

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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



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IEC 61467

Edition 1.0 2008-08

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX



ICS 29.080.10; 29.240.20

ISBN 2-8318-9953-2

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INSULATORS FOR OVERHEAD LINES – INSULATOR STRINGS AND SETS FOR LINES WITH A NOMINAL VOLTAGE GREATER THAN 1 000 V – AC POWER ARC TESTS

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International Standard IEC 61467 has been prepared by subcommittee 36B: Insulators for overhead lines, of IEC technical committee 36: Insulators.

This first edition cancels and replaces IEC/TR 61467, which was published as a technical report in 1997. It constitutes a technical revision and now has the status of an International Standard.

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

FDIS	Report on voting
36B/277/FDIS	36B/280/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.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
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- amended.

INSULATORS FOR OVERHEAD LINES – INSULATOR STRINGS AND SETS FOR LINES WITH A NOMINAL VOLTAGE GREATER THAN 1 000 V – AC POWER ARC TESTS

1 Scope and object

This International Standard applies to insulator strings and sets comprising string insulator units of ceramic material, glass or composite material for use on a.c. overhead lines and traction lines with a nominal voltage above 1 000 V and a frequency between 15 Hz and 100 Hz.

This standard also applies to insulator strings or sets of similar design used in substations.

This standard establishes a standard test procedure for power arc tests on insulator sets. It also establishes a standard test procedure for power arc tests on short strings.

This standard does not apply to insulator sets mounted on non-metallic poles or towers.

This standard cannot be directly applied to line post insulators or sets, or to insulating structures such as braced line-posts, since their mounting arrangement cannot be reproduced by the standard arrangements as described herein. However, this standard can be used as a basis for agreement for tests on such insulators and arrangements.

The object of this standard is

- to define the terms used,
- to prescribe a standard test procedure,
- to prescribe criteria to evaluate the results of the tests.

Power arc tests are not an obligatory element of line insulator specifications. The standard test procedures and the evaluation criteria described in this standard are intended to provide testing guidance when power arc tests are felt to be necessary. It is not the object of this standard to introduce a general obligation to execute these tests.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60797, *Residual strength of string insulator units of glass or ceramic material for overhead lines after mechanical damage of the dielectric*

IEC 60826, *Design criteria of overhead transmission lines*

3 Terms and definitions

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

NOTE Definitions of other terms used in this standard can be found in IEC 60050-471, IEC 60383-1 and IEC 60383-2.

**3.1
test**

one application of the specified test current for the specified duration to the insulator string or set

**3.2
test sequence**

three successive tests on the same insulator string or set

**3.3
test series**

a group of test sequences used to characterize the power arc performance of an insulator string or set

**3.4
per cent initial asymmetry of current**

deviation of the current from a symmetrical wave during the first cycle of a power arc

NOTE Per cent initial asymmetry is expressed as a function of the absolute peak value of the current of the first cycle (I_m) divided by the r.m.s. value of the current (I) as follows:

$$\left(\frac{|I_m|}{I \times \sqrt{2}} - 1 \right) \times 100$$

**3.5
supply circuit**

electrical connection through which the current of a power arc flows to the line side of the test object from the power source

**3.6
return circuit**

electrical connection through which the current of power arc flows from the earth side of the test object to the power source

**3.7
balanced circuit**

supply or return circuit in which the current flow is in two diametrically opposed directions

**3.8
unbalanced circuit**

supply or return circuit in which the current flow is principally in one direction

**3.9
short string (cap and pin units)**

string of three to six insulator units having a minimum arcing distance of 400 mm

**3.10
short string (long rod and composite units)**

string of one or more insulator units having an arcing distance between 400 mm and 1 000 mm

4 Symbols and abbreviations

The following symbols and abbreviations are principally used in the tables and figures hereafter.

Unless otherwise stated currents and voltages are expressed as r.m.s values.

I	Arc current
I_n	Specified arc current
t	Arc time
t_n	Specified arc time
I_m	Peak current value
$I_{R1,2}$	Currents in the return circuit
$I_{S1,2}$	Currents in the supply circuit
I_{sys}	Rated short-circuit current of the network system
L_A	Length of the insulator string
L_B	Length of the insulator set
L_R	Length of simulation of the return circuit
L_S	Length of simulation of the supply circuit
D	Distance from the centre point of the tested insulator set to the surrounding framework
M_L	Mechanical load on the tested insulator set
α	Angle from the horizontal plane of a tension insulator set
SFL	Specified minimum (electro-)mechanical failing load
SML	Specified mechanical load

5 Characteristics of the test current

The tests shall be made with single-phase alternating current. Initial asymmetry (d.c. component) shall not exceed 30 %.

NOTE This requirement is explained by the fact that the flashovers on a contaminated insulator set in service generally occur in the vicinity of a voltage peak, consequently with a minimal direct current component.

For 50 Hz or 60 Hz systems, the frequency of the test circuit shall be from 45 Hz to 65 Hz. For other system frequencies, the frequency of the test supply shall not in principle deviate from the specified value by more than 10 %. By agreement with the user, tests may be performed at a higher or lower frequency than the intended operating frequency. The frequencies may vary within the above limits during each test.

The test circuit shall be adequate to supply the specified values of arc current (r.m.s) and arc duration. Annex C gives information on no-load voltages suggested to achieve specified current values. Unless agreed otherwise, the permissible tolerance of the arc current with respect to the specified r.m.s. value of the current is ± 10 %.

The actual arc current during the test shall be practically sinusoidal. The r.m.s. value of the test current may be derived from the arithmetic mean of the peak values during the test duration (see Annex B). If the measuring equipment permits, the r.m.s. value may be calculated from the current function.

The test current shall be essentially constant over the arcing time. During the arcing time, the following deviations from the specified value are permissible:

- the arc current crest values shall not deviate from the specified value ($I_n\sqrt{2}$) by more than ± 20 %;
- for arcing times greater than 0,2 s, the above tolerance may be exceeded during not more than 20 % of the total arcing time.

In any case, the product of the actual arc current and duration $I \times t$ shall be within ± 10 % of the product of the specified arc current and duration $I_n \times t_n$.

In cases where the movement of the arc root onto the tower or along the line conductor occurs, these tolerances may be exceeded.

6 Supply and return circuit conditions

The supply and return circuits depend on the service conditions, notably on the location of the insulator set along the line and on the tower geometry. The characteristic cases to be simulated in tests are given in Table 1 and illustrated in Figure 1 for complete sets and in Figure 3 for short strings.

Table 1 – Supply and return conditions

	Balanced supply circuit	Unbalanced supply circuit
Balanced return circuit	A circuit $I_{R1} = I_n/2$ $I_{R2} = I_n/2$ $I_{S1} = I_n/2$ $I_{S2} = I_n/2$ For example: Insulator set in the centre phase window of a tower in the middle of a line	B circuit $I_{R1} = I_n/2$ $I_{R2} = I_n/2$ $I_{S1} = I_n$ $I_{S2} = 0$ For example: Insulator set in the centre phase window of a tower at the extremity of a line
Unbalanced return circuit	C circuit $I_{R1} = I_n$ $I_{R2} = 0$ $I_{S1} = I_n/2$ $I_{S2} = I_n/2$ For example: Insulator set on the lateral phase cross-arm of a tower in the middle of a line	D circuit $I_{R1} = I_n$ $I_{R2} = 0$ $I_{S1} = I_n$ $I_{S2} = 0$ For example: Insulator set on the lateral phase cross-arm of a tower at the extremity of a line

The permissible deviation of the currents I_{R1} and I_{R2} , I_{S1} and I_{S2} from their specified value shall not exceed $\pm 20\%$. This may be verified by a circuit calibration test.

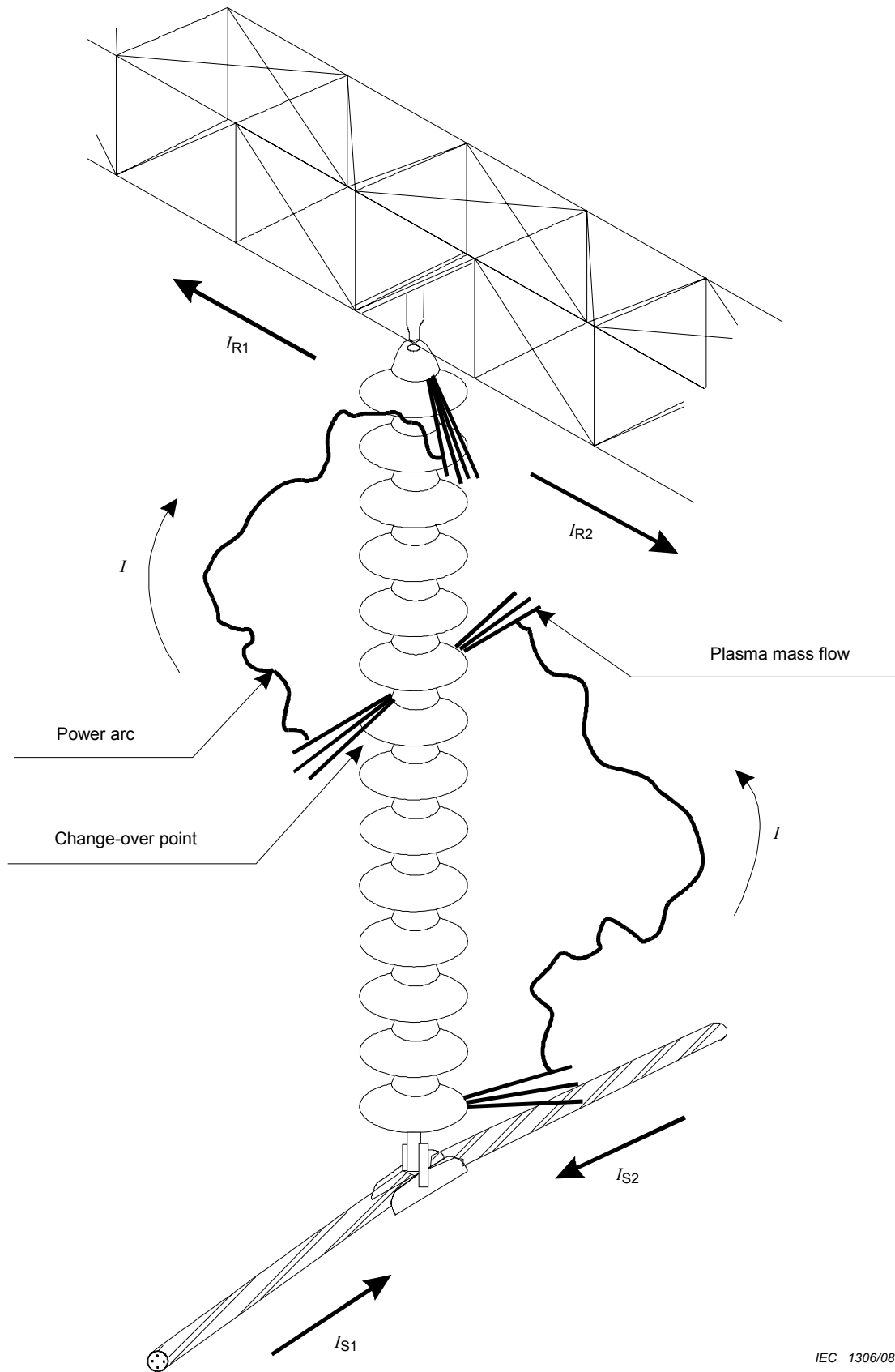


Figure 1 – Illustration of supply and return currents

IEC 1306/08

7 Tests on insulator sets

7.1 General remarks

The test procedure for insulator sets described in this standard consists of two possible series of three power arc applications (sequences) at different current levels and of different duration. This test procedure is intended to cover fault current conditions occurring at representative points along a line. The test procedure is also intended to reproduce pollution-induced power arc flashover, which creates the most severe conditions.

As the test procedure for insulator sets described in this standard is intended to simulate conditions encountered in service, attention is drawn to the fact that it is not possible to extrapolate the behaviour of an insulator set of a given length to that of an insulator set of different length or equipped with fittings of different design or materials.

7.2 Test arrangement

The test arrangement shall duplicate the actual configuration of the complete insulator set and as closely as possible that of the conductor and of the part of the tower nearest to the insulator set. The actual protective fittings shall be used and their position with respect to the insulator units, the clamps and the conductor shall be reproduced. The aim of the true simulation of the actual configuration is to recreate the real electromagnetic field affecting the arc movement.

The distances between the insulator set and the grounded structures simulating the tower shall be the same as for the service configuration. In the case of some insulator sets (e.g. extra high voltage, special configurations), the actual simulation of the tower may be limited by the facilities of test laboratories. In the case of long insulator sets ($L_B > 6$ m), a distance D of 6 m between tower and line conductors is sufficient.

The distance from the conductors to the ground plane shall be at least $L_B/2$ or 3 m for $L_B > 6$ m.

The test arrangement shall include a conductor or conductor bundle having characteristics similar to the one used in service. To create the real electrodynamic forces affecting the arc movement, the conductor length on both sides of the insulator sets shall be at least equal to the insulator set length but its minimum length shall be 2,5 m. In the case of long insulator sets ($L_B > 6$ m), a conductor length L_S of 6 m is sufficient (see Annex A).

Some appropriate test arrangements and tower simulations (return circuit) are shown in Annex A.

In order to avoid poor electrical contacts and to ensure that the insulator set is correctly positioned, a mechanical load shall be applied to the insulator set. In the case of vertical insulator sets, this load can be applied by means of a suitable weight suspended from the suspension clamp or conductor by means of an insulated link. The value of the load shall be at least 5 kN on the complete insulator set. In the case of tension insulator sets, a higher mechanical load may be necessary to reproduce the service angle of the insulator set (see Figure A.4).

7.3 Test current

The characteristics of the test current shall be in accordance with Clause 5.

7.4 Supply and return circuit conditions

The supply and return circuits shall be chosen to represent the service conditions being simulated (see Clause 6).

7.5 Arc initiation

The arc shall be initiated by fusible wire of a low resistance material (e.g. silver, aluminium, copper) with a maximum total cross-section of 1 mm². If more than one wire is used, they shall be twisted together in parallel.

NOTE If there are problems in initiating the arc, a larger diameter fusible wire may be used. However it should be noted that this can have an adverse effect on the test result due to reduced initial arc mobility and deposition of metal on the insulator surface.

The aim of the specified arc initiation is to create conditions similar to that of a flashover occurring on a contaminated insulator set. This kind of flashover can cause the arc to root on intermediate points along the string. The description of the arcing phenomenon and the detailed explanation of the positioning of fusible wires are given in Annex D.

The fusible wires shall be attached to the metal parts by a single point contact in the following manner and as shown in Figure 2.

a) *Cap and pin insulator sets*

The first wire shall be attached to the cap of the earth side unit and to the pin of an intermediate unit at an interval of three to five units. The following wire is placed in the same manner, but on the opposite side of the string. This method shall be repeated up to the end of the string. Figure 2a shows the positioning of the wires and the connection of the wire to the limit point of the cap and the shed and to the pin. When there are practical difficulties to attach the fusible wire to the pin (e.g. due to the shape of the insulators), it is allowed to attach it to the cap of the next insulator.

In case of short insulator sets, having less than 6 units, one change-over point shall be created on the string approximately in the middle.

b) *Long rod and composite insulator sets*

The wire shall be attached between the metal parts of the insulator and be wrapped around the core in the middle of the insulator and continuing from there to the opposite side. The different units shall have separate fuse wires according to Figure 2b.

In the case of longer insulator sets (e.g. unit insulator length >1,5 m) the wire shall be attached between the metal parts of the insulator and be wrapped around the core and continuing from there to the opposite side of the insulator at distances of 0,6 m to 0,8 m according to Figure 2c.

In all cases (cap and pin, long rod, composite insulator sets, vertical-, Vee-, horizontal insulator sets) the plane of the fuse wires shall have an angle of 45° to the conductors (see Figures 2d and 2e).

The attachment point of the fusible wire shall be moved to an adjacent quadrant for each successive test.

In case of multiple string insulator sets (Vee, double, etc.), the arcs in one test sequence shall always be initiated on the same string. This string shall be chosen in such a manner that the normal displacement of the arc due to electromagnetic forces is towards the other string(s) of the insulator set.

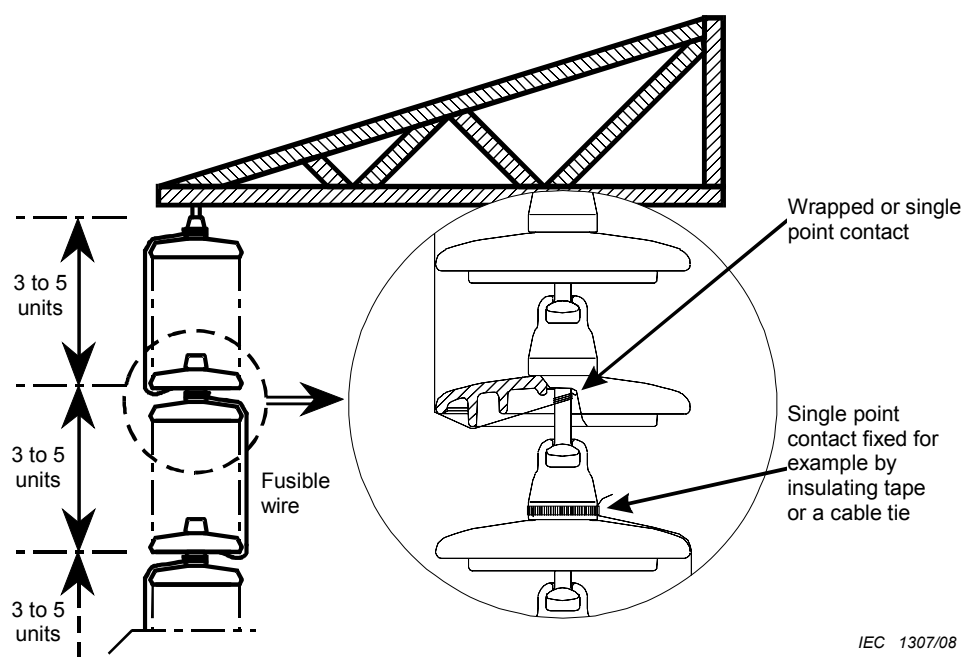
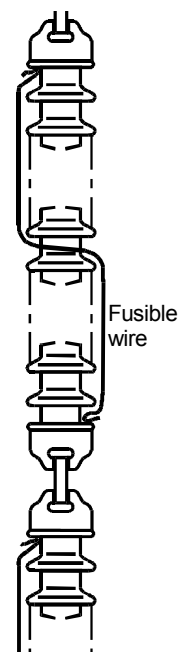
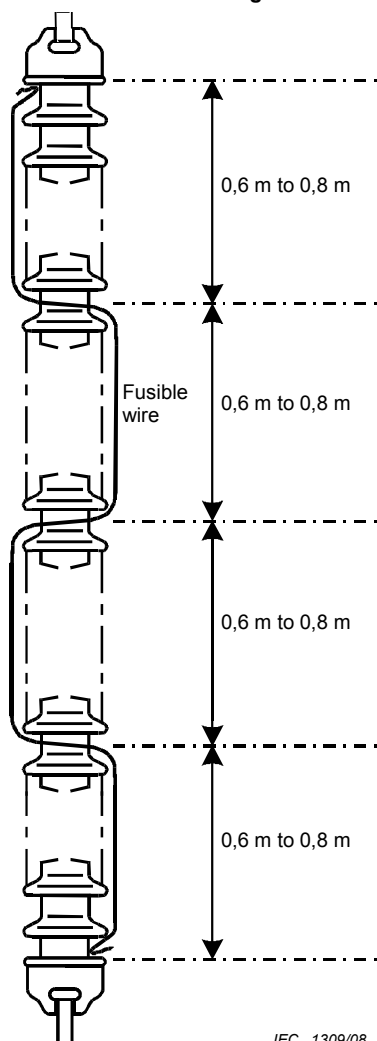


Figure 2a – Cap and pin insulators



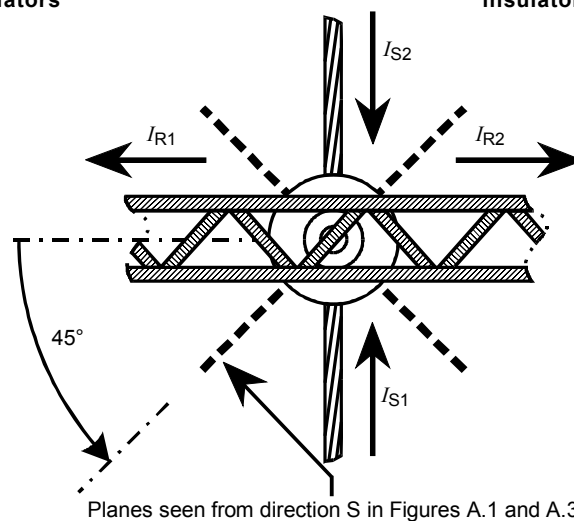
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Figure 2b – Long rod insulators



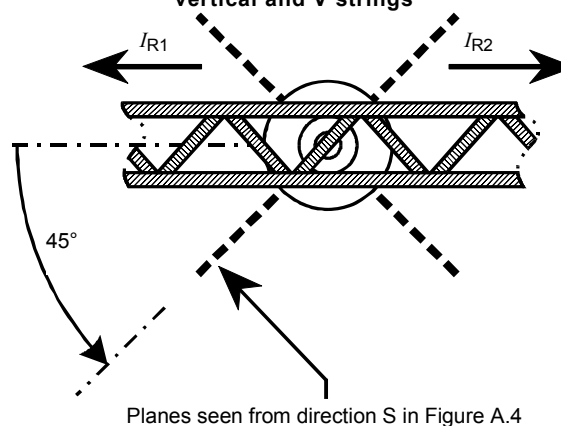
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Figure 2c – Longer sets



IEC 1310/08

Figure 2d – Planes of the fusible wires, vertical and V strings



IEC 1311/08

Figure 2e – Planes of the fusible wires, horizontal strings

Figure 2 – Arc initiation

7.6 Ambient conditions

The wind velocity and all other ambient conditions (atmospheric pressure, rain, humidity and temperature) shall be recorded in all cases.

As the wind has an influence on the arc movement, the tests may be carried out in a test chamber or, when performed outdoors, shall be carried out in calm weather whenever possible. To enable efficient comparison of lower current power arc tests (<10 kA), a maximum wind speed of 5 m/s is allowed.

Annex E gives an explanation of the importance of wind on power arc tests.

Other atmospheric conditions are considered to have no significant influence on the results.

7.7 Test series and characteristics of the power arcs

In accordance with Table 1 and Figure 1, the X or Y test series from Table 2 shall be chosen depending on the type of the tower. To choose the test series Y is reasonable only if the return circuit is always unbalanced, for example when the tower does not have a centre phase window. For practical purposes, in applications where different tower geometries exist and would normally require both X and Y test series, the X series shall be chosen in preference, this being more stringent. In all cases, if the test series X is performed, then series Y is not necessary.

Table 2 – Test series for insulator sets

Test series	Test circuit (see Table 1)	Short-circuit current	Number and duration of tests (test sequence)
X	A	$I_n = 0,2 I_{sys}$	Two of $t_n = 0,2$ s and one of $t_n = 1$ s
	A	$I_n = 0,5 I_{sys}$	Two of $t_n = 0,2$ s and one of $t_n = 1$ s
	B	$I_n = I_{sys}$	Two of $t_n = 0,2$ s and one of $t_n = 0,5$ s
Y	C	$I_n = 0,2 I_{sys}$	Two of $t_n = 0,2$ s and one of $t_n = 1$ s
	C	$I_n = 0,5 I_{sys}$	Two of $t_n = 0,2$ s and one of $t_n = 1$ s
	D	$I_n = I_{sys}$	Two of $t_n = 0,2$ s and one of $t_n = 0,5$ s

The minimum interval between two successive tests shall be 20 min. The replacement of damaged units or of the whole insulator set is allowed after every 3 tests performed at the same current.

The number of tests and their duration are chosen to represent the conditions arising on the majority of systems. If different values are required to represent specific network characteristics, they shall be subject to prior agreement.

Annex F gives an explanation of the above prescribed values.

8 Tests on short strings

8.1 General remark

The test procedure for short strings is included in this standard as a means to evaluate the behaviour of insulator materials, design and construction under the thermal stresses encountered during a power arc. This test cannot be used to determine or predict the behaviour of a complete insulator set.

8.2 Test arrangement

The test arrangement for short strings is shown in Figure 3. The short string is hung vertically by an insulated conductor (wire, tube or rod) below an insulating plate intended to avoid transfer of the arc onto surrounding equipment. A weight or mechanical load is applied to the bottom of the string by a second insulated conductor. The supply and return circuits are connected perpendicular to these conductors, at a distance from the string of one to two times the arcing distance of the string.

The distances between the insulator string and the grounded structures shall be sufficient to avoid transfer of the arc onto the structures. The distance from the conductors to the ground plane shall be at least 1 m.

The value of the load applied to the string shall be at least 5 kN.

The fittings used to connect the conductors to the string shall be of appropriate size and shape to match the end fittings of the string under test.

8.3 Test current

The characteristics of the test current shall be in accordance with Clause 5.

8.4 Supply and return circuit conditions

The supply and return circuits shall both be unbalanced (see Clause 6 and Figure 3).

8.5 Arc initiation

The arc shall be initiated by fusible wire of a low resistance material (e.g. silver, aluminium, copper) with a maximum total cross-section of 1 mm². If more than one wire is used, they shall be twisted together in parallel.

NOTE If there are problems in initiating the arc, a larger diameter fusible wire may be used. However, it should be noted that this can have an adverse effect on the test result due to reduced initial arc mobility and deposition of metal on the insulator surface.

The fusible wire shall be attached to the metal of top and bottom fittings of the insulator string preferably by a single point contact or alternatively by wrapping. The wire shall follow the arcing distance of the string, as shown in Figure 3. If the string does not have metal end fittings, the wire shall be attached to the closest point on the mating fitting of the test arrangement.

Whenever possible, (cap and pin, long rod, composite insulator strings) the plane of the fuse wires shall have an angle of 45° to the supply and return conductors.

The attachment point of the fusible wire shall be moved to an adjacent quadrant for each successive test.

8.6 Ambient conditions

If the test is performed outdoors, the wind velocity and all other ambient conditions (atmospheric pressure, rain, humidity and temperature) shall be recorded. For tests performed indoors, atmospheric pressure, humidity and temperature shall be recorded.

As the wind has an influence on the arc movement, the tests may be carried out in a test chamber or, when performed outdoors, shall be carried out in calm weather whenever possible. To enable efficient comparison of lower current power arc tests (<10 kA), a maximum wind speed of 5 m/s is allowed.

Annex E gives an explanation of the importance of wind on power arc tests.

Other atmospheric conditions are considered to have no significant influence on the results.

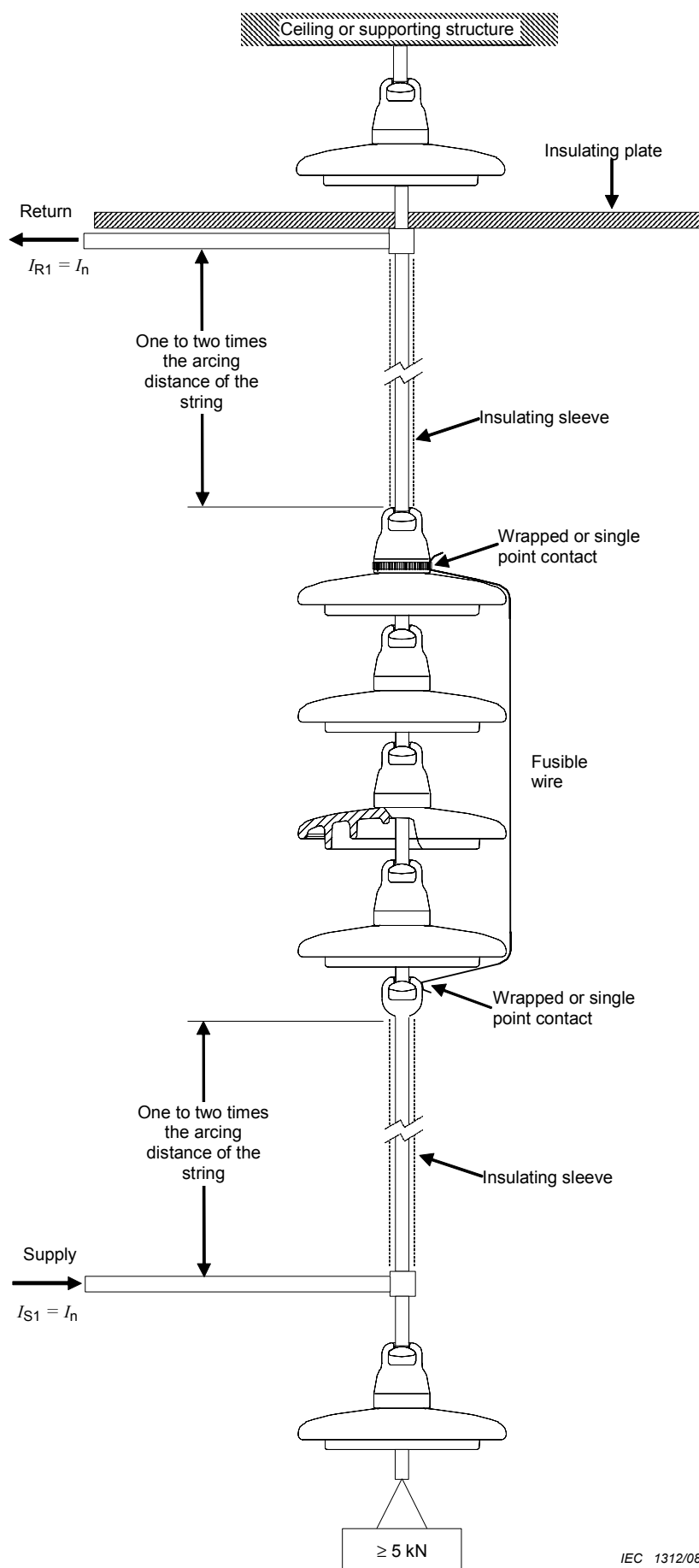
8.7 Test series and characteristics of the power arcs

The test series for short strings consists of three successive tests where in each a short string is tested with one short-circuit application only. The entire short string is changed after each arc application. Table 3 gives the currents and durations of the tests in the series.

Table 3 – Test series for short insulator strings

Test circuit (see Table 1)	Short-circuit current ^a	Number and duration of tests ^a (test sequence)
D	$I_n = 12 \text{ kA}$	One of $t_n = 0,1 \text{ s}$
D	$I_n = 12 \text{ kA}$	One of $t_n = 0,1 \text{ s}$
D	$I_n = 12 \text{ kA}$	One of $t_n = 0,1 \text{ s}$
^a Alternatively, and after agreement between the interested parties, the tests may be carried out at 6 kA for 0,2 s.		

The mechanical load on the string shall be maintained for 5 min after the application of the arc.



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Figure 3 – Mounting arrangement for short strings

9 Test report

In order to harmonize the format of the test reports, the information to be included in the test documentation shall appear in the following sequence:

- a) an appropriate front sheet;
- b) complete details of ratings assigned by the applicant for the tests;
- c) a list of the tests performed and, if appropriate, a list of persons witnessing the tests, as well as the circulation of the test documentation.

The remainder of the test document can be arranged to suit the convenience of the testing laboratory. The preferable format for the report is given in Annex G.

10 Evaluation of results

10.1 General remark

This clause sets forth criteria, to be used as guidelines only, for evaluating the effects on operational reliability of the insulator set or string.

The evaluation consists of two parts. A visual examination is performed first, followed by a series of analytical tests to determine the suitability of the insulators to continue in service.

For tests on insulator sets, the visual examination also includes all mechanical components and fittings of the insulator set; this information is recorded for use by other relevant product standards as necessary. The criteria for evaluation of these fittings and connections are beyond the scope of this standard.

10.2 Visual examination

A thorough visual examination, including photographs, shall record all significant damage sustained by the insulator units, fittings, protective fittings, and conductor(s):

- Metallic insulator components and all load-bearing fittings shall be examined and photographed for arc damage that could have an effect on their mechanical strength. This includes partial melting, arc puddling, and metallic evaporation.
- Metallic components that are galvanized shall be examined for damage to the coating that could sustain future corrosion.
- Metallic components that carry significant levels of surface electrical stress shall be examined for localized contour changes which might induce excessive corona and radio noise.

10.3 Porcelain or glass insulators

In addition to the visual examination for damage to the hardware components of insulators, porcelain or glass insulators shall be examined for damage to the insulating component. Damage to the insulating component can include the following:

- partial or complete breakage of sheds;
- burning or scaling of the insulating surfaces.

Ring testing of the sheds of cap and pin insulators can be helpful as a preliminary means of detecting possible internal dielectric fractures in porcelain insulators. However, this method is somewhat subjective, and can be used only as a preliminary assessment before performing the analysis outlined in Table 4.

10.4 Composite insulators

In addition to visual examination for hardware damage, composite insulators shall be examined for damage to the insulating element. Damage to the insulating element can include the following:

- surface changes such as discoloration, erosion or arc plasma deposits;
- splitting or puncture of individual sheds;
- major housing damage which allows exposure of the fibreglass rod, loss of seal at end fittings or joints, or exudation of sealing grease, where used.

10.5 Acceptance criteria

The acceptance criteria is that the insulator set or string shall be operationally safe after the conclusion of the test series. The operational safety conditions shall be verified both for the mechanical and electrical behaviour, in accordance with the criteria defined in Table 4 below.

Special care shall be taken in judging the test results.

Table 4 – Test assessment criteria

Criteria or test to be performed	Assessment criteria	
	Insulator sets	Short strings
Insulator separation during the test	Not permitted	Not permitted
Burning, breaking of sheds or ribs, glaze removal, melting of galvanized surfaces	Permitted ^a	Permitted
Exposure of the fibreglass core (composite insulators only)	Not permitted	Not permitted
Dry power frequency flashover to check for puncture (class B only)	All units shall be tested and external flashover shall occur	All units shall be tested and external flashover shall occur
Mechanical failing load test	The failing load on all selected units shall be at least 70 % of SFL or SML ^{b, c}	The failing load on all selected units shall be at least 70 % of SFL or SML ^c
Tests on fittings and conductors	In accordance with the relevant IEC standards or by agreement	N/A
^a If more than one-third of the units or of the length of an insulator set exhibits severe damage which could affect electrical performance (shed breakage, severe burning, conductive deposits, etc.), it may be necessary to carry out additional electrical tests to verify the withstand characteristics of the set. ^b For cap and pin insulator sets, the units to be tested shall be the first three units from the line side, the first three units from the earth side and the three central units from the ignited branch plus any other severely damaged units. For long rod and composite sets, all the insulator units shall be tested. ^c The value of 70 % is given to ensure compatibility with the requirements of IEC 60826 for insulators. Alternatively, following agreement between the customer and the supplier, the acceptance criteria of IEC 60797 may be applied.		

Annex A (normative)

Examples of test arrangements and practical methods of tower simulation (return circuit)

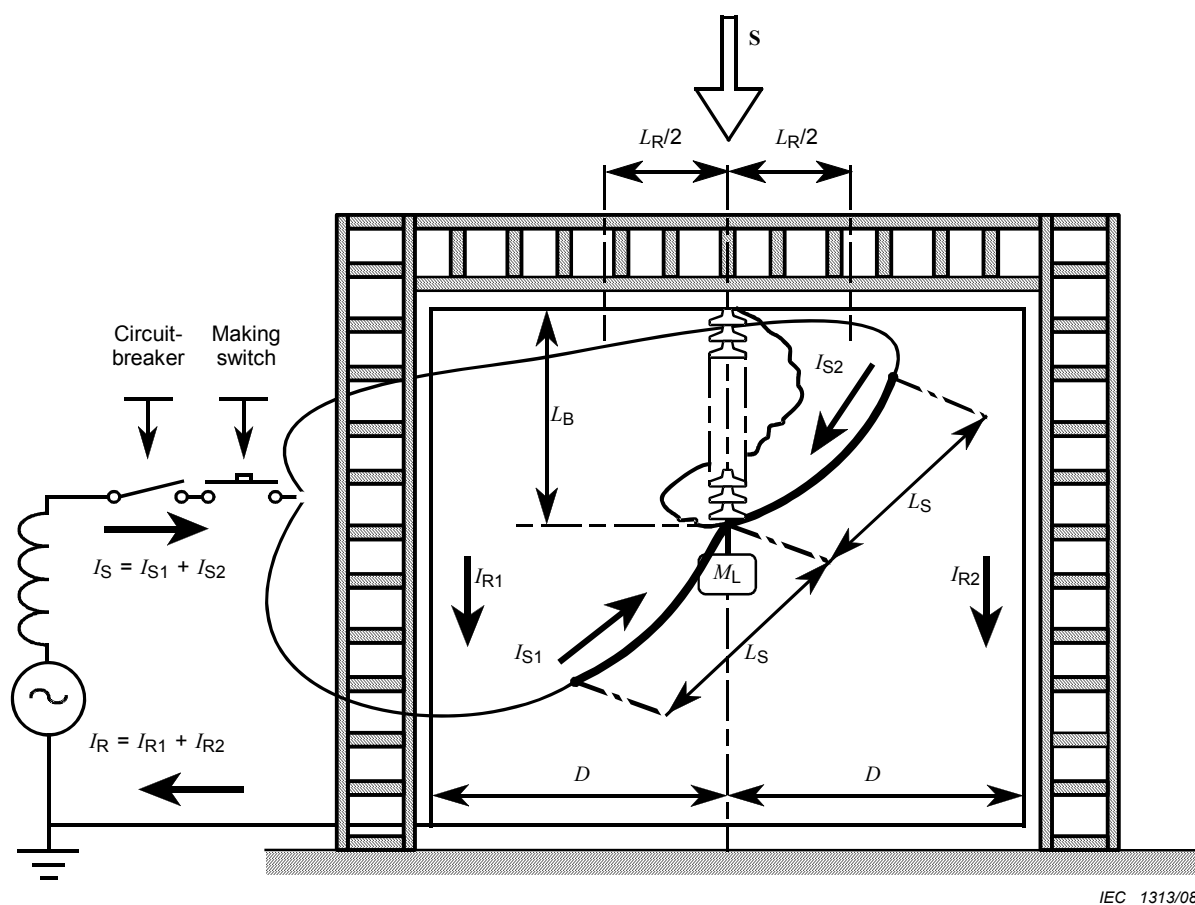
In the return circuit, the current can flow either in the metallic structure simulating the tower or alternatively in conductor(s) placed within the structure itself. In the latter case, the conductor may be fixed parallel to the steel structure without insulation, but by agreement the conductor may be fixed parallel and insulated from the structure (see Figure A.2).

In both cases, the simulation of the configuration of the parts of the tower facing the insulator set shall be constructed of a suitable framework of dimensions not less than the length of the insulator set, with a minimum length of 2,5 m (see L_R in Figures A.1, A.2 and A.3).

In the case of long insulator sets, a length L_R of 6 m is sufficient (see Figures A.1, A.2 and A.3).

For tests on insulators sets intended for networks with U_m of 90 kV or less, the conductor lengths L_S may be reduced to 1,25 m.

When the tower configuration is unknown, a realistic value for the dimensions of the tower simulation shall be agreed. The reason for the simulation of the tower near to the earthed end of the insulator set is to permit the arc root to transfer onto the structure.

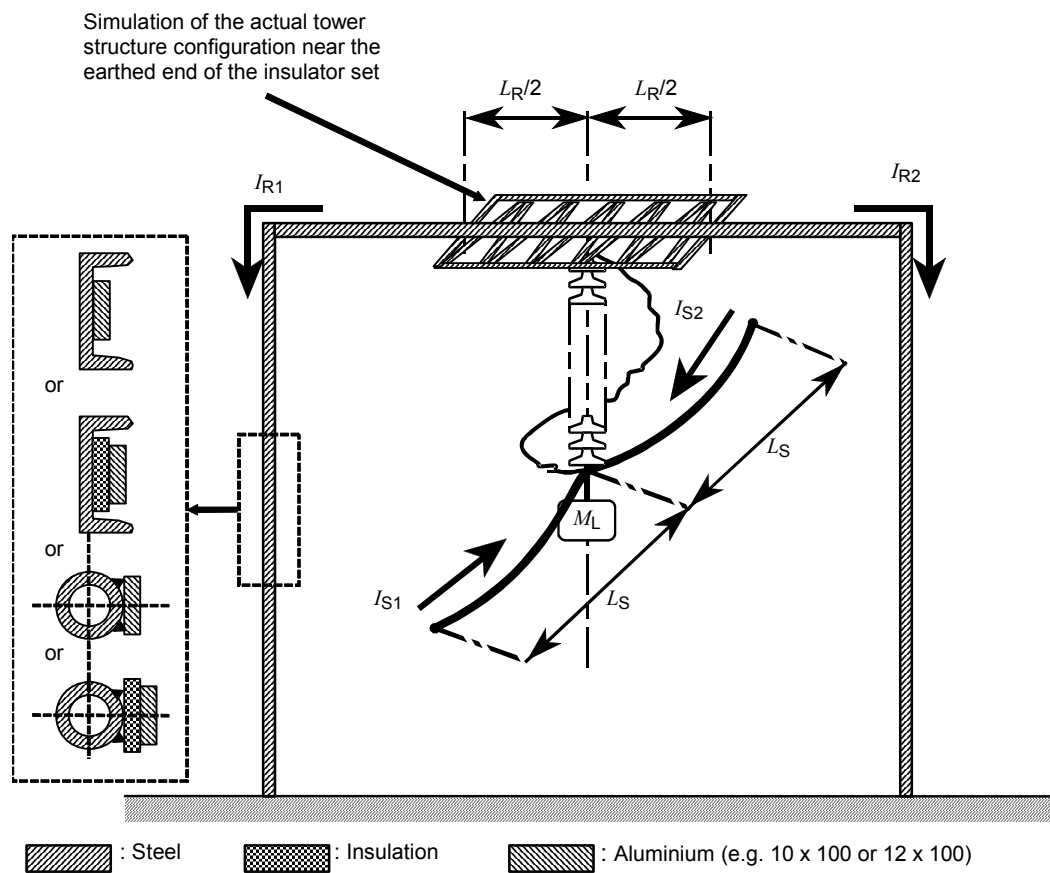


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Key
 $L_R \geq L_B$ and $L_R \geq 2,5$ m

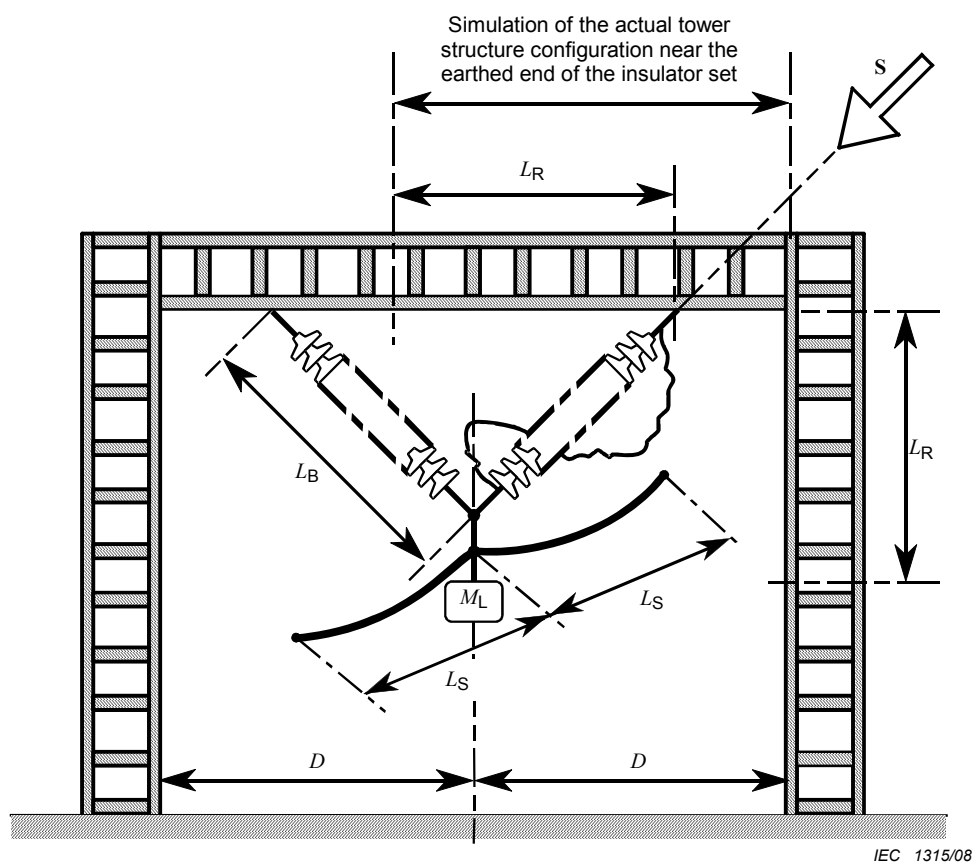
 $L_S \geq L_B$ and $L_S \geq 2,5$ m

 For long insulator sets ($L_B \geq 6$ m) D , L_R and $L_S \geq 6$ m.
Figure A.1 – Test arrangement of vertical insulator set



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Figure A.2 – Test arrangement of vertical insulator set using simplified tower steel structure

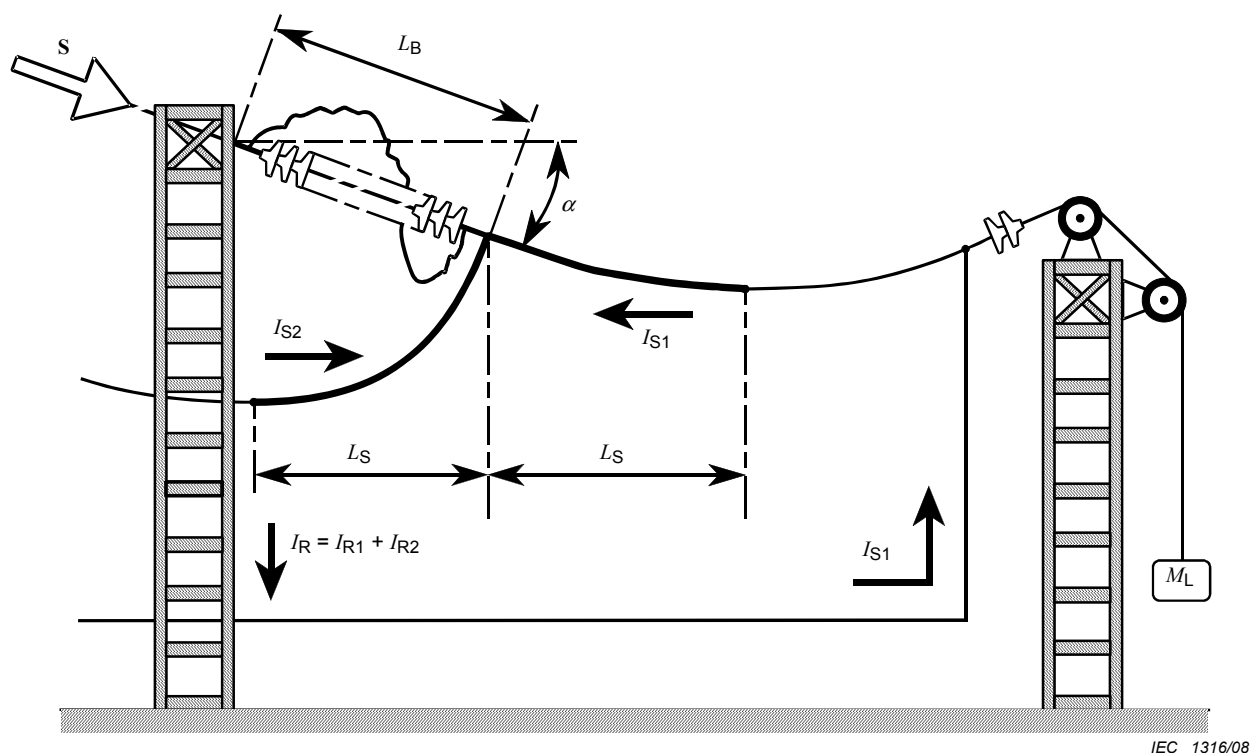
**Key**

$L_R \geq L_B$ and $L_R \geq 2,5$ m

$L_S \geq L_B$ and $L_S \geq 2,5$ m

For long insulator sets ($L_B \geq 6$ m) D , L_R and $L_S \geq 6$ m.

Figure A.3 – Test arrangement of Vee insulator set located in the centre of the tower (for the simplified tower steel structure and return circuit, see Figures A.1 and A.2)



IEC 1316/08

Key

$$10^{\circ} \leq \alpha \leq 20^{\circ}$$
$$L_S \geq L_B \text{ and } L_S \geq 2,5 \text{ m}$$

For long insulator sets ($L_B \geq 6$ m) D , L_R and $L_S \geq 6$ m.

Figure A.4 – Test arrangement of horizontal insulator (for the simplified tower steel structure and return circuit, see Figures A.1 and A.2)