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Lignes aériennes –
Exigences et essais applicables aux entretoises

Overhead lines –
Requirements and tests for spacers

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Overhead lines – Requirements and tests for spacers

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

OVERHEAD LINES – REQUIREMENTS AND TESTS FOR SPACERS

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 61854 has been prepared by IEC technical committee 11: Overhead lines.

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

FDIS	Report on voting
11/141/FDIS	11/143/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.

Annex A forms an integral part of this standard.

Annexes B, C and D are for information only.

OVERHEAD LINES – REQUIREMENTS AND TESTS FOR SPACERS

1 Scope

This International Standard applies to spacers for conductor bundles of overhead lines. It covers rigid spacers, flexible spacers and spacer dampers.

It does not apply to interphase spacers, hoop spacers and bonding spacers.

NOTE – This standard is written to cover the line design practices and spacers most commonly used at the time of writing. There may be other spacers available for which the specific tests reported in this standard may not be applicable.

In many cases, test procedures and test values are left to agreement between purchaser and supplier and are stated in the procurement contract. The purchaser is best able to evaluate the intended service conditions, which should be the basis for establishing the test severity.

In annex A, the minimum technical details to be agreed between purchaser and supplier are listed.

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 61284:1997, *Overhead lines – Requirements and tests for fittings*

IEC 60888:1987, *Zinc-coated steel wires for stranded conductors*

ISO 34-1:1994, *Rubber, vulcanized or thermoplastic – Determination of tear strength – Part 1: Trouser, angle and crescent test pieces*

ISO 34-2:1996, *Rubber, vulcanized or thermoplastic – Determination of tear strength – Part 2: Small (Delft) test pieces*

ISO 37:1994, *Rubber, vulcanized or thermoplastic – Determination of tensile stress-strain properties*

ISO 188:1982, *Rubber, vulcanized – Accelerated ageing or heat-resistance tests*

ISO 812:1991, *Rubber, vulcanized – Determination of low temperature brittleness*

ISO 815:1991, *Rubber, vulcanized or thermoplastic – Determination of compression set at ambient, elevated or low temperatures*

ISO 868:1985, *Plastics and ebonite – Determination of indentation hardness by means of a durometer (Shore hardness)*

ISO 1183:1987, *Plastics – Methods for determining the density and relative density of non-cellular plastics*

ISO 1431-1:1989, *Rubber, vulcanized or thermoplastic – Resistance to ozone cracking – Part 1: static strain test*

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

ISO 1817:1985, *Rubber, vulcanized – Determination of the effect of liquids*

ISO 2781:1988, *Rubber, vulcanized – Determination of density*

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 level (LQ) for isolated lot inspection*

ISO 2921:1982, *Rubber, vulcanized – Determination of low temperature characteristics – Temperature-retraction procedure (TR test)*

ISO 3417:1991, *Rubber – Measurement of vulcanization characteristics with the oscillating disc curemeter*

ISO 3951:1989, *Sampling procedures and charts for inspection by variables for percent nonconforming*

ISO 4649:1985, *Rubber – Determination of abrasion resistance using a rotating cylindrical drum device*

ISO 4662:1986, *Rubber – Determination of rebound resilience of vulcanizates*

[1)] To be published.

3 Definitions

For the purpose of this International Standard the definitions of the *International Electrotechnical Vocabulary (IEV)* apply, in particular IEC 60050(466). Those which differ or do not appear in the IEV are given below.

3.1
rigid spacer
spacer allowing no relative movement between the subconductors at the spacer location

3.2
flexible spacer
spacer allowing relative movements between the subconductors at the spacer location

3.3
spacer system
complex of spacers and the relevant in-span distribution

4 General requirements

4.1 Design

The spacer shall be designed as to

- maintain subconductor spacing (at spacer locations), within any prescribed limits, under all conditions of service excluding short-circuit currents;
- prevent, in subspans between spacers, physical contact between subconductors, except during the passage of short circuit currents when the possibility of contact is accepted provided that the specified spacing is restored immediately following fault clearance;
- withstand mechanical loads imposed on the spacer during installation, maintenance and service (including short circuit conditions) without any component failure or unacceptable permanent deformation;
- avoid damage to the subconductor under specified service conditions;
- be free from unacceptable levels of corona and radio interference under specified service conditions;
- be suitable for safe and easy installation. For the bolted and latching clamp the design shall retain all parts when opened for attachment to the conductor;
- ensure that individual components will not become loose in service;
- be capable of being removed and re-installed on the subconductors without damage to the spacer or subconductors;
- maintain its function over the entire service temperature range;
- avoid audible noise.

NOTE – Other desirable characteristics, which are not essential to the basic functions of the spacer but which may be advantageous to the purchaser, include:

- verification of proper installation from the ground,
- ease of installation and removal from energized lines.

4.2 Materials

4.2.1 General

Spacers shall be made of any materials suitable for their purpose. Unless additional requirements are stated, the material shall conform to the requirements of IEC 61284.

4.2.2 Non-metallic materials

In addition to the requirements of IEC 61284, the conductivity of the various non-metallic components shall be such that when properly installed

- potential differences between metallic components do not cause damage due to discharge;
- any current flow between subconductors does not degrade spacer materials.

4.3 Mass, dimensions and tolerances

Spacer mass and significant dimensions, including appropriate tolerances, shall be shown on contract drawings.

NOTE – Tolerances applied to the mass and to the dimensions should ensure that the spacers meet their specified mechanical and electrical requirements.

4.4 Protection against corrosion

In addition to the applicable requirements of IEC 61284, stranded steel wires, if used, shall be protected against corrosion in accordance with IEC 60888.

4.5 Manufacturing appearance and finish

The spacers shall be free of defects and irregularities; all outside surfaces shall be smooth and all edges and corners well-rounded.

4.6 Marking

The fitting marking requirements of IEC 61284 shall be applied to all clamp assemblies including those using breakaway bolts.

Correct position of the top of the spacer (for example arrows pointing upward), if necessary, shall also be provided.

4.7 Installation instructions

The supplier shall provide a clear and complete description of the installation procedure and, if required, the in-span location of the spacers.

The supplier shall make available any special installation tool that is required.

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 spacers during the manufacturing process.

Detailed information on the use of quality assurance is given in the following ISO standards ISO 9000-1 [1]; ISO 9001 [2]; ISO 9002 [3]; ISO 9003 [4] and ISO 9004-1 [5]*.

It is recommended that test equipment used to verify compliance to this standard is routinely maintained and calibrated in accordance with a relevant quality standard.

6 Classification of tests

6.1 Type tests

6.1.1 General

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

6.1.2 Application

Spacers shall be subjected to type tests as per table 1. Each type test shall be performed on three samples which are identical, in all essential respects, with the spacers to be supplied under contract to the purchaser. All units shall pass the tests.

The spacers used for tests during which no damage occurs to the units or their components may be used in subsequent tests.

NOTE – The unit subjected to type tests can be either a complete spacer or a component of the spacer as appropriate to the test.

6.2 Sample tests

6.2.1 General

Sample tests are required to verify that the spacers meet the performance specifications of the type test samples. In addition, they are intended to verify the quality of materials and workmanship.

6.2.2 Application

Spacers shall be subjected to sample tests as per 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.

* Figures in square brackets refer to the bibliography.

The spacers used for tests during which no damage occurs to the units or their components may be used in subsequent tests.

NOTE – The unit subjected to sample tests can be either a complete spacer or a component of the spacer as appropriate to the test.

6.2.3 Sampling and acceptance criteria

The sampling plan procedures according to ISO 2859-1 and ISO 2859-2 (inspection by attributes) and ISO 3951 (inspection by variables) and the detailed procedures (inspection level, AQL, single, double or multiple sampling, etc.) shall be agreed between purchaser and supplier for each different attribute or variable.

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 customer may choose to use an attributes acceptance sampling plan to assure 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 of concern with gradual trends or changes which may affect the 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 spacers to specific requirements and are made on every spacer. The tests shall not damage the spacers.

6.3.2 Application and acceptance criteria

Whole lots of spacers may be subjected to routine tests. Any spacer which does not conform to the requirements shall be discarded.

6.4 Table of tests to be applied

Table 1 indicates the tests which shall be performed. These are marked with an "X" in the table.

However, the purchaser may specify additional tests which are included in the table and marked with an "O".

Units or components damaged during the tests shall be excluded from the delivery to the customer.

Table 1 – Tests on spacers

Clause	Test	Spacer damper			Flexible spacer			Rigid spacer		
		Type test	Sample test	Routine test	Type test	Sample test	Routine test	Type test	Sample test	Routine test
7.1	**Visual examination**	X	X	O	X	X	O	X	X	O
7.2	**Verification of dimensions, material and mass**	X	X	O	X	X	O	X	X	O
7.3	**Corrosion protection tests**	X [1]	X [1]		X [1]	X [1]		X [1]	X [1]	
7.4	**Non-destructive tests**	O	O	O	O	O	O	O	O	O
7.5	**Mechanical tests**									
7.5.1	– clamp slip tests	X	O		X	O		X	O	
7.5.2	– breakaway bolt test	X	X		X	X		X	X	
7.5.3	– clamp bolt tightening test	X	X		X	X		X	X	
7.5.4	– simulated short-circuit current test and compression and tension tests	X	O		X	O		X	O	
7.5.5	– characterisation of the elastic and damping properties	X	O		O	O				
7.5.6	– flexibility tests	X	O		X	O				
7.5.7	– fatigue tests	X			O					
7.6	**Tests to characterise elastomers**	X	O		X [1]	O [1]				
7.7	**Electrical tests**									
7.7.1	– corona and radio interference voltage (RIV) tests	X			X			X		
7.7.2	– electrical resistance test	X	O		X [1]	O [1]		O [1]		
7.8	**Verification of vibration behaviour of the bundle/spacer system**									
D.2	– aeolian vibration	O			O [2]					
D.3	– subspan oscillation	O			O					

[1] If applicable.

[2] When used in conjunction with vibration dampers.

NOTE – The supplier should state in the tender quality plan, or other tender documentation, which testing is already complete (i.e: which type test) and which tests (sample or routine) are included in the tender, subject to the approval or change required by the purchaser.

7 Test methods

7.1 Visual examination

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

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

The sample test procedures and acceptance criteria shall be agreed between purchaser and supplier.

For spacers 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 specified or agreed by the purchaser.

7.2 Verification of dimensions, materials and mass

Type, sample and, if required, routine tests shall include verification of dimensions to ensure that spacers 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.

Type, sample and, if required, routine tests shall also include verification of materials to ensure that they are in accordance with contract drawings and documents. This verification shall normally be carried out by the purchaser inspecting the supplier's documentation relating to material specifications, certificates of conformity or other quality documentation.

The total mass of the spacer complete with all its components shall comply with the mass shown on the contract drawing (within given tolerances).

7.3 Corrosion protection test

7.3.1 Hot dip galvanized components (other than stranded galvanized steel wires)

Hot dip galvanized components other than stranded galvanized steel wires shall be tested in accordance with the requirements specified in ISO 1461.

The coating thicknesses shall conform to tables 2 and 3 unless otherwise agreed between purchaser and supplier. However, for the purpose of this standard, tables 2 and 3 of ISO 1461 shall apply to the following categories of items (and not to the categories specified in ISO 1461).

Table 2: coating thickness on all 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).

7.3.2 Ferrous components protected from corrosion by methods other than hot dip galvanizing

Ferrous components protected from corrosion by methods other than hot dip galvanizing shall be tested in accordance with the requirement of the relevant IEC/ISO standards, agreed between purchaser and supplier.

7.3.3 Stranded galvanized steel wires

Stranded galvanized steel wires shall be tested in accordance with the requirements specified in IEC 60888.

7.3.4 Corrosion caused by non-metallic components

By agreement between purchaser and supplier, evidence of non-corrosion compatibility between the elastomer and the conductor or spacer components, as appropriate, shall be demonstrated by a corrosion test or by suitable service experience. Alternatively, and where appropriate, the purchaser may specify for each subassembly containing an elastomer, a range of electrical resistance which provides adequate conductivity for electrical charging but minimizes galvanic action.

NOTE – Non-metallic components, especially elastomeric elements lining a spacer clamp or providing the flexibility and damping in a spacer damper, are commonly made electrically conducting to avoid any problems that might otherwise arise from the capacitive charging of the arms or body of the spacer. Carbon is frequently used in elastomer formulations, both to achieve the desired stiffness and damping, and to provide electrical conductivity. However, carbon in contact with aluminium may lead to severe galvanic corrosion of the latter in a polluted environment. Other constituents of non-metallic components, such as chlorides, free sulphur, etc. may also have corrosive effects.

7.4 Non-destructive tests

The purchaser shall specify or agree to relevant test methods (ISO or other) and acceptance criteria. Examples of non-destructive tests are as follows:

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

7.5 Mechanical tests

7.5.1 Clamp slip tests

The tests shall be performed using the conductor for which the clamps are intended. The conductor shall be "as new", i.e. free of any deterioration or damage. The minimum length of the test conductor between its terminating fittings shall be, with the exception of the test in clause 7.5.1.2 B), 4 m. The conductor shall be tensioned to 20 % of its rated tensile strength.

Clamps shall be installed on an unused portion of conductor for each test.

Precautions shall be taken to avoid birdcaging of the conductor.

The clamps shall be tested individually. The clamp shall be installed in accordance with the supplier's instructions. In the case of breakaway bolts, the installation torque shall be the design value minus the tolerance agreed between purchaser and supplier (see 7.5.3).

NOTE – The use of other conductor, conductor lengths and tensions can be agreed between purchaser and supplier.

7.5.1.1 Longitudinal slip test

A) By means of a suitable device (see figure 1a), a load coaxial to the conductor shall be applied to the clamp.

The load shall be gradually increased (not faster than 100 N/s) until it reaches the specified minimum slip load value. This load shall be kept constant for 60 s. Then the load shall be gradually increased until slippage of the clamp occurs. The slip load value shall be recorded.

For metal surface clamps, slip shall be considered as having occurred when a movement of the clamp on the conductor of 1,0 mm is measured.

NOTE – The following values for rubber-lined clamps and clamps using helical rods are given for reference:

- rubber-lined clamp: 2,5 mm;
- clamp using helical rods: 12,0 mm.

- Acceptance criteria

No slippage shall occur at or below the minimum specified value. If both minimum and maximum slip requirements are stated, the slip shall occur between those values. Surface flattening of the outer strands of the conductor is acceptable.

B) An alternative test arrangement which evaluates the performance of the whole spacer assembly under simulated broken conductor conditions, as well as clamp slip, is shown in figure 1b.

NOTE – The effects imposed by the two test methods A) and B) are not equivalent.

For a bundle of N subconductors, N-1 subconductors shall be tensioned. A spacer shall be mounted on the subconductors and a longitudinal force shall be applied to the untensioned subconductor.

The load shall be gradually increased (not faster than 100 N/s) until it reaches the specified minimum slip load value. This load shall be kept constant for 60 s. Then the load shall be gradually increased until slippage of the clamp occurs. The slip load value shall be recorded.

For metal surface clamps, slip shall be considered as having occurred when a movement of the clamp on the conductor of 1,0 mm is measured.

NOTE – The following values for rubber-lined clamps and clamps using helical rods are given for reference:

- rubber-lined clamp: 2,5 mm;
- clamp using helical rods: 12,0 mm.

- Acceptance criteria

The slip force of the clamp on the subconductor or the failure load of the spacer shall not be less than the minimum specified value. In addition, if required by the purchaser, the longitudinal movement of the initially untensioned subconductor with respect to its initial position shall be higher than the minimum specified value at the moment of the slippage.

7.5.1.2 Torsional slip test

A) A torque (see figure 2a) shall be applied to the clamps in order to rotate it around the axis of the conductor.

The torque shall be gradually increased until it reaches the specified minimum slip torque. This torque shall be kept constant for 60 s. Then the torque shall be gradually increased until slippage of the clamp by torsion occurs. The slip torque value shall be recorded.

The test shall be carried out applying the torque in the direction of lay of the outer conductor strands. The test shall be repeated by applying the torque in the opposite direction.

Clamp slip shall be considered as having occurred when a slip value greater than one strand diameter is measured after the release of load.

- Acceptance criteria

No slippage shall occur at or below the minimum specified value.

B) An alternative test arrangement is shown in figure 2b.

A conductor of length L equal to the average sub-span associated with the tested spacer, shall be tensioned to 20 % of its rated tensile strength. The spacer shall be mounted at the centre of the test conductor ($l_1 = l_2 = L/2$). Then the tension on the test conductor shall be increased to 40 % of its rated tensile strength. The spacer shall be rotated to an angle γ_l, specified or agreed by the purchaser, around the axis of the conductor.

The test shall be carried out applying the torque in the direction of lay of the outer conductor strands. The test shall be repeated by applying the torque in the opposite direction.

NOTE – The test may be performed with unequal lengths l_1 and l_2. In this case, the recommended angle of rotation is

$$\gamma = \frac{4\gamma_l}{L}\left(\frac{l_1 \times l_2}{l_1 + l_2}\right) \text{ (degrees)}$$

Clamp slip shall be considered as having occurred when a slip value greater than one strand diameter is measured after release of load.

- Acceptance criteria

No slippage shall occur at or below γ_l.

7.5.2 Breakaway bolt test

The breakaway bolt, if used, shall be tested by applying increasing torque to the breakaway portion of the bolt until it breaks away. The breakaway torque shall be recorded. The breakaway torque shall be within the tolerance agreed between purchaser and supplier.

7.5.3 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 bolt(s) or nut(s) shall be tightened to a torque 10 % above the specified installation torque. Clamps with breakaway bolts shall have the breakaway portion of the head removed prior to the test and shall be tightened with the specified torque value plus the agreed tolerance. The threaded connection shall remain serviceable for any number of subsequent installations and removals and all components of the clamp shall be undamaged. No unacceptable damage shall occur on the conductor inside the clamp. Unacceptable damage shall be agreed between purchaser and supplier.

Lastly, the torque shall be increased either to twice the specified installation torque or the maximum torque value recommended by the bolt supplier, whichever is lower. This increase shall not result in any breakage of threaded parts or other components.

7.5.4 Simulated short-circuit current test and compression and tension tests

The purpose of these tests is to ensure that the spacers will be able to withstand, without failure or permanent deformation, the compressive and tensile load which may occur in service.

The purchaser shall specify or agree to one of the following tests, or any combination of tests.

NOTE – The effects imposed by the loads in the different tests, or combination of tests, are not necessarily equivalent.

7.5.4.1 Simulated short-circuit current test

Suitable devices (see figure 3) which are able to apply compressive forces (directed toward the centre of the conductor bundle) and tensile forces (directed away from the centre of the conductor bundle) to all spacer clamps simultaneously shall be used.

- Compression

The compressive forces shall be gradually increased until they reach the specified value. At this value the forces shall be held constant for 60 s and then removed. The test shall be executed twice; the first one with the spacer in its normal position and the second one with one clamp displaced longitudinally of an agreed amount, with reference to the other clamp(s).

The value of the compressive force specified above can be calculated using the formula given in annex B unless a different value is agreed between purchaser and supplier.

- Tension

Following compressive forces, tensile forces shall be applied. These forces shall be gradually increased until they reach the specified value at which they shall be maintained for 60 s. The value of the tensile forces shall be taken as 50 % of the corresponding compressive forces, unless a different value is agreed between purchaser and supplier.

• Acceptance criteria

After the test,

- it shall be possible to return the spacer clamps to their design position using only slight hand pressure;
- the spacer shall be examined by disassembly if necessary. There shall be no deformation or damage which would impair the efficiency of the spacer or affect its function of maintaining the normal bundle spacing.

7.5.4.2 Compression and tension test

The spacer assembly shall be installed on a suitable device (see figure 4) able to apply compression and tension forces between each pair of adjacent clamps.

The clamp bolts, when used, shall be tightened to the specified installation torque.

For each pair of adjacent clamps, the compressive force shall first be applied. The force shall be gradually increased until it reaches the specified value which shall be maintained for 60 s. Then the compressive force shall be removed and the tensile force shall be applied to the same pair of clamps and held for 60 s at the specified value.

The value of the compressive and tensile forces to be applied shall be agreed between purchaser and supplier.

• Acceptance criteria

After the test,

- it shall be possible to return the spacer clamps to their design position using only slight hand pressure;
- the spacer shall be examined by disassembly if necessary. There shall be no deformation or damage which would impair the efficiency of the spacer or affect its function of maintaining the normal bundle spacing.

7.5.5 Characterisation of the elastic and damping properties

Tests to determine the elastic and damping properties of spacer dampers shall be performed in accordance with one or more of the following methods as specified or agreed by the purchaser.

NOTE 1 – The stiffness and damping values do not provide direct confirmation of the performance of spacer dampers installed on conductor bundles, but they may be used in analytical models used to provide indication of performance, particularly with regard to aeolian vibration.

NOTE 2 – The stiffness and damping values determined in type tests can be used to establish acceptance criteria for sample tests as specified or agreed by the purchaser.

NOTE 3 – The elastic and damping characteristics determined in the following different tests are not equivalent.

A) Stiffness-damping method

The frame of the spacer shall be fixed securely and a rigid tube or rod shall be securely held in one of the spacer clamps. The tube/rod shall be oscillated (see annex C) such that the angle of deflection of the spacer arm from its unloaded position follows a sinusoid, i.e.

$$\varphi = \Phi \sin \omega t$$

where

φ is the angle of deflection

Φ is the peak value of deflection selected for the measurement.

The peak force F required to oscillate the spacer arm through the angle measurement $\pm\Phi$ shall be determined (measured at approximately 90° to the arm axis in the plane of the spacer and passing through the centre of the clamp).

The phase angle, α, between the force and arm deflection angle shall also be determined.

If necessary the arm oscillation shall be maintained for a period long enough to stabilize the temperature of the damping element(s) before measuring F and α.

The angle α may be measured directly by comparing the force and arm angle wave forms. It may also be determined indirectly by measuring the area of the hysteresis loop formed by displaying the force and arm angle deflection in X-Y form. In this case α can be calculated as follows:

$$\alpha = \arcsin [E/(F\, l\, \pi\, \Phi)]$$

where

α is the phase angle between arm deflection and force (rad);

E is the area of the moment/angular deflection loop (J);

F is the peak force (N);

l is the arm length measured between clamp centre and effective frame/arm pivot point (m);

Φ is the peak arm deflection (rad).

The test shall be carried out at a frequency between 1 Hz and 2 Hz with a peak-to-peak displacement equivalent to the diameter of the conductor for which the clamp is intended to be used.

NOTE – Tests at a variety of frequencies and/or displacements can be used to characterize spacer dampers for computer programs.

From the measurements of F and α, the torsional stiffness K_t and the damping constant H_t shall be calculated as follows:

$$K_t = (F \times l \times \cos \alpha) / \Phi \quad \text{(Nm/rad)}$$

$$H_t = K_t \times \tan \alpha \quad \text{(Nm/rad)}$$

- Acceptance criteria

– The torsional stiffness K_t shall not differ by more than ±20 % from the value declared by the supplier and stated on contract drawings.

– The ratio H_t/K_t shall not be lower than 20 % of the value declared by the supplier and stated on contract drawings.

B) Stiffness method

After being held at a test reference temperature of (20 ± 5) °C for at least 3 h, the horizontal stiffness of a spacer shall be determined in the following manner:

- the spacer shall be held (preferably in its working orientation) by two adjacent clamps installed on horizontal rods which are free to rotate;
- one rod shall be held in position and a force shall be applied to the other rod just sufficient to move the clamp arms to their stops in tension, i.e. the spacing shall have been increased from X_{nom} to X_{max} which shall be recorded;
- the above shall be repeated for the arms in compression for X_{min} to be recorded;
- spacings X_t and X_c shall then be determined, where

$$X_t = X_{nom} + 0,9\ (X_{max} - X_{nom})$$

$$X_c = X_{nom} - 0,9\ (X_{nom} - X_{min})$$

- The spacer arms shall then be moved in the following cycle:
  - starting at X_{nom} the spacing shall be increased to X_t at a uniform rate between 50 mm/min and 100 mm/min;
  - the spacing shall be held at X_t and after 60 s the force F_t required to hold this spacing shall be recorded;
  - the spacing shall then be decreased at a uniform rate between 20 mm/min and 50 mm/min until the spacing is again equal to X_{nom};
  - after holding the spacing at X_{nom} between 0 s and 20 s, the spacing shall be decreased to X_c at a uniform rate between 50 mm/min and 100 mm/min;
  - the spacing shall be held at X_c and after 60 s the force F_c required to hold this spacing shall be recorded;
  - the stiffness shall then be determined as $(F_t + F_c)/(X_t - X_c)$.

NOTE – To illustrate the above, assume that the test is carried out on a 400 mm twin spacer which has stops at spacings of 420 mm and 370 mm. It will then be necessary to record the tensile force F_t (N) required to maintain a spacing of 418 mm and the compression force F_c (N) required to maintain a spacing of 373 mm. The stiffness will then be $(F_t + F_c)/45$ (N/mm).

- Acceptance criteria

The stiffness shall not differ by more than ±20 % from the value declared by the supplier and stated on contract drawings.

C) Damping method

The damping characteristic shall be determined as follows.

The body of the spacer shall be fixed rigidly, and a mass shall be added to one arm such that the natural frequency of oscillation is between 1 Hz and 2 Hz. The arm shall then be moved to one of the end stops and, after 1 min, suddenly released. The movement of the arm shall be recorded for at least two complete cycles. If the initial swing (from starting position to maximum deflection in the opposite direction) is Y_1 and subsequent swings (peak to peak) are Y_2, Y_3, Y_4 the log decrement shall be taken to be equal to

$$\ln\left[\frac{1}{2}\left(\frac{Y_1}{Y_3}+\frac{Y_2}{Y_4}\right)\right]$$

NOTE – This definition is different to the conventional one $(\ln[A_o/A_n]/n)$ but is less sensitive to measurement error and does not require the zero deflection position to be determined.

- Acceptance criteria

The log decrement shall not differ by more than ±20 % from the value declared by the supplier and stated on contract drawings.

7.5.6 Flexibility tests

The purpose of these tests is to ensure and prove that the spacer damper or flexible spacer will accommodate any expected relative movement or displacement of the subconductors, during the normal working life of the line, without damage to conductors or the spacer.

The values of the displacements to be used for the tests shall be agreed between purchaser and supplier.

The spacer shall be installed on a length of the specified subconductor bundle tensioned at 20 % of its rated tensile strength, tightening the clamp bolts to the specified installation torque. As an alternative, the spacer may be installed on rods or tubes of the correct size.

The following displacements shall be applied:

a) longitudinal displacement (see figure 5): horizontal, longitudinal, parallel movement of one subconductor relative to the other(s) as measured by the deflection of the vertical long axis of the spacer from its position normal to the conductor;

b) vertical displacement (see figure 6): vertical movement of one subconductor relative to the other(s) as measured by the vertical deflection of the horizontal axis of the spacer from its position normal to the conductor;

c) conical displacement (see figure 7): conical or angular movement of the spacer clamp on one sub-conductor as measured conically about the normal subconductor axis;

d) transversal displacement (see figure 8): relative movement of two spacer clamps horizontally aligned perpendicular to the subconductor axes, as measured by the increase and decrease of conductor separation.

- Acceptance criteria

The above movements or displacements shall be executed without slip or damage to the subconductors and spacer, as detected by visual examination after removal of the spacer.

7.5.7 Fatigue tests

7.5.7.1 General

Tests shall be performed to verify the fatigue behaviour of spacers subjected to alternating motions or simulating vibrations (aeolian vibration and subspan oscillation) occurring in service.

Unless otherwise agreed between purchaser and supplier, two spacers shall be tested: one for subspan oscillation and one for aeolian vibration.

NOTE – In the following test additional requirements may be agreed between purchaser and supplier to match very severe service conditions.

7.5.7.2 Subspan oscillation

The spacer shall be installed in a test rig designed to subject the spacer to oscillatory compressive/tensile forces directed between two horizontally opposite clamps (see figure 9a).

The central frame of the spacer shall be unrestrained.

Alternatively, the frame of the spacer shall be held in a fixed position and oscillatory forces shall be applied to one clamp, approximately 90° to the arm axis (see figure 9b).

Each clamp under test shall be installed on a rigid tube or rod having the same diameter as the conductor for which the spacer is intended to be used. The clamp fasteners, if threaded, shall be tightened to the specified installation torque. The above tube(s) or rod(s) shall be connected to the drive mechanism.

The test shall be performed in one of the following two ways:

- either with a displacement (peak-to-peak) resulting from the application of a sinusoidal force having a peak-to-peak value of 600 N. The displacement shall be determined at the beginning of the test and shall be kept constant during all the test;
- or with a clamp displacement or an arm rotation equal to 90 % of the maximum allowed by the spacer.

The test shall be carried out at a frequency between 1 Hz and 2 Hz for a number of cycles, agreed between purchaser and supplier.

NOTE – Tests in which actual conductors are involved are under consideration.

- Acceptance criteria

At the end of the test, the phase angle α (as determined in 7.5.5 A) and the force required to maintain the horizontal displacement shall not be less than 70 % of their initial value. There shall be no deterioration in the metal components of the spacer, and the residual tightening torque of the clamp fastener (if threaded) shall not be less than 50 % of the original value (i.e. half the specified installation torque).

NOTE – The residual tightening torque (RTT) is measured by means of a torque wrench which is applied to the bolt and operated in the tightening sense. The RTT value is read on the torque meter when the bolt begins to move.

7.5.7.3 Aeolian vibration

The following test simulates the behaviour of a spacer positioned at a node.

The frame of the spacer shall be fixed in a position as in service and a spacer clamp shall be installed on a rigid tube or rod having the same diameter as the conductor for which the spacer is designed (see figure 10). The clamp fastener (if threaded) shall be tightened to the specified installation torque.

The tube or rod shall be connected to the driving mechanism and shall be subjected to a vibration of a total angle equal to 0,2° peak-to-peak, in a vertical plane parallel to the conductor, at a fixed frequency of 20 Hz, for 100 million cycles.

- Acceptance criteria

At the end of the test the torque required to maintain the agreed angle shall be not less than 70 % of the initial value, there shall be no deterioration in the metal component of the spacer, and the residual tightening torque of the clamp fastener (if threaded) shall be not less than 50 % of the original value (i.e. half the specified installation torque).

7.6 Tests to characterise elastomers

7.6.1 General

These tests shall be performed on samples taken from elastomeric components or test slabs and buttons as appropriate. These test data, along with supplier's guaranteed values, shall form the basis for acceptance of sample tests during production.

7.6.2 Tests

The tests reported in table 2 shall be performed. The test values shall fall within the values guaranteed by the supplier.

Table 2 – Tests on elastomers

Recommended tests	Required value	Test methods
Room temperature tests		
– Specific gravity and density	Supplier specified range	ISO 1183 – ISO 2781
– Vulcanization characteristics	Supplier specified range	ISO 3417
– Hardness shore A	Supplier specified range	ISO 868
– Tensile properties		ISO 37
Tensile strength	Supplier specified min. value	ISO 37
Ultimate elongation	Supplier specified min. value	ISO 37
Modulus at 100 % elongation	Supplier specified min. value	ISO 37
Modulus at 300 % elongation	Supplier specified min. value	ISO 37
– Compression set 70 h, 20 °C	Supplier specified max. value	ISO 815
– Rebound resilience at 20 °C	Supplier specified range	ISO 4662
– Ozone resistance	To meet 7.6.3	ISO 1431-1
– Abrasion resistance	Supplier specified min. value	ISO 4649
– Tear resistance	Supplier specified min. value	ISO 34-1/34-2
– Electrical resistance	Supplier specified range	As per 7.7.2
High temperature tests		
– Compression set, 70 h, 100 °C	Supplier specified max. value	ISO 815
– Rebound resilience at 100 °C	Supplier specified range	ISO 4662
– Water immersion		ISO 1817
Volume change	Supplier specified max. value	ISO 1817
Weight change	Supplier specified max. value	ISO 1817
– Oil* conditioning 72 h, 70 °C		ISO 1817
Volume change	Supplier specified range	ISO 1817
Weight change	Supplier specified range	ISO 1817
Hardness change	Supplier specified range	ISO 1817
Tensile strength change	Supplier specified range	ISO 1817
Ultimate elongation change	Supplier specified range	ISO 1817
– Air-oven ageing, 72 h, 70 °C		ISO 188
Volume change	Supplier specified max. value	ISO 188
Weight change	Supplier specified max. value	ISO 188
Hardness change	Supplier specified max. value	ISO 188
Tensile strength change	Supplier specified max. value	ISO 188
Ultimate elongation change	Supplier specified max. value	ISO 188
Low temperature tests		
– Brittleness	Supplier specified min. value	ISO 812
– Compression set, 70 h, at minimum user service temperature	Supplier specified max. value	ISO 815
– Rebound resilience at minimum user service temperature	Supplier specified range	ISO 4662
– T10 Modulus temperature	Supplier specified range	ISO 2921
* The test oil shall be agreed between purchaser and supplier.		

7.6.3 Ozone resistance test

- Scope

The purpose of this test is to verify the resistance of the elastomer to the attack of ozone, universally present in the atmosphere and generated by the electrical discharges around high-voltage cables (corona).

- Test procedures

There are several test procedures covered by international standards. The test method to be used shall be agreed between purchaser and supplier. The recommended method is described in ISO 1431-1, procedure A, and the following parameters are recommended.

Ozone chamber temperature	(40 ± 2) °C
Ozone concentration	(50 ± 5) pp hm (parts per hundred million of air by volume)
Exposure time	72 h

As far as specimens are concerned, ISO 1431-1 (procedure A) prescribes thin rectangular test strips clamped at an elongation of 20 %. Alternatively, the test may be performed on finished elastomer components. The elastomer components shall be tested in their metal housing and at least one of them shall be subjected to the maximum tensile deformation allowed by the spacer design. In both cases, the elastomer under test shall be conditioned for 48 hours in the dark at room temperature before being placed in the ozone chamber.

- Acceptance criteria

Ozone attack is usually evidenced by the formation of a few deep cracks or a myriad of small parallel cracks. They occur at right angles to the direction of applied stress. No cracks shall be observed at ×7 magnification on the surface of the specimens elongated or deformed as above.

7.7 Electrical tests

7.7.1 Corona and radio interference voltage (RIV) tests

The tests shall be carried out according to clause 14 of IEC 61284.

7.7.2 Electrical resistance test

The purpose of the test is to verify that the conductivity of the various components is such that potential differences and current flows do not result in deterioration of spacer components or conductors.

The electrical resistance shall be measured between each pair of subconductors.

When conductive current paths are used and, due to special design considerations, conductive current paths do not exist between all pairs of subconductors, the resistance shall be measured between the two most remote spacer components which are supposed to be connected via a conductive path.

An appropriate method shall be applied for measuring the resistance.

The test parameter and the test results shall be recorded.

- Acceptance criteria

All the electrical resistance measurements obtained shall be in the range agreed between purchaser and supplier.

7.8 Verification of vibration behaviour of the bundle/spacer system

Criteria and tests to verify the vibration behaviour of the bundle/spacer system can be agreed between purchaser and supplier following the suggestions reported in annex D.

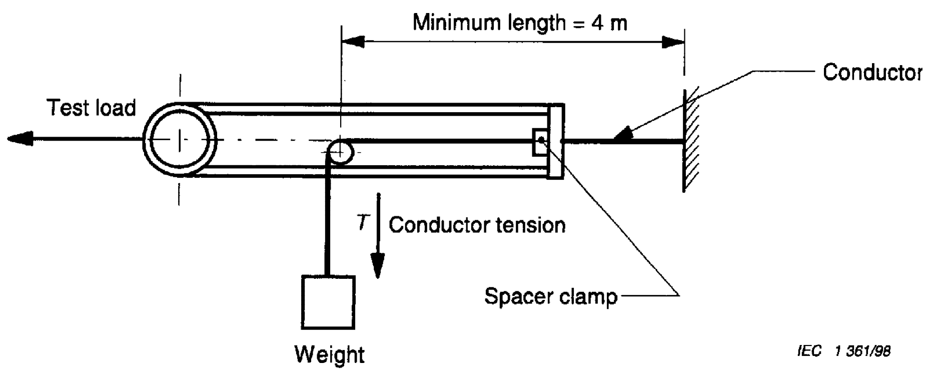


Figure 1a – Method A

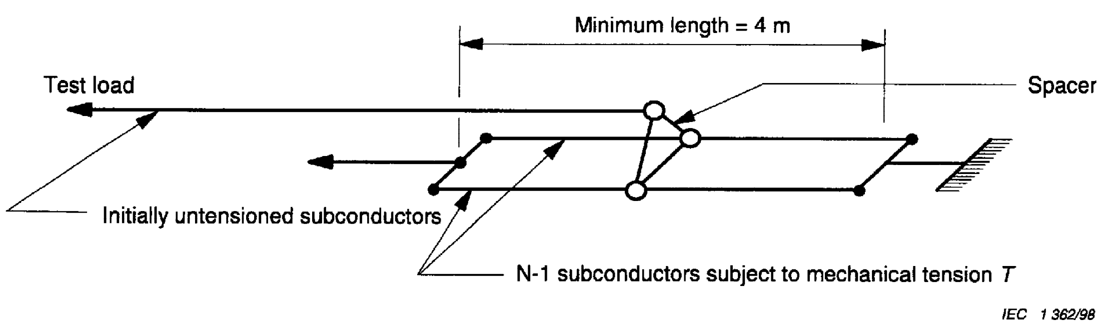


Figure 1b – Method B

Figure 1 – Test arrangements for longitudinal slip tests

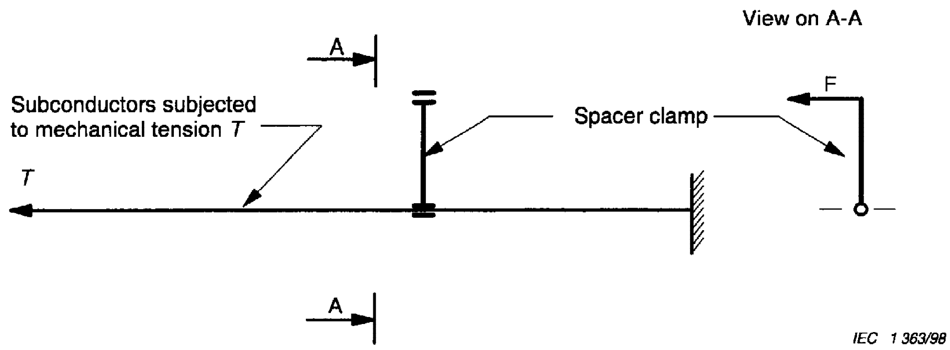


Figure 2a – Method A

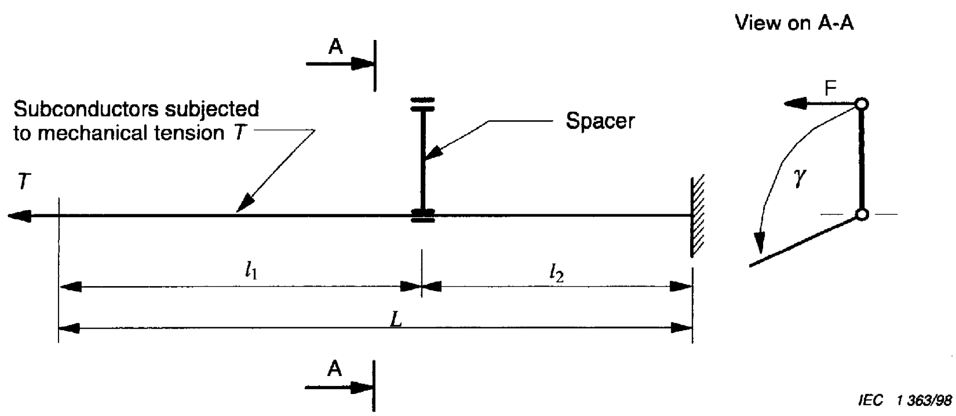
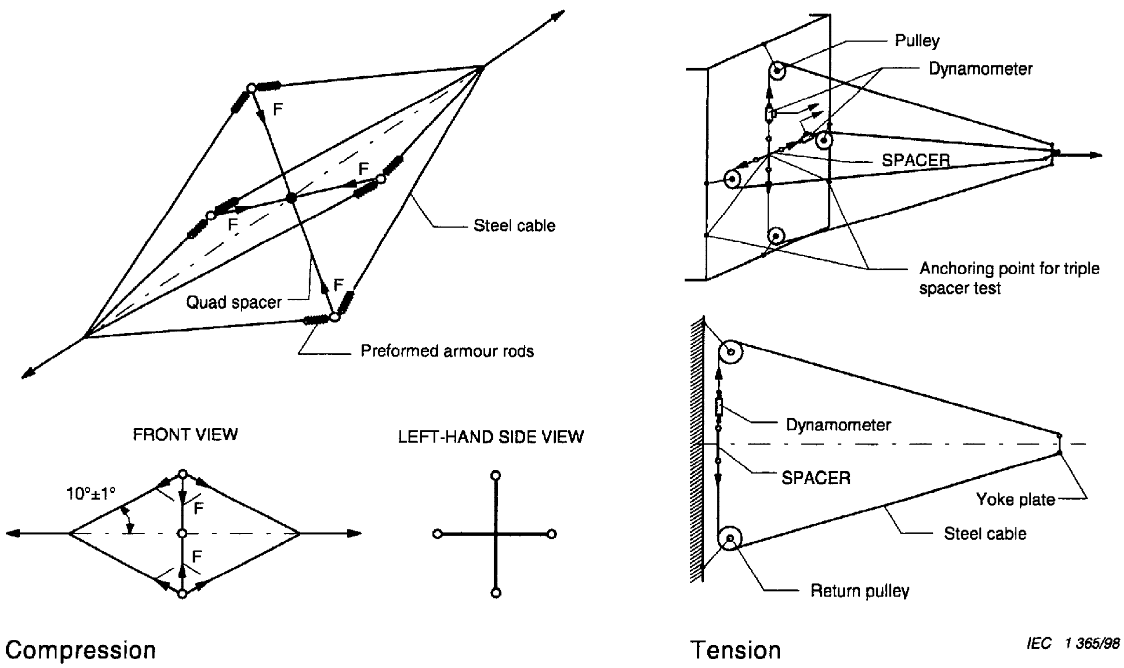


Figure 2b – Method B

Figure 2 – Test arrangements for torsional slip tests



NOTE – The subconductors may be replaced by steel cables of smaller diameter fitted with preformed armour rods in order to match the conductor diameter. These cables shall be so deformed that the angle between a subconductor and the axis of the bundle is equal to (10 ± 1)°.

Figure 3a – Variant A

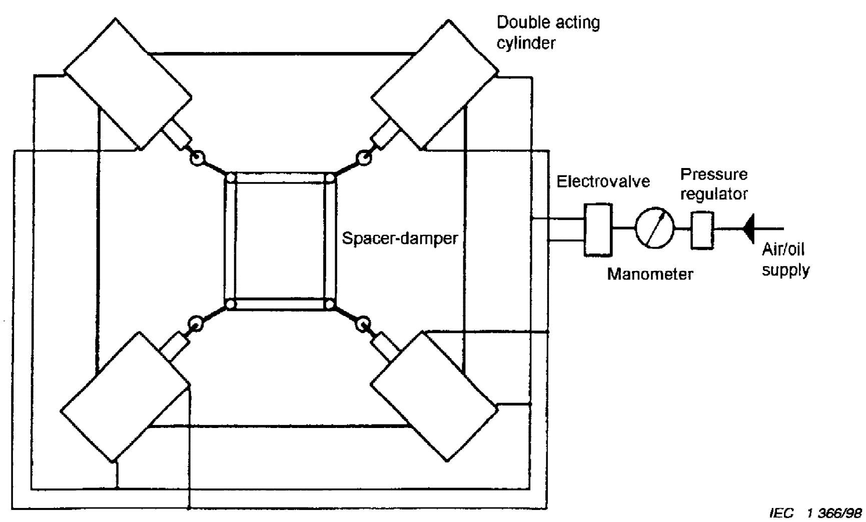


Figure 3b – Variant B

Figure 3 – Test arrangements for simulated short-circuit current tests

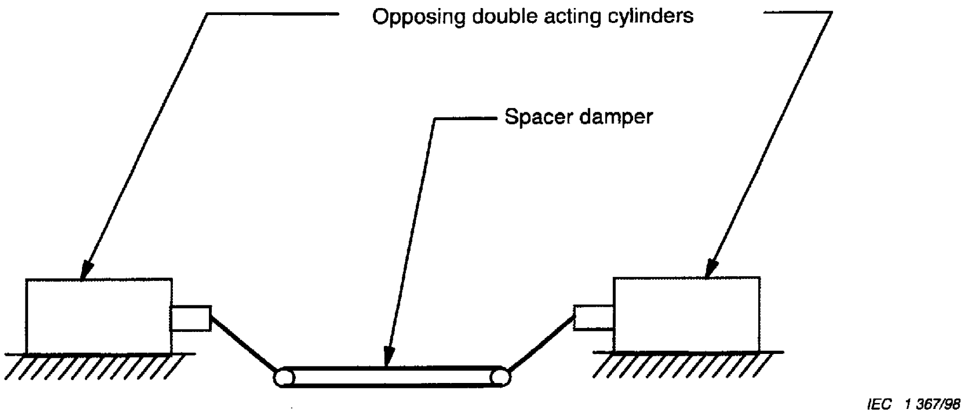


Figure 4 – Example of device for compression and tension test

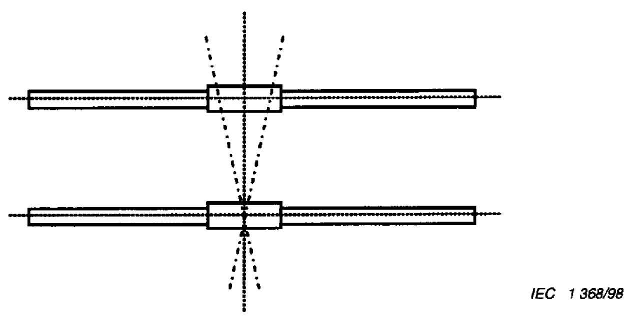
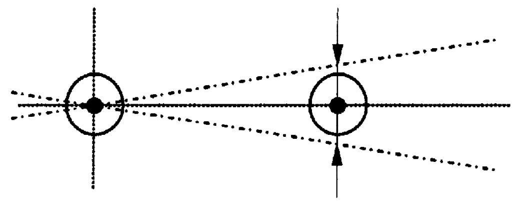
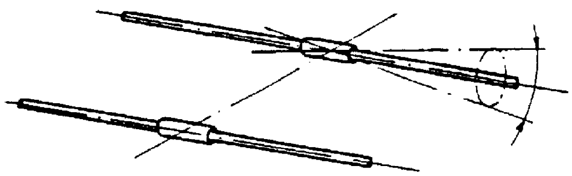


Figure 5 – Sketch of longitudinal displacement test



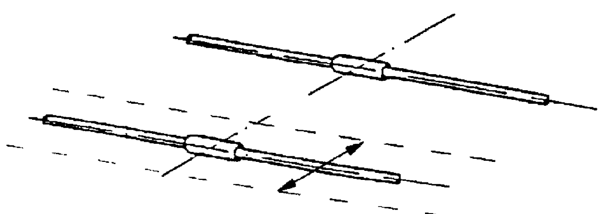
IEC 1 369/98

Figure 6 – Sketch of vertical displacement test



IEC 1 370/98

Figure 7 – Sketch of conical displacement test



IEC 1 371/98

Figure 8 – Sketch of transverse horizontal displacement test

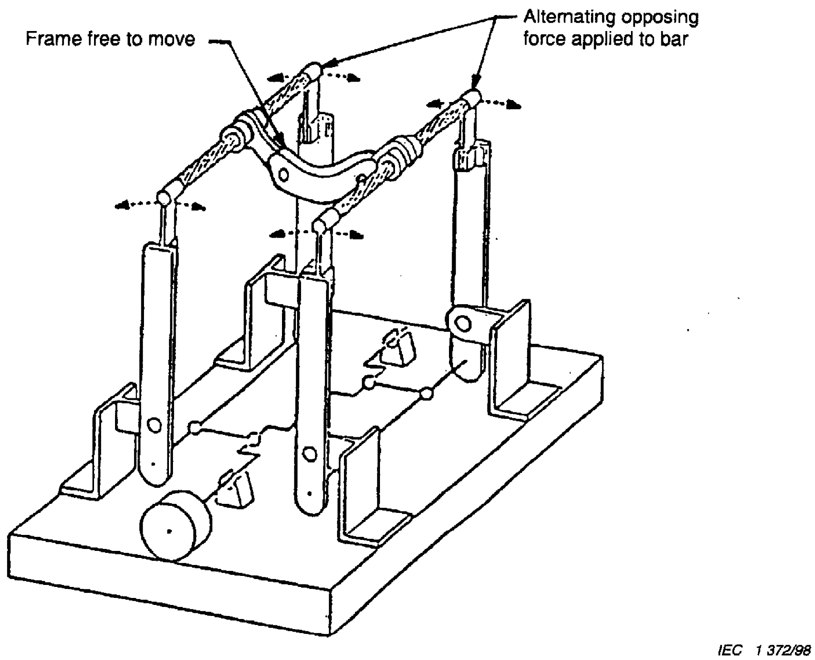


Figure 9a – Spacer frame free to move

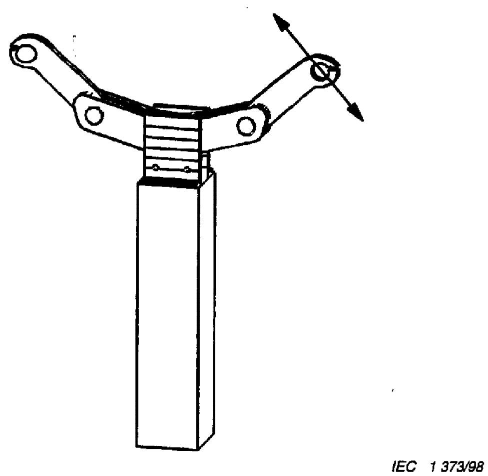


Figure 9b – Spacer frame fixed

Figure 9 – Test arrangements for subspan oscillation tests

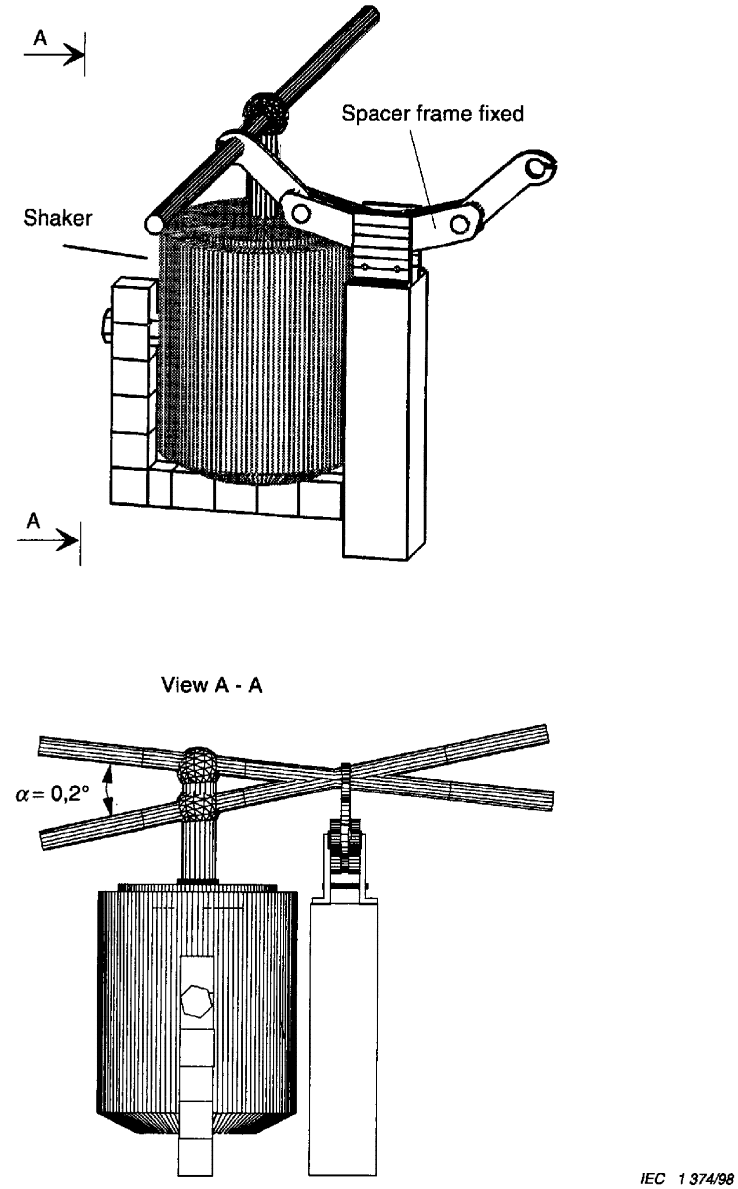


Figure 10 – Example of aeolian vibration test at a node

Annex A
(normative)

Minimum technical details to be agreed between purchaser and supplier

Reference subclause		Test option	Details to be agreed
6.2.3	Sampling and acceptance criteria	Inspection by variables	Inspection level, AQL,sampling instruction
		Inspection by attributes	Inspection level, AQL,sampling instruction
7.5.1	Clamp slip test		Tolerance if breakaway bolts are used
7.5.1.1	Longitudinal slip test	Variant A	Specified values
		Variant B	Specified values
7.5.1.2	Torsional slip test	Variant A	Specified load
		Variant B	Rotation angle γ_l
7.5.2	Breakaway bolt test		Tolerance
7.5.3	Clamp bolt tightening test		Tolerance if breakaway bolts are used
7.5.4	Simulated short-circuit test	Simulated short circuit current	Compressive force
		Compression and tension	Compressive and tensile force
7.5.5	Characterisation of the elastic and damping properties	Stiffness-damping-method	
		Stiffness method	
		Damping method	
7.5.6	Flexibility tests		Values of the displacements: – longitudinal – vertical – conical – transversal
7.5.7.2	Fatigue tests – subspan oscillation		Number of cycles
7.7.1	Corona and radio interference voltage (RIV) tests	Voltage method	Specified corona extinction voltage
		Voltage gradient method	Specified corona extinction test voltage gradient
7.7.2	Electrical resistance test		Range of the electrical resistance

Annex B
(informative)

Compressive forces in the simulated short-circuit current test

To calculate the value of the compressive force, the following formula [9] may be applied, unless a different value is agreed between purchaser and supplier:

$$F_{max} = K I_{cc} \sqrt{T \lg \frac{S}{D}}$$

where

F_{max} is the maximum compressive force (N);

I_{cc} is the specified short-circuit current in the bundle (I_{rms} value) (kA);

T is the subconductor tensile load (N);

S is the bundle diameter (diameter of the circumscribing circle) (m);

D is the subconductor diameter (m);

K is the factor depending on the number of subconductors in the bundle [$N^{0,5}$ A^{-1}]:

Number of subconductors	*K* factor
2	1,585
3	1,450
4	1,260
6	1,014

Example 1

Bundle type:	quad
Spacing:	450×10^{-3} m
Bundle diameter *S*:	636×10^{-3} m
Subconductor type:	ACSR Curlew
Overall diameter *D*:	$31,68 \times 10^{-3}$ m
Tensile load *T*:	32 000 N
Short-circuit current I_{cc}:	50 kA

$$F_{max} = 1{,}26 \times 50 \times \sqrt{32\ 000 \times \lg \frac{636}{31{,}68}} = 12\ 863 \text{ N}$$

Example 2

Bundle type:	twin
Spacing:	400×10^{-3} m
Bundle diameter *S*:	400×10^{-3} m
Subconductor type:	AAAC Flint
Overall diameter *D*:	$25{,}16 \times 10^{-3}$ m
Tensile load *T*:	21 700 N
Short-circuit current I_{cc}:	20 kA

$$F_{max} = 1{,}585 \times 20 \times \sqrt{21\,700 \times \lg \frac{400}{25{,}16}} = 5\,118 \text{ N}$$

Annex C
(informative)

Characterisation of the elastic and damping properties Stiffness-Damping Method

With reference to figure C.1, by assuming $\frac{H_t}{\omega}$ as the equivalent viscous damping of the hinge and the force f always perpendicular to the arm, the rotation of the spacer arm around the centre of the hinge is described by the equation:

$$J \cdot \varphi'' + \frac{H_t}{\omega} \cdot \varphi' + K_t \cdot \varphi = f \cdot l \qquad \text{(C.1)}$$

where

J	is the moment of the inertia of the arm in respect of the centre of rotation;
φ, φ', φ''	are respectively the instantaneous values of the angle of rotation of the arm and the associated first and second derivative;
ω	is the circular frequency;
H_t	is the damping constant;
K_t	is the torsional stiffness;
f	is the instantaneous value of the applied force;
l	is the arm length.

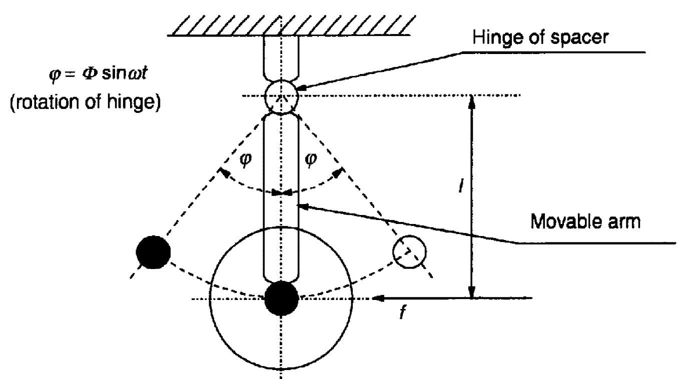


Figure C.1 – Rotation of spacer arm around the centre of the hinge

By assuming a sinusoidal force

$f = F \times e^{j\omega t}$ (F = peak value, complex representation)

the angle of rotation will be sinusoidal

$$\varphi = \Phi \cdot e^{j\omega t} \cdot e^{-j\alpha} \ (\Phi = \text{peak value})$$

and will satisfy equation (C.1)

$$-\omega^2 \cdot \Phi \cdot e^{j\omega t} \cdot e^{-j\alpha} + H_t \cdot j \cdot \Phi \cdot e^{j\omega t} \cdot e^{-j\alpha} + K_t \cdot \Phi \cdot e^{j\omega t} \cdot e^{-j\alpha} = F \cdot l \cdot e^{j\omega t} \qquad \text{(C.2)}$$

The relevant vector representation is illutrated in figure C.2.

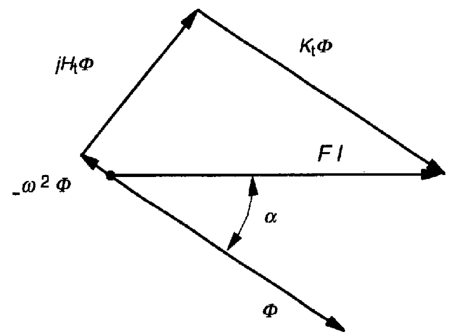


Figure C.2 – Vector representation of equation C.2

For very low frequency v ($\omega = 2\,\pi v$) and for a typical spacer damper, it is possible to neglect $\omega^2 \cdot J \cdot \Phi$ with respect to $K_t \cdot \Phi$, therefore

$$\tan\,\alpha = \frac{H_t}{K_t}$$

$$\text{and, } K_t = \frac{F \cdot l \cdot \cos\,\alpha}{\Phi}$$

The energy dissipated by the hinge in one period is equal to

$$E = \int f \cdot l \cdot \mathrm{d}\varphi = \int f \cdot l \cdot \frac{\mathrm{d}\varphi}{\mathrm{d}t} \cdot \mathrm{d}t$$

and with

$f = F \cdot \sin\,\omega t$

$\varphi = \Phi \cdot \sin\,(\omega t - \alpha)$

$$E = F \cdot l \cdot \Phi \cdot \omega \cdot \int_0^{\frac{2\pi}{\omega}} \sin\omega t \cdot \cos\left(\omega t - \alpha\right) \cdot \mathrm{d}t = \pi \cdot F \cdot l \cdot \Phi \cdot \sin\alpha$$

Annex D
(informative)

Verification of vibration behaviour of the bundle/spacer system

D.1 General

Bundled conductors of overhead lines are subject to aeolian vibration and subconductor oscillation which, under severe conditions, may lead to fatigue failure of conductor strands or fittings. Spacer dampers are frequently used to reduce the amplitudes of these wind-induced vibrations and hence avoid the associated fatigue problems.

NOTE 1 – Sometimes the damping system for bundle conductors comprises either flexible spacers or spacer dampers together with vibration dampers.

The performance of a given spacer system in respect of vibratory behaviour is strictly correlated to the characteristics of the bundle (type of conductors, spacing, tensile load, etc.); as a consequence, the bundle plus spacer system shall be considered as a "whole" in evaluating the vibratory behaviour.

The performance verification of the bundle/spacer system, if agreed between purchaser and supplier, should consider aeolian vibration since this is the most common vibration phenomenon. Performance verification for subspan oscillation may also be agreed.

The performance verification should be made in one of the following two ways:

- analytically, determining the vibratory behaviour through the use of specific computer programs based on mathematical models of the system. The analytical performance verification should be carried out by the supplier;
- experimentally, carrying out field tests on overhead lines or experimental spans exposed to natural wind.

NOTE 2 – If agreed between purchaser and supplier, test evidence regarding previous experimental verification of the proposed damping systems can be accepted to evaluate the performance without any other additional field tests.

D.2 Aeolian vibration

The analytical verifications of aeolian vibration behaviour should be carried out for at least two spans of different length.

The purchaser should provide the following additional information, where available:

- the length of the two spans;
- the characteristics of the conductor (type, stranding, mass per length, RTS);
- the tensile load of the conductors (to be based on the yearly distribution of the minimum daily temperature);
- the conductor self-damping, or alternatively a section of conductor to be used by the supplier for evaluating, experimentally, the conductor self-damping; experimental data available for similar conductors can also be used for determining theoretically the self-damping coefficient;

- the type of suspension clamp (conventional, AGS, etc);
- the characteristics of armour rods, if applied;
- the characteristics of devices, other than damping elements, attached to the conductor and their in-span distribution;
- the conditions of the terrain surrounding the line (flat, hilly, woody, etc);
- the yearly distribution of the average wind velocity (10 min mean) at the site relevant to the overhead line.

The experimental verification of aeolian vibration behaviour should be carried out for at least two spans of different length. The purchaser and supplier shall agree upon the period of time for the field tests, the measurements to be made (bending amplitude or strain at the suspension clamp, at the spacer-clamps, wind speed and direction, turbulence, etc.), the instrumentation and transducers to be used and the procedures for processing and presenting the experimental data.

NOTE – The specified period of time for the field tests should be extended if during the same period the frequency of occurrence of wind perpendicular to the test spans with speeds in the range 0,5 m/s to 10 m/s, is deemed to be insufficient.

- Suggested acceptance criteria

The acceptance criteria should take into consideration the strains on the conductor at the suspension clamps, at the spacer-clamps and at the damper clamps, if dampers are used.

The acceptance criteria should be agreed between purchaser and supplier making reference to IEEE WPM 31 TP 65-156 [6], CIGRE SC22-WG04 [7] and CIGRE SC22-WG11-TF2 [8] or to other equivalent publications.

D.3 Subspan oscillation

The analytical verification of subspan oscillation behaviour should be carried out for at least two spans of different length.

The purchaser should provide:

- the length of the two spans;
- the tensile load of the conductors;
- the characteristics of the conductor (type, stranding, mass per length, RTS);
- the conditions of the terrain surrounding the line (flat, hilly, woody, etc);
- the characteristics of devices, other than damping elements, attached to the conductor and their in-span distribution;
- the yearly distribution of the average wind velocity (10 min mean) at the site relevant to the overhead line, if available.

The experimental verification of subspan oscillation behaviour should be carried out for at least two adjacent spans of different length. The purchaser and supplier should agree upon the period of time for the field tests, the measurements to be made (amplitude of oscillation at mid-subspan and/or at a quarter-subspan, bending amplitude or strain at the spacer clamps, direction, speed and turbulence of the wind, etc.), the instrumentation and transducers to be used, and the procedures for processing and presenting the experimental data.

- Suggested acceptance criteria

The acceptance criteria should take into consideration the amplitude of oscillation at mid-subspan and at a quarter-subspan.

Propagation to adjacent subspans the subspan oscillations, strains at the spacer clamps or at the suspension clamps can also be considered.

The acceptance criteria should be agreed between purchaser and supplier.

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

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

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

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

[6] IEEE Committee report, *Standardization of conductor vibration measurements*; IEEE WPM 1965; 31TP 65-156

[7] CIGRE SC22 WG04, *Recommendations for the evaluation of the lifetime of transmission line conductors*; Electra **63**, March 1979

[8] CIGRE SC22 WG11-TF2, *Guide to vibration measurements on overhead lines* – Electra **163**, Dec 1995

[9] Manunzio C. *An investigation on the forces on bundle conductor spacers under fault conditions* – IEEE T & D, June-July 1965, Paper 31TP 65-707

Q1 Please report on **ONE STANDARD** and **ONE STANDARD ONLY**. Enter the exact number of the standard: *(e.g. 60601-1-1)*

....

Q2 Please tell us in what capacity(ies) you bought the standard *(tick all that apply)*. I am the/a:

- purchasing agent ❑
- librarian ❑
- researcher ❑
- design engineer ❑
- safety engineer ❑
- testing engineer ❑
- marketing specialist ❑
- other...

Q3 I work for/in/as a: *(tick all that apply)*

- manufacturing ❑
- consultant ❑
- government ❑
- test/certification facility ❑
- public utility ❑
- education ❑
- military ❑
- other...

Q4 This standard will be used for: *(tick all that apply)*

- general reference ❑
- product research ❑
- product design/development ❑
- specifications ❑
- tenders ❑
- quality assessment ❑
- certification ❑
- technical documentation ❑
- thesis ❑
- manufacturing ❑
- other...

Q5 This standard meets my needs: *(tick one)*

- not at all ❑
- nearly ❑
- fairly well ❑
- exactly ❑

Q6 If you ticked NOT AT ALL in Question 5 the reason is: *(tick all that apply)*

- standard is out of date ❑
- standard is incomplete ❑
- standard is too academic ❑
- standard is too superficial ❑
- title is misleading ❑
- I made the wrong choice ❑
- other ....

Q7 Please assess the standard in the following categories, using the numbers:
(1) unacceptable,
(2) below average,
(3) average,
(4) above average,
(5) exceptional,
(6) not applicable

- timeliness ....
- quality of writing...................................
- technical contents...................................
- logic of arrangement of contents ....
- tables, charts, graphs, figures...............
- other ....

Q8 I read/use the: *(tick one)*

- French text only ❑
- English text only ❑
- both English and French texts ❑

Q9 Please share any comment on any aspect of the IEC that you would like us to know:

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Q1 Veuillez ne mentionner qu'**UNE SEULE NORME** et indiquer son numéro exact: (*ex. 60601-1-1)*

....

Q2 En tant qu'acheteur de cette norme, quelle est votre fonction?
(cochez tout ce qui convient)
Je suis le/un:

- agent d'un service d'achat ❑
- bibliothécaire ❑
- chercheur ❑
- ingénieur concepteur ❑
- ingénieur sécurité ❑
- ingénieur d'essais ❑
- spécialiste en marketing ❑
- autre(s)...

Q3 Je travaille:
(cochez tout ce qui convient)

- dans l'industrie ❑
- comme consultant ❑
- pour un gouvernement ❑
- pour un organisme d'essais/ certification ❑
- dans un service public ❑
- dans l'enseignement ❑
- comme militaire ❑
- autre(s)...

Q4 Cette norme sera utilisée pour/comme
(cochez tout ce qui convient)

- ouvrage de référence ❑
- une recherche de produit ❑
- une étude/développement de produit ❑
- des spécifications ❑
- des soumissions ❑
- une évaluation de la qualité ❑
- une certification ❑
- une documentation technique ❑
- une thèse ❑
- la fabrication ❑
- autre(s)...

Q5 Cette norme répond-elle à vos besoins:
(une seule réponse)

- pas du tout ❑
- à peu près ❑
- assez bien ❑
- parfaitement ❑

Q6 Si vous avez répondu PAS DU TOUT à Q5, c'est pour la/les raison(s) suivantes:
(cochez tout ce qui convient)

- la norme a besoin d'être révisée ❑
- la norme est incomplète ❑
- la norme est trop théorique ❑
- la norme est trop superficielle ❑
- le titre est équivoque ❑
- je n'ai pas fait le bon choix ❑
- autre(s) ....

Q7 Veuillez évaluer chacun des critères ci-dessous en utilisant les chiffres
(1) inacceptable,
(2) au-dessous de la moyenne,
(3) moyen,
(4) au-dessus de la moyenne,
(5) exceptionnel,
(6) sans objet

- publication en temps opportun ....
- qualité de la rédaction..........................
- contenu technique ....
- disposition logique du contenu ....
- tableaux, diagrammes, graphiques, figures ....
- autre(s) ....

Q8 Je lis/utilise: *(une seule réponse)*

- uniquement le texte français ❑
- uniquement le texte anglais ❑
- les textes anglais et français ❑

Q9 Veuillez nous faire part de vos observations éventuelles sur la CEI:

....
....
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