10 Artificial rain parameters for wet tests

The standard wet test procedure described in IEC 60060-1 shall be used. The artificial rain shall be in accordance with the requirements of IEC 60060-1.

NOTE When tests are made on insulators in the horizontal or inclined positions, an agreement should be reached between the purchaser and the manufacturer regarding direction of rainfall.

11 Mounting arrangements for electrical tests

The particular mounting arrangements are specified in the clause relevant to the type of insulator to be tested.

12 Dry lightning impulse voltage tests

12.1 General

The normal procedure for determining the dry lightning impulse withstand voltage on single insulators and short standard strings shall be by calculation from the 50 % flashover voltage level determined by the up and down method described in IEC 60060-1.

NOTE By agreement between purchaser and manufacturer, the withstand voltage can be verified by the 15-impulse method as described in IEC 60060-1.

12.2 Test procedure

The standard 1,2/50 lightning impulse shall be used (see IEC 60060-1).

The insulator shall be tested under the conditions prescribed in Clause 9.

Impulses of both positive and negative polarity shall be used.

The number of insulators to be tested shall be in accordance with 8.1.

12.3 Acceptance criteria

The 50 % lightning impulse flashover voltage determined by the above procedure shall be corrected to standard reference atmosphere in accordance with IEC 60060-1.

When the test is made on one insulator or on a short standard string, the insulator passes the test if the 50 % lightning impulse flashover voltage is not less than $1/(1 - 1,3 \sigma) = 1,040$ times

the specified lightning impulse withstand voltage, where σ is the standard deviation (assumed equal to 3 %).

When the test is made on three insulator units, the mean value of the three 50 % lightning impulse flashover voltages is calculated. The insulators pass the test if the mean 50 % lightning impulse flashover voltage is not less than $1/(1 - 1,3\sigma) = 1,040$ times the specified lightning impulse withstand voltage, where σ is the standard deviation (assumed equal to 3 %).

The insulators shall not be damaged by these tests; but slight marks on the surface of the insulating parts or chipping of the cement or other material used for assembly shall be permitted.

13 Wet power frequency withstand voltage tests

13.1 Test procedure

The test circuit shall be in accordance with IEC 60060-1.

The insulator shall be tested under the conditions prescribed in Clauses 9 and 10.

The test voltage to be applied to the insulator shall be the specified wet power-frequency withstand voltage adjusted for atmospheric conditions at the time of the test. The test voltage shall be maintained at this value for 1 min.

The number of insulators to be tested shall be in accordance with 8.1.

NOTE When this test is carried out on insulators for overhead traction lines, the standard frequency of the test voltage is applicable to insulators intended for use at other frequencies from 0 Hz to 100 Hz.

13.2 Acceptance criteria

When the test is made on one insulator unit or one standard string, the test is passed if no flashover or puncture occurs during the test.

When the test is made on three insulator units the test is passed if no flashover or puncture occurs on any unit.

NOTE If flashover occurs on any insulator tested, a second test on the same unit can be performed after verifying the rain conditions.

To provide information when specially requested at the time of order, the wet flashover voltage of the insulator may be determined by increasing the voltage gradually from about 75 % of the wet power-frequency withstand voltage with a rate of rise of about 2 % of this voltage per second. The flashover voltage shall be the arithmetic mean of five consecutive readings and the value after correction to standard atmospheric conditions shall be recorded.

14 RIV test

14.1 Test procedure

RIV test shall be performed on single insulator units. The test circuit, equipment and atmospheric conditions shall be according to IEC 60437.

For cap and pin insulators, the test shall be performed at one voltage level: 10 kV. A test voltage of 20 kV can be applied upon agreement between manufacturer and purchaser.

For pin type and line post type insulators, the test voltage shall be the RMS phase to earth value of the highest rated voltage for the equipment (see IEC 60071-1).

14.2 Acceptance criteria

Acceptance criteria for type test of cap and pin shall be:

- $\leq 50 \mu\text{V}$ (34 dB) at 10 kV AC
- $\leq 320 \mu\text{V}$ (50 dB) at 20 kV AC.

Acceptance criteria for type test of pin type, line post type and long rod class B insulators shall be:

- $\leq 50 \mu\text{V}$ (34 dB) for test voltage $\leq 10 \text{ kV AC}$
- $\leq 100 \mu\text{V}$ (40 dB) for $10 \text{ kV} < \text{test voltage} \leq 25 \text{ kV AC}$.
- $\leq 200 \mu\text{V}$ (46 dB) for $25 \text{ kV} < \text{test voltage} \leq 50 \text{ kV AC}$

NOTE 1 For porcelain pin insulators some of the acceptance criteria can only be achieved by using semiconducting glaze.

NOTE 2 The choice of test voltage is determined by the rated line voltage.

For test voltages higher than 50 kV the acceptance criteria shall be agreed between manufacturer and purchaser.

For sample tests the acceptance criteria shall be the same unless otherwise specified depending on the specific application and voltage distribution measurement. The re-test procedure in 8.3 applies to this test (only sample test).

15 Puncture withstand test

15.1 General

The puncture test may be either an impulse puncture withstand test or a power-frequency puncture withstand test. This test is performed to evaluate the puncture strength of the insulator, which depends on both the design and quality of manufacturing.

15.2 Impulse puncture testing in air

The number of insulators to be tested shall be in accordance with Table 1, Table 3 or Table 4. The insulators to be tested shall be dry and clean.

The test set-up, test voltage generation, measuring equipment and test procedure shall be according to IEC 61211.

No impulses with reduced amplitude shall be applied between the polarity changes.

Puncture determination:

An insulator passes the test if: every steep-front impulse voltage application result in an external flashover, and the test record or peak voltage indicator does not show any marked reduction in voltage between impulse applications;

Acceptance criteria and retest procedure in accordance with IEC 61211 shall be applied.

5 of the test samples for type test and half of E3 (immediately higher entire number) for sample test shall be subjected to an electromechanical failing load test (ceramic insulators) Clause 18 or mechanical failing load test (toughened glass insulators) Clause 19.

15.3 Power frequency puncture withstand test

At the start of the test the insulators and insulating media shall be at room temperature. Insulators shall be cleaned and dried and completely immersed in a tank containing a suitable insulating medium to prevent surface discharges on them. If the tank is made of metal, its dimensions shall be such that the shortest distance between any part of the insulator and the side of the tank is not less than 1,5 times the diameter of the largest insulator shed. The insulating medium temperature shall be at about room temperature.

The resistivity of the oil shall be between $10^6 \Omega\text{m}$ and $10^8 \Omega\text{m}$. The resistivity of the oil shall be measured before the test with an adapted megohm-meter or similar.

NOTE Additives (e.g. surfactants (non-ionic surfactant, anionic surfactant), steam etc) can be used to maintain a stable resistivity.

The test voltage shall be applied between those parts which normally have the operating voltage between them. During immersion in the insulating medium, precautions shall be taken to avoid air pockets under the sheds of the insulator.

The test voltage shall be raised as rapidly as is consistent with its value being indicated by the measuring instrument to the specified puncture voltage. No puncture shall occur below the specified puncture voltage.

To provide information, and when specially requested at the time of ordering, the voltage may be raised until puncture occurs and the puncture voltage recorded.

The re-test procedure in 8.3 applies to this test (only sample test).

16 Routine electrical test

String insulator units and rigid insulators of ceramic material or annealed glass shall be subjected to a continuously applied alternating voltage.

Rigid insulators shall be placed head downwards in a tank containing water to a depth sufficient to cover the side conductor groove. The voltage shall be applied between the tank and the water practically filling the pin hole or cavity of each insulator. Alternatively, metal electrodes may be used provided the electric stress in the porcelain or glass is not reduced.

The alternating voltage may be at power-frequency or at high frequency.

When using power-frequency the test voltage shall be applied for three to five consecutive minutes and shall be sufficiently high to produce sporadic or occasional flashover (every few seconds).

When using high frequency this shall be a suitably damped alternating voltage with a frequency between 100 kHz and 500 kHz. The test voltage shall be applied for at least three consecutive seconds and shall be sufficiently high to cause continuous flashover. A power-frequency voltage applied to the insulators, or any other suitable means, shall be used to detect puncture of the insulator either during or after the high frequency test.

Insulators which puncture during the test shall be rejected.

Unless otherwise specified, this test shall be carried out after the mechanical routine test, in order to eliminate insulators which may have been partially damaged in the mechanical test.

NOTE For certain designs of class B rigid insulator, it may not be possible to apply the test described above. By agreement between the purchaser and the manufacturer at the time of ordering, the test on the assembled insulator can then be replaced by a test on the insulating components before assembly.

17 Verification of the dimensions

The dimensions of the tested insulators shall be checked in accordance with the relevant drawings, particularly with regard to any dimensions to which special tolerances apply (e.g. spacing specified in IEC 60305 and IEC 60433) and details affecting interchangeability (e.g. coupling dimensions which form the subject of IEC 60120 and IEC 60471).

Gauging of ball and socket couplings of string insulator units shall be verified on both E1 and E2 samples, for other dimensions and other types of insulators only the E2 sample shall be used.

Unless otherwise agreed, a tolerance of:

$\pm (0,04d + 1,5)$ mm when $d \leq 300$ mm and for all lengths of nominal creepage distance,

or

$\pm (0,025d + 6)$ mm when $d > 300$ mm

or

$\pm (0,03d + 0,3)$ mm for the spacing deviation of cap and pin when applicable.

is allowed on all dimensions for which special tolerances do not apply (d being the checked dimension in millimeters).

The tolerances given above apply to all dimensions, even if they are specified as a minimum or maximum nominal value.

The re-test procedure in 8.3 applies to this test.

18 Electromechanical failing load test

18.1 Test procedure

This test shall be applied to string insulator units of types such that an internal electrical discharge will serve to indicate mechanical failure of the insulating part.

The string insulator units shall be subjected individually to a power-frequency voltage and a tensile load applied simultaneously between the metal parts. The voltage shall be maintained throughout the test.

The voltage to be applied shall be equal to the value of the specified wet power-frequency withstand voltage of the short standard string divided by the number of units in the short standard string.

As regards their essential dimensions, the coupling pieces of the testing machine shall be in accordance with IEC 60120 for insulators with ball and socket couplings and with IEC 60471 for insulators with clevis and tongue couplings. For insulators for overhead traction lines or other special insulators to which this part is applied, special couplings may be necessary. Coupling pieces of the same strength (standard or reinforced) shall be used in the type and sample tests.

The tensile load shall be increased from zero, rapidly but smoothly, up to approximately 75 % of the specified electromechanical failing load and shall then be gradually increased at a rate of increase between 100 % and 35 % of the specified electromechanical failing load per minute until electrical or mechanical failure of the insulator occurs or the failing load defined in clause 3 is reached and the value recorded. (The rates indicated correspond to reaching the specified electromechanical failing load in a time between 15 s and 45 s).

NOTE The rate of change of load increase may alter upon achieving specified failing load

18.2 Acceptance criteria

See 19.4.

19 Mechanical failing load test

19.1 Test procedure for pin and line post insulators

The pin or line post insulator shall be mounted as specified in the relevant subclause (32.3 or 34.3), and a mechanical bending load shall be applied. The load shall be increased from zero, rapidly but smoothly, up to approximately 75 % of the specified mechanical failing load and shall then be gradually increased, at a rate of increase between 100 % and 35 % of the specified mechanical failing load per minute, until the latter is reached for pin insulators or until the mechanical failing load as defined in Clause 3, is reached for line post insulators (the rates indicated correspond to reaching the specified mechanical failing load in a time between 15 s and 45 s). The mechanical failing load of line post insulators shall be recorded.

NOTE The rate of change of load increase may alter upon achieving specified failing load.

19.2 Test procedure for string insulator units

The string insulator units shall be subjected individually to a tensile load applied between their metal parts. As regards their essential dimensions, the coupling pieces of the testing machine shall be in accordance with IEC 60120 for insulators with ball and socket couplings and with IEC 60471 for insulators with clevis and tongue couplings. For insulators for overhead traction lines or other special insulators to which this part is applied, special couplings may be necessary. Coupling pieces of the same strength (standard or reinforced) shall be used in the type and sample tests.

The tensile load shall be increased from zero, rapidly but smoothly, up to approximately 75 % of the specified mechanical failing load and shall then be gradually increased, at a rate of increase between 100 % and 35 % of the specified mechanical failing load per minute until the failing load as defined in Clause 3, is reached and the value recorded (the rates indicated correspond to reaching the specified mechanical failing load in a time between 15 s and 45 s).

NOTE The rate of change of load increase may alter upon achieving specified failing load

19.3 Acceptance criteria for pin insulators

The insulator passes the test if the specified mechanical failing load is reached without mechanical failure of the insulating component. Additionally, for insulators with integral pin, the residual deflection of the insulating component at the point of application of the test load shall not exceed 20 % of the height of this point above the supporting plane.

The re-test procedure in 8.3 is applicable to this test for pin insulators.

19.4 Acceptance criteria for string insulator units and line post insulators

From the individual failing loads X obtained during the electromechanical or mechanical failing load test the mean value $\bar{X}$ and the standard deviation σ_{n-1} shall be calculated.

The following symbols are used:

$\bar{X}_T$: Mean value of the type test results

$\bar{X}_1$: Mean value of the sample test results

- $\overline{X}_2$: Mean value of the re-test results
 σ_T : Standard deviation of the type test results
 σ_1 : Standard deviation of the sample test results
 σ_2 : Standard deviation of the re-test results
 C_{0123} : Acceptance constants

A type test is passed, if

$$\overline{X}_T \geq SFL + C_0 \sigma_T$$

A sample test is passed, if

$$\overline{X}_1 \geq SFL + C_1 \sigma_1$$

If $SFL + C_2 \sigma_1 \leq \overline{X}_1 < SFL + C_1 \sigma_1$, a re-test with the double sample size is permitted in sample tests.

The re-test is passed, if

$$\overline{X}_2 \geq SFL + C_3 \sigma_2$$

in which the mean value $\overline{X}_2$ and standard deviation σ_2 are obtained from the re-test results only.

If the re-test is not passed the lot is considered as not complying with this part of IEC 60383 and an investigation shall be performed in order to find out the causes of failure. (Where a lot has been divided into smaller lots, and one of the smaller lots does not comply, the investigation may be extended to the other lots.)

The values of the acceptance coefficients C_0 , C_1 , C_2 and C_3 to be applied are specified in Clauses 33 and 35 respectively.

A method of comparison of the results of electromechanical or mechanical type and sample tests is given in Annex A. A complete acceptance schedule for type and sample tests as well as calculated examples is given in Annex B.

NOTE When calculating the standard deviation σ , attention is drawn to the fact that it is the sample standard deviation where the denominator is $n-1$.

20 Thermal-mechanical performance test

20.1 Test procedure

The insulator units shall be subjected to four 24-hour cycles of cooling and heating with a simultaneously applied tensile load maintained between 60 % and 70 % of the specified electromechanical or mechanical failing load. Each 24-hour cycle shall start with one cooling period of $(-30 \pm 5)^\circ\text{C}$ followed by one heating period of $(+40 \pm 5)^\circ\text{C}$. The tolerances on the temperatures of the hot and cold cycles shall be respected in such a way as to ensure a minimum difference of 70 K between the recorded hot and cold temperatures. The maximum and minimum temperatures shall be maintained for at least four consecutive hours of the temperature cycle. The rate of temperature change is not of practical importance and will

depend on the test facilities. All temperatures shall be measured on or near a metallic part of one of the insulators.

The tensile load shall be applied to the insulator unit at room temperature before starting the first thermal cycle. It shall be completely removed and re-applied at the end of each heating period, the last one excepted. After the fourth 24-hour cycle, and after cooling to room temperature, the tensile load shall be removed. The test procedure is schematically represented in Figure 1.

The electromechanical (Clause 18) or the mechanical failing load test (Clause 19) shall be carried out within 24h from that the tensile load has been removed from the insulator unit.

The insulator units may be coupled together in series and/or in parallel when subjected to the thermal cycles and the mechanical load. When coupled in parallel, the insulator units shall be equally loaded.

Loose coupling pins, for example those used with insulators of the long rod type, shall not be included in the mechanical test since they are not part of the internal design of the insulator.

20.2 Acceptance criteria

The acceptance criteria for the electromechanical and mechanical failing load tests shall be used (see 19.4). If any insulator fails during the cycles of heating and cooling, the insulators are considered as not complying with this part.

21 Residual strength test

21.1 General

The residual strength is the maximum mechanical load which can be reached when an insulator unit, which has had its insulating part mechanically damaged in the prescribed manner, is tested under the prescribed conditions.

21.2 Previous tests

The residual strength test shall be preceded by the temperature cycle test according to 24.1.

21.3 Preparation of the test pieces

After the insulators have undergone the temperature cycle test, the shed of the insulating part of the insulators shall be broken off by mechanical means, for example by hammer blows. No portion of the shed shall remain outside the maximum diameter of the cap.

NOTE Results of completed tests have shown that, as far as results of the residual strength test are concerned, it does not make any difference in which way the sheds are broken.

According to available test results, the presence of a mechanical load during the breakage of the shed has no influence on the residual strength.

The total removal of the ceramic outside the maximum diameter of the cap has been chosen as the only possibility of defining the amount of the ceramic breakage to obtain satisfactory reproducibility during the tests, and also become it is current practice.

It should be noted that, in service, such an amount of damage is very rare. The damage caused by power arcs, gunshots, etc, is normally less severe, thus there will be usually less reduction of the mechanical strength.

The total removal of all the glass outside the maximum diameter of the cap always occurs when toughened glass sheds are broken.

21.4 Test procedure

After preparation of the test pieces according to 21.3, they shall be subjected to the following mechanical failing load

The string insulator units shall be subjected individually to a tensile load applied between their metal parts.

As regards their essential dimensions, the coupling pieces of the testing machine shall be in accordance with IEC 60120 for insulators with ball and socket couplings and with IEC 60471 for insulators with clevis and tongue couplings.

The tensile load shall be increased from zero, rapidly but smoothly, up to approximately 50 % of the specified mechanical or electromechanical failing load of the completed insulator and shall then be gradually increased, at a rate of increase between 0,5 % and 1 % of the specified mechanical or electromechanical failing load per second until breakage occurs. The maximum load reached during the test is recorded as the residual strength of the piece.

21.5 Test results

In the residual strength test, the pieces may exhibit two alternative modes of breakage at the maximum load:

- the cap and the pin separate, for example the pin is pulled out,
or
- the metal part breaks (the cap or the pin).

Therefore, a method is specified for evaluating the residual strength to be compared with SFL:

- a) If on all 25 test pieces, the metal parts are separated, then the mean failing load $\bar{X}$ and the standard deviation s shall be calculated, and the ratio

$$k = \frac{\bar{X} - 1,645 s}{SFL}$$

shall deduced, where k is the acceptance constant.

- b) If one or more of the 25 test pieces fail by breakage of the metal parts, then the acceptance constant k of the remaining pieces should be calculated as in Item a), above.

21.6 Acceptance criteria

For pieces fail by breakage of the metal parts, the failing load of these pieces should be not less than SFL.

The acceptance constant k should be greater than or equal to 0,65.

Additionally, the formula given in Item a) is not valid when the number of breakages by separation is less than 10. In this case, the failing load of these pieces should be not less than 0,65 SFL.

22 Verification of the axial, radial and angular displacements

22.1 Test procedure

The string insulator unit is placed in light tension between suitably mounted coupling pieces which are in accordance with IEC 60120 or IEC 60471. In the case of clevis and tongue couplings it may be necessary to add shims to centre the metal fittings in the couplings. The two coupling pieces shall be on the same vertical axis and shall be free to rotate.

For cap and pin insulator units:

The upper mounting piece shall be either a socket or a clevis so that the insulator under test hangs by its ball or tongue with the cap located by the lower mounting piece. Two measuring devices A and B are arranged as shown in figure 2a so that they make contact with the insulating component at the point of maximum diameter and at the tip of the outermost rib respectively.

The insulator is rotated through 360° and the maximum variation in the readings of the measuring devices is noted.

NOTE The variation in the reading of measuring device A will include any variation in the flatness of the insulating component. Normally acceptable variations will fall within the specified maximum values. Excessive variations from flatness will result in the variations of the measurements with device A being above the specified maximum value.

For long rod insulator units:

The measuring device B is arranged as shown in Figure 2b) so that it makes contact with the core of the insulating component as close as possible to the centre of the insulator.

The insulator is rotated through 360° and the maximum variation in the reading of the measuring device is noted.

In addition, the angular displacement α of the coupling pieces shall be measured by a suitable method, for example, as in Figure 3.

22.2 Acceptance criteria

For cap and pin insulator units:

The following maximum variations in the readings of the measuring devices are given:

- variation on A: 4 % of the nominal insulator diameter
- variation on B: 3 % of the nominal insulator diameter

The re-test procedure in 8.3 applies to this test.

For long rod insulator units:

The following maximum variations in the readings of the measuring devices are given.

Variation on B:

- 1,4 % of the insulator length for insulator lengths ≤ 750 mm
- 1,2 % of the insulator length for insulator lengths > 750 mm

The value of the angular displacement α of the coupling pieces shall not exceed the following value:

For clevis and tongue couplings:	$\alpha \leq 4^\circ$
For ball and socket caps:	$\alpha \leq 15^\circ$
For other combinations of coupling pieces:	$\alpha \leq 15^\circ$ unless otherwise agreed between the purchaser and the manufacturer.

The re-test procedure in 8.3 applies to this test.

23 Verification of the locking system

23.1 General

This test is applicable to string insulator units with ball and socket couplings. The test comprises four parts:

- Conformity of the locking device
- Verification of locking
- Position of the locking device (for split-pin types only)
- Operation test

The re-test procedure in 8.3 applies to these tests.

23.2 Conformity of the locking device

The insulator or fitting manufacturer shall verify that the locking devices conform to the requirements of IEC 60372. This verification shall be confirmed by a test certificate held available by the insulator manufacturer.

NOTE If there is no evidence that the locking devices equipping the insulators presented for acceptance belong to the same lot for which the certificate was established, tests conforming to IEC 60372 can be carried out on a number of locking devices not more than the sample size E2 given in 8.2.

23.3 Verification of locking

The insulators are connected in strings of two units for cap and pin insulators. In the case of long rod insulators, the insulator unit is assembled with the corresponding ball-link. The locking device is placed in the locking position. Then, by applying movements comparable to those experienced in service, the string or ball-link is checked to see that no uncoupling can occur.

23.4 Position of the locking device

For split-pin types, the locking position for the legs is checked to see that they do not protrude beyond the entry of the socket and that it is possible to introduce a sharp tool of half the eye diameter into the eye, to pull the split-pin from the locking position to the coupling position.

NOTE 1 See IEC 60372 for an illustration of coupling and locking positions.

NOTE 2 In the case of split-pin types, attention is drawn to the fact that excessive impact on the head of the pin during placement in the locking position may cause deformation to the extent that the locking capability is affected. Care is to be taken that the functioning of the split-pin is not affected by deformation caused during opening out of the tips.

NOTE 3 For standard coupling 11, split-pin legs can extend beyond the socket entry by not more than 5 mm.

23.5 Procedure for the operation test

The locking device is placed in the locking position.

For split-pin types:

By means of an appropriate device, a tensile load F is applied to the eye of the split-pin along this axis.

For W-clips:

By means of a steel bar having a rectangular cross-section dimension of $F_5 \times T$ (for these dimensions see IEC 60372), a load F is applied to the two rounded extremities of the clip, along its axis.

The load is gradually increased until the locking device moves to the coupling position. The operation from the locking to the coupling position shall be carried out three times in succession. The load F which causes the locking device to move from the locking to the coupling position is noted for each operation. After this, a load $F_{\max}$, as shown in the acceptance criteria below, shall be applied without causing complete removal of the locking device from the socket.

23.6 Acceptance criteria for the operation test

The values of the load F for the three operations shall lie between the values of $F_{\min}$ and $F_{\max}$ given below:

	Split-pins	W-clips
for standard coupling 11	$F_{\min} = 30 \text{ N}$	$F_{\min} = 25 \text{ N}$
	$F_{\max} = 300 \text{ N}$	$F_{\max} = 250 \text{ N}$
for standard coupling 16A-16B, 20, 24	$F_{\min} = 50 \text{ N}$	$F_{\min} = 25 \text{ N}$
	$F_{\max} = 500 \text{ N}$	$F_{\max} = 250 \text{ N}$
28, 32	$F_{\min} = 100 \text{ N}$	$F_{\min} = 25 \text{ N}$
	$F_{\max} = 650 \text{ N}$	$F_{\max} = 650 \text{ N}$
36, 40	$F_{\min} = 100 \text{ N}$	-
	$F_{\max} = 650 \text{ N}$	-

NOTE 1 In the case of split-pins made from very hard rust-resisting steels, loads of 300 N and 500 N may sometimes be insufficient to cause movement from the locking to the coupling position. By agreement between the purchaser and the manufacturer, higher value for $F_{\max}$ (up to 650 N for designated size of couplings) can be specified if the live-line working methods used permit such higher loads.

NOTE 2 For designated size of couplings 36 and 40, the values $F_{\min}$ and $F_{\max}$ for W-clips are to be agreed between the purchaser and the manufacturer.

24 Temperature cycle test

24.1 Test procedure for ceramic or toughened glass material

Insulators with their integral metal parts, if any, shall be quickly and completely immersed, without being placed in an intermediate container, in a water bath maintained at a temperature of $85 \pm 5 \text{ }^{\circ}\text{C}$ with a minimum of 70 K temperature difference than that of the cold bath used in the rest of the tests and left submerged for a duration T expressed in minutes:

$T = 15 + 0,7 m \text{ min}$ with a maximum of 30 min for class A insulators (where m is the mass of the insulator in kilograms);

$T = 15 \text{ min}$ for class B insulators.

They shall be withdrawn and quickly and completely immersed, without being placed in an intermediate container, in the cold water bath where they shall remain submerged for the same time. This heating and cooling cycle shall be performed three times in succession. The time taken to transfer from either bath to the other shall be as short as possible and not exceed 30 s.

On completion of the third cycle, the insulators (except toughened glass material) shall be examined to verify that they have not cracked, and shall then be subjected to the following test where applicable:

Class A insulators for which a routine mechanical test is specified: