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Railway applications — Fixed installations — D.C. surge arresters and voltage limiting devices -

Part 1: Surge arresters

National foreword

This British Standard is the UK implementation of EN 50526-1:2012. It supersedes BS EN 50123-5:2003 which is withdrawn.

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Contents

Foreword

This document (EN 50526-1:2012) has been prepared by SC 9XC, Electric supply and earthing systems for public transport equipment and ancillary apparatus (Fixed installations), of Technical Committee CENELEC TC 9X, Electrical and electronic applications for railways.

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2012-10-10
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2014-10-10

This document supersedes EN 50123-5:2003.

The existing standard EN 50123-5:2003 covers the case of the old technologies of the gapped arresters with SiC resistors and of the low voltage limiters (LVL) with gaps. These technologies at present are superseded. The present standard deals with the new technologies of the gapless metal-oxide arresters and of the LV limiters for application in the electric railway d.c. fixed installations. Guidance for selection and application of SA and LVL is missing in the old standard while it is added in the third part of the new standard.

As there is no standard available at the moment for surge arrester on rolling stock it seems convenient for the WG to note that the same electrical requirements apply for arresters on rolling stock, taking into account other specific requirements.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Introduction

This European Standard is in three parts:

- Part 1 deals with metal-oxide arresters without gaps for d.c. railway traction systems (fixed installations) and is based on EN 60099-4:2004 + A1:2006 + A2:2009;

- Part 2 deals with voltage limiting devices for specific use in d.c. railway traction systems (fixed installations);

- Part 3 deals with a Guide of application of metal-oxide arresters and of voltage limiting devices.

1 Scope

This European Standard applies to non-linear metal-oxide resistor type surge arresters without spark gaps designed to limit voltage surges on d.c. systems with nominal voltage up to 3 kV.

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.

EN 50124-1:2001, *Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment*

EN 50125-2:2002, *Railway applications – Environmental conditions for equipment – Part 2: Fixed electrical installations*

EN 60060-1:2010, *High-voltage test techniques - Part 1: General definitions and test requirements (IEC 60060-1:2010)*

EN 60270:2001, *High-voltage test techniques – Partial discharge measurements (IEC 60270:2000)*

EN 61109:2008, *Insulators for overhead lines – Composite suspension and tension insulators for a.c. systems with a nominal voltage greater than 1 000 V – Definitions, test methods and acceptance criteria (IEC 61109:2008)*

EN ISO 4287:1998, *Geometrical Product Specifications (GPS) - Surface texture: Profile method - Terms, definitions and surface texture parameters (ISO 4287:1997)*

EN ISO 4892-1:2000, *Plastics - Methods of exposure to laboratory light sources - Part 1: General guidance (ISO 4892-1:1999)*

EN ISO 4892-2:2006, *Plastics - Methods of exposure to laboratory light sources - Part 2: Xenon-arc lamps (ISO 4892-2:2006)*

EN ISO 4892-3:2006, *Plastics - Methods of exposure to laboratory light sources - Part 3: Fluorescent UV lamps (ISO 4892-3:2006)*

3 Terms and definitions

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

3.1
nominal voltage U_n

designated value for a system

[EN 50163:2004]

3.2
highest permanent voltage U_{max1}

maximum value of the voltage likely to be present indefinitely

[EN 50163:2004]

3.3
highest non-permanent voltage U_{max2}

maximum value of the voltage likely to be present for a limited period of time

NOTE Adapted from EN 50163:2004.

3.4
rated insulation voltage U_{Nm}

d.c withstand voltage value assigned by the manufacturer to the equipment or a part of it, characterising the specified permanent (over five minutes) withstand capability of its insulation

NOTE Adapted from EN 50124-1:2001.

3.5
rated impulse withstand voltage U_{Ni}

impulse voltage value assigned by the manufacturer to the equipment or a part of it, characterising the specified withstand capability of its insulation against transient overvoltages

NOTE Adapted from EN 50124-1:2001.

3.6
overvoltage

voltage having a peak value exceeding the corresponding peak value of the highest non-permanent voltage U_{max2}

3.7
transient overvoltage

short duration overvoltage of a few (up to 20 ms) milliseconds or less associated with a transient regime. Two particular transient overvoltages are defined: switching overvoltage and lightning overvoltage

NOTE Adapted from EN 50124-1:2001.

3.8
switching overvoltage

transient overvoltage at any point of the system due to specific switching operation or fault

[EN 50124-1:2001]

3.9
lightning overvoltage

transient overvoltage at any point of the system due to a lightning discharge

[EN 50124-1:2001]

3.10
surge arrester

device intended to limit the transient overvoltages to a specified level

3.11
metal-oxide surge arrester

arrester having non-linear metal-oxide resistors connected in series and/or in parallel without any integrated series or parallel spark gaps

3.12
continuous operating voltage of an arrester U_c

designated permissible d.c. voltage value that may be applied continuously between the arrester terminals

NOTE Adapted from EN 60099-4:2004.

3.13
rated voltage of an arrester U_r

voltage by which the arrester is designated

NOTE Because of the particular nature of the d.c. electrical installation dealt with, the rated voltage of a d.c. arrester coincides with the continuous operating voltage.

3.14
elevated continuous operating voltage U_c*

test voltage U_c* that, when applied to new metal-oxide resistor, gives the same power losses as the voltage U_c when applied to aged metal-oxide resistors

3.15
lightning impulse protection level U_{pl}

the maximum residual voltage for the nominal discharge current

3.16
switching impulse protection level U_{ps}

maximum residual voltage at the specified switching impulse current

3.17
charge transfer capability Q_t

maximum charge per impulse that can be transferred during the charge transfer test and during the operating duty test

3.18
discharge current of an arrester

impulse current which flows through the arrester

3.19
nominal discharge current of an arrester I_n

peak value of lightning current impulse which is used to classify an arrester

[EN 60099-4:2004]

3.20
high current impulse of an arrester

peak value of discharge current having a 4/10 μs impulse shape which is used to test the stability of the arrester on direct lightning strokes

[EN 60099-4:2004]

3.21
steep current impulse
current impulse with a virtual front time of 1 µs with limits in the adjustment of equipment such that the measured values are from 0,9 µs to 1,1 µs and the virtual time to half-value on the tail is not longer than 20 µs

NOTE Adapted from EN 60099-4:2004.

3.22
lightning current impulse
8/20 current impulse with limits on the adjustment of equipment such that the measured values are from 7 µs to 9 µs for the virtual front time and from 18 µs to 22 µs for the time to half-value on the tail

[EN 60099-4:2004]

3.23
direct lightning current impulse

impulse defined by the charge Q and the peak value of the current impulse I_{imp}

3.24
switching current impulse of an arrester I_{sw}

peak value of discharge current having a virtual front time greater than 30 µs but less than 100 µs and a virtual time to half value on the tail of roughly twice the virtual front time

[EN 60099-4:2004]

3.25
reference current of an arrester I_{ref}

d.c. current defined by the manufacturer used to determine the reference voltage of the arrester

NOTE Adapted from EN 60099-4:2004

3.26
reference voltage of an arrester U_{ref}

d.c. voltage across the arrester when the reference current is flowing through it

NOTE Adapted from EN 60099-4:2004.

3.27
residual voltage of an arrester U_{res}

peak value of voltage that appears between the terminals of an arrester during the passage of discharge current

[EN 60099-4:2004]

3.28
rated short circuit current of an arrester I_s

maximum current that may flow in case of an arrester failure for a specified time

3.29
shed

insulating part projecting from the housing, intended to increase the creepage distance

[EN 60099-4:2004]

3.30
porcelain-housed arrester

arrester using porcelain as housing material, with fittings and sealing systems

[EN 60099-4:2004]

3.31
polymer-housed arrester

arrester using polymeric and/or composite materials for housing

NOTE Adapted from EN 60099-4.2004.

3.32
bending moment

horizontal force acting on the arrester housing multiplied by the vertical distance between the mounting base (lower level of the flange) of the arrester housing and the point of application of the force

[EN 60099-4:2004]

3.33
torsional loading

horizontal force at the top of a vertical mounted arrester housing which is not applied to the longitudinal axis of the arrester

NOTE Adapted from EN 60099-4:2004.

3.34
breaking load

force perpendicular to the longitudinal axis of a porcelain-housed arrester leading to mechanical failure of the arrester housing

[EN 60099-4:2004]

3.35
mean breaking load
MBL

the average breaking load for porcelain arresters determined from tests

NOTE Adapted from EN 60099-4: A2:2009.

3.36
specified long-term load
SLL

force perpendicular to the longitudinal axis of an arrester, allowed to be continuously applied during service without causing any mechanical damage to the arrester

[EN 60099-4: A2: 2009]

3.37
specified short-term load
SSL

greatest force perpendicular to the longitudinal axis of an arrester, allowed to be applied during service for short periods and for relatively rare events (for example, short-circuit current loads, extreme wind gusts) without causing any mechanical damage to the arrester

[EN 60099-4: A2: 2009]

3.38
non-linear metal-oxide resistor

part of the surge arrester which, by its non-linear voltage versus current characteristic, acts as a low resistance to overvoltages, thus limiting the voltage across the arrester terminals, and as a high resistance at normal operating voltage

NOTE Adapted from EN 60099-4:2004.

3.39
pressure-relief device of an arrester

means for relieving internal pressure in an arrester and preventing violent shattering of the housing following prolonged passage of fault current or internal flashover of the arrester

[EN 60099-4:2004]

3.40
internal part

metal-oxide resistor element with supporting structure

[EN 60099-4:2004]

3.41
seal (gas/water tightness)

ability of an arrester to avoid ingress of matter affecting the electrical and/or mechanical behaviour into the arrester

[EN 60099-4:2004]

3.42
disruptive discharge

phenomena associated with the failure of insulation under electric stress, which include a collapse of voltage and the passage of current

NOTE 1 The term applies to electrical breakdowns in solid, liquid and gaseous dielectric, and combinations of these.

NOTE 2 Adapted from EN 60099-4:2004.

3.43
puncture (breakdown)

disruptive discharge through a solid

[EN 60099-4:2004]

3.44
flashover

disruptive discharge over a solid surface

[EN 60099-4:2004]

3.45
impulse

unidirectional wave of voltage or current which without appreciable oscillations rises rapidly to a maximum value and falls, usually less rapidly, to zero with small, if any, excursions of opposite polarity

NOTE The parameters which define a voltage or current impulse are polarity, peak value, front time and time to half value on the tail.

[EN 60099-4:2004]

3.46
type test (design test)

conformity test made on one or more items representative of the production

[IEV 151-16-16]

3.47
routine test

conformity test made on each individual item during or after manufacture

[IEV 151-16-17]

3.48
acceptance test

contractual test to prove to the customer that the item meets certain conditions of its specification

[IEV 151-16-23]

3.49
prospective short circuit current

current which would flow in a circuit if it were short-circuited by a link of negligible impedance

NOTE Adapted from EN 60099-4:2004.

4 Characteristics

4.1 Marking

Surge arresters shall be identified by the following minimum information which shall appear on the rating plate (nameplate):

– rated voltage Ur = Uc;
– nominal discharge current In in kA;
– rated short circuit current Is in kA;
– manufacturer's name or trademark, type and identification;
– year of manufacture;
– serial number;
– arrester class

NOTE The rated voltage of a d.c. metal-oxide arresters coincides with continuous operating voltage as per the operating duty test.

Conditions in a.c. systems:

According to EN 60099-4:2004, 3.8, the rated voltage of a surge arrester is defined as the maximum permissible r.m.s. value of power-frequency voltage between its terminals at which it is designed to operate correctly under long-term overvoltage conditions as established in the operating duty test. The rated voltage is the 10 s power-frequency voltage used in the operating duty test after high-current or long-duration impulses. U_c is applied for 30 min immediately after the application of rated voltage in the operating duty test where thermal stability has to be demonstrated. Typically the ratio between rated voltage and Uc is about 1,25 for surge arresters in a.c. systems corresponding to a specific long-term overvoltage, which may occur during fault conditions in the a.c. system.

Conditions in d.c. systems:

According to EN 50163 the supply voltages of traction systems are defined. The highest non-permanent voltage U_{max2} is defined for durations from 1 s to 5 min. By selection of the surge arrester by $U_c > U_{max2}$, the operating duty test as specified in 6.5 covers all effects of long-term overvoltages longer than 1 s with significant margin. No higher long-term overvoltages, which could be assigned to a "rated voltage" occur in d.c. systems.

4.2 Service conditions

4.2.1 Normal service conditions

Surge arresters which conform to this European Standard shall be suitable for operation under the following normal service conditions:

1) ambient temperature within the range of -40 °C to +40 °C;
2) solar radiation (see 4.8 of EN 50125-2:2002);
3) altitude not exceeding 2 000 m (from EN 50124-1);
4) pollution not exceeding PD 1 for indoor installations and PD 4 for outdoor installations as given in EN 50124-1;
5) installation in the vicinity of a rail track on foundations designed so as to damp the main effects of the passage of the trains. Nevertheless a limited vibration or limited shocks may affect the equipment, which shall be capable of operating satisfactorily when subjected to the following conventional accelerations separately applied:
   – g_v: vertical acceleration: 5 m/s²;
   – g_h: horizontal acceleration: 5 m/s².
6) Surge arrester shall comply with condition for class W3 (wind speed 32m/s) as defined in 4.4.1 of EN 50125-2:2002;

4.2.2 Abnormal service conditions

The following are typical abnormal service conditions which may require special consideration in the manufacture or application of surge arresters and should be called to the attention of the manufacturer:

a) temperature in excess of +40 °C or below -40 °C;
b) application at altitudes higher than 2 000 m;
c) fumes or vapours which may cause deterioration of insulating surface or mounting hardware;
d) excessive contamination by smoke, dirt, salt spray or other conducting materials;
e) excessive exposure to moisture, humidity, dropping water or steam;
f) live washing of arrester;
g) explosive mixtures of dust, gases or fumes;
h) abnormal mechanical conditions (earthquakes, vibrations, high ice loads, high cantilever stresses);
i) unusual transportation or storage;
j) heat sources near the arrester;
k) non-vertical erection and suspended erection;
l) torsional loading of the arrester;
m) tensile loading of the arrester;
n) use of the arrester as a mechanical support.

4.3 Requirements

4.3.1 Insulation withstand of the arrester housing

The insulation of the arrester housing shall be coordinated with the arrester protective characteristics. Tests shall be performed according to 6.2.

4.3.2 Reference voltage

Measurement of reference voltage is necessary for the selection of a correct test sample in the operating duty test, see 6.5.

The reference voltage of a d.c. surge arrester is measured at a specific reference current, The reference current is typically in the range of 0,05 mA to 1,0 mA per square centimetre of disc area for single column arresters.

The minimum reference voltage of the arrester at the reference current used for routine tests shall be specified and published in the manufacturer’s data.

4.3.3 Residual voltages

The maximum residual voltages for a given design and for all specified currents and wave shapes shall be obtained from the type test data and from the maximum residual voltage at a lightning impulse current used for routine test as specified and published by the manufacturer.

The maximum residual voltage of a given arrester design for any current and wave shape shall be calculated from the residual voltage of samples tested during type test multiplied by a specific scale factor. This scale factor is equal to the ratio of the declared maximum residual voltage, as checked during the routine test, to the measured residual voltage of the samples at the same current and wave shape.

4.3.4 Internal partial discharges

The internal partial discharges of the arrester energized at 1,05 times its continuous operating voltage shall not exceed 10 pC.

4.3.5 Seal leakage

For arresters having an enclosed gas volume and a separate sealing system, seal leak rates shall be specified as defined in 6.9.

4.3.6 Current distribution in a multi-column arrester

The manufacturer shall specify the unbalance of the current distribution in a multicolumn arrester.

4.3.7 Charge transfer

Arresters shall be able to withstand the charge transfer test as specified in 6.4.

4.3.8 Operating duty

Arresters shall be able to withstand the combination of stresses arising in service as demonstrated by the operating duty tests, see 6.5.

4.3.9 Short circuit behaviour

Arresters shall be able to withstand a short circuit test as specified in 6.6. The arrester shall not fail in a manner that causes violent shattering of the housing and that self-extinguishing of open flames (if any) occurs within a specified period of time.

4.3.10 Protective characteristics of the arresters

The protective characteristics of the arresters are given by the following:

a) residual voltage for steep current impulse according to 6.3.2;
b) residual voltage versus discharge current characteristic for lightning impulses according to 6.3.3;
c) residual voltage for switching impulse U_{ps} according to 6.3.4.

5 Arrester classification

Surge arresters are classified by Q_t and their nominal discharge current according to Table 1.

Table 1 – Arrester classification

Class	Charge transfer capability Q_t As	Nominal discharge current I_n kA
DC-A	1,0	10
DC-B	2,5	10
DC-C	7,5	20

Classes DC-A, DC-B and DC-C correspond to increasing discharge requirements. The selection of the appropriate class shall be based on system requirements.

6 Type test

6.1 General

Type tests shall be carried out as given in Table 2.

Once made, these type tests need not be repeated unless the design is changed so as to modify its performance. In such a case only the relevant tests need be repeated.

Table 2 – Type tests

Tests	Subclause
1. Insulation withstand tests on the arrester housing	6.2
2. Residual voltage tests a) Steep current impulse residual voltage test b) Lightning impulse residual voltage test c) Switching impulse residual voltage test	6.3
3. Charge transfer test	6.4
4. Operating duty test	6.5
5. Short circuit test	6.6
6. Internal partial discharge test	6.7
7. Bending moment test	6.8
8. Seal leak rate test	6.9
9. Environmental tests a) Polluted housing test (for porcelain-housed arresters, only) b) Weather ageing test (for polymer-housed arresters, only)	6.10

Where a test shall be performed at several samples, the required number of samples and their conditions are specified in the individual clauses. Arresters which differ only in methods of mounting or arrangement of the supporting structure and which are otherwise based on the same components and similar construction resulting in the same performance characteristics including their heat dissipation conditions and internal atmosphere, shall be considered to be of the same design.

Housing is the external insulating part of an arrester, which provides the necessary creepage distance and protects the internal parts from the environment. The housing may consist of several parts providing mechanical strength and protection against the environment.

A direct lightning impulse test according to Annex B may be performed optionally.

6.2 Insulation withstand tests on the arrester housing

6.2.1 General

These tests demonstrate the voltage withstand capability of the external insulation of the arrester housing.

The tests shall be performed in the conditions and with the test voltages specified in EN 60060-1:2010. The outside surface of insulating parts shall be carefully cleaned.

The internal parts shall be removed or rendered inoperative to permit these tests. The internal parts may be replaced by an equivalent grading arrangement to provide similar voltage distribution along the arrester axis. In design cases where the external insulation is moulded directly onto the metal-oxide resistors or some insulating material substrate, these tests may be performed with the housing moulded on a suitable insulating substrate.

The applicable tests shall be run on the longest arrester housing. If this does not represent the highest specific voltage stress per unit length, additional tests shall be performed on the unit housing having the highest specific voltage stress.

6.2.2 Ambient air conditions during tests

The voltage to be applied during a withstand test is determined by multiplying the specified withstand voltage by the correction factor taking into account density and humidity (see EN 60060-1:2010).

Humidity correction shall not be applied for wet tests.

6.2.3 Wet test procedure

The external insulation of outdoor arresters shall be subjected to wet withstand tests under the test procedure given in EN 60060-1:2010.

6.2.4 Lightning impulse voltage test

The arrester shall be subjected to a standard lightning impulse voltage dry test according to EN 60060-1:2010.

Fifteen consecutive impulses at the test voltage value shall be applied for each polarity. The arrester shall be considered to have passed the test if no internal disruptive discharges occur and if the number of the external disruptive discharges does not exceed two in each series of 15 impulses. The test voltage shall be equal to the lightning impulse protection level of the arrester multiplied by 1,47.

If the dry arcing distance is greater than the test voltage divided by 500 kV/m, this test is not required.

6.2.5 d.c. voltage withstand test

The housings of arresters for outdoor use shall be tested in wet conditions, and housings of arresters for indoor use, in dry conditions.

Housings shall withstand a d.c. voltage equal to the lightning impulse protection for a duration of 1 min.

6.3 Residual voltage tests

6.3.1 General

The purpose of the residual voltage type test is to obtain the data necessary to derive the maximum residual voltage as explained in 3.27. It includes the calculation of the ratio between voltages at specified impulse currents and the voltage level checked in routine tests. The latter voltage can be either the reference voltage or the residual voltage at a suitable lightning impulse current in the range 0,1 to 2 times the nominal discharge current depending on the manufacturer's choice of routine test procedure.

The maximum residual voltage at a lightning impulse current used for routine tests shall be specified and published in the manufacturer's data. Maximum residual voltages of the design for all specified currents and wave-shapes are obtained by multiplying the measured residual voltages of the test sample by the ratio of the declared maximum residual voltage at the routine test current to the measured residual voltage for the sample at the same current.

All residual voltage tests shall be made on the same three samples of complete arresters or metal-oxide resistors. The time between discharges shall be sufficient to permit the samples to return to approximately ambient temperature. For multi-column arresters the test may be performed on only one column; the residual voltages are then measured for currents obtained from the total currents in the complete arrester divided by the number of columns, considering current sharing requirements.

6.3.2 Steep current impulse residual voltage test

One steep current impulse with a peak value equal to the nominal discharge current of the arrester ± 5 % and a virtual front time between 0,9 µs to 1,1 µs shall be applied to each of the three samples. Time to half value on the tail is not critical and may have any tolerance. The peak value and the impulse shape of the voltage appearing across the three samples shall be recorded and, if necessary, corrected for inductive effects of the voltage measuring circuit as well as the geometry of the test sample and the test circuit.

The following procedure shall be used to determine if an inductive correction is required. A steep current impulse as described above shall be applied to a metal block having the same dimensions as the metal-oxide resistor samples being tested. The peak value and the shape of the voltage appearing across the metal block shall be recorded. If the peak voltage on the metal block is less than 2 % of the peak voltage of the metal-oxide resistor samples, no inductive correction to the metal-oxide resistor measurements is required. If the peak voltage on the metal block is between 2 % and 20 % of the peak voltage on the metal-oxide resistor sample, then the impulse shape of the metal block voltage shall be subtracted from the impulse shape of each of the metal-oxide resistor voltages and the peak values of the resulting impulse shapes shall be recorded as the corrected metal-oxide resistor voltages. If the peak voltage on the metal block is greater than 20 % of the peak voltage on the metal-oxide resistor samples, then the test circuit and the voltage measuring circuit shall be improved.

The steep current impulse residual voltage of the arrester is the sample impulse voltage (corrected if necessary) with highest peak value multiplied by the scale factor.

NOTE A possible way to achieve identical current wave shapes during all measurements is to perform them with both the test sample and the metal block in series in the test circuit. Only their positions relative to each other need to be interchanged for measuring the voltage drop on the metal block or on the test sample.

6.3.3 Lightning impulse residual voltage test

The test shall be applied to three samples. Each sample shall be submitted to three lightning current impulses in accordance with 3.22 with peak values of approximately 50 %, 100 % and 200 % of the nominal discharge current of the arrester. Virtual front time shall be within 7 µs to 9 µs while the half-value time may have any tolerance, as it is not critical. The residual voltages are determined in accordance with 3.27. The maximum values of the determined residual voltages shall be drawn in a residual voltage versus discharge current curve. The residual voltage read on such a curve corresponding to the nominal discharge current is defined as the lightning impulse protection level of the arrester.

6.3.4 Switching impulse residual voltage test

One switching current impulse in accordance with the specified value in Table 3 shall be applied to each of the three samples with a tolerance of ± 5 %. The highest of these three voltages is defined as the switching impulse residual voltage of the arrester at the respective current.

Table 3 – Peak currents for switching impulse residual voltage test

Arrester class	Switching current impulse I_{sw} A
DC-A	500
DC-B	1 000
DC-C	2 000

6.4 Charge transfer test

6.4.1 General

Before the tests the residual voltage and reference voltage of each test sample shall be measured for evaluation purposes.

The charge transfer test shall be made on three new samples of complete arresters or metal-oxide resistors which have not been subjected previously to any test except that specified above for evaluation purposes. The non-linear metal-oxide resistors may be exposed to the open air at a still air temperature of 20 °C ± 15 °C during these tests.

Each charge transfer test shall consist of 18 discharge operations divided into six groups of three impulses. Intervals between the discharge operations shall be 50 s to 60 s and intervals between each group of three such that the sample cools to near ambient temperature.

Following the charge transfer test and after the sample has cooled to near ambient temperature, the residual voltage and reference voltage test which were made before the charge transfer test shall be repeated for comparison with the values obtained before the test, and the values shall not have changed by more than 5 %.

Visual examination of the test samples after the test shall reveal no evidence of puncture, flashover, cracking or other significant damage of the metal-oxide resistors.

6.4.2 Charge transfer test requirements

This test consists in the application of current impulses to the test sample to prove the charge transfer capability Q_t of the surge arrester. The test parameters are given in Table 4.

Table 4 – Parameters for the charge transfer test

Class	**Charge transfer capability Q_t** As	**Virtual duration of peak of current impulse T_d** ms
DC-A	1,0	1,0 - 2,5
DC-B	2,5	2,0 – 3,5
DC-C	7,5	2,5 – 5,0

The test shall be carried out with any test generator for long duration rectangular current impulses fulfilling the following requirements:

a) the virtual duration of the peak (T_d) of the current impulse shall be between 1 ms and 5 ms (see Figure 1);

b) the virtual total duration (T_t) of the current impulse shall not exceed 150 % of the virtual duration of the peak (see Figure 1).

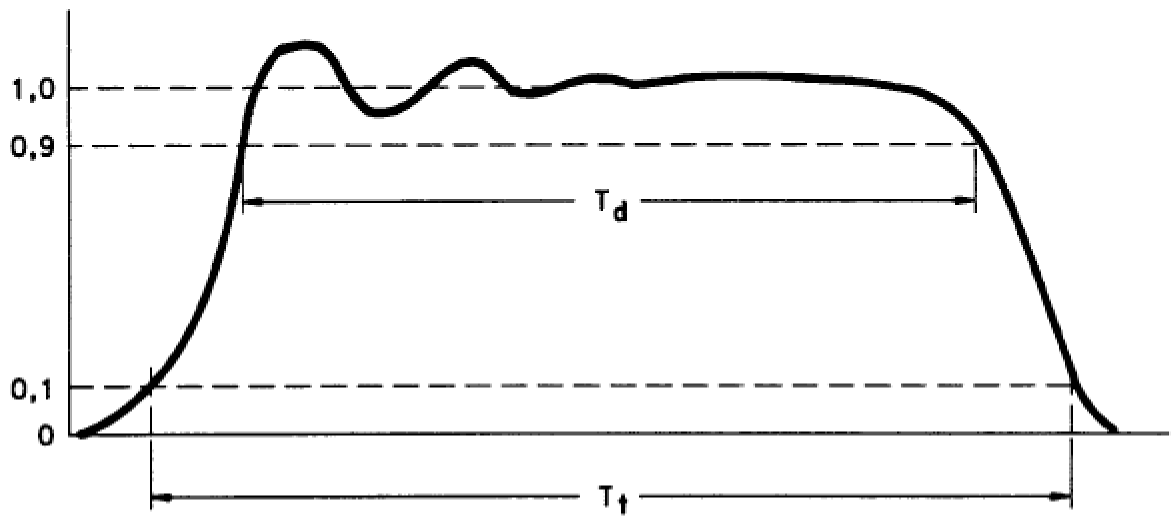


Figure 1 – Impulse current – Rectangular

The charge on each tested sample shall lie between 90 % and 110 % of the specified value for the first impulse and between 100 % and 110 % of this value for the following impulses.

Records of the applied voltage and current waveforms of the first and the last impulse applied shall be supplied on the same time base for each sample. The peak value of the current, the charge and the energy shall be provided for each impulse.

6.5 Operating duty tests

6.5.1 General

In these tests service conditions are simulated by the application to the arrester of a stipulated number of specified impulses in combination with energisation by a power supply of specified d.c. voltage. The voltage shall be measured with an accuracy of ± 1 %. During the operating duty tests, the d.c. voltage shall not deviate from the specified values by more than ± 1 %.

The main requirement to pass these tests is that the arrester is able to cool down during the d.c. voltage application, i.e. thermal runaway does not occur.

Thermal runaway of an arrester is the situation when the sustained power loss of an arrester exceeds the thermal dissipation capability of the housing and connections, leading to a cumulative increase in the temperature of the metal-oxide resistor elements culminating in failure.

An arrester is thermally stable if, after an operating duty causing temperature rise, the temperature of the metal-oxide resistor elements decreases with time when the arrester is energized at specified continuous operating voltage and at specified ambient conditions.

The test sequence comprises

– initial measurements,
– conditioning,
– application of impulses,
– final measurements and examination.

This sequence is given in Table 6.

The test shall be made on three samples of complete arresters at an ambient temperature of 20 °C ± 15 K.

The critical arrester parameter for successfully passing the operating duty test is the metal-oxide resistor power loss. The operating duty test shall, therefore, be carried out on new metal-oxide resistors at elevated test voltage U_c* that gives the same power losses as the continuous operating voltage with aged metal-oxide resistors. These elevated test voltage shall be determined from the accelerated ageing procedure in the way described in 6.5.2.

The d.c. test voltage to be applied to the test arresters shall be the continuous operating voltage (see 3.12). This voltage is modified according to 6.5.2 to establish the elevated test voltage U_c*.

NOTE The established preheat temperature of 60 °C ± 3 K specified in Table 6 is a weighted average that covers the influence of ambient temperature and solar radiation.

6.5.2 Accelerated ageing procedure

6.5.2.1 General

This test procedure is designed to determine the voltage value U_c* used in the operating duty test (see Figure 2) which will allow this test to be carried out on new metal-oxide resistors. A d.c. test voltage shall be applied.

NOTE This test does not consider polarity change during service.

6.5.2.2 Test procedure

Three metal-oxide resistor samples shall be stressed at the continuous operating voltage U_c of the sample for 1 000 h, during which the temperature shall be controlled to keep the surface temperature of the metal-oxide resistor at 115 °C ± 4 K.

All material (solid or liquid) in direct contact with the metal-oxide resistors shall be present during the ageing test with the same design as used in the complete arrester.

During this accelerated ageing, the metal-oxide resistor shall be in the surrounding medium used in the arrester. In this case, the procedure shall be carried out on single metal-oxide resistors in a closed chamber where the volume of the chamber is at least twice the volume of the metal-oxide resistor and where the density of the medium in the chamber shall not be less than the density of the medium in the arrester.

6.5.2.3 Determination of elevated continuous operating voltages

The three test samples shall be heated to 115 °C ± 4 K and the metal-oxide resistor power losses P_{1ct} shall be measured at a voltage of U_c 1 h to 2 h after the voltage application. The metal-oxide resistor power losses shall be measured once in every 100 h time span after the first measurement giving P_{1ct}. Finally, the metal-oxide resistor power losses P_{2ct} shall be measured after 1 000 h to 1 100 h of ageing under the same conditions. Accidental intermediate de-energizing of the test samples, not exceeding a total duration of 24 h during the test period is permissible. The interruption will not be counted in the duration of the test. The final measurement shall be performed after not less than 100 h of continuous energizing. Within the temperature range allowed, all measurements shall be made at the same temperature ± 1 K.

The minimum power losses value among those measured at least every 100 h time span shall be called P_{3ct}. This is summarized in Figure 2.

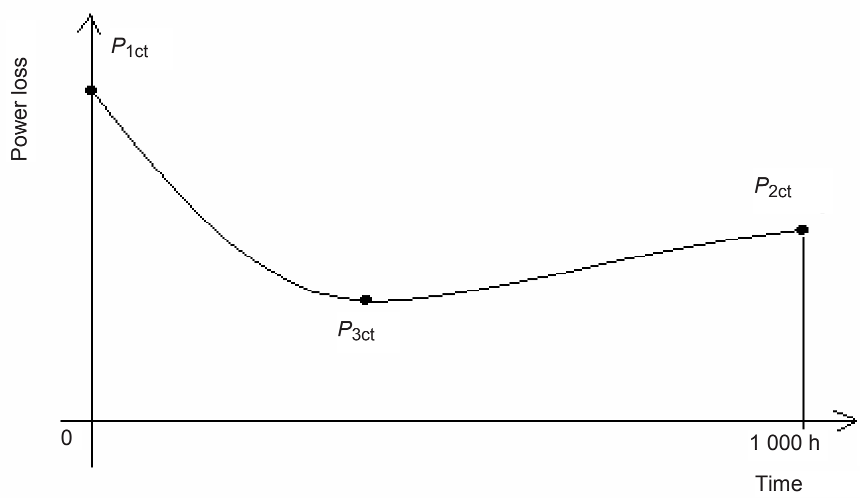


Figure 2 – Power losses of the metal-oxide resistor at elevated temperatures versus time

If P_{2ct} is equal to, or less than, 110 % P_{3ct}, then the test according to 6.5.3 shall be performed on new metal-oxide resistors:

- if P_{2ct} is equal to, or less than, P_{1ct}, U_c is used without any modification;
- if P_{2ct} is greater than P_{1ct}, the ratio P_{2ct}/P_{1ct} is determined for each sample. The highest of these three ratios is called K_{ct}. On three new metal-oxide resistors at ambient temperature, the power losses P_{1ct} are measured at U_c. Thereafter, the voltage is increased so that the corresponding power losses P_{2ct} fill the relation:

$$\frac{P_{2ct}}{P_{1ct}} = K_{ct};$$

U_c* is the highest of the three increased voltages obtained (K_{ct} U_c). As an alternative, aged metal-oxide resistors may also be used after agreement between the user and the manufacturer.

If P_{2ct} is greater than 110 % P_{3ct}, and

– P_{2ct} is lower than P_{1ct} then aged metal-oxide resistors shall be used for the following tests of 6.5.3. U_c is used without modification;
– P_{2ct} is greater than or equal to P_{1ct} then aged metal-oxide resistors shall be used for the following tests of 6.5.3. New metal-oxide resistors with corrected value U_c* can be used, but only after agreement between the user and the manufacturer.

Metal-oxide resistors subjected to the above test during more than 1 000 h are considered as aged.

Table 5 summarizes these cases.

Table 5 – Determination of elevated continuous operating voltage

Power losses measured	Test samples for the operating duty test	Test voltage for the operating duty test
$P_{2ct} \leq 1{,}1 \times P_{3ct}$ and $P_{2ct} \leq P_{1ct}$	New samples	U_c
$P_{2ct} \leq 1{,}1 \times P_{3ct}$ and $P_{2ct} > P_{1ct}$	New samples	U_c*
$P_{2ct} > 1{,}1 \times P_{3ct}$ and $P_{2ct} < P_{1ct}$	Aged samples	U_c
$P_{2ct} > 1{,}1 \times P_{3ct}$ and $P_{2ct} \geq P_{1ct}$	Aged samples	U_c
	New samples (alternatively after agreement between manufacturer and purchaser)	U_c*

Where aged metal-oxide resistors are used in the operating duty test, the time delay between the ageing test and the operating duty test should be not more than 24 h.

The measuring time shall be short enough to avoid increased power loss due to heating.

6.5.3 Operating duty test

6.5.3.1 Test sequence

The complete test sequence is given in Table 6.

Table 6 – Test procedure of operating duty test

Step		Operation
1. Initial measurement		Residual voltage measurement at nominal discharge current and reference voltage measurement
		Time interval not specified
2. Conditioning (see 6.5.3.2)	Part I	4 groups of 5 impulses at I_n 8/20 µs
		Time interval not specified at ambient temperature
	Part II	High current impulse 4/10 µs Cooling to ambient temperature High current impulse 4/10 µs
3. Operating duty test		Preheat to 60 °C ± 3 K
		One impulse of the charge transfer test (see 6.4.2)
		50 s to 60 s
		One impulse of the charge transfer test (see 6.4.2)
		As short as possible, no longer than 100 ms
		Elevated continuous operation voltage, 30 min (see 6.5.2.3)
		Cooling to ambient temperature
4. Final measurement and examination		Residual voltage measurement at nominal discharge current and reference voltage measurement
		Visual examination of test sample

NOTE In case of limited generator performance it is allowed to apply the total charge transfer of 2 operations with 3 operations carried out within 2 min. This is acceptable because the operating duty test demonstrates the thermal stability of the surge arrester after energy absorption.

Before the operating duty test the reference voltage and residual voltage at nominal discharge current of each of the three test samples shall be determined at ambient temperature (see 6.3.3).

The test samples shall be suitably marked to ensure the correct polarity of application in the following subclauses.

6.5.3.2 Conditioning

The samples are exposed to a conditioning test. The first part of test consists of 20 current impulses according to 6.5.3 and a peak value equal to the nominal discharge current of the arrester. The 20 impulses are applied in 4 groups of 5 impulses. The interval between the impulses shall be 50 s to 60 s and the interval between groups shall be such that the samples cool down to near ambient temperature.

The second part of the conditioning is the application of two 4/10 µs high current impulses I_{hc} with peak value as specified in Table 7. The measured peak value of the current impulses shall be within 90 % and 110 % of the specified peak value.

The conditioning shall be carried out on the test samples in open air at a still air temperature of 20 °C ± 15 K.

Table 7 – Requirements for high current impulses

Class	Peak value I_{hc} kA
DC-A, DC-B	100
DC-C	200

After this conditioning the test samples shall be stored for future use in the operating duty test.

6.5.3.3 Application of impulses

After conditioning, the arrester shall be heated up to 60 °C ± 3 K. The test shall be carried out at the ambient temperature of 20 °C ± 15 K.

If a higher temperature is deemed necessary because of high pollution or abnormal service conditions, then the higher value may be used for the test if agreed between manufacturer and purchaser.

The arrester shall be subjected to two charge transfer operations with rated charge Q_t as specified in Table 4 for the relevant arrester class. The time interval between the impulses shall be 50 s to 60 s.

After the second charge transfer operation, the arrester shall be disconnected from the impulse generator and connected to the d.c. source as soon as possible but not later than 100 ms after the impulse. The elevated continuous operating voltage U_c*, determined from the accelerated ageing procedure described in 6.5.2, shall be applied for a time period of 30 min to prove thermal stability or thermal runaway.

To reproduce actual system conditions the second charge transfer operation shall be applied while the sample is energized at U_c*. The 100 ms limit is permitted in view of practical limitation in the test circuit.

Oscillographic records of the voltage across and current through the test sample shall be made of all charge transfer operations. The charge and energy dissipated by the test sample during the operation shall be determined from the voltage and current oscillograms and charge and energy values shall be recorded in the type test report.

Metal-oxide resistor temperature or d.c. current or power loss shall be monitored during the d.c. voltage application to prove thermal stability or thermal run-away.

Following the complete test sequence, and after the test sample has cooled to near ambient temperature, the reference voltage and residual voltage at nominal discharge current of each of the three arresters is determined at ambient temperature.

6.5.3.4 Evaluation of thermal stability in the operating duty tests

The samples subjected to the operating duty tests are considered to be thermally stable if the d.c. current or power loss or metal-oxide resistor temperature steadily decreases during the last 15 min of U_c voltage application in the procedure shown.

The d.c. current is strongly influenced by the stability of the applied voltage and also by the change in ambient temperature. Because of this, the judgement whether the arrester is thermally stable or not may in some cases not be clear at the end of the U_c* voltage application. If that is the case, the time of the U_c* voltage application shall be extended until the steady decrease in the current or power loss or temperature is clearly confirmed. If an increasing trend of current or power dissipation or temperature is not observed within 3 h of voltage application the sample is considered stable.

6.5.3.5 Conditions for a successful test

The arrester has passed the test if all the following conditions are met:

– the thermal stability is achieved;

– the change in residual voltage measured before and after the test is not more than 5 %;
– the change in reference voltage measured before and after the test is not more than 10 %;
– visual examination of the test samples after the test reveals no evidence of puncture, flashover or cracking of the non-linear metal-oxide resistors.

6.6 Short-circuit tests

6.6.1 General

The tests shall be performed in order to show that an arrester failure does not result in a violent shattering of the arrester housing, and that self-extinguishing of open flames (if any) occurs within a defined period of time. Each arrester type is tested with three values of short-circuit currents. If the arrester is equipped with some other arrangement as a substitute for a conventional pressure relief device, this arrangement shall be included in the test.

6.6.2 Preparation of the test samples

The tests shall be carried out on complete arresters for the highest voltage rating.

The complete arresters shall be electrically pre-failed with a d.c. or a.c. overvoltage applied to the terminals of the arresters. No physical modification shall be made to the arresters between pre-failing and the actual short-circuit current test.

The overvoltage for pre-failing shall cause the arrester to fail within 5 min ± 3 min. The metal-oxide resistors are considered to have failed when the voltage across the arrester falls below 10 % of the originally applied voltage. The pre-failing current shall not exceed 30 A.

The time between pre-failure and the rated short-circuit current test shall not exceed 15 min.

The pre-failure shall be achieved by either applying a voltage source or a current source to the sample.

For voltage source method: The initial current should typically be in the range 5 mA/cm² to 10 mA/cm². The pre-failing short-circuit current should typically be in between 1 A and 30 A. The voltage source need not to be adjusted after the initial setting, although small adjustments might be necessary in order to fail the metal-oxide resistors in the given time range.

For current source method: Typically a current density of around 15 mA/cm² with a variation of ± 50 %, will result in failure of the metal-oxide resistors in the given time range. The pre-failing short-circuit current should typically be between 10 A and 30 A. The current source need not be adjusted after the initial setting, although small adjustments might be necessary in order to fail the metal-oxide resistors in the given time range.

6.6.3 Mounting of the test sample

For a base-mounted arrester, the mounting arrangement is shown in Figure 3. The distance to the ground of the insulating platform and the conductors shall be as indicated in Figure 3.

For non-base-mounted arresters the test sample shall be mounted on hardware typically used for real service installation. For the purpose of the test, the mounting bracket shall be considered as a part of the arrester base. The installation recommendations of the manufacturer shall be considered.

For base-mounted arresters, the bottom end fitting of the test sample shall be mounted on a test base that is at the same height as a surrounding circular or square enclosure. The test base shall be of insulating material or may be of conducting material if its surface dimensions are smaller than the surface dimensions of the arrester bottom end fitting. The test base and the enclosure shall be placed on top of an insulating platform, as shown in Figure 3. For non-base-mounted arresters, the same requirements apply to the bottom of the arrester. The arcing distance between the top end cap and any other metallic object (floating or earthed), except for the base of the arrester, shall be at least 160 % the height of the sample arrester, but not less than 0,9 m. The enclosure shall be made of non-metallic material and be positioned symmetrically with respect to the axis of the test sample. The height of the enclosure shall be 40 cm ± 10 cm, and its diameter (or side, in case of a square enclosure) shall be equal to the greater of 1,8 m or D in the equation below. The enclosure shall not be permitted to open or move during the test.

$$D = 1{,}2 \times (2 \times h + D_{arr})$$

where

h = height of tested arrester unit;

D_{arr} = diameter of tested arrester unit.

The arresters shall be mounted according to Figure 3 in the vertical position unless agreed upon otherwise between the manufacturer and the purchaser.

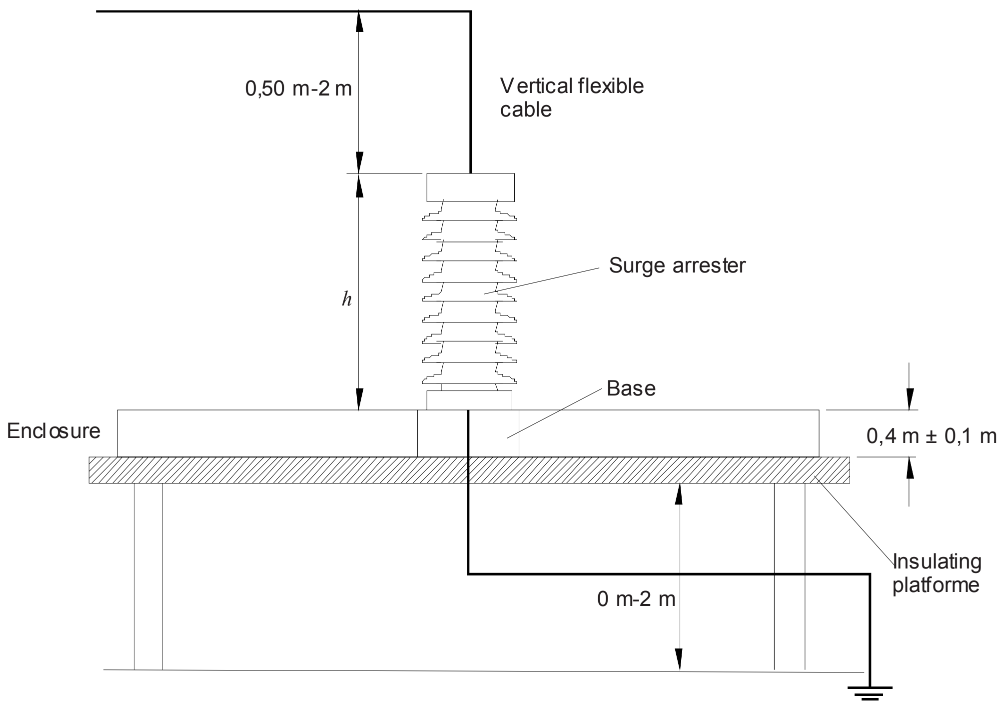


Figure 3 – Circuit layout for short-circuit test (all leads and venting systems in the same plane)

6.6.4 Short-circuit tests

The tests shall be carried out with d.c. currents.

Arresters shall be tested at the rated short-circuit current I_s, the reduced short-circuit current and the low short circuit current according to Table 8. The measured mean value of the test current shall be at least the rated short-circuit current and within the tolerance limits for the reduced and low short-circuit currents.

Table 8 – Required currents for short-circuit tests

Short-circuit current	Current A	Tolerance on current %	Duration s
Rated	40 000		0,2
Reduced	25 000	± 20	0,2
Low	600	± 33	1,0

All arresters shall be prepared according to 6.6.2 and mounted according to 6.6.3.

Tests shall be made in a test circuit, with an open circuit test voltage of 77 % to 107 % of the continuous voltage of the test sample. The measured total duration of test current flowing through the circuit shall be as indicated in Table 8. For surge arresters with pressure relief devices the low short-circuit current shall flow until venting occurs.

The prospective current shall first be measured by making a test with the arrester short-circuited or replaced by a solid link of negligible impedance. The duration of such a test may be limited to the minimum time required to measure the peak and current waveform. The solid shorting link shall be removed after checking the prospective current and the arrester sample(s) shall be tested with the same circuit parameters. The short-circuit current versus time shall be recorded during all short-circuit tests.

NOTE Pre-failed arresters can build up considerable arc resistance, which limits the current through the arrester. It is therefore recommended to perform the short-circuit tests as soon as possible after the pre-failure, preferably before the test samples have cooled down.

For pre-failed arresters, therefore, it is recommended to ensure that the arrester represents a sufficiently low impedance prior to applying the short-circuit current by reapplying the prefailing, or similar, circuit for maximum 2 s immediately before applying the short-circuit test current, see Figure 3. It is allowed to increase the short-circuit current of the pre-applied circuit up to 300 A. If so, its maximum duration t_{rpf}, which depends on the current magnitude I_{rpf}, shall not exceed the following value:

$$t_{\mathrm{rpf}} \leq Q_{\mathrm{rpf}} / I_{\mathrm{rpf}}$$

where

t_{rpf} = re-prefailing time in s;

Q_{rpf} = re-prefailing charge = 60 As;

I_{rpf} = re-prefailing current in A.

6.6.5 Evaluation of test results

The test is considered successful if the following three criteria are met:

1) no violent shattering;
2) no parts of the test sample are found outside the enclosure, except for
   – fragments, less than 60 g each, of ceramic material such as metal-oxide or porcelain,
   – pressure relief vent covers and diaphragms,
   – soft parts of polymeric materials;
3) the arrester is able to self-extinguish open flames within 2 min after the end of the test. Any ejected part (in or out of the enclosure) also self-extinguishes open flames within 2 min.

Structural failure of the sample is permitted as long as all criteria are met.

NOTE If the arrester has not visibly vented at the end of the test, caution should be exercised, as the housing may remain pressurised after the test. This applies to all levels of test current, but is of particular relevance to the low current short-circuit tests.

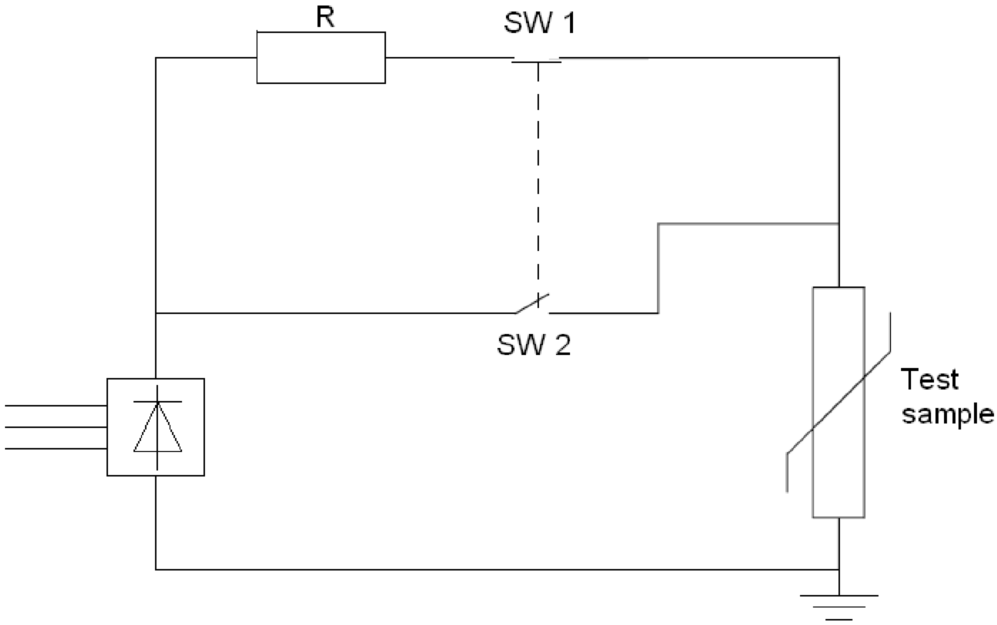


Figure 4 – Example of a test circuit for re-applying pre-failing immediately before applying the short-circuit test current

6.7 Internal partial discharge tests

This test shall be carried out at a.c. voltage. The a.c. r.m.s. voltage (U_{tac}) to be applied shall be U_c of the sample divided by √2.

The test voltage shall be increased to 125 % of U_{tac}, held for 2 s to 10 s, and then decreased to 105 % of U_{tac}. At that voltage, the partial discharge level shall be measured according to EN 60270. The measured value for the internal partial discharge shall not exceed 10 pC.

This test shall be performed on one sample of a complete arrester. The test sample may be shielded against external partial discharges.

6.8 Bending moment test

6.8.1 General

The test applies to polymer-housed arresters with and without enclosed gas volume and to porcelain-housed arresters.

The complete test procedure for different arrester designs shall be as stated in the following and illustrated in Figure A.1. For porcelain-housed arresters SLL is specified as 40 % of SSL. For polymer-housed arresters SLL is lower than SSL, see Figure 8.

This test demonstrates the ability of the arrester to withstand the manufacturer's declared values for bending loads. Normally, an arrester is not designed for torsional loading. If an arrester is subjected to torsional loads, a specific test may be necessary by agreement between manufacturer and user. The test shall be performed on complete arresters.

6.8.2 Test on porcelain-housed arresters

6.8.2.1 Sample preparation

One end of the sample shall be firmly fixed to a rigid mounting surface of the test equipment, and a load shall be applied to the other (free) end of the sample to produce the required bending moment at the fixed end. The direction of the load shall pass through and be perpendicular to the longitudinal axis of the arrester. If the arrester is not axi-symmetrical with respect to its bending strength, the manufacturer shall provide information regarding this non-symmetric strength, and the load shall be applied in an angular direction that subjects the weakest part of the arrester to the maximum bending moment.

6.8.2.2 Test procedure to verify the Specified Short-Term Load (SSL)

Three samples shall be tested. Prior to the tests, each test sample shall be subjected to a leakage check (see of 7.1 d) and an internal partial discharge test (see 7.1 c).

On each sample the bending load shall be increased smoothly to SSL, tolerance + 5 % / - 0 %, within 30 s to 90 s. When the test load is reached, it shall be maintained for 60 s to 90 s. The force and deflection shall be measured continuously from the beginning up to the end of the test. Then the load shall be released smoothly and the residual deflection shall be recorded.

The residual deflection shall be measured in the interval 1 min to 10 min after the release of the load.

6.8.2.3 Test evaluation

The arrester shall have passed the test if

– there is no visible mechanical damage,
– the residual deflection is less than or equal to the greater of 3 mm or 10 % of maximum deflection during the test,
– the test samples pass the leakage test in accordance with 6.9,
– the internal partial discharge level of the test samples does not exceed the value specified in 6.7.

6.8.3 Test on polymer-housed arresters with and without enclosed gas volume

6.8.3.1 Sample preparation

A test in two steps shall be performed one after the other on three samples.

Prior to the bending-moment test, each sample shall be subjected to the following:

- electrical tests made in the following sequence:
- power losses measured at U_c and at an ambient temperature of 20 °C ± 15 K;
- internal partial discharge test according to 6.7;
- residual voltage test at the nominal discharge current;
- leakage tests in accordance with 6.9 for arresters with enclosed gas volume and separate sealing system.

One end of the sample shall be firmly fixed to a rigid mounting surface of the test equipment, and a load shall be applied to the other (free) end of the sample to produce the required bending moment at the fixed end. The direction of the load shall pass through and be perpendicular to the longitudinal axis of the arrester. If the arrester is not axi-symmetrical with respect to its bending strength, the manufacturer shall provide information regarding this non-symmetric strength, and the load shall be applied in an angular direction that subjects the weakest part of the arrester to the maximum bending moment.

6.8.3.2 Test procedure

6.8.3.2.1 Overview

Tolerance on specified loads shall be + 5 % / - 0 %. The test is undertaken in two steps:

Step 1.1: two samples shall be submitted to the short-term load test as described in 6.8.3.2.2;

Step 1.2: the third sample shall be submitted to the mechanical preconditioning as per 6.8.3.2.3;

Step 2: all three samples shall be submitted to the water immersion test as per 6.8.3.2.4.

6.8.3.2.2 Short-term load test

Two samples shall be tested at the specified short-term load (SSL). The bending load shall be increased smoothly to a test load equal to SSL within 30 s to 90 s. When the test load is reached, it shall be maintained for 60 s to 90 s. The force and deflection shall be measured continuously from the beginning up to the end of the test then the load shall be released smoothly. The residual deflection shall be measured in the interval 1 min to 10 min after the release of the load.

The maximum deflection during the test and any residual deflection shall be recorded.

6.8.3.2.3 Mechanical preconditioning

This step constitutes a part of the test procedure and shall be performed on one of the test samples.

Terminal torque preconditioning shall be achieved by applying the arrester terminal torque as specified by the manufacturer to the test sample for a duration of 30 s.

Thermo mechanical preconditioning is achieved by submitting the arrester to the specified continuous load (SLL) in four directions and in thermal variations as described in Figure 5 and Figure 6.

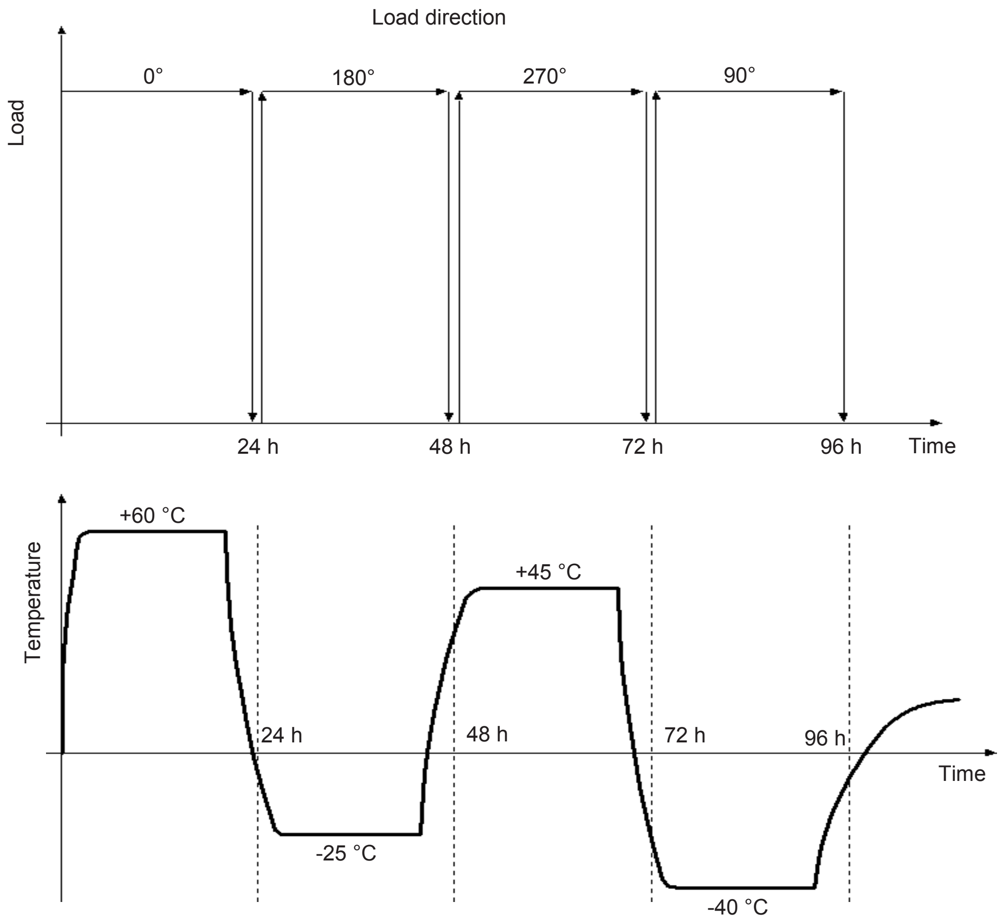
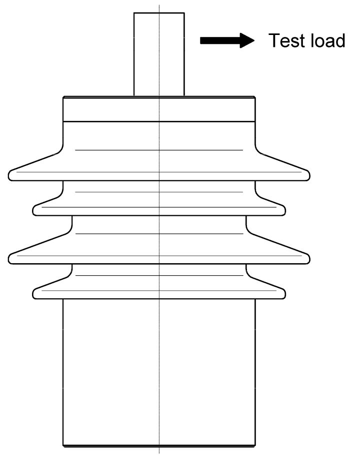


Figure 5 – Thermomechanical preconditioning

NOTE If, in particular applications, other loads are dominant, the relevant loads should be applied instead. The total test time and temperature cycle should remain unchanged.

If the sample has no cylindrical symmetry, the load direction shall be chosen in such a manner as to achieve the maximum mechanical stress.



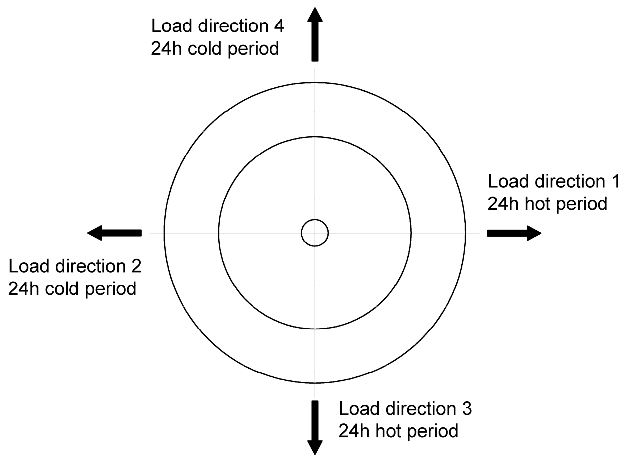


Figure 6 – Example of the arrangement for the thermo-mechanical preconditioning and directions of the cantilever load

The thermal variations consist of two 48 h cycles of heating and cooling as described in Figure 6. The temperature of the hot and cold periods shall be maintained for at least 16 h. The preconditioning shall be conducted in air.

The applied static mechanical load shall be equal to SLL defined by the manufacturer. Its direction changes every 24 h as defined in Figure 6.

The preconditioning may be interrupted for maintenance for a maximum aggregate duration of 4 h and restarted after interruption. The cycle then remains valid.

Any permanent deformation measured from the initial no-load position shall be reported.

6.8.3.2.4 Water immersion test

The test samples shall be kept immersed in a vessel, in boiling deionised water with 1 kg/m³ of NaCl, for 42 h. The vessel shall be covered by a lid during boiling to prevent boiling away of water.

NOTE The characteristics of the water described above are those measured at the beginning of the test.

This temperature (boiling water) may be reduced to (80 ± 5) °C (with a minimum duration of 52 h) by agreement between the user and the manufacturer, if the manufacturer claims that its sealing material is not able to withstand the boiling temperature for a duration of 42 h. This value of 52 h may be expanded up to 168 h (i.e. one week) after agreement between the manufacturer and the user.

At the end of this step, the arrester shall remain in the vessel until the water cools to (50 ± 5) °C This holding temperature is important only if it is necessary to delay the verification tests until the end of the water immersion test as shown in Figure 7. The arrester shall be maintained at this temperature until verification tests are performed according to 6.8.3.3. These verification tests shall be performed on samples having cooled to ambient temperature in still air. The cooling time shall be not longer than 2 h in still air at ambient temperature. The verification tests shall thereafter be performed within 8 h.

After removing the sample from the water it may be washed with tap water.

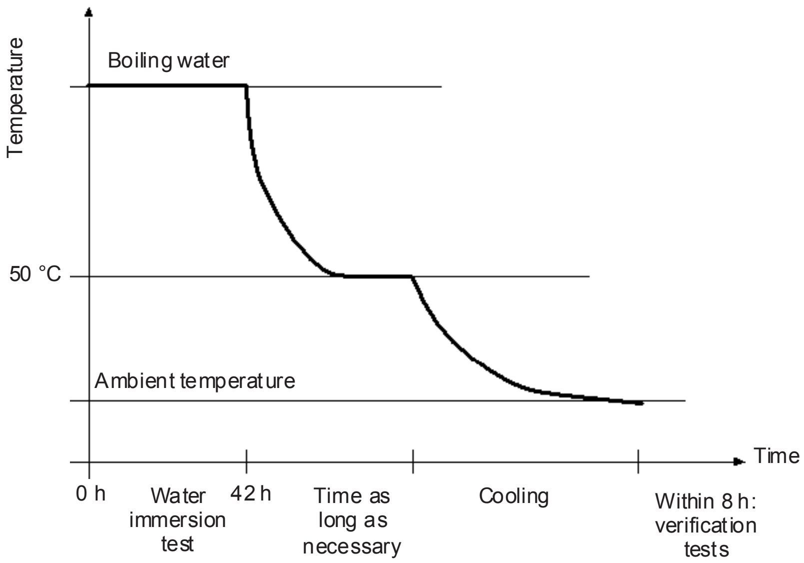


Figure 7 – Water immersion test

6.8.3.3 Test evaluation

After the test, the tests as per 6.8.3.1 shall be repeated.

The arrester has successfully passed the test if the following is demonstrated.

After step 1:

– no visible damage;
– the slope of the force-deflection curve remains positive up to the SSL value except for dips not exceeding 5 % of SSL magnitude. The sampling rate of digital measuring equipment shall be at least 10 sample/s. The cut-off frequency of the measuring equipment shall be not less than 5 Hz.

Maximum deflection during step 1 and any residual deflection after the test shall be reported but do not count as pass criteria.

After step 2:

– for arresters with enclosed gas volume and separate sealing system, the samples pass the leakage test in accordance with 6.9;
– the increase in watt losses, measured at Uc and at an ambient temperature that does not deviate by more than 3 K from the initial measurements, is not more than the greater of 20 mW/kV of Uc (measured at Uc) or 20 %;
– the internal partial discharge measured at 105 % Uc does not exceed 10 pC;

the change in residual voltage measured before and after the test is not more than 5 %.

6.8.4 Definition of mechanical loads

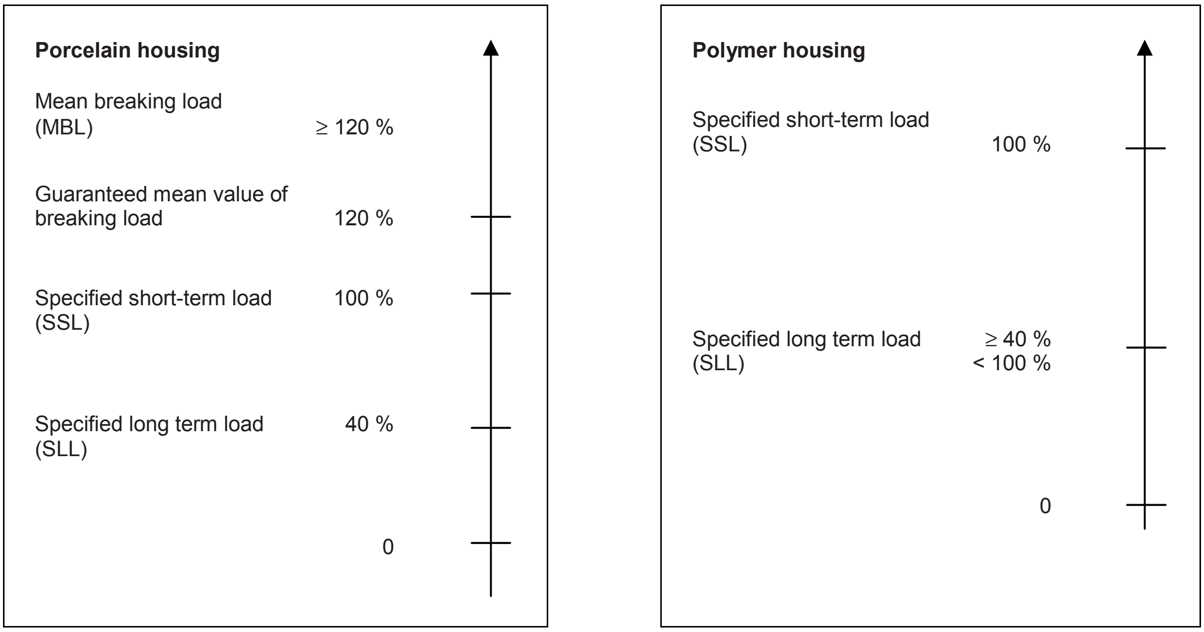


Figure 8 – Definition of mechanical loads (base load = SSL)

6.9 Seal leak rate test

6.9.1 General

This test demonstrates the gas/water tightness of the complete system. It applies to arresters having seals and associated components essential for maintaining a controlled atmosphere within the housing (e.g. arresters with enclosed gas volume and a separate sealing system).

The test shall be performed on one complete arrester unit. The internal parts may be omitted. If the arrester contains units with differences in their sealing system, the test shall be performed on one unit each, representing each different sealing system.

6.9.2 Definition of seal leak rate

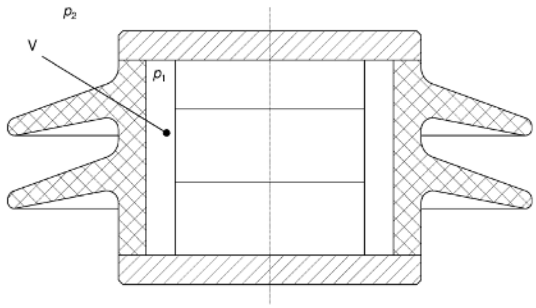


Figure 9 – Surge arrester unit

The seal leak rate specifies the quantity of gas per unit of time which passes the seals of the housing at a pressure difference of at least 70 kPa. If the efficiency of the sealing system depends on the direction of the pressure gradient, the worst case shall be considered.

Seal leak rate $= \dfrac{\Delta p_1 \times V}{\Delta t}$ at $|p_1 - p_2| \geq 70$ kPa and at a temperature of +20 °C ± 15 K,

where

Δp_1 = $p_1(t_2) - p_1(t_1)$;

$p_1(t)$ = internal gas pressure of the arrester housing as a function of time (Pa);

p_2 = gas pressure exterior to the arrester (Pa);

t_1 = start time of the considered time interval (s);

t_2 = end time of the considered time interval (s);

Δt = $t_2 - t_1$;

V = internal gas volume of the arrester (m³).

6.9.3 Sample preparation

The test sample shall be new and clean.

6.9.4 Test procedure

The manufacturer may use any sensitive method suitable for the measurement of the specified seal leak rate.

NOTE Some test procedures are specified in EN 60068-2-17.

6.9.5 Test evaluation

The maximum seal leak rate (see 6.9.2) shall be lower than

1 μW = 1×10^{-6} Pa m³/s

6.10 Environmental tests

6.10.1 Artificial pollution test on porcelain-housed metal-oxide surge arresters

Under consideration

6.10.2 Weather ageing test on polymer-housed surge arresters

6.10.2.1 Test procedure

This test shall be performed on surge arresters for outdoor use only. It shall be performed on one surge arrester of highest U_c and minimum specific creepage distance.

The test is a time-limited continuous test under salt fog at constant d.c. voltage equal to U_c. The test is carried out in a moisture-sealed corrosion-proof chamber. An aperture of not more than 80 cm² shall be provided for the natural evacuation of exhaust air. A turbo sprayer or room humidifier of constant spraying capacity shall be used as a water atomizer.

The fog shall fill up the chamber and not be directly sprayed onto the test specimen. The salt water prepared with NaCl and deionized water will be supplied to the sprayer. The d.c. test circuit, when loaded with a current of 250 mA on the high-voltage side, shall experience a maximum voltage drop of 5 %.

The protection level shall be set at 1 A. The test specimen shall be cleaned with deionized water before starting the test.

The test specimen shall be tested when mounted vertically. There shall be sufficient clearance between the roof and walls of the chamber and the test specimen in order to avoid electrical field disturbance. These data shall be found in the manufacturer’s installation instructions.

Duration of the test	1 000 h
Water flow rate	0,4 l/h/m³ ± 0,1 l/h/m³
Size of droplets	5 µm to 10 µm
Temperature	20 °C ± 5 °C
NaCl content of water	between 1 kg/m³ to 10 kg/m³

The manufacturer shall state the starting value of the salt content of the water. The water flow rate is defined in litres per hour per cubic metre of the test chamber. It is not permitted to re-circulate the water. Interruptions due to flashovers are permitted. If more than one flashover occurs, the test voltage is interrupted. However, the salt fog application shall continue until the washing of the arrester with tap water is started. Interruptions of salt fog application shall not exceed 15 min. The test shall then be restarted at a lower value of the salt content of the water. If again more than one flashover occurs, this procedure shall be repeated. Interruption times shall not be counted as part of the test duration.

The NaCl content of the water, the number of flashovers and the duration of the interruptions shall be recorded.

NOTE 1 Within this range of salinity, lower salt content may increase test severity. Higher salt content increases flashover probability, which makes it difficult to run the test on larger diameter housings.

NOTE 2 The number of overcurrent trippings should be recorded and taken into account in the evaluation of the duration of the test.

6.10.2.2 Evaluation of the test

The test is regarded as passed, if

– no tracking occurs (see EN 61109),
– erosion does not occur through the entire thickness of the external coating up to the next layer of material,
– sheds and housing are not punctured,

– the reference voltage measured before and after the test has not decreased by more than 5 %,

– the partial discharge measurement performed before and after the test is satisfactory, i.e. the partial discharge level does not exceed 10 pC according to 7.1 c).

6.10.3 Accelerated weathering test

6.10.3.1 Test procedure

Three specimens of shed and housing materials shall be selected for this test (with markings included, if applicable).

The insulator housing shall be subjected to a 1 000 h UV light test using one of the following test methods. Markings on the housing, if any, shall be directly exposed to UV light.

- xenon-arc methods: EN ISO 4892-1 and EN ISO 4892-2 using method A without dark periods:
  - standard spray cycle;
  - black-standard/black panel temperature of 65 °C;
  - an irradiance of around 550 W/m².
- fluorescent UV Method: EN ISO 4892-1 and EN ISO 4892-3, using type I fluorescent UV lamp:
  - exposure method 2.

Tests without water shall not be employed.

6.10.3.2 Acceptance criteria

After the test, markings on shed or housing material shall still be legible; surface degradations such as cracks and blisters are not permitted.

In case of doubt concerning such degradation, two surface roughness measurements shall be made on each of the three specimens. The crack depth, R_z as defined in EN ISO 4287, shall be measured along a sampling length of at least 2,5 mm. R_z shall not exceed 0,1 mm.

NOTE EN ISO 3274 gives details of surface roughness measurement instruments.

7 Routine tests and acceptance tests

7.1 Routine tests

The minimum requirement for routine tests to be made by the manufacturer shall be

a) measurement of reference voltage U_{ref} at direct current. The measured values shall be within a range specified by the manufacturer;

b) residual voltage test. The test may be performed either on complete arresters or several metal-oxide resistor elements. The manufacturer shall specify a suitable lightning impulse current in the range between 1 % and 200 % of the nominal current at which the residual voltage is measured. If not directly measured, the residual voltage of the complete arrester is taken as the sum of the residual voltages of the metal-oxide resistor elements or the individual arrester units. The residual voltage for the complete arrester shall not be higher than the value specified by the manufacturer;

c) internal partial discharge test as described in Cl 6.7;

d) for arresters with sealed housing, a leakage check shall be made on each arrester by any sensitive method adopted by the manufacturer;

e) current distribution test for multi-column arrester. This test shall be carried out on all groups of parallel metal-oxide resistors. The manufacturer shall specify a suitable impulse current in the range 1 % to 100 % of the nominal discharge current at which the current through each column shall be measured. The highest current value shall not be higher than an upper limit specified by the manufacturer. The current impulse shall have a virtual front time of not less than 7 µs. The half-value time may have any value.

7.2 Acceptance tests

When the purchaser specifies acceptance tests in the purchase agreement, the following tests shall be made on the nearest lower whole number to the cube root of the number of arresters to be supplied:

a) measurement of reference voltage U_{ref} at direct current on the complete arrester. The measured values shall be within a range specified by the manufacturer;

b) lightning impulse residual voltage on the complete arrester at nominal discharge current if possible or at a current value chosen according to 6.3.3. In this case, the virtual time to half-value on the tail is less important and need not be complied with. The residual voltage for the complete arrester shall not be higher than a value specified by the manufacturer;

c) internal partial discharge test as described in 6.7.

Annex A
(normative)

Flowchart of testing procedure of bending moment

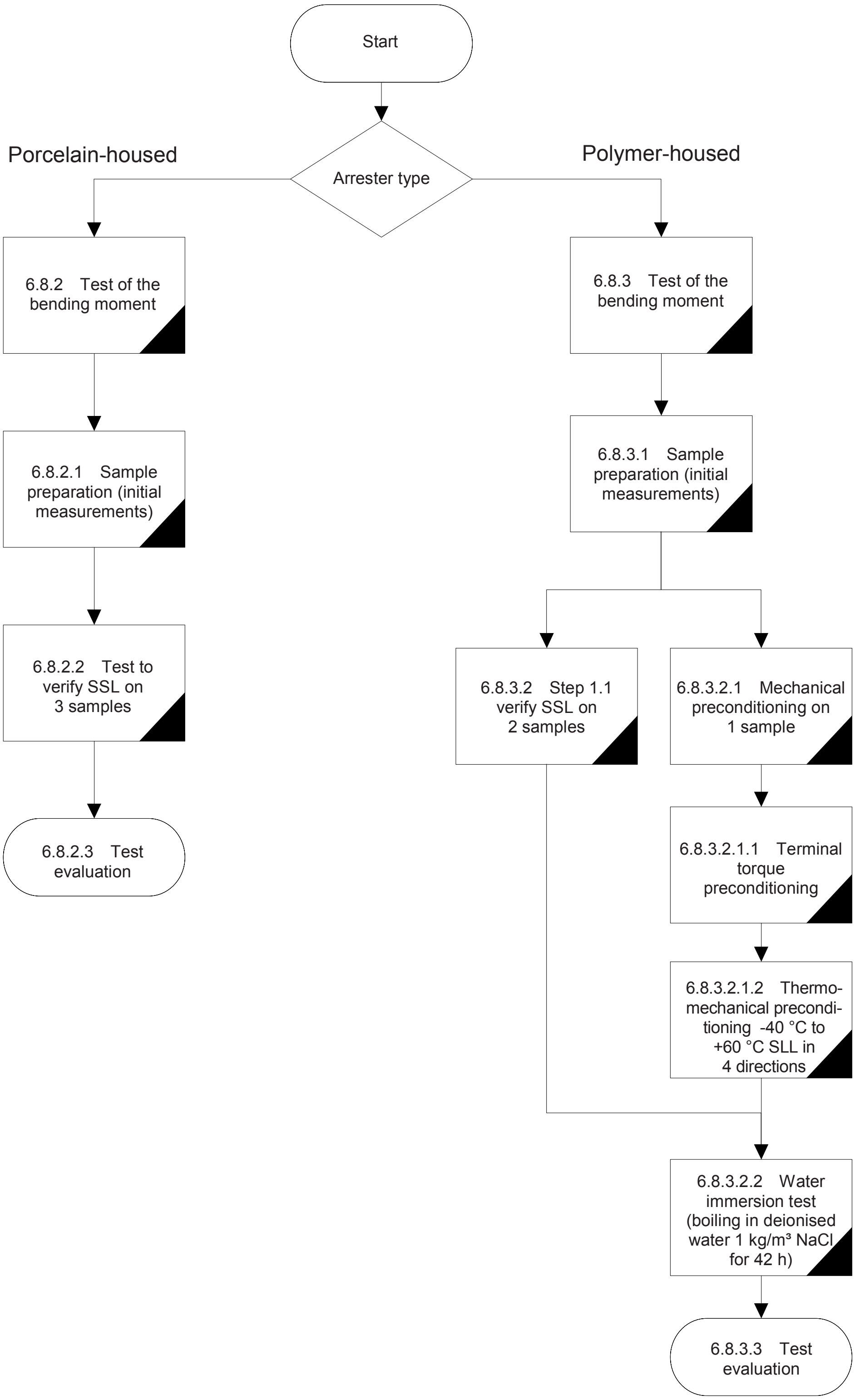


Figure A.1 – Flowchart of testing procedure of bending moment

Annex B
(normative)

Direct lightning current impulse withstand test

This test is optional and intended to prove the ability of the arrester to withstand direct lightning current. Before the tests the reference voltage and lightning impulse residual voltage at nominal discharge current of each test sample shall be measured for evaluation purposes.

Each direct lightning current impulse withstand test shall be made on 3 new samples of complete arresters which have not been subjected previously to any test except that specified above for evaluation purposes. The tests are carried out at ambient temperature of 20 °C ± 15 K.

The samples shall be energized at the d.c. voltage U_c during the complete test sequence. The voltage shall not deviate from the specified value by more than ± 1 %. Two consecutive direct lightning impulses with values according to Table C.1 shall be applied. The interval between the direct lightning impulses shall be no more than 60 s. The d.c. voltage U_c shall remain applied for 30 min after the second direct lightning impulse to check thermal stability. The sample is considered to be thermally stable, if the peak of the leakage current through the test sample, the power dissipation or temperature steadily decreases during the last 15 min of U_c voltage application.

It is acceptable, too, if the sample is only connected to the d.c. voltage U_c not later than 100 ms after the second direct lightning impulse for the specified 30 min to check thermal stability.

The direct lightning impulse is defined by the charge Q and the peak value of the current impulse I_{imp}. The peak current value I_{imp} of the direct lightning impulse shall be reached within 50 µs and the rated charge Q shall be transferred within 10 ms.

NOTE The 10 ms has been chosen to allow the full charge Q to be deposited when testing using a 10/350 µs generator.

Table B.1 – Parameters for the direct lightning impulse

Class	Rated charge Q As	Direct lightning current I_{imp} kA
DC-A	1,0	2
DC-B	2,5	5
DC-C	7,5	15

Oscillographic records of the voltage across and current through the test sample shall be made of all direct lightning discharges. The charge of direct lightning impulse shall not be lower than the rated value and the measured value of I_{imp} shall at least reach 90 % of the specified value. The charge and energy dissipated by the test sample during the operation shall be determined from the voltage and current oscillograms. All of these values shall be reported in the type test report.

Following the complete test sequence, and after the test sample has cooled to near ambient temperature, the measurement of the reference voltage and lightning impulse residual voltage at nominal discharge current shall be repeated on each test sample for comparison with the values obtained before the test.

The arrester has passed the test if

- thermal stability is achieved,
- the change in reference voltage and residual voltage measured before and after the test is not more than 5 %,
- visual examination of the test samples after the test reveals no evidence of puncture, flashover or cracking of the non linear metal-oxide resistors.

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1) Under consideration.

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