

INTERNATIONAL STANDARD

Insulators for overhead lines – Composite suspension and tension insulators with AC voltage greater than 1 000 V and DC voltage greater than 1 500 V – Definitions, test methods and acceptance criteria



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IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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COMMENTED VERSION

INTERNATIONAL STANDARD

**Insulators for overhead lines – Composite suspension and tension insulators
with AC voltage greater than 1 000 V and DC voltage greater than 1 500 V –
Definitions, test methods and acceptance criteria**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**INSULATORS FOR OVERHEAD LINES
COMPOSITE SUSPENSION AND TENSION INSULATORS
~~FOR A.C. SYSTEMS WITH A NOMINAL AC VOLTAGE GREATER THAN~~
~~1 000 V AND DC VOLTAGE GREATER THAN 1 500 V~~ **1** –
DEFINITIONS, TEST METHODS AND ACCEPTANCE CRITERIA**

FOREWORD

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This commented version (CMV) of the official standard IEC 61109:2025 edition 3.0 allows the user to identify the changes made to the previous IEC 61109:2008 edition 2.0. Furthermore, comments from IEC TC 36 experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

IEC 61109 has been prepared by subcommittee 36B: Insulators for overhead lines, of IEC technical committee 36: Insulators. It is an International Standard.

This third edition cancels and replaces the second edition published in 2008. This edition constitutes a technical revision.

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

- a) extension of this document to apply both to AC and DC systems;
- b) modifications of Clause 3, Terms, definitions and abbreviations;
- c) removal of Clause 7, Hybrid insulators, from this document;
- d) modifications of tests procedures recently included in IEC 62217 (hydrophobicity transfer test, stress corrosion, water diffusion test on the core with housing);
- e) modifications on environmental conditions;
- f) modifications on classification of tests and include the relevance of the interfaces;
- g) clarification and modification of the parameters determining the need to repeat design and type tests;
- h) revision of Table 1;
- i) revision of electrical type tests;
- j) revision of re-testing procedure of sample test;
- k) addition of a new Annex D on electric field control for AC;
- l) addition of a new Annex E on typical sketch for composite insulators assembly;
- m) addition of a new Annex F on mechanical evaluation of the adhesion between core and housing;
- n) addition of a new Annex G on applicability of design- and type tests for DC applications.

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

Draft	Report on voting
36/609/FDIS	36/611/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.

This International Standard is to be used in conjunction with IEC 62217:2012.

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,
- withdrawn, or
- revised.

INTRODUCTION

Composite suspension and tension ² insulators (in the following the term "composite insulator" is used) consist of fibreglass insulating core, bearing the mechanical load protected by a polymeric housing, the load being transmitted to the core by metallic end fittings. Despite these common features, the materials used and the ~~construction~~ design details and manufacturing process used by different manufacturers may differ.

Some tests have been grouped together as "Design tests", to be performed only once on insulators which satisfy the same design conditions. For all design tests of these composite ~~suspension and tension~~ insulators, the appropriate common clauses defined in IEC 62217 are applied. As far as practical, the influence of time on the electrical and mechanical properties of its components (core ~~material~~, housing, interfaces etc.) and of the complete composite insulators has been considered in specifying the design tests to ensure a satisfactory lifetime under normally known stress conditions of transmission lines. Explanation of the principles of the damage limit, load coordination and testing are presented in Annex A.

It has not been considered useful to specify a power arc test as a mandatory test. The test parameters are manifold and can have very different values depending on the configurations of the network and the supports and on the design of arc-protection devices. The heating effect of power arcs ~~should need to~~ be considered in the design of metal fittings. Critical damage to the metal fittings resulting from the magnitude and duration of the short-circuit current can be avoided by properly designed arc-protection devices. This document, however, does not exclude the possibility of a power arc test by agreement between the ~~user and~~ manufacturer and customer. IEC 61467 gives details on AC power arc testing of complete insulator sets, that match their configuration with actual protective and string fittings, to recreate the real electromagnetic field affecting the arc movement.

~~Composite insulators are used in both a.c. and d.c. applications. In spite of this fact, a specific tracking and erosion test procedure for d.c. applications as a design test has not yet been defined and accepted. The 1 000 h a.c. tracking and erosion test of IEC 62217 is used to establish a minimum requirement for the tracking resistance of the housing material.~~

~~The mechanism of brittle fracture has been investigated by CIGRE B2.03⁴ and conclusions are published in [2, 3]. Brittle fracture is a result of stress corrosion induced by internal or external acid attack on the resin bonded glass fibre core. CIGRE D1.14 has developed a test procedure for core materials based on time load tests on assembled cores exposed to acid, along with chemical analysis methods to verify the resistance against acid attack [4]. In parallel IEC TC36WG 12 is studying preventive and predictive measures.~~

This document covers both AC and DC composite insulators. Before the appropriate standard for DC applications is issued, the majority of tests listed in this document can also be applicable for DC (Annex G). Due to the difference in AC and DC tracking performance, a specific tracking and erosion test procedure for DC applications as a design test is planned to be developed. The 1 000 h AC tracking and erosion test of IEC 62217 can be used only to establish a minimum requirement for the tracking and erosion resistance. This 1 000 h salt fog tracking and erosion test is considered as a screening test intended to reject materials in combination with the design which are inadequate. Tracking and erosion tests are not intended to evaluate long term performance of insulators. Such tests, e.g. the 5 000 h multiple stress test and wheel test in IEC TR 62730 [1]², or other tests intended for research or sometimes used as a supplementary design test, are not considered in this document.

Composite suspension and tension insulators are, in general, not intended for torsion or other non-tensile loads. However, due to consideration to non-standard applications (interphase

⁴ ~~International Council on Large High Voltage Electric Systems: Working Group B2.03.~~

² Numbers in square brackets refer to the bibliography.

| spacers etc.) loads during handling and installation have to be considered in the design. Guidance on non-standard loads is given in Annex C.

Wherever possible, IEC Guide 111 [2] has been followed for the drafting of this document.

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1 000 V AND DC VOLTAGE GREATER THAN 1 500 V –
DEFINITIONS, TEST METHODS AND ACCEPTANCE CRITERIA**

1 Scope ~~and object~~

This International Standard applies to composite ~~suspension/tension~~ insulators for overhead lines consisting of a load-bearing cylindrical insulating solid core consisting of fibres – usually glass – in a resin-based matrix, a housing (~~outside~~ surrounding the insulating core) made of polymeric material and metal end fittings permanently attached to the insulating core.

Composite insulators covered by this document are intended for use as suspension/tension line insulators, but ~~it should be noted that~~ these insulators ~~can~~ could occasionally be subjected to compression or bending, for example when used as ~~phase~~ interphase-spacers. Guidance on such loads is outlined in Annex C.

~~This standard can be applied in part to hybrid composite insulators where the core is made of a homogeneous material (porcelain, resin), see Clause 8.~~

The object of this document is to

- define the terms used,
- ~~prescribe~~ specify test methods,
- ~~prescribe~~ specify acceptance criteria.

This document does not include requirements dealing with the choice of insulators for specific operating conditions or environments beyond normal environmental conditions defined in Table 1.

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 60383-1, *Insulators for overhead lines with a nominal voltage above 1000 V – Part 1: Ceramic or glass insulator units for AC systems – Definitions, test methods and acceptance criteria*

IEC 60383-2, *Insulators for overhead lines with a nominal voltage above 1 000 V – Part 2: Insulator strings and insulator sets for AC systems – Definitions, test methods and acceptance criteria*

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

IEC 61284, *Overhead lines – Requirements and tests for fittings*

IEC 61466-1, *Composite string insulator units for overhead lines with a nominal voltage greater than 1 000 V – Part 1: Standard strength classes and end fittings*

IEC 61467, *Insulators for overhead lines – Insulator strings and sets for lines with a nominal voltage greater than 1 000 V – AC power arc tests*

IEC 62217:~~2005~~³, *Polymeric HV insulators for indoor and outdoor use ~~with a nominal voltage > 1 000 V~~* – General definitions, test methods and acceptance criteria

IEC 62231, *Composite station post insulators for substations with AC voltages greater than 1 000 V up to 245 kV – Definitions, test methods and acceptance criteria*

ISO 3452 (all parts), *Non-destructive testing – Penetrant testing*

3 Terms, definitions and abbreviated terms

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

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

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

Note 1 to entry: Certain terms from IEC 62217:2012 are reproduced here for ease of reference. Additional definitions applicable to insulators can be found in IEC 60050-471 [3].

3.1 Terms and definitions

3.1.1

polymeric insulator

insulator whose insulating body consists of at least one organic based material

Note 1 to entry: Polymeric insulators are also known as non-ceramic insulators.

Note 2 to entry: Coupling devices may be attached to the ends of the insulating body.

[SOURCE: IEC 60050-471:2007, 471-01-13]

3.1.2

composite insulator

insulator made of at least two insulating parts, namely a core and a housing equipped with ~~metal~~ end fittings

Note 1 to entry: Composite insulators can consist either of individual sheds mounted on the core, with or without an intermediate sheath, or alternatively, of a housing directly moulded or cast in one or several pieces on to the core.

[SOURCE: IEC 60050-471:2007, 471-01-02]

3.1.3

core (of a ~~composite~~ an insulator)

~~internal insulating part of a composite insulator which is designed to ensure the mechanical characteristics~~

~~NOTE The core usually consists of either fibres (e.g. glass) which are positioned in a resin based matrix or a homogeneous insulating material (e.g. porcelain or resin).~~

³ Under preparation. Stage at the time of publication: IEC/RFDIS 62217:2025.

~~[IEV 471-01-03, modified]~~

central insulating part of an insulator which provides the mechanical characteristics

Note 1 to entry: The housing and sheds are not part of the core.

[SOURCE: IEC 60050-471:2007, 471-01-03]

3.1.4

insulator trunk

central insulating part of an insulator from which the sheds project

Note 1 to entry: Also known as shank on smaller insulators.

[SOURCE: IEC 60050-471:2007, 471-01-11]

3.1.5

housing

external insulating part of composite insulator providing the necessary creepage distance and ~~protecting~~ protects the core from the environment

Note 1 to entry: An intermediate sheath made of insulating material may be part of the housing.

[SOURCE: IEC 60050-471:2007, 471-01-09]

3.1.6

shed (of an insulator)

insulating part, projecting from the insulator trunk, intended to increase the creepage distance

Note 1 to entry: The shed can be with or without under-ribs.

[SOURCE: IEC 60050-471:2007, 471-01-15]

3.1.7

interface

~~contact~~ surface between the different materials

Note 1 to entry: Various interfaces exist in composite insulators, e.g.:

- between housing and ~~fixing devices~~ end fittings;
- between various parts of the housing; e.g. between separately manufactured sheds, or between sheath and sheds;
- between core and housing;
- between sealant and core;
- between sealant and end fittings.

(Annex E: Typical sketches for composite insulator assemblies)

~~[Definition 3.10 of IEC 62217]~~

[SOURCE: IEC 62217:—, 3.11, modified – "contact" added in definition, Note 1 to entry modified]

3.1.8

end fitting

integral component or formed part of an insulator intended to connect it to a supporting structure, or to a conductor, or to an item of equipment, or to another insulator

Note 1 to entry: Where the end fitting is metallic, in general the term "metal fitting" is used.

Note 2 to entry: Standard end fittings are defined in IEC 61466-1.

[SOURCE: IEC 60050-471:2007, 471-01-06]

3.1.9

connection zone

zone where the mechanical load is transmitted between the ~~insulating body~~ core and the end fitting

~~[Definition 3.12 of IEC 62217]~~

[SOURCE: IEC 62217:2012, 3.13, modified – "insulating body and the fixing device" replaced by "core and the end fitting"]

3.1.10

coupling

part of the end fitting which transmits the load to the accessories external to the insulator

~~[Definition 3.13 of IEC 62217, modified]~~

[SOURCE: IEC 62217:2012, 3.14, modified – "fixing device" replaced by "end fitting", "hardware" replaced by "accessories"]

3.1.11

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

[SOURCE: IEC 60050-471:2007, 471-01-04]

3.1.12

arcing distance

shortest distance in the air external to the insulator between the metallic parts which normally have the operating voltage between them

Note 1 to entry: The term "dry arcing distance" is also used.

[SOURCE: IEC 60050-471:2007, 471-01-01]

3.1.13

specified mechanical load

SML

~~withstand~~ load, specified by the manufacturer, which is used for mechanical tests in this document

3.1.14

routine test load

RTL

load applied to all assembled composite insulators during a routine mechanical test

3.1.15

mechanical failing load

maximum load that is reached when the insulator is tested under the ~~prescribed~~ standard conditions

[SOURCE: IEC 60050-471:2007, 471-01-12, modified – "prescribed" replaced by "standard", Note 1 to entry removed]

3.1.16**insulator set**

assembly of one or more insulator strings suitably connected together, complete with end fittings and protective devices as required in service

Note 1 to entry: The terms "arcing and field grading devices" is also used for protective devices.

[SOURCE: IEC 60050-471:2007, 471-03-02]

3.1.17**string insulator unit**

cap and pin insulator or long rod insulator of which the end fittings are suitable for flexible attachment to other similar string insulator units or to connecting accessories

Note 1 to entry: Cap and pin insulators are not composite insulators and are not part of this document.

[SOURCE: IEC 60050-471:2007, 471-03-08]

3.1.18**sealing**

method for providing the ability of a component to resist the ingress of contaminants

Note 1 to entry: Contaminants include pollution and moisture.

[SOURCE: IEC 60050-581:2008, 581-23-16]

3.1.19**sealant**

additional material used for sealing

Note 1 to entry: Typically RTV-silicones are used for composite insulators.

Note 2 to entry: See sealant in Annex E: Typical principles sketch for composite insulators assembly.

3.1.20**grading/corona ring**

protective devices made from metal attached to the composite insulator end fitting or intermediate string fitting intended to keep the electric field anywhere along the surface of composite insulator below the specified maximum value

3.2 Abbreviated terms

The following abbreviated terms are used in this document:

E1, E2	Sample sets for sample tests
M_{AV}	Average 1 min failing load of the core assembled with fittings
RTL	Routine test load
RTV	Room-temperature-vulcanizing silicone
SML	Specified mechanical load

4 Identification

In addition to the requirements of IEC 62217, each insulator shall be marked with the SML.

It is recommended that each insulator is marked or labelled by the manufacturer to show that it has passed the routine mechanical test.

5 Environmental conditions **3**

The normal environmental conditions to which insulators are submitted in service are defined in IEC 62217 and shown in Table 1. Terms are defined as follows:

- Indoor environment: installation within a building or other construction where the insulators are protected against wind, rain, snow, periodical fast-built pollution deposits, abnormal condensation, ice and hoar frost.
- Outdoor environment: installation in open air outside any building or shelter, where the insulators are submitted to wind, rain, snow, periodical fast-built pollution deposits, high condensation, ice and hoar frost.

If service conditions of polymeric insulators deviate significantly from the parameters in Table 1, the insulator is to be designed or evaluated according to agreement between the customer and manufacturer. Alternatively, if positive service experience ("i.e. no failures") is available for a specific environment and specific insulator design (including material and profile), the insulator can be used for this specific environment, deviating from normal environmental conditions.

Table 1 – Normal environmental conditions

	Indoor insulation	Outdoor insulation
Maximum ambient air temperature ^a	Does not exceed 40 °C and its average value measured over a period of 24 h does not exceed 35 °C	
Minimum ambient air temperature ^b	–25 °C	–40 °C
Vibration	Negligible vibration due to causes external to the insulators or to earth tremors ^c .	
Solar radiation ^d	Not applicable	Up to a level of 1 120 W/m ²
Site pollution severity ^e	No significant pollution by dust, smoke, corrosive and/or flammable gases, vapours, or salt.	Pollution by dust, smoke, corrosive gases, vapours or salt occurs. Pollution does not exceed SPS class "heavy" as defined in IEC TS 60815-1 [5].
Humidity ^f	No rain, snow, abnormal humidity, condensation, ice and hoar frost	Rain, snow, abnormal humidity, condensation, ice and hoar frost occur.

^a If exceeded, follow the recommendations of IEC TR 62039 [5] for the core and adhesive materials (like glue) in "glass transition temperature" section.

^b In general, temperatures below –40 °C are non-critical for service. However, for handling and installation the crystallization temperature of the polymeric housing is to be considered. For line installations with temperatures below –20 °C, special steel grades with low ductile transition temperature can be specified.

^c Vibration due to external causes can be dealt with in accordance to IEC 60721-1 [6].

^d For outdoor application, the influence of deviation from the assumed level of 1 120 W/m².

depends on the insulator material. If service conditions of polymeric insulators deviate significantly from the parameters in Table 1, the insulator is to be designed/evaluated taking into account relevant service experience. In the absence of significant service experience, special tests simulating the solar radiation condition of the installation area have to be carried out.

^e In general, pollution is not an issue for indoor insulators. In particular cases, such as DC.

indoor conditions, the insulators can accumulate some contamination due to DC electrical field. However, the pollution flashover phenomena cannot develop when the humidity is controlled. For outdoor conditions the requirements of IEC 62217 are specified for stresses arising in relatively harsh but not extreme environments (see e.g. hydrophobicity verification and tracking and erosion tests for which criteria are provided in IEC 62039).

^f Insulator for indoor applications can also be used in presence of limited deviations from the above conditions if positive service experience "i.e. no failures" is available and condensation occurs only occasionally.

To limit condensation-related phenomena, the average value of the normal humidity condition, measured over a period of 24 h does not exceed 95 % and when measured over a period of one month, does not exceed 90 %. Exceeding these values is considered as abnormal humidity condition.

6 Transport, storage and installation

In addition to the requirements of IEC 62217, information on handling of composite insulators can be found in CIGRE TB 184 [7] and TB 919 [9]. During installation, or when used in non-standard configurations, composite ~~suspension~~ insulators may be submitted to high torsion, compression or bending loads for which they are not designed. Annex C gives guidance ~~on catering~~ for such loads.

Where required the assembly instruction of the grading/corona rings should be supplied to the client, containing the correct positioning and installation of the grading/corona rings on the insulators.

~~7 Hybrid insulators~~ 4

~~As stated in Clause 1, this standard can be applied in part to hybrid composite insulators where the core is made of a homogeneous material (porcelain, resin). In general, the load time mechanical tests and tests for core material are not applicable to porcelain cores. For such insulators, the purchaser and the manufacturer shall agree on the selection of tests to be used from this standard and from IEC 60383-1.~~

7 Tolerances

Unless otherwise agreed, a tolerance of

$$\pm (0,04 \times d + 1,5) \text{ mm when } d \leq 300 \text{ mm,}$$

$$\pm (0,025 \times d + 6) \text{ mm when } d > 300 \text{ mm with a maximum tolerance of } \pm 50 \text{ mm}$$

shall be allowed on all dimensions for which specific tolerances are not requested or given on the insulator drawing (d being the dimension in millimeters).

The measurement of creepage distances shall be related to the design dimensions and tolerances as determined from the insulator drawing, even if this dimension is greater than the value originally specified. When a minimum creepage is specified, the negative tolerance ~~is also limited by this value~~ for minimum creepage distance is zero 5.

In the case of insulators with creepage distance exceeding 3 m, it is allowed to measure a short section around 1 m long of the insulator and to extrapolate, provided that the unmeasured lengths have the same shed diameters, profiles and spacing as the measured section on which the extrapolation is based.

8 Classification of tests

8.1 Design tests

These tests are intended to verify the suitability of the design, materials and method of manufacture (technology). A composite ~~suspension~~ insulator design is defined by the following elements:

- ~~— materials of the core, housing and their manufacturing method;~~
- ~~— material of the End fittings, their design and method of attachment (excluding the coupling);~~
- ~~— layer Thickness of the housing over the core (including a sheath where used);~~
- ~~— Diameter of the core.~~
- Housing materials, including their formulation and manufacturing process.
- Core materials.

- End fittings materials, their manufacturing process and method of attachment (excluding the coupling).
- Thickness of the housing surrounding the core (including a sheath where used).
- Diameter of the core.
- Interfaces
 - Core/housing interface design including type of coupling agent (primer) and assembly;
 - Housing/end fitting interface design;
 - Core end fitting interface;
 - Trunk/shed interface and trunk/trunk interface (if applicable).

When changes in the design occur, re-qualification shall be carried out in accordance with Table 2.

When a composite ~~suspension~~ insulator is submitted to the design tests, it becomes ~~a parent~~ an equivalent design insulator for a given design and the results shall be considered valid for that design only. This tested ~~parent~~ equivalent design insulator defines a particular design of insulators which have all the following characteristics:

- a) same materials (including their formulations) for the core and housing and same manufacturing method (including an assembly process of the housing);
- b) same material of the fittings, the same ~~connection-zone~~ core/end fitting interface design, and the same housing-to-fitting interface geometry;
- c) same or greater minimum layer thickness of the housing ~~over~~ surrounding the core (including a sheath where used);
- d) same or smaller stress under mechanical loads;

NOTE As an example, the SML can serve as mechanical reference load. The stress is calculated by dividing the load by the cross-sectional area of the core.

- e) same or greater diameter of the core;
- f) equivalent housing profile parameters; see Note (a) in Table 2.

8.2 Type tests

The type tests are intended to verify the main characteristics of a composite insulator, which depend mainly on its shape and size. They also confirm the mechanical characteristics of the assembled core (see Clause A.4). They are made on insulators whose class has satisfied the design tests, ~~more details are given in Clause 11.~~

An insulator type is electrically defined by the arcing distance, creepage distance, inclination, overhang and spacing of the sheds of an insulator.

Furthermore, outlines the insulator design characteristics that, when changed, also require a repeat of the electrical type tests.

An insulator type is mechanically defined by a maximum SML for the given core diameter, method of attachment and coupling design. The typical coordination between SML and service loads can be found in Annex A.

The mechanical type tests shall be performed only once on insulators satisfying the criteria for each type.

Furthermore, Table 2 indicates additional insulator design characteristics that, when changed, require a repeat of the mechanical type tests.

8.3 Sample tests

The sample tests are for the purpose of verifying other characteristics of composite insulators, including those which depend on the quality of manufacture and on the materials used. They are made on insulators taken at random from lots offered for acceptance.

8.4 Routine tests

The aim of these tests is to eliminate composite insulators with manufacturing defects. Routine tests are carried out on every composite insulator ~~offered for acceptance~~.

Table 2 – Tests to be carried out after design changes

~~IF the change in insulator design concerns:~~		~~THEN the following tests shall be repeated:~~									
		~~Design tests~~								~~Type tests~~	
		~~62247~~	~~61109~~	~~62247 Tests on housing material~~				~~62247 Tests on the core material~~		~~61109~~	
		~~Interface and connections of end fittings~~	~~Assembled core load – time tests~~	~~Hardness test~~	~~Accelerated weathering test~~	~~Tracking and erosion test~~	~~Flammability test~~	~~Dye penetration test~~	~~Water diffusion test~~	~~Electrical type tests~~	~~Mechanical type tests~~
1	~~Housing materials~~	X	X ^{e)}	X	X	X	X				
2	~~Housing profile^{a)}~~	X				X				X	
3	~~Core material~~	X	X					X	X		X
4	~~Core diameter^{b)}~~	X	X					X	X		X
5	~~Core and end fitting manufacturing process~~	X	X					X	X		X
6	~~Core and end fitting assembly process~~	X	X								X
7	~~Housing manufacturing process~~	X	X ^{e)}	X	X	X	X				X ^{e)}
8	~~Housing assembly process~~	X	X ^{e)}			X					X ^{e)}
9	~~End fitting material~~	X	X								X
10	~~End fitting connection zone design~~	X	X								X
11	~~Core/housing/end fitting interface design~~	X	X ^{e)}			X					X ^{e)}
12	~~Coupling type~~										X
~~a) Variations of the profile within following tolerances do not constitute a change:~~ ~~– overhang : ± 10 %~~ ~~– diameter : +15 %, – 0 %~~ ~~– thickness at base and tip : ± 15 %~~ ~~– spacing : ± 15 %~~ ~~– shed inclinations : ± 3°~~ ~~– shed repetition : identical~~ ~~b) Variations of the core diameter within ± 15 % do not constitute a change.~~ ~~c) Not necessary if it can be demonstrated that the change has no influence on the assembled core strength.~~											

If the change in insulator design concerns:				THEN the following tests shall be repeated:											
				Design tests										Type tests	
		IEC 62217	IEC 61109	IEC 62217 Tests on housing material						IEC 62217 Tests on core material				IEC 62217 Tests on core with housing	IEC 61109
		Interfaces and connections of end fittings	Assembled core load–time tests	Hardness test	Accelerated weathering test	Tracking and erosion test	Flammability test	Hydrophobicity transfer test	Dye penetration test	Water diffusion test	Stress corrosion test	Water diffusion test on core with housing	Electrical type tests	Mechanical type tests	
1	Housing														
1a	Material, formulation ¹ or manufacturing process ²	X	X	X	X ^{d)}	X	X ^{d)}	X ^{e)}				X			
1b	Assembly process ²	X ^{b)}				X								X ^{b)}	
1c	Profile 6					X ^{a)}							X ^{a)}		
2	Core														
2a	Material, formulation or manufacturing process ³	X	X						X	X	X ^{a),d),e)}	X		X	
2b	Diameter	X ^{b),c)}	X ^{b), c)}	X ^{b)}	8	X ^{b)}			X ^{b)}	X ^{b)}		X ^{b)}		X ^{b),c)}	
3	End fitting														
3a	Material or manufacturing or assembly process ⁴	X	X											X	
3b	End fitting connection zone design ⁵	X	X											X	
3c	Coupling type													X	
4	Interface 9														
4a	Core/ housing interface design ⁶	X										X			
4b	Housing/end fitting interface design ⁷	X				X								X	
4c	Trunk and shed interface design ⁸	X				X						X			

a) Not necessary if thickness of the housing surrounding the core (including a sheath where used) is equal or greater than that of the equivalent design insulator. The following relative numbers as tolerances are provided as a reference, which do not constitute a change of the profile:

- shed overhang: ±10 %;
- shed thickness at base and tip: ±15 %;
- shed spacing: ±15 %;
- shed inclinations: ±3°;
- shed repetition: identical.

These relatively strict tolerances can result in an increased demand for the tracking and erosion testing due to varieties of today's housing profiles. Especially profile parameters as shed overhang and shed spacing may create such variations. Therefore, deviations of a candidate profile, exceeding the above stated tolerances for shed overhang and shed spacing, can be aligned between manufacturer and a customer if a candidate profile does not exceed minor deviations defined in IEC TS 60815-3 [8] for shed overhang and shed spacing compared to successfully tested shed profiles in the tracking and erosion test. Then the candidate profile parameters shall be in between tested profile parameters.

- b) Variations of the core diameter within ± 15 % do not constitute a change.
- c) Not necessary if the stress under mechanical loads is the same or smaller.
- d) Not necessary for change in manufacturing process without material change.
- e) Applicable to materials that shall show this property.

1 Housing materials / formulations:

Ethylene Propylene Diene Monomer, High Temperature Vulcanized Silicone, Liquid Silicone Rubber, Room Temperature Vulcanizing Silicone, etc.

Formulation: any changes in the material formulation, either by changes of ingredients or their dosage (can be verified by incoming inspection e.g. Fingerprint test acc CIGRE TB 595 [10]).

2 Housing manufacturing /assembly process:

Manufacturing: injection moulding, modular process, one-piece compression moulding.

Assembly: shed and sheath are assembled separately.

3 Core materials (Polyester resin, Epoxy resin, ...), their formulation (e.g. glass content) and their manufacturing process (e.g. pultrusion, filament winding).

4 End fittings materials (steel, ductile iron, malleable iron) and their manufacturing process method (forging, casting) and method of attachment (excluding the coupling).

5 End fitting connection zone design: Interfaces core/end fitting interface design (e.g. crimping surface: core diameter & crimp length, roughness ...).

6 Interfaces core/housing interface design incl. type of coupling agent (primer) and assembly.

7 Interfaces housing/end fitting (e.g. overmoulded / non-overmoulded).

8 Interfaces trunk/sheds and trunk/trunk if applicable.

NOTE Sketches of the different kinds of interfaces are shown in Annex E.

9 Design tests

9.1 General

These tests consist of the tests ~~prescribed~~ specified in IEC 62217 and a specific assembled core load-time test as listed in Table 3. The design tests are performed only once, and the results are recorded in a test report. Each part can be performed independently on new test specimens, where appropriate. The composite insulator of a particular design shall be qualified only when all insulators or test specimens pass the design tests.

Table 3 – Design tests

Tests on interfaces and connections of end fittings
Reference disruptive-discharge dry power frequency test
Pre-stressing – Sudden load release pre-stressing Thermal-mechanical pre-stressing (see 9.3.1 and 9.3.2)
Water immersion pre-stressing
Verification tests
Visual examination
Steep-front impulse voltage test
Dry power-frequency voltage tests
Tests on ~~shed and~~ housing material
Hardness test
Accelerated weathering test
Tracking and erosion test – see 9.2.2 for specimens
Flammability test
Hydrophobicity transfer test
Tests on core material – see 9.2.3 for specimens
Dye penetration test
Water diffusion test
Stress corrosion test
Tests on core with housing – see 9.2.4 for specimens
Water diffusion test on the core with housing
Assembled core load-time test – see 9.4 for specimens
Determination of the average failing load of the core of the assembled insulator
~~Control of the slope of the strength-time curve of the insulator~~
Verification of the 96 h withstand load

The applicability of design tests for direct current (DC) applications is shown in Annex G.

9.2 Test specimens ~~for IEC 62217~~

9.2.1 Tests on interfaces and connections of end fittings

Three production insulators ~~assembled on the production line~~ shall be tested. The insulation length (metal to metal spacing) shall not be less than 800 mm. Both end fittings shall be the same as used on standard production insulators. The end fittings shall be assembled so that the insulating part from the fitting to the closest shed shall be identical to that of the production line insulator. If spacers, joining rings or other ~~features~~ components creating interfaces are

used in the insulator design (notably for longer insulators), the sample shall include any such devices in a typical position.

NOTE 1 A fourth insulator might be necessary for calibration of the steep-front impulse voltage test circuit.

NOTE 2 If the manufacturer only has facilities to produce insulators shorter than 800 mm, the design tests ~~may~~ can be performed on insulators with available length, but the results are only valid for up to the lengths tested.

9.2.2 Tracking and erosion test

If spacers, joining rings or other ~~features~~ components creating interfaces are used in the insulator design (notably for longer insulators), the samples for this test shall include any such devices in a typical position.

Creepage distance of the sample shall be between 500 mm and 800 mm as specified in IEC 62217. If the inclusion of spacers or joints, as mentioned above, requires a longer creepage distance, the design tests may be performed on insulators of lengths that provide leakage distances as close to 800 mm as possible. If the manufacturer only has facilities to produce insulators with creepage shorter than 500 mm, the design tests may be performed on insulators of available lengths, but the results are only valid for up to the tested lengths.

9.2.3 Tests on core material

~~The specimens shall be as specified in IEC 62217. However, if the housing material is not bonded to the core, then it shall be removed and the remaining core thoroughly cleaned to remove any traces of sealing material before cutting and testing.~~

The specimens, test method and acceptance criteria shall be as specified in IEC 62217.

9.2.4 Tests on core with housing

The specimens, test method and acceptance criteria shall be as specified in IEC 62217.

NOTE Annex F describes additional mechanical methods applicable to verify the level of adhesion core/housing. For design tests, method A is preferable. If both water diffusion test on core with housing and pull-off tests are performed, the same specimens used first in water diffusion test on core with housing can be used for the pull-off test as described in Annex F.

9.3 Product specific pre-stressing for ~~IEC 62217~~ tests on interfaces and connections of end fittings

9.3.1 General

The tests shall be carried out on the three specimens in the sequence as indicated in this subclause.

9.3.2 Sudden load release

The purpose of this test is the pre-stressing all interfaces and connections including the interface of shed and trunk. It is not related to the connection of the end fittings only.

With the insulator at $-20\text{ }^{\circ}\text{C}$ to $-25\text{ }^{\circ}\text{C}$ at the start of the test, every test specimen is subjected to five sudden load releases from a tensile load amounting to 30 % of the SML hold for at least 1 min.

~~NOTE 1~~ Annex B describes two examples of possible devices for sudden load release. If another process/device is used, the time of sudden load release shall be $< 50\text{ ms}$.

~~NOTE 2~~ In certain cases, a lower temperature ~~may~~ can be selected by agreement.

9.3.3 Thermal-mechanical pre-stress

Before commencing the test, the specimens shall be loaded at the ambient temperature by at least 5 % of the SML for 1 min, during which the length of the specimens shall be measured to an accuracy of 0,5 mm. This length shall be the reference length.

The specimens are then submitted to temperature cycles under a continuous mechanical load as described in Figure 1, the 24 h temperature cycle being performed four times. Each 24 h cycle has two temperature levels with a duration of at least 8 h, one at $(+50 \pm 5) ^\circ\text{C}$, the other at $(-35 \pm 5) ^\circ\text{C}$. The cold period shall be at a temperature at least 85 K below the value actually applied in the hot period. The pre-stressing can be conducted in air or any other suitable medium.

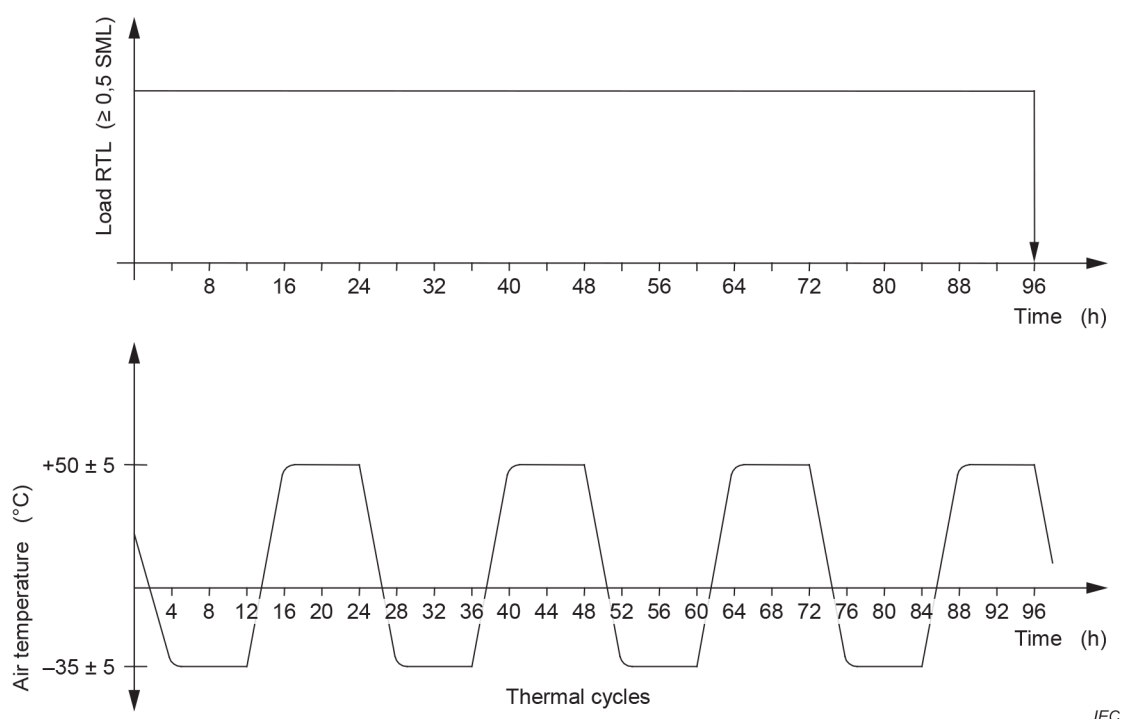


Figure 1 – Thermal-mechanical pre-stressing

The applied mechanical load shall be equal to the RTL (at least 50 % of the SML) of the specimen. The specimen shall be loaded at ambient temperature before beginning the first thermal cycle.

The cycles may be interrupted for maintenance of the test equipment for a total duration of 2 h. The starting point after any interruption shall be the beginning of the interrupted cycle.

After the test, the length shall again be measured in a similar manner at the same load and at the original specimen temperature (this is done in order to provide some additional information about the relative movement of the metal fittings).

NOTE 1 The temperatures and loads in this pre-stressing are not intended to represent service conditions, they are designed to produce specific reproducible stresses in the interfaces on the insulator.

NOTE 2 In certain cases, a lower temperature can be selected by agreement.

9.4 Assembled core load-time tests

9.4.1 Test specimens

Six insulators made on the production line shall be tested. The insulation length (metal to metal spacing) shall be not less than 800 mm. Both end fittings shall be identical in all aspects to

those used on production line insulators, except that they may be modified beyond the end of the connection zone in order to avoid failure of the couplings.

The six insulators shall be examined visually and a check made that their dimensions conform with the drawing.

NOTE If the manufacturer only has facilities to produce insulators shorter than 800 mm, the design tests ~~may~~ can be performed on insulators of available lengths, but the results are only valid for up to the tested lengths.

9.4.2 Mechanical load test

9.4.2.1 General

This test is performed in two parts at ambient temperature.

9.4.2.2 Determination of the average failing load of the core of the assembled insulator (M_{AV})

Three of the ~~specimens~~ composite insulators shall be subjected to a tensile load. The tensile load shall be increased rapidly but smoothly from zero to approximately 75 % of the ~~expected mechanical failing load~~ SML and shall then be gradually increased in a time between 30 s and 90 s to the SML. Once the SML is reached, the load is gradually increased until breakage of the core or complete pull-out occurs. The average of the three failing loads M_{AV} shall be calculated.

9.4.2.3 Verification of the 96 h withstand load

The remaining three ~~specimens~~ composite insulators shall be subjected to a tensile load. The tensile load shall be increased rapidly but smoothly from zero up to 60 % of M_{AV} , as calculated in 9.4.2.2 and then maintained at this value for 96 h without failure (breakage or complete pull-out). If for any reason the load application is interrupted, then the test shall be restarted on a new specimen.

10 Type tests

10.1 General

~~An insulator type is electrically defined by the arcing distance, creepage distance, shed inclination, shed diameter and shed spacing.~~

~~The electrical type tests shall be performed only once on insulators satisfying the conditions above and shall be performed with arcing or field control devices (which are generally necessary on composite insulators at transmission voltages) if they are an integral part of the insulator type.~~

~~Furthermore, Table 1 outlines the insulator design characteristics that, when changed, also require a repeat of the electrical type tests.~~

~~An insulator type is mechanically defined principally by a maximum SML for the given core diameter, method of attachment and coupling design.~~

~~The mechanical type tests shall be performed only once on insulators satisfying the criteria for each type.~~

~~Furthermore, Table 1 indicates additional insulator design characteristics that, when changed, require a repeat of the mechanical type tests.~~

The applicability of type tests for DC applications is given in Annex G.

10.2 Electrical tests on string insulator units 10

10.2.1 General

~~The electrical tests in Table 3 shall be performed according to IEC 60383-2 to confirm the specified values. Interpolation of electrical test results may be used for insulators of intermediate length, provided that the factor between the arcing distances of the insulators whose results form the end points of the interpolation range is less than or equal to 1,5. Extrapolation is not allowed.~~

The electrical type tests shall be performed only once on composite insulators satisfying conditions given in Table 2. If protective arcing and electric field control grading devices are used in service and are an integral part of a given insulator design, they shall be used in the electrical testing of string insulator units according to a manufacturer drawing and specification.

Electrical tests specified in this document are part of a product type testing and are valid for given string insulator units. Such tests and their test results differ from fully assembled insulator sets due to associated protective fittings and conductor configuration and therefore it is necessary to define if the specified electrical values are for the insulator unit alone or for the complete insulator set. The application of string insulator units and insulator sets are given in Table 4.

Interpolation of electrical test results may be used for string insulator units of intermediate length, provided that the factor between the arcing distances of the insulators whose results from the end points of the interpolation range is less than or equal to 1,5. Extrapolation is not allowed.

Test values and procedures generally depend on application (indoor, outdoor, installation) and are therefore to be applied with respect to the customer's specification.

NOTE The electrical type tests of string insulator units can be performed under customer specific conditions if required and agreed between manufacturer and customer.

10.2.2 Test specimens

One insulator taken from the production line shall be used for each test. The insulator shall be examined visually and checked to see that the dimensions conform with the drawing.

If a string insulator unit is fitted with electric field grading rings as integral parts and those are specified in a manufacturer's product drawing, they shall be used in the testing.

10.2.3 Mounting arrangements for electrical tests

The mounting arrangements for electrical tests on string insulator units shall be as specified in Table 4.

The testing shall be done according to IEC 60060-1.

10.2.4 Dry lightning impulse withstand voltage test

The test circuit, test voltage and test procedure shall be in accordance with the criteria stated in IEC 60060-1.

The test is applicable to string insulator units to be used in indoor and outdoor applications.

10.2.5 Wet power-frequency voltage tests

Wet power frequency withstand voltage test shall be preferably done.

Wet power frequency disruptive-discharge voltage test could be done additionally.

The test circuit, test voltage and test procedure shall be in accordance with the criteria stated in IEC 60060-1.

The testing under wet condition is applicable to composite string insulator units to be used in outdoor applications only.

For insulators to be used in indoor applications, testing under dry condition according to IEC 60060-1 is required.

10.2.6 Wet switching impulse withstand voltage test

Wet switching impulse withstand voltage test are required for insulators intended for systems with $U_m \geq 300$ kV.

The test circuit, test voltage and test procedure shall be in accordance with the criteria stated in IEC 60060-1.

The testing under wet condition is applicable to composite string insulator units to be used in outdoor applications only.

For insulators to be used in indoor applications, testing under dry condition according to IEC 60060-1 is required.

10.2.7 Corona and radio interference voltage (RIV) tests

Corona/RIV tests are related mainly to fully assembled insulator sets. These tests can be completed on string insulator units also if the system voltage level or application requires the use of electric field grading rings as their integral parts and those are specified in string insulator unit's product drawings. The control of electrical fields is described in Annex D.

10.2.8 Power arc test

The power arc test is typically not required to be completed on string insulator units.

Table 4 – Application and mounting arrangements for electrical tests

Test	Mounting arrangement
~~Dry lightning impulse withstand voltage test~~	~~Standard mounting arrangement of an insulator string or insulator set when switching impulse tests are not required~~
~~Wet power frequency test~~	~~Standard mounting arrangement of an insulator string or insulator set when switching impulse tests are not required~~
~~Wet switching impulse withstand voltage test for insulators intended for systems with $U_m \geq 300$ kV~~	~~Standard mounting arrangement of an insulator string or insulator set when switching impulse tests are required~~

Test	String Insulator Unit (single composite insulator)	Insulator Set ² (informative)
Dry lightning impulse withstand voltage test	according to IEC 60383-2 and IEC 60060-1	according to IEC 60383-2, IEC 61284 and IEC 60060-1
Wet power-frequency withstand voltage test ¹	according to IEC 60383-2 and IEC 60060-1	according to IEC 60383-2, IEC 61284 and IEC 60060-1
Wet power-frequency disruptive-discharge (flashover) voltage test ¹	according to IEC 60383-2 and IEC 60060-1	according to IEC 60383-2, IEC 61284 and IEC 60060-1
Wet switching impulse withstand voltage test for insulators intended for systems with $U_m \geq 300$ kV ¹	according to IEC 60383-2 and IEC 60060-1	according to IEC 60383-2, IEC 61284 and IEC 60060-1
Corona/RIV Tests	Not mandatory and typically, not applicable	according to IEC 61284 and IEC 60437
Power Arc Test	Not mandatory and typically, not applicable	according to IEC 61467
¹ The test is applicable to string insulator units to be used in outdoor applications. ² If required, the Water drop induced corona (WDIC) test can be done on insulator sets (instead of or in addition to electric field calculations) as a physical test to verify the electric field grading and to prevent negative effects of water drop induced corona phenomena on polymeric housing material [9].		

10.3 Damage limit proof test and test of the tightness of the interface between end fittings and insulator housing

10.3.1 Test specimens

Four insulators taken from the production line shall be tested. In the case of long insulators, specimens may be manufactured, assembled on the production line, with an insulation length (metal to metal spacing) not less than 800 mm. Both end fittings shall be the same as on standard production insulators. The fittings shall be assembled such that the insulating part from the fitting to the closest shed is identical to that of the production line insulator. The insulators shall be examined visually and checked to see that the dimensions conform with the drawing; they shall then be subjected to the mechanical routine test according to 12.1.

NOTE If the manufacturer only has facilities to produce insulators shorter than 800 mm, the design tests ~~may~~ can be performed on insulators of those lengths available to them, but the results are only valid for up to the lengths tested.

10.3.2 Performance of the test

- The four specimens are subjected to a tensile load applied between the couplings at ambient temperature. The tensile load shall be increased rapidly but smoothly from zero up to 70 % of the SML and then maintained at this value for 96 h.
- Both ends of one of the four specimens shall, at the end of the 96 h test, be subjected to crack indication by dye penetration, in accordance with ISO 3452, on the housing in the

zone embracing the complete length of the interface between the housing and metal fitting and including an additional area, sufficiently extended, beyond the end of the metal part.

The indication shall be performed in the following way:

- the surface shall be properly pre-cleaned with the cleaner;
- the penetrant shall be applied on the cleaned surface and left to act for 20 min;
- the surface shall be cleaned of the excess penetrant and dried;
- the developer shall be applied, if necessary;
- the surface shall be inspected.

Some housing materials may be penetrated by the penetrant. In such cases, evidence shall be provided to validate the interpretation of the results.

After the penetration test the specimen shall be inspected. If any cracks are visible, the housing and, if necessary, the metal fittings and the core shall be cut perpendicular to the crack in the middle of the widest of the indicated cracks, into two halves. The surface of the two halves shall then be investigated to measure the depth of the cracks.

- c) The three remaining specimens are then again subjected to a tensile load applied between the couplings at ambient temperature. ~~The tensile load shall be increased rapidly but smoothly from zero to approximately 75 % of the SMS and then gradually increased in a time between 30 s to 90 s to the SMS. If 100 % of the SML is reached in less than 90 s, the load (100 % of SML) shall be maintained for the remainder of the 90 s (this test is considered to be equivalent to a 1 min 100 % withstand test at SML).~~ The tensile load shall be increased rapidly but smoothly from zero to approximately 75 % of the SML and then gradually increased in a time between 30 s to 90 s to the SML and then maintained at 100 % of the SML for 60 s. Examples for load-time curves as shown in Figure 2.

In order to obtain more information from the test, unless special reasons apply (for instance the maximum tensile load of the test machine), the load may be increased until the failing load is reached and its value recorded.

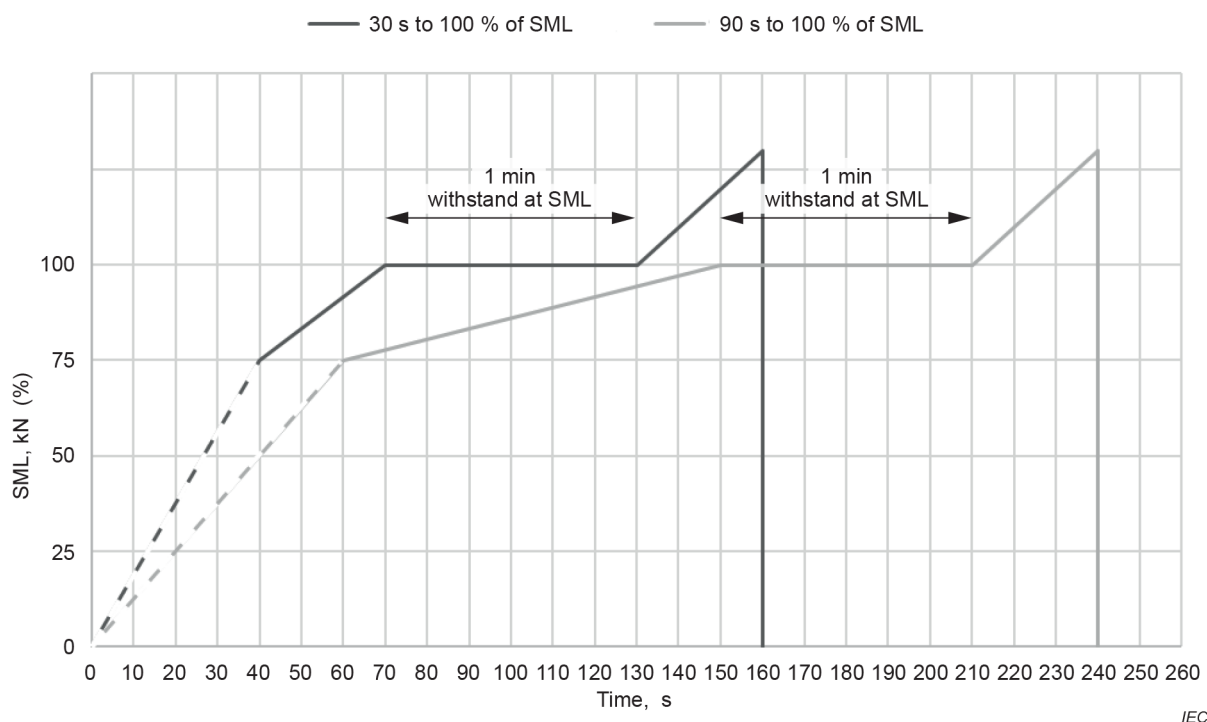


Figure 2 – Examples for 1 min SML withstand test

10.3.3 Evaluation of the test

The test is passed if:

- no failure (breakage, slip of end fitting, or complete pull-out of the core, or fracture of the metal fitting) occurs either during the 96 h test at 70 % of the (SML 10.3.2 a)) and during the 1 min 100 % withstand test at SML (10.3.2 c)),
- ~~– no cracks are indicated by the dye penetration method described in 11.2.2 b),~~
- ~~– the investigation of the halves described in 11.2.2 b) shows clearly that the cracks do not reach the core.~~
- if cracks are indicated by the dye penetration method (10.3.2 b)), the investigation of the halves described in 10.3.2 b) shows clearly that the cracks do not reach the core.

NOTE For non-overmoulded designs, the positions of the fittings can be marked on the housing before the test.

11 Sample tests

11.1 General rules

For the sample tests, two samples are used, E1 and E2. The sizes of these samples are indicated in Table 5. If more than 10 000 insulators are concerned, they shall be divided into an optimum number of lots comprising between 2 000 and 10 000 insulators. The results of the tests shall be evaluated separately for each lot.

The insulators shall be selected from the lot at random. The purchaser has the right to make the selection. The samples shall be subjected to the applicable sampling tests.

The sample tests are as follows:

- | | |
|---|-----------|
| a) verification of dimensions | (E1 + E2) |
| b) verification of the ~~locking system~~ end fittings | (E2) |
| c) verification of the tightness of
the interface between end fittings and insulator housing | (E2) |
| d) verification of the specified mechanical load, SML | (E1) |
| e) galvanizing test | (E2) |
| f) minimum sheath thickness..... | (E1) |

In the event of a failure of the sample to satisfy a test, the re-testing procedure shall be applied as specified in 11.7.

~~Insulators of sample E2 only can be used in service and only if the galvanizing test is performed with the magnetic method.~~

Weak adhesion between core and housing can lead to moisture ingress and a failure of the composite insulator in service. For an evaluation of the adhesion between core and housing additional sample tests defined in Annex F as methods A (only pull-off test performed by tensile machine or manual load cell), B and C can be performed by agreement between purchaser and manufacturer.

Table 5 – Sample sizes

Lot size	Sample size	
	E1 destructive	E2 non-destructive
N	Subject of agreement	
$N \leq 300$		
$10 < N \leq 30$	2	1
$30 \leq N \leq 300$	3	2
$300 < N \leq 2\,000$	4	3
$2\,000 < N \leq 5\,000$	8	4
$5\,000 < N \leq 10\,000$	12	6
Insulators of sample E2 only can be used in service and only if the galvanizing test is performed with the magnetic method. The dye penetration test shall rule out later use of these samples for visual reasons.		

11.2 Verification of dimensions (E1 + E2)

The dimensions given in the drawings shall be verified. The tolerances given in the drawings are valid. If no tolerances are given in the drawings the values mentioned in Clause 7 shall be used.

11.3 Verification of the end fittings (E2)

The dimensions and gauges for end fittings are given in IEC 61466-1. The appropriate verification shall be made for the types of fitting used including, if applicable, verification of the locking system in accordance with IEC 60383-1.

11.4 Verification of tightness of the interface between end fittings and insulator housing (E2) and of the specified mechanical load, SML (E1)

- a) One insulator, selected randomly from the sample E2, shall be subjected to crack indication by dye penetration, in accordance with ISO 3452, on the housing in the zone embracing the complete length of the interface between the housing and metal fitting and including an additional area, sufficiently extended, beyond the end of the metal part.

The indication shall be performed in the following way:

- the surface shall be properly pre-cleaned with the cleaner;
- the penetrant, which shall act during 20 min, shall be applied on the cleaned surface;
- within 5 min after the application of the penetrant, the insulator shall be subjected, at the ambient temperature, to a tensile load of 70 % of the SML, applied between the metal fittings; the tensile load shall be increased rapidly but smoothly from zero up to 70 % of the SML, and then maintained at this value for 1 min;
- the surface shall be cleaned with the excess penetrant removed, and dried;
- the developer shall be applied, if necessary;
- the surface shall be inspected.

Some housing materials may be penetrated by the penetrant. In such cases, evidence shall be provided to validate the interpretation of the results.

After the 1 min test at 70 % of the SML, if any cracks occur, the housing and, if necessary, the metal fittings and the core shall be cut perpendicular to the crack in the middle of the widest of the indicated cracks, into two halves. The surface of the two halves shall then be investigated to measure the depth of the cracks.

- b) The insulators of the sample E1 shall be subjected to a tensile load applied between the couplings at ambient temperature. The tensile load shall be increased rapidly but smoothly

from zero to approximately 75 % of the SML and then gradually increased in a time between 30 s to 90 s to the SML and then maintained at 100 % of the SML for 60 s.

~~If 100 % of the SML is reached in less than 90 s, the load (100 % of the SML) shall be maintained for the remainder of the 90 s (this test is considered to be equivalent to a 1 min withstand test at the SML).~~

In order to obtain more information from the test, unless special reasons apply (for instance the maximum tensile load of the test machine), the load may be increased until the failing load is reached, and its value recorded. Examples for load-time curves are shown in Figure 2.

The insulators have passed this test if:

- no failure (breakage or complete pull-out of the core, or fracture of the metal fitting) occurs either during the 1 min 70 % withstand test (a) or during the 1 min 100 % withstand test (b),
- no cracks are indicated after the dye penetration method described in 11.4 a),
- the investigation of the halves described in 11.4 a) shows clearly that the cracks do not reach the core.

NOTE In case of agreement between the client and manufacturer the verification of tightness in a) could be done on the E1 samples. The specified mechanical load test in b) can be done on the same sample.

11.5 Galvanizing test (E2)

This test shall be performed on all galvanized parts in accordance with IEC 60383-1.

11.6 Minimum sheath thickness (E1)

The layer thickness shall be measured on 4 positions offset by 90°. A criterion is minimum sheath thickness of 3 mm in any of test positions.

For the insulators with section length more than 1 meter, it is recommended to use at least three positions for measurement, cut from the top, middle and bottom sections, (in total 12 measurements) see example in Figure 3.

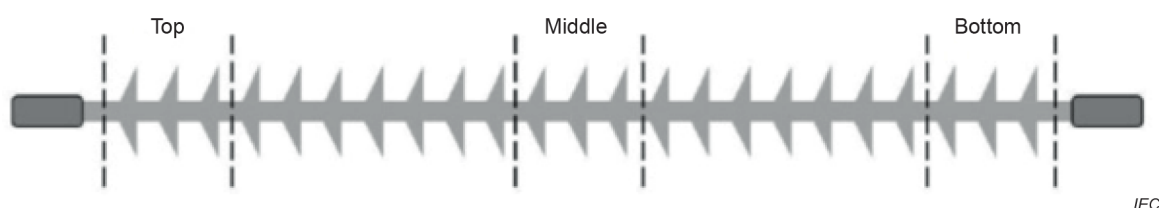


Figure 3 – Location for minimum sheath thickness measurement

NOTE Non-destructive test methods like an ultra-sonic tester can also be used for measuring minimum sheath thickness.

11.7 Re-testing procedure

~~If only one insulator or end fitting fails to comply with the sampling tests, re-testing shall be performed using a new sample size equal to twice the quantity originally submitted to the tests.~~

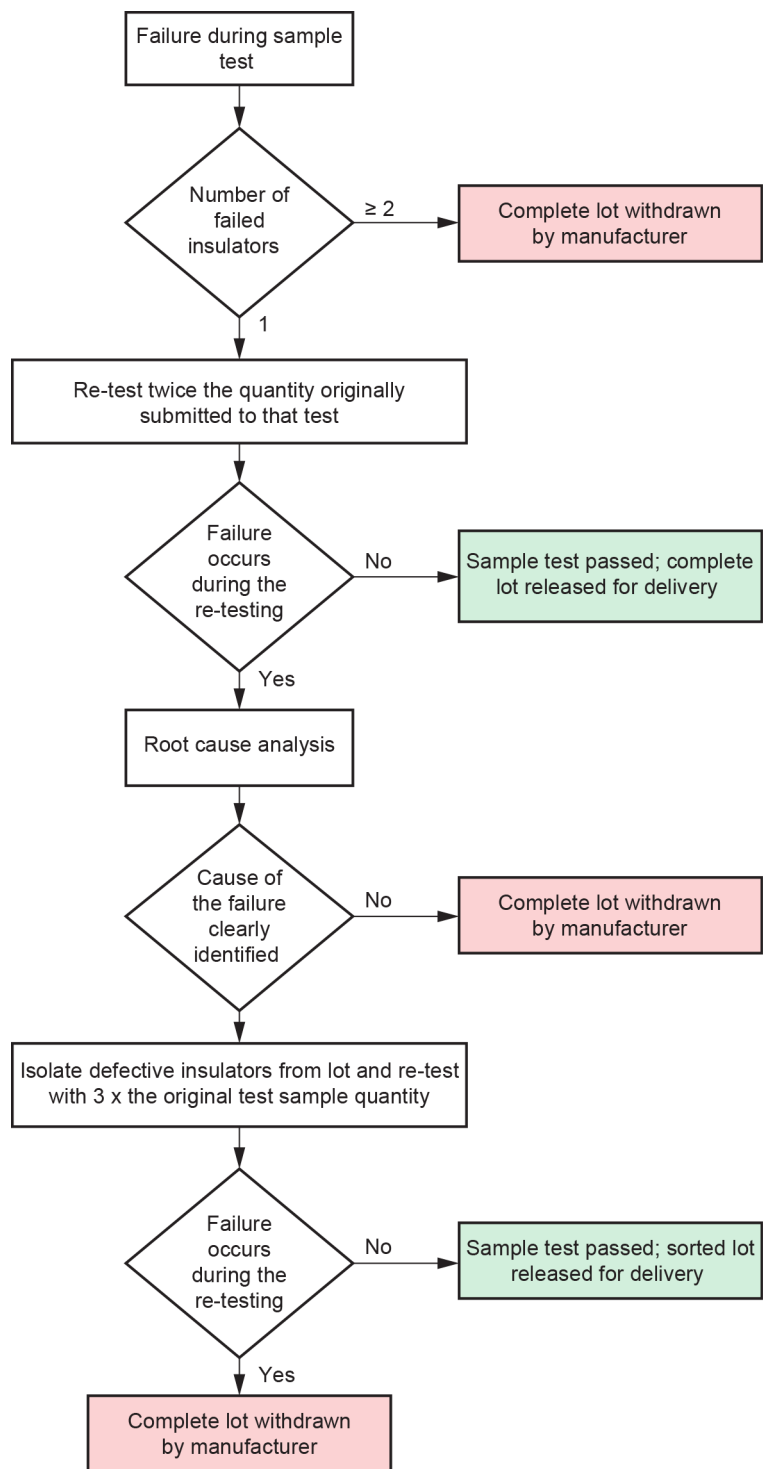
~~The re-testing shall comprise the test in which failure occurred.~~

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 ~~standard~~ part of the testing and shall be withdrawn by the manufacturer.

Provided the cause of the failure in the increased sample size can be clearly identified to the satisfaction of the purchaser and there is no risk that it can pass the repeated sample tests undetected, 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 ~~standard~~ part of the testing and shall be withdrawn by the manufacturer.

The flow-chart of re-testing procedure is shown in Figure 4.



IEC

Figure 4 – Method of re-testing at different stages

12 Routine tests

12.1 Mechanical routine test

Every insulator shall withstand, at ambient temperature, a tensile load at RTL corresponding to $0,5 \times \text{SML} \left(\begin{smallmatrix} +10\% \\ 0 \end{smallmatrix} \right)$ for at least 10 s.

12.2 Visual examination

Each insulator shall be examined. The mounting of the end fittings on the insulating parts shall be in accordance with the drawings. The color of the insulator shall be approximately as specified in the drawings. The markings shall be in conformance with the requirements of this document (see Clause 4).

The following defects are not permitted:

- a) superficial defects of an area greater than 25 mm² (the total defective area not to exceed 0,2 % of the total insulator surface) or of depth greater than 1 mm;
- b) cracks at the root of the shed, notably next to the metal fittings;
- c) separation or lack of bonding at the housing to metal fitting joint ~~(if applicable)~~ for overmoulded design;
- d) separation or bonding defects at the shed to sheath interface,
- e) moulding flashes protruding more than 1 mm above the housing surface.

Annex A (informative)

Principles of the damage limit, load coordination and testing for composite suspension and tension insulators

A.1 Introductory remark

This Annex A is intended to explain the long-term behaviour of composite suspension and tension insulators under mechanical load, to show typical coordination between SML and service loads and to explain the mechanical testing philosophy.

A.2 Load-time behaviour and the damage limit

An essential part of the mechanical behaviour of resin bonded fibre cores, typically used for composite insulators, is their load-time behaviour, which deserves some explanation.

The vast experience gained with composite insulators loaded with tension loads, both in the laboratory and confirmed in service, has shown that the load-time curve is indeed a curve, and not a straight line as was presented in the first version of IEC 61109. This straight line had often been misinterpreted, leading to the deduction that a composite insulator would only retain a small fraction of its original mechanical strength after a period of 50 years, whatever the applied load.

It is now known that the time to failure of composite insulators under static tensile loads follows a curve such as that presented in Figure A.1. To take into account the dispersion in the tensile characteristic of the insulator, the withstand curve is positioned, as shown in Figure A.1, below the failure curve. Being asymptotic, it shows that for a given insulator, there is a load below which the insulator will not fail no matter how long the load is applied since there is no damage to the core. This load level is known as the damage limit. Typically, the damage limit lays around 60 % to 70 % of the ultimate strength of the core when assembled with fittings. The damage limit represents the load value which causes inception of microscopic mechanical damage within the core material.

The damage limit depends on the kind of core material, on the type of end fitting and on the design of the connection zone. Despite the fact that the damage limit is primarily defined as core property, the type of end fitting and the design of the connection zone (e.g. the internal shape of the end fitting) can have a significant influence to the mechanical insulator performance.

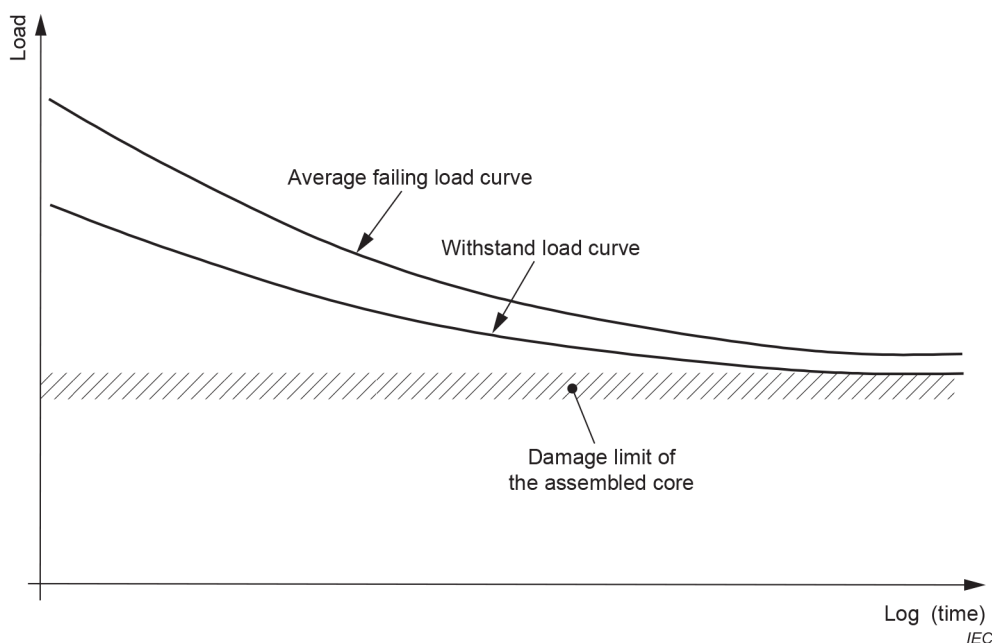


Figure A.1 – Load-time strength and damage limit of a core assembled with fittings

A.3 Service load coordination

For both short- and long-term mechanical loading of the entire composite insulator, the mechanical properties of the individual end fitting types also have to be considered. The maximum admissible working load value for the metal end fittings is limited by the elastic limit of the metal material and the design (mechanically stressed cross-section) of the weakest end fitting part. The maximum admissible load for the entire insulator is therefore given either by the elastic limit of the end fittings or by the damage limit of the assembled core (under normal environmental conditions as given in ~~IEC 62247~~ Table 1).

Figure A.2 shows a graphical representation of the typical relationship of the damage limit to the mechanical characteristics of an insulator with a 16 mm diameter core for typical service loads.

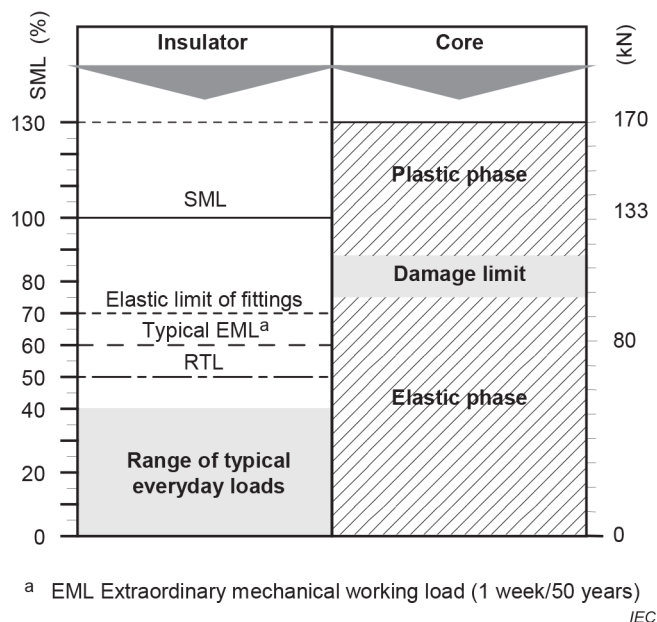


Figure A.2 – Graphical representation of the relationship of the damage limit to the mechanical characteristics and service loads of an insulator with a 16 mm diameter core and an SML rating of 133 kN

In all cases, the maximum working load (static and dynamic) shall be below the damage limit of the insulator. It is normal practice to adopt a safety factor of at least 2 between the SML and the maximum working load; this generally ensures that there is also a sufficient margin between the damage limit of the insulator and all service loads. IEC 60826 [11] gives guidance for calculation of loads and application of proper safety factors.

Further examples of tensile load coordination based on Figure A.2 used by utilities are shown in Figure A.3 and Figure A.4:

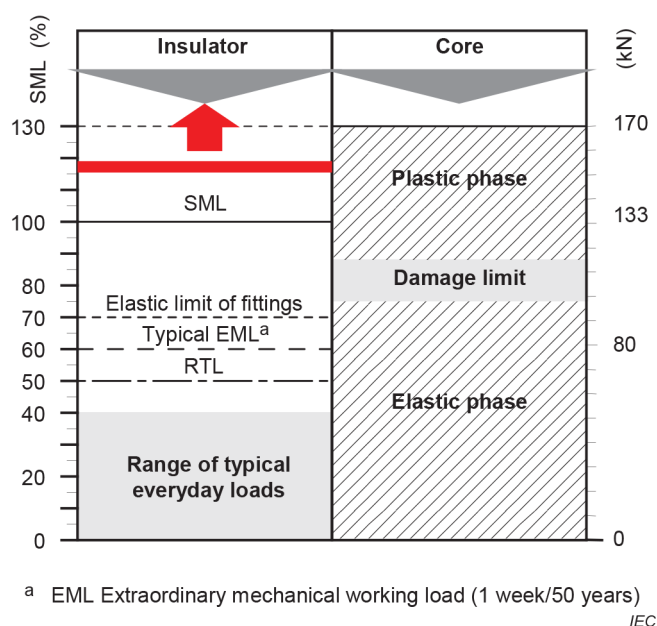


Figure A.3 – Applied specific force relationship, example 1

All individual failing load values e. g. $1,15$ or $1,2 \times$ SML-value or a fixed value for identical ultimate failing modes (e.g. end fitting slip-off). This approach takes care of the statistical variation of the failing load values of an insulator batch manufactured with a defined family of raw materials.

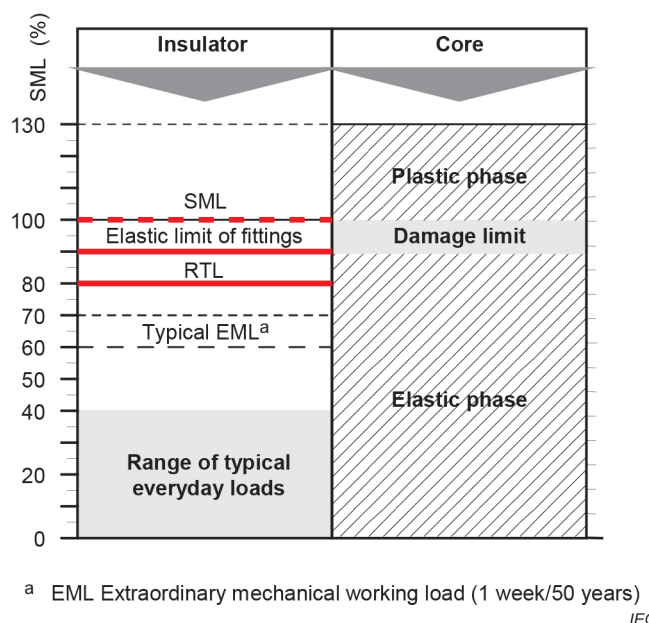


Figure A.4 – Applied specific force relationship, example 2

Example is taken from the test requirements of porcelain long rod insulator history. The difference to the other test scenarios shown in Figure A.2 and Figure A.3 is that the RTL value is 80 % of the SML value. This higher load in comparison to the standard requirement of 50 % has an impact to the dimensioning of the core and the end fittings. In the example, the elastic limit of fittings raises from 70 % to 90 % and the damage limit of the core from 80 % to 90 %.

A.4 Verification tests

Two tests are ~~prescribed~~ specified in this document to check mechanical strength and damage limit:

- a design test "96 h withstand load test" (load/time pairs D1 and D2 in Figure A.5) to check the position of the strength/time curve of the insulator (see 9.4.2);
- a type test "damage limit proof test" (load/time pairs T1 and T2 in Figure A.5) to check the damage limit after loading with a constant load of 0,7 SML for 96 h (see 10.3).

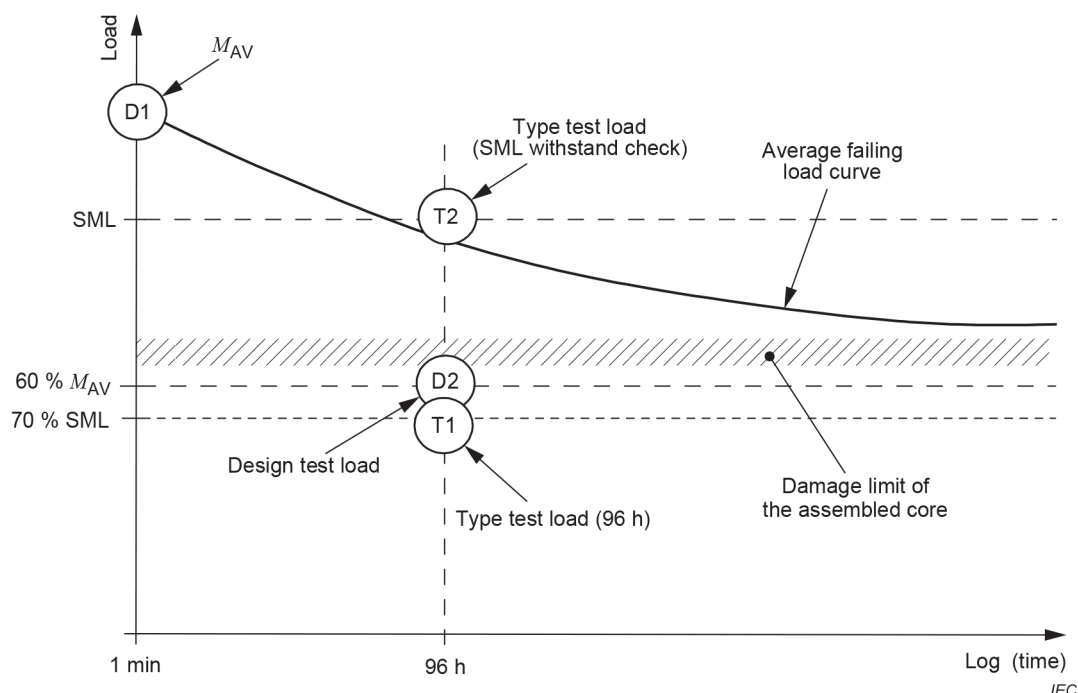


Figure A.5 – Test loads

The design test verifies the starting point of the actual initial load time curve by using M_{AV} (average failing load of the assembled core) and the minimum position of the damage limit by a withstand test for 96 h at $0,6 M_{AV}$.

The choice of the SML with respect to M_{AV} is made by the manufacturer as a function of statistical data, design and process. There is no simple rule governing this relation. In order to check the coherence of the chosen SML with respect to the damage limit of the assembled insulator, the type test requires the insulator to withstand 70 % of the SML during 96 h followed by the SML for one minute. If the strength coordination is correct, then the insulator will not suffer any damage during the 96 h and will still be able to withstand the SML.

NOTE In some cases, depending on the chosen SML level, it is possible for the 96 h load for the type test to be higher than the 96 h load for the design test. This does not preclude the need for the design test.

Annex B (informative)

Example of two possible devices for sudden release of load

B.1 Device 1 (Figure B.1)

The device consists of a hook A, a release lever B and a mounting plate C. Hook A can rotate on its pivot which is attached to the mounting plate. Tension is applied to the insulator by means of a suitable bolt or shackle, D.

During the time the insulator is under load, the release lever is retained in the position shown by the unbroken lines. Due to the length of the release lever B, a small force is sufficient to move it to the position shown by a broken line, rotating it on its pivot and moving the pivot in the direction X.

This operation of the release lever causes the hook to rotate on its pivot, hence releasing the bolt or shackle, D.

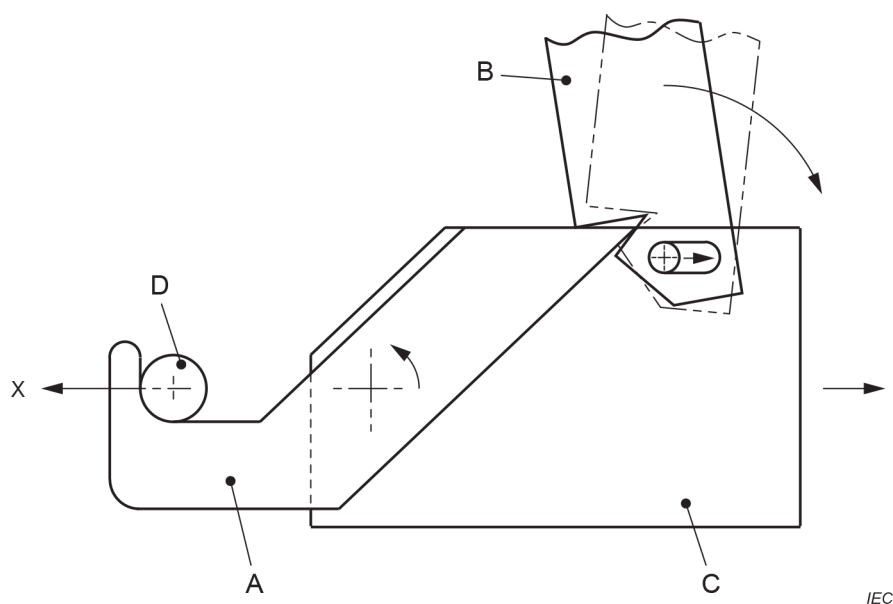


Figure B.1 – Example of possible device 1 for sudden release of load

B.2 Device 2 (Figure B.2)

The device consists of a breakage piece E screwed into two metallic extremities F and G which link the insulator to the tensile machine.

The breakage piece E is in the form of a dumb bell whose diameter is calibrated as a function of the steel used and of the desired breaking load.

The steel utilized for the piece E shall have a yield stress close to the ultimate tensile stress.

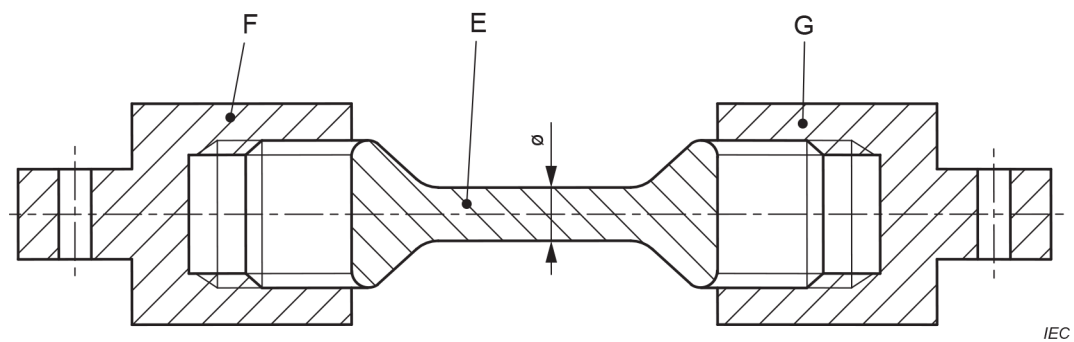


Figure B.2 – Example of possible device 2 for sudden release of load

Annex C (informative)

Guidance on non-standard mechanical stresses and dynamic mechanical loading of composite ~~tension/suspension~~ insulators

C.1 Introductory remark

This Annex C provides guidance on service conditions where non-standard mechanical loads are introduced to the composite suspension/tension insulator. Examples of such non-standard mechanical loads are torsion, compression (buckling) and bending stress loads. Reference is made, based on insulator field experience to date, on the expected mechanical performance of composite insulators subjected to in-service dynamic mechanical loads.

Composite ~~suspension/tension~~ insulators are primarily designed to operate under mechanical tensile loads/stresses. However, in certain operations/applications, additional non-standard loads can be applied to the insulator. Avoidance of subjecting ~~tension/suspension~~ these insulators to non-standard loads should be made where possible. Guidance on minimizing the introduction of such load conditions is given in the CIGRE Composite Insulator Handling Guide [7].

C.2 Torsion loads

In line stringing operations, if twisting of the conductor bundle occurs and it is attempted to be corrected by rotation of the composite insulator, then a torsion stress can be introduced to the composite insulator. Furthermore, the probability of damage to the insulator is increased if a single strain insulator is used to support a twin conductor bundle. In such cases, the use of two insulators, either with or without inter-connecting yoke plates, is preferred. The introduction of torsion stresses should be avoided as much as possible during conductor stringing. Subjecting the insulators to excess torsion loads can lead to a reduction in the mechanical integrity of the composite insulator.

SToL (Specified Torsion load)	torsion load level which can be withstood by the insulator when tested under the specified conditions. [IEC 62231]
MDToL (maximum design Torsion load)	torsion load level above which damage to the insulator begins to occur and that should not be exceeded in service. [IEC 62231]

C.3 Compressive (buckling) loads

Special conditions arise in the case of insulator V-string applications shown in Figure C.1 where the ~~suspension~~ insulator may be subjected to compressive loads (if the wind load is greater than the mass supported, then the leeward insulator carries no load, and the unit goes into compression). As a result of critical buckling loads being introduced to the insulator, significant damage may occur. The same can occur when composite insulators are used as interphase-spacers shown in Figure C.2.

SCoL (Specified compression load)	compression load which can be withstood by the insulator when tested under the specified conditions. [IEC 62231]
MDCoL (maximum design compression load)	load level above which damage to the insulator begins to occur and that shall not be exceeded in service. [IEC 62231]

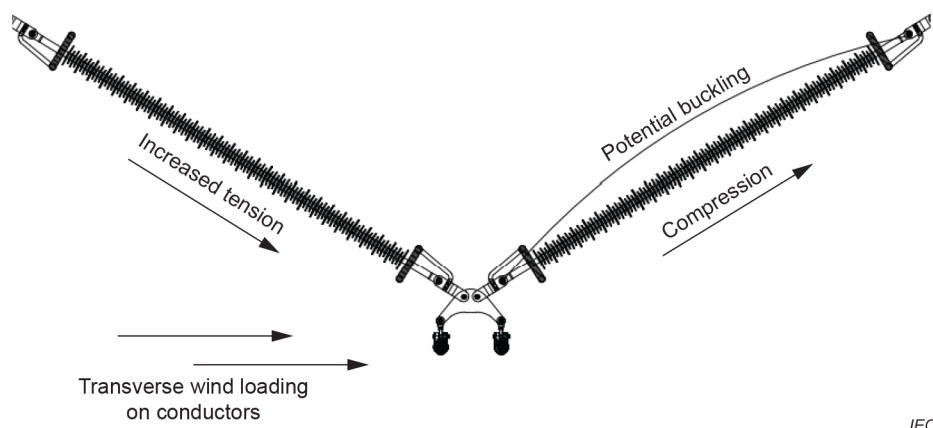


Figure C.1 – Example of compression loads in V-string assemblies

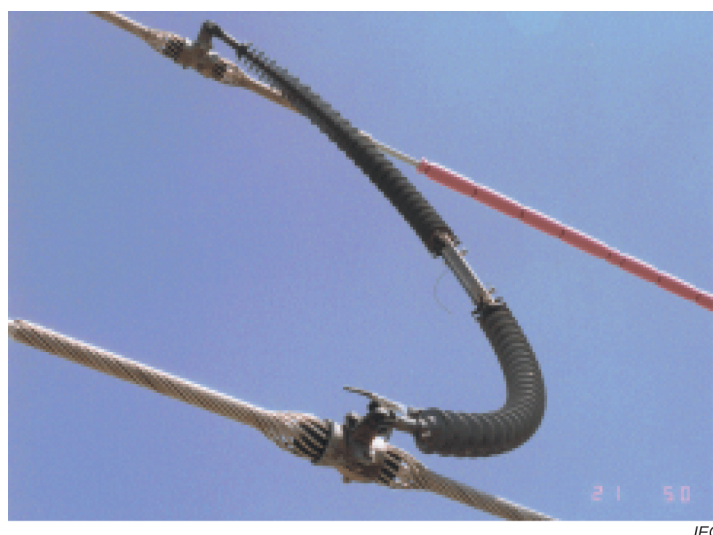


Figure C.2 – Buckling of composite insulator in a phase-to-phase configuration

C.4 Bending loads

~~Long red~~ Composite insulators may be subjected to critical bending loads during stringing operations. The introduction of such bending stresses should be avoided as much as possible. Subjecting the insulator to critical bending stresses can cause large deflection of the insulator, which can cause damage and loss of mechanical integrity of the insulator.

C.5 Dynamic mechanical loads

~~Service experience to date indicates that dynamic loads are unlikely to be of amplitude or duration to be detrimental to the mechanical performance of composite suspension/tension insulators.~~

To increase the reliability of high-voltage lines, insulator sets with multiple parallel insulators can be used. If one insulator string fails, the resulting load transposition can cause high dynamic tensile and transversal forces. Especially in the case of double insulator suspension or tension sets, bending stress might occur in the remaining intact string, which shall withstand the loads (which includes the hardware as well). This situation has been systematically investigated for porcelain long rod insulators [12]. Composite insulators are typically of longrod type but do not show the brittleness of porcelain. Thus, the failure of an insulator string due to mechanical

mishandling is less likely. However, the insulators shall be designed to withstand a load transposition situation. The dynamic loads can exceed typical EML loads.

These dynamic loads can be determined by simulation or testing. If testing is performed, insulators set completely assembled with all hardware components shall be evaluated.

C.6 Limits

It is difficult to give general limiting values for non-standard stresses due to the varied designs and materials used for composite ~~suspension~~ insulators. The intrinsic maximum stress for common core materials, before damage occurs, is of the order of 400 MPa in bending and 60 MPa in torsion – where the strength of the end fitting assembly onto the rod also comes into play. However, the often-large displacements caused by non-standard loads can induce stress in the housing materials and their interfaces with the core or fittings, leading to their damage.

For example, at a stress of 400 MPa, a 2 m long insulator with a 16 mm diameter core would have a deflection of 1,8 m. For this reason, it is recommended that the purchaser bring to the attention of the manufacturer, whenever possible, any anticipated non-standard loads or displacements to determine if they are critical for the product. In this way, working loads/displacements, the need for a test, the test procedure and the test loads/displacements can then be determined by agreement.

Annex D (informative)

Electric field control for AC

Composite insulators were first used with success in polluted areas and thereafter also in relatively clean environments mainly due to simplicity of handling, aesthetic, and compaction advantages. The hydrophobicity and hydrophobicity transfer properties are the key parameters for the application of composite insulators in polluted condition. However, the excellent hydrophobic properties of composite insulators when new might be deteriorated in service. Discontinuous corona activity on the housing material itself (the so-called water drop corona) or continuous corona from the metal end fittings can lead to the reduction of hydrophobicity.

The occurrence of corona discharges may be one of the specific ageing mechanisms for composite insulator, which should be considered already at the design stage, i.e. electric field should be controlled in the discharge-prone areas or sensitive areas of an insulator. Due to relatively small dimensions of insulation end fittings for line composite insulators, this issue is of significant importance for these types of insulators, which is also confirmed by service experience. Even insulators with good design and manufactured with high quality should be equipped by appropriately selected grading/corona ring(s), one or two per insulator in the region of the highest electric field stresses depending on voltage class.

For a proper field grading, especially in the region of the metal end fittings of the insulator, the sealing concept shall also be considered. Two principle sealing configurations can be found (see Annex E). In Figure E.1, the sealant is formed of one or more layers which are made of a different, usually less tracking and erosion resistant material as the remaining housing. In Figure E.2, the end fitting is embedded partially by the housing material. Another term that is referred to when it comes to electric field grading is the so-called triple point. It forms the position where metallic end fitting, insulation material (sealant or housing) and the surrounding atmosphere do meet. In the case of hydrophobicity loss, the leakage surface current and surface discharge activity at the housing may start and end at this point.

Due to electro hydrodynamic phenomena, the inception field stress at water drops depends on the direction of the electric field. Electric field investigations have shown that water drop corona occurs at lower electric field stresses by a factor of 2 to 3 for tangential field stress compared to the normal field stress. Therefore, to prevent the ignition of water drop corona at the insulator surface, including the sealing area, the calculation of the electric field distribution, separated in tangential and normal field stresses at the insulator surface, is a holistic approach.

Typically, the electric field stress at the insulator surfaces is predominantly of tangential character at the trunk surface and of normal character on shed surfaces, while both components can occur in different ratios at the sealing area, depending on the geometry, see Annex E. A commonly simplified approach is the evaluation along the trunk area by considering tangential electric field stress only. Nonetheless, the sensitive sealing area shall be evaluated separately in terms of tangential and normal field stress shown in Figure D.1.

To prevent the phenomenon of corona on string elements and water drop corona, different thresholds were introduced and are recommended for electric field grading of composite line insulators:

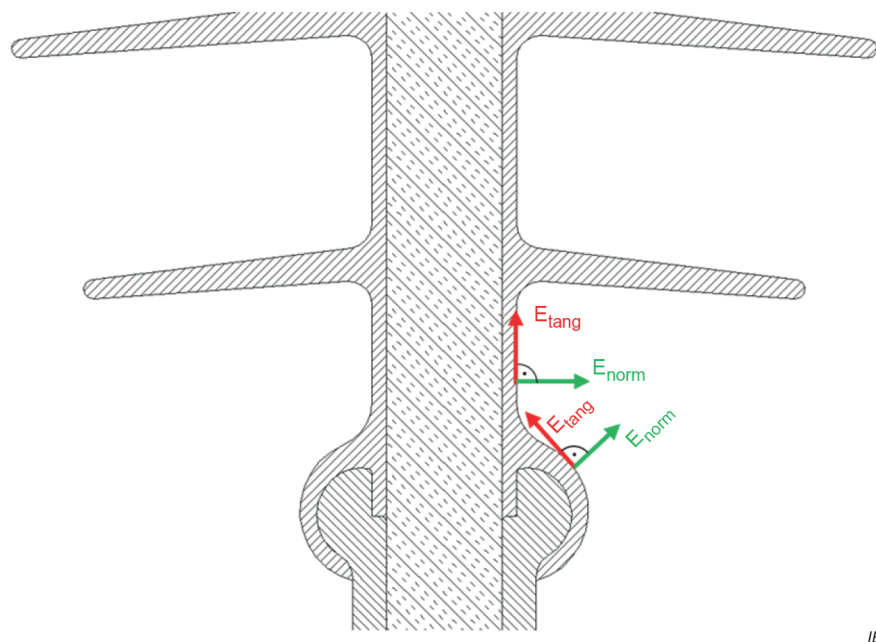
- 1) electric field on the grading/corona ring and end fitting, proven by test and simulation [13][14][15]; a criterion for maximum allowable field stresses is recommended with $E_{\max} < 18 \text{ kV/cm}$;
- 2) electric field along the housing trunk surface, proven by test and simulation [13][14][15] and, including the sealing area for an overmoulded insulator design (see Figure E.2); a criterion for maximum allowable tangential field stresses is recommended with $E_{\max}^{\text{tangential}} < 4,2 \text{ kV/cm}$ averaged for 10 mm;

- 3) electric field at the sealant, see Figure E.1. If the sealant is exposed to the environment, an additional criterion for limitation of the normal electric field stress with $E_{\max}$ at the surface of the sealant needs to be considered to respect the usually less tracking and erosion resistance of such materials. Currently, no criterion is specified yet but an indication from investigations at water drops on model arrangements with $E_{\max}^{\text{normal}} < 8 \text{ kV/cm}$ can be given.

These limitations are included in CIGRE TB 919 [9] prepared by B2.57 and are under consideration of B2.80. Since the applied voltage level at the energized components is typically taken as maximum system operating phase-to-earth-voltage and an RMS value, the calculated electric field stress is considered as maximal electric field stress as an RMS value as well.

The first limitation can be verified by a standard RIV test described in IEC 60437 and IEC 61284.

A verification of a water drop corona free string design can be proven by the Water Drop Induced Corona (WDIC) test [15][16][17][18].



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Figure D.1 – Example for electrical field vectors on a composite insulator

Annex E
(informative)

Typical sketches for composite insulator assemblies

Figure E.1 and Figure E.2 show two typical composite insulator assemblies, a modular design with non-overmoulded end fitting and a moulded assembly with overmoulded end fitting.

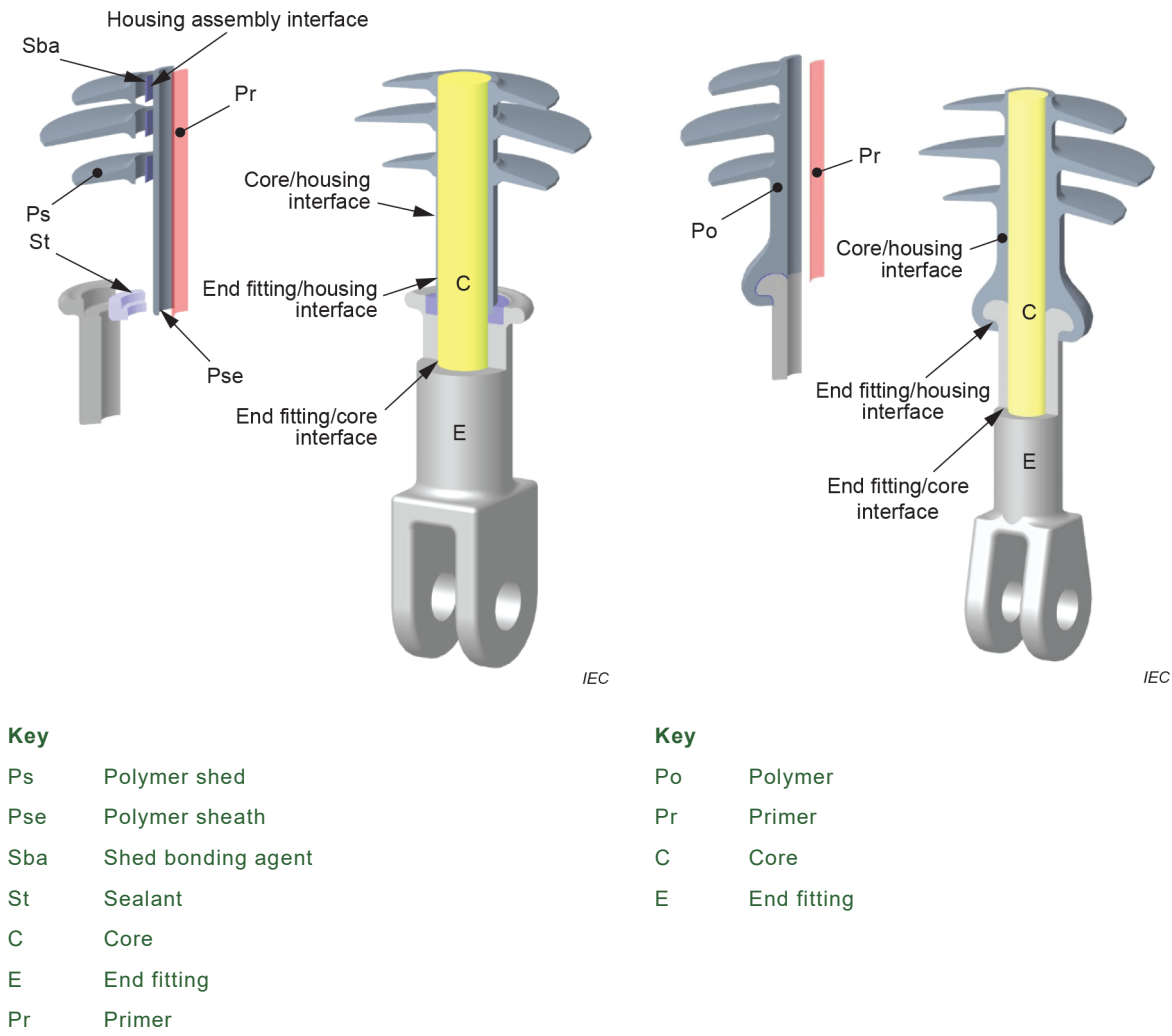


Figure E.1 – Interface description for insulator with housing made by modular assembly and external sealant

Figure E.2 – Interface description for insulator with housing made by injection molding and overmoulded end fitting

Annex F (informative)

Mechanical evaluation of the adhesion between core and housing

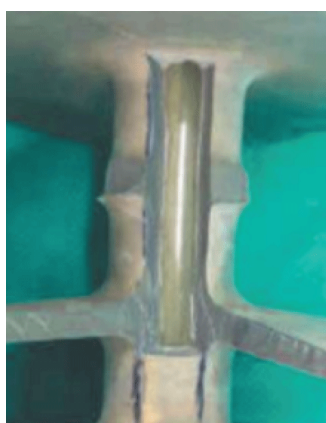
F.1 General

Mechanical adhesion tests are frequently used to evaluate the adhesion between core and housing of composite insulators but are not yet formally standardized. Therefore, this Annex is intended to guide through the available mechanical adhesion tests. Several mechanical, destructive testing methods have been developed and are intended for a qualitative and quantitative evaluation of the adhesion between core and housing. As a common principle of such tests, the housing material is sectioned into specific areas by cuts at defined positions onto the core and a mechanical force is applied to remove the housing from the core. In these tests, the separation of the housing from the core can occur either cohesive with fracture of the housing without any exposure of the core, adhesive with a complete removal of the housing material from the core or mixed type of separation all shown in Figure F.1.



IEC

a) Cohesive separation



IEC

b) Adhesive separation



IEC

c) Mixed separation

Figure F.1 – Example for type of housing separation

In the following, two different types of adhesion tests including acceptance criteria are presented:

- 1) Application of a defined tensile stress and force measurement with a qualitative and quantitative evaluation of the adhesion (pull-off test and peel test).

Acceptance criterion: average breaking stress for all 4 measurements (see F.2.3) per shed $> 1,5 \text{ N/mm}^2$. The type of housing separation shall be documented and serves as additional, qualitative information.

- 2) Application of a manual shear stress with a qualitative, visual evaluation of the adhesion (shear test).

Acceptance criterion: Cohesive housing separation only.

If the adhesion test is to be conducted as a sample test, test samples from E1 according to Table 5 shall be used before performing the minimum sheath thickness test.

F.2 Method A: Pull-off test

F.2.1 General

With the pull-off test, the adhesion between the composite insulator housing and core can be qualitatively and quantitatively evaluated at the section with a shed.

F.2.2 Specimens

Specimens with housing and one shed are cut perpendicular to the axis of the insulator with a diamond-coated circular saw blade under running cold water. At least three specimens with one shed per sample, cut from the top, middle and bottom sections shall be used. The length of the specimens shall be the same as for the water diffusion test according to IEC 62217. The same specimen is used first for the 100 h water diffusion test and then additionally prepared for the pull-off test.

A specimen for the pull-off test is prepared after completion of the water diffusion test from the shed by two parallel cuts through the shed and sheath material onto the core along the axis of the insulator. The distance between the two parallel cuts shall be 8 ± 3 mm, projected to the core surface. Thereafter, two further parallel cuts, perpendicular to the insulator axis with a distance of 15 ± 5 mm, projected to the core surface, shall be made above and below the shed.

F.2.3 Procedure

The entire test consists of the following steps:

- 1) Pre-stressing by boiling for 100 h as per IEC 62217
- 2) Water diffusion test according to IEC 62217
- 3) Pull-off test

The pull-off test shall be performed at 4 locations per shed (separated radially by 90°), for each of the 3 specimens taken at top, middle and bottom section of the insulator.

The specimen is then mounted in a tensile test machine as shown in Figure F.2.