IEC 61109

Edition 3.0 2025-02
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

IEC 61109:2025-02 CMV(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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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 B2.03[1] 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

[1] 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.

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 – 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/m^2.

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

± (0,04 × d + 1,5) mm when $d \leq 300$ mm,

± (0,025 × d + 6) mm when $d > 300$ mm with a maximum tolerance of ± 50 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	
		62217	61109	62217 Tests on housing material				62217 Tests on the core material		61109	
		Interfaces 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[c]	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[c]	X	X	X	X				X[c]
8	Housing assembly process	X	X[c]			X					X[c]
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[c]			X					X[c]
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) 7	X b), c)			X b) 8			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 °C to –25 °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 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 ± 5) °C, the other at (–35 ± 5) °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.

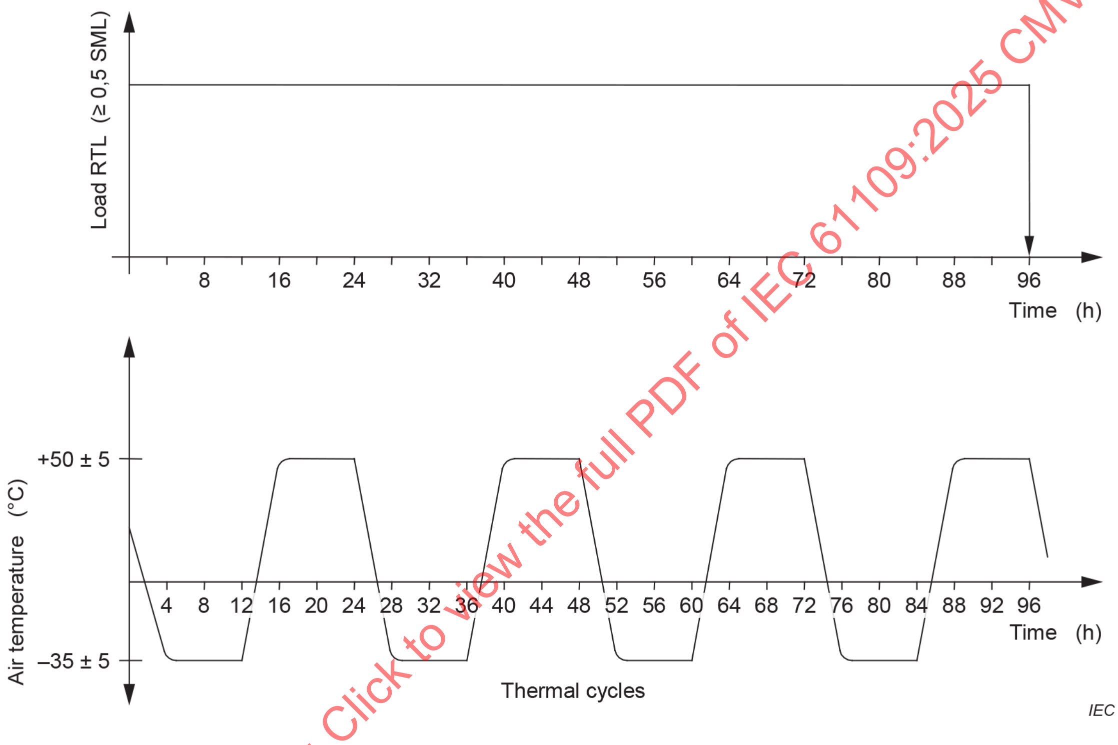


Figure 1 – Thermal-mechanical pre-stressing

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

a) 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.

b) 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.

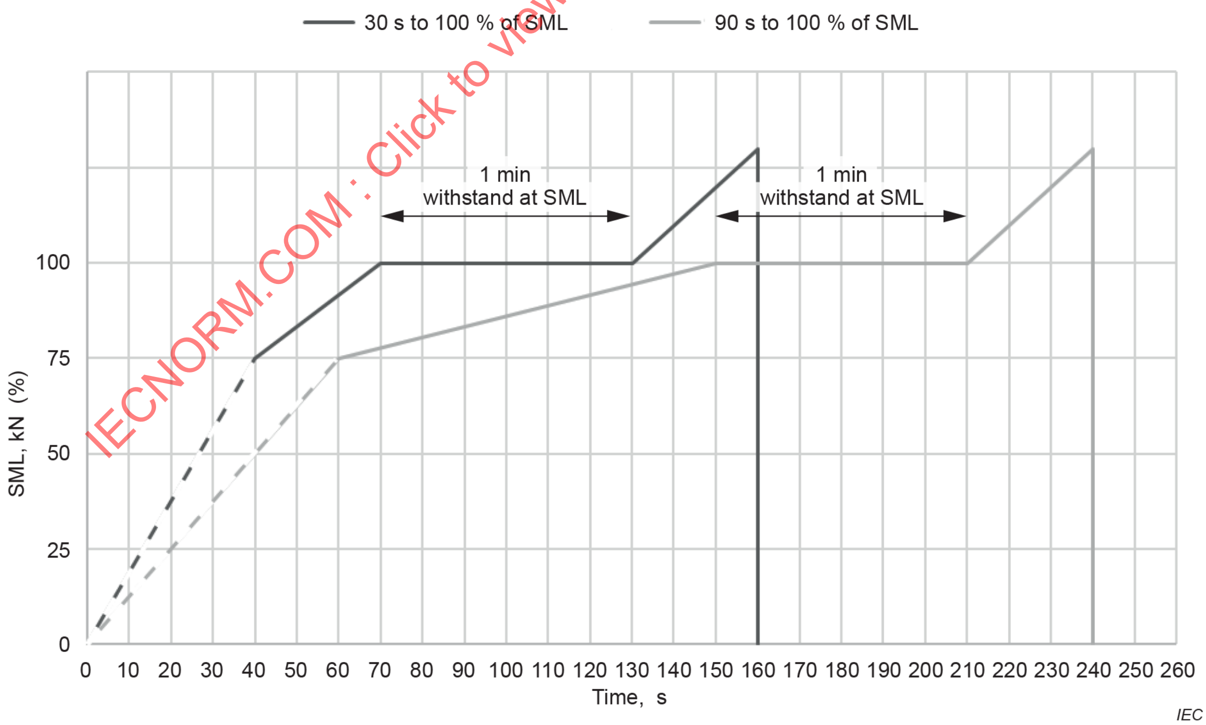


Figure 2 – Examples for 1 min SML withstand test

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	
N	E1 destructive	E2 non-destructive
N ≤ ~~300~~ 10	Subject of agreement	
10 < N ≤ 30	2	1
30 ≤ N 300	3	2
300 < N ≤ 2 000	4	3
2 000 < N ≤ 5 000	8	4
5 000 < N ≤ 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.

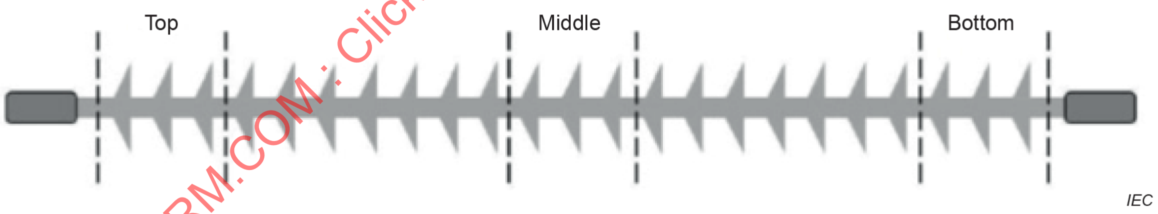


Figure 3 – Location for minimum sheath thickness measurement

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.

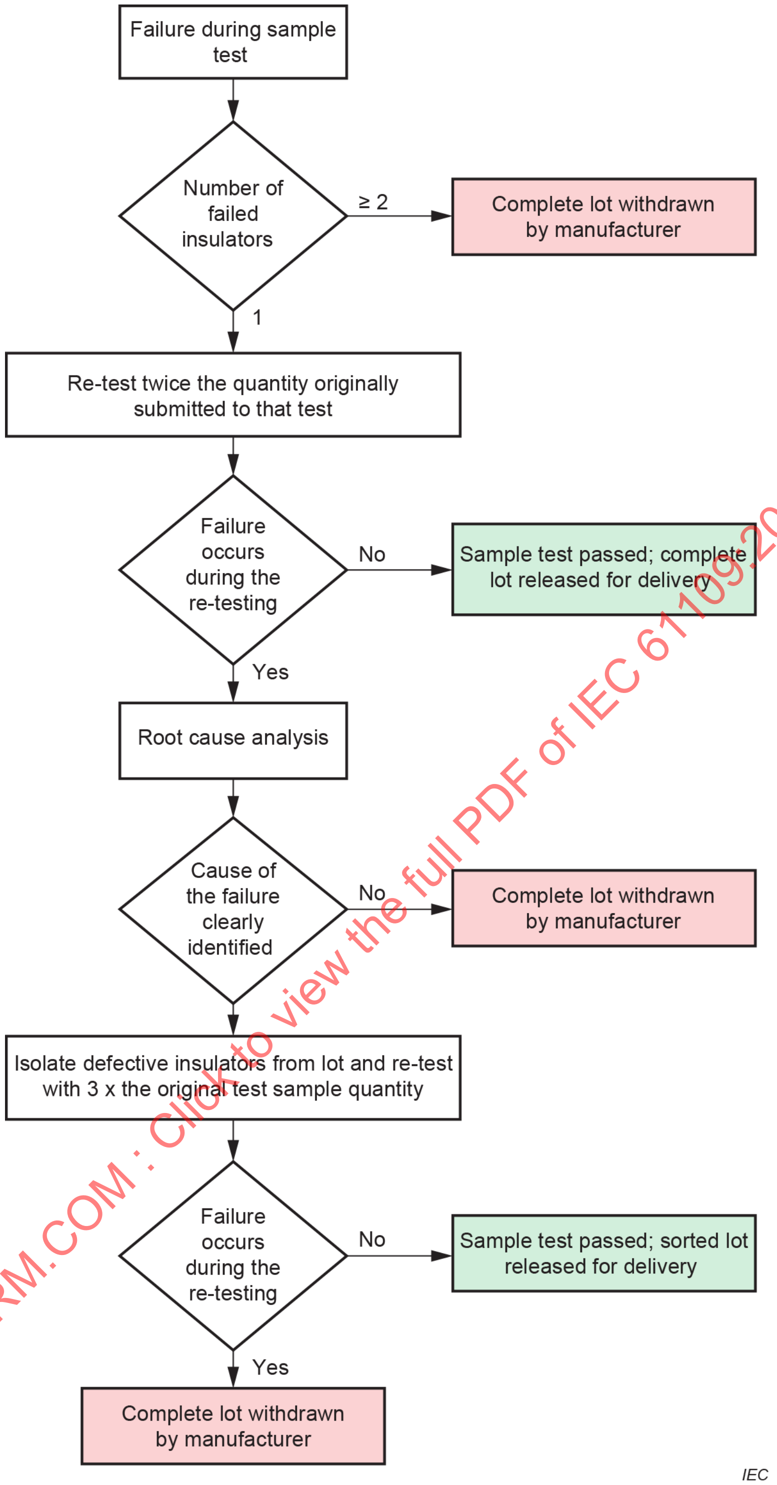


Figure 4 – Method of re-testing at different stages

12 Routine tests

12.1 Mechanical routine test

Every insulator shall withstand, at ambient temperature, a tensile load at RTL corresponding to 0,5 × SML ($^{+10\%}_{0}$) 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 mm^2 (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.

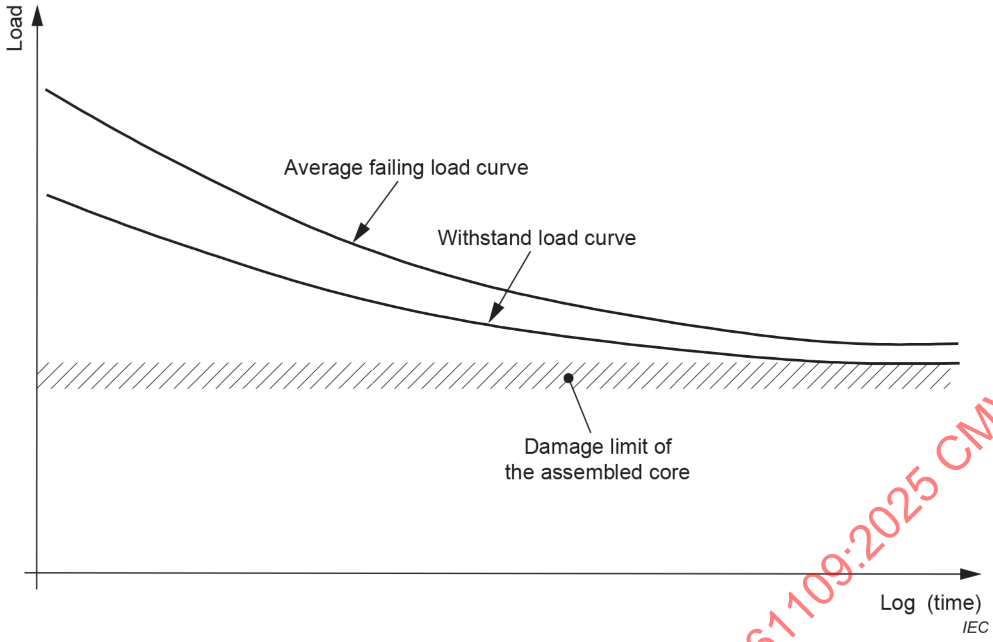


Figure A.1 – Load-time strength and damage limit of a core assembled with fittings

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 62217~~ 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.

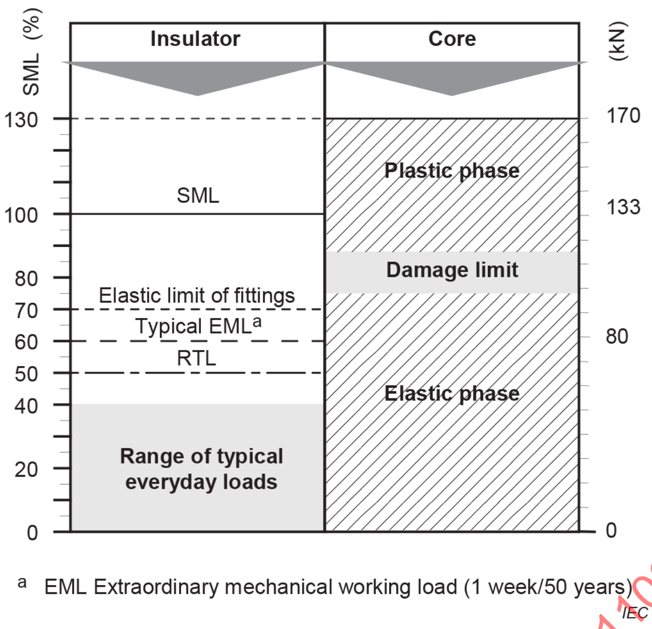


Figure A.2 – Graphical representation of the relationship of the damage limit to the mechanical characteristics and service loads of an insulator with a 16 mm diameter core and an SML rating of 133 kN

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:

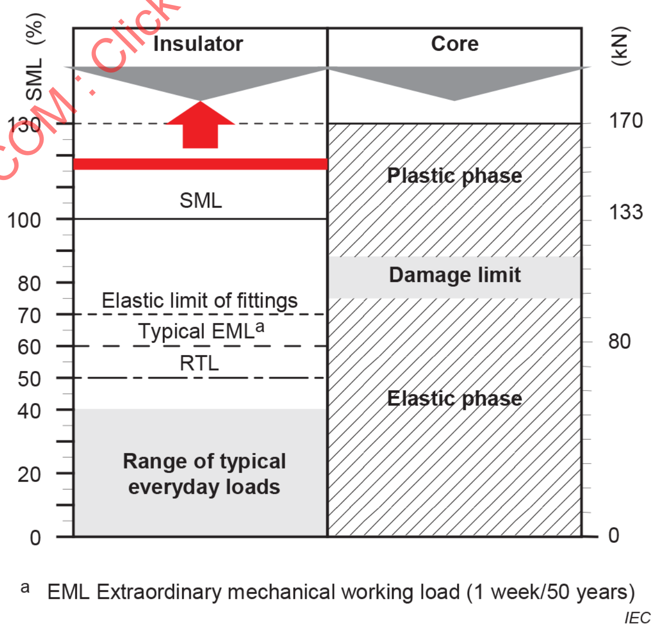


Figure A.3 – Applied specific force relationship, example 1

All individual failing load values e. g. 1,15 or 1,2 × 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.

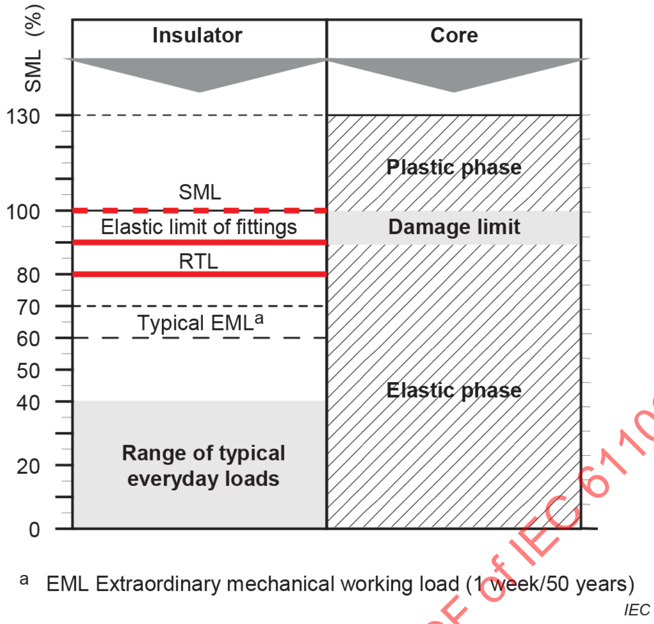


Figure A.4 – Applied specific force relationship, example 2

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).

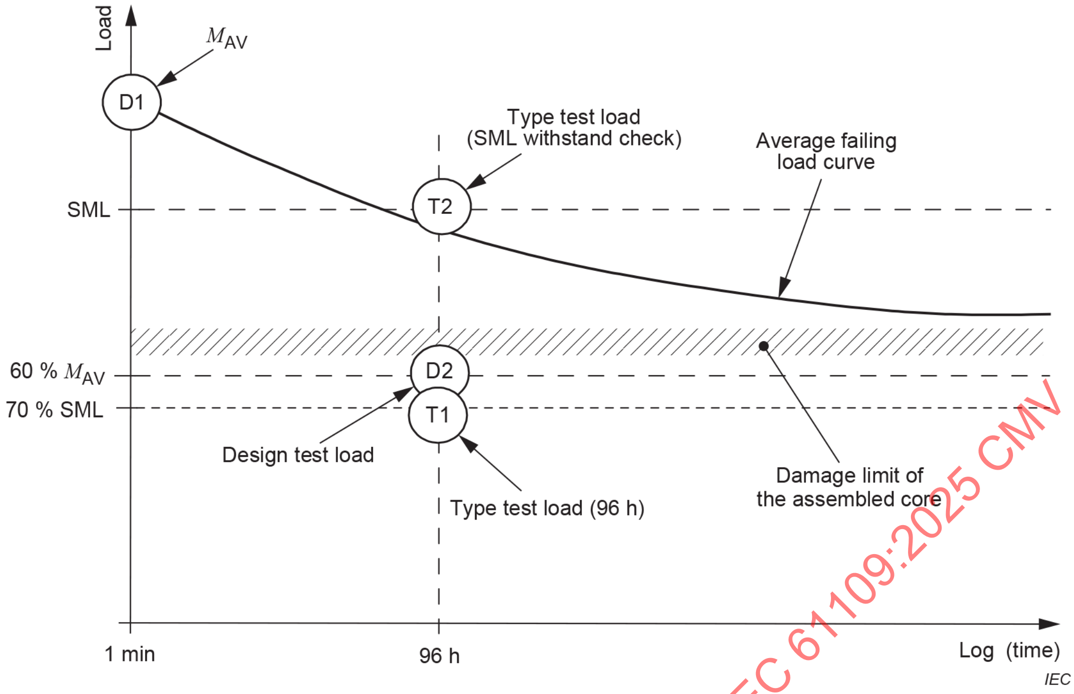


Figure A.5 – Test loads

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.

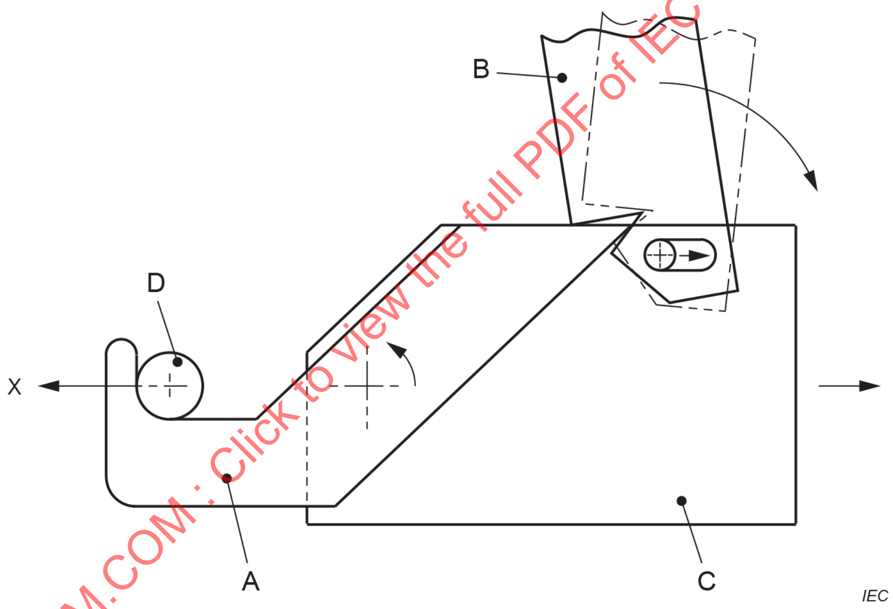


Figure B.1 – Example of possible device 1 for sudden release of load

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.

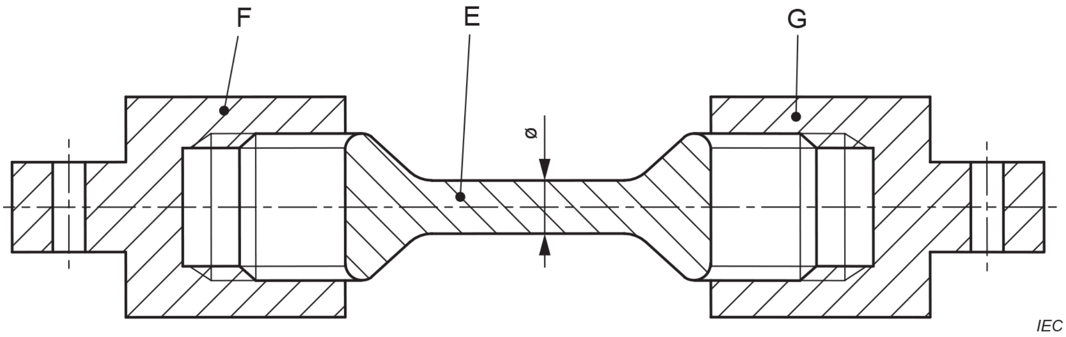


Figure B.2 – Example of possible device 2 for sudden release of load

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.

STоL (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]

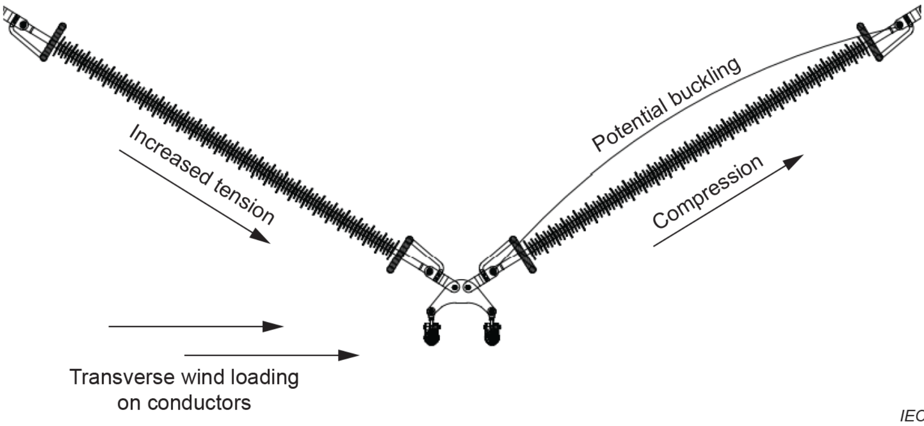


Figure C.1 – Example of compression loads in V-string assemblies

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

C.4 Bending loads

~~Long rod~~ 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 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 $E^{\mathrm{tangential}}_{\mathrm{max}}$ < 4,2 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^{normal}_{max} < 8 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].

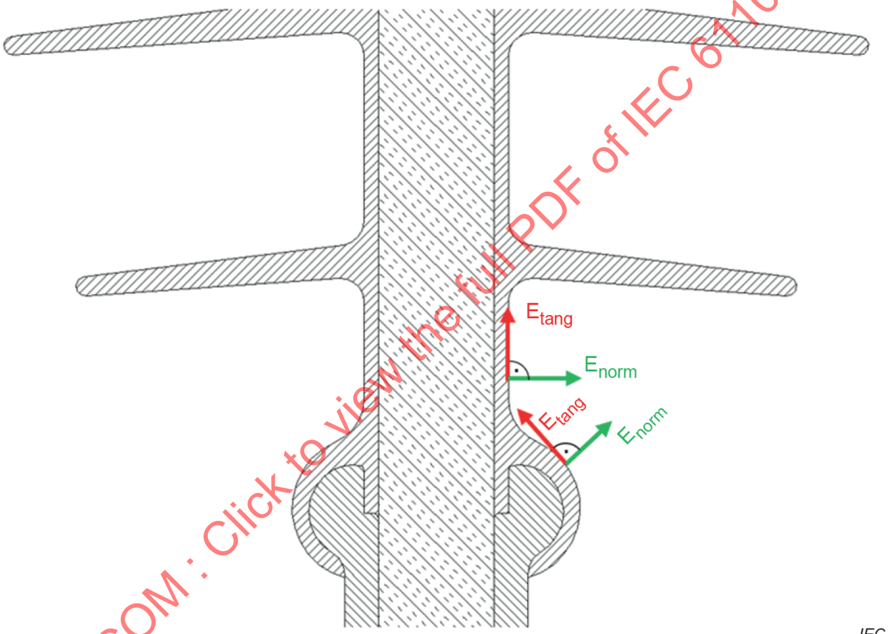
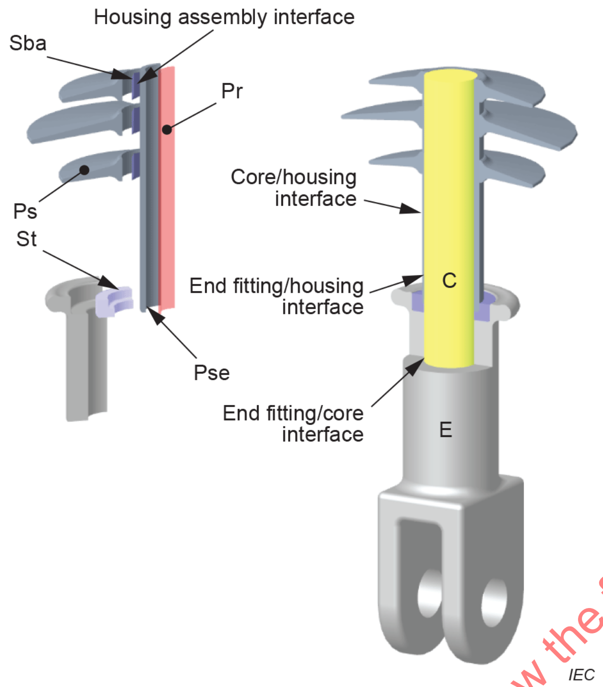


Figure D.1 – Example for electrical field vectors on a composite insulator

Annex E
(informative)

Typical sketches for composite insulator assemblies

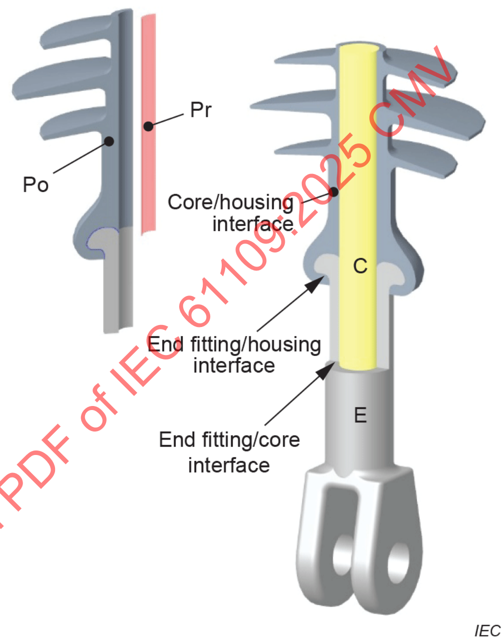
Figure E.1 and Figure E.2 show two typical composite insulator assemblies, a modular design with non-overmoulded end fitting and a moulded assembly with overmoulded end fitting.



Key

Ps	Polymer shed
Pse	Polymer sheath
Sba	Shed bonding agent
St	Sealant
C	Core
E	End fitting
Pr	Primer

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



Key

Po	Polymer
Pr	Primer
C	Core
E	End fitting

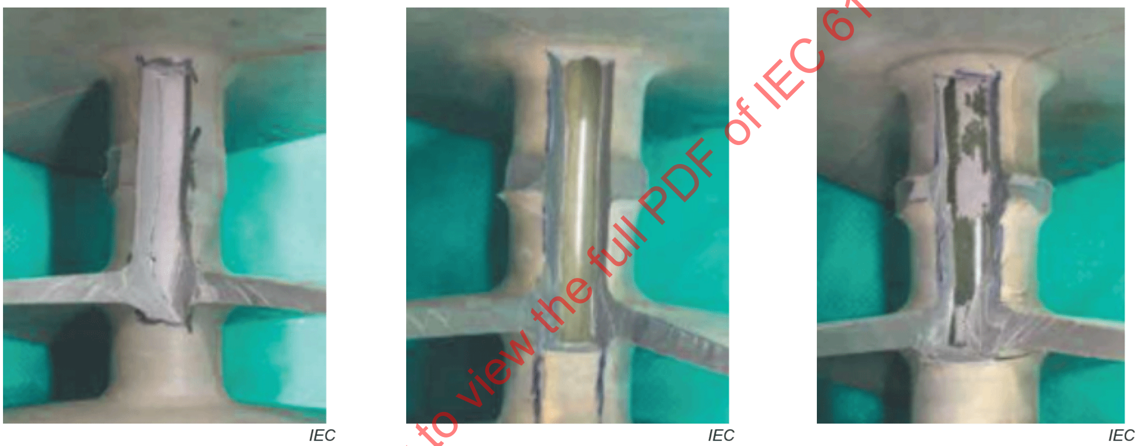
Figure E.2 – Interface description for insulator with housing made by injection molding and overmolded end fitting

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.



a) Cohesive separation **b) Adhesive separation** **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 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.

Figure F.2 – Example of specimen mounted in a tensile test machine

To assure a perpendicular force application to the interface to be tested, it is recommended to clamp the movable terminal of the tensile test machine to the cut shed segment first and then to fix the core in the static attachment of the tensile test machine. The application of the tensile stress is shown in Figure F.3. A fixed rate of terminal separation of 50 mm/min is applied and the tensile force is recorded until the housing separation occurs. Typically, a load cell with a maximum force load of 5 kN is sufficient for the pull-off test. After the separation, the rectangular cross-sectional area of the specimen interface between the housing and the core is measured, e.g. by using a calliper.

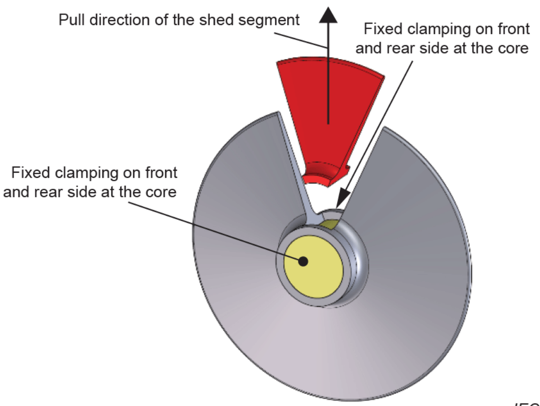


Figure F.3 – Example of test object for pull-off test and application clamping and force

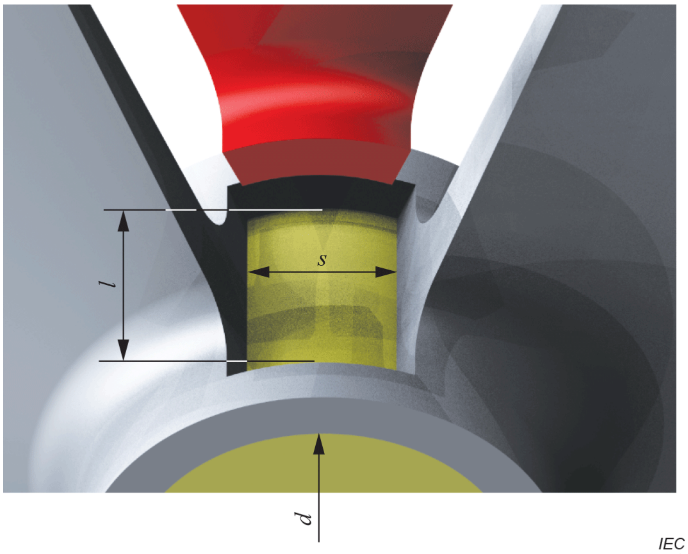


Figure F.4 – Relevant dimensions for the calculation of the area of the pull-off section

The quantitative evaluation is conducted by calculating the ultimate breaking stress when the separation occurs. The ultimate breaking stress σ is calculated as the maximum applied force F_{max} divided by the measured cross-sectional area A of the specimen interface between the housing and the core:

$$\sigma = \frac{F_{max}}{A}$$

Where the area A is calculated considering the length of the section along the axis of the core (l), the chord length (s) and the diameter of the core (d) as shown in Figure F.4:

$$A = l \times \arcsin\left(\frac{s}{d}\right) \times d$$

The complete adhesion test (both parts) is passed if the water diffusion test with housing according to IEC 62217 and criterion 1 defined in Clause F.1 are fulfilled. Note that water diffusion test with housing can be failed due to high current through the core, even if the adhesion is very good.

F.3 Method B: Peel test

F.3.1 General

With the peel test, the adhesion between the composite insulator housing and core can be qualitatively and quantitatively evaluated at any place (trunk or under the shed if it is removed) and can be applied in case an insulator has no sheds or is with sheds that cannot be tested with the pull-off test.

F.3.2 Specimens

The peel test is performed at 4 locations per specimen. The locations are distributed around the circumference. Making three parallel cuts with width of 5±2 mm, crossing the original cuts at 90° so that lattice pattern is formed in four circumferential directions (see Figure F.5). In this way, four grid specimen surface is created at the interface between rubber and core materials.

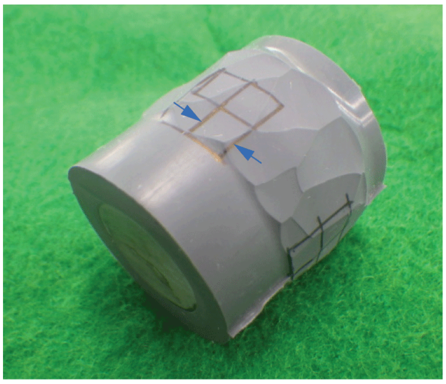


Figure F.5 – Example of test specimen for peel test

F.3.3 Procedure

For the peel test, the ultimate force required to pull off the rubber specimen from the core shall be recorded using a tensile machine. Manual type with gauge is applicable as well. Rate of elongation shall be controlled within 50 mm/min to 55 mm/min. The force should be applied perpendicular to the insulator axis by clamping one grid shape rubber with pliers, see Figure F.6. After the separation, the actual cross-section area of the specimen interface between the housing and the rod shall be measured using a sliding calliper.

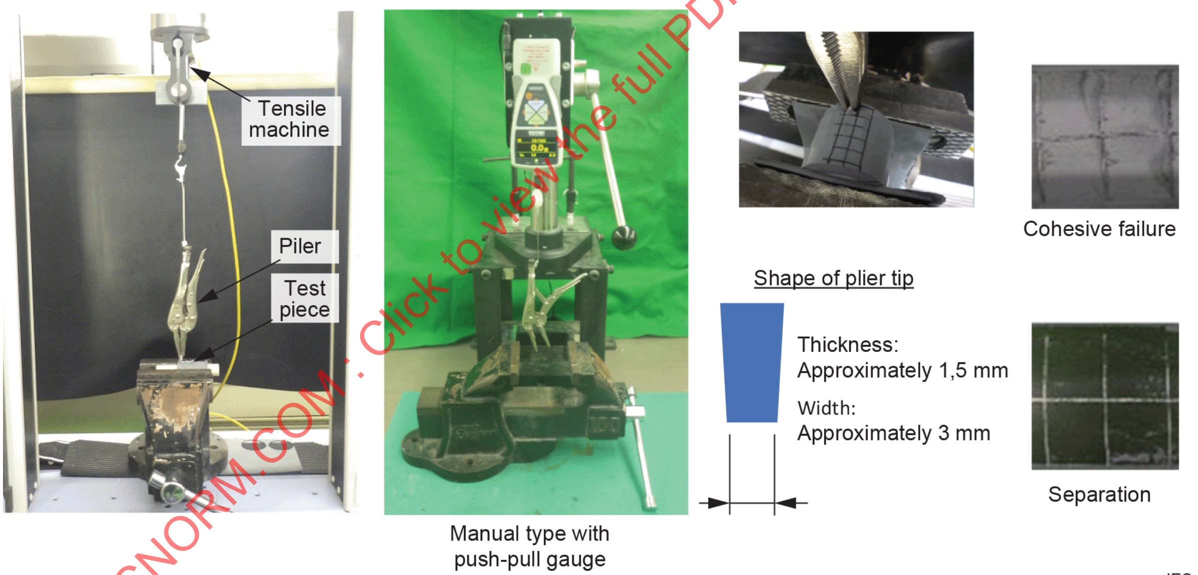


Figure F.6 – Method of peel test and tested specimens after peel test

The quantitative evaluation is conducted by calculating the ultimate breaking stress when the separation occurs. The ultimate breaking stress σ is calculated as the maximum applied force F_{max} divided by the measured cross-sectional area. The cross-sectional area is obtained by multiplying the lengths of the two sides of the pulled off rubber piece, which can be measured by use of a caliper.

The adhesion test is passed if criterion 1 defined in Clause F.1 is fulfilled.

F.4 Method C: Shear test 11

F.4.1 General

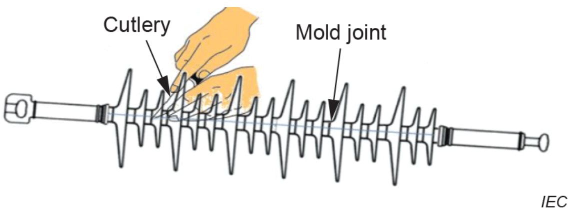
This shear test is used for the qualitative evaluation of the adhesion between the housing and the core of composite insulators over the entire length, including the adhesion between housing and end fitting for overmoulded designs.

F.4.2 Specimens

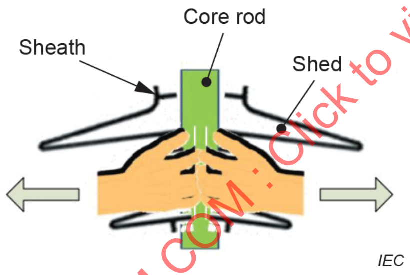
The samples from E1 (destructive) shall be used for this test before performing the minimum sheath thickness test.

F.4.3 Procedure

The housing is cut over the entire length with 2 cuts approximately 1 cm apart along the surface of the core, see Figure F.7. In case of injection moulded insulators, the cuts shall be done at least 30° offset to the mould parting line. The housing strip between the 2 cuts is scraped-off/pushed off with a sharp-edged tool like a screwdriver, for example and the sheds are pulled apart manually with hands.



a) Rip the sheath and sheds along a straight line with knife



b) Tear sheath and sheds along the cutting line with hands

Figure F.7 – Method of shear test and tested samples after shear test with cohesive bonding, sample passed the test

The adhesion test is passed if criterion 2 defined in Clause F.1 is fulfilled.

Annex G
(informative)

Applicability of design and type tests for DC applications

This Annex G provides guidance on applicable design and type tests modified for DC applications (see Table G.1).

Table G.1 – Design and type tests for DC applications

			Applicability for DC insulators	Comments
Design tests	Interfaces and connections of end fittings		X	
	Assembled core load–time tests		X	
	Tests on shed and housing material	Hardness test	X	
		Accelerated weathering test	X	
		Tracking and erosion test (1 000 h salt fog test)	X with modification	
		Flammability test	X	
		Hydrophobicity transfer test	X	
	Tests on the core material	Dye penetration test	X	
		Water diffusion test	X	
		Stress corrosion test	X	
	Tests on the core with housing	Water Diffusion Test on Core with Housing	X	
Type tests	Electrical type tests		X with modification	DC withstand voltage test IEC according 60060-1 POS & NEG polarities DC Corona test
	Mechanical type tests		X	

For a proper selection of polymeric materials for outdoor use under HV stress, IEC TR 62039 [5] gives guidance and defines different material properties. Next to already mentioned defined test methods in the table above, the tracking and erosion resistance according to IEC 60587 [19] as well as the retention of hydrophobicity are of relevance as well. None of these two properties have internationally defined test methods for DC application yet but are under intensive evaluation, such as CIGRE TB 611 [20] for the tracking and erosion resistance. Currently, active CIGRE Working Groups deal with the development of test methods and acceptance criteria, i.e. WG D1.58 for evaluation of the retention of hydrophobicity and WG D1.72 for the evaluation of tracking and erosion resistance under DC application.

At present there is no standardized tracking and erosion test for DC voltage. For many test parameters it can be defined similar as to the standard tests available for AC, the most important question, however, is the applied voltage. There is numerous data for tracking and erosion tests showing that when a DC voltage stress corresponds to the RMS value of AC voltage stress the level of deterioration will be higher at DC than at AC for the same test insulators. The corrosion stress on couplings is higher than in AC tests. In order not to impact the results of the housing test, the influence of the fittings can be removed by appropriate protective measures, for example by painting.

Annex D related to electrical field control is not applicable for DC grading rings. However, this may be still useful in DC if there is the need to prevent corona from the fittings and protect the triple point, but the electric field along the insulator is not controlled by capacitive distribution as for AC. Arcing devices are also less important in DC to limit the effect of power arc (protective function) due to the faster switch-off in case of short circuit and the reduced propensity of power arcs in DC [21].

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[4] IEC TS 60815-1, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

[5] IEC TR 62039, *Selection guidelines for polymeric materials for outdoor use under HV stress*

[6] IEC 60721-1, *Classification of environmental conditions; part 1: environmental parameters and their severities*

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List of comments

1 Title is changed to cover AC and DC applications. At this stage the maintenance team (MT 18) was not able to define mandatory test procedures for DC applications, but Annex G give some informative proposals for DC special type and design tests. It is planned for the next revision to define DC specific test procedures and maybe design proposals.

2 This standard defines composite suspension and tension insulators, and in edition 2.0 the definition “long rod” was used in some chapters. MT 18 decided to replace “long rod” by “composite insulators” in the whole standard, the definition “long rod” is used for porcelain insulators.

3 The environmental conditions are identical to IEC 62217, but MT 18 decided to add it here as well to make this standard easier to handle for the user.

4 Hybrid insulators is removed, due to the availability of the new standard IEC 62896.

5 The redefining of tolerances for creepage distances was under discussion in MT 18. The question was whether we have to define a maximum tolerance as well. It was decided that having more creepage than required will not worsen the performance of the insulator, and it should be possible for manufacturers to meet customer requirements with higher creepage distances. This should avoid unnecessary tool investment and test costs. However, for test samples, the realized creepage distance should be documented in the test reports, especially for the 1000-hour salt fog test, as this information is important.

6 Repetition of interface test after profile change is removed. The shed profile itself does not influence this test. In edition 2.0 the shed profile was defined among other parameters on the shed diameter, this includes overhang and trunk/core diameter. In this edition 3.0 it is replaced by the shed overhang. The influence of the core diameter on the interface test is covered by line 2b.

7 Comment c) “Not necessary if it can be demonstrated that the change has no influence on the assembled core strength” is replaced by “Not necessary if the stress under mechanical loads is the same or smaller” and is applicable for core diameter changes only. Changes in the manufacturing processes, for example preheating-, injection- or curing temperatures might influence the assembled core load strength. Changes in the material or formulation might need adjustments in the manufacturing processes as well.

8 The repetition of the tracking and erosion test after core diameter is added to cover the redefinition of shed profile (diameter → overhang).

9 Interfaces is added to give the user a better understanding on the importance of interfaces for composite insulators.

10 This chapter is updated to clarify the differences between string insulator units and insulator sets. This standard define string insulator units only but we want to make sure that power arc tests and RIV corona tests are important but shall be done on complete insulator sets.

11 The method C is done without prestressing by boiling. This reduces the time to perform the adhesion tests, to make it applicable for standard FAT or sample tests. But the results are not comparable with Method A or B. The adhesion test after prestressing by boiling is the stronger test method providing a stress acceleration and gives more comprehensive information about the strength of the adhesion.

IEC 61109

Edition 3.0 2025-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

Isolateurs pour lignes aériennes – Isolateurs composites de suspension et d'ancrage de tension supérieure à 1 000 V en courant alternatif et à 1 500 V en courant continu – Définitions, méthodes d'essai et critères d'acceptation

IEC 61109:2025-02(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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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

FOREWORD

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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 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 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 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, 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 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 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.

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][1], 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 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.

[1] Numbers in square brackets refer to the bibliography.

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

1 Scope

This International Standard applies to composite 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 (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 these insulators could occasionally be subjected to compression or bending, for example when used as interphase-spacers. Guidance on such loads is outlined in Annex C.

The object of this document is to

– define the terms used,

– specify test methods,

– 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:—[2], *Polymeric HV insulators for indoor and outdoor use – 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 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 an insulator)
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]

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[2] Under preparation. Stage at the time of publication: IEC/RFDIS 62217:2025.

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 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 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)

[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 core and the end fitting

[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

[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 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

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/m²
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 insulators may be submitted to high torsion, compression or bending loads for which they are not designed. Annex C gives guidance 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 Tolerances

Unless otherwise agreed, a tolerance of

± (0,04 × d + 1,5) mm when $d \leq 300$ mm,

± (0,025 × d + 6) mm when $d > 300$ mm with a maximum tolerance of ± 50 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 for minimum creepage distance is zero.

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 insulator design is defined by the following elements:

– 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 insulator is submitted to the design tests, it becomes an equivalent design insulator for a given design and the results shall be considered valid for that design only. This tested 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 core/end fitting interface design, and the same housing-to-fitting interface geometry;
c) same or greater minimum layer thickness of the housing 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.

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.

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**	
		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					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)			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													
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 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 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
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

9.2.1 Tests on interfaces and connections of end fittings

Three production insulators 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 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 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 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, 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 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 °C to –25 °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.

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 ms.

NOTE In certain cases, a lower temperature 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 ± 5) °C, the other at (–35 ± 5) °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.

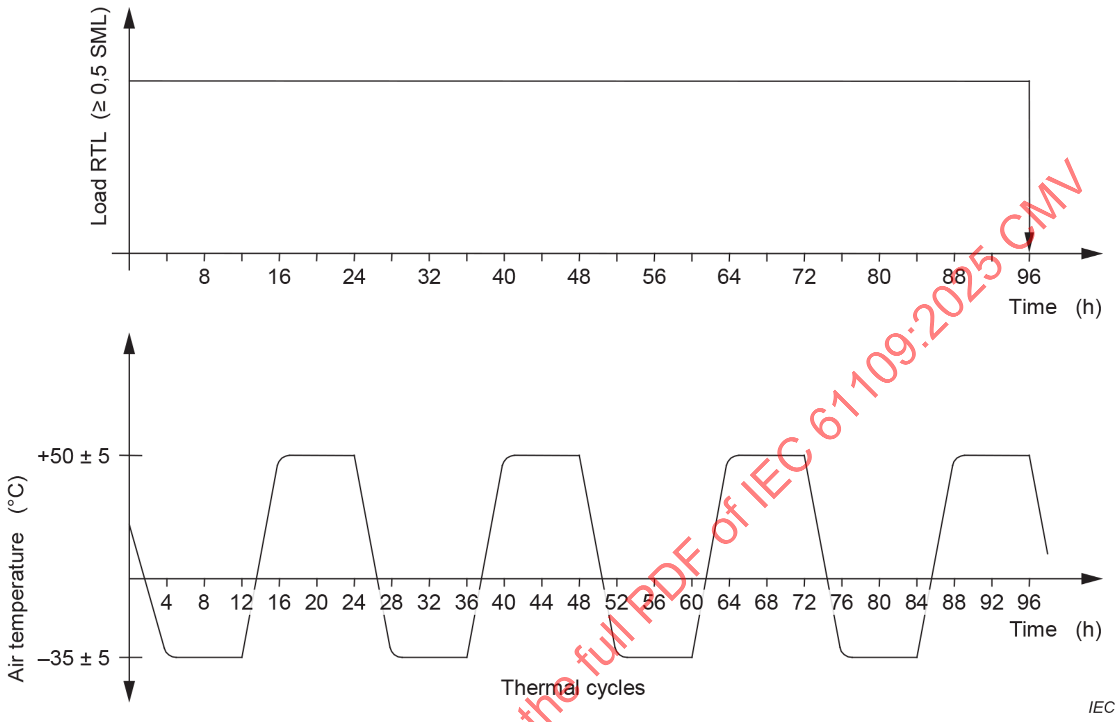


Figure 1 – Thermal-mechanical pre-stressing

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 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 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 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 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

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

10.2 Electrical tests on string insulator units

10.2.1 General

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	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 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

a) 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.

b) 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 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.

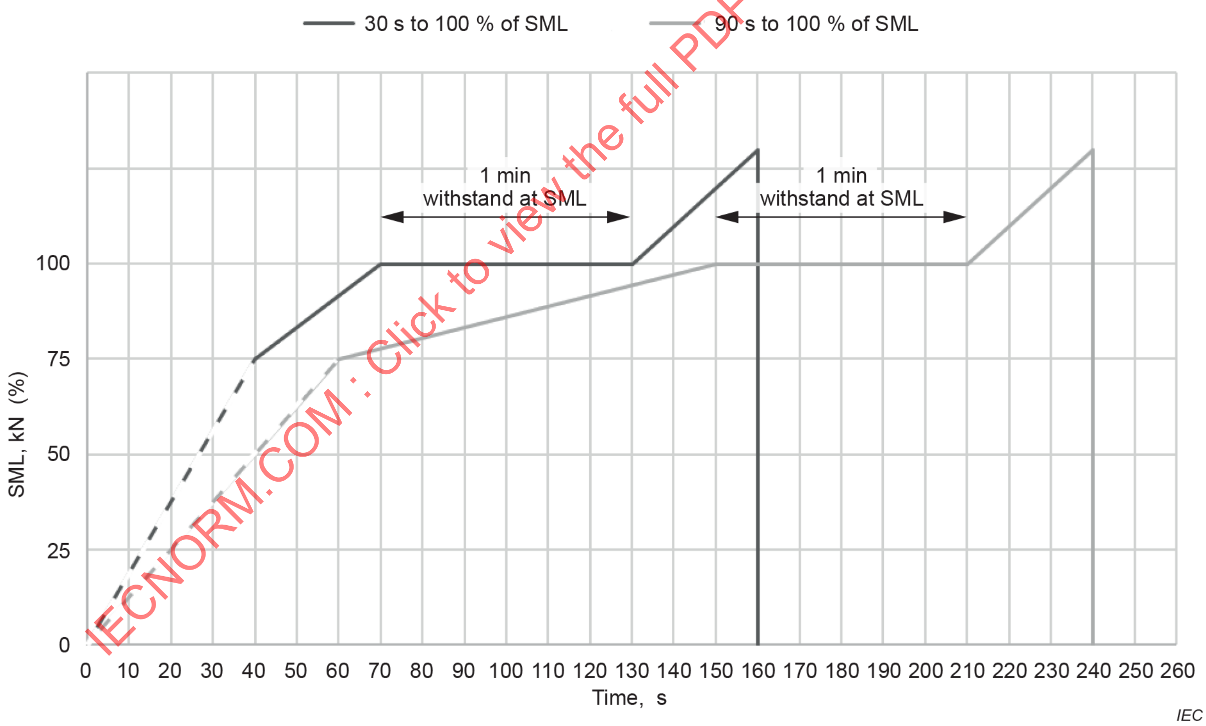


Figure 2 – Examples for 1 min SML withstand test

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)),
- 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 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.

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	
N	E1 destructive	E2 non-destructive
N ≤ 10	Subject of agreement	
10 < N ≤ 30	2	1
30 ≤ N 300	3	2
300 < N ≤ 2 000	4	3
2 000 < N ≤ 5 000	8	4
5 000 < N ≤ 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.

   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.

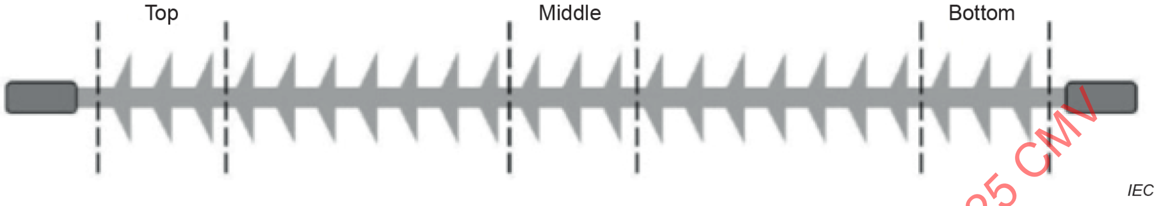


Figure 3 – Location for minimum sheath thickness measurement

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

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

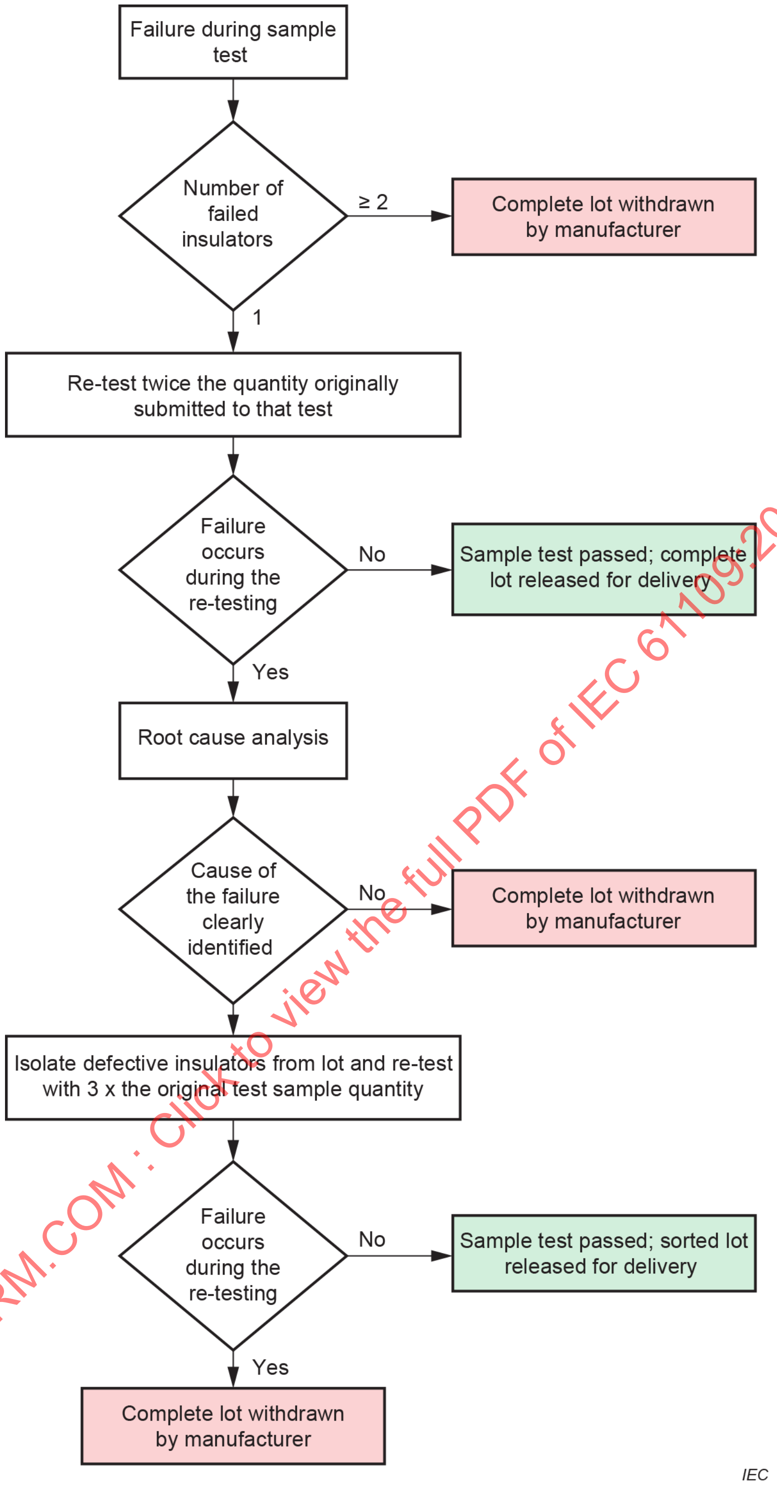


Figure 4 – Method of re-testing at different stages

12 Routine tests

12.1 Mechanical routine test

Every insulator shall withstand, at ambient temperature, a tensile load at RTL corresponding to 0,5 × SML ($^{+10\%}_{0}$) 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 mm^2 (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 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.

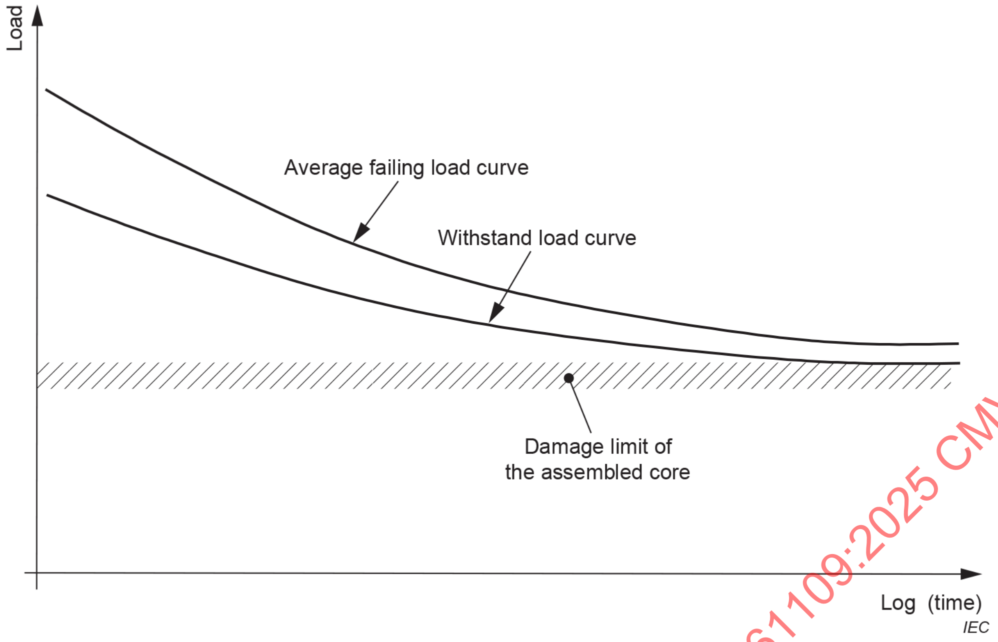


Figure A.1 – Load-time strength and damage limit of a core assembled with fittings

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 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.

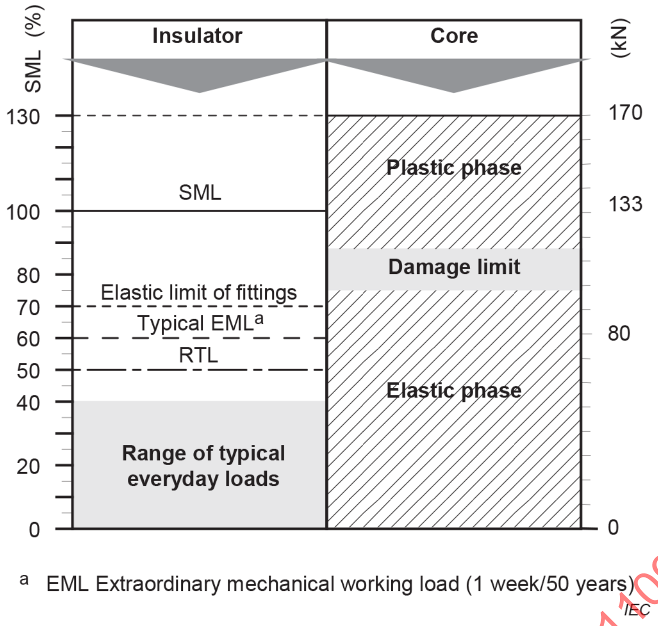


Figure A.2 – Graphical representation of the relationship of the damage limit to the mechanical characteristics and service loads of an insulator with a 16 mm diameter core and an SML rating of 133 kN

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:

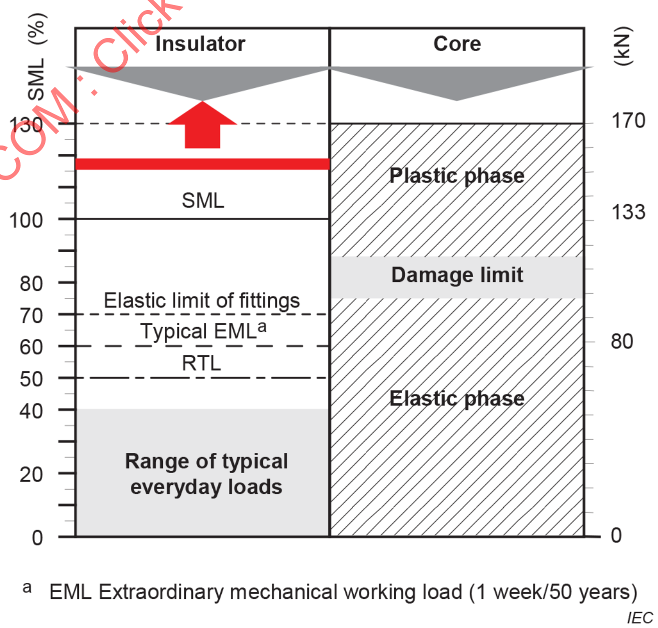
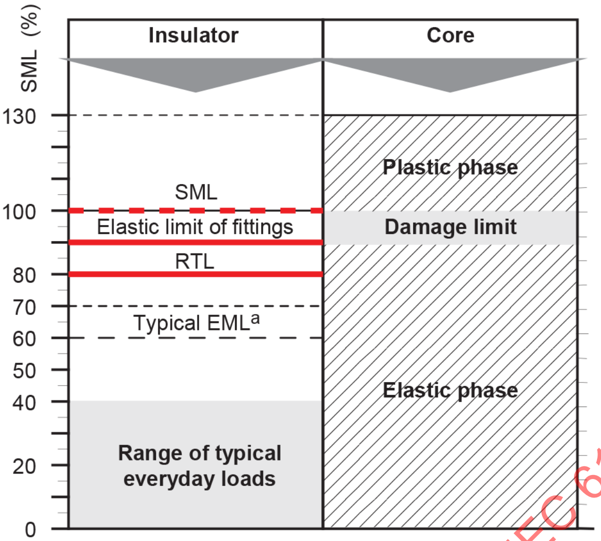


Figure A.3 – Applied specific force relationship, example 1

All individual failing load values e. g. 1,15 or 1,2 × 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.



[a] EML Extraordinary mechanical working load (1 week/50 years)

IEC

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 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).

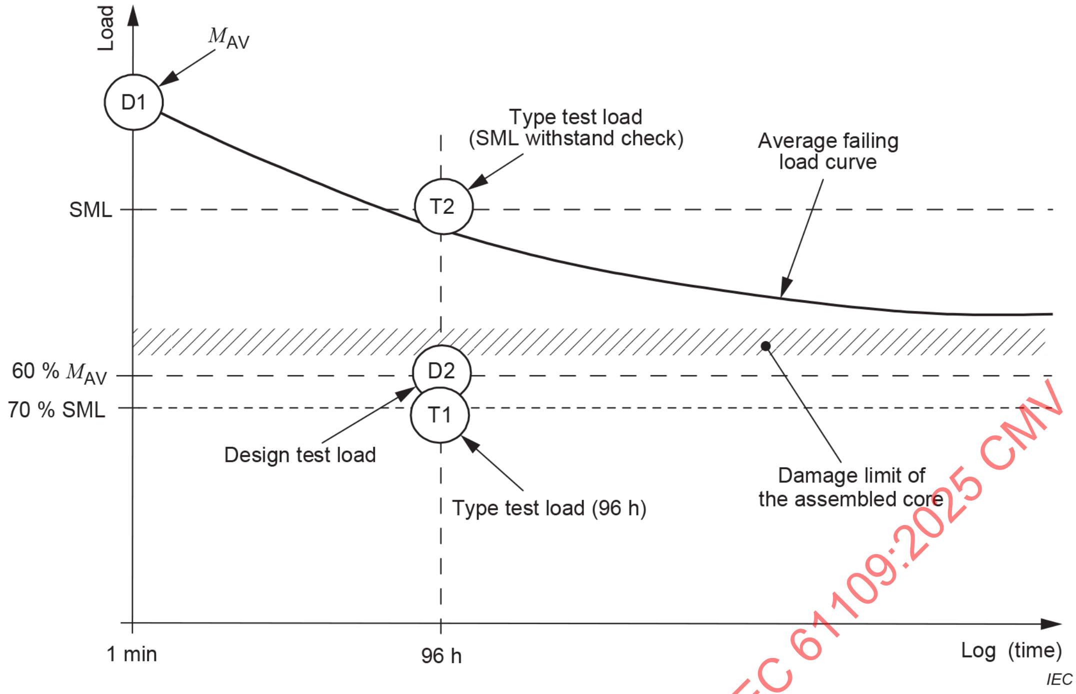


Figure A.5 – Test loads

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.

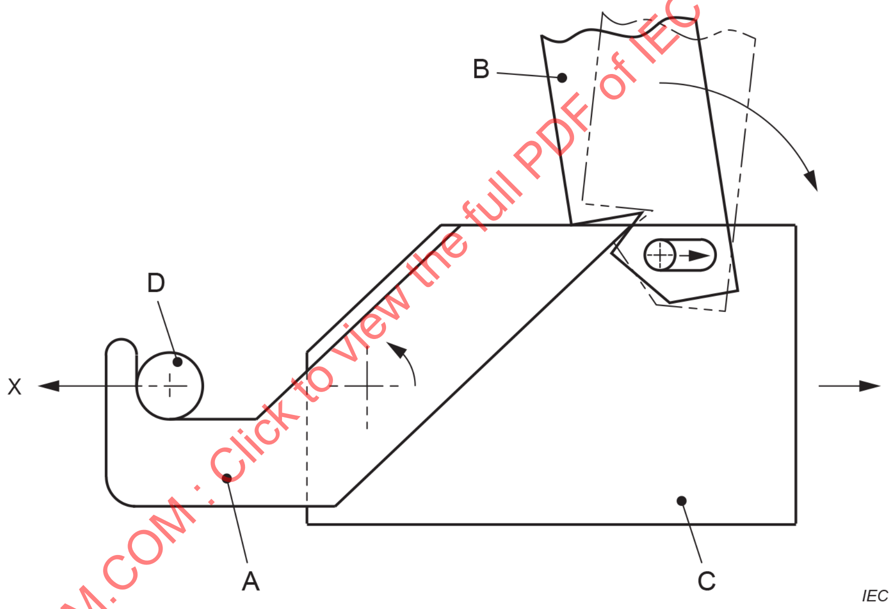


Figure B.1 – Example of possible device 1 for sudden release of load

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.

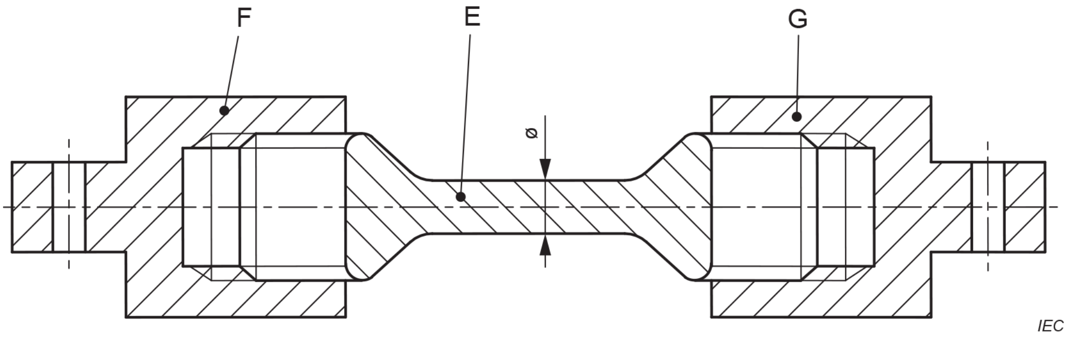


Figure B.2 – Example of possible device 2 for sudden release of load

Annex C
(informative)

Guidance on non-standard mechanical stresses and dynamic mechanical loading of composite 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 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 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.

STоL (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 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]

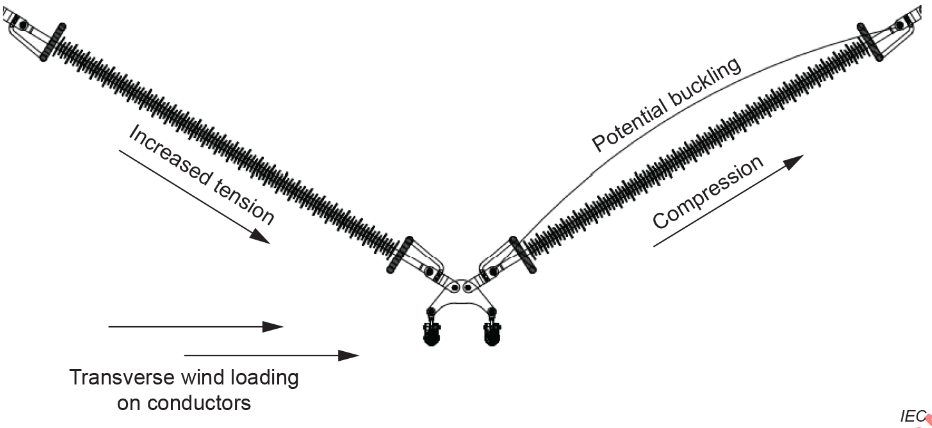


Figure C.1 – Example of compression loads in V-string assemblies

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

C.4 Bending loads

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

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 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 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 $E^{\text{tangential}}_{\text{max}}$ < 4,2 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 $E^{normal}{}_{max}$ < 8 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].

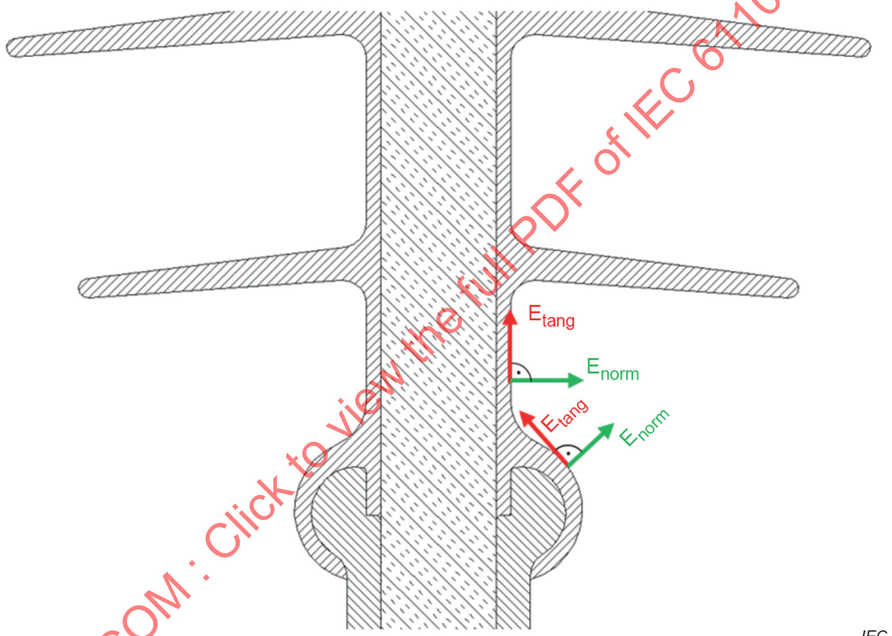
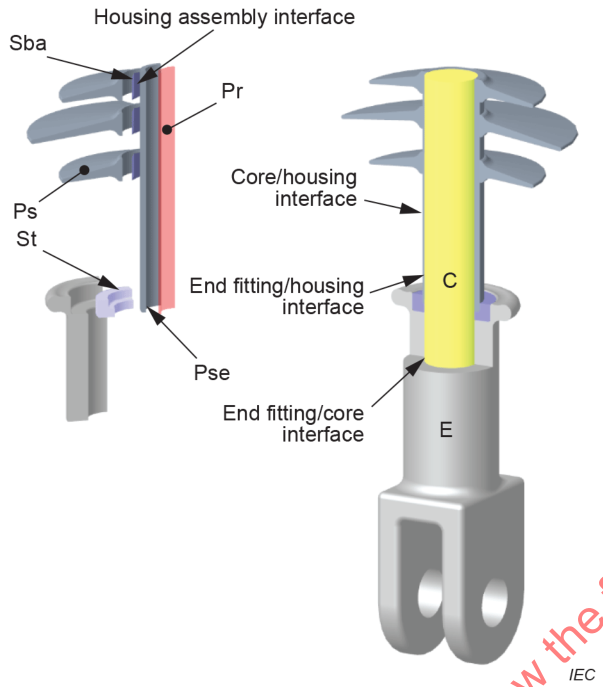


Figure D.1 – Example for electrical field vectors on a composite insulator

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.



Key

Ps Polymer shed

Pse Polymer sheath

Sba Shed bonding agent

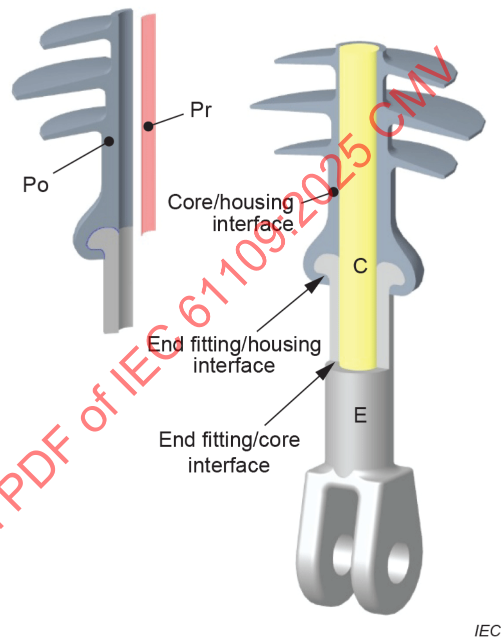
St Sealant

C Core

E End fitting

Pr Primer

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



Key

Po Polymer

Pr Primer

C Core

E End fitting

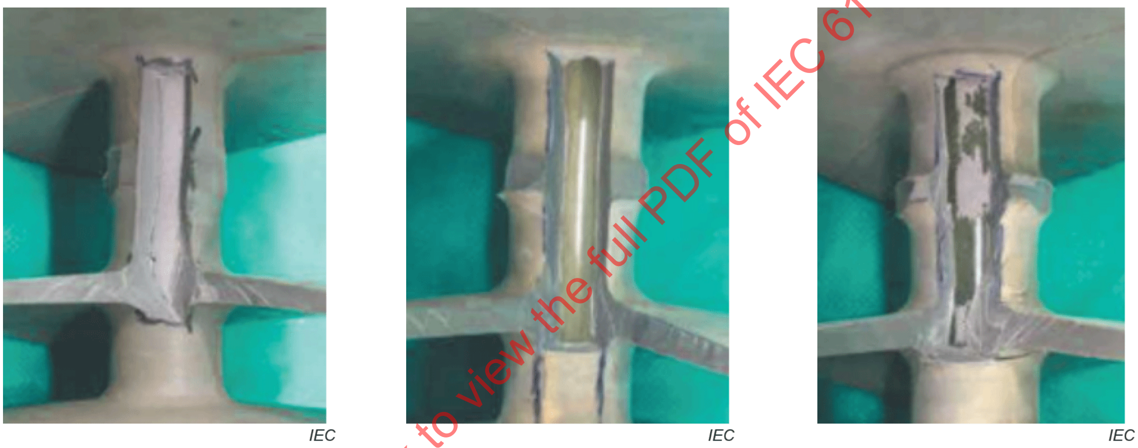
Figure E.2 – Interface description for insulator with housing made by injection molding and overmolded end fitting

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.



a) Cohesive separation **b) Adhesive separation** **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 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.

Figure F.2 – Example of specimen mounted in a tensile test machine

To assure a perpendicular force application to the interface to be tested, it is recommended to clamp the movable terminal of the tensile test machine to the cut shed segment first and then to fix the core in the static attachment of the tensile test machine. The application of the tensile stress is shown in Figure F.3. A fixed rate of terminal separation of 50 mm/min is applied and the tensile force is recorded until the housing separation occurs. Typically, a load cell with a maximum force load of 5 kN is sufficient for the pull-off test. After the separation, the rectangular cross-sectional area of the specimen interface between the housing and the core is measured, e.g. by using a calliper.

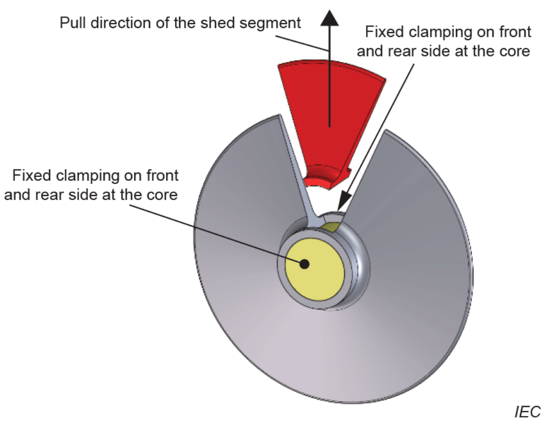


Figure F.3 – Example of test object for pull-off test and application clamping and force

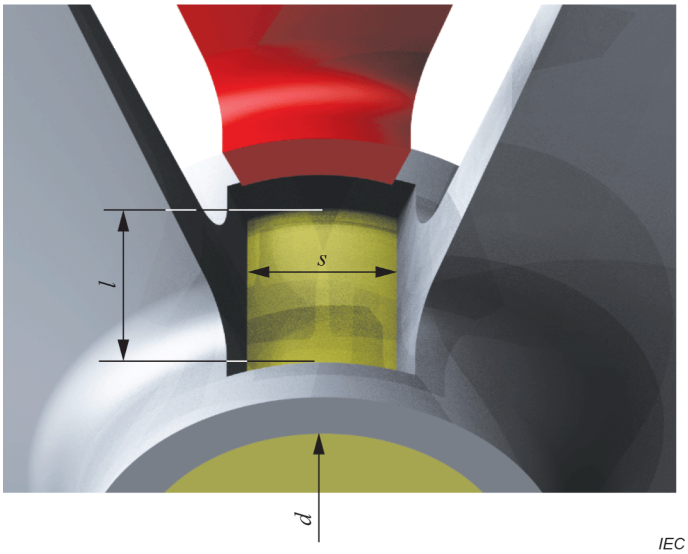


Figure F.4 – Relevant dimensions for the calculation of the area of the pull-off section

The quantitative evaluation is conducted by calculating the ultimate breaking stress when the separation occurs. The ultimate breaking stress σ is calculated as the maximum applied force F_{max} divided by the measured cross-sectional area A of the specimen interface between the housing and the core:

$$\sigma = \frac{F_{max}}{A}$$

Where the area A is calculated considering the length of the section along the axis of the core (l), the chord length (s) and the diameter of the core (d) as shown in Figure F.4:

$$A = l \times \arcsin\left(\frac{s}{d}\right) \times d$$

The complete adhesion test (both parts) is passed if the water diffusion test with housing according to IEC 62217 and criterion 1 defined in Clause F.1 are fulfilled. Note that water diffusion test with housing can be failed due to high current through the core, even if the adhesion is very good.

F.3 Method B: Peel test

F.3.1 General

With the peel test, the adhesion between the composite insulator housing and core can be qualitatively and quantitatively evaluated at any place (trunk or under the shed if it is removed) and can be applied in case an insulator has no sheds or is with sheds that cannot be tested with the pull-off test.

F.3.2 Specimens

The peel test is performed at 4 locations per specimen. The locations are distributed around the circumference. Making three parallel cuts with width of 5±2 mm, crossing the original cuts at 90° so that lattice pattern is formed in four circumferential directions (see Figure F.5). In this way, four grid specimen surface is created at the interface between rubber and core materials.

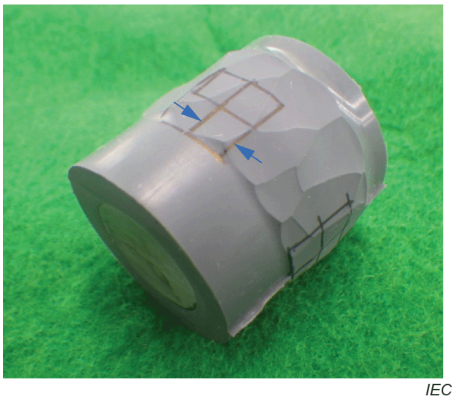


Figure F.5 – Example of test specimen for peel test

F.3.3 Procedure

For the peel test, the ultimate force required to pull off the rubber specimen from the core shall be recorded using a tensile machine. Manual type with gauge is applicable as well. Rate of elongation shall be controlled within 50 mm/min to 55 mm/min. The force should be applied perpendicular to the insulator axis by clamping one grid shape rubber with pliers, see Figure F.6. After the separation, the actual cross-section area of the specimen interface between the housing and the rod shall be measured using a sliding calliper.

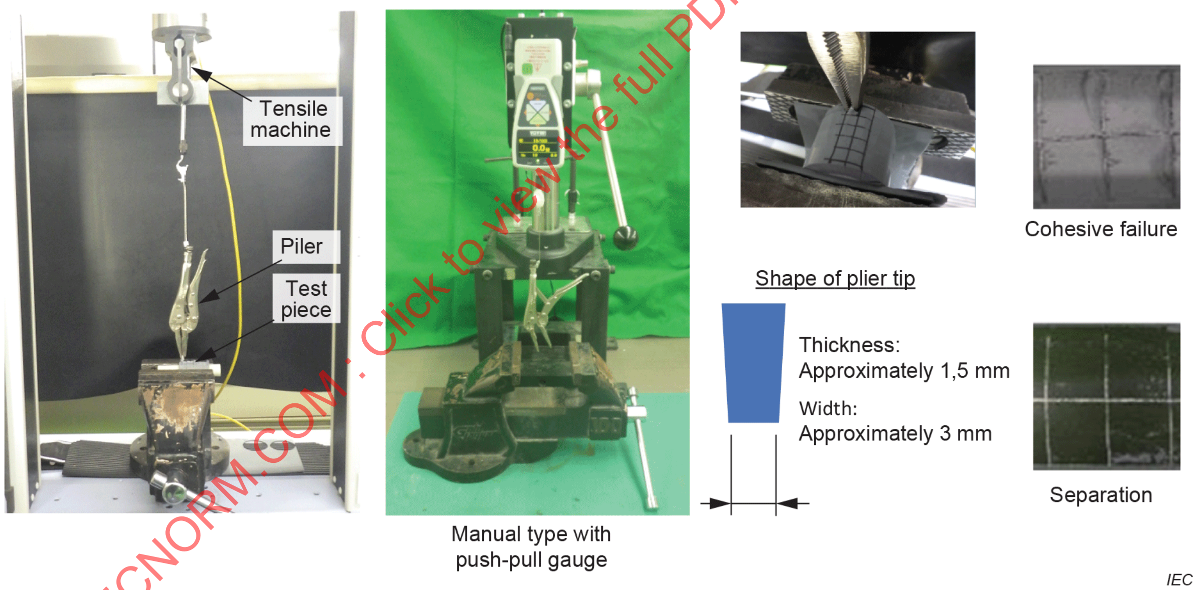


Figure F.6 – Method of peel test and tested specimens after peel test

The quantitative evaluation is conducted by calculating the ultimate breaking stress when the separation occurs. The ultimate breaking stress σ is calculated as the maximum applied force F_{max} divided by the measured cross-sectional area. The cross-sectional area is obtained by multiplying the lengths of the two sides of the pulled off rubber piece, which can be measured by use of a caliper.

The adhesion test is passed if criterion 1 defined in Clause F.1 is fulfilled.

F.4 Method C: Shear test

F.4.1 General

This shear test is used for the qualitative evaluation of the adhesion between the housing and the core of composite insulators over the entire length, including the adhesion between housing and end fitting for overmoulded designs.

F.4.2 Specimens

The samples from E1 (destructive) shall be used for this test before performing the minimum sheath thickness test.

F.4.3 Procedure

The housing is cut over the entire length with 2 cuts approximately 1 cm apart along the surface of the core, see Figure F.7. In case of injection moulded insulators, the cuts shall be done at least 30° offset to the mould parting line. The housing strip between the 2 cuts is scraped-off/pushed off with a sharp-edged tool like a screwdriver, for example and the sheds are pulled apart manually with hands.

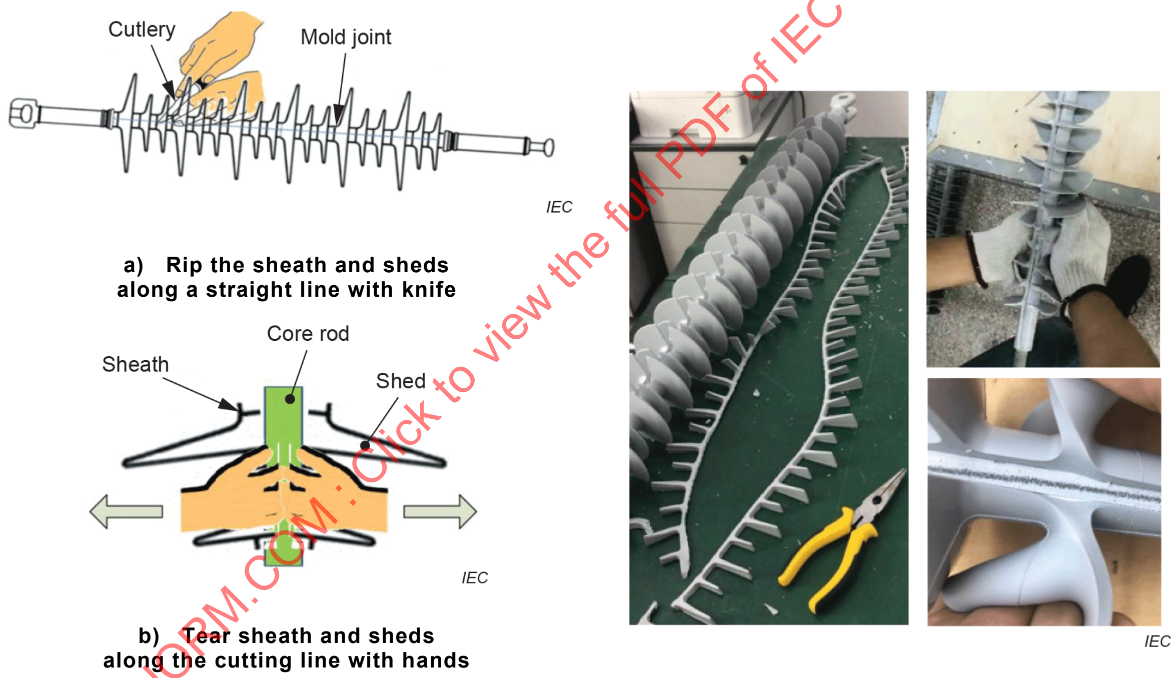


Figure F.7 – Method of shear test and tested samples after shear test with cohesive bonding, sample passed the test

The adhesion test is passed if criterion 2 defined in Clause F.1 is fulfilled.

Annex G
(informative)

Applicability of design and type tests for DC applications

This Annex G provides guidance on applicable design and type tests modified for DC applications (see Table G.1).

Table G.1 – Design and type tests for DC applications

			Applicability for DC insulators	Comments
Design tests	Interfaces and connections of end fittings		X	
	Assembled core load–time tests		X	
	Tests on shed and housing material	Hardness test	X	
		Accelerated weathering test	X	
		Tracking and erosion test (1 000 h salt fog test)	X with modification	
		Flammability test	X	
		Hydrophobicity transfer test	X	
	Tests on the core material	Dye penetration test	X	
		Water diffusion test	X	
		Stress corrosion test	X	
	Tests on the core with housing	Water Diffusion Test on Core with Housing	X	
Type tests	Electrical type tests		X with modification	DC withstand voltage test IEC according 60060-1 POS & NEG polarities DC Corona test
	Mechanical type tests		X	

For a proper selection of polymeric materials for outdoor use under HV stress, IEC TR 62039 [5] gives guidance and defines different material properties. Next to already mentioned defined test methods in the table above, the tracking and erosion resistance according to IEC 60587 [19] as well as the retention of hydrophobicity are of relevance as well. None of these two properties have internationally defined test methods for DC application yet but are under intensive evaluation, such as CIGRE TB 611 [20] for the tracking and erosion resistance. Currently, active CIGRE Working Groups deal with the development of test methods and acceptance criteria, i.e. WG D1.58 for evaluation of the retention of hydrophobicity and WG D1.72 for the evaluation of tracking and erosion resistance under DC application.

At present there is no standardized tracking and erosion test for DC voltage. For many test parameters it can be defined similar as to the standard tests available for AC, the most important question, however, is the applied voltage. There is numerous data for tracking and erosion tests showing that when a DC voltage stress corresponds to the RMS value of AC voltage stress the level of deterioration will be higher at DC than at AC for the same test insulators. The corrosion stress on couplings is higher than in AC tests. In order not to impact the results of the housing test, the influence of the fittings can be removed by appropriate protective measures, for example by painting.

Annex D related to electrical field control is not applicable for DC grading rings. However, this may be still useful in DC if there is the need to prevent corona from the fittings and protect the triple point, but the electric field along the insulator is not controlled by capacitive distribution as for AC. Arcing devices are also less important in DC to limit the effect of power arc (protective function) due to the faster switch-off in case of short circuit and the reduced propensity of power arcs in DC [21].

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[4] IEC TS 60815-1, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

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[6] IEC 60721-1, *Classification of environmental conditions; part 1: environmental parameters and their severities*

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[20] CIGRE Technical Brochure 611: *Feasibility study for a DC tracking & erosion test*, Cigré Technical Brochure, 2015

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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ISOLATEURS POUR LIGNES AÉRIENNES – ISOLATEURS COMPOSITES DE SUSPENSION ET D'ANCRAGE DE TENSION SUPÉRIEURE À 1 000 V EN COURANT ALTERNATIF ET À 1 500 V EN COURANT CONTINU – DÉFINITIONS, MÉTHODES D'ESSAI ET CRITÈRES D'ACCEPTATION

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L'IEC 61109 a été établie par le sous-comité 36B: Isolateurs pour lignes aériennes, du comité d'études 36 de l'IEC: Isolateurs. Il s'agit d'une Norme internationale.

Cette troisième édition annule et remplace la deuxième édition parue en 2008. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) élargissement du présent document pour inclure les systèmes à courant alternatif et à courant continu;
b) modifications de l'Article 3, Termes, définitions et abréviations;
c) suppression de l'Article 7, Isolateurs hybrides, dans le présent document;
d) modifications des procédures d'essai récemment incluses dans l'IEC 62217 (essai de transfert d'hydrophobie, essai de corrosion sous contrainte, essai de pénétration d'eau sur le noyau avec le revêtement);
e) modifications des conditions d'environnement;
f) modifications de la classification des essais et ajout de la pertinence des interfaces;
g) clarification et modification des paramètres qui déterminent la nécessité de répéter les essais de conception et de type;
h) révision du Tableau 1;
i) révision des essais électriques de type;
j) révision de la procédure de contre-épreuve de l'essai sur prélèvement;
k) ajout d'une nouvelle Annexe D sur la maîtrise des champs électriques pour les applications en courant alternatif;
l) ajout d'une nouvelle Annexe E sur les croquis types pour l'assemblage des isolateurs composites;
m) ajout d'une nouvelle Annexe F sur l'évaluation mécanique de l'adhérence entre le noyau et le revêtement;
n) ajout d'une nouvelle Annexe G sur l'applicabilité des essais de conception et de type pour les applications en courant continu.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
36/609/FDIS	36/611/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

La présente Norme internationale doit être utilisée conjointement avec l'IEC 62217:2012.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera

- reconduit,
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- révisé.

INTRODUCTION

Les isolateurs composites de suspension et d'ancrage (ci-après désignés par le terme "isolateur composite") consistent en un noyau isolant en fibres de verre, qui supporte les charges mécaniques et qui est protégé par un revêtement en polymère, les charges étant transmises au noyau par les armatures d'extrémité métalliques. Malgré ces caractéristiques communes, les matériaux, les détails de conception et le procédé de fabrication utilisés par les fabricants peuvent différer.

Certains essais ont été regroupés dans la classe des "essais de conception" et ne doivent être effectués qu'une seule fois sur des isolateurs présentant les mêmes conditions de conception. Pour tous les essais de conception de ces isolateurs composites, les articles communs appropriés définis dans l'IEC 62217 sont appliqués. Dans la mesure du possible, l'influence du temps sur les propriétés électriques et mécaniques de ses composants (noyau, revêtement, interfaces, etc.) et des isolateurs composites complets a été prise en compte lors de la spécification des essais de conception, afin de procurer une durée de vie satisfaisante des isolateurs dans les conditions de charge normalement connues pour les lignes de transport. L'Annexe A explique les principes de la limite d'endommagement, la coordination des charges et les essais associés.

Il n'a pas été jugé pertinent de spécifier un essai d'arc de puissance comme obligatoire. Les paramètres d'essai sont multiples et peuvent avoir des valeurs très différentes selon les configurations du réseau et des supports et la conception des dispositifs de protection contre les arcs. L'effet thermique des arcs de puissance doit être pris en compte dans la conception des armatures métalliques. Des dommages majeurs sur les armatures métalliques causés par l'amplitude et la durée du courant de court-circuit peuvent être évités par l'emploi de dispositifs de protection contre les arcs bien dimensionnés. Néanmoins, le présent document n'exclut pas la possibilité d'un essai d'arc de puissance sous réserve d'un accord entre le fabricant et le client. L'IEC 61467 donne des détails sur les essais d'arc de puissance en courant alternatif de chaînes équipées complètes, qui reproduisent fidèlement leur configuration avec des dispositifs de protection et de fixation réels, afin de recréer les champs électromagnétiques réels qui agissent sur le mouvement des arcs.

Le présent document couvre les isolateurs composites à courant alternatif et à courant continu. En attendant la publication de la norme pertinente pour les applications en courant continu, la majorité des essais définis dans le présent document peuvent également s'appliquer au courant continu (Annexe G). En raison de la différence entre les performances de cheminement en courant alternatif et en courant continu, il est prévu d'élaborer une procédure d'essai de cheminement et d'érosion spécifique pour les applications en courant continu dans le cadre d'un essai de conception. L'essai de cheminement et d'érosion en courant alternatif de 1 000 h de l'IEC 62217 peut être utilisé afin de définir une exigence minimale pour la résistance au cheminement et à l'érosion. Cet essai de cheminement et d'érosion au brouillard salin de 1 000 h est considéré comme un essai de sélection destiné à rejeter les matériaux associés à la conception qui ne sont pas appropriés. Les essais de cheminement et d'érosion ne sont pas destinés à évaluer les performances à long terme des isolateurs. Ces essais, par exemple l'essai sous contraintes multiples de 5 000 h et l'essai à la roue de l'IEC TR 62730 [1][1] ou d'autres essais, destinés à la recherche ou parfois utilisés comme essai de conception supplémentaire, ne sont pas pris en compte dans le présent document.

Les isolateurs composites de suspension et d'ancrage ne sont généralement pas prévus pour supporter des charges de torsion ou d'autres charges autres que la traction. Toutefois, pour les applications non normalisées (entretoises interphases, etc.), la conception doit prendre en compte les charges induites par la manipulation et l'installation. L'Annexe C fournit des recommandations pour les charges non normalisées.

1 Les chiffres entre crochets renvoient à la Bibliographie.

Le Guide 111 de l'IEC [2] a été suivi autant que possible pour l'élaboration du présent document.

ISOLATEURS POUR LIGNES AÉRIENNES – ISOLATEURS COMPOSITES DE SUSPENSION ET D'ANCRAGE DE TENSION SUPÉRIEURE À 1 000 V EN COURANT ALTERNATIF ET À 1 500 V EN COURANT CONTINU – DÉFINITIONS, MÉTHODES D'ESSAI ET CRITÈRES D'ACCEPTATION

1 Domaine d'application

La présente Norme internationale s'applique aux isolateurs composites pour lignes aériennes qui sont constitués d'un noyau isolant plein cylindrique réalisé en fibres – généralement de verre – qui supporte les charges. Ces isolateurs possèdent une matrice en résine, un revêtement (recouvrant le noyau isolant) en matériau élastomère et des armatures d'extrémité métalliques fixées au noyau isolant.

Les isolateurs composites couverts par le présent document sont destinés à être utilisés pour la suspension ou l'ancrage de lignes, mais ces isolateurs peuvent parfois être sollicités en compression ou en flexion, par exemple lorsqu'ils sont utilisés comme entretoises interphases. L'Annexe C fournit des recommandations pour ces types de charges.

L'objet du présent document est de:

– définir les termes utilisés;
– spécifier les méthodes d'essai;
– spécifier les critères d'acceptation.

Le présent document ne définit pas d'exigences concernant le choix des isolateurs destinés à des conditions ou des environnements d'exploitation spécifiques, qui diffèrent des conditions normales d'environnement indiquées dans le Tableau 1.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60060-1, *Techniques d'essai à haute tension – Partie 1: Définitions générales et exigences d'essai*

IEC 60383-1, *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*

IEC 60383-2, *Isolateurs pour lignes aériennes de tension nominale supérieure à 1 000 V – Partie 2: Chaînes d'isolateurs et chaînes d'isolateurs équipées pour systèmes à courant alternatif – Définitions, méthodes d'essai et critères d'acceptation*

IEC 60437, *Essai de perturbations radioélectriques des isolateurs pour haute tension*

IEC 61284, *Lignes aériennes – Exigences et essais pour le matériel d'équipement*

IEC 61466-1, *Éléments de chaîne d'isolateurs composites pour lignes aériennes de tension nominale supérieure à 1 000 V – Partie 1: Classes mécaniques et armatures d'extrémité normalisées*

IEC 61467, *Isolateurs pour lignes aériennes – Chaînes d'isolateurs et chaînes d'isolateurs équipées pour lignes de tension nominale supérieure à 1 000 V – Essais d'arc de puissance en courant alternatif*

IEC 62217:—[2], *Isolateurs polymériques à haute tension pour usage intérieur ou à l'extérieur – Définitions générales, méthodes d'essai et critères d'acceptation*

IEC 62231, *Isolateurs supports composites rigides à socle destinés aux postes à courant alternatif de tensions supérieures à 1 000 V jusqu'à 245 kV – Définitions, méthodes d'essai et critères d'acceptation*

ISO 3452 (toutes les parties), *Essais non destructifs – Examen par ressuage*

3 Termes, définitions et abréviations

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

Note 1 à l'article: Certains termes de l'IEC 62217:2012 sont reproduits ici pour faciliter l'utilisation de la norme. D'autres définitions relatives aux isolateurs peuvent être trouvées dans l'IEC 60050-471 [3].

3.1 Termes et définitions

3.1.1
isolateur polymérique
isolateur dont le corps isolant se compose d'au moins un matériau organique

Note 1 à l'article: Cette note ne s'applique qu'au texte anglais.

Note 2 à l'article: Des dispositifs de couplage peuvent être fixés aux extrémités du corps isolant.

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

3.1.2
isolateur composite
isolateur constitué d'au moins deux parties isolantes, un noyau et un revêtement, et équipé d'armatures d'extrémité

Note 1 à l'article: Les isolateurs composites, par exemple, peuvent être constitués soit d'ailettes individuelles montées sur le noyau, avec ou sans gaine intermédiaire, ou alternativement, d'un revêtement moulé ou coulé directement sur le noyau en une ou plusieurs parties.

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

[2] En preparation. Stade au moment de la publication: IEC/RFDIS 62217:2025.

3.1.3
noyau (d'un isolateur)
partie isolante interne d'un isolateur qui assure les caractéristiques mécaniques

Note 1 à l'article: Le revêtement et les ailettes ne font pas partie du noyau.

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

3.1.4
fût d'un isolateur
partie isolante centrale d'un isolateur situé entre les ailettes

Note 1 à l'article: Cette note ne s'applique qu'au texte anglais.

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

3.1.5
revêtement
partie isolante externe d'un isolateur composite, qui assure la ligne de fuite nécessaire et protège le noyau de l'environnement

Note 1 à l'article: Une gaine intermédiaire en matériau isolant peut faire partie du revêtement.

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

3.1.6
ailette (d'un isolateur)
partie isolante en saillie sur le fût d'un isolateur, destinée à augmenter la ligne de fuite

Note 1 à l'article: Une ailette peut être avec ou sans ondulations.

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

3.1.7
interface
surface de contact entre les différents matériaux

Note 1 à l'article: Les isolateurs composites comportent plusieurs interfaces, par exemple:

- entre le revêtement et les armatures d'extrémité;
- entre les différentes parties du revêtement, par exemple entre les ailettes fabriquées séparément ou entre les ailettes et la gaine;
- entre le noyau et le revêtement;
- entre le produit d'étanchéité et le noyau;
- entre le produit d'étanchéité et les armatures d'extrémité

(Annexe E: Croquis types pour l'assemblage des isolateurs composites

[SOURCE: IEC 62217:—, 3.11, modifiée – La modification apportée à la définition ne s'applique qu'au texte anglais, et la Note 1 à l'article a été modifiée]

3.1.8
armature de fixation,
armature d'extrémité
dispositif, faisant partie d'un isolateur, qui sert à fixer celui-ci à une structure de support, à un conducteur, à une partie d'un équipement ou à un autre isolateur

Note 1 à l'article: Lorsque le dispositif de fixation est métallique, l'appellation "armature métallique" est généralement utilisée.

Note 2 à l'article: Les armatures d'extrémité normalisées sont définies dans l'IEC 61466-1.

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

3.1.9
zone de connexion
zone dans laquelle la charge mécanique est transmise entre le noyau et l'armature d'extrémité

[SOURCE: IEC 62217:2012, 3.13, modifiée – "entre le corps isolant et l'armature de fixation" a été remplacé par "entre le noyau et l'armature d'extrémité"]

3.1.10
couplage
partie de l'armature d'extrémité qui transmet la charge aux accessoires externes à l'isolateur

[SOURCE: IEC 62217:2012, 3.14, modifiée – "armature de fixation" a été remplacé par "armature d'extrémité", et "matériel externe" a été remplacé par "accessoires externes"]

3.1.11
ligne de fuite
distance la plus courte ou somme des distances les plus courtes le long de la surface d'un isolateur entre deux parties conductrices qui supportent normalement la tension de service entre elles

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

3.1.12
distance d'arc
plus courte distance dans l'air à l'extérieur de l'isolateur entre les parties métalliques sur lesquelles on applique normalement la tension de service

Note 1 à l'article: Le terme "distance d'arc à sec" est également utilisé.

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

3.1.13
charge mécanique spécifiée
CMS
tenue en charge, spécifiée par le fabricant, qui est utilisée pour les essais mécaniques du présent document

3.1.14
charge mécanique individuelle
CMI
charge appliquée à l'ensemble des isolateurs composites assemblés au cours d'un essai mécanique de série

3.1.15
charge de rupture mécanique
charge maximale qui est atteinte lorsque l'isolateur est soumis à l'essai dans les conditions prescrites

[SOURCE: IEC 60050-471:2007, 471-01-12, modifié - modifiée – La modification apportée à la définition ne s'applique qu'au texte anglais, et la Note 1 à l'article a été supprimée]

3.1.16
chaîne équipée
assemblage d'une ou plusieurs chaînes d'isolateurs convenablement reliées et munies de tous les dispositifs de fixation et de protection prévus en service

Note 1 à l'article: Les termes "dispositifs d'extinction et de protection contre les champs" sont également utilisés pour désigner ces dispositifs de protection.

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

3.1.17
élément de chaîne d'isolateurs
isolateur à capot et tige ou isolateur à long fût dont les dispositifs de fixation sont conçus pour assurer une liaison flexible avec les autres éléments de chaîne similaires ou avec les accessoires de connexion

Note 1 à l'article: Les isolateurs à capot et tige ne sont pas des isolateurs composites et ne font pas partie du présent document.

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

3.1.18
étanchéité
méthode assurant l'aptitude d'un composant à résister à la pénétration d'agents atmosphériques polluants

Note 1 à l'article: Les agents atmosphériques polluants comprennent la pollution et l'humidité.

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

3.1.19
produit d'étanchéité (agent d'étanchéité)
matériau supplémentaire utilisé pour l'étanchéité

Note 1 à l'article: Généralement, des silicones RTV sont utilisés pour les isolateurs composites.

Note 2 à l'article: Voir le produit d'étanchéité à l'Annexe E: Schéma de principe type pour l'assemblage des isolateurs composites.

3.1.20
anneau de garde/anneau anti-effluves
dispositif de protection métallique fixé à l'armature d'extrémité de l'isolateur composite ou dispositif de fixation intermédiaire de la chaîne dont la fonction est de maintenir le champ électrique, en tout point le long de la surface de l'isolateur composite, au-dessous de la valeur maximale spécifiée

3.2 Abréviations

Les abréviations suivantes sont utilisées dans le présent document:

E1, E2	ensembles d'échantillons destinés aux essais sur prélèvements
M_{AV}	charge de rupture moyenne sur 1 min du noyau de l'isolateur assemblé avec ses armatures
CMI	charge mécanique individuelle
RTV (Room-Temperature-Vulcanizing Silicone)	silicone vulcanisé à température ambiante
CMS	charge mécanique spécifiée

4 Identification

Outre les exigences de l'IEC 62217, la CMS doit être apposée par marquage sur chaque isolateur.

Il est recommandé au fabricant de marquer ou d'étiqueter chaque isolateur pour indiquer que ce dernier a satisfait à l'essai mécanique de série.

5 Conditions d'environnement

Les conditions normales d'environnement auxquelles sont soumis les isolateurs en service sont définies dans l'IEC 62217 et indiquées dans le Tableau 1. Les termes sont définis comme suit:

- Environnement intérieur: installation à l'intérieur d'un bâtiment ou d'une autre construction dans laquelle les isolateurs sont protégés contre le vent, la pluie, la neige, les dépôts périodiques de pollution rapide, la condensation anormale, la glace et le givre.
- Environnement extérieur: installation à l'air libre, en dehors de tout bâtiment ou abri, dans laquelle les isolateurs sont soumis au vent, à la pluie, à la neige, aux dépôts périodiques de pollution rapide, à une condensation importante, à la glace et au givre.

Si les conditions de service des isolateurs polymériques s'écartent sensiblement des paramètres du Tableau 1, l'isolateur doit être conçu ou évalué dans le cadre d'un accord entre le client et le fabricant. Par ailleurs, si une expérience en service positive ("aucune défaillance") a été acquise pour un environnement et une conception d'isolateur spécifiques (y compris le matériau et le profil), l'isolateur peut être utilisé pour cet environnement spécifique, même en cas d'écart par rapport aux conditions normales d'environnement.

Tableau 1 – Conditions normales d'environnement

	Isolation intérieure	Isolation extérieure
Température de l'air ambiant maximale [a]	Ne dépasse pas 40 °C, et sa valeur moyenne mesurée sur une période de 24 h ne dépasse pas 35 °C	
Température de l'air ambiant minimale [b]	–25 °C	–40 °C
Vibrations	Vibrations mineures dues à des causes externes aux isolateurs ou à des secousses sismiques [c]	
Rayonnement solaire [d]	Non applicable	Jusqu'à un niveau de 1 120 W/m^2
Sévérité de pollution du site (SPS) [e]	Absence de pollution significative par poussière, fumée, gaz corrosifs et/ou inflammables, vapeurs, ou sel	Présence d'une pollution par poussière, fumée, gaz corrosifs, vapeurs ou sel. La pollution ne dépasse pas le niveau de la classe SPS "heavy" (élevée) définie dans l'IEC TS 60815-1 [5].
Humidité [f]	Absence de pluie, de neige, d'humidité anormale, de condensation, de glace et de givre	Présence de pluie, de neige, d'humidité anormale, de condensation, de glace et de givre

[a] En cas de dépassement de la température, suivre les recommandations de l'IEC TR 62039 [5] pour le noyau et les matériaux adhésifs (comme la colle) fournies dans le paragraphe "glass transition temperature".

[b] En général, les températures inférieures à –40 °C ne sont pas essentielles pour le service. Cependant, pour la manipulation et l'installation, la température de cristallisation du revêtement en polymère doit être prise en compte. Pour les installations de lignes exposées à des températures inférieures à –20 °C, des nuances d'acier spéciales présentant une faible température de transition ductile peuvent être spécifiées.

[c] Les vibrations dues à des causes externes peuvent être traitées conformément à l'IEC 60721-1 [6].

[d] Pour les applications extérieures, l'influence d'un écart par rapport au niveau indiqué de 1 120 W/m^2 dépend du matériau de l'isolateur.

Si les conditions de service des isolateurs polymériques s'écartent sensiblement des paramètres du Tableau 1, l'isolateur doit être conçu/évalué en tenant compte de l'expérience acquise en service. Si l'expérience acquise en service n'est pas suffisante, des essais spéciaux simulant les conditions de rayonnement solaire de la zone d'installation doivent être effectués.

[e] En général, la pollution n'est pas problématique pour les isolateurs pour usage intérieur. Dans certains cas particuliers, comme les conditions intérieures en courant continu, les isolateurs peuvent être plus ou moins contaminés par les champs électriques générés par le courant continu.

Cependant, le phénomène de contournement dû à la pollution ne peut pas se produire lorsque l'humidité est maîtrisée. Pour les conditions extérieures, l'IEC 62217 spécifie des exigences pour les contraintes rencontrées dans des environnements relativement difficiles, mais pas extrêmes (voir, par exemple, les essais de contrôle de l'hydrophobie et les essais de cheminement et d'érosion pour lesquels des critères sont fournis dans l'IEC TR 62039).

[f] Si les écarts sont limités par rapport aux conditions susmentionnées, les isolateurs pour usage intérieur peuvent également être utilisés sous réserve qu'une expérience en service positive ("aucune défaillance") ait été acquise et si la condensation est occasionnelle.

Pour limiter les phénomènes liés à la condensation, la valeur moyenne de la condition d'humidité anormale mesurée ne dépasse pas 95 % lorsqu'elle est mesurée sur une période de 24 h ou 90 % lorsqu'elle est mesurée sur une période d'un mois. Le dépassement de ces valeurs est considéré comme une condition d'humidité anormale.

6 Transport, stockage et installation

Outre les exigences de l'IEC 62217, des informations relatives à la manipulation des isolateurs composites peuvent être trouvées dans les documents TB 184 [7] et TB 919 [9] du CIGRÉ. Pendant l'installation ou lorsqu'ils sont utilisés dans des configurations non normalisées, les isolateurs composites peuvent être soumis à de fortes contraintes de torsion, de compression ou de flexion pour lesquelles ils n'ont pas été conçus. L'Annexe C fournit des recommandations pour ces types de charges.

Lorsque cela est exigé, il convient de fournir au client les instructions d'assemblage des anneaux de garde/anneaux anti-effluves, qui expliqueront notamment comment positionner et installer correctement les anneaux de garde/anneaux anti-effluves sur les isolateurs.

7 Tolérances

Sauf spécification contraire, une tolérance de

± (0,04 × d + 1,5) mm lorsque $d \leq 300$ mm,

± (0,025 × d + 6) mm lorsque $d > 300$ mm avec une tolérance maximale d ± 50 mm

doit être autorisée sur toutes les dimensions pour lesquelles des tolérances spécifiques ne sont pas demandées ou indiquées sur le plan de l'isolateur (dimension d exprimée en millimètres).

Les lignes de fuite mesurées doivent être cohérentes avec les dimensions et les tolérances de conception déterminées à partir du plan de l'isolateur, même si cette dimension est supérieure à la valeur initialement spécifiée. Lorsqu'une ligne de fuite minimale est spécifiée, la tolérance négative sur la ligne de fuite minimale est de zéro.

Pour les isolateurs présentant une ligne de fuite supérieure à 3 m, il est permis de mesurer une courte section de l'isolateur sur une longueur de 1 m environ et d'effectuer le calcul par extrapolation, à condition que les longueurs non mesurées aient les mêmes diamètres, profils et espacements des ailettes que la section mesurée sur laquelle est effectuée l'extrapolation.

8 Classification des essais

8.1 Essais de conception

L'objet des essais de conception est de vérifier l'adéquation de la conception, des matériaux et de la méthode (technologie) de fabrication. Une conception d'isolateur composite est définie par les éléments suivants:

– matériaux de revêtement, y compris leur formulation et le procédé de fabrication utilisé;
– matériaux de noyau;
– matériaux, procédé de fabrication et méthode de fixation (à l'exclusion du couplage) des armatures d'extrémité;
– épaisseur du revêtement recouvrant le noyau (y compris la gaine le cas échéant);
– diamètre du noyau;
– interfaces:
  - conception de l'interface noyau/revêtement, y compris le type d'agent de couplage (primaire) et l'assemblage;
  - conception de l'interface revêtement/armature d'extrémité;
  - interface noyau/armature d'extrémité;
  - interfaces fût/ailette et fût/fût (le cas échéant).

Si des modifications sont apportées à la conception d'un isolateur, une requalification doit alors être effectuée conformément au Tableau 2.

Lorsqu'un isolateur composite est soumis aux essais de conception, il devient un isolateur de conception équivalente pour une conception donnée et les résultats doivent être considérés comme valables pour cette conception seulement. L'isolateur de conception équivalente, qui a ainsi été soumis aux essais, définit une conception particulière d'isolateurs partageant l'ensemble des caractéristiques suivantes:

a) matériaux identiques (y compris leurs formulations) du noyau et du revêtement et méthode de fabrication identique (y compris le procédé d'assemblage du revêtement);
b) matériau identique des armatures, conception identique de l'interface noyau/armature d'extrémité et géométrie identique de l'interface revêtement/armature;
c) épaisseur de couche minimale du revêtement recouvrant le noyau (y compris la gaine le cas échéant) identique ou supérieure;
d) contrainte sous charges mécaniques identique ou inférieure;

NOTE Par exemple, la CMS peut servir de charge de référence mécanique. La contrainte est calculée en divisant la charge par la section du noyau.

e) diamètre du noyau identique ou supérieur;
f) paramètres de profil de revêtement équivalents, voir la Note (a) dans le Tableau 2.

8.2 Essais de type

L'objet des essais de type est de vérifier les caractéristiques principales d'un isolateur composite, qui dépendent essentiellement de la forme et de la taille de l'isolateur. Ils permettent également de confirmer les caractéristiques mécaniques du noyau assemblé (voir l'Article A.4). Ils sont effectués sur des isolateurs dont la classe a satisfait aux essais de conception.

Un type d'isolateur est défini électriquement par la distance d'arc, la ligne de fuite, l'inclinaison, la projection et l'espacement des ailettes d'un isolateur.

En outre, le Tableau 2 répertorie les caractéristiques de conception des isolateurs qui, lorsqu'elles sont modifiées, exigent également la répétition des essais électriques de type.

Un type d'isolateur est défini mécaniquement par une CMS maximale pour un diamètre de noyau, une méthode de fixation et une conception des couplages donnés. L'Annexe A traite de la coordination type entre la CMS et les charges de service.

Les essais mécaniques de type doivent être effectués une seule fois sur les isolateurs remplissant les critères ci-dessus pour chaque type.

En outre, le Tableau 2 répertorie les autres caractéristiques de conception des isolateurs qui, lorsqu'elles sont modifiées, exigent également la répétition des essais mécaniques de type.

8.3 Essais sur prélèvements

L'objet des essais sur prélèvements est de vérifier les autres caractéristiques des isolateurs composites, notamment celles qui dépendent de la qualité de fabrication et des matériaux utilisés. Ils sont effectués sur des isolateurs prélevés de manière aléatoire dans les lots présentés pour acceptation.

8.4 Essais individuels de série

L'objet des essais individuels de série est d'éliminer les isolateurs composites qui présentent des défauts de fabrication. Des essais individuels de série sont effectués sur chaque isolateur composite.

Tableau 2 – Essais à effectuer après des modifications de conception

Si la modification de conception de l'isolateur concerne:				**ALORS** les essais suivants doivent être répétés:											
				Essais de conception										**Essais de type**	
		IEC 62217	IEC 61109	IEC 62217 Essais sur le revêtement du matériau					IEC 62217 Essais sur le matériau du noyau			IEC 62217 Essais sur le noyau avec le revêtement		IEC 61109	
		Interfaces et connexions des armatures d'extrémité	**Essais de charge-temps du noyau assemblé**	**Essai de dureté**	**Essai climatique accéléré**	**Essai de cheminement et d'érosion**	**Essai d'inflammabilité**	**Essai de transfert d'hydrophobie**	**Essai de pénétration de colorant**	**Essai de pénétration d'eau**	**Essai de corrosion sous contrainte**	**Essai de pénétration d'eau sur le noyau avec le revêtement**		**Essais électriques de type**	**Essais mécaniques de type**
1	Revêtement														
1a	Matériau, formulation [1] ou procédé de fabrication [2]	X	X	X	X d)	X	X d)	X e)				X			
1b	Procédé d'assemblage [2]	X b)				X									X b)
1c	Profil					X a)								X a)	
2	Noyau														
2a	Matériau, formulation ou procédé de fabrication [3]	X	X						X	X	X a),d),e)	X			X
2b	Diamètre	X b),c)	X b), c)			X b)			X b)	X b)		X b)			X b),c)
3	Armature d'extrémité														
3a	Matériau ou procédé de fabrication ou procédé d'assemblage [4]	X	X												X
3b	Conception de la zone de connexion de l'armature d'extrémité [5]	X	X												X
3c	Type de couplage														X
4	Interface														
4a	Conception de l'interface noyau/revêtement [6]	X										X			
4b	Conception de l'interface revêtement/armature d'extrémité [7]	X				X									X
4c	Conception de l'interface fût/ailette [8]	X				X						X			

[a] Pas nécessaire si l'épaisseur du revêtement recouvrant le noyau (y compris la gaine le cas échéant) est supérieure ou égale à celle de l'isolateur de conception équivalente. Les nombres relatifs suivants sont fournis à titre de référence et ne constituent pas une modification du profil:

– projection des ailettes:	±10 %;
– épaisseur des ailettes à la base et à l'extrémité:	±15 %;
– espacement des ailettes:	±15 %;
– inclinaisons des ailettes:	±3°;
– répétition des ailettes:	identique.

Ces tolérances relativement strictes peuvent entraîner une augmentation de la demande d'essais de cheminement et d'érosion en raison de la variété des profils de revêtement existants. Certains paramètres du profil, comme la projection et l'espacement des ailettes, peuvent causer de telles variations. Par conséquent, les écarts d'un profil candidat, qui dépassent les tolérances susmentionnées pour la projection et l'espacement des ailettes, peuvent être adaptés par accord entre le fabricant et le client si le profil candidat ne dépasse pas les écarts mineurs définis dans l'IEC TS 60815-3 [10] pour la projection et l'espacement des ailettes par rapport aux profils d'ailettes qui ont satisfait à l'essai de cheminement et d'érosion. Les paramètres du profil candidat doivent alors se situer entre les paramètres du profil qui a été soumis à l'essai.

[b] Des variations du diamètre du noyau de ±15 % ne constituent pas une modification.

[c] Pas nécessaire si la contrainte sous charges mécaniques est identique ou inférieure.

[d] Pas nécessaire en cas de modification du procédé de fabrication sans changement de matériau.

[e] Applicable aux matériaux qui doivent posséder cette propriété.

[1] Matériaux de revêtement/formulations:

éthylène propylène diène monomère (EPDM), silicone vulcanisé à haute température, caoutchouc silicone liquide, silicone vulcanisé à température ambiante, etc.

Formulation: toute modification dans la formulation du matériau, que ce soit par des changements d'ingrédients ou de leur dosage (cet aspect peut être vérifié par un contrôle à la réception, par exemple l'essai d'empreinte selon le document TB 595 [10] du CIGRÉ).

[2] Processus de fabrication/assemblage du revêtement:

Fabrication: moulage par injection, procédé modulaire, moulage par compression en une seule pièce.

Assemblage: l'ailette et la gaine sont assemblées séparément.

[3] Matériaux des noyaux (résine polyester, résine époxy, ...), leur formulation (par exemple, teneur en verre) et procédé de fabrication associé (par exemple, pultrusion, enroulement filamentaire).

[4] Matériaux des armatures d'extrémité (acier, fonte ductile, fonte malléable), procédé de fabrication associé (forgeage, moulage) et méthode de fixation associée (à l'exclusion du couplage).

[5] Conception de la zone de connexion de l'armature d'extrémité: conception de l'interface noyau/armature d'extrémité (par exemple, surface de sertissage: diamètre du noyau et longueur de sertissage, rugosité, etc.).

[6] Conception de l'interface noyau/revêtement, y compris le type d'agent de couplage (primaire) et l'assemblage.

[7] Interfaces revêtement/armature d'extrémité (par exemple, surmoulées/non surmoulées).

[8] interfaces fût/ailettes et fût/fût le cas échéant.

NOTE L'Annexe E fournit des croquis des différents types d'interfaces.

9 Essais de conception

9.1 Généralités

Ces essais comprennent les essais spécifiés dans l'IEC 62217 ainsi qu'un essai spécifique de charge-temps du noyau assemblé, indiqué dans le Tableau 3. Les essais de conception sont effectués une seule fois, et leurs résultats sont consignés dans un rapport d'essai. Chaque partie peut être effectuée indépendamment sur des éprouvettes neuves, le cas échéant. L'isolateur composite d'une conception particulière ne doit être qualifié que lorsque les isolateurs ou éprouvettes ont tous satisfait aux essais de conception.

Tableau 3 – Essais de conception

Essais sur les interfaces et les connexions des armatures d'extrémité
Essai de décharge disruptive à fréquence industrielle à sec de référence
Précontraintes – Précontrainte par suppression brutale de la charge Précontrainte thermomécanique (voir le 9.3.1 et le 9.3.2)
Précontrainte par immersion dans l'eau
Essais de vérification
Examen visuel
Essai sous onde de choc à front raide
Essais de tension à fréquence industrielle à sec
Essais sur le matériau du revêtement
Essai de dureté
Essai climatique accéléré
Essai de cheminement et d'érosion – voir le 9.2.2 pour les spécimens
Essai d'inflammabilité
Essai de transfert d'hydrophobie
Essais sur le matériau du noyau – voir le 9.2.3 pour les spécimens
Essai de pénétration de colorant
Essai de pénétration d'eau
Essai de corrosion sous contrainte
Essais sur le noyau avec le revêtement – voir le 9.2.4 pour les spécimens
Essai de pénétration d'eau sur le noyau avec le revêtement
Essai de charge-temps du noyau assemblé – voir le 9.4 pour les spécimens
Détermination de la charge de rupture moyenne du noyau de l'isolateur assemblé
Vérification de la tenue en charge sur 96 h

L'Annexe G traite de l'applicabilité des essais de conception pour les applications en courant continu.

9.2 Éprouvettes

9.2.1 Essais sur les interfaces et les connexions des armatures d'extrémité

Trois isolateurs prélevés sur la chaîne de production doivent être soumis à l'essai. La longueur d'isolement (espacement des parties métalliques) ne doit pas être inférieure à 800 mm. Les deux armatures d'extrémité doivent être identiques à celles qui équipent les isolateurs de production normale. Les armatures d'extrémité doivent être assemblées de telle sorte que la partie isolante entre l'armature et l'ailette la plus proche soit identique à celle de l'isolateur prélevé sur la chaîne de production. Si des entretoises, des bagues de fixation ou d'autres composants créant des interfaces sont utilisés dans la conception de l'isolateur (en particulier les isolateurs plus longs), le prélèvement doit inclure ces dispositifs dans leur position normale.

NOTE 1 Un quatrième isolateur peut être nécessaire pour l'étalonnage du circuit d'essai sous onde de choc à front raide.

NOTE 2 Si le fabricant ne peut produire que des isolateurs de moins de 800 mm, les essais de conception peuvent être effectués sur des isolateurs de la longueur disponible, mais les résultats ne seront valables que jusqu'aux longueurs soumises à l'essai.

9.2.2 Essai de cheminement et d'érosion

Si la conception de l'isolateur (en particulier les isolateurs plus longs) incorpore des entretoises, des bagues de fixation ou d'autres composants qui créent des interfaces, les prélèvements pour cet essai doivent inclure ces dispositifs dans leur position normale.

La ligne de fuite de l'échantillon doit être comprise entre 500 mm et 800 mm, comme cela est spécifié dans l'IEC 62217. Si la présence d'entretoises ou de joints (voir ci-dessus) exige une ligne de fuite plus élevée, les essais de conception peuvent être effectués sur des isolateurs qui présentent des distances de fuite d'une longueur la plus proche possible de 800 mm. Si le fabricant ne peut produire que des isolateurs avec une ligne de fuite inférieure à 500 mm, les essais de conception peuvent être effectués sur des isolateurs de la longueur disponible, mais les résultats ne seront valables que jusqu'aux longueurs soumises à l'essai.

9.2.3 Essais sur le matériau du noyau

Les spécimens, la méthode d'essai et les critères d'acceptation doivent être conformes aux spécifications de l'IEC 62217.

9.2.4 Essais sur le noyau avec le revêtement

Les spécimens, la méthode d'essai et les critères d'acceptation doivent être conformes aux spécifications de l'IEC 62217.

NOTE L'Annexe F décrit les méthodes mécaniques supplémentaires applicables pour vérifier le niveau d'adhérence à l'interface noyau/revêtement. Pour les essais de conception, la méthode A est préférentielle. Si un essai de pénétration d'eau sur le noyau avec le revêtement et des essais d'arrachement sont effectués, les mêmes spécimens que ceux utilisés préalablement lors de l'essai de pénétration d'eau sur le noyau avec le revêtement peuvent être utilisés pour l'essai d'arrachement, comme cela est décrit à l'Annexe F.

9.3 Précontrainte spécifique au produit pour les essais sur les interfaces et les connexions des armatures d'extrémité

9.3.1 Généralités

Les essais doivent être effectués sur les trois spécimens, selon la séquence décrite dans le présent paragraphe.

9.3.2 Suppression brutale de la charge

L'objet de cet essai est d'appliquer une précontrainte sur l'ensemble des interfaces et connexions, y compris l'interface ailette/fût. Il ne porte pas sur la connexion des armatures d'extrémité uniquement.

Lorsque la température de l'isolateur est comprise entre -20 °C et -25 °C au début du test, chaque éprouvette est soumise pendant au moins 1 min à cinq suppressions brutales d'une charge de traction correspondant à 30 % de la CMS.

L'Annexe B décrit deux exemples de dispositifs possibles pour la suppression brutale de la charge. Si un autre procédé/dispositif est utilisé, la durée de suppression brutale de la charge doit être < 50 ms.

NOTE Dans certains cas, une température plus basse peut être fixée par accord.

9.3.3 Précontrainte thermomécanique

Avant de commencer l'essai, les spécimens doivent être soumis à température ambiante à au moins 5 % de la CMS pendant 1 min. La longueur des spécimens doit être mesurée avec une exactitude de 0,5 mm pendant cette période. Cette longueur doit être prise comme la longueur de référence.

Les spécimens sont ensuite soumis à des cycles de température sous une charge mécanique continue (voir la Figure 1), en exécutant quatre fois le cycle de température de 24 h. Chaque cycle de 24 h consiste en l'application de deux niveaux de température pendant au moins 8 h chacun, l'un à (+50 ± 5) °C et l'autre à (–35 ± 5) °C. La période froide doit correspondre à une température d'au moins 85 K au-dessous de la valeur réellement appliquée pendant la période chaude. La précontrainte peut être appliquée dans l'air ou tout autre milieu adapté.

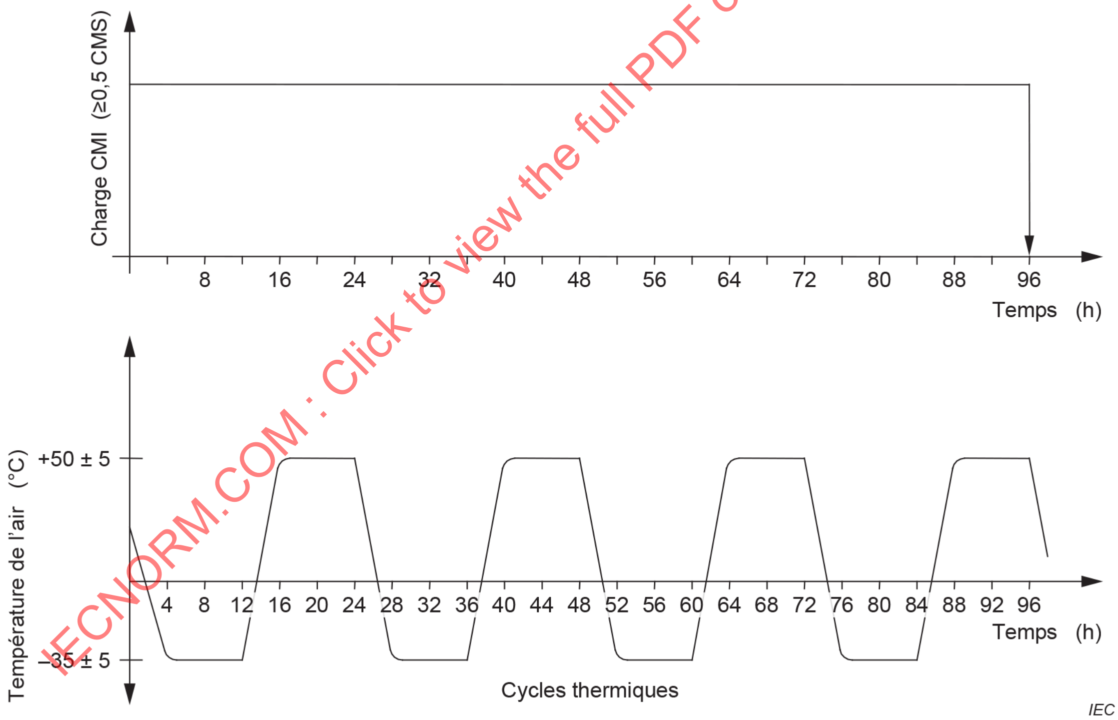

Figure 1 – Précontrainte thermomécanique

La charge mécanique appliquée doit être égale à la CMI (au moins 50 % de la CMS) du spécimen. Le spécimen doit être soumis, à température ambiante, à une charge avant de commencer le premier cycle thermique.

Les cycles peuvent être interrompus pour effectuer l'entretien du matériel d'essai pour une durée totale de 2 h. Le point de départ après toute interruption doit être le début du cycle interrompu.

Après l'essai, la longueur doit de nouveau être mesurée de manière similaire, sous la même charge et à la température initiale du spécimen (afin d'obtenir des informations supplémentaires concernant le déplacement relatif des armatures métalliques).

NOTE 1 Les températures et les charges dans cette précontrainte ne sont pas destinées à représenter les conditions de service, mais ont pour objet de produire des contraintes reproductibles spécifiques au niveau des interfaces de l'isolateur.

NOTE 2 Dans certains cas, une température plus basse peut être fixée par accord.

9.4 Essais de charge-temps du noyau assemblé

9.4.1 Éprouvettes

Six isolateurs prélevés sur la chaîne de production doivent être soumis à l'essai. La longueur d'isolement (espacement des parties métalliques) ne doit pas être inférieure à 800 mm. Les deux armatures d'extrémité doivent être identiques en tout point à celles qui équipent les isolateurs prélevés sur la chaîne de production, excepté qu'elles peuvent être modifiées en aval de l'extrémité de la zone de connexion afin d'éviter une défaillance des couplages.

Les six isolateurs doivent être soumis à un examen visuel, en vérifiant notamment que leurs dimensions sont conformes aux plans.

NOTE Si le fabricant ne peut produire que des isolateurs de moins de 800 mm, les essais de conception peuvent être effectués sur des isolateurs de la longueur disponible, mais les résultats ne seront valables que jusqu'aux longueurs soumises à l'essai.

9.4.2 Essai de charge mécanique

9.4.2.1 Généralités

Cet essai est effectué en deux parties, à température ambiante.

9.4.2.2 Détermination de la charge de rupture moyenne du noyau de l'isolateur assemblé (M_{AV})

Trois des isolateurs composites doivent être soumis à une charge de traction. Cette charge de traction doit être augmentée rapidement, mais sans à-coups, de zéro à environ 75 % de la CMS. Elle doit ensuite être augmentée progressivement dans un délai de 30 s à 90 s jusqu'à la CMS. Lorsque celle-ci est atteinte, la charge est augmentée progressivement jusqu'à la rupture ou l'arrachement complet du noyau. La moyenne des trois charges de rupture M_{AV} doit être calculée.

9.4.2.3 Vérification de la tenue en charge sur 96 h

Les trois isolateurs composites restants doivent être soumis à une charge de traction. Cette charge de traction doit être augmentée rapidement, mais sans à-coups, de zéro à 60 % de la M_{AV}, calculée au 9.4.2.2. Elle doit être maintenue à cette valeur pendant 96 h sans défaillance (rupture ou arrachement complet). Si l'application de la charge est interrompue pour une quelconque raison, alors l'essai doit être redémarré sur un spécimen neuf.

10 Essais de type

10.1 Généralités

L'Annexe G traite de l'applicabilité des essais de type pour les applications en courant continu.

10.2 Essais électriques sur les éléments de chaîne d'isolateurs

10.2.1 Généralités

Les essais électriques de type doivent être effectués une seule fois sur les isolateurs composites remplissant les conditions indiquées dans le Tableau 2. Si des dispositifs de protection contre les arcs et de maîtrise des champs électriques sont utilisés en service et qu'ils sont incorporés à une conception d'isolateur donnée, ces dispositifs doivent être utilisés pour les essais électriques des éléments de chaîne d'isolateurs conformément aux plans et aux spécifications du fabricant.

Les essais électriques spécifiés dans le présent document font partie des essais de type de produit et sont valables pour des éléments de chaîne d'isolateurs spécifiques. Ces essais et leurs résultats diffèrent de ceux applicables aux chaînes équipées entièrement assemblées, en raison de la configuration des pièces de garde et des conducteurs associés. C'est pourquoi il est nécessaire de déterminer si les valeurs électriques spécifiées s'appliquent à un élément de la chaîne d'isolateurs en particulier ou à la chaîne équipée complète. Le Tableau 4 indique l'application des éléments de chaîne d'isolateurs et des chaînes équipées.

Les résultats des essais électriques peuvent être déterminés par interpolation pour les éléments de chaîne d'isolateurs de longueur intermédiaire, à condition que le facteur entre les distances d'arc des isolateurs observées aux bornes de la plage d'interpolation, soit inférieur ou égal à 1,5. Il n'est pas autorisé de procéder par extrapolation.

Les valeurs et les procédures d'essai dépendent généralement de l'application (usage en intérieur ou en extérieur) et doivent donc être appliquées conformément aux spécifications du client.

NOTE Les essais électriques de type des éléments de chaîne d'isolateurs peuvent être effectués dans des conditions spécifiques au client, si cela est exigé et fixé par accord entre le fabricant et le client.

10.2.2 Éprouvettes

Un isolateur prélevé sur la chaîne de production doit être soumis à l'essai. L'isolateur doit être soumis à un examen visuel, en vérifiant notamment que ses dimensions sont conformes aux plans.

Si un élément de chaîne d'isolateurs incorpore des anneaux de protection contre les champs électriques (anneaux de garde) et que ceux-ci sont spécifiés dans le plan du produit d'un fabricant, ces anneaux doivent être utilisés lors de l'essai.

10.2.3 Configurations de montage pour les essais électriques

Les configurations de montage pour les essais électriques sur les éléments de chaîne d'isolateurs doivent être conformes aux spécifications du Tableau 4.

Les essais doivent être effectués conformément à l'IEC 60060-1.

10.2.4 Essai de tension de tenue aux chocs de foudre à sec

Le circuit d'essai, la tension d'essai et la procédure d'essai doivent être conformes aux critères définis dans l'IEC 60060-1.

Cet essai s'applique aux éléments de chaîne d'isolateurs destinés à être utilisés en intérieur et en extérieur.