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Lignes aériennes –

Exigences et essais pour le matériel d'équipement

Overhead lines –

Requirements and tests for fittings

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For general terminology, readers are referred to IEC 60050: *International Electrotechnical Vocabulary* (IEV).

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IEC publications prepared by the same technical committee

The attention of readers is drawn to the end pages of this publication which list the IEC publications issued by the technical committee which has prepared the present publication.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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OVERHEAD LINES –

REQUIREMENTS AND TESTS FOR FITTINGS

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61284 has been prepared by IEC technical committee 11: Overhead lines.

This second edition cancels and replaces the first edition published in 1995 and constitutes a technical revision.

The text of this standard is based on the following documents:

FDIS	Report on voting
11/119/FDIS	11/133/RVD

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

Annexes A, B, C, D and E form an integral part of this standard.

Annexes F, G, H, I and J are for information only.

The contents of the corrigendum of Septembre 1998 have been included in this copy.

OVERHEAD LINES –

REQUIREMENTS AND TESTS FOR FITTINGS

1 Scope

This International Standard applies to fittings for overhead lines of nominal voltage above 45 kV. It may also be applied to fittings for overhead lines of lower nominal voltage and to similar fittings for substations.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication of this standard, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60050(466): 1990, *International Electrotechnical Vocabulary (IEV) – Chapter 466: Overhead lines*

IEC 60060-1: 1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60120: 1984, *Dimensions of ball and socket couplings of string insulator units*

IEC 60372: 1984, *Locking devices for ball and socket couplings of string insulator units – Dimensions and tests*

IEC 60471: 1977, *Dimensions of clevis and tongue couplings of string insulator units*

IEC 60826: 1991, *Loading and strength of overhead transmission lines*

IEC 61089: 1991, *Round wire concentric lay overhead electrical stranded conductors*

CISPR 16-1: 1993, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1: Radio disturbance and immunity measuring apparatus*

CISPR 18-2: 1986, *Radio interference characteristics of overhead power lines and high-voltage equipment – Part 2: Methods of measurement and procedure for determining limits*

ISO 1461, — *Hot dip galvanized coatings on fabricated ferrous products – Specifications*[1)]

[1)] To be published.

ISO 9000-1: 1994, *Quality management and quality assurance standards – Part 1: Guidelines for selection and use*

ISO 9001: 1994, *Quality systems – Model for quality assurance in design, development, production, installation and servicing*

ISO 9002: 1994, *Quality systems – Model for quality assurance in production, installation and servicing*

ISO 9003: 1994, *Quality systems – Model for quality assurance in final inspection and test*

ISO 9004-1: 1994, *Quality management and quality system elements – Part 1: Guidelines*

ISO 2859-1: 1989, *Sampling procedures for inspection by attributes – Part 1: Sampling plans indexed by acceptable quality level (AQL) for lot-by-lot inspection*

ISO 2859-2: 1985, *Sampling procedures for inspection by attributes – Part 2: Sampling plans indexed by limiting quality (LQ) for isolated lot inspection*

ISO 3951: 1989, *Sampling procedures and charts for inspection by variables for percent non-conforming*

3 Definitions

For the purpose of this International Standard the following definitions apply. These definitions are those which do not appear in the International Electrotechnical Vocabulary (IEV) or differ from those given in the IEV.

3.1 **ball and socket coupling:** Coupling consisting of a ball, a socket and a locking device.

3.2 **bimetallic fitting:** Device which is suitable for jointing conductors of different materials.

3.3 **characteristic dimension:** Dimension of a component of the test circuit or of a fitting which characterizes its effect on the electric field. In the case of a bundle, this dimension is approximately the diameter of an enclosing circle; in the case of a corona ring or sphere, it is its largest dimension, etc.

3.4 **clevis and tongue coupling:** Coupling consisting of a clevis, a tongue and a clevis pin or bolt.

3.5 **connector:** Device for jointing one or more conductors or earth wires. It may be a tension or non-tension fitting.

3.6 **corona discharge:** Electric discharge that only partially breaks down the gas insulation around the fittings under test.

3.7 **corona extinction:** Voltage or conductor voltage gradient at which corona discharges cease during a decreasing test voltage sequence.

3.8 **corona inception:** Voltage or conductor voltage gradient at which corona discharges initiate during an increasing test voltage sequence.

3.9 **earth wire fitting:** Any component of an assembly for attaching an earth wire to a supporting structure other than a suspension clamp, a tension fitting or a mechanical protective fitting.

3.10 **factory-formed helical conductor fitting:** Fitting consisting of helically formed wires which provide the force necessary to grip the conductor or earth wire by self-tightening.

3.11 **insulator set fitting:** Any component of a suspension or tension insulator set other than a string insulator unit, a suspension clamp, a conductor tension fitting, an insulator protective fitting or a mechanical protective fitting.

3.12 **joint:** Connector and that part of the conductor or earth wire that has been brought into intimate contact with it by compression or other mechanical means.

3.13 **mechanical damage load:** Maximum load which can be applied to a fitting without an unacceptable permanent deformation when the fitting is tested under specified test conditions.

NOTE – The unacceptable permanent deformation should be agreed upon between purchaser and supplier.

3.14 **mechanical failure load:** Maximum load which can be applied to a fitting under specified test conditions.

3.15 **mechanical protective fitting:** Any device attached to a conductor or to an earth wire for their mechanical protection.

3.16 **radio-interference voltage (RIV):** Voltage in the radio frequency range produced by an electromagnetic disturbance and which can be measured in accordance with CISPR 16 on the test circuit equipped with the fitting.

3.17 **spacer damper:** Device which keeps apart the subconductors of a bundle in a given geometrical configuration and is able to reduce aeolian vibrations and subspan oscillations of the subconductors. [IEV 466-11-02, modified]

3.18 **specified maximum radio-interference voltage:** Maximum acceptable radio-interference voltage at a specified test voltage or conductor voltage gradient. This is specified by the purchaser or declared by the supplier.

3.19 **specified minimum corona extinction:** Minimum acceptable voltage or conductor voltage gradient at which corona discharges cease. This is specified by the purchaser or declared by the supplier.

3.20 **specified minimum failure load:** Minimum load specified by the purchaser or declared by the supplier at which mechanical failure will not take place.

NOTE – From the probabilistic point of view, the specified minimum failure load corresponds to the value having the probability of e % in the distribution function of the strength of the fitting. The exclusion limit e % is usually taken within 2 % to 5 % with 10 % being the upper limit (see IEC 60826).

3.21 **specified minimum mechanical damage load:** Minimum load specified by the purchaser or declared by the supplier at which unacceptable permanent deformation will not take place.

3.22 **specified minimum slip load:** Minimum load specified by the purchaser or declared by the supplier at which slippage will not take place.

3.23 **vibration damper:** Device attached to a conductor or an earth wire in order to reduce aeolian vibrations. [IEV 466-11-16, modified]

4 Requirements

4.1 *General requirements*

4.1.1 *Design*

The fittings shall be designed so as to

- avoid damaging the conductor under service conditions;
- withstand the mechanical loads relevant to installation, maintenance and service, the designed service current, including short-circuit current, the service temperatures and environmental circumstances;
- ensure that individual components are secured against becoming loose in service;
- have limited corona effects.

Fittings for live line maintenance shall be suitably designed for safe and easy handling.

Surfaces of compression fittings in contact with the conductor or earth wire shall be protected from becoming contaminated before installation.

Brittleness of finished parts shall be avoided by adopting suitable materials and manufacturing process.

4.1.2 *Materials*

Fittings shall be made of any material suitable for the purpose.

4.1.2.1 *Metallic materials*

The materials shall meet service life requirements and shall not be liable to intergranular or stress corrosion. They shall not cause corrosion of any other parts of the conductor or earth wire.

The materials of compression fittings shall be capable of withstanding the cold working due to compression. Furthermore, the steel compression components shall also have a sufficient impact strength after the compression.

Examples of suitable materials are the following:

- aluminium or aluminium alloy;
- galvanized steel;
- galvanized malleable or ductile iron;
- stainless steel;
- copper and copper alloys.

It is recommended that ISO standards for materials be used where they exist. Examples of ISO standards for fitting materials are listed in annex F.

4.1.2.2 *Non-metallic materials*

Non-metallic materials employed shall have good resistance to ageing and be capable of withstanding service temperatures without detrimental change of properties. Materials shall have adequate resistance to the effects of ozone, ultra-violet radiation and air pollution over the whole range of the service temperature.

They shall not induce corrosion in materials which are in contact with them.

4.1.3 *Dimensions and tolerances*

The dimensions shall be shown on contract drawings.

Particular regard shall be paid to those dimensions which involve interchangeability, correct assembly, and those for which gauges are specified. Reference shall be made to relevant standards, for example IEC 60120, IEC 60372, etc.

Tolerances applied to dimensions shall ensure that the fittings meet their specified mechanical and electrical requirements.

4.1.4 *Protection against corrosion*

All parts of insulator, conductor and earth wire fittings shall be either inherently resistant to atmospheric corrosion or be suitably protected against corrosion, such as can occur in transport, storage and in service. All ferrous parts which will be exposed to the atmosphere in service, except those made of appropriate stainless steel, shall be protected by hot dip galvanizing in accordance, for example, with ISO 1461 or other means giving equivalent protection.

Moreover, unless special measures are taken, there shall never be contact between metals for which the difference in electrochemical potential can give rise to galvanic corrosion capable of impairing the efficiency of the whole equipment. This applies especially to those parts of the fittings that are in direct contact with the conductor.

All external threads shall be cut or rolled before hot dip galvanizing. Internal threads can be cut before or after hot dip galvanizing. If cut after galvanizing they shall be oiled or greased.

4.1.5 *Marking*

Marking shall ensure the system of traceability for each of the component parts of the fittings.

When practicable, and unless otherwise agreed between purchaser and manufacturer, fittings shall be clearly and indelibly marked as follows:

Fittings used as individual components

Castings

a) identification of fittings
(reference number/specified minimum failure load);

b) manufacturer's identification;

c) date of manufacture (month and year);

d) cast code.

Forgings

a) identification of fittings
(reference number/specified minimum failure load);

b) manufacturer's identification;

c) date of manufacture (month and year).

Links and plates

a) identification of fittings
(reference number/specified minimum failure load);

b) manufacturer's identification;

c) date of manufacture (month and year).

Assemblies of fittings

a) identification
(reference number/specified minimum failure load);

b) manufacturer's identification;

c) date of manufacture of individual items (month and year);

d) conductor diameter range or conductor code(s), as agreed between purchaser and supplier;

e) fitting bolt installation torque (unless breakaway torque bolts are used).

Conductor compression fittings

a) identification
(reference number/specified minimum failure load);

b) manufacturer's identification;

c) date of manufacture (month and year);

d) conductor size or code name;

e) compression die sizes;

f) length to be compressed.

4.1.6 *Instructions for assembly*

The manufacturers shall provide the assembly instructions of the fittings as far as necessary.

4.2 *Requirements for specific fittings*

4.2.1 *Insulator set fittings and earth wire fittings*

For parts made of forged steel, holes which are under mechanical stress can be made by hot punching provided that the holes conform to tolerances on at least 70 % of punched thickness. For parts made of forged steel, holes which are not under mechanical stress can be made by cold or hot punching without the aforementioned limits.

4.2.2 *Suspension clamps*

The conductor or the earth wire installed in the suspension clamps can be used bare or equipped with armour rods.

The suspension clamps shall be so designed that the effects of vibration, both on the conductor or on the earth wire and on the clamps themselves, are minimized. The clamps shall be designed to avoid localized pressure or damage to the conductor or the earth wire.

The suspension clamps shall have sufficient contact surface to avoid damage by fault currents.

The wear resistance of the articulation assembly shall be sufficient to prevent deterioration in service.

Magnetic losses shall not exceed the laid down value, if specified.

The body of a suspension clamp shall permit oscillation around a horizontal axis perpendicular to the conductor.

Typical suspension clamps are

– clamps with articulation above the conductor; the pivot is above the horizontal plane passing through the conductor axis at the suspension point (see figure 1a);

– clamps with articulation in the plane of the axis of the conductor (twin or triple articulation) (see figure 1b); one of the three articulations is in the horizontal plane of the conductor axis;

– clamps with articulation under the axis of the conductor (see figure 1c).

The manufacturer shall provide the purchaser with the usage limits of the suspension clamps.

NOTE – For each type of clamp, the purchaser can choose between

– standard clamps: the slip load of the conductor or earth wire is not lower than a specified minimum slip load;

– controlled slippage clamps: the slip load of the conductor remains between two values defined by mutual agreement between the purchaser and the supplier.

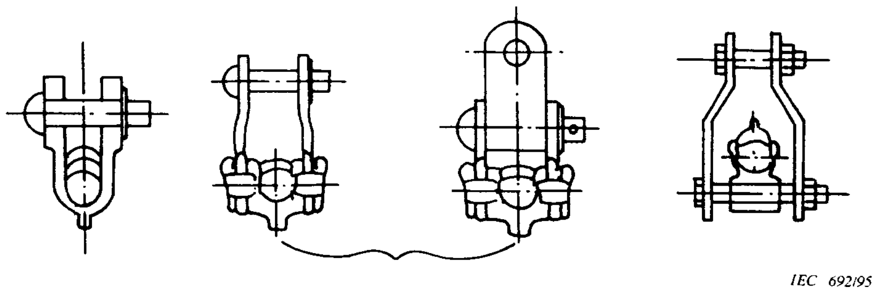


Figure 1a **Figure 1b** **Figure 1c**

Figure 1 – Typical suspension clamps

4.2.3 *Fittings for jointing, terminating and repairing conductor and earth wire*

Fittings for the purpose of jointing, terminating and repairing conductor and earth wire include, but are not limited to, the following:

– compression type connectors;
– cone or wedge type clamps;
– bolted type clamps;
– factory-formed helical fittings;
– fittings installed using an explosive charge.

The above fitting types may be used for tension and non-tension joints, and T connectors. When the fittings are designed so as not to provide electrical continuity of the conductor (e.g. a tension clamp) the fittings shall not reduce the electrical capability of the conductor or earth wire.

Fittings used for electrical continuity connections shall meet the requirements of clause 13.

Those fittings with auxiliary eyes intended for use during construction or maintenance shall be marked with a specified minimum failure load stated by the manufacturer.

All fittings shall be designed to minimize internal voids and to prevent the ingress or entrapment of moisture during service.

Fittings may be provided with an oxide-inhibiting compound intended to reduce metal oxidation at metal-to-metal electrical contact points. These compounds are commonly used in compression fittings to fill internal voids and to prevent ingress of water during service.

Fittings and connectors shall be designed in such away that after installation, the initial contact area between the fitting and the conductor does not raise stresses which can lead to failure under aeolian vibration or other conductor oscillation conditions.

Fittings and connectors intended to connect conductors of two dissimilar materials shall be designed to avoid bimetallic corrosion.

Fittings and connectors shall be designed to avoid localized pressures which may cause excessive cold flow of the conductor or earth wire material.

Fittings and connectors intended for the restoration of electrical and mechanical properties of a conductor shall have clearly defined manufacturer's instructions as to the extent of damage which they are intended to repair.

4.2.4 *Insulator protective fittings*

Should steel tubes be used for insulator protective fittings, both the internal and external surfaces of the tubes shall be hot dip galvanized.

When the tube is sealed after galvanizing, the quality of the internal surface shall be agreed between purchaser and supplier.

For insulator protective fittings designed to protect insulator sets against damage caused by power arcs (arcing horns, arcing rings, rings), the short-circuit current conditions shall be stated by the customer in the order.

The protective fittings shall be designed in such a way as not to be subject to breakage through fatigue due to vibration caused by the wind. The insulator protective fittings shall withstand a static mechanical load agreed upon between supplier and purchaser.

5 Quality assurance

A quality assurance programme taking into account the requirements of this standard can be used by agreement between the purchaser and the supplier to verify the quality of the fittings during the manufacturing process.

Detailed information on the use of quality assurance is given in the following ISO standards: ISO 9000-1, ISO 9001, ISO 9002, ISO 9003, ISO 9004-1.

6 Classification of tests – type tests, sample tests, routine tests

6.1 *Type tests*

6.1.1 *General*

Type tests are intended to establish design characteristics. They are normally only made once and repeated only when the design or the material of the fitting is changed. The results of type tests are recorded as evidence of compliance with design requirements.

6.1.2 *Application*

Fittings shall be subject to type tests in accordance with table 1. In addition other tests may be agreed between purchaser and supplier, for example corrosion tests, ageing tests, fatigue tests, short-circuit tests and power arc tests.

6.2 *Sample tests*

6.2.1 *General*

Sample tests are intended to verify the quality of materials and workmanship.

Table 1 – Tests on fittings

		Insulator set fittings and earth wire fittings			Suspension clamps			Tension joints and tension clamps			Partial tension fittings			Repair sleeve			Insulator protective fittings [1]		
Clause	Test	Type tests	Sample tests	Routine tests	Type tests	Sample tests	Routine tests	Type tests	Sample tests	Routine tests	Type tests	Sample tests	Routine tests	Type tests	Sample tests	Routine tests	Type tests	Sample tests	Routine tests
7	Visual examination	X	X[2]	X[3]	X	X[2]	X[3]	X	X[2]	X[3]	X	X[2]	X[3]	X	X[2]	X[3]	X	X[2]	X[3]
8	Dimensional and material verification	X	X	X[3]	X	X	X[3]	X	X	X[3]	X	X	X[3]	X	X	X[3]	X	X	X[3]
9	Hot dip galvanizing	X[3]	X		X[3]	X		X[3]	X		X[3]	X		X[3]			X[3]	X	
10	Non-destructive testing	X[3]	X[3]	X[3]	X[3]	X[3]	X[3]	X[3]	X[3]	X[3]	X[3]	X[3]					X[3]	X[3]	X[3]
11	Mechanical tests – damage and failure load test	X	X	X[3][4]	X	X	X[3][4]	X	X[3]								X[3]	X[3]	X[3]
	– slip test				X	X													
	– clamp bolt tightening test				X	X[2]		X	X[2]										
	– tensile test							X	X		X			X	X				
	– damage and failure load test of the attachment point used during erection	X	X[3]					X	X[3]	X[3][4]									
12	Magnetic losses test				X[3]			X[3]											
13	Heat cycle tests							X[5]			X[5]								
14	Corona and RIV test	X[3][6]			X[3][6]			X[3]			X[3]			X[3]			X[3][6]		

[1] Includes electrical gradient devices
[2] Inspection by attributes only
[3] By agreement between purchaser and supplier
[4] Only as regards damage load test
[5] Only for current-carrying joints
[6] Only in connection with the complete insulator set

6.2.2 *Application*

Overhead line fittings shall be subjected to sample tests as listed in table 1. The samples to be tested shall be selected at random from the lot offered for acceptance. The purchaser has the right to make the selection.

6.2.3 *Sampling and acceptance criteria*

Unless otherwise agreed between purchaser and supplier, the sampling plan procedures according to ISO 2859-1 and ISO 2859-2 (inspection by attributes) and to ISO 3951 (inspection by variables) shall be applied.

For each sample test, the type of inspection (by attributes or by variables) and the detailed procedures (inspection level, acceptable quality level, single, double or multiple sampling, etc.) shall be agreed between purchaser and supplier (see example in annex I for inspection by attributes, and annex J for inspection by variables).

NOTE – Sampling inspection by variables is an acceptance sampling procedure to be used in place of inspection by attributes when it is more appropriate to measure on some continuous scale the characteristic(s) under consideration. In the case of failure load tests and similar expensive tests, better discrimination between acceptable quality and objective quality is available with acceptance sampling by variables than by attributes for the same sample size.

The purpose of the sampling process may also be important in the choice between a variables or attributes plan. For example, a purchaser may choose to use an attributes acceptance sampling plan to ensure that parts in a shipment lot are within a required dimensional tolerance; the manufacturer may make measurements under a variables sampling plan of the same dimensions because he is concerned with gradual trends or changes which may affect his ability to provide shipment lots which meet the AQL.

6.3 *Routine tests*

6.3.1 *General*

Routine tests are intended to prove conformance of fittings to specific requirements and are made on every fitting. The tests shall not damage the fitting.

6.3.2 *Application and acceptance criteria*

Whole lots of fittings may be subjected to routine tests as listed in table 1. Fittings which do not conform to the requirements shall be discarded.

7 Visual examination

Type tests shall include visual examination to ascertain conformity of the fittings, in all essential respects, with the contract drawings. Deviations from the drawings shall be subject to agreement between supplier and purchaser and shall be appropriately documented as an agreed concession.

Sample tests include visual examination in accordance with 6.2.3. Visual examination shall ensure conformity of manufacturing process, shape, coating and surface finish of the fitting with the contract drawings. Particular attention shall be given to markings required and to the finish of surfaces which come into contact with the conductor.

NOTE – Verification of marking may include marking required by the purchaser in order to verify inspection or testing (e.g. hardness tests, indent marks, inspectors' stamps, etc.).

For fittings subject to corona type tests, the sample test shall include a comparison of shape and surface finish with one of the corona type test samples when agreed between purchaser and supplier.

Routine tests do not include visual examination unless otherwise agreed between supplier and purchaser or unless included in the quality assurance system of the supplier.

8 Dimensional and material verification

Type and sample tests shall include verification of dimensions, in accordance with clause 6, to ensure that fittings are within the dimensional tolerances stated on contract drawings. The purchaser may choose to witness the measurement of selected dimensions or may inspect the supplier's documentation when this is available. Measuring devices/gauges shall be selected with regard to the required precision and accuracy. Documentary evidence of calibration of such devices shall be provided on request.

Routine tests shall include a specified level of dimensional checking when required by the contract quality plan.

NOTE – Particular attention should be given to those dimensions potentially affecting fitting interchangeability (for example ball and socket couplings (IEC 60120); clevis and tongue couplings (IEC 60471)) or mechanical and/or electrical performance.

Type and sample tests shall also include verification of materials to ensure that they are in accordance with contract documents. This verification shall normally be carried out by the purchaser inspecting the supplier's documentation relative to material purchasing specifications, certificates of conformity or other quality documentation. When agreed between purchaser and supplier, material verification shall include tests appropriate to the material specification.

Routine tests shall include a specified level of material verification (including tests) when required by the contract quality plan.

9 Hot dip galvanizing

Type and sample tests shall include galvanizing tests in accordance with clause 6 to ensure that galvanized coatings comply with the requirements as specified in future ISO 1461.

The coating thickness shall conform to tables 2 and 3 of the above-mentioned standard unless otherwise specified or agreed by the purchaser. However, for the purpose of this standard, tables 2 and 3 of future ISO 1461 shall apply to the following categories of items (and not to the categories specified in future ISO 1461):

Table 2: Coating thickness on samples except

- washers;
- threaded components;
- small parts which are centrifuged (significant surface area ≤ 1 000 mm²).

Table 3: Coating thickness on

- washers;
- threaded components;
- small parts which are centrifuged (significant surface area ≤ 1 000 mm²).

10 Non-destructive testing

The purchaser shall specify or agree to relevant test methods, classification (type, sample, routine tests) and acceptance criteria.

Examples of non-destructive tests are as follows:

- magnetic test;
- eddy current test;
- radiograph test;
- ultrasonic test;
- proof load test;
- dye penetrant test;
- hardness test.

11 Mechanical tests

11.1 *Number of fittings to be tested*

Type tests

Mechanical type tests shall be carried out on three fittings. All fittings shall pass the test.

Sample tests

Mechanical sample tests shall be carried out according to sampling procedures reported in 6.2.3.

11.2 *Test piece and attachments for mechanical damage and failure load tests, conductors used in the mechanical tests*

A fitting under test shall be complete with all components and shall be tested in a manner as near as possible to the arrangement used in service. In order to avoid their unacceptable deformation, it is permissible to strengthen the attachments required to transmit the mechanical loads to the test fitting.

A number of mechanical tests involve the use of conductors loaded to failure. The intent of these tests is to evaluate fitting performance on the conductor(s) for which it is intended. Requirements and tests for conductors are covered by IEC 61089.

Throughout this standard, the word "conductor" is used when the test applies to fittings for conductors or earth-wires.

11.3 *Insulator set fittings and earth wire fittings*

The fitting under test shall be loaded in a direction which is as close as possible to the direction of load in service (see figure 2).

In cases where it is difficult, in a single test arrangement, to reproduce the load distribution which occurs in service, this may be represented by part loads applied in successive tests on the same fitting, or on others taken from the same sample. However, it shall first have been ascertained that this splitting of loads is valid for the purpose of verifying the performance required of the fitting.

11.3.1 *Mechanical damage and failure load test* (see figure 3)

The fitting shall be held in a tensile testing machine and the load shall be gradually increased until it reaches the specified minimum damage load. This load shall be kept constant for 60 s. It shall then be removed and the measurement of the permanent deformation of the fitting carried out. Then the load shall be gradually increased until it reaches the specified minimum failure load at which it shall be kept constant for 60 s. Then the load shall be increased until the failure of the fitting occurs.

NOTE – For very high mechanical failure loads, when the safety of equipment and operators is at risk, the test may be stopped at 1,2 times the specified minimum failure load. In this case inspection by attributes shall be used.

Acceptance criteria

Type tests — Regarding damage load, the test is passed if no permanent deformation of the fitting greater than that agreed occurs at or below the specified minimum damage load.

Regarding failure load, the test is passed if failure of the fitting does not occur at a load less than or equal to the specified minimum failure load.

Sample tests — As stated in 6.2.3, the test data shall be evaluated following the sampling procedure and relevant acceptance criteria agreed between purchaser and supplier. With inspection by attributes, each fitting which complies with the requirements specified in the acceptance criteria for type tests shall be considered a conforming unit.

11.3.2 *Mechanical damage and failure load test of the attachment point used during erection*

The test shall be carried out following the scheme agreed between purchaser and supplier. The method for increasing the load during the test and the method for evaluating the test results shall be that shown in figure 3.

11.4 *Suspension clamps*

11.4.1 *Vertical damage load and failure load test*

The test shall be performed in accordance with the following method A or method B.

Method A

The test shall be carried out as in figure 4a or 4b or according to an equivalent scheme. Armour rods shall be applied to the conductor if they are used in service. The number of fittings tested, the method for increasing the load during the test and the method for evaluating the test result shall be those stated for the damage and failure load test of insulator set fittings. The angle α, at the specified minimum damage load, shall be the maximum design angle specified by the supplier.

Method B

First step — The clamp shall be mounted in the testing machine, as shown in figure 4a or 4b, and loaded to achieve the angle α. Then the load shall be gradually increased to the specified minimum damage load which shall be kept constant for 60 s. Afterwards, the clamp shall be unloaded and measurements of the permanent deformations, if any, carried out and recorded.

Second step — Instead of the conductor, the clamp shall be installed on a rigid bar of suitable size and mounted, complete with the suspension straps, in the testing machine. With α approximately zero, the clamp shall be loaded similarly to figure 4b and the load gradually increased to the specified minimum failure load. This load shall be kept constant for 60 s and afterwards increased until failure of the fitting.

NOTE – For very high mechanical failure loads, when the safety of equipment and operators is at risk, the test may be stopped at 1,2 times the specified minimum failure load. In this case inspection by attributes shall be used.

The acceptance criteria are as in 11.3.1

11.4.2 *Slip test on standard clamps with a specified minimum and maximum slip load*

The conductor used in the test shall be the one for which the clamp is intended. The test shall be carried out as follows (see figure 5a):

a) assembly of the conductor section between the extremities of a tension machine, the conductor being subjected to a load equal to 20 % of its Rated Tensile Strength (RTS);

b) assembly of the clamp on the conductor thus set up, the nuts or bolts being tightened with the torque specified by the supplier;

c) reduction to zero of the load applied to the conductor and detachment of the conductor from one end of the tension machine;

d) attachment of the clamp to the free extremity of the tension machine;

e) application to the whole unit of a load equal to 20 % of the specified minimum slip load and application of a displacement transducer in such a way that movement of the conductor relative to the fitting can be detected. In the absence of a transducer, a mark shall be made on the conductor to detect the above-mentioned movement;

f) gradual increase of the load until it reaches the specified minimum slip load. This load shall be kept constant for 60 s;

g) gradual increase of the load until the slippage of the conductor inside the clamp occurs.

As an alternative to the above procedure the slip test may be conducted in accordance with the method shown in figure 5b which is as follows:

1) assembly of the conductor section between the extremities of a tension machine, the conductor being subjected to a load equal to 20 % of its RTS;

2) assembly of the clamp on the conductor thus tensioned, the nuts or bolts being tightened with the torque laid down by the supplier;

3) connection of the clamp at extremity W of an appropriate tensioning device, and application of a displacement transducer or a reference mark on the conductor at the end of the clamp, in order to measure slippage between the conductor and the clamp;

4) gradual increase of the load applied to the clamp until it reaches the specified minimum slip load. This load shall be kept constant for 60 s. The load, as sketched in figure 5b, shall be applied to the clamp coaxially with the conductor to prevent the application of torque that might cause the clamp to rotate;

5) gradual increase of the load until the slippage of the conductor occurs inside the clamp.

Acceptance criteria

Type tests No slippage* shall occur at or below the specified minimum slip load; the slippage shall occur between the specified minimum and maximum slip load.

Sample tests As stated in 6.2.3, the test data shall be evaluated according to the sampling procedure and relevant acceptance criteria agreed between purchaser and supplier. With inspection by attributes, each fitting which complies with the requirements specified in the acceptance criteria for type tests shall be considered a conforming unit.

11.4.3 *Slip test on standard clamps with only specified minimum slip load*

The test shall be carried out following all the steps stated for the previous standard clamp up to step f) (figure 5a procedure) or up to step 4) (figure 5b procedure). After step f) or 4), the test shall be carried out following one of the two procedures h) and i) described below (the procedure shall be agreed between the purchaser and the supplier):

h) gradual increase of the load until the slippage of the conductor inside the clamp occurs (the value of the slip load shall be recorded in the test report), or

i) disconnection of the link between the clamp and the tension machine and reconnection of the free end of the conductor to the tension machine (figure 5a procedure) or disconnection from the extremity W of the appropriate tensioning device (figure 5b procedure). This shall be done without removing the clamp under test or changing the tightening torque. The load shall then be increased until breakage of the conductor is obtained.

Acceptance criteria

Type tests The test is passed if the conductor does not slip* through the clamp at or below the specified minimum slip load. In addition, for the i) procedure, the conductor shall not break at a load lower than 95 % of its RTS.

Sample tests As stated in 6.2.3, the test data shall be evaluated following the sampling procedure and relevant acceptance criteria agreed between purchaser and supplier. Using inspection by attributes, each fitting which complies with the requirements specified in the acceptance criteria for type tests shall be considered a conforming unit.

11.4.4 *Slip test on controlled slippage clamps*

The conductor used in the test shall be the one for which the clamp is intended. In each test, a new specimen suspension clamp shall be used. Armour rods shall be applied to the conductor if they are used in service.

The test arrangement shall make it possible for the conductor to slide through the suspension clamp. An example of a machine for testing the sliding characteristics of suspension clamps is shown in figure 6.

* Any relative movement less than 2 mm is accepted. The possible couplings or elongations produced by the cable as a result of the test itself are not regarded as slippage.

Determination of friction coefficient

When specified by the purchaser, the friction coefficient shall be determined by the following test.

This test is performed with the conductor resting on the body of the suspension clamp without the keeper. The turning angle α, and the vertical load F_V shall be agreed on between the purchaser and the supplier.

During this test, the conductor is subjected to tension on both sides.

The sliding force shall be measured at the rotational axis of the suspension clamp over a conductor length of 1 m.

The friction coefficient is determined from the ratio of the maximum measured sliding force F_S to the vertical load F_V.

Measurement of sliding force

When preparing this test, the conductor shall be stressed at 20 % of its RTS in a suspension clamp with a turning angle agreed between the purchaser and supplier.

The clamping bolts shall then be tightened in accordance with the installation instructions and the conductor released.

The suspension clamp is then pulled.

The sliding force shall be measured at the rotational axis of the suspension clamp while the fitting is sliding over a conductor length fixed by the purchaser.

NOTE – After agreement between purchaser and supplier, this test may be carried out without releasing the mechanical tension on one side of the conductor.

Acceptance criteria

Type tests — The friction coefficient and the sliding force shall be in the range of values agreed between the purchaser and supplier and no damage, other than surface flattening of the strands, shall occur on the conductor. If it is required by the purchaser, the tensile strength of the conductor shall be recorded during the test.

Sample tests — As stated in 6.2.3 the test data shall be evaluated following the sampling procedure and relevant acceptance criteria agreed between purchaser and supplier. Using inspection by attributes, each fitting which complies with the requirements specified in the acceptance criteria for type tests shall be considered a conforming unit.

11.4.5 *Clamp bolt tightening test*

The test shall be performed by installing the clamp on a conductor with a diameter equal to that for which the clamp is intended to be used, the bolts and/or nuts being tightened with the installation torque specified by the supplier.

This torque is then increased to the specified installation value times a factor of 1,1. The threaded connection shall remain serviceable for any number of subsequent installations or removals, and all components comprising the clamp shall be undamaged. No unacceptable damage shall occur to the conductor inside the clamp.

Lastly, the torque shall be increased up to either twice the specified installation value or the maximum torque value recommended by the bolt supplier, whichever is lower.

This increase shall not result in any breakage either to threaded parts or to the components connected to them.

11.5 *Tension clamps, dead-end tension joints and mid-span tension joints*

The conductor used in the test shall be the one for which the fitting is intended.

11.5.1 *Tensile test*

The fitting shall be installed on the conductor or earth wire in accordance with the supplier's recommendations and the assembly shall be mounted in a tensile testing machine, precautions being taken to avoid birdcaging of the conductor.

The length of conductor between the fitting under test and any other clamp or joint in the test assembly shall be equal to or greater than 100 times the overall diameter of the conductor or 2,5 m, whichever is less.

NOTE – It is very important for tests performed on relatively short test lengths of conductor that measures be taken during the installation of the test fittings to ensure that the conductor strands remain tight.

A mid-span joint may be placed in the centre of the conductor section in such a way as to test two dead-end tension clamps/tension joints and one mid-span tension joint simultaneously (see figure 7).

In accordance with figure 8, the load P shall be raised gradually until it reaches the M value, with $M \leq 20$ % of the RTS of the conductor. A displacement transducer shall then be installed in such a way that movement of the conductor relative to the fitting can be detected.

In the absence of a transducer, a mark shall be made on the conductor to detect the above-mentioned movement. Then the load shall be gradually increased until it reaches 60 % of the specified minimum failure load (SMFL) of the tension joint/clamp. The load shall be maintained to this value for a time T agreed between purchaser and supplier ($T \leq 1$ h).

The test shall then be continued according to one of the following alternatives:

a) without any subsequent adjustment of the fitting, the load shall be steadily increased, in not less than 30 s, until the SMFL is reached. Such a load shall be kept constant for 60 s at least.

When agreed between purchaser and supplier the load shall then be gradually increased until failure of the clamp/joint or conductor wires occurs. The failure load shall be recorded for information purposes only;

b) without any subsequent adjustment of the fitting, the load shall be steadily increased until failure occurs. The failure load shall be recorded.

Acceptance criteria

Type tests The test is passed if no movement* of the conductor relative to the joint/clamp and no failure of the joint/clamp or conductor occurs.

– for alternative a), at or before the end of the application of the SMFL for 60 s;

– for alternative b), at or below the SMFL.

Sample tests As stated in 6.2.3, the test data shall be evaluated following the sampling procedure and relevant acceptance criteria agreed between purchaser and supplier. With inspection by attributes, each fitting which complies with the requirements reported in the acceptance criteria for type tests shall be considered a conforming unit.

NOTE – For this test the SMFL refers to the grip of the clamp/joint on the conductor and is equal to:

$$\text{SMFL} = X \cdot 0{,}95\ \text{RTS}$$

where $X \le 1$ is defined by the purchaser.

11.5.2 *Mechanical damage and failure load test*

The fitting shall be held in a tensile test machine. The conductor shall be replaced by a round bar or steel cable of the same size (see figure 9).

The method for increasing the load during the test and the method for evaluating the test results shall be those stated in 11.3 for the damage and failure load test of insulator set fittings.

NOTE – This test refers to the strength of the fitting itself.

11.5.3 *Mechanical damage and failure load test of the attachment point used during erection*

The test shall be carried out as shown in figure 10 (or equivalent). The method for increasing the load during the test and the method for evaluating the test results shall be those stated in 11.3 for the damage and failure load test of insulator set fittings.

11.5.4 *Clamp bolt tightening test*

The test shall be carried out as described in 11.4

11.6 *Partial tension fittings*

The conductor used in the test shall be the one for which the fitting is intended. If one size of fitting is offered for more than one size of conductor, the test shall be carried out on both the largest and smallest of such conductor sizes or, in the case of T connectors, on both the largest and smallest combinations of conductors. Where a range of conductor fittings is to a common design and the range includes three or more different sizes, the type test shall be carried out on the largest and smallest size and one intermediate size of the fitting. If a fitting is offered for application to conductors of more than one material (e.g. copper, copper cadmium, aluminium, aluminium alloy, ACSR) then the type tests shall be carried out on each conductor material and stranding.

* Any relative movement less than 2 mm is accepted. The possible couplings or elongations produced by the cable as a result of the test itself are not regarded as slippage.

11.6.1 *Partial tension fittings other than T connectors*

Tensile test

The joint shall be assembled in accordance with the supplier's recommendations on conductors of the sizes and types with which it is to be used. The assembly shall be mounted in a tensile testing machine and anchored in such a way that the test load is applied in the direction of the conductor.

The method for increasing the load during the test and the criteria for evaluating the test results shall be those stated for the tensile test in 11.5.1.

11.6.2 *T connectors*

11.6.2.1 *Tensile tests with mechanical tension between joint and T conductor*

The test specified in 11.6.1 shall be carried out with the tension applied between the joint and the T conductor in the direction in which the T conductor emerges from the joint.

11.6.2.2 *Tensile test with mechanical tension on the main conductor*

A tensile load equal to 10 % of its RTS shall be applied to a length of main conductor of the size and type with which the joint is to be used. The joint, complete with T conductor, shall be assembled in accordance with the supplier's recommendations on the tensioned main conductor. The length of conductor on each side of the T joint shall be equal to or greater than 100 times the overall diameter of the conductor or 2,5 m, whichever is lower.

The load shall be raised gradually until it reaches 50 % of the RTS of the conductor.

This load shall be kept constant for 120 s.

Without any subsequent adjustment of the fitting, the load shall be steadily increased, in not less than 30 s, until 95 % of RTS of the conductor is reached.

This load shall be kept constant for 60 s at least.

Acceptance criteria

The test is passed if there is no failure of the main conductor.

11.7 *Repair sleeves*

Tensile test

A length of conductor of the size and type for which the sleeve is to be used shall have a number of adjacent severed strands in the outermost layer. The number of severed strands and their location shall be the most severe for which the sleeve was designed.

The repair sleeve shall then be assembled to repair the damaged conductor in accordance with the supplier's recommendations.

The assembly shall be mounted in a tensile testing machine and anchored so that service conditions are simulated, precautions being taken to avoid birdcaging of the conductor.

The clear length of conductor on each side of the repair sleeve shall be equal to or greater than 100 times the overall diameter of the conductor or 2,5 m, whichever is the smaller.

The tensile test specified in 11.5.1 shall then be completed.

11.8 *Insulator protective fittings*

The purchaser shall specify or agree relevant test methods and acceptance criteria.

12 Magnetic losses test

12.1 *General*

This type test is aimed at ascertaining the magnetic losses of suspension clamps and U-bolt type tension clamps for overhead line conductors (clamps for earth wires are excluded). The test shall be carried out as agreed between purchaser and supplier (see 6.1.2 and table 1).

12.2 *Test procedure*

A power frequency current (see figure 11) shall be passed through a suitable length of conductor and the power losses shall be measured both with and without the fittings assembled on the conductor. Armour rods shall be applied to the conductor if they are used in service. The test circuit geometry shall be exactly the same for both measurements. In each case, the conductor shall be allowed to reach its steady temperature. The conductor shall have the maximum diameter for which the fitting is designed. To measure the power losses of the fitting, a minimum number of five units shall be mounted on the conductor, spaced not less than 50 cm apart. The fittings under test shall be complete with all components assembled as defined in the supplier's drawing of the fitting. The test shall employ an a.c. voltage at a frequency of 50 Hz or 60 Hz and the magnitude for the current shall be according to table 2. In countries where metric cables are not used, the test current shall be that of the smaller, nearest equivalent metric size conductor.

Table 2 – Current magnitudes for magnetic losses test

Conductive cross-section mm²	Current A	
	Aluminium and aluminium alloy	Copper
25	115	125
50	175	230
75	230	310
100	275	365
150	355	470
200	435	575
250	500	670
300	565	760
400	680	910
500	785	1 030
600	875	1 140
700	955	1 240
800	1 025	1 330
900	1 100	1 410
1 000	1 170	1 490
NOTE – For cross-sections not included, take the next higher value in the table.		

Acceptance criteria

The test is passed if the magnetic losses of the clamp are less than or equal to α times the power losses per unit length of the conductor. The condition corresponds to the relation

$$\frac{P_D - P_C}{N} \leq \alpha \cdot \frac{P_C}{L}$$

where

P_C are the power losses of the reference length of the conductor without fittings, in watts;

P_D are the power losses of the reference length of the conductor with fittings, in watts;

L is the reference length of the conductor in metres;

N is the number of fittings mounted;

α is the evaluation coefficient. Unless otherwise stated by the purchaser or supplier it shall be taken as equal to 1.

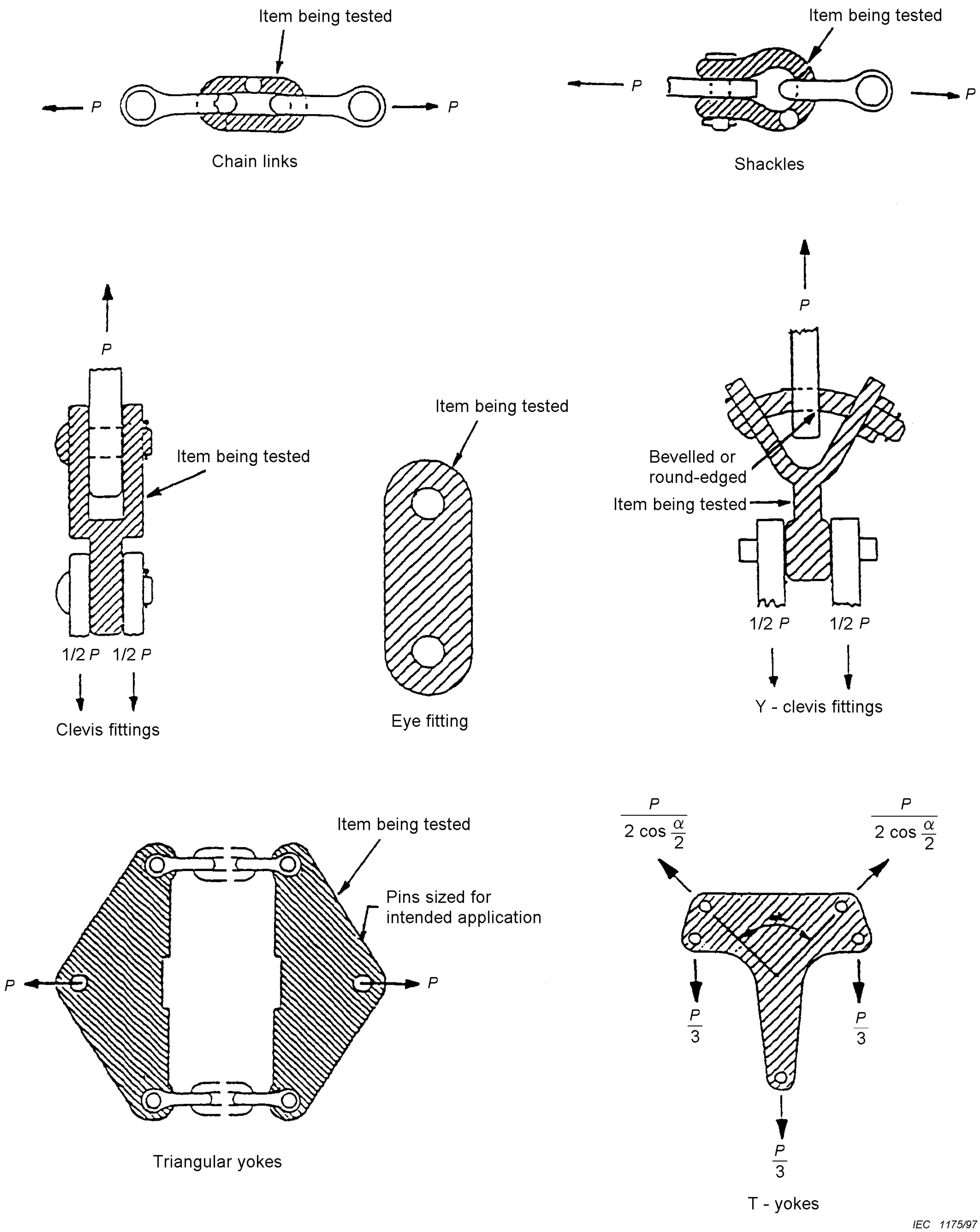
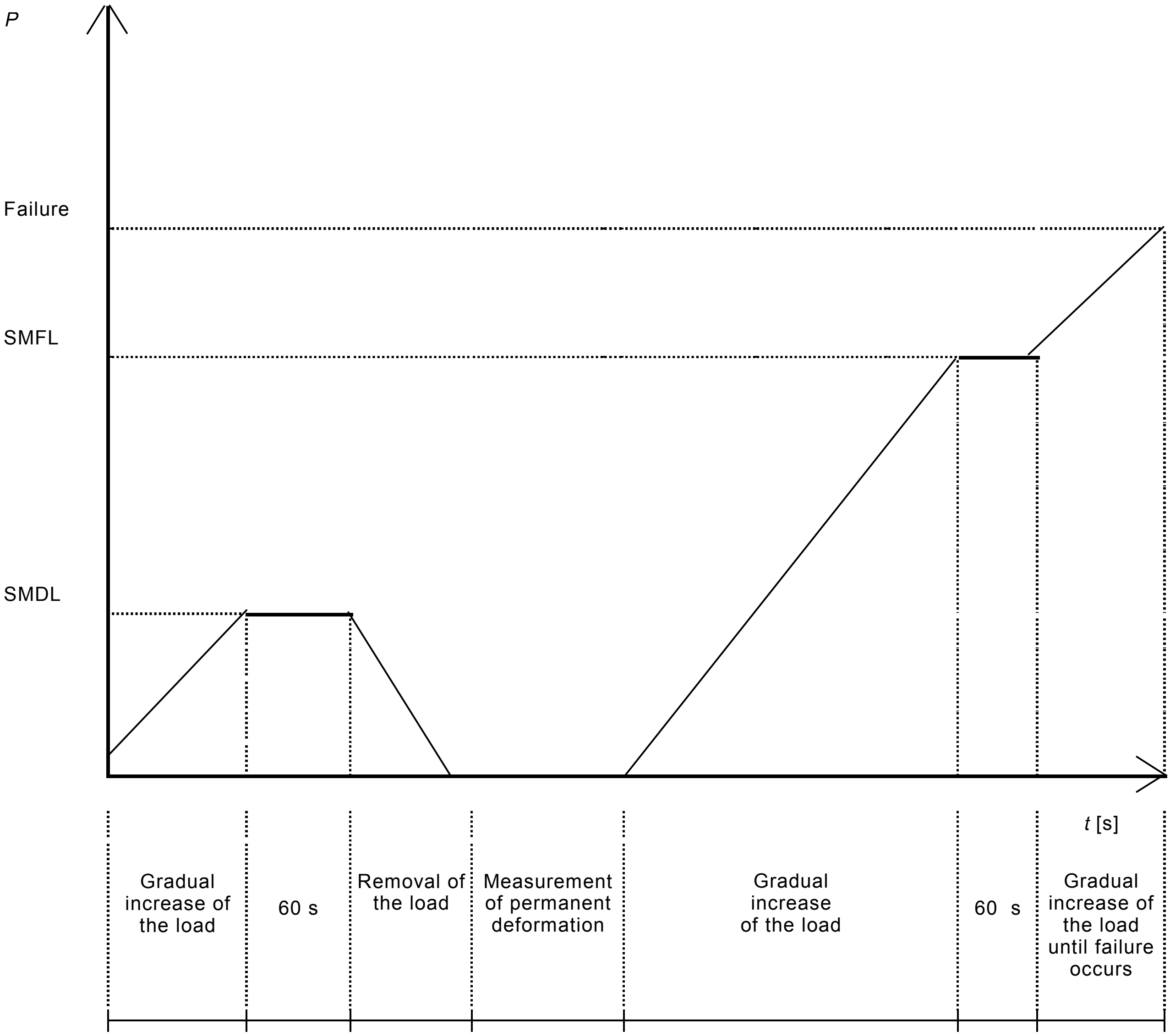


Figure 2 – Insulator set fittings and earth wire fittings – damage load and failure load test: diagrams showing the typical application of load



SMFL = Specified minimum failure load

SMDL = Specified minimum damage load

Figure 3 – Insulator set fittings and earth wire fittings – mechanical damage and failure load test: rate of increase of load

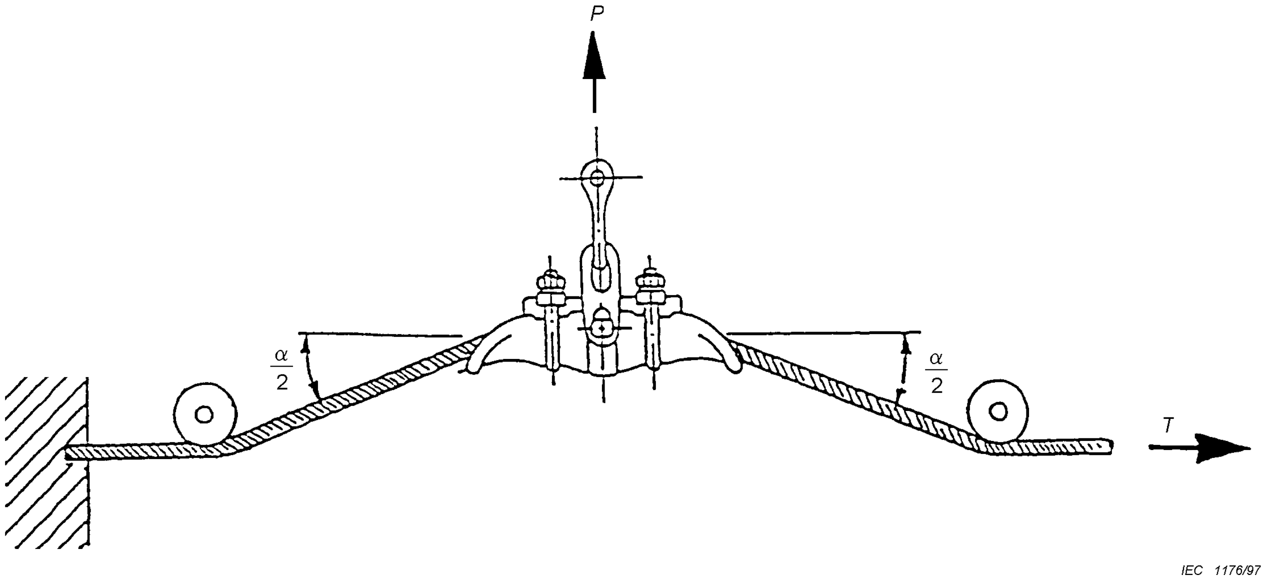


Figure 4a

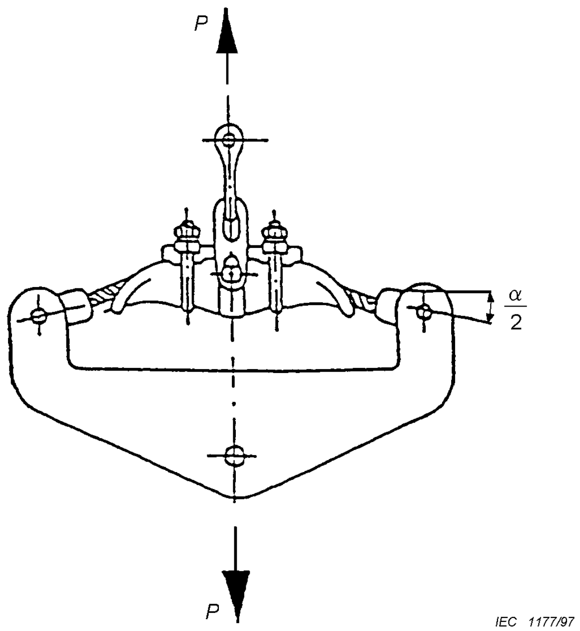


Figure 4b

Figure 4 – Suspension clamp – vertical damage load and failure load test: diagram showing the typical application of load

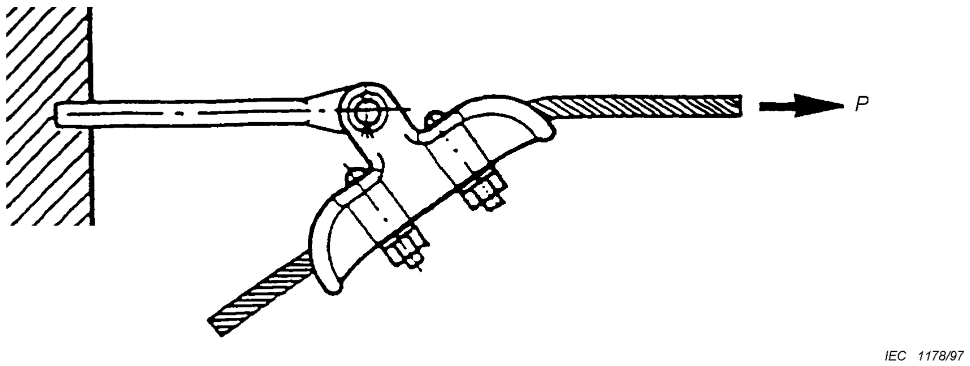


Figure 5a

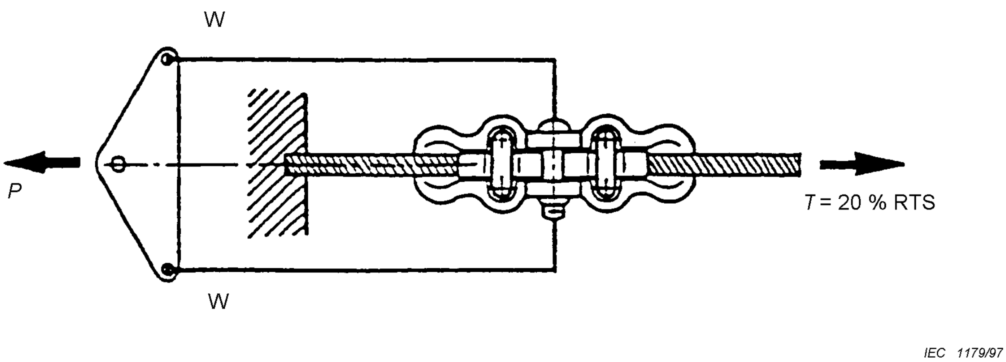


Figure 5b

Figure 5 – Suspension clamp (standard type) – slip test: diagram showing the typical application of load

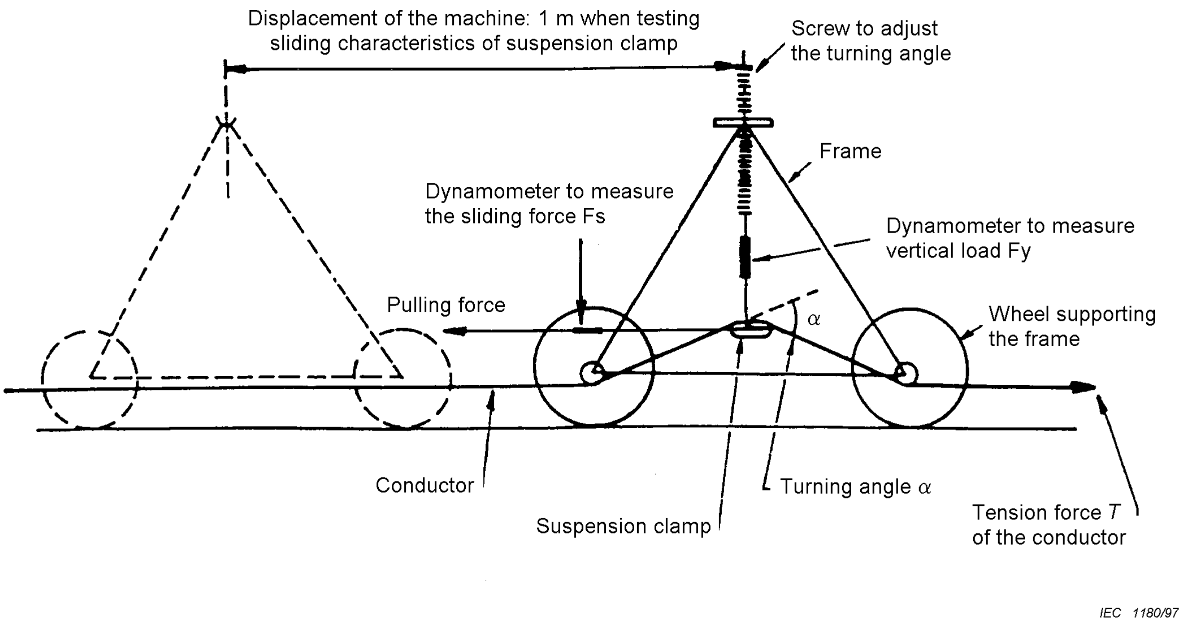
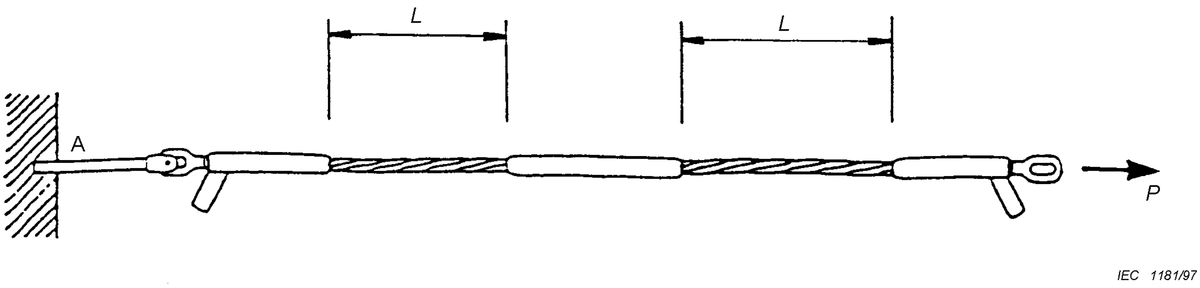


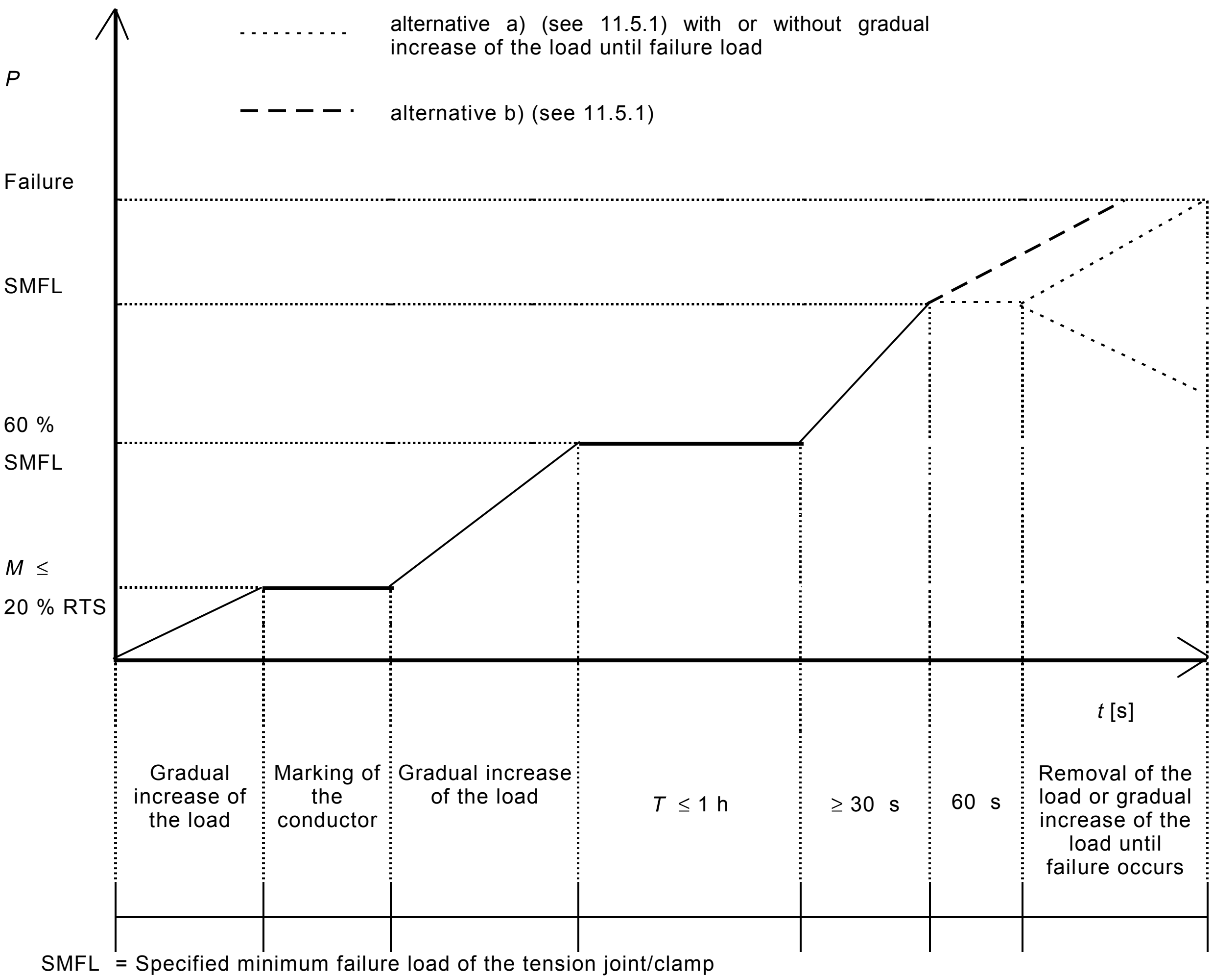
Figure 6 – Suspension clamp (controlled slippage type) – slip test: diagram showing the typical application of load



L ≥ (100 *D* or 2,5 m, whichever is less)

D is the conductor diameter, in metres

Figure 7 – Tension clamps, dead-end tension joints and tension joints – tension test: diagram showing the typical application of load



SMFL = Specified minimum failure load of the tension joint/clamp

RTS = Rated tensile strength of the conductor

M = Load for the marking of the conductor

Figure 8 – Tension clamps, dead-end tension joints and tension joints – tensile test: rate of increase of load

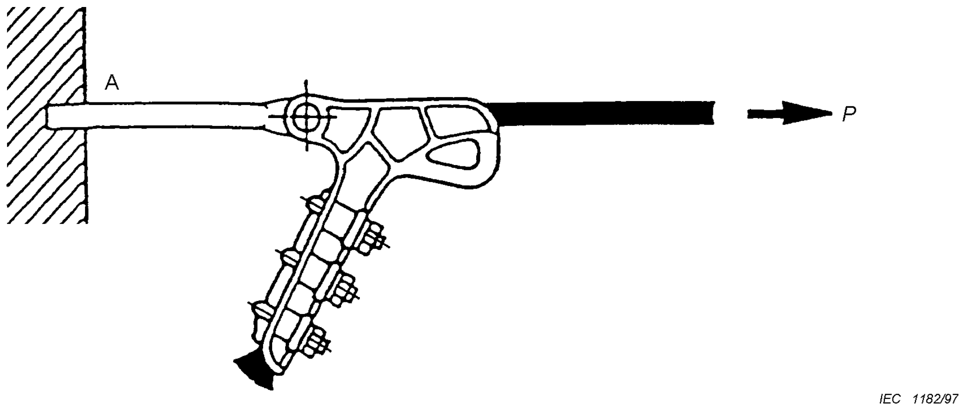


Figure 9 – Tension clamps and tension joints – mechanical damage and failure load test: diagram showing the typical application of load

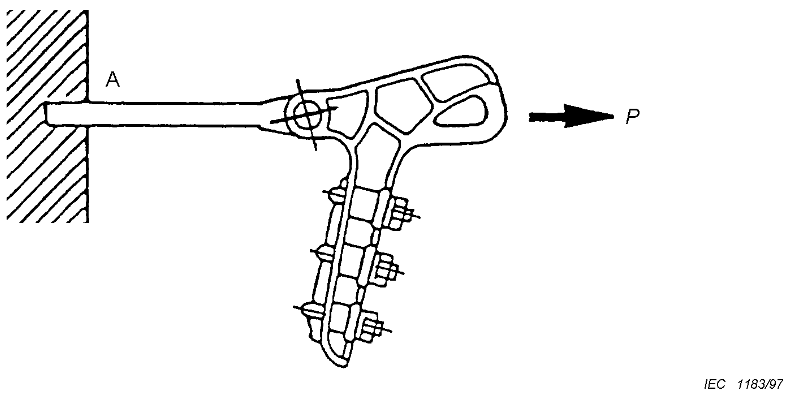


Figure 10 – Tension clamp and tension joints – mechanical damage and failure load test of the attachment point used during erection: diagram showing the typical application of load

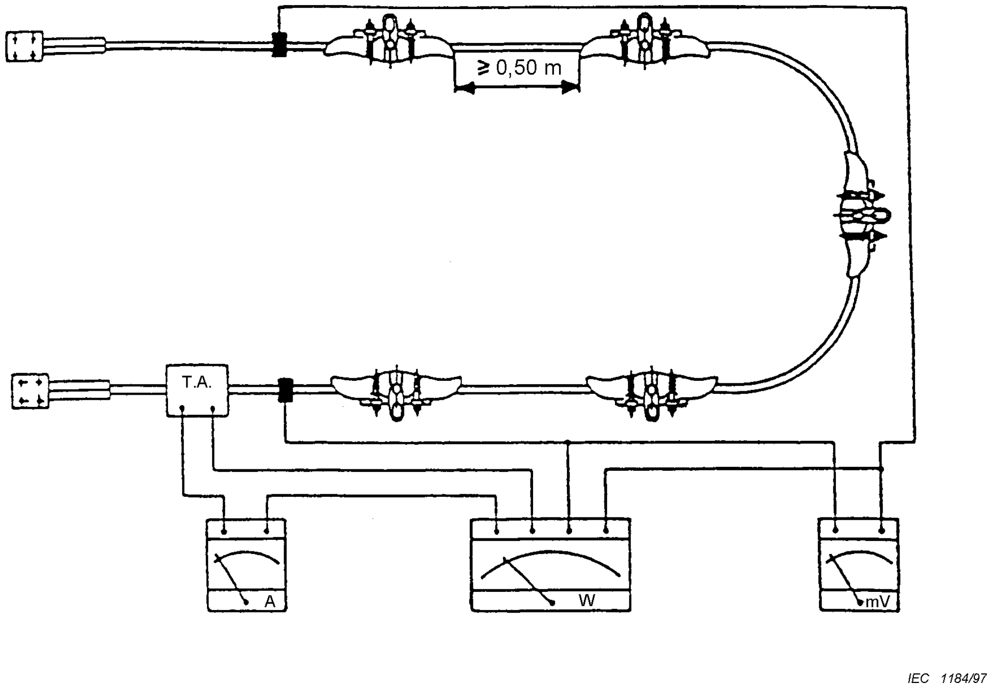


Figure 11 – Magnetic losses test

13 Heat cycle tests

13.1 *Purpose*

Heat cycle tests are type tests aimed at ascertaining the long-term electrical performance of current-carrying joints.

When a design of joint meets the requirements of this clause, then it is expected that in service:

a) the electrical resistance of the joint will remain stable;

b) the temperature of the joint will not exceed that of the conductor to which it is attached;

c) if the design and intended use of the joint demands the application of short-time overcurrent tests, such currents will not adversely affect the performance of the joints.

13.2 *Joints*

13.2.1 *General*

The current-carrying joints consisting of compression and all other forms of mechanical connectors can be divided into two main groups regarding the tensile strength: tension joints and non-tension joints (see annex A).

13.2.2 *Service temperatures*

The heat cycle tests specified in this clause apply to the joints for use on conductors having the following maximum permissible temperature in service:

– continuous current rating ≤ 80 °C

– temperature during the short circuit ≤ 200 °C

In special cases, if a joint is designed for higher conductor temperatures than those shown above, the test temperatures of 13.5.2.1 and 13.5.3.1 shall be modified correspondingly, as agreed upon between supplier and purchaser.

13.2.3 *Classification for test purposes*

Although all possible joint applications may not be clearly identified, the following two classes of joints are defined for the test purposes:

– class A: the joints are subjected to electrical heat cycles only. Typical joints for class A joints are tension joints (see 13.2.1);

– class B: the joints are subjected to electrical heat cycles and a short-time overcurrent pulse test. Typical joints for class B joints are non-tension joints (see 13.2.1).

The short-time overcurrent pulse test is omitted in class A because the construction of tension joints is normally so massive in order to meet the mechanical requirements that this test is not necessary, except if a joint consists of helically formed wires where the current path is unlikely to be uniform in all strands.

However, the short-time overcurrent pulse test can also be made on the joints of class A if agreed between the supplier and the purchaser.

13.3 *Test specimens*

13.3.1 *General*

The number of joints to be tested shall be four.

The connectors supplied for the test shall be identical to those to be delivered commercially.

13.3.2 *Multi-range connectors*

In general, connectors shall be tested on all configurations of conductor for which they are designed.

However, with the agreement of the purchaser the following exception is allowed to limit the number of tests: if a connector is designed for more than one size of conductor, the test shall be made on both the largest and smallest of such conductor sizes within the supplier's declared design range.

13.3.3 *Preparation*

The contact surfaces of the connectors and conductors shall be prepared in accordance with the supplier's instructions.

The connectors shall be installed strictly according to the supplier's instructions on conductors of the size and type with which they are to be employed without any further preparation. No subsequent tightening of the joints shall be made.

13.3.4 *Data on test specimens*

The following technical details of the test connectors and conductors shall be recorded before making any test.

Connectors

– manufacturer, catalogue or reference number;
– class of joint: A or B;
– assembly technique: preparation of contact surfaces, joint grease (if any), details of installation method and tooling to be employed.

Conductors

– specification;
– material;
– size and stranding.

13.4 *Test arrangements*

13.4.1 *Test conditions*

The test shall be carried out in reasonably draught-free conditions at an ambient temperature between 15 °C and 30 °C. The test assembly shall be erected so that the distance between joints, or any other connections introduced to facilitate testing, shall be sufficient to ensure negligible thermal interference. The assembly shall be supported in such a way that air may freely circulate around the assembly to provide cooling by natural convection. If accelerated cooling is employed this shall affect the whole assembly uniformly.

The tests shall be carried out employing new conductors, and a mechanical tension not exceeding 20 % of the rated tensile strength of the main conductor may be applied to the assembly of tension joints (see annex A).

13.4.2 *Reference conductor*

For the purpose of resistance and temperature measurements, the assembly shall contain a length of unjointed conductor which shall be used as the reference for resistance and temperature measurements. If a joint is such that two sizes of conductor are being connected into the assembly, the smaller of the two shall be used as the reference conductor. The length of the reference conductor shall be no less than 100 times its diameter, up to a maximum of 4 m long.

13.4.3 *Potential points*

Potential points for resistance measurements shall be installed on the conductor at a distance of 25 mm from the ends of all test joints. For the reference conductor, the potential points of the joints shown in annexes B and C shall be used.

NOTE – See annex G for an example of a method for providing a practical potential point. Other types of frequently used potential points could be used.

13.4.4 *Installation of test loop*

Typical arrangements of the test loop are shown in annexes B and C, together with the minimum conductor lengths between the joints and other connections.

On the T joints both current paths can be tested separately if agreed between purchaser and supplier.

13.4.5 *Measurements*

13.4.5.1 *Resistance measurement*

The resistance of each test joint and reference conductor shall be measured between the potential points installed in accordance with 13.4.3.

In carrying out resistance measurements, the temperature of reference conductor and test joints shall be read and the resistance value obtained shall be related to 20 °C by means of the following formula:

$$R_{20} = \frac{R_\theta}{1 + \alpha_{20}(\theta - 20)}$$

where

R_θ is the measured resistance;

θ is the temperature (in degree Celsius) of the joint or the reference conductor when it is measured;

α_{20} is the thermal coefficient of resistance.

This coefficient can be taken equal to

α_{20} = 4 × 10^{-3}/°C for copper, aluminium and ACSR;

α_{20} = 3,6 × 10^{-3}/°C for aluminium alloy.

The resistance measurements shall be made with direct current having a magnitude not higher than 10 % of the a.c. test current. The temporary current connections used for resistance measurements shall be at a distance of not less than 50 times the diameter of the conductor from the joint and shall be made so that effective contact is made with all those strands of the conductor which would be taken into account in calculating its equivalent resistance.

Instruments used for resistance measurement shall be accurate to within 1 % or 0,5 μΩ, whichever is the greater when the instrument is calibrated against a certified standard resistance bar.

NOTE – It is important to note that errors in resistance measurement increase the chance of rejection when applying the method of mathematical assessment described in annex E. For example, the following matters should be taken into account.

– Thermoelectric e.m.f can affect the accuracy of low-resistance measurements (by some 10 μΩ). To compensate for this, two resistance measurements should be taken by reversing the measuring current between readings. The mean of the two readings is then regarded as the actual resistance of the sample.

– The length of time for which samples are allowed to stand to cool before resistance measurements are made can have an effect on the value of resistance measured and sufficient time should be allowed to elapse after switching off the load cycling test current. For larger joints exceeding 200 mm², this may be up to 12 h.

In order to reduce overall testing time, forced cooling of the test samples is permitted.

13.4.5.2 *Temperature measurements*

The temperatures of the joints and reference conductors, including ambient, shall be measured by thermocouples or by other suitable means with an accuracy of 2 °C or better.

The joint temperature recorded shall be that of the hottest part of its surface. The thermocouple may either be inserted in a small hole drilled into the joint or secured to the outside surface.

On the reference conductor the thermocouple shall be positioned at the mid-point and securely located, either in a small hole drilled into a solid conductor or by sliding it under the strands of the outer layer of a stranded conductor (see annexes B and C).

The devices to measure the ambient temperature throughout the test shall be placed so as not to be influenced by the heat dissipation of the test circuit.

13.4.5.3 *Measurement of short-time overcurrent (class B joints)*

It is recommended that the magnitude and duration of the waveform of the short-time overcurrent are measured using a storage oscilloscope or equivalent technique.

13.5 *Heat cycle test procedure*

13.5.1 *General*

The heat cycle test shall consist of *N* electrical load cycles. The number *N* of cycles shall be chosen from table 3. Short-time overcurrent impulses shall be applied to class B joints in accordance with 13.3.1 and also to class A joints when *N* cycles = 100.

Each cycle includes a heating period where the test assembly is loaded by the test current, followed by a subsequent cooling period with the current switched off.

The heat cycle test shall be carried out employing an alternating current.

Table 3 – Conditions for heat cycle test

N (cycles)	T_f (°C) (temperature rise)	N_{sc} (pulses)
1 000	70	3 *
500	100	3 *
100	130 ***	8 **

N is the number of cycles
T_f is the temperature rise of the reference conductor above the ambient
N_{sc} is the number of short-circuit pulses for class B joints
* Pulses applied after N cycles
** Pulses applied after 0,5 N cycles
*** For all types of conductors, the temperature (temperature rise plus ambient temperature) shall be less than 150 °C.

13.5.2 *Joints of class A*

13.5.2.1 *Test procedure*

The joints of class A shall be tested by the electrical heat cycle (N cycles) method described below.

1) The test shall be carried out on the joints prepared in accordance with 13.3.3. After the four joints have been placed in the test assembly, but prior to heat cycling, the resistance across each joint and the resistance of the reference conductor shall be measured as specified in 13.4.5.1. Taking into account the length of the joint, the resistance of an equivalent length of the reference conductor shall then be calculated.

2) A test current shall then be passed through the assembly. The value and duration of the test current shall be such as to raise the reference conductor temperature to the value of $T_f\,^{+5}_{0}$ °C (see table 3) above ambient and maintain this temperature for 30 min. The use of an initial current of value not greater than 150 % of the test current, to provide accelerated heating so as to reduce the time to raise the conductor to $T_f\,^{+5}_{0}$ °C above ambient, is permitted.

3) At the end of the heating period the current shall be interrupted and the conductor allowed to cool to within 5 °C above ambient. Forced cooling to reduce the time cycle is permitted.

4) This sequence of operation shall be repeated so that 0,1 N cycles (± 0,02 N cycles) of heating and cooling are applied.

5) On one occasion during the last five cycles of the 0,1 N cycles (± 0,02 N cycles), the conductor temperature and temperature of each joint shall be measured during the last 15 min of the 30 min period.

6) The assembly shall then be allowed to cool to ambient and the resistance of each joint measured and recorded.

7) Heat cycling shall then be continued with temperature and resistance measurement at the end of each 0,1 N cycles until 0,5 N cycles have been completed.

8) A further 0,5 N cycles shall then follow with resistance measurements taken every 0,05 N cycles (± 0,01 N cycles) and temperature measurement every 0,1 N cycles (± 0,02 N cycles).

The joints shall not be tightened or adjusted during the test.

The above sequence is shown in diagrammatic form in annex D.

In the event of short-time overcurrent tests being required, these tests shall be carried out in accordance with 13.5.3.1 for class B joints.

13.5.2.2 *Acceptance criteria (class A joints)*

Each joint shall meet the following criteria.

1) The initial resistance of the joint shall not differ by more than 30 % from the mean of the initial resistance of each of the four joints assembled for test.

2) The temperature of the surface of the joint, measured every 0,1 *N* cycles when the test current is flowing, shall not exceed that of the reference conductor.

3) The electrical resistance of the joint, measured at the end of every 0,1 *N* cycles at ambient temperature, shall not exceed 75 % of the measured resistance of the equivalent length of the reference conductor.

4) The average resistance of the joint over the last 0,5 *N* cycles shall not exceed the initial resistance of the joint by more than 50 %.

5) A graph of resistance against number of cycles shall demonstrate with a reasonable probability that the rise in resistance over the last 0,5 *N* cycles is not more that 15 % of the average resistance over the same period. The method employed for the determination of this probability shall be in accordance with annex E.

13.5.3 *Joints of class B*

13.5.3.1 *Test procedure*

The test procedure shall be the same as in 13.5.2.1 for joints of class A with the following exceptions.

1) Short-time overcurrent pulses shall be applied to the test assembly.

2) If the number *N* of heat cycles is 1 000 or 500, three short-time overcurrent pulses shall be applied after the *N* heat cycles (see table 3).

If the number *N* of heat cycles is 100, eight short-time overcurrent pulses shall be applied after 50 heat cycles (see table 3).

The value of current shall be of a magnitude sufficient to raise the reference conductor temperature to a value of 180 °C ± 10 °C above ambient.

The duration of the pulse shall be 1 s for conductors ≤100 mm² and up to 5 s for conductors >100 mm² actual cross-section.

It is permissible for the temperature to be attained after the current pulse has been switched off.

The test assembly shall be allowed to cool to ambient between pulses.

On completion of the short-time overcurrent pulse testing the assembly shall be allowed to cool to ambient temperature.

3) The resistance of each joint under test shall be measured and recorded before and after the short-time overcurrent pulse test.

13.5.3.2 *Acceptance criteria (class B)*

Each joint shall meet the following criteria.

1) The initial resistance of the joint shall not differ by more than 30 % from the mean of the initial resistance of each of the four joints assembled for test.

2) The temperature of the surface of the joint, measured every 0,1 *N* cycles when the test current is flowing, shall not exceed that of the reference conductor.

3) The average resistance of the joint over the last 0,5 *N* cycles shall not exceed the initial resistance of the joint by more than 50 %.

4) A graph of resistance against number of cycles shall demonstrate with a reasonable probability that the rise in resistance over the last 0,5 *N* cycles is not more than 15 % of the average resistance over the same period.

The method employed for the determination of this probability shall be in accordance with annex E.

5) The joint resistance measured after the short-time overcurrent pulse test shall not exceed the resistance value measured before the short-time overcurrent pulse test by more than 50 %.

14 Corona and radio interference voltage (RIV) tests

14.1 *Purpose*

This clause outlines test methods to be used in determining the RIV and corona performance of fittings. It does not address permissible RI limits or specified corona extinction voltages or corona extinction voltage gradients which are set by regulations or utility practice. Corona and RIV tests are type tests.

14.2 *Description of test methods*

The test is carried out to determine RIV levels and/or the extinction values of corona (the corona may be positive or negative as specified by the purchaser). If the purchaser specifies that the RIV level needs to be determined, it shall be carried out in accordance with CISPR 16-1 and CISPR 18-2. It should be noted that the RIV level is closely correlated to positive corona (see figure 12 and annex H).

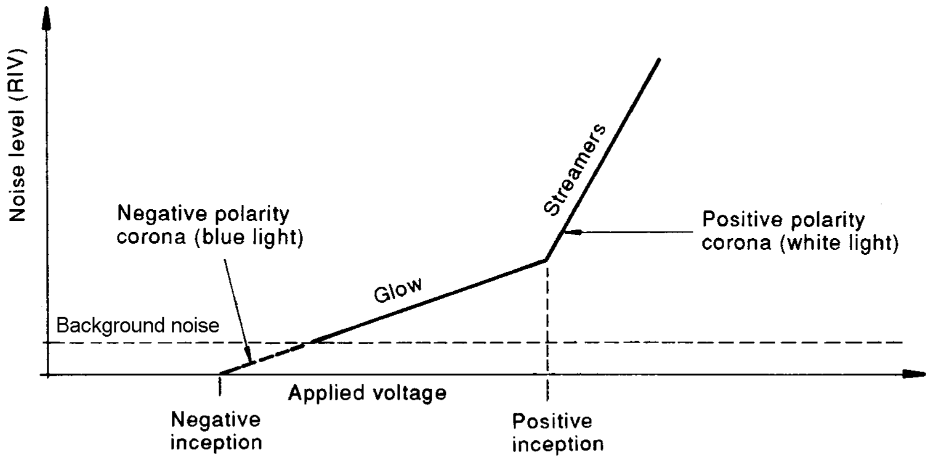


Figure 12 – Typical relationship between observed corona and RIV

There are two test methods described in this standard:

Voltage method

This specifies a fixed test voltage V, at which there shall be no corona, and simulates service conditions by detailing the proximity of earth planes.

Voltage gradient method

This specifies a fixed voltage gradient at the surface of the test conductor, at which there shall be no corona, and simulates service conditions by using suitable earth planes. The test voltage required to produce this gradient depends on the proximity of the earth planes and shall not deviate from the maximum operating phase to earth voltage by more than ±30 %.

In addition to the corona observation, the RIV performance of the fittings can be determined using either test set-up.

14.3 *General*

Type tests on individual fittings shall be carried out on three samples. Type tests on complete insulator sets shall be carried out on one sample assembly. The assembly with the fittings under test shall represent as closely as possible the service conditions.

The test shall be carried out with a relative humidity of between 20 % and 80 %.

The geometrical configuration as well as the maximum operating voltage of the overhead line for which the test fitting is intended shall be known. In this test, a single phase is used to produce specified voltage or voltage gradients related to those that occur on the conductors of the three-phase transmission line.

The fitting shall be attached to a length of conductor or sub-conductor of the size and type with which the fitting is to be used. Smooth metal rods or tubes with the same overall diameter as the conductor may be used to simulate the conductors.

The test conductor shall be positioned parallel to a conducting reference earth plane and terminated with corona free spheres or rings. The diameter of the spheres or rings shall be in accordance with 14.8.2.

The earth plane may be represented by a suitable ceiling, wall, floor, or by a structure built specifically for the purpose.

The conductor and suggested plane structure shall be so positioned that the conductor is approximately centred with respect to the plane. Earthed objects not forming part of the test arrangement shall not be closer to any point on the test conductor than 1,4 times the distance between conductor and reference earth.

The test assembly may be supported or positioned by suitable non-conducting, noise-free rods, ropes or chains. The connection to the test supply shall be made from one end of the conductor. The test supply and connection shall be positioned so as not to affect the gradient at the test object.

Suspension assembly

The test conductor, or bundle, shall be mounted horizontally. At the midpoint, support shall be provided by the suspension clamp test specimen in combination with the suspension insulator set.

The voltage method shall use simulated towers, crossarms and earth planes in accordance with 14.8. The voltage gradient method shall use suitable earth screens in accordance with 14.9.

Tension assembly

The test assembly shall be assembled as in service and shall include the dead-end tension joint or clamp, complete with jumper terminals and conductor. The test assembly shall be mounted with the insulators vertical or horizontal as agreed between the purchaser and supplier.

The voltage method shall use simulated towers, crossarms, earth planes and jumpers in accordance with 14.8. The voltage gradient method shall use suitable earth screens in accordance with 14.9.

Other fittings

The fittings such as spacers, vibration dampers, mid-span joints, etc. shall be set up as in service. The conductor, or bundle, shall be supported, or tensioned horizontally, by any of the means described above.

The conductor free length, and the minimum clearance to the reference earth plane, shall be in accordance with 14.8 and 14.9. The conductor shall be connected at one end to the test supply.

NOTE – Insulator type and condition can affect the corona and RIV performance of the hardware assembly. Especially when using cap and pin insulators, relative humidity below 40 % can lead to a serious increase of RIV. Alternatively, the corona performance of the hardware assembly may affect the insulator string attached to it. It is important that different assemblies be tested with the same type and manufacture of insulator. These insulators should, if possible, be the same as those intended for service. Also, if possible, the insulators used for testing should be agreed between supplier and purchaser.

14.4 *Test circuit and instruments*

Test conditions shall be monitored and correction factors applied in accordance with IEC 60060-1.

RIV procedures shall be carried out in accordance with CISPR 16-1.

The corona test shall be performed in a fully-darkened room. Observers usually require a minimum of 15 min to be conditioned to the dark. The use of field glasses or an image intensifier is recommended.

NOTE – Recommended viewing equipment is: field glasses 7 × 50 (min.), image intensifiers with light amplification greater than 40 000.

A photographic record of the corona, if required, shall be made with film and equipment suitable for long exposure times.

NOTE – Sensivity of the film ≥1 000 ASA and time of exposure ≥60 s are recommended.

Supplementary information can be obtained with ultrasonic directional receivers or other appropriate means.

14.5 *Corona and RIV test procedures*

The test fitting shall be mounted in the test assembly. Voltage shall be applied and increased to 120 % of the specified minimum corona extinction. The voltage shall be held for a minimum of 5 min. The voltage shall then be reduced to 30 % of the specified minimum corona extinction and again increased to 120 %. Lastly, it shall be gradually decreased to 30 %.

During the last decreasing run, radio-interference voltages and/or corona extinction shall be recorded. It is acceptable to do separate tests for corona extinction and RIV measurements.

NOTE – In cases where a corona glow effect occurs below the required corona extinction, it is permissible to clean the fitting surface with a clean dry cloth.

14.6 *Acceptance criteria*

a) The corona extinction of the fitting obtained during the test shall exceed the specified minimum corona extinction. The selection of uncorrected or corrected values shall be by agreement between purchaser and supplier.

NOTE – Corrected values should be determined in accordance with IEC 60060-1.

b) The RIV of the fitting recorded at the specified test voltage or conductor voltage gradient shall not exceed the specified maximum RIV.

c) The curve indicating the RIV against the test voltage shall not present any sudden change between the specified test voltage or conductor voltage gradient and 110 % of the specified test voltage or conductor voltage gradient.

14.7 *Test report*

The test report shall contain the following details:

a) name of manufacturer and type designation;

b) maximum voltage for equipment U_m;

c) details of test arrangements, including dimensions;

d) atmospheric conditions prevailing during the test, temperature, barometric pressure and air humidity, and the calculated correction factors;

e) type of method used to determine the corona extinction values;

f) corona extinction values corrected and uncorrected with details of discharge point;

g) radio interference voltage value.

Subject to agreement between the manufacturer and purchaser, the photographs taken at the extinction voltage level may also be included in the report.

14.8 *Voltage method*

14.8.1 *Adjacent conductors in a three-phase system*

Depending on the type of tower or structure, three variants are possible in the three-phase system:

a) one live conductor not influenced by adjacent conductors;

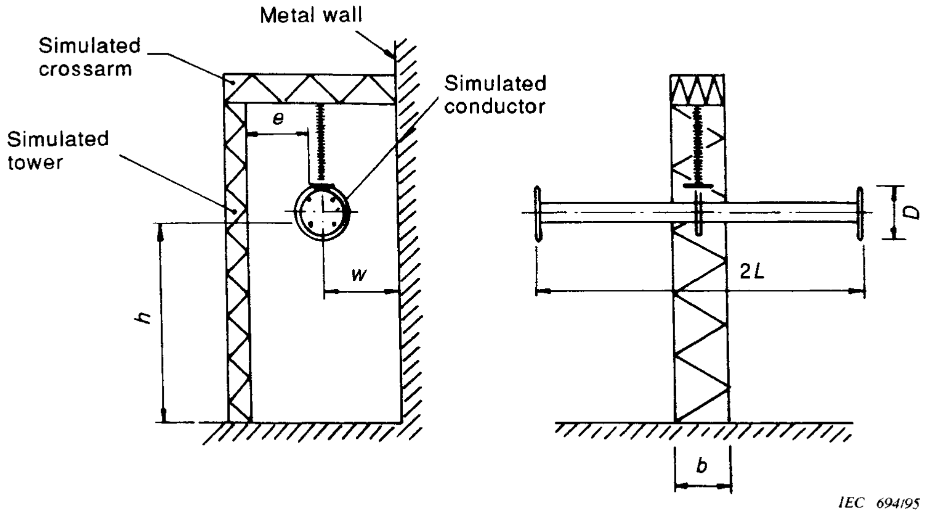
b) two live conductors at the same level;

c) three live conductors at the same level.

The tests on tension and suspension assemblies shall be carried out on the critical variant found in service. This is normally variant b) for the suspension and usual tension assemblies, and variant c) for the tension assembly at substations. The respective adjacent conductor is simulated by setting up the arrangement at a predetermined distance, from an earthed metallic wall (charge reflection) parallel to the live conductor. This will allow single-phase testing of each variant.

14.8.2 *Test set-up and dimensions* (see figures 13 to 18)

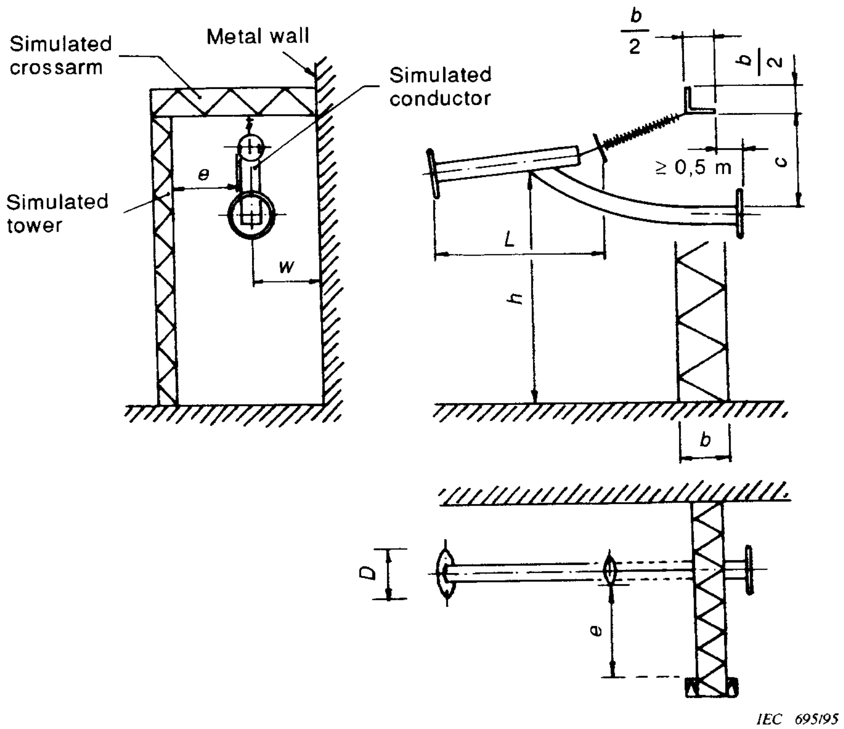
Suspension assembly



For the dimensions, see table 4.

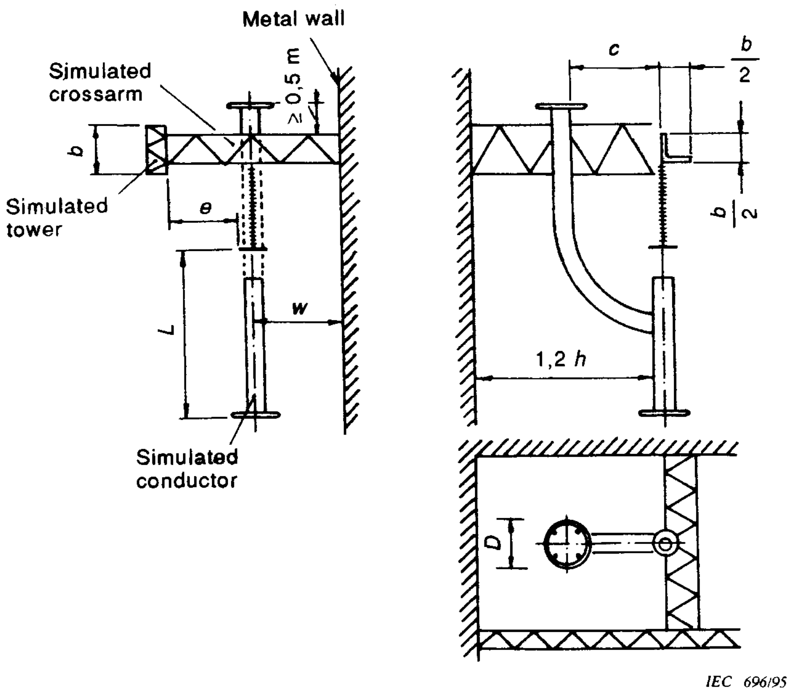
Figure 13 – Suspension test arrangement, critical variant b)

Tension assembly



For dimensions, see table 4.

Figure 14 – Tension test arrangement, critical variant b)

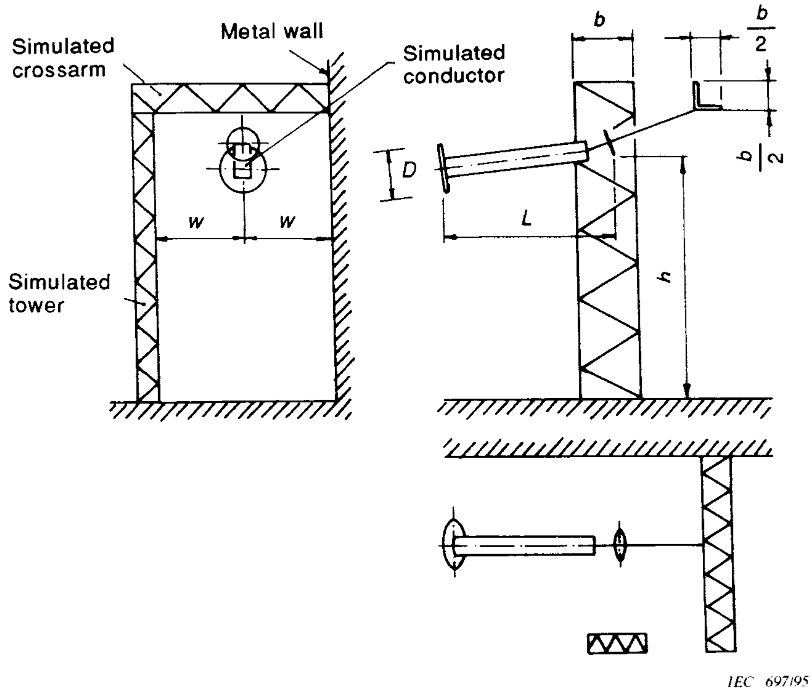


For dimensions, see table 4.

Figure 15 – Tension test arrangement, critical variant b), hanging vertically from the ceiling

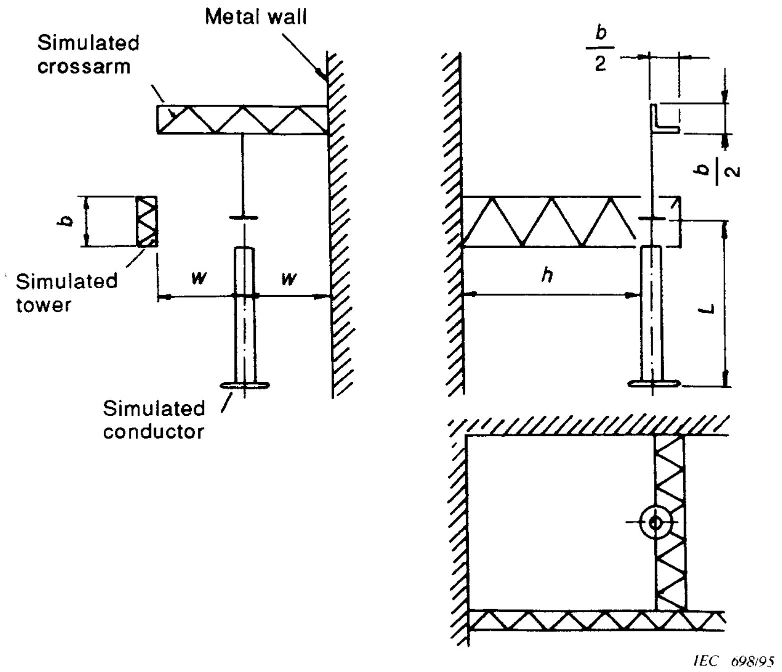
Tension assembly at substation

The second adjacent conductor is taken into account by charge-reflection on the simulated tower.



For dimensions, see table 4.

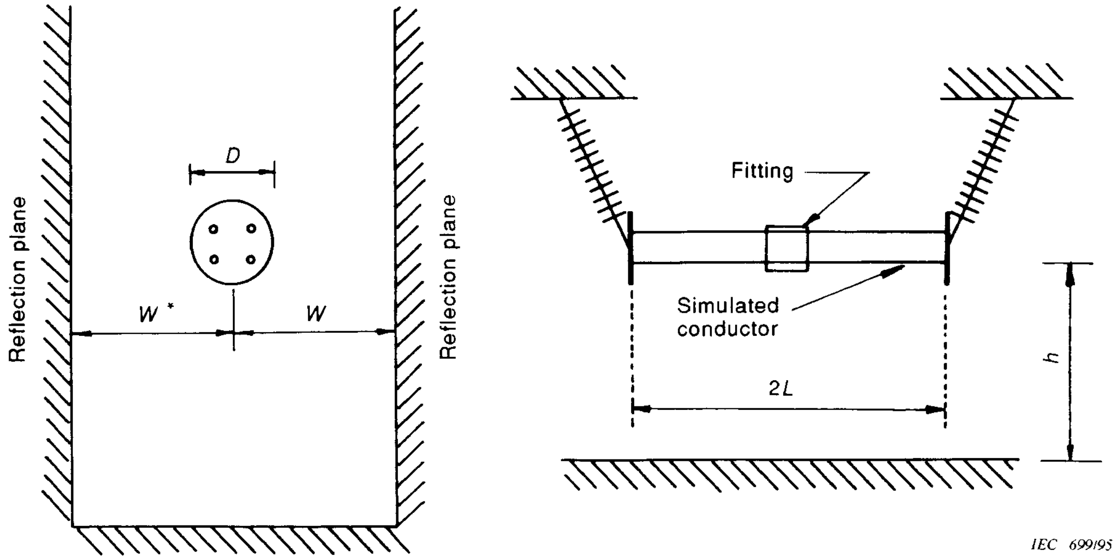
Figure 16 – Tension test arrangement, critical variant c)



For dimensions, see table 4.

Figure 17 – Tension test arrangement, critical variant c), hanging vertically from the ceiling

In-span fittings



* Required for variant c).

For dimensions, see table 4.

Figure 18 – Test arrangement for in-span fittings, critical variant b) or c)

Screening electrode

The diameter *D* (m) of the screening electrode at the end of simulated conductor shall be:

– for a single conductor	$D \geq 0{,}001\ U_m$ (U_m is the maximum operating voltage of the line in kV)
	$D \leq 0{,}1\ L$ (L is the length of the simulated conductors in metres)
– for a bundle conductor	$D > 1{,}2$ times the bundle diagonal

Table 4 – Test voltages and dimensions

U_m [1)] kV	Dimensions (m) [2) 3)]						
	e		*h*	*b*	*L*		*c*
	Overhead line	Substation	±10 %	±15 %	Single conductor	Bundle conductor	
123	2	0,95	4	1	≥ 3	–	1,5
245	3,5	1,85	4,5	1,5	≥ 4,5	≥ 10 *D*	2,5
420	5	2,9	5	2	≥ 5	≥ 10 *D*	3,5
525	6	3,5	6	2	–	≥ 10 *D*	4
765	7	5,1	6,5	2,5	–	≥ 10 *D*	5,5

1) Figures can be linearly interpolated for other voltages.

2) V-insulator sets shall be tested using the actual as-built tower clearance dimensions.

3) The dimensions in table 4 are suitable for typical conventional structures. In the case where dimensions shown are inappropriate, alternative dimensions may be agreed between purchaser and supplier.

List of symbols:

e is the horizontal distance between simulated tower and insulator protective fitting;

h is a height or a distance;

b is the width of the simulated tower;

L is the length of the simulated conductor;

c is the horizontal distance between simulated cross-arm and conductor supply;

D is the diameter of the screening electrode at the end of the simulated conductor;

W is the distance of the simulated conductor from the wall used as reflection plane.

14.8.3 *Critical variant*

The test arrangements specified in 14.8.2 adequately account for almost all arrangements occurring in practical operation, for example a tension tower with Double-Delta-configuration, variant b). Arrangements such as vertical and Y-tower configurations are tested according to variant a), in which case only adjacent earthed components are simulated. Fittings in the span (e.g. spacers) are tested according to figure 18.

14.8.4 *Distance from wall (reflection plane) w*

The distance w from the wall used as the reflection plane is obtained from

$$w = 0{,}7 \times d$$

where

d is the centre line spacing between two adjacent conductors.

NOTE – The reflection plane is not required if the centre-line spacing is more than 6 m in the case of single conductors, and more than 7,5 m (more than 9 m at U_m = 765 kV) in the case of bundled conductors.

Exception

If with a variant c) suspension arrangement the in-service conductor-to-tower clearance is less than the wall distance w, obtained from the conductor centre-line spacing d, this suspension arrangement shall be tested in the same way as for variant b) described in 14.8.1.

14.8.5 *Minimum clearance from adjacent live components*

Where possible, voltage infeed should be in the direction of the simulated conductor. Where this is not possible, the minimum clearance between the infeed and the test specimen shall not be less than 1,3 times the height h.

The minimum clearance between the test specimen and other live electrodes not forming part of the test arrangement as specified in 14.8.2 is 5 × *f*, where *f* is the maximum characteristic dimension of the electrodes.

14.8.6 *Metallic wall*

An earthed metal grid may also be understood as being a metallic wall with an area consisting at least of height *h*, plus the length of the insulator sets multiplied by length *L* of the simulated conductor. The mesh size of the metal grid shall not be more than 0,5 m.

14.9 *Voltage gradient method*

14.9.1 *Conductor voltage on three-phase system*

The minimum corona extinction voltage gradient is established by taking into consideration the maximum operating voltage of the transmission line on which the fitting is to be installed and the geometry of the line. Once the minimum corona extinction voltage gradient has been established, corona tests can be performed with a single-phase voltage supply. To produce the required voltage gradients at the test location, the conductor gradient sufficiently far away from the fitting assembly and the shielding devices is used as the reference.

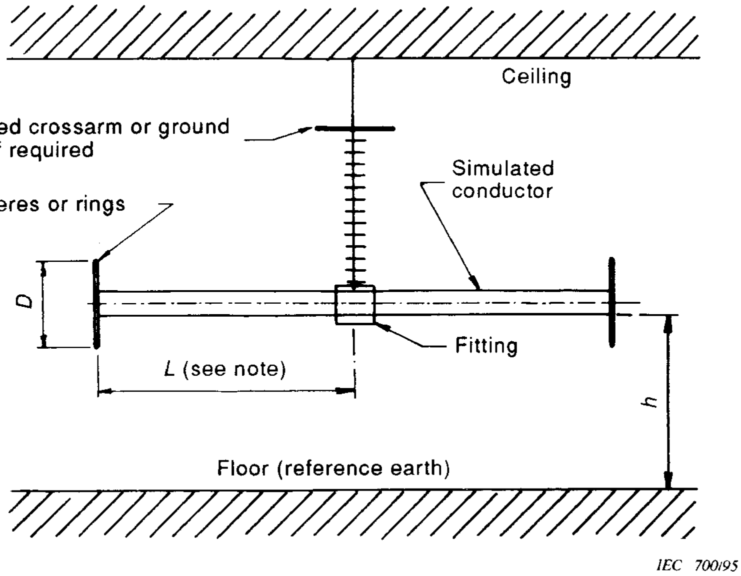
14.9.2 *Test set-up and dimensions*

Clearances to earthed and energized objects shall be provided such that relatively uniform conductor gradients are achieved in the vicinity of the test fitting. Typical test arrangements are shown in figures 19 and 20. Because the voltage gradient method uses test voltages determined from actual measured conductor gradients, it is not necessary to specify earth plane distances. However, the earth plane arrangement shall approximate service conditions; this is strictly necessary for tests on suspension assemblies when the minimum corona extinction voltage gradient is not established considering proximity effects of the tower window.

Earthed and energized objects shall be positioned in such a way that the test voltage required to reach the specified minimum corona extinction is within ± 30 % of the maximum operating phase-to-earth voltage.

14.9.3 *Test method*

To determine the test voltage required for corona extinction, the maximum conductor gradient shall be determined as a function of applied voltage. As the voltage gradient is directly proportional to the applied voltage, only one calibration point is required. This point can be obtained using a calibrator as described in annex H or measured using other suitable devices.

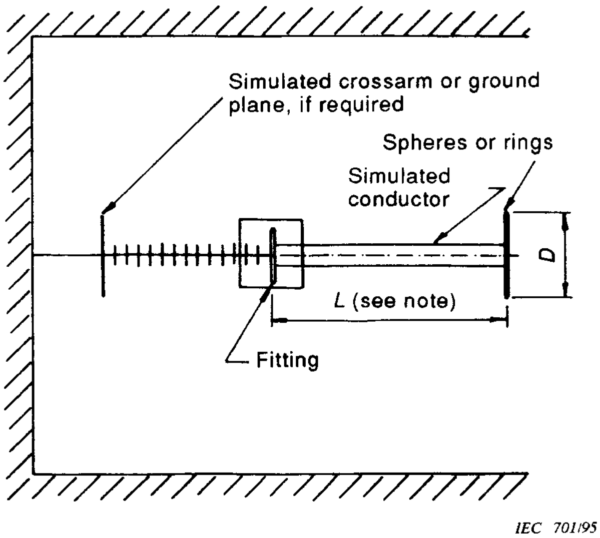


NOTE – Bundle conductors:

D > 1,2 times the diameter of the bundle

L > 10 *D*

Figure 19 – Typical test arrangement – suspension assembly



NOTE – Bundle conductors:

D > 1,2 times the diameter of the bundle

L > 10 *D*

Figure 20 – Typical test arrangement – tension assembly

Annex A
(normative)

Typical joint types

Class A tension

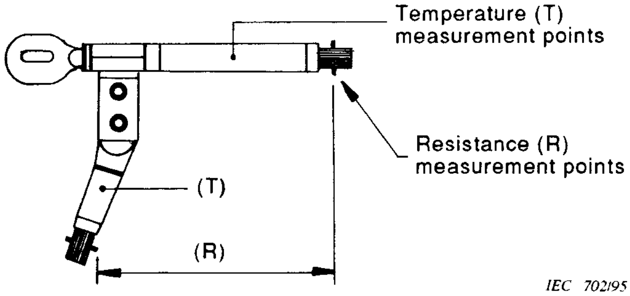


Figure A.1 – Dead-end tension joint assembly

This example also applies to repair sleeves and patch sleeves

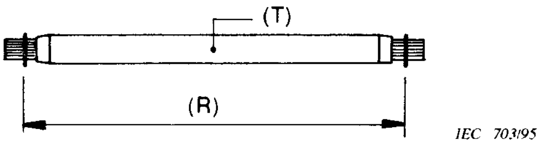
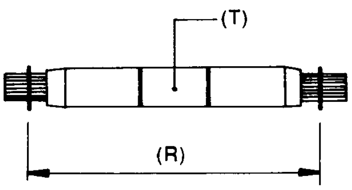


Figure A.2 – Mid-span tension joint

Class B non-tension



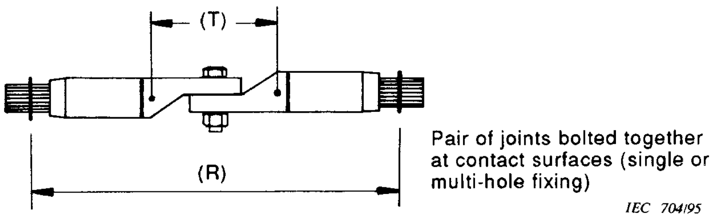
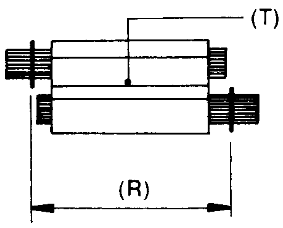
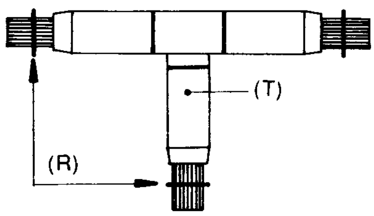


Figure A.3 – Splice (jumper)

Figure A.4 – Terminal lug





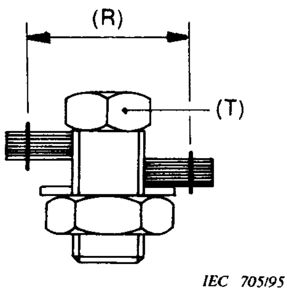


Figure A.5a – Parallel type

Figure A.5b – T or L type

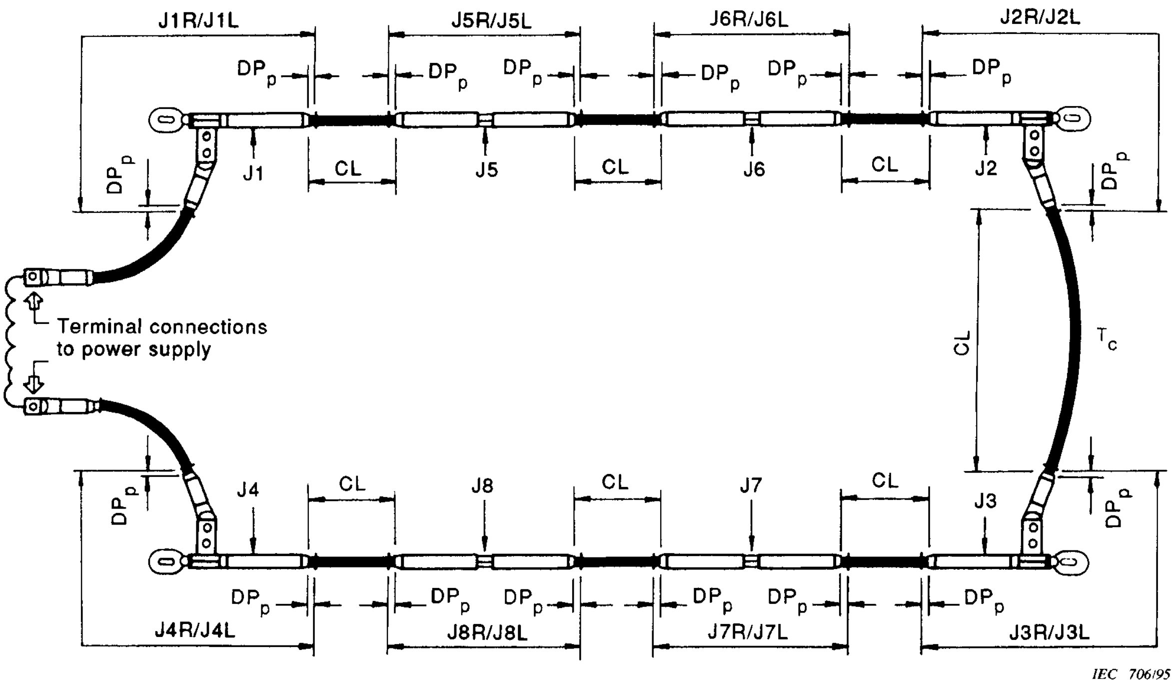
Figure A.5c – Bolted type

Figure A.5 – Tap or service joint

NOTE – The temperature measurement points shall be at the hottest point of each joint. The diagrams are for guidance only in this respect.

Annex B
(normative)

Typical test circuit – Class A joints



NOTES

1 Joints of different types may be connected in series in the test circuit.

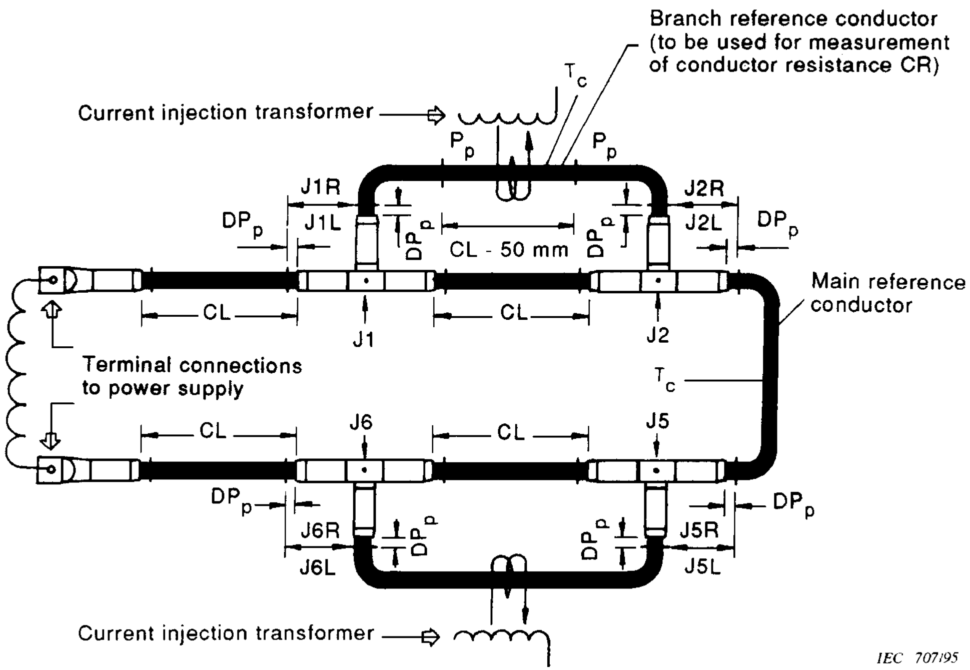
2 In this circuit for example:

J1 – J4	are the dead-end tension joint assembly;
J5 – J8	are the mid-span tension joint;
DP_p	= 25 mm (potential points), see annex G;
T_c	is the reference conductor temperature measurement point (°C);
CL	is the reference conductor length; 100 × conductor diameter between joints (mm) (maximum 4 m);
JL	is the joint length (mm);
JR	is the joint resistance (μΩ)
CR	is the conductor resistance (μΩ)
CR'	$= \dfrac{CR}{(CL - 50\ mm)}$ = conductor resistance (mm);
JR'	$= \dfrac{JR - CR' \times 50\ mm}{(JL - 50\ mm)}$ = joint resistance (mm);
C_{eq}	= CR' × JL = resistance of the equivalent length of the reference conductor (see 13.5.2.1).

3 To meet test acceptance criteria, see 13.5.2.2.

Annex C
(normative)

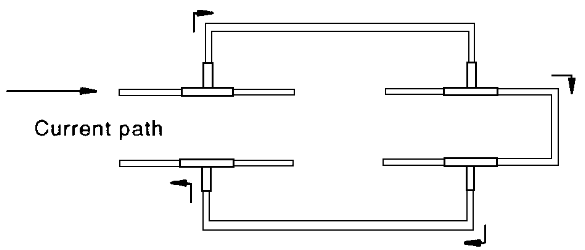
Typical test circuit – Class B joints



IEC 707/95

The reason for the current injection transformers is to ensure that the main reference conductor and the branch reference conductor can be run at the appropriate temperature as required by 13.5.2.1.

When the main and branch conductor are the same size, current transformers will not be needed and the test loop circuit is modified as follows:



IEC 708/95

NOTES

1 It is permitted to connect, into the test circuit, joints of different types in series.

2 In this circuit example:

J1 – J4	are the branch T joints;
P_p	are the potential points;
DP_p	are the 25 mm (potential points), see annex G;
T_c	is the reference conductor temperature measurement point (°C);
CL	is the reference conductor length; 100 × conductor diameter between joints (mm) (maximum 4 m);
JL	is the joint length (mm);
JR	is the joint resistance (μΩ);
CR	is the conductor resistance (μΩ);

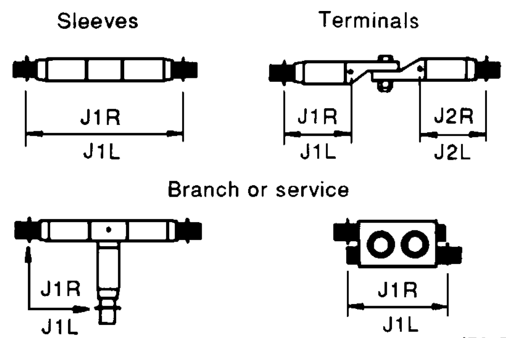
$$CR' = \frac{CR}{(CL - 50\ \text{mm})} = \text{conductor resistance (mm);}$$

$$JR' = \frac{JR - CR' \times 50\ \text{mm}}{(JL - 50\ \text{mm})} = \text{joint resistance (mm);}$$

C_{eq} = CR' × JL = resistance of the equivalent length of the reference conductor (see 13.5.2.1).

3 To meet test acceptance criteria, see 13.5.2.2.

Potential points for non-tension joint types.



IEC 709/95

Annex D
(normative)

Diagrammatic representation of heat cycle test sequence

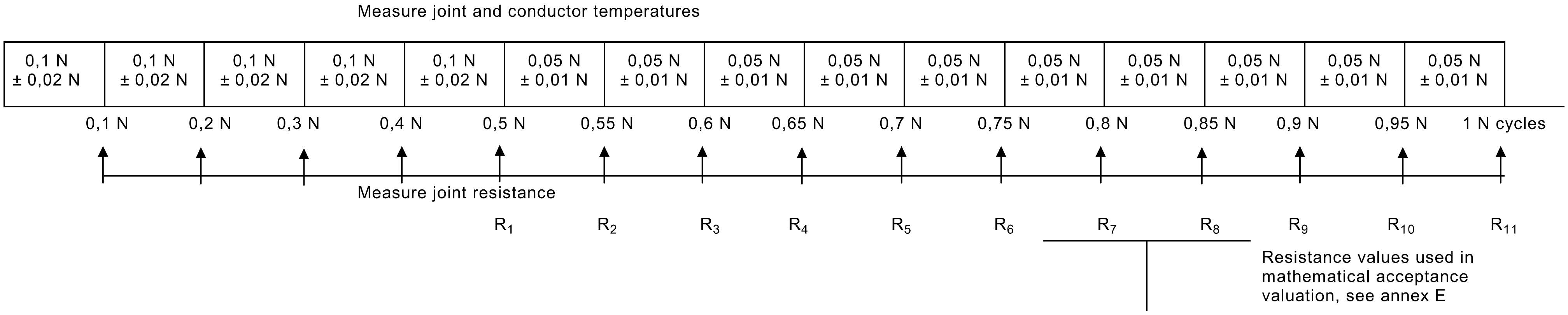


Figure D.1 – Detail of full test sequence

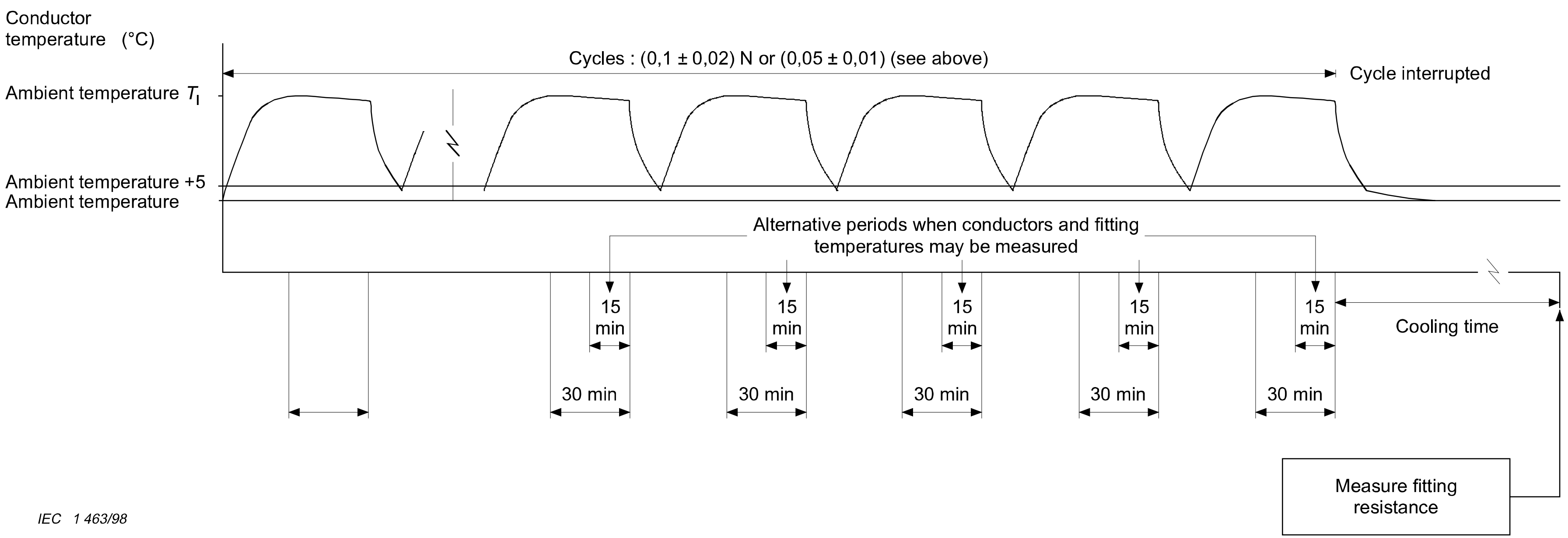


Figure D.2 – Detail of 0,1 N or 0,05 N cycle sequence

Annex E
(normative)

Mathematical acceptance criterion

E.1 General

Throughout this annex, the word acceptance relates only to the requirements of 13.5.2.2 and 13.5.3.2.

The mathematical acceptance method set out in this annex is meant to provide a non-subjective means of assessing load cycling test results over the interval 0,5 N-N cycles including when the assessment is not obvious from the inspection of the graphs. It is not intended, however, that the use of judgement in interpreting results should be entirely disregarded in favour of this mathematical assessment. Although each of the 11 test results is taken into account in the statistical assessment of a single sample, one reading that deviates appreciably from the line of best fit can have an overriding effect on the result, leading to a rejection indication. Where, for example for class B joints, three samples out of four have definitely passed the test, and the fourth would pass but for a single reading, it is not unlikely that the rogue reading is due to a testing error; it would be contrary to common sense to reject a design on the basis of one bad resistance reading in 44. Continuation of the test, or even acceptance, despite the one bad reading, might be agreed between the parties to the test according to other evidence.

The acceptance criterion is determined in the following three successive stages.

a) The calculation of the change (rise or fall) of resistance between 0,5 N and N load cycles, using as a basis the line of best fit (obtained by the method of least squares) for the data. This change of resistance is expressed as a fraction of the mean of the resistance readings from 0,5 N to N load cycles inclusive, and is designated M.

NOTE – M is a change (rise or fall) and is therefore always positive.

b) The calculation of a quantity, the magnitude of which depends upon the "scatter" of the resistance values about the line of best fit. This is expressed as a fraction of the mean resistance between 0,5 N and N load cycles and is designated S.

c) The calculation of a quantity D = M + S

D is in fact the change of resistance between 0,5 N and N load cycles, calculated as a fraction of the mean resistance in this interval, with 95 % confidence based on the assumption that the distribution of the resistance values about the line of best fit is normal. The acceptance criterion is that D should not exceed 0,15.

The following is a step-by-step instruction written for direct application at a test site. The following procedure is repeated for each test sample.

E.2 Designation of resistance measurements

Resistance measurements are designated as follows:

Cycles N	0,5	0,55	0,6	0,65	0,7	0,75	0,8	0,85	0,9	0,95	1
Resistance measurement	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}

E.3 Calculation of mean resistance

$$\text{Mean resistance} = R = \frac{R_1 + R_2 + \ldots\ldots + R_{11}}{11}$$

E.4 Calculation of slope of line of best fit of resistance measurements

$$\text{Slope} = B = \frac{-5R_1 - 4R_2 - 3R_3 - 2R_4 - R_5 + R_7 + 2R_8 + 3R_9 + 4R_{10} + 5R_{11}}{110}$$

B may be positive or negative.

E.5 Calculation of change of resistance as a fraction of mean resistance based on line of best fit

$$\text{Change of resistance} = M = \frac{10\,B}{R}$$

E.6 Comparison of M with acceptance criterion

If $M > 0{,}15$, the sample is rejected

If $M \leq 0{,}15$, proceed with E.7.

E.7 Extend change of resistance calculation to take account of the scatter of resistance readings around the line of best fit

Calculate $$S = \frac{2{,}07}{R}\sqrt{\frac{A_1^2 + A_2^2 + \ldots\ldots + A_{11}^2}{9}}$$

where

$$\begin{aligned}
A_1 &= R_1 - R + 5B \\
A_2 &= R_2 - R + 4B \\
A_3 &= R_3 - R + 3B \\
A_4 &= R_4 - R + 2B \\
A_5 &= R_5 - R + B \\
A_6 &= R_6 - R \\
A_7 &= R_7 - R - B \\
A_8 &= R_8 - R - 2B \\
A_9 &= R_9 - R - 3B \\
A_{10} &= R_{10} - R - 4B \\
A_{11} &= R_{11} - R - 5B
\end{aligned}$$

E.8 Compare M + S with acceptance criterion

For acceptance of the fittings: $D = M + S \leq 0{,}15$

Annex F
(informative)

Examples of normative documents recommended for fitting materials

IEC 60437: 1973, *Radio interference test on high-voltage insulators*

ISO 209-1: 1989, *Wrought aluminium and aluminium alloys – Chemical composition and forms of products – Part 1: Chemical composition*

ISO 426-1: 1983, *Wrought copper-zinc alloys – Chemical composition and forms of wrought products – Part 1: Non-leaded and special copper-zinc alloys*

ISO 426-2: 1983, *Wrought copper-zinc alloys – Chemical composition and forms of wrought products – Part 2: Leaded copper-zinc alloys*

ISO 427: 1983, *Wrought copper-tin alloys – Chemical composition and forms of wrought products*

ISO 428: 1983, *Wrought copper-aluminium alloys – Chemical composition and forms of wrought products*

ISO 630: 1995, *Structural steels – Plates, wide flats, bars, sections and profiles*

ISO 683-1: 1987, *Heat-treatable steels, alloy steels and free-cutting steels – Part 1: Direct-hardening unalloyed and low-alloyed wrought steel in form of different black products*

ISO 683-13: 1986, *Heat-treatable steels, alloy steels and free-cutting steels – Part 13: Wrought stainless steels*

ISO 1083: 1987, *Spheroidal graphite cast iron – Classification*

ISO 1187: 1983, *Special wrought copper alloys – Chemical composition and forms of wrought products*

ISO 1336: 1980, *Wrought coppers (having minimum copper contents of 97,5 %) – Chemical composition and forms of wrought products*

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

ISO 1460: 1992, *Metallic coatings – Hot dip galvanized coatings on ferrous materials – Gravimetric determination of the mass per unit area*

ISO 1463: 1982, *Metallic and oxide coatings – Measurement of coating thickness – Microscopical method*

ISO 2604-1: 1975, *Steel products for pressure purposes – Quality requirements – Part 1: Forgings*

ISO 3506: 1979, *Corrosion-resistant stainless steel fasteners – Specifications*

ISO 3522: 1984, *Cast aluminium alloys – Chemical composition and mechanical properties*

ISO 3574: 1986, *Cold-reduced carbon steel sheet of commercial and drawing qualities*

ISO 3755: 1991, *Cast carbon steels for general engineering purposes*

ISO 5922: 1981, *Malleable cast iron*

ISO 6361-2: 1990, *Wrought aluminium and aluminium alloy sheets, strips and plates – Part 2: Mechanical properties*

ISO 6362-2: 1990, *Wrought aluminium and aluminium alloy extruded rods/bars, tubes and profiles – Part 2: Mechanical properties*

ISO 6363-2: 1993, *Wrought aluminium and aluminium alloy cold-drawn rods/bars and tubes – Part 2: Mechanical properties*

ISO 6932: 1986, *Cold-reduced carbon steel strip with a maximum carbon content of 0,25 %*

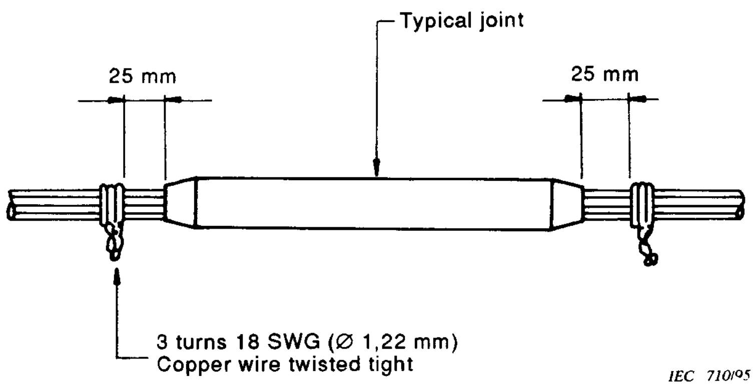
Annex G
(informative)

Potential points

For stranded conductors an example of a practical potential point consists of three turns of tinned copper wire.

Care should be taken to ensure that the potential point is twisted tightly in position before measurements are taken.

Example



Annex H
(informative)

Test voltage calibration device

H.1 Description of voltage gradient calibrator

The calibrator consists of a small sphere attached to a wire loop so that it can be attached to the test conductor as shown in figure H.1.

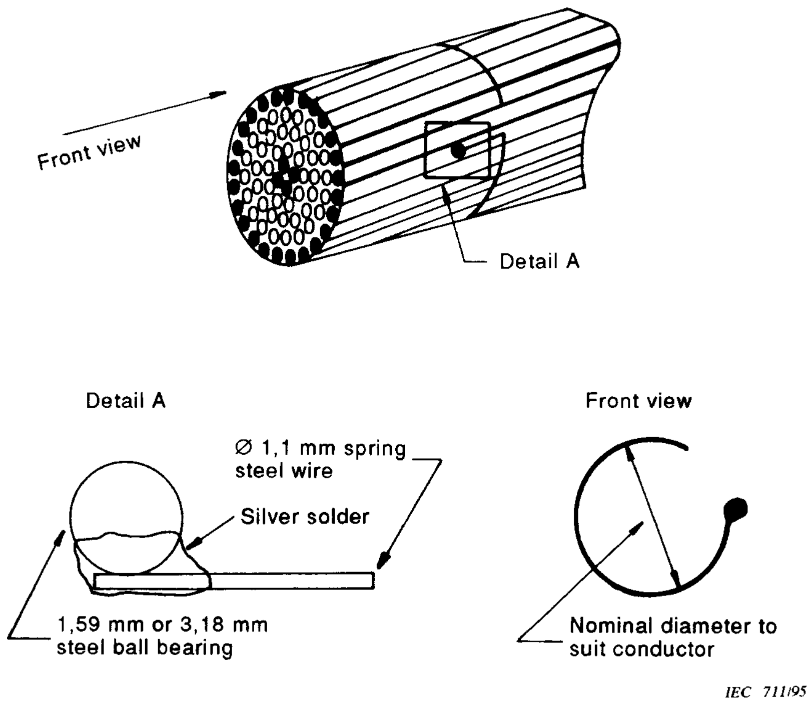


Figure H.1 – Voltage gradient calibrator

A spherical projection of this type has a well-defined positive corona inception which can be expressed in terms of the nominal conductor surface voltage gradient. This inception for a given sphere and conductor size can be pre-determined in a known concentric cylinder or conductor and ground plane arrangement, and is summarized in figure H.2. The nominal conductor surface voltage gradient in a concentric cylinder geometry is given by:

$$E = \frac{V}{r \ln \frac{R}{r}}$$

where

V is the voltage of the conductor;

R is the radius of the test cylinder;

r is the radius of the conductor.

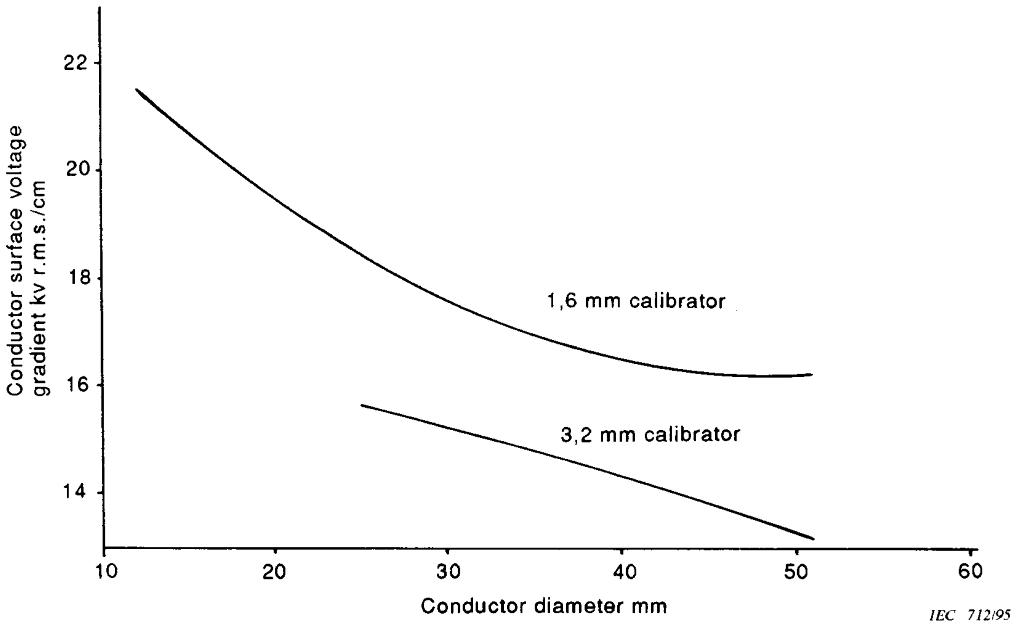


Figure H.2 – Typical positive corona inception gradient for different calibrators on various sizes of conductors

When the calibration of the device is carried out with a single ground plane, the above gradient is given by

$$E = \frac{V}{r \ln \frac{2h}{r}}$$

where h is the height of the test conductor above the ground.

To prevent flashovers, the radius of the test cylinder or the height above the ground plane should be at least 20 times larger than the conductor radius.

H.2 Voltage determination

To determine the test voltage for specified minimum corona extinction or specified maximum RIV, the calibration device described in H.1 can be used. Where a stranded conductor is used, the sphere of the calibration device shall be located on an outer strand at the maximum distance from the conductor axis. Where bundle subconductors are used, not only shall the above apply, but the sphere shall also be positioned on one of the subconductors in the appropriate position indicated in figure H.3 (the gradient calibrator shall be located at the point of maximum gradient of conductor or bundle).

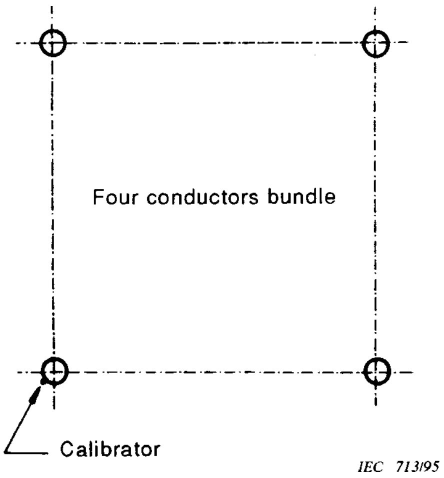


Figure H.3

For tests on compression fittings, the calibrating sphere shall be located within a distance of at most 10 times the fittings diameter from one end of the connector.

For tests on suspension assemblies, if the voltage gradient was not calculated considering proximity effects of the tower window, the test voltage shall be established on the conductor away from the influence of the test assembly, and ground planes shall be used to simulate a tower window. This can be achieved by either locating the gradient calibrator sufficiently far away from the simulated window to be unaffected by it or by determining the gradient in the absence of the test assembly.

In other cases, the gradient of the fitting shall be established by calibrating with the sphere at the mid-point of a test conductor.

The calibration device and conductor shall be cleaned. Voltage shall then be applied to the conductor. This voltage shall be steadily increased to the minimum value at which positive polarity corona occurs at the calibration device. The voltage at which positive polarity corona is observed shall be noted. This positive polarity corona inception or extinction voltage shall be used to determine the test voltage. The value thus obtained is that of the voltage to be applied in the corona test:

$$V_R = \frac{E_S}{E_C} V_C$$

where

V_C is the voltage required for positive corona inception (or extinction) on the calibration device;

V_R is the required test voltage to achieve the specified minimum corona extinction or maximum RIV;

E_C is the positive corona inception (or extinction) gradient for conductor-mounted calibration device;

E_S is the voltage gradient specified for minimum corona extinction or maximum RIV.

NOTE – Care should be taken to ensure that positive polarity corona is not confused with negative polarity corona (corona generated on the negative half-cycle). The two are easily distinguishable. Negative polarity corona occurs first, that is, at a lower voltage than does positive polarity corona. With the inception of positive polarity corona, sudden and marked changes occur simultaneously to the visual, aural and electrical characteristics. The negative polarity corona blue light, emitted from a point source located at the calibration sphere surface, is no longer apparent because of the whiter light from a positive polarity corona streamer, 25 mm or more in length, that emanates from the same point source. Further, the negative polarity corona high-frequency hissing is rendered inaudible because of the positive polarity corona low-frequency crackling. Finally, where RIV readings are being taken, the quasi-peak detector reading for positive polarity corona will be greater than for negative by a factor of 50 or more, provided ambient RIV levels are very low (less than 25 µV at 1 MHz when measured using the circuit for the measurement of the RIV of high-voltage apparatus, described in IEC 60437 and CISPR 16).

Annex I
(informative)

Example of sampling with inspection by attributes

An example of the procedure for inspection by attributes agreed between purchaser and supplier is as follows:

a) inspection level: S4;

b) sampling plan: single sampling plan for normal inspection;

c) acceptance quality level (AQL):

1) 0,1 for all items and characteristics thereof which are vital for safe and reliable service of the transmission line;

2) 1,0 for all other items and their pertinent characteristics.

The above procedure requires, for example

– for lot or batch size = 100

code letter D

sample size 8

AQL	0,1	Acceptance	:	zero nonconformity
		Rejection	:	one (or more) nonconformity
AQL	1,0	Acceptance	:	zero nonconformity
		Rejection	:	one (or more) nonconformity

– for lot or batch size = 12 500

code letter H

sample size 50

AQL	0,1	Acceptance	:	zero nonconformity
		Rejection	:	one (or more) nonconformity
AQL	1,0	Acceptance	:	one nonconformity
		Rejection	:	two (or more) nonconformity

Annex J
(informative)

Example of sampling with inspection by variables

An example of the procedure for inspection by variables agreed between purchaser and supplier is as follows:

a) inspection level: S4;

b) type of method: *s* method;

c) acceptance quality level (AQL):

1) 0,1 for all items and characteristics thereof which are vital for safe and reliable service of the transmission line;

2) 1,0 for all other items and their pertinent characteristics.

The above procedure requires, for example

– for lot or batch size = 100

code letter C

sample size 4

AQL 0,1 Acceptability constant k = 2,42

AQL 1,0 Acceptability constant k = 1,45

– for lot or batch size = 12 500

code letter I

sample size 25

AQL 0,1 Acceptability constant k = 2,50

AQL 1,0 Acceptability constant k = 1,85

____