IEC 60099-6

Edition 2.0 2019-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Surge arresters –
Part 6: Surge arresters containing both series and parallel gapped structures – System voltage of 52 kV and less

Parafoudres –
Partie 6: Parafoudres contenant des structures à éclateurs en série et en parallèle – Tension de réseau inférieure ou égale à 52 kV

IEC 60099-6:2019-05(en-fr)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

A propos de l'IEC
La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC - webstore.iec.ch/advsearchform
La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,…). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished
Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

Electropedia - www.electropedia.org
Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 000 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary
67 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

IEC 60099-6

Edition 2.0 2019-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Surge arresters –
Part 6: Surge arresters containing both series and parallel gapped structures – System voltage of 52 kV and less

Parafoudres –
Partie 6: Parafoudres contenant des structures à éclateurs en série et en parallèle – Tension de réseau inférieure ou égale à 52 kV

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.240.10

ISBN 978-2-8322-6919-0

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

SURGE ARRESTERS –

Part 6: Surge arresters containing both series and parallel gapped structures – System voltage of 52 kV and less

FOREWORD

International Standard IEC 60099-6 has been prepared by IEC technical committee 37: Surge arresters.

This second edition cancels and replaces the first edition published in 2002. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) A new concept of arrester classification and energy withstand testing was introduced: the line discharge classification was replaced by a classification based on repetitive charge transfer rating (Q_{rs}) and thermal charge transfer rating (Q_{th}). The new concept clearly differentiates between impulse and thermal energy handling capability, which is reflected in the requirements as well as in the related test procedures.

b) Power-frequency voltage versus time tests – with and without prior duty – were introduced as type tests.

c) Requirements and tests on disconnectors were added.

d) Definitions for new terms have been added.

e) Clause 10 contains particular requirements for polymer-housed surge arresters. These are indicated in the form of replacements, additions or amendments to the original clauses or subclauses concerned.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
37/450/FDIS	37/451/RVD

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

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

A list of all parts in the IEC 60099 series, published under the general title *Surge arresters*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This part of IEC 60099 presents the minimum criteria for the requirements and testing of metal-oxide surge arresters containing gapped structures that are applied to AC power systems with U_s above 1 kV up to and including 52kV.

Arresters covered by this document can be applied to overhead installations in place of the non-linear type arresters covered in IEC 60099-4.

An accelerated ageing procedure is incorporated in this document to simulate the long-term effects of voltage and temperature on the arrester. This is necessary since during the arrester's service life the gaps and resistor elements will have portions of the system power frequency voltage continuously applied across them.

SURGE ARRESTERS –

Part 6: Surge arresters containing both series and parallel gapped structures – System voltage of 52 kV and less

1 Scope

This part of IEC 60099 applies to non-linear metal-oxide resistor type surge arresters with spark gaps designed to limit voltage surges on AC power circuits with system voltages U_s above 1 kV up to and including 52 kV. This document basically applies to all metal-oxide distribution class surge arresters with internal series and/or parallel gaps and housed in either porcelain or polymeric housings.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60060-2, *High-voltage test techniques – Part 2: Measuring systems*

IEC 60068-2-11:1981, *Basic environmental testing procedures – Part 2-11: Tests – Test Ka: Salt mist*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60071-2:2018, *Insulation co-ordination – Part 2: Application guidelines*

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

IEC TS 60815-2, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 2: Ceramic and glass insulators for a.c. systems*

IEC 62217, *Polymeric HV insulators for indoor and outdoor use – General definitions, test methods and acceptance criteria*

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

ISO 4892-1, *Plastics – Methods of exposure to laboratory light sources – Part 1: General guidance*

ISO 4892-2, *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

ISO 4892-3, *Plastics – Methods of exposure to laboratory light sources – Part 3: Fluorescent UV lamps*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
acceptance test
test made on arresters or representative samples after agreement between manufacturer and user

3.2
arrester disconnector
device for disconnecting an arrester from the system in the event of arrester failure, to prevent a persistent fault on the system and to give visible indication of the failed arrester

Note 1 to entry: Clearing of the fault current through the arrester during disconnection generally is not a function of the device.

3.3
bending moment
force perpendicular to the longitudinal axis of an arrester multiplied by the vertical distance between the mounting base (lower level of the flange) of the arrester and the point of application of the force

3.4
breaking load
force perpendicular to the longitudinal axis of a porcelain-housed or cast resin arrester leading to mechanical failure of the arrester housing

3.5
cast resin housed arrester
arrester using a housing made from only one organic based material (e.g. cycloaliphatic epoxy) that fractures similarly to a porcelain housing under mechanical overstress

3.6
continuous current of an arrester
current flowing through the arrester when energized at the continuous operating voltage

3.7
continuous operating voltage of an arrester
U_c
designated permissible RMS value of power-frequency voltage that may be applied continuously between the arrester terminals in accordance with 8.5

3.8
damage limit
<mechanical>
lowest value of a force perpendicular to the longitudinal axis of a polymer-housed arrester leading to mechanical failure of the arrester housing

3.9
designation of an impulse shape
combination of two numbers, the first representing the virtual front time (T_1) and the second the virtual time to half-value on the tail (T_2)

Note 1 to entry: This is written as T_1/T_2, both in microseconds, the sign "/" having no mathematical meaning.

3.10
discharge current of an arrester
impulse current which flows through the arrester

3.11
disruptive discharge
phenomenon associated with the failure of insulation under electric stress, which includes a collapse of voltage and the passage of current

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

Note 2 to entry: A disruptive discharge in a solid dielectric produces permanent loss of electric strength. In a liquid or gaseous dielectric the loss may be only temporary.

3.12
distribution class arrester
arrester intended for use on distribution systems, typically of $U_s \leq 52$ kV, to protect components primarily from the effects of lightning

Note 1 to entry: Distribution class arresters may have nominal discharge currents, I_n, of 2,5 kA; 5 kA or 10 kA.

Note 2 to entry: Distribution arresters are classified as “Distribution DH”, “Distribution DM” and “Distribution DL” (see Table 1).

3.13
electrical unit
portion of an arrester in which each end of the unit is terminated with an electrode which is exposed to the external environment

3.14
fault indicator
device intended to provide an indication that the arrester is faulty and which does not disconnect the arrester from the system

3.15
flashover
disruptive discharge over a solid surface

3.16
follow current
current from the connected power source that flows through an arrester during and following the passage of discharge current

3.17
front of an impulse
part of an impulse which occurs prior to the peak

3.18
high current impulse
<of an arrester> peak value of discharge current having a 4/10 impulse shape which is used to test the stability of the arrester on direct lightning strokes

3.19
housing
external insulating part of an arrester, which provides the necessary creepage distance and protects the internal parts from the environment

Note 1 to entry: A housing may consist of several parts providing mechanical strength and protection against the environment.

3.20
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, with defining parameters being polarity, peak value, front time and time to half-value

3.21
insulating base
a short insulator (or set of insulators) on which the arrester is mounted to provide a means of connecting a current monitoring device between the base of the arrester and earth

3.22
internal grading components of an internally gapped arrester
grading impedances, connected in parallel with the internal gap(s), to control the voltage across the gap section

3.23
internal parts
MO resistor with supporting structure and internal grading system, if equipped

3.24
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

Note 1 to entry: The time to half-value is not critical and may have any tolerance during the residual voltage type tests (see 8.3.2.3).

3.25
lightning impulse discharge
an approximately sine half-wave current impulse having a time duration within 200 μs to 230 μs during which the instantaneous value of the impulse current is greater than 5 % of its peak value

3.26
lightning impulse protection level
LIPL or U_{pl}
the maximum residual voltage of the arrester for the nominal discharge current

3.27
long-duration current impulse
rectangular current impulse which rises rapidly to maximum value, remains substantially constant for a specified period and then falls rapidly to zero, with defining parameters being polarity, peak value, virtual duration of the peak and virtual total duration.

3.28
mean breaking load
MBL
the average breaking load for porcelain or cast resin-housed arresters determined from tests

3.29
mechanical unit
portion of an arrester in which the MO resistors within the unit are mechanically restrained from moving in an axial direction

Note 1 to entry: An arrester may contain more than one mechanical units within an electrical unit (see Figure 5).

Note 2 to entry: A mechanical unit may have more than one electrical unit (see Figure 5).

3.30
mounting bracket
means by which a distribution class arrester is physically attached to a pole or other structure

Note 1 to entry: For polymer housed distribution class arresters, the mounting bracket is typically of an insulating material and is typically attached to the bottom (ground) end of the arrester; for porcelain-housed distribution class arresters, the bracket is typically metal (often steel) and is connected by a “belly band” around the porcelain housing at some distance from the ground end of the arrester.

3.31
I_n
nominal discharge current of an arrester
peak value of lightning current impulse, which is used to classify an arrester

3.32
MO resistor
part of the surge arrester which, by its non-linear voltage versus current characteristics, acts as a low resistance to overvoltages, thus limiting the voltage across the arrester terminals, and as a high resistance at normal power-frequency voltage

3.33
peak value of an impulse
crest value of an impulse
maximum value of a voltage or current impulse

Note 1 to entry: Superimposed oscillations may be disregarded.

3.34
peak value of opposite polarity of an impulse
crest value of opposite polarity of an impulse
maximum amplitude of opposite polarity reached by a voltage or current impulse when it oscillates about zero before attaining a permanent zero value

3.35
polymer-housed surge arrester
arrester using polymeric and composite materials for housing

Note 1 to entry: Designs with an enclosed gas volume are possible. Sealing may be accomplished by use of the polymeric material itself or by a separate sealing system.

3.36
porcelain-housed surge arrester
arrester using porcelain as housing material, with fittings and sealing systems

3.37
power-frequency voltage versus time characteristic
<of an arrester> maximum time durations for which corresponding power-frequency voltages may be applied to arresters without causing damage or thermal instability, under specified conditions in accordance with 6.10

3.38
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

3.39
prospective current
<of a circuit> current that would flow at a given location in a circuit if it were short-circuited at that location by a link of negligible impedance

3.40
protective characteristics
<of an arrester> combination of lightning impulse protection level (LIPL), switching impulse protection level (SIPL) and steep current impulse protection level (STIPL)

3.41
puncture
breakdown
disruptive discharge through a solid

3.42
rated frequency of an arrester
frequency of the power system on which the arrester is designed to be used

3.43
I_{s}
rated short-circuit current
highest tested power-frequency current that may develop in a failed arrester as a short-circuit current without causing violent shattering of the housing or any open flames for more than two minutes under the specified test conditions

3.44
U_{r}
rated voltage of an arrester
maximum permissible 10 s power frequency RMS overvoltage that can be applied between the arrester, as verified in the TOV test and the operating duty test

Note 1 to entry: The rated voltage is used as a reference parameter for the specification of operating characteristics.

3.45
repetitive charge transfer rating
Q_{rs}
maximum specified charge transfer capability of an arrester, in the form of a single event or group of surges that may be transferred through an arrester without causing mechanical failure or unacceptable electrical degradation to the MO resistors

Note 1 to entry: The charge is calculated as the absolute value of current integrated over time. For the purpose of this document this is the charge that is accumulated in a single event or group of surges lasting for not more than 2 s and which may be followed by a subsequent event at a time interval not shorter than 60 s.

3.46
U_{res}
residual voltage of an arrester
peak value of voltage that appears between the terminals of an arrester during the passage of discharge current

Note 1 to entry: The term "discharge voltage" is used in some countries.

3.47
routine tests
tests made on each arrester, or on parts and materials, as required, to ensure that the product meets the design specifications

3.48
seal
<gas/water tightness>
ability of an arrester to avoid ingress of matter affecting the electrical and/or mechanical behaviour

3.49
series gap
intentional gap(s) between spaced electrodes, in series with the valve element of the arrester, substantially isolating the element from line or ground, or both, under normal line-voltage conditions

3.50
section of an arrester
<prorated section>
complete, suitably assembled part of an arrester necessary to represent the behaviour of a complete arrester with respect to a particular test

Note 1 to entry: A section of an arrester is not necessarily a unit of an arrester. For certain tests, a MO resistor alone constitutes a section.

3.51
shed
insulating part projecting from the housing, intended to increase the creepage distance

3.52
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

3.53
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 and extreme wind gusts) without causing any mechanical damage to the arrester

Note 1 to entry: SSL does not relate to mechanical strength requirements for seismic loads. See C.2.

3.54
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 1 to entry: The time to half-value on the tail is not critical and may have any tolerance during the residual voltage type tests (see 8.3.2.2).

3.55
steep current impulse protection level
STIPL
maximum residual voltage of the arrester for a steep current impulse of magnitude equal to the magnitude of the nominal discharge current

3.56
tail of an impulse
part of an impulse which occurs after the peak

3.57
terminal line force
force perpendicular to the longitudinal axis of the arrester measured at the centre line of the arrester

3.58
thermal charge transfer rating
Q_{th}
maximum specified charge that may be transferred through an arrester or arrester section within 3 minutes in a thermal recovery test without causing a thermal runaway

Note 1 to entry: This rating is verified by the operating duty type test.

3.59
thermal runaway
<of an arrester>ituation 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 MO resistor elements culminating in failure

3.60
thermal stability
<of an arrester> state of an arrester if, after an operating duty causing temperature rise, the temperature of the MO resistors decreases with time when the arrester is energized at specified continuous operating voltage and at specified ambient conditions

3.61
torsional loading
each horizontal force at the top of a vertical mounted arrester housing which is not applied to the longitudinal axis of the arrester

3.62
type tests
design tests
tests which are made upon the completion of the development of a new arrester design to establish representative performance and to demonstrate compliance with the relevant standard

Note 1 to entry: Once made, these 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.

3.63
unipolar sine half-wave current impulse
unipolar current impulse consisting of one half-cycle of an approximately sinusoidal current

3.64
unit of an arrester
arrester unit
completely housed part of an arrester which may be connected in series and/or in parallel with other units to construct an arrester of higher voltage and/or current rating

3.65
T_1
virtual front time of a current impulse
time in microseconds equal to 1,25 multiplied by the time in microseconds for the current to increase from 10 % to 90 % of its peak value

Note 1 to entry: If oscillations are present on the front, the reference points at 10 % and 90 % should be taken on the mean curve drawn through the oscillations.

3.66
virtual origin
<of an impulse> point on a graph of voltage versus time or current versus time determined by the intersection between the time axis at zero voltage or zero current and the straight line drawn through two reference points on the front of the impulse

Note 1 to entry: For current impulses the reference points shall be 10 % and 90 % of the peak value.

Note 2 to entry: This definition applies only when scales of both ordinate and abscissa are linear.

Note 3 to entry: If oscillations are present on the front, the reference points at 10 % and 90 % should be taken on the mean curve drawn through the oscillations.

3.67
virtual steepness of the front of an impulse
quotient of the peak value and the virtual front time of an impulse

3.68
virtual time to half-value on the tail of an impulse
T_2
time interval between the virtual origin and the instant when the voltage or current has decreased to half its peak value, expressed in microseconds

4 Identification and classification

4.1 Arrester identification

Metal-oxide surge arresters containing gapped structures shall be identified by the following minimum information which shall appear on a nameplate permanently attached to the arrester:

– designation of arrester (see Table 1)
– continuous operating voltage;
– rated voltage;
– rated frequency, only if other than one of the standard frequencies, see 5.2;
– nominal discharge current;
– rated short-circuit current in kiloamperes (kA). For arresters for which no short-circuit rating is claimed, the value "0" shall be indicated;
– manufacturer's name or trade mark, type and identification of the complete arrester;
– year of manufacture:
– if sufficient space is available the nameplate should also contain:
– repetitive charge transfer rating, Q_{rs}.

4.2 Arrester classification

Distribution class arresters are classified as indicated in Table 1, and they shall meet at least the test requirements and performance characteristics specified in Table 3.

Table 1 – Arrester classification

Arrester class	Distribution		
Designation	**DH**	**DM**	**DL**
Nominal discharge current[a]	10 kA	5 kA	2,5 kA
Q_{rs} (C)	≥ 0,4	≥ 0,2	≥ 0,1
Q_{th} (C)	≥ 1,1	≥ 0,7	≥ 0,45

[a] Other currents may be specified upon agreement between manufacturer and user.

NOTE The letters "H", "M" and "L" in the designation stand for "high", "medium" and "low" duty, respectively.

5 Standard ratings and service conditions

5.1 Standard rated voltages

Standard values of rated voltages for arresters (in kV RMS) are specified in Table 2 in equal voltage steps within specified voltage ranges:

Table 2 – Steps of rated voltages

Range of rated voltage kV	**Steps of rated voltage** kV RMS
3 to 30	1 kV
30 to 52	3 kV

Other values of rated voltages may be accepted.

5.2 Standard rated frequencies

The standard rated frequencies are 50 Hz and 60 Hz.

5.3 Standard nominal discharge currents

The standard nominal 8/20 discharge currents are: 10 kA, 5 kA, and 2,5 kA.

5.4 Service conditions

5.4.1 Normal service conditions

Surge arresters that conform to this document shall be suitable for normal operation under the following normal service conditions:

a) ambient air temperature within the range of –40 °C to +40°C;

b) solar radiation;

NOTE The effects of maximum solar radiation (1,1 kW/m^2) have been taken into account by preheating the test specimen in the type tests. Other heat sources that may affect the application of the arrester are not considered under normal service condition

c) altitude not exceeding 1 000 m;

d) frequency of the AC power supply shall not be less than 48 Hz and not exceeding 62 Hz;

e) power frequency voltage applied continuously between the terminals of the arrester not exceeding its continuous operating voltage;

f) wind speeds ≤ 34 m/s;

g) vertical erection, not suspended.

5.4.2 Special environmental conditions

Surge arresters subject to other than normal application or service conditions may require special consideration in design, manufacture or application. The use of this document in case of special environmental conditions is subject to agreement between the manufacturer and the purchaser. A list of possible abnormal service conditions is given in Annex A.

6 Requirements

6.1 Insulation withstand

The arrester shall be designed such that the housings are able to adequately withstand voltages during conduction of lightning currents and during anticipated maximum power frequency overvoltages. The external insulation withstand capability of the housings shall be demonstrated by tests according to 8.2, while the internal insulation withstand capability shall be demonstrated by tests according to 8.13.

6.2 Residual voltages

The purpose of the measurement of residual voltages is to obtain the maximum residual voltages for a given design for all specified currents and wave shapes. These are derived from the type test data and from the maximum residual voltage at a lightning current impulse used for routine tests as specified and published by the manufacturer.

The maximum residual voltage of a given arrester design for any current and wave shape is calculated from the residual voltage of sections tested during type tests 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 tests, to the measured residual voltage of the sections at the same current and wave shape.

Manufacturers' literature shall contain, for each arrester listed, the following residual voltage information:

- Maximum lightning impulse residual voltage for impulse currents of at least 0,5; 1 and 2 times the nominal discharge current of the arrester (see 8.3.2.3)
- Maximum steep current impulse residual voltage, excluding inductive voltage contribution, for an impulse current having peak value equal to the nominal discharge current of the arrester (see 8.3.2.2)
- Maximum steep current impulse residual voltage, including inductive voltage contribution for an impulse current having peak value equal to the nominal discharge current of the arrester. This residual voltage shall be equal to

  NOTE Typical maximum residual voltages for different types of arrester are given in Annex F of IEC 60099-5:2018.

6.3 Impulse protective levels

The arrester shall be tested to determine whether the protective level for a specified waveshape is a function of the maximum impulse sparkover value (8.3.3) or residual voltage (8.3.2) whichever is greatest.

6.4 Internal partial discharges

Under normal and dry operating conditions, internal partial discharges shall be below a level that might cause damage to internal parts. This shall be demonstrated by routine test according to item c) of 9.1.

6.5 Seal leak rate

For arresters having an enclosed gas volume and a separate sealing system, seal leak rates shall be specified as defined in 8.12 and item d) of 9.1.

6.6 Thermal stability

When agreed between manufacturer and purchaser, a special thermal stability test may be performed according to 9.2.2

6.7 Heat dissipation behaviour of test sample

In the operating duty test (8.5) and the power frequency voltage-versus-time test (8.6), the behaviour of the test sample is to a great extent dependent on the ability of the sample to dissipate heat, i.e. to cool down after being stressed by a discharge.

Consequently, the test samples shall have a transient and a steady-state heat dissipation capability and heat capacity equivalent to the complete arrester if correct information is to be obtained from the test. For the same ambient conditions the MO resistors in the sample and in the complete arrester should in principle reach the same temperature when subjected to the same voltage stress.

6.8 Repetitive charge transfer withstand

Complete arresters shall withstand repetitive charge transfers as checked during type tests (see 8.4).

The repetitive charge transfer withstand is demonstrated on complete arresters with voltage ratings between 3 and 12kV in the test to verify the repetitive charge transfer rating (see 8.4.2.2).

NOTE There may be special applications where single event charge transfers cause energy dissipations higher than the rated thermal charge transfer rating.

6.9 Operating duty

Arresters shall be able to absorb energy from switching events or transfer charge from lightning events and subsequently thermally recover under applied temporary overvoltage and following continuous operating voltage conditions. This capability is demonstrated by the operating duty test (see 8.5).

6.10 Power-frequency voltage versus time characteristics of an arrester

The manufacturer shall supply data on the allowable time duration of power-frequency voltage and the corresponding voltage value which may be applied to the arrester after the arrester has been preheated to the start temperature as per 8.5.2.3 without damage or thermal runaway. The data shall be given without prior energy or charge duty and – in case of I_n = 10 kA – the thermal charge transfer rating Q_{th}.

This information shall be presented as power-frequency voltage versus time curves (TOV curves) with the energy or charge duty prior to this power-frequency voltage application stated on the above-mentioned curve. The TOV characteristic is demonstrated on complete arrester that represents the worst case heat transfer in the test to verify the power frequency voltage versus time characteristic (TOV test) (see 8.6).

6.11 Short-circuit performance

The manufacturer shall declare a short-circuit current rating for each family of arresters. Only for applications with expected short-circuit currents below 1 kA may the rated value “zero” be claimed. In this case “0” shall be indicated on the name plate. In any case, the arrester shall be subjected to a short-circuit test according to 8.9 to show that it will not fail in a manner that causes violent shattering of the housing and that self-extinguishing of open flames (if any) occurs within a defined period of time.

6.12 Disconnectors

6.12.1 Disconnector withstand

When an arrester is fitted or associated with a disconnector, this device shall withstand, without operating, each of the following tests:

– test to verify the repetitive charge transfer rating, Q_{rs} (see 8.4.2.2);

– operating duty test with rated values of thermal charge rating, Q_{th} (see 8.5.2);

– mechanical tests on agreement between manufacturer and user (see NOTE to 8.7.4.1)

– temperature cycling and seal pumping test (see 8.7.5)

6.12.2 Disconnector operation

The time delay for the operation of the disconnector is determined for three values of current according to 8.7.3. There shall be clear evidence of effective and permanent disconnection by the device.

6.13 Requirements on internal grading components

Internal grading components, if used in the arrester, shall be able to withstand the combination of stresses arising in service, and the impedance of the grading components shall also show sufficient stability during the service life. This shall be demonstrated by operating duty test (see 8.5) and the TOV test (see 8.6) being performed with internal grading components included in the test sections.

Furthermore, the components shall withstand the accelerated ageing and cyclic tests as specified in 8.13.

6.14 Power-frequency sparkover

A power-frequency sparkover test shall be performed on gapped arresters. The minimum power-frequency sparkover voltage of the arrester shall be stated by the manufacturer.

6.15 Mechanical loads

6.15.1 General

The manufacturer shall specify the maximum permissible terminal loads relevant for installation and service, such as cantilever, torque and tensile loads.

6.15.2 Bending moment

The arrester shall be able to withstand the manufacturer's declared values for bending loads (see 8.10).

When determining the mechanical load applied to a surge arrester, the user should consider, for example, wind, ice and electromagnetic forces likely to affect the installation.

Surge arresters enclosed within their package should withstand the transportation loads specified by the user in accordance with IEC 60721-3-2, but not less than Class 2M1.

NOTE Unlike porcelain-housed arresters, polymer-housed arresters might show mechanical deflections in service.

6.15.3 Resistance against environmental stresses

The arrester shall be able to withstand environmental stresses as defined in 8.11.

6.15.4 Insulating base and mounting bracket

When an insulating base and/or a mounting bracket is provided with the arrester, the base and/or bracket shall be subjected to mechanical tests separately from the arrester (see 8.10.6).

6.15.5 Mean value of breaking load (MBL)

For porcelain and cast-resin housed arresters the MBL shall be ≥ 1,2 times the specified short-term load (SSL). This shall be demonstrated in the bending moment test of 8.10.

6.16 Electromagnetic compatibility

Arresters are not sensitive to electromagnetic disturbances and therefore no immunity test is necessary.

In normal dry operating conditions, surge arresters shall not emit significant disturbances. On request from users, each manufacturer shall give enough information so that all the arrester components may be scrapped and/or recycled in accordance with international and national regulations.

6.17 End of life

On request from users, each manufacturer shall give enough information so that all the arrester components may be scrapped and/or recycled in accordance with international and national regulations.

7 General testing procedures

7.1 Measuring equipment and accuracy

The measuring equipment shall meet the requirements of IEC 60060-2. The values obtained shall be accepted as accurate for the purpose of compliance with the relevant test clauses.

Unless elsewhere stated, all tests with power-frequency voltages shall be made with an alternating voltage having a frequency between the limits of 48 Hz and 62 Hz and an approximately sinusoidal waveshape.

7.2 Test samples

7.2.1 General

Unless otherwise specified, all tests shall be made on complete arrester units. They shall be new, clean, completely assembled (for example, with grading rings if applicable) and arranged to simulate as closely as possible the conditions in service.

In general, the samples shall cover the highest residual voltage and the lowest reference voltage of the type of MO resistors used in the arrester. If thermal charge transfer rating is specified in the operating duty test and for the TOV test (see 8.5 and 8.6) the samples shall have the highest lightning impulse protection level U_{pl} per unit length of the design. If thermal energy rating is specified in the operating duty test the test samples shall have a reference voltage value at the lower end of the variation range declared by the manufacturer. In order to comply with these demands the following shall be fulfilled:

a) The ratio between the rated voltage of the complete arrester to the rated voltage of the section is defined as n. The volume of the MO resistor elements used as test samples shall not be greater than the minimum volume of all MO resistor elements used in the complete arrester divided by n.
b) The continuous operating voltage applied in tests involving thermal recovery shall fulfil the following requirement: The ratio of the continuous operating voltage to the rated voltage of the section shall be not less than the maximum ratio claimed for the arrester type.

7.2.2 Samples for residual voltage tests

Samples for the residual voltage tests shall be complete arresters, stacks of series connected MO resistors or individual MO resistors in still air. For multi-column arresters the samples may be made of the actual number of MO resistors or resistor columns in parallel or of only one MO resistor or resistor column, respectively.

7.2.3 Samples for the test to verify the repetitive charge transfer rating, Q_{rs}

7.2.3.1 General

Both MO resistors and series gaps shall be tested.

7.2.3.2 MO resistors

Samples shall be either complete arresters, MO resistors either in still air or in the actual surrounding medium of the design. The choice is at the discretion of the manufacturer.

The samples shall be of the longest length of the type of MO resistors used in the design, and shall have a 10-kA residual voltage stress of not less than 0,97 × ($U_{10\ kA}$ per mm of MO resistor length)$_{max}$, where ($U_{10\ kA}$ per mm of MO resistor length)$_{max}$ is the highest 10-kA residual voltage stress specified by the manufacturer for any length of the type of MO resistors used in the arrester. If only samples of lower 10-kA residual voltage stress are available, the required transferred charge shall be increased for the test by the factor

$$(U_{10\ kA} \text{ per mm of MO resistor length})_{max} / (U_{10\ kA} \text{ per mm of MO resistor length})_{actual}$$

7.2.3.3 Gaps

Samples shall be gaps having the shortest gap spacing of gaps used in the arrester design.

8 Type tests (design tests)

8.1 General

Type tests defined in this clause apply to porcelain-housed arresters. The tests also apply to polymer-housed arresters unless otherwise noted in 10.8.

Type tests shall be made as indicated in Table 3.

Table 3 – Arrester type tests

Arrester class	Distribution
Nominal discharge current	10 kA 5 kA 2,5 kA
Typical U_s (kV), rms value	≤ 52
1 Insulation withstand tests on the arrester housing	
a) Lightning impulse	8.2.5
c) Power-frequency	8.2.6
2 Impulse protective level test	8.3
3 Repetitive charge transfer withstand	8.4
4 Operating duty test	8.5
5 Power-frequency voltage versus time	8.6
6 Arrester disconnector/fault indicator (when fitted)	8.7
7 Power frequency sparkover voltage test	8.8
8 Short-circuit tests	8.9
9 Bending moment	8.10
10 Environmental tests	8.11
11 Seal leak rate	8.12
12 Test to verify the dielectric withstand of the internal components of an arrester	8.13
13 Test of internal grading components	8.14
Numbers in rows 1 to 13 refer to clauses and subclauses in this document. NOTE Type tests for polymer-housed arresters are specified in 10.8.	

The required numbers of samples and their conditions are specified in the individual clauses. Arresters that 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, are considered to be of the same design.

8.2 Insulation withstand tests

8.2.1 General

The voltage withstand tests demonstrate the voltage withstand capability of the external insulation of the arrester housing. For other designs the test has to be agreed upon between the manufacturer and the user.

The tests shall be performed in the conditions and with the test voltages specified in 6.1 and repeated below. The outside surface of insulating parts shall be carefully cleaned and the internal parts removed or rendered inoperative to permit these tests.

If any of the conditions relating dry arc distance to test voltage, as described in 8.2.5 or 8.2.6, is fulfilled then the relevant test specified in 8.2.5 or 8.2.6 need not be performed, since, under these conditions, the insulation withstand voltage of the arrester will inherently meet the minimum requirement.

8.2.2 Tests on individual unit housing

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.

For the test, the MO resistors shall be removed from the housing or replaced by insulators.

8.2.3 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 IEC 60060-1.

Humidity correction shall not be applied for wet tests.

8.2.4 Wet test procedure

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

8.2.5 Lightning impulse voltage test

The arrester shall be subjected to a standard lightning impulse voltage dry test according to IEC 60060-1. The test voltage shall be at least 1,3 times the maximum residual voltage of the arrester at nominal discharge current.

NOTE The 1,3 factor is obtained from $1{,}15 * e^{1\,000/8\,150}$, which reflects a 15 % coordination factor to take into account discharge currents higher than nominal and the statistical nature of the withstand voltage of the insulation, and a 13 % margin to account for variation in air pressure from sea level up to normal service altitudes not exceeding 1 000 m.

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 standard lightning impulse protection level of the arrester multiplied by 1,3.

If the dry arcing distance or the sum of the partial dry arcing distances is larger than the test voltage divided by 500 kV/m, this test is not required.

8.2.6 Power- frequency voltage test

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

Housings of distribution class arresters according to Table 1 shall withstand a power-frequency voltage with a peak value equal to the lightning impulse protection level multiplied by 0,88 for a duration of 1 min.

NOTE 1 The factor of 0,88 takes into account a safety margin of 1,15 for lightning impulse currents higher than nominal discharge current, an altitude correction factor of 1,13 for 1 000 m installation altitude, a factor 0,8 as a typical ratio between switching and lightning impulse protection level and a test conversion factor of $0{,}6 \times \sqrt{2}$ for conversion from switching impulse voltage to peak value of power-frequency voltage according to Table 2 of IEC 60071-2:2018.

NOTE 2 If the dry arcing distance or the sum of the partial dry arcing distances is larger than given by the equation $d = [1{,}82 \times (e^{(U/859)} - 1)]^{0{,}833}$, where d is the distance in m and U is the peak value of the power-frequency test voltage in kV, this test is not required.

NOTE 3 The equation is derived from formula G.1 of IEC 60071-2:2018, where the peak value of U_{50} is given as $750 \times \sqrt{2} \times \ln(1 + 0{,}55 \times d^{1{,}2})$, d being the distance. Following the recommendations given in IEC 60071-2, for the purpose of this doucment the gap factor k is assumed to be equal to 1, the withstand voltage is assumed to be 90 % of U_{50}, and a 10 % reduction in U_{50} is assumed for wet conditions compared to dry.

8.3 Impulse protective level tests

8.3.1 General

The purpose of the impulse protective level measurement is to obtain the maximum protective level for a given design for all specified currents and voltage waveshapes.

The general test procedure shall be as follows:

a) Apply prospective impulse voltage waves, measure the resulting peak arrester voltages and compare these voltages with the appropriate residual voltage level.
b) Where the maximum arrester voltage resulting from application of these prospective voltage impulses is less than the arrester residual voltage level, then the protective level for that waveshape is the arrester residual voltage level.
c) Otherwise, sparkover tests shall be made and the protective level for that waveshape is the maximum sparkover value. Impulse protective levels shall be established by the front-of-wave sparkover and 1,2/50 impulse sparkover.

8.3.2 Residual voltage tests

8.3.2.1 General

The purpose of the residual voltage type test is to obtain the data necessary to derive the maximum residual voltage. It includes the calculation of the ratio between voltages at specified impulse currents and the voltage level checked in routine tests. The latter residual voltage can be either at the nominal discharge current or the residual voltage at a suitable lightning impulse current in the range 0,01 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 waveshapes are obtained by multiplying the measured residual voltages of the test sections by the ratio of the declared maximum residual voltage at the routine test current to the measured residual voltage for the section at the same current.

All residual voltage tests shall be made on the same three samples of complete arresters or arrester sections. The time between discharges shall be sufficient to permit the samples to return to within 5 °C of ambient temperature.

8.3.2.2 Steep current impulse residual voltage test

One steep current impulse with a peak value equal to the nominal discharge current of the arrester ±5 % shall be applied to each of the three samples. 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 non-ferrous metal block having the same dimensions as the MO 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 MO resistor samples, no inductive correction to the MO resistor measurements is required.
- If the peak voltage on the metal block is between 2 % and 20 % of the peak voltage on the MO resistor sample, then the impulse shape of the metal block voltage shall be subtracted

from the impulse shape of each of the MO resistor voltages and the peak values of the resulting impulse shapes shall be recorded as the corrected MO resistor voltages.

- If the peak voltage on the metal block is greater than 20 % of the peak voltage on the MO resistor samples, then the test circuit and the voltage measuring circuit shall be improved and the test shall be repeated.

  NOTE 1 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.

The highest of the three measured residual voltages, corrected if necessary as indicated above, and multiplied by the scale factor (see 7.2) is defined as the steep current protection level of the arrester excluding the inductive voltage contribution of the arrester.

NOTE 2 Connecting leads to connect the arrester to the power system will introduce additional inductive voltage drop for steep current impulse currents.

8.3.2.3 Lightning impulse residual voltage test

One lightning current impulse shall be applied to each of the three samples for each of the following three peak values of approximately 0,5, 1 and 2 times the nominal discharge current of the arrester. Virtual front time shall be within 7 μs to 9 μs while the time to half-value (which is not critical) may have any tolerance. The residual voltages are determined in accordance with 6.2. 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.

If a complete arrester routine test cannot be carried out at one of the above currents, then additional type tests shall be carried out at a current in the range of 0,01 to 0,25 times nominal discharge current for comparison to the complete arrester.

8.3.3 Sparkover tests

8.3.3.1 General

Sparkover tests shall be made on three samples of complete arresters of each voltage rating tested. The performance for other voltage ratings of the same design within ±20 % (or 3 kV, whichever is greater) of a test sample rating can be determined by adjusting the voltage level in proportion to the voltage ratings. In view of the dependency of gap sparkover on temperature, the tests should be carried out at 20 °C to 25 °C, and an additional test carried out at an elevated temperature (preferably between 40 °C and 50 °C). If there is a difference between the results, then the higher of the two results shall be used for subsequent tests and comparisons.

8.3.3.2 Fast front protective level

8.3.3.2.1 General

This test determines whether the arrester sparkover for a front-of-wave lightning impulse can exceed its steep current residual voltage.

8.3.3.2.2 Front-of-wave impulse sparkover determination test

This test is performed using both positive and negative polarity impulses. The prospective magnitude of the test wave shall be a minimum of 1,2 times the arrester's steep current residual voltage. At least five discharges shall be measured for each polarity. The nominal rate of rise of the test wave front shall be 8,33 kV/μs for each kilovolt of arrester voltage rating.

The maximum arrester voltage recorded during five positive and five negative polarity impulses shall be compared to the steep current residual voltage. If the steep current residual voltage exceeds the voltage values measured during the impulse test described above, the steep current residual voltage is the fast front protective level and no further testing is required on this waveshape. If the voltage measured during the impulse test exceeds the steep current residual voltage, proceed to 8.3.3.2.3 to determine the fast front protective level.

8.3.3.2.3 Front-of-wave impulse sparkover tests

This test shall be made using both positive and negative polarity impulses. The prospective crest value of the test wave shall be high enough that the sparkover of the arrester occurs before 90 % of the crest value of the test wave is reached. At least five sparkovers shall be recorded for each polarity and the highest crest value so recorded shall be reported as the maximum front-of-wave sparkover value of the test arrester and taken as the fast front protective level. The nominal rate of rise of the test wave front shall be the same as described in 8.3.3.2.2.

8.3.3.3 Standard lightning impulse protective level test

8.3.3.3.1 General

This test series determines whether the arrester sparkover voltage for a standard lightning impulse can exceed the residual voltage obtained from an 8/20 impulse at nominal current as shown in 8.3.3.3.2.

8.3.3.3.2 Standard lightning impulse sparkover determination test

The test is performed using at least five positive and five negative waves. A minimum prospective magnitude of 1,2 times the arrester's residual voltage at the nominal discharge current as indicated in 8.3.2.3 shall be used. The maximum arrester voltage recorded during the five positive and five negative polarity standard lightning impulses shall be compared to the residual voltage obtained with the nominal discharge currents in 8.3.2.3. If the nominal discharge current residual voltage exceeds the voltage values measured during the standard lightning impulse sparkover voltage test described earlier, the nominal discharge current residual voltage is the standard lightning protective level and no further testing is required on this waveshape. If the voltage measured during the standard lightning impulse test exceeds the nominal discharge current residual voltage, proceed to 8.3.3.3.3, the standard lightning impulse sparkover voltage test, to determine the standard lightning impulse protective level.

8.3.3.3.3 The standard lightning impulse sparkover test

The purpose of this test is to determine the highest standard lightning impulse voltage greater than 3 μs duration that the arrester will withstand without sparkover.

For each polarity, the test procedure shall be:

a) Determine the base generator charge voltage, U_G, according to the method described in the following note and record crest voltage and time to sparkover (where sparkover occurs) for each of the 20 impulses used for establishing U_G.

   NOTE The procedure for establishing U_G is as follows: Start by applying an impulse having a prospective crest voltage somewhat lower than the expected sparkover voltage of the arrester, raising the generator charge voltage in approximately 5 % steps for subsequent impulses until sparkover occurs. Then apply a series of 20 impulses, decreasing the prospective crest voltage by about 5 % after every sparkover and increasing the prospective crest voltage by about 5 % after every withstand. U_G is the average generator charge voltage used during the series of 20 impulses.

b) Apply five impulses using a generator charge voltage not more than 1,05 U_G and record crest voltage and time to sparkover. If sparkover does not occur within 3,0 μs after the virtual zero point on each of the five impulses, raise generator charge voltage in additional increments not greater than 0,05 U_G until a level is reached that results in sparkover within 3,0 μs after the virtual zero point on each of the five applications. The higher prospective crest voltage of either polarity required to obtain five sparkovers on five successive applications of test impulses with constant generator charge voltage shall be reported as the standard lightning impulse protective level of the arrester.

8.4 Test to verify the repetitive charge transfer rating, Q_{rs}

8.4.1 General

The purpose of this test is to verify the repetitive charge transfer rating, Q_{rs}, of an arrester. An arrester shall be assigned a Q_{rs} value from the values in Table 1.

Repetitive charge transfer capability is specified as an impulse current stress that can be withstood by the MO resistors and gaps of an arrester twenty times without mechanical or unacceptable electrical damage. One impulse current stress is considered to represent a charge transfer event that may occur under real system conditions.

The repetitive charge transfer rating is related to a certain very low failure probability and is thus not a deterministic but a statistical value. The test is performed on individual MO resistors and gaps at a charge value of at least 1,1 times the Qrs rated value selected from Table 1 according to the class of arrester being tested.

Charge has been chosen as a test basis for the purpose of better comparison between different makes of MO resistors.

Lightning impulse currents 8/20 μs shall be used.

8.4.2 MO resistors

8.4.2.1 General

Tests shall be performed on 10 MO resistor samples selected according to 7.2.3.2. At the manufacturer’s discretion, the samples may be individual MO resistors or may be combined in stacks of two or more resistors provided that 10 resistors in total are tested.

8.4.2.2 Test procedure

Figure 1 gives an overview of the test procedure for MO resistors.

Initial measurements • Residual voltage test at nominal discharge current
Application of 1,1 times Q_{rs} • 1^{st} sequence:, 20 impulses per sample • if not more than one MO resistor sample failure during 1^{st} sequence: MO resistor test passed • if not more than two sample MO resistor failures during 1^{st} sequence: conduct 2^{nd} sequence with 10 new MO resistor samples, 20 impulses per sample if more than two MO resistor sample failures in 1^{st} sequence or any MO resistor sample failure in 2^{nd} sequence: MO resistor test failed
Final measurements • withstand capability to one 8/20 current impulse of at least 0,5 kA/cm^2 peak current density or 2 times I_n, whichever is lower Residual voltage test at nominal discharge current

IEC

Figure 1 – procedure to verify the repetitive charge transfer rating, Q_{rs}, for MO resistors

The following procedure shall be followed:

- Each sample shall be subjected to a residual voltage test at nominal discharge current. For samples of multi-column arresters the nominal discharge current applied in the test is the highest nominal discharge current used for the type of sample in any design.
- In a first test sequence, each sample shall be subjected to twenty 8/20 lightning current impulses administered in ten groups of two impulses, with time between impulses within a group of 50 s to 60 s and time between groups sufficient for cooling to ambient temperature.

  The charge content of each impulse shall be at least equal to the claimed repetitive charge transfer rating multiplied by 1,1;

  NOTE The requirement of testing at least 1,1 times the rated charge values is considered to give sufficient confidence that the performance of the individual MO resistors can also be assigned to complete arresters built from this type of MO resistors.
- If one sample fails, a second sequence identical to the first shall be performed on an additional 10 samples (if more than one sample fails, the entire test is failed).
- Surviving samples shall be subjected to one 8/20 current impulse of at least 0,5 kA/cm^2 peak current density or 2 times I_n, whichever is lower.
- Surviving samples shall again be subjected to a residual voltage test at nominal discharge current.

8.4.2.3 Test evaluation

The test shall be considered passed for MO resistors if all the following requirements are met:

- not more than one sample failed during the first sequence, or not more than two samples failed during two sequences.

  NOTE If only one failure occurs during the first sequence and this happens, in the worst case, at the very first impulse application, 180 impulses without failure will have been applied at the end, giving a failure probability of max. 1/181 = 0,005 6 or 0,56 % for the complete test. If two failures occur during the first sequence and this happens, again as a worst case, at the very first applications on two of the samples, 360 impulses without failure will have been applied at the end of both sequences, giving again a failure probability of max. 2/362 = 0,005 6 or 0,56 % for the complete test.
- there is no mechanical damage of surviving resistors at visual inspection
- each surviving sample demonstrates a withstand capability to one 8/20 current impulse of at least 0,5 kA/cm^2 peak current density or 2 times I_n, whichever is lower
- the change of residual voltage of surviving samples at nominal discharge current is within ±5 %

8.4.3 Series gaps

8.4.3.1 General

Tests shall be performed on three series gaps having the shortest gap spacing of all series gaps used in the arrester design. At the manufacturer’s discretion, the gaps may be tested separately from the MO resistors or may be tested in series with three of the MO resistor samples (see 8.4.2).

8.4.3.2 Test procedure

Figure 2 gives an overview of the test procedure for series gaps.

Initial measurements • Power-frequency sparkover voltage test • Lightning impulse sparkover voltage test
Application of 1,1 times Q_{rs}
Final measurements • Power-frequency sparkover voltage test • Lightning impulse sparkover voltage test

IEC

Figure 2 – Procedure to verify the repetitive charge transfer rating, Q_{rs}, for series gaps

The following procedure shall be followed:

- Each sample shall be subjected to a power frequency sparkover test and a lightning impulse sparkover voltage test.
- Each sample shall be subjected to twenty current impulses administered in ten groups of two impulses, with time between impulses within a group of 50 s to 60 s and time between groups sufficient for cooling to ambient temperature.

  The wave shape and duration of the current impulses is not important, except that the charge content of each impulse shall be at least equal to the claimed repetitive charge transfer rating multiplied by 1,1.
- Each sample shall be again subjected to a power frequency sparkover test and a lightning impulse sparkover voltage test.

8.4.3.3 Evaluation

The test shall be considered passed if both of the following requirements are met:

- power-frequency sparkover voltage of all three series gap samples is not below claimed sparkover value
- lightning impulse sparkover voltage of all three series gap samples is not above the claimed protection level.

8.5 Operating duty tests

8.5.1 General

The purpose of this test is to verify the arrester’s ability to thermally recover after injection of the rated thermal energy, Q_{th}, respectively, under applied temporary overvoltage and following continuous operating voltage conditions. The test shall be performed on three samples.

NOTE Though thermal stability has basically no statistical character, three test samples are specified. This compensates for statistical factors such as incorrect voltage adjustment, variability in the power loss characteristic, tolerance during energy injection etc.

The samples shall fulfil the requirements of 7.2.

Each design of arrester shall be assigned a thermal energy rating, Q_{th}, from Table 5.

The characterization and conditioning part of the test (8.5.2.2) may be performed at an ambient temperature of 20 °C ± 15 K on the MO resistors in still air or on an arrester.

The thermal recovery part of this test (8.5.2.3) shall be performed on complete arresters (see 6.7). It shall be demonstrated by adequate methods that the start temperature requirement is fulfilled at the beginning of the thermal recovery part of the test.

The relative uncertainty between measurements of the applied voltage shall not be more than ±1 %. This may be achieved by any suitable means, e.g. by using identical measuring setups or by calibration of all used measuring setups to ±1 %. The peak value of the voltage shall not vary by more than 1 % from no-load to full-load condition. The ratio of peak voltage to RMS value shall not deviate from √2 by more than 2 %. During the tests, the power frequency voltage shall not deviate from the specified values by more than ±1 %.

8.5.2 Test procedure

8.5.2.1 General

Figure 3 gives an overview of the test procedure.

Pre-tests • Verification of thermal equivalence of the complete arrester
Initial tests for sample characterization • Residual voltage test at nominal discharge current
Determination of sample's continuous operating voltage and rated voltage (see, 7.2)
Conditioning Conditioning test; 4 groups of 5 impulses superimposed on a continuous power frequency voltage of U_r One high current impulse (as per Table 4)
Hold for future use
Preheating to start temperature as per 8.5.2.3.
Distribution class arresters: • Rated thermal charge transfer, Q_{th}, within one minute by two lightning current impulses 8/20 µs according to 8.5.3
Application of sample's rated voltage for 10 s (within 100 ms after energy or charge injection)
Application of sample's continuous operating voltage for at least 30 min (until pass or fail is evident)
Test evaluation • Thermal recovery • No physical damage • Change of residual voltage at nominal discharge current within ±5% • Final interruption of the follow current shall occur not later than at the end of the half cycle following that in which the impulse is applied

IEC

Figure 3 – Test procedure to verify the thermal charge transfer rating, Q_{th}

Requirements for start temperature are given in 8.5.2.3.

8.5.2.2 Characterization and conditioning

The following procedure shall be applied for characterization and conditioning:

- Each sample shall be subjected to a residual voltage test at the nominal discharge current before and after the test.
- Each sample shall be subjected to 4 groups of 5 impulses superimposed on a continuous power frequency voltage of U_r. The interval between the impulses shall be 50 s to 60 s and the interval between groups shall be 25 min to 30 min. It is not required that the test sample be energized between groups of impulses.
- For the purpose of conditioning, the samples shall be subjected to one high current impulse as specified in Table 4.
- The impulse shall be of the same polarity as that of the current impulses for the charge transfer, in the thermal recovery part of the test.
- After application of the high current impulse the samples shall be stored at room temperature.

Heating the samples for longer time at very high temperatures, application of alternating voltage or application of impulse currents of opposite polarity might lead to recovery from possible electrical ageing effects and is therefore not permitted.

Table 4 – Requirements for high current impulses

Arrester classification	**Peak current 4/10** kA
10 kA	100
5 kA	65
2,5 kA	25

The tolerances on the adjustment of the equipment shall be such that the measured values of the current impulses are within the following limits:

a) from 90 % to 110 % of the specified peak value;

b) from 3,5 µs to 4,5 µs for virtual front time;

c) from 9 µs to 11 µs for virtual time to half-value;

d) the peak value of any opposite polarity current wave shall be less than 20 % of the peak value of the current;

e) small oscillations on the impulse are permissible provided their amplitude near the peak of the impulse is less than 5 % of the peak value. Under these conditions, for the purpose of measurement, a mean curve shall be accepted for determination of the peak value.

8.5.2.3 Thermal recovery test

The following procedure shall be applied for the thermal recovery part of the test:

- The complete test samples shall be preheated to a start temperature of at least 60 °C.
- The preheating shall take not more than twenty hours.
- The temperature of the MO resistors shall be immediately prior to the transfer of charge.
- Each sample shall be subjected to transfer of charge. Within 100 ms from the charge transfer, a voltage equal to the sample's rated voltage(see 7.2), shall be applied for 10 s and thereafter a voltage equal to the sample's continuous operating voltage (see 7.2) shall be applied for a minimum of 30 minutes to demonstrate thermal stability. Resistive component of current or power dissipation or temperature or any combination of them

shall be monitored until the measured value is appreciably reduced (success), but for at least 30 minutes, or thermal runaway condition (failure) is evident.

8.5.2.4 Test evaluation

The test shall be considered passed if all the following criteria are met:

- thermal recovery has been demonstrated;
- no physical damage is evident;
- any change of the residual voltage at nominal discharge current before and after the test is within ±5 %.

Final interruption of the follow current shall occur not later than at the end of the half cycle following that in which the impulse is applied

8.5.3 Rated thermal charge values, Q_{th}

The values of thermal charge rating, Q_{th}, given in C, shall be taken from Table 5.

Table 5 – Rated values of thermal charge transfer rating, Q_{th}

Nominal discharge current (kA)	**Q_{th} rating** (C)	**Q_{th} per impulse** (C)	**Corresponding 8/20 µs current amplitude (kA) (approximately) (informative)**
2,5	0,45	0,23 (±10 %)	14
5	0,7	0,35 (±10 %)	22
10	1,1	0,55 (±10 %)	34

8.6 Power-frequency voltage-versus-time test

8.6.1 General

The purpose of this test is to demonstrate the TOV (temporary overvoltage) withstand capability of the arrester. In this test, the TOV is strictly a power-frequency overvoltage for time periods from 0,1 s to 3 600 s.

Manufacturers' published data shall include curves with abscissa scaled in time and ordinate in per unit of U_r. In addition, the manufacturer shall publish a table of TOV values listed in per unit of U_r to three significant digits, for times 0,1 s, 1 s, 10 s, 100 s, and 1 000 s. The table values shall be taken from the curves and shall include data "without prior duty" and "with prior duty". The published curve and table shall state the range of arrester ratings for which they apply.

The TOV value "with prior duty" and 10 s time duration shall be at least equal to U_r.

Figure 4 gives an overview of the test procedure.

Initial tests • Residual voltage test at nominal discharge current
Determination of continuous operating voltage and rated voltage.
Preheating to start temperature as per 8.5.2.3
With prior duty (4 new samples) (only for DH arresters) • Rated thermal charge transfer, Q_{th}, within one minute by two lightning current impulses 8/20 μs according to 8.5.3 • Application of test voltage and duration according to TOV curve (within 100 ms) • Application of continuous operating voltage for at least 30 min (until pass or fail is evident)
Without prior duty (2 new samples) • Application of test voltage and duration according to TOV curve • Application of continuous operating voltage for at least 30 min (until pass or fail is evident)
Test evaluation • Thermal recovery • No physical damage • Change of residual voltage at nominal discharge current within ±5 % • Power-frequency sparkover voltage test shall not be below claimed sparkover value

IEC

Figure 4 – Test procedure to verify the power frequency versus time characteristic (TOV test)

8.6.2 Test samples

The test samples shall fulfil the requirements in 7.2.

The test samples shall be complete arresters with rated voltages of 3 kV to 12 kV may be used provided the arrester's cooling rate represents the slowest cooling rate for all ratings of the design.

A total of six samples shall be tested as follows:

- "with prior duty" – one sample in each of the four ranges listed in 8.6.4.2.
- "without prior duty" – one sample in each of two ranges selected from the list in 8.6.4.2.

For a given type and design arrester, when various size MO resistors are used, the MO resistors selected for the TOV test section shall have the minimum material volume per U_c.

8.6.3 Initial measurements

An initial measurement of residual voltage test shall be made at nominal discharge current.

8.6.4 Test procedure

8.6.4.1 General

The test sample shall be connected to a power supply having a frequency within the range of 48 Hz to 62 Hz. Nominal test frequency (50 Hz or 60 Hz) shall be stated with published data. The peak values of power-frequency voltage shall be measured at the arrester terminals during the overvoltage. The minimum measured peak value divided by $\sqrt{2}$ is the per-unit value that shall be used for data display referenced to rated voltage.

Care shall be taken in the case of a weak voltage source. Distortion of the voltage (flat peak) under severe non-linear current loading may lead to much higher energy injection at a given peak voltage level compared to the situation for an ideally sinusoidal voltage shape. It is therefore recommended to use a voltage source of a short-circuit current of at least 3 kA in order to avoid unrealistically high energy injection to the sample at a given peak voltage level.

The tests shall be performed in still air at 20 °C ± 15 K on thermally prorated sections. The samples shall be heated for a time sufficient to obtain thermal equilibrium, and the MO resistors shall be at a temperature of at least 60 °C. It shall be demonstrated by adequate methods that the start temperature requirement is fulfilled at the beginning of the thermal recovery parts of the test.

8.6.4.2 "With prior duty" test

This test is applicable to arresters of I_n = 10 kA only. Four new test samples shall be tested "with prior duty". One sample each shall be tested in the ranges (in seconds) given below:

1) 0,1 to 1
2) 1,1 to 10
3) 10,1 to 100
4) 101 to 3 600

The manufacturer shall publish TOV data for conditions "with prior duty" for each of the four listed time periods. The prior duty consists of injection of the thermal charge rating Q_{th}. The test procedure shall be the procedure given in 8.5.2.3, where the rated voltage is replaced by the specified TOV. The charge (in C), respectively, shall be measured and shall be stated with the relevant published prior duty TOV data.

8.6.4.3 "Without prior duty" test

This test is applicable to arresters of all nominal discharge currents. Two new test samples shall be tested "without prior duty". The manufacturer shall publish TOV data for conditions "without prior duty" for two of the four time periods listed in 8.6.4.2. One new sample in each of two non-adjacent time ranges selected from this list shall be tested . Immediately after the sample's overvoltage, the continuous operating voltage (see 7.2) shall be applied for a minimum of 30 min. MO resistor temperature, resistive component of current or power dissipation shall be monitored until the measured value is appreciably reduced (success) or a thermal runaway condition is evident (failure).

8.6.5 Test evaluation

A sample shall be considered passed if all the following criteria are met:

- thermal recovery has been demonstrated;
- no physical damage is evident;
- any change of the residual voltage at nominal discharge current before and after the test is within ±5 %;
- power frequency sparkover voltage test shall not be below claimed sparkover value.

The manufacturer's published curve has been verified when all six samples have been tested at TOV voltages and corresponding durations that are equal to or greater than the values indicated on the curve, and all samples have passed the evaluation criteria. All test points shall be displayed on the curve.

8.7 Tests of arrester disconnectors

8.7.1 General

The purpose of the disconnector test is to verify that the disconnector of an arrester can withstand all stresses related to their application in arresters without operating. The test also demonstrates that the disconnector will perform according to the time-current characteristic published by the manufacturer. Furthermore the water tightness and the mechanical strength of the disconnector have to be verified (see 6.12).

These tests shall be made on arresters which are fitted with arrester disconnectors or on the disconnector assembly alone if its design is such as to be unaffected by the heating of adjacent parts of the arrester in its normally installed position. The test sample shall be mounted in accordance with the manufacturer's published recommendations using the maximum recommended size and stiffness and the shortest recommended length of connecting lead. In the absence of published recommendations, the conductor shall be hard-drawn bare copper approximately 5 mm in diameter and 30 cm long, arranged to allow freedom of movement of the disconnector/fault indicator when it operates.

8.7.2 Operating withstand test

8.7.2.1 General

For disconnectors designed for attachment to an arrester or for insertion into the line or ground lead as an accessory, a charge transfer test and an operating duty test shall be made either separately or in conjunction with tests on arrester samples. For arresters with built-in disconnectors, the tests shall be made at the same time as the tests on the arresters. The disconnectors shall withstand the tests without operating.

8.7.2.2 Test to verify the repetitive charge transfer rating Q_{rs}

This test shall be made in accordance with 8.4, with charge transfer values corresponding to the highest classification of arresters with which the disconnector is designed to be used. The test shall be made with lightning impulse currents 8/20 μs. The test shall be made on three samples with the same charge as specified for the arrester (see 8.4.4).

8.7.2.3 Operating duty test

This test shall be made in accordance with 8.5 with the sample disconnector in series with a test sample of the arrester design. The test shall be made on three samples with the same thermal charge rating as specified for the arrester.

8.7.2.4 Test evaluation

The tests shall be considered passed if

- there is no operation of any sample during the testing of 8.7.2.2 and 8.7.2.3

and

- either
  - the resistance or capacitance of the grading elements have not changed by more than 20 %

  or

  - if each of the samples used for the tests of 8.7.2.2 and 8.7.2.3 successfully operates in a subsequent test of operation when conducting a current of 20 A rms symmetrical

8.7.3 Disconnector operation

8.7.3.1 Time-versus-current test

An operation test shall be made on arrester disconnectors to determine a time-current characteristic; that is, the relation between the time in seconds and the current in rms symmetrical amperes required to cause the disconnector to operate. It is permissible for the actual operation of the disconnector to occur after the current has ceased.

Data for a time-versus-current curve shall be obtained at three different symmetrically initiated current levels with five samples each – 20 A, 200 A and 800 A RMS ± 10 % – flowing through test sample disconnectors with or without arresters as required by 8.7.1. If lower currents are claimed they shall be tested (e.g. 5 A). For tests on disconnectors affected by internal heating of the associated arresters, the MO resistors in the arrester shall be bypassed with a bare copper wire 0,08 mm to 0,13 mm in diameter in order to start the internal arcing.

The test voltage may be any convenient value so long as it is sufficient to maintain full current flow in the arc over the arrester elements and sufficient to cause and maintain arcing of any gaps upon which operation of the disconnector may depend. The test voltage shall not exceed the rated voltage of the lowest rated arrester with which the disconnector is designed to be used.

Because the disconnector is not a fault-clearing device, the test circuits shall include devices with interrupting capabilities. An opening device such as a fuse or switch may be used with provision for adjusting the duration of current through the test sample.

NOTE One method of preparing the test circuit is to first adjust the parameters of the test circuit with the test sample temporarily shunted by a link of negligible impedance to produce the required value of current. A closing switch can be timed to close the circuit within a time corresponding to a few degrees of voltage crest to produce approximately symmetrical current.

The RMS value of current through the specimen and the duration to the first movement of the disconnector shall be plotted for all the samples tested. The time-versus-current characteristic curve of the disconnector shall be drawn as a smooth curve through the points representing maximum duration.

Depending on the test setup and the amplitude of the test current the arc will not distinguish after disconnector operation. In this case the time-versus-current curve test shall be made by subjecting the test samples to controlled durations of current flow to determine the minimum duration for each of the three current levels which will consistently result in successful operation of the disconnector. For the points to be used for the time-versus-current curve, successful operation of the disconnector shall occur in five tests out of five trials, or, if one unsuccessful test occurs, five additional tests at the same current level and duration shall result in successful operations.

8.7.3.2 Evaluation of disconnector performance

There shall be clear evidence of effective and permanent disconnection by the device. If there is no clear evidence of effective and permanent disconnection by the device, a power-frequency voltage equal to 1,2 times the rated voltage of the highest rated arrester with which the disconnector is designed to be used, shall be applied for 1 min without current flow in excess of 1mA RMS. At each value of current, the established characteristic curve shall have a time value that is equal to or lower than that shown in manufacturer’s published data.

8.7.4 Mechanical tests

8.7.4.1 General

Bending moment, tensile load and torsional load tests shall be performed on disconnectors used with NGLA. For arresters other than NGLA these tests may be performed on agreement between user and manufacturer.

NOTE Typically, disconnectors used on these distribution class arresters would be subjected to very small loading due to weight of connecting leads, and would therefore not be subject to this test. However, disconnectors might be exposed to torque or other loads during installation even though mechanical stress in service is negligible .

8.7.4.2 Bending moment test

The test shall be made on five new samples. On each sample, the bending load shall be increased smoothly until breaking occurs within 30 s to 90 s. The test is passed if the values of breaking load exceed the value specified by the manufacturer. If one sample fails to reach the specified breaking value, five additional samples shall be tested successfully.

8.7.4.3 Tensile load test

The test shall be made on five new samples. On each sample, the tensile load shall be increased smoothly until breaking occurs within 30 s to 90 s. The test is passed if the values of breaking load exceed the value specified by the manufacturer. If one sample fails to reach the specified breaking value, five additional samples shall be tested successfully.

8.7.4.4 Torsional load test

The test shall be made on five new samples. On each sample, the torsional load shall be increased smoothly until breaking occurs within 30 s to 90 s. The test is passed if the values of breaking load exceed the value specified by the manufacturer. If one sample fails to reach the specified breaking value, five additional samples shall be tested successfully.

8.7.5 Temperature cycling and seal pumping test

A temperature cycling test shall be made on 10 new samples, in accordance with 8.11.3.2, followed by a seal pumping test on each sample.

In the seal pumping test the test samples shall be uniformly heated to 60 °C ± 3 °C and maintained at that temperature for a minimum of 1 h. The samples shall then be placed in a cold water bath having a temperature of 4 °C ± 3 °C for a minimum of 2 h. The transfer time between the hot and cold media shall be not more than 5 min. The test cycle shall be performed 10 times. The cold water bath shall have a water weight at a minimum of 10 times the weight of the test samples.

Within 24 h after having reached ambient temperature the resistance or capacitance of the grading element of each sample shall be measured and the samples shall be opened for visual inspection. The disconnectors shall have passed the tests if no moisture is found within the test samples upon visual examination of the internal parts and surfaces and if the resistance or capacitance of the grading element has not changed by more than 20 %.

8.8 Power-frequency voltage sparkover tests

Dry and wet tests shall be made on three samples of complete arresters of each voltage rating tested. The performance for other voltage ratings of the same design within ±20 % (or 3 kV, whichever is greater) of a test sample rating can be determined by adjusting the voltage level in proportion to the voltage ratings. The voltage applied to the arrester shall be switched on at a value low enough to avoid sparkover of the arrester by the resulting switching surge and raised rapidly at a uniform rate until sparkover of the series gap occurs. The time during which the voltage may exceed the rated voltage of the arrester shall be in the range of 2 s to 5 s when testing arresters using grading resistors which may be damaged by overheating if the applied voltage exceeds the rated voltage for too long. After sparkover, the test voltage shall be switched off as rapidly as possible, preferably by automatic tripping and in any case within 0,5 s.

The load imposed on the testing circuit by a surge arrester having non-linear grading resistors of high conductivity gives rise to harmonics and the test circuit shall have a sufficiently low impedance to maintain the waveform of the voltage across the specimen within the limits specified in IEC 60060-1 and IEC 60060-2.

The voltage shall be applied not less than five times with an interval of about 10 s between successive applications.

The average sparkover value of the five tests is adopted as the power frequency sparkover voltage for purposes of comparison of tests made before and after other type tests.

8.9 Short-circuit tests

8.9.1 General

All arresters shall be tested to show that 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 up to four 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.

The frequency of the short-circuit test current supply shall be between 48 Hz and 62 Hz.

With respect to the short-circuit current performance, it is important to distinguish between two designs of surge arresters.

- "Design A" arresters have a design in which a gas channel runs along the entire length of the arrester unit and fills ≥50 % of the internal volume not occupied by the internal active parts.
- "Design B" arresters are of a solid design with no enclosed volume of gas or having an internal gas volume filling <50 % of the internal volume not occupied by the internal active parts.

NOTE 1 Typically, "Design A" arresters are porcelain-housed arresters, or polymer-housed arresters with a composite hollow insulator which are equipped either with pressure-relief devices, or with prefabricated weak spots in the composite housing which burst or flip open at a specified pressure, thereby decreasing the internal pressure.

Typically, "Design B" arresters do not have any pressure relief device and are of a solid type with no enclosed volume of gas. If the MO resistors fail electrically, an arc is established within the arrester. This arc causes heavy evaporation and possibly burning of the housing and/or internal material. These arresters' short-circuit performance is determined by their ability to control the cracking or tearing-open of the housing due to the arc effects, thereby avoiding violent shattering.

NOTE 2 "Active parts" in this context are the MO resistors and any metal spacers directly in series with them.

NOTE 3 Following agreement between the manufacturer and the user, the test procedure can be modified to include, for example, a number of reclosing operations, with the procedure and acceptance criteria being agreed upon between the manufacturer and the user.

8.9.2 Preparation of the test samples

8.9.2.1 General

Depending on the type of arrester and test voltage, different requirements apply with regard to the number of test samples, initiation of short-circuit current and amplitude of the first short-circuit current peak. Table 6 shows a summary of these requirements.

For the high-current tests, the test samples shall be the longest arrester unit used for the design with the highest rated voltage of that unit used for each different arrester design.

For the low-current test, the test sample shall be an arrester unit of any length with the highest rated voltage of that unit used for each different arrester design. Figure 5 shows different examples of arrester units.

8.9.2.2 “Design A” arresters

The samples shall be prepared with means for conducting the required short-circuit current using a fuse wire. The fuse wire shall be in direct contact with the MO resistors and be located as far away as possible from the gas channel and shall short-circuit the entire internal active part, as illustrated in Figure 6 for different possible constructions of Design B arresters. The actual location of the fuse wire in the test shall be reported in the test report.

Fuse wire along surface of MO resistors; located as far away as possible from the gas channel The fuse wire material and size shall be selected so that, for the high and reduced short-circuit current tests, the wire will melt within the first 30 electrical degrees after initiation of the test current. For the low short-circuit current test, there is no limitation on time to melt.

In order to have melting of the fuse wire within the specified time limit and create a suitable condition for arc ignition, it is generally recommended that a fuse wire of a low resistance material (for example copper, aluminium or silver) with a diameter of about 0,2 mm to 0,5 mm be used. Higher fuse-wire cross-sections are applicable to surge arrester units prepared for higher short-circuit test currents. When there are problems in initiating the arc, a fuse wire of larger size but with a diameter not exceeding 1,5 mm, may be used since it will help arc establishment. In such cases, a specially prepared fuse wire, having a larger cross-section along most of the arrester height with a short thinner section in the middle, may also help.

“Design A” arresters with polymeric sheds which are applied to a primary housing of porcelain or other hollow insulator that is as brittle as ceramic, shall be considered and tested as porcelain-housed arresters.

The test samples shall be filled with the surrounding medium (gas) used in the arresters.

8.9.2.3 “Design B” arresters

The samples shall be prepared with means for conducting the required short-circuit current using a fuse wire. The fuse wire shall be in direct contact with the MO resistors and be located as far away as possible from the gas channel and shall short-circuit the entire internal active part, as illustrated in Figure 7 for different possible constructions of Design B arresters. The actual location of the fuse wire in the test shall be reported in the test report.

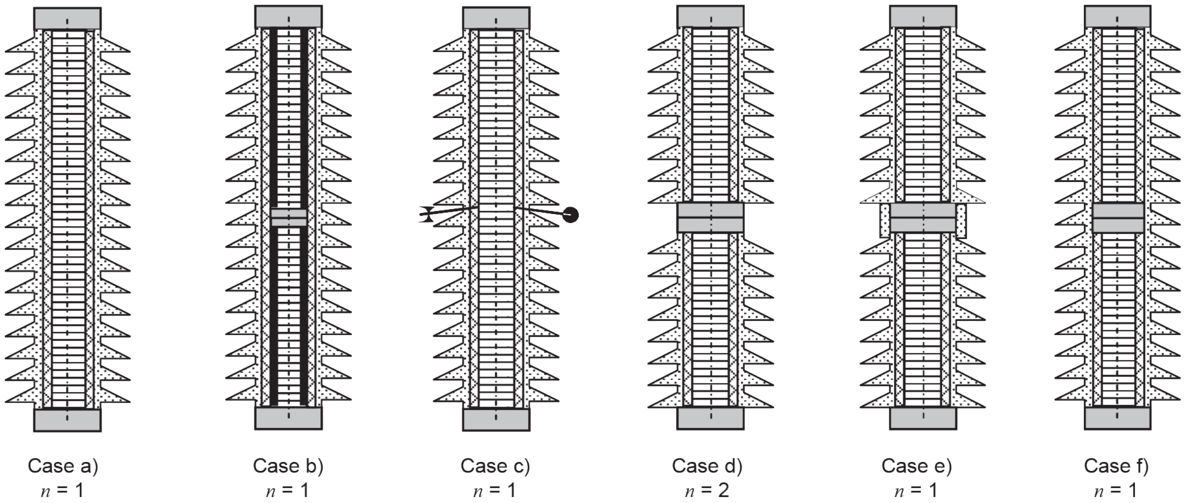
The fuse wire material and size shall be selected so that, for the high and reduced short-circuit current tests, the wire will melt within the first 30 electrical degrees after initiation of the test current. For the low short-circuit current test, there is no limitation on time to melt.

In order to have melting of the fuse wire within the specified time limit and create a suitable condition for arc ignition, it is generally recommended that a fuse wire of a low resistance material (for example copper, aluminium or silver) with a diameter of about 0,2 mm to 0,5 mm be used. Higher fuse-wire cross-sections are applicable to surge arrester units prepared for higher short-circuit test currents. When there are problems in initiating the arc, a fuse wire of larger size but with a diameter not exceeding 1,5 mm, may be used since it will help arc establishment. In such cases, a specially prepared fuse wire, having a larger cross-section along most of the arrester height with a short thinner section in the middle, may also help.

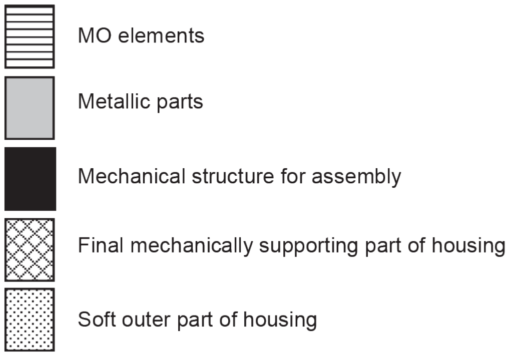
In case of an internal gas volume, the test samples shall be filled with the surrounding medium (gas) used in the arresters.

Table 6 – Test requirements for porcelain housed arresters

	Required number of test samples	Initiation of short-circuit current	Ratio of first current peak value to r.m.s. value of required short-circuit current taken from Table 7					
			Test voltage: 77 % to 107 % of U_r			Test voltage: < 77 % of U_r		
			Rated short-circuit current	Reduced short-circuit current	Low short-circuit current	Rated short-circuit current	Reduced short-circuit current	Low short-circuit current
"Design A"	4	Fuse wire along surface of MO resistors; within, or as close as possible to, the gas channel	Prospective: ≥ 2,5 Actual: no requirement	Prospective: ≥ √2 Actual: no requirement	Actual: ≥ √2	Actual: ≥ 2,5	Actual: ≥ √2	Actual: ≥ √2
"Design B"	4	Fuse wire along surface of MO resistors; located as far away as possible from the gas channel	Prospective: ≥ √2 Actual: no requirement	Prospective: ≥ √2 Actual: no requirement	Actual: ≥ √2	Actual: ≥ √2	Actual: ≥ √2	Actual: ≥ √2



Case a) One mechanical and electrical unit
Case b) Two mechanical internal assemblies covered by one common housing providing final mechanical strength
Case c) One mechanical unit covered by a housing with an intermediate potential grading element
Case d) Two mechanical units covered by individual housings each and assembled afterwards
Case e) Two mechanical units of final mechanical strength, intermediate flanges covered by soft insulating material after assembly
Case f) Two mechanical units covered by individual housings each and assembled afterwards
n … number of units



IEC

Figure 5 – Examples of arrester units

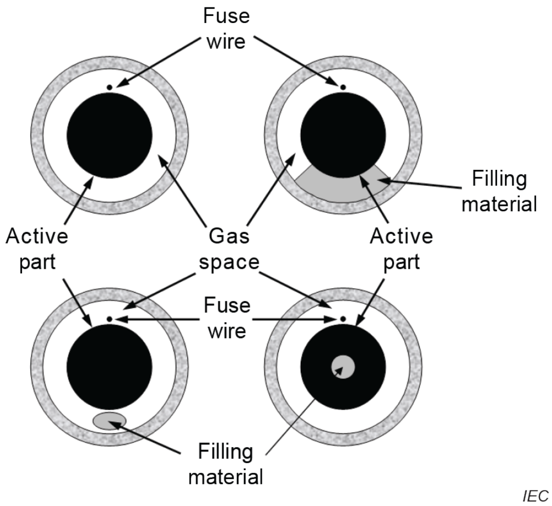


Figure 6 – Examples of fuse wire locations for "Design A" arresters

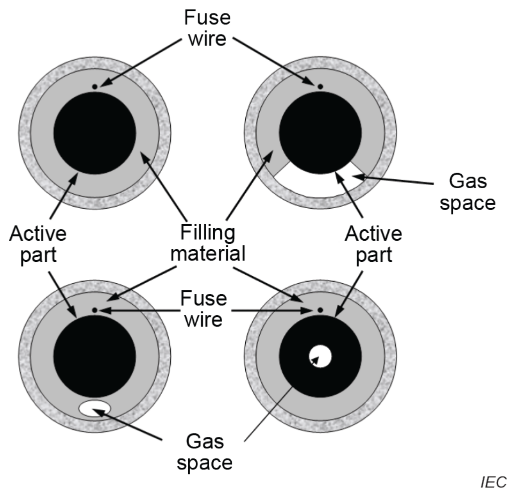
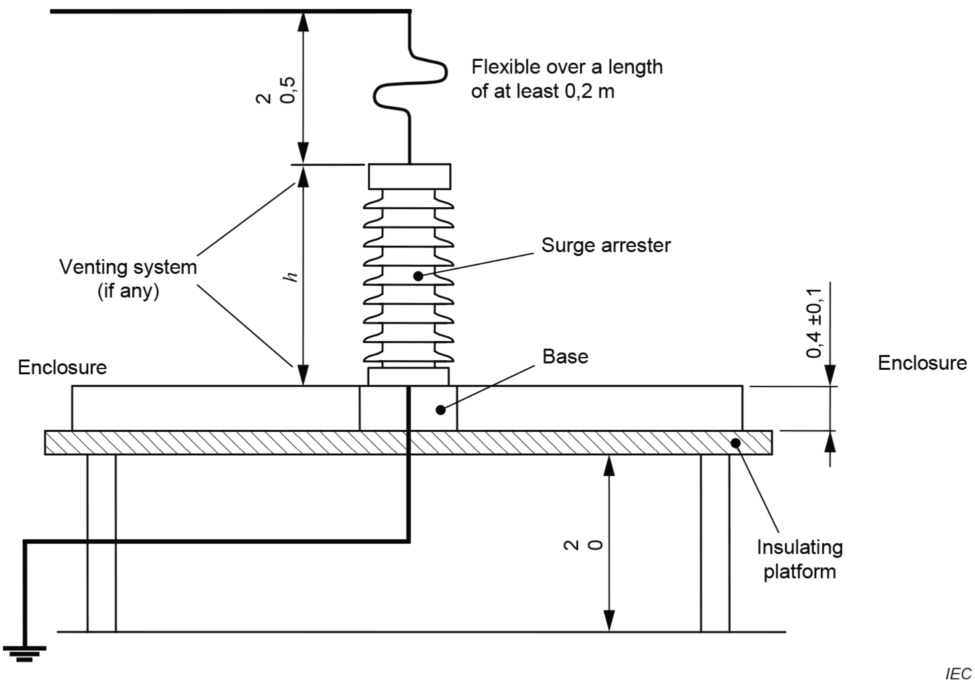


Figure 7 – Examples of fuse wire locations for "Design B" arresters

8.9.3 Mounting of the test sample

For a base-mounted arrester, the mounting arrangement is shown in Figure 8. The distance to the ground from the insulating platform and the conductors shall be as indicated in this figure.

Dimensions in metres



NOTE All leads and venting systems in the same plane.

Figure 8 – Short-circuit test setup for porcelain-housed arresters

For non-base-mounted arresters (for example, pole-mounted arresters), the test sample shall be mounted on a non-metallic pole using mounting brackets and 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. In cases where the foregoing is at variance with the manufacturer's instructions, the arrester shall be mounted in accordance with the installation recommendations of the manufacturer. The entire lead between the base and the current sensor shall be insulated for at least 1 000 V. The top end of the test sample shall be fitted with the base assembly of the same design of an arrester or with the top cap.

The mounting of the arrester during the short-circuit test and, more specifically, the routing of the conductors shall represent the most unfavourable condition in service.

NOTE The routing shown in Figure 8 is the most unfavourable to use during the initial phase of the test before venting occurs (especially in the case of a surge arrester fitted with a pressure relief device). Positioning the sample as shown in Figure 8, with the venting ports facing in the direction of the test source, may cause the external arc to be swept in closer proximity to the arrester housing than otherwise. As a result, a thermal shock effect may cause excessive chipping and shattering of porcelain weather sheds, as compared to the other possible orientations of the venting ports.

8.9.4 High-current short-circuit tests

8.9.4.1 General

A total of three samples shall be tested at currents based on selection of a rated short-circuit current selected from Table 7. All three samples shall be prepared according to 8.9.2 and mounted according to 8.9.3.

Tests shall be made in a single-phase test circuit, preferably with an open-circuit test voltage of 77 % to 107 % of the rated voltage of the test sample, as outlined in 8.9.4.2. However, it is expected that tests on high-voltage arresters will have to be made at laboratories which might not have the sufficient short-circuit power capability to carry out these tests at 77 % or more of the test sample rated voltage. Accordingly, an alternative procedure for making the high-current, short-circuit tests at a reduced voltage is given in 8.9.4.3. The measured total duration of test current flowing through the circuit shall be ≥0,2 s.

Table 7 – Required currents for short-circuit tests

Arrester class = nominal discharge current	Rated short-circuit current I_s	Reduced short-circuit currents ±10 %		Low short-circuit current with a duration of 1 s [a]
kA	kA	kA		A
10 or 5	20	12	6	600 ± 200
10 or 5	16	6	3	600 ± 200
10, 5, or 2,5	10	6	3	600 ± 200
10, 5, or 2,5	5	3	1,5	600 ± 200
10, 5 or 2,5	2,5 kA	–	–	600 ± 200
10, 5 or 2,5	1 kA	–	–	Amplitude and time on agreement between user and manufacturer
10, 5 or 2,5	< 1 kA[b]	–	–	Amplitude and time on agreement between user and manufacturer

[a] For surge arresters to be installed in resonant earthed or unearthed neutral systems, the increase of the test duration to longer than 1 s, up to 30 min, may be permitted after agreement between the manufacturer and the user. In this case the low short-circuit current shall be reduced to 50 A ± 20 A, and the test sample and acceptance criteria shall be agreed between the manufacturer and the user.

[b] High current tests are not required in this case.

NOTE If an existing arrester is qualified for one of the rated short-circuit currents in this table, it is deemed to have passed the test for any value of rated current lower than this one.

If an existing type of arrester already qualified for one of the rated currents in this table is being qualified for a higher rated-current value available in the table, it should be tested only at the new rated value. Any extrapolation can only be extended by two steps of rated short-circuit current.

If a new arrester type is to be qualified for a higher rated current value than available in this table, it shall be tested at the proposed rated current, at 50 % and at 25 % of this rated current.

8.9.4.2 High-current tests at full voltage (77 % to 107 % of rating)

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 symmetrical component of the current waveform.

For “Design B” arresters tested at rated short-circuit current, the peak value of the first half-cycle of the prospective current shall be at least √2 times the RMS value of the rated short circuit current .

For all the reduced short-circuit currents, the RMS value shall be in accordance with Table 7 and the peak value of the first half-cycle of the prospective current shall be at least √2 times the RMS value of this current.

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.

NOTE The resistance of the restricted arc inside the arrester might reduce the RMS. symmetrical component and the peak value of the measured current. This does not invalidate the test, since the test is being made with at least normal service voltage and the effect on the test current is the same as would be experienced during a fault in service.

The X/R ratio of the test circuit impedance, without the arrester connected, should preferably be at least 15. In cases where the test circuit impedance X/R ratio is less than 15, the test voltage may be increased or the impedance may be reduced, in such a way that,

- for the rated short-circuit current, the peak value of the first half-cycle of the prospective current is equal to, or greater than, 2,5 times the required test current level;
- for the reduced current level tests, the tolerances in Table 7 are met.

8.9.4.3 High-current test at less than 77 % of rated voltage

When tests are made with a test circuit voltage <77 % of the rated voltage of the test samples, the test circuit parameters shall be adjusted in such a way that the RMS value of the symmetrical component of the actual arrester test current shall equal or exceed the required test current selected from Table 7.

For "Design B" arresters tested at rated short-circuit current, the peak value of the first half-cycle of the actual arrester test current shall be at least √2 times the RMS value of the rated short circuit current.

For all the reduced short-circuit currents the RMS value shall be in accordance with Table 7 and the peak value of the first half-cycle of the actual arrester test current shall be at least √2 times the RMS value of this current.

8.9.5 Low-current short-circuit test

The test shall be made by using any test circuit that will produce a current through the test sample of 600 A ± 200 A RMS, measured at approximately 0,1 s after the start of the short circuit current flow. The current shall flow for at least 1 s after the fuse wire melts.

Refer to 8.9.6 with regard to handling an arrester that fails to vent.

8.9.6 Evaluation of test results

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

a) No violent shattering. Structural failure of the sample is permitted as long as criteria b) and c) are met.
b) No parts of the test sample shall be allowed to be found outside the enclosure, except for
   – fragments, less than 60 g each, of ceramic material such as MO resistors or porcelain;
   – pressure relief vent covers and diaphragms;
   – soft parts of polymeric materials.
c) The arrester shall be able to self-extinguish open flames within 2 min after the end of the test. Any ejected part (in or out of the enclosure) shall also self-extinguish open flames within 2 min. A shorter duration of self-extinguishing open flames for ejected parts may be agreed upon between the manufacturer and the user.

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

For arresters to be used in applications where mechanical integrity and a strength is required after failure, different test procedures and evaluations may be established between the manufacturer and the user (as an example, it may be required that after the tests the arrester should still be able to be lifted and removed by its top end).

8.10 Test of the bending moment

8.10.1 General

This test applies to porcelain and cast-resin housed arresters for $U_s \leq 52$ kV for which the manufacturer claims cantilever strength. The test shall be performed on the arrester without insulating base or mounting bracket.

The complete test procedure is shown by the flow chart in Annex C.

8.10.2 Overview

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 arrester units without insulating base or mounting bracket and without internal overpressure. For single-unit arrester designs, the test shall be performed on the longest unit of the design. Where an arrester contains more than one unit or where the arrester has different specified bending moments in both ends, the test shall be performed on the longest unit of each different specified bending moment, with loads determined according to C.1.

The test shall be performed in two parts that may be done in any order:

- a bending moment test to determine the mean value of breaking load (MBL);
- a static bending moment test with the test load equal to the specified short-term load (SSL), i.e. the 100 % value of C.2.

8.10.3 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.

8.10.4 Test procedure

8.10.4.1 Test procedure to determine mean value of breaking load (MBL)

Three samples shall be tested. If the test to verify the SSL (see 8.10.4.2) is performed first, then samples from that test may be used for determination of MBL. The test samples need not contain the internal parts. On each sample, the bending load shall be increased smoothly until breaking occurs within 30 s to 90 s. “Breaking” includes fracture of the housing and damages that may occur to fixing device or end fittings.

The mean breaking load, MBL, is calculated as the mean value of the breaking loads for the test samples.

NOTE The housing of an arrester might splinter while under load and might present a handling hazard.

8.10.4.2 Test procedure to verify the specified short-term load (SSL)

Three samples shall be tested. The test samples shall contain the internal parts. Prior to the tests, each test sample shall be subjected to a leakage check (see item d) of 9.1) and an internal partial discharge test (see item c) of 9.1). If these tests have been performed as routine tests, they need not be repeated at this time.

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. During this time the deflection shall be measured. 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.

NOTE The housing of an arrester might splinter while under load and might present a handling hazard.

8.10.5 Test evaluation

The arrester shall have passed the test if

- the mean value of breaking load, MBL, is ≥ 1,2 × SSL;
- for the SSL test
  - there is no visible mechanical damage;
  - the remaining permanent deflection is ≤ 3 mm or ≤ 10 % of maximum deflection during the test, whichever is greater;
  - the test samples pass the leakage test in accordance with item d) of 9.1;
  - the internal partial discharge level of the test samples does not exceed the value specified in 9.1 c).

8.10.6 Test on insulating base and mounting bracket

If the arrester is supplied with an insulating base and/or a mounting bracket, the base and/or bracket shall be subjected to a bending test. Three samples of each shall be tested. On each sample, the bending load shall be increased smoothly to a load equivalent to the arrester SSL within 30 s to 90 s. When the test load is reached, it shall be maintained for 60 s to 90 s. Then the load shall be released smoothly.

The samples shall have passed the test if there is no visible mechanical damage.

8.11 Environmental tests

8.11.1 General

These tests apply to porcelain and cast resin-housed arresters. The environmental tests demonstrate by accelerated test procedures that the sealing mechanism and the exposed metal combinations of the arrester are not impaired by environmental conditions.

The test shall be performed on complete arrester units of any length.

For arresters with an enclosed gas volume and a separate sealing system, the internal parts may be omitted.

Arresters whose units differ only in terms of their lengths, and which are otherwise based on the same design and material, and have the same sealing system in each unit, are considered to be the same type of arrester.

8.11.2 Sample preparation

Prior to the tests, the test sample shall be subjected to the leakage check of item e) of 9.1.

8.11.3 Test procedure

8.11.3.1 General

The tests specified in 8.11.3.2 and 8.11.3.3 shall be performed on one sample in the sequence given.

8.11.3.2 Temperature cycling test

The test shall be performed according to test Nb of IEC 60068-2-14.

The hot period shall be at a temperature of at least +40 °C, but not higher than +70 °C. The cold period shall be at least 85 K below the value actually applied in the hot period; however, the lowest temperature in the cold period shall not be lower than –50 °C:

- temperature change gradient: 1 K/min;
- duration of each temperature level: 3 h;
- number of cycles: 10.

8.11.3.3 Salt mist test

The test shall be performed according to Clause 4 and Subclause 7.6, as applicable, of IEC 60068-2-11:1981:

- salt solution concentration: 5 % ± 1 % by weight;
- test duration: 96 h.

8.11.4 Test evaluation

The arrester shall have passed the tests if the sample passes the leakage check in accordance with item e) of 9.1.

8.12 Seal leak rate test

8.12.1 General

This test applies to arresters having an enclosed gas volume and a separate sealing system. The test demonstrates the gas/water tightness of the complete system.

If a routine test for seal leak rate (see item e) of 9.1) is performed with acceptance criteria at least as stringent as specified in this clause, then a type test is not required. Otherwise, a type 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.

8.12.2 Sample preparation

The test sample shall be new and clean.

8.12.3 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 IEC 60068-2-17.

8.12.4 Test evaluation

The maximum seal leak rate (see C.3) shall be lower than 1×10^{-6} Pa x m^3/s

8.13 Test to verify the dielectric withstand of internal components

8.13.1 General

The purpose of this test is to verify the internal dielectric withstand capability of an arrester even under impulse currents of amplitudes higher than nominal discharge current.

If it can be demonstrated by calculations that, for a specific arrester, the electrical field at critical locations is less than or equal to the electrical field on an arrester which has been successfully tested at higher or equal voltage, no test is required.

The test shall be performed on one test sample.

No internal temperature sensor shall be installed.

8.13.2 Test procedure

The test sample shall be heated in an oven for a time sufficient to obtain thermal equilibrium to at least 60 °C. The test shall be performed within 10 minutes after removing the sample from the oven. The test consists of one application of a high-current impulse with amplitude according to Table 4.

Oscillograms of current and voltage shall be taken for the impulse application.

8.13.3 Test evaluation

The sample has passed the test if all the following criteria are met:

- there is no evidence of a dielectric breakdown from the oscillograms;
- any change of the residual voltage at nominal discharge current before and after the test is within ± 5 %;
- the following requirements are met:
  - – if the manufacturer declares that the resistors may be removed from the test sample, a visual examination of the resistors shall be made and it shall be verified that the test has not caused puncture, flashover or cracking of the resistors.
  - – if the manufacturer declares that the MO resistors cannot be removed from the test sample, the following additional test shall be performed to be sure that no damage occurred during the test:
    1) after the check of residual voltage at I_n, two current impulses 8/20 of an amplitude resulting in a current density of at least 0,5 kA/cm^2 or in 2 times I_n, whichever is lower, shall be applied to the sample. The first impulse shall be applied after sufficient time to allow the cooling of the sample to ambient temperature. The second impulse shall be applied between 50 s to 60 s after the first one. During the two impulses, the oscillograms of both voltage and current shall not reveal any breakdown.

8.14 Test of internal grading components

8.14.1 Test to verify long term stability under continuous operating voltage

If internal grading components such as capacitors or (non-linear) resistors are used in the arrester they shall be tested in an accelerated test to verify long term stability under continuous operating voltage. The test samples may be individual components or a stack of such components.

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

During the test, the test samples shall be placed in a temperature-controlled oven in the same surrounding medium as used in the arrester. The volume of the oven chamber shall be at least twice the volume of the test sample and the density of the medium in the chamber shall not be less than the density of the medium in the arrester.

NOTE The medium surrounding the grading components within the arrester may be subject to a modification during the normal life of the arrester due to internal partial discharges. Possible change of the medium surrounding the grading components in the field can significantly change their electrical properties.

A suitable test procedure taking into account such modifications is under consideration. During this time an alternative procedure consists in performing the test in N_2 with a low oxygen concentration (less than 0,1 % in volume). This ensures that even in the total absence of oxygen, the grading components will not age.

If the manufacturer can prove that the test carried out in the open air is equivalent to that carried out in the actual medium, the ageing procedure can be carried out in the open air.

Three samples shall be tested for 1 000 h, during which the temperature shall be controlled to keep the surface of the samples at 115 °C ± 4 K. During the 1 000 h test, the samples shall be energized at a voltage corresponding to the maximum continuous operating voltage for the number of MO resistors installed in parallel to the grading components in the arrester. The impedance of the grading components shall be measured at 20 °C ± 15 K before and after the 1 000 h test.

The samples shall have passed this part of the test if

- there is no evidence of a dielectric breakdown;
- examination after the test reveals no evidence of puncture, flashover or cracking of the grading components;
- a partial discharge test at the test voltage reveal partial discharges not exceeding 10 pC;
- the change in impedance of the grading components due to the 1 000 h test is not greater than ±5 %.

If the samples pass the above evaluation criteria, then MO resistors, equal in number to those used in parallel to the grading components in the arrester, shall be connected in parallel to the test sample, and two 8/20 lightning impulses with peak current density of 0,5 kA/cm^2 in the MO resistors or 2 times I_n, whichever is lower, shall be applied to the sample. The first impulse shall be applied after sufficient time to allow the cooling of the sample to ambient temperature. The second impulse is applied between 50 s to 60 s after the first impulse. The impedance of the grading components shall be measured at 20 °C ± 15 K before and after the two impulses. The samples shall have passed the test if

- oscillograms of voltage and current taken during each impulse reveal no electrical breakdown
- the change in impedance of the grading components due to the two impulses is not greater than ±5 %.

8.14.2 Thermal cyclic test

Three samples shall be subjected to thermal variations without voltage applied. The thermal variations consist of five 48 h cycles of heating and cooling to 60 °C and – 40 °C respectively. The hot and cold periods shall be maintained for at least 16 h. The test shall be conducted in air. The impedance of the grading components shall be measured at 20 °C ± 15 K before and after the thermal cycles.

The samples have passed this part of the test if

- examination after the test reveals no evidence of cracking of the grading components;
- a partial discharge test at the test voltage corresponding to the maximum continuous operating voltage for the number of MO resistors installed in parallel to the grading components in the arrester reveal partial discharges not exceeding 10 pC;
- the change in impedance of the grading components due to the thermal cycles is not greater than ±5 %.

If the samples pass the above evaluation criteria, then MO resistors, equal in number to those used in parallel to the grading components in the arrester, shall be connected in parallel to the test sample, and two 8/20 lightning impulses with peak current density of at least 0,5 kA/cm^2 in the MO resistors shall be applied to the sample. The first impulse shall be applied after sufficient time to allow the cooling of the sample to ambient temperature. The second impulse is applied between 50 s to 60 s after the first impulse. The impedance of the grading components shall be measured at 20 °C ± 15 K before and after the two impulses. The samples shall have passed the test if

- oscillograms of voltage and current taken during each impulse reveal no electrical breakdown;
- the change in impedance of the grading components due to the two impulses is not greater than ±5 %.

9 Routine tests and acceptance tests

9.1 Routine tests

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

a) Measurement of power-frequency spark-over voltage on the arrester. The measured value shall be within a range specified by the manufacturer.

b) Residual voltage test. This test is compulsory for arresters with rated voltage above 1 kV. The test may be performed either on complete arresters or assembled arrester units. The manufacturer shall specify a suitable lightning current impulse in the range between 0,01 and 2 times 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 MO resistors or the individual arrester units. The residual voltage for the complete arrester shall not be higher than the value specified by the manufacturer.

   NOTE When 5 kA and 2,5 kA arresters below 36 kV rating are supplied in volume, the residual voltage test may be omitted in the routine tests if agreed between manufacturer and user.

c) Internal partial discharge test. This test shall be performed on each arrester unit. The test sample may be shielded against external partial discharges.

   The power-frequency voltage shall be increased to the rated voltage of the sample, held for 2 s to 10 s, and then decreased to 1,05 times the continuous operating voltage of the sample. At that voltage, the partial discharge level shall be measured according to IEC 60270. The measured value for the internal partial discharge shall not exceed 10 pC. Alternatively, the manufacturer may carry out the partial discharge measurement at the rated voltage or at a higher value without reducing the test voltage afterwards.

d) In order to reduce test efforts during production, higher values of seal leak rate than required for type testing (see 8.13.4) may be used in this routine test for verification of correct assembly; for arrester units with an enclosed gas volume and separate sealing system, a leakage check shall be made on each unit by any sensitive method adopted by the manufacturer.

e) Proper assembly of each disconnector has to be demonstrated by either measurement of resistance / capacitance or partial discharges. The values of resistance or capacitance shall be in a range specified by the manufacturer. The measured value for the partial discharge shall not exceed 10 pC.

9.2 Acceptance tests

9.2.1 Standard 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 power-frequency spark-over voltage on the arrester. The measured value shall be within a range specified by the manufacturer.

b) Lightning impulse residual voltage on the arrester at nominal discharge current if possible or at a current value chosen according to 8.3. In this case, the virtual time to half-value is less important and need not be complied with.

   For a multi-unit arrester, measurements may be made on individual units of the arrester. The residual voltage of the complete arrester is taken as the sum of the residual voltages of the individual arrester units.

   The residual voltage for the complete arrester shall not be higher than a value specified by the manufacturer.

c) Internal partial discharge test

   The test shall be performed on the complete arrester or, for a multi-unit arrester, on the individual units of the arrester. The test sample may be shielded against external partial discharges.

   The power-frequency voltage shall be increased to the rated voltage of the sample, held for 2 s to 10 s, and then decreased to 1,05 times the continuous operating voltage of the sample. At that voltage, the partial discharge level shall be measured according to IEC 60270. The measured value for the internal partial discharge shall not exceed 10 pC.

Any alteration in the number of test samples or type of test shall be negotiated between the manufacturer and the user.

9.2.2 Special thermal stability test

The following test requires additional agreement between manufacturer and user prior to the commencement of arrester assembly (see 6.6).

This test shall be performed on three sections using MO resistors taken from current routine production and having the same dimensions and characteristics as those of the arresters under test. The test consists of the thermal recovery portion of the operating duty test (see 8.5.2.3).

MO resistor temperature or resistive component of current or power dissipation shall be monitored during the power frequency voltage application to prove thermal stability. The test is passed if thermal stability occurs in all three samples (see 8.5.2.4). If one sample fails, agreement shall be reached between the manufacturer and the user regarding any further tests.

10 Test requirements on polymer-housed surge arresters

Clauses 1 to 5 and Clause 7 apply in their entirety to polymer-housed arresters. Many of the requirements in Clause 6 and many of the tests prescribed in Clause 8 also apply without change to polymer-housed arresters. Where there is a variation, of any degree, from the requirements of Clauses 6 and 8, that variation is provided here for polymer-housed arresters.

10.1 Scope

Clause 1 applies without modification.

10.2 Normative references

Clause 2 applies without modification.

10.3 Terms and definitions

Clause 3 applies without modification.

10.4 Identification and classification

Clause 4 applies without modification.

10.5 Standard ratings and service conditions

Clause 5 applies without modification.

10.6 Requirements

Clause 6 applies except as follows:

10.6.11 Short-circuit performance

Replacement of Subclause 6.11:

The manufacturer shall declare a short-circuit current rating for each family of arresters. Only for applications with expected short-circuit currents below 1 kA the rated value “zero” may be claimed. In this case “0” shall be indicated on the name plate. In any case, the arrester shall be subjected to a short-circuit test according to 10.8.9 to show that it will not fail in a manner that causes violent shattering of the housing and that self-extinguishing of open flames (if any) occurs within a defined period of time.

10.6.15.2 Bending moment

Replacement of Subclause 6.15.2:

The arrester shall be able to withstand the manufacturer's declared values for bending loads (see 10.8.10).

NOTE 1 Forces other than those applied by physical connections might affect the mechanical loading of an arrester; for example: wind, ice and electromagnetic forces.

NOTE 2 Unlike porcelain housed arresters, polymer-housed arresters might show mechanical deflections in service

Surge arresters enclosed within their package should withstand the transportation loads specified by the user in accordance with IEC 60721-3-2, but not less than Class 2M1.

10.6.15.4 Insulating base

Replacement of Subclause 6.15.4:

When an arrester is fitted with an insulating base, this device shall withstand the following test without any damage, which could affect its normal function:

– test of the bending moment (see 8.10.6).

10.7 General testing procedure

Clause 7 applies without modification.

10.8 Type tests (design tests)

10.8.1 General

Amendment of Subclause 10.8.1:

Type tests shall be performed as defined in Clause 8, except for specific changes indicated below (list numbers refer to numbers in rows of Table 3):

10) Environmental tests do not apply

In addition, the following test is to be made for polymer-housed arresters intended for outdoor use

14) Weather ageing test (see 10.8.15)

10.8.2 Insulation withstand tests

Subclause 8.2 applies without modification.

10.8.3 Impulse protective level tests

Subclause 8.3 applies without modification.

10.8.4 Test to verify the repetitive charge transfer rating, Q_{rs}

Subclause 8.4 applies without modification.

10.8.5 Operating Duty tests

Subclause 8.5 applies except as follows:.

10.8.5.2.4 Test evaluation

Replacement of Subclause 8.5.2.4:

The test shall be considered passed if all the following criteria are met:

- thermal recovery has been demonstrated;
- any change of the residual voltage at nominal discharge current before and after the test is within ± 5 %;
- the following requirements are met:
  - if the manufacturer declares that the resistors may be removed from the test sample, a visual examination of the resistors shall be made and it shall be verified that the test has not caused puncture, flashover or cracking of the resistors.
  - if the manufacturer declares that the MO resistors cannot be removed from the test sample for visual examination, the following additional test shall be performed to be sure that no damage occurred during the test:
    - i) after the check of residual voltage at In, two further current impulses 8/20 at In shall be applied to the sample. The first impulse shall be applied after sufficient time to allow the cooling of the sample to ambient temperature. The second impulse shall be applied between 50 s to 60 s after the first one. During the two impulses, the oscillograms of both voltage and current shall not reveal any breakdown. The variation of the residual voltage between the initial measurement and the last impulse shall not be greater than ± 5 %.

10.8.6 Power frequency voltage-versus-time test

Subclause 8.6 applies, except as follows:

10.8.6.5 Test evaluation

Replacement of Subclause 8.6.5:

A sample shall be considered passed if all the following criteria are met:

- thermal recovery has been demonstrated;
- any change of the residual voltage at nominal discharge current before and after the test is within ± 5 %.
- the following requirements are met:
  - if the manufacturer declares that the resistors may be removed from the test sample, a visual examination of the resistors shall be made and it shall be verified that the test has not caused puncture, flashover or cracking of the resistors.
  - If the manufacturer declares that the MO resistors cannot be removed from the test sample for visual examination, the following additional test shall be performed to be sure that no damage occurred during the test:
    i) after the check of residual voltage at I_{n}, two current impulses 8/20 of an amplitude resulting in a current density of at least 0,5 kA/cm² or in 2 times I_{n}, whichever is lower, shall be applied to the sample. The first impulse shall be applied after sufficient time to allow the cooling of the sample to ambient temperature. The second impulse shall be applied between 50 s to 60 s after the first one. During the two impulses, the oscillograms of both voltage and current shall not reveal any breakdown.

The manufacturer’s published curve has been verified when all six samples have been tested at TOV voltages and corresponding durations that are equal to or greater than the values indicated on the curve, and all samples have passed the evaluation criteria. All test points shall be displayed on the curve.

10.8.7 Tests of arrester disconnectors

Subclause 8.7 applies without modification.

10.8.8 Power frequency voltage sparkover tests

Subclause 8.8 applies without modification.

10.8.9 Short-circuit tests

Subclause 8.9 applies, except as follows:

10.8.9.2 Preparation of the test samples

Replacement of Subclause 8.9.2:

Depending on the type of arrester and test voltage, different requirements apply with regard to the number of test samples, initiation of short-circuit current and amplitude of the first short-circuit current peak. Table 8 shows a summary of these requirements.

For the high-current tests, the test samples shall be the longest arrester unit used for the design with the highest rated voltage of that unit used for each different arrester design.

For the low-current test, the test sample shall be an arrester unit of any length with the highest rated voltage of that unit used for each different arrester design. Figure 5 shows different examples of arrester units.

10.8.9.2.3 "Design B" arresters

Replacement of Subclause 8.9.2.3:

The samples shall be prepared with means for conducting the required short-circuit current using a fuse wire across the internal gap. The fuse wire shall be in direct contact with the gap structure as illustrated in Figure 7 for different possible constructions of Design B arresters. The actual location of the fuse wire in the test shall be reported in the test report.

The overvoltage shall be run on completely assembled test units. No physical modification shall be made to the units between pre-failing and the actual short-circuit current test.

The overvoltage given by the manufacturer shall be a voltage exceeding 1,15 times U_c. The voltage shall cause the arrester to fail within (5 ± 3) min. The MO resistors are considered to have failed when the voltage across the MO resistors falls below 10 % of the originally applied voltage. The short-circuit current of the pre-failing test circuit 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 can be achieved by either applying a voltage source or a current source to the samples.

- Voltage source method: the initial current should typically be in the range 5-10 mA/cm^2. The short-circuit current should typically be between 1 A and 30 A. The voltage source need not be adjusted after the initial setting, although small adjustments might be necessary in order to fail the MO resistors in the given time range.
- Current source method: Typically a current density of around 15 mA/cm^2 with a variation of ±50 %, will result in failure of the MO resistors in the given time range. The 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 MO resistors in the given time range.

Table 8 – Test requirements for polymer-housed arresters

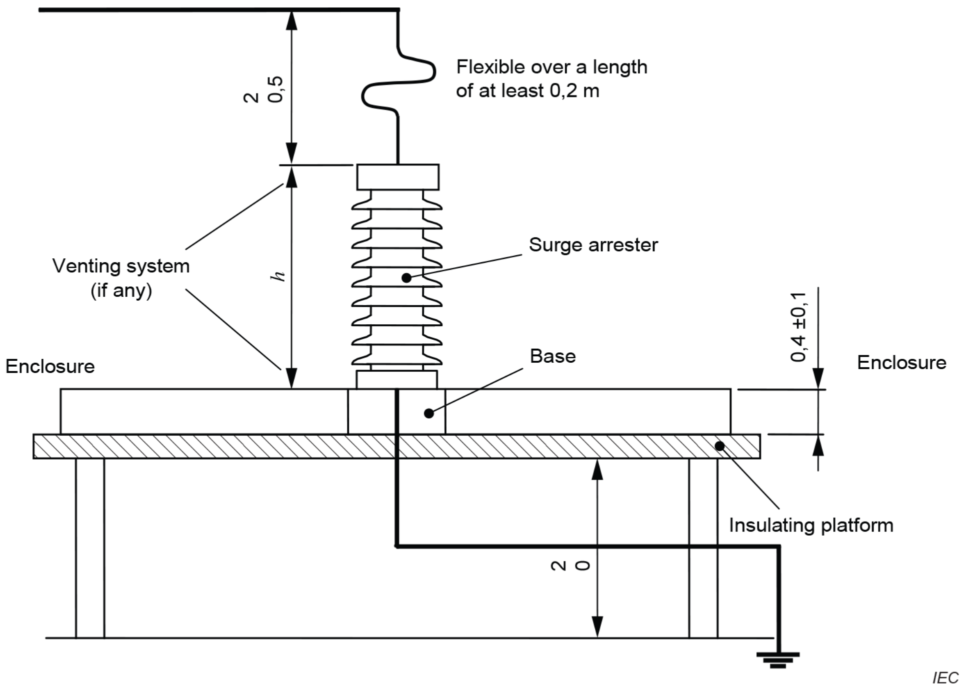
	Required number of test samples	Initiation of short-circuit current	Ratio of first current peak value to r.m.s. value of required short-circuit current taken from Table 7					
			Test voltage: 77 % to 107 % of U_r			Test voltage: < 77 % of U_r		
			Rated short-circuit current	Reduced short-circuit current	Low short-circuit current	Rated short-circuit current	Reduced short-circuit current	Low short-circuit current
"Design B"	4	Pre-failing by constant voltage or constant current source	Prospective: ≥ √2 Actual: no requirement	Prospective: ≥ √2 Actual: no requirement	Actual: ≥ √2	Actual: ≥ √2	Actual: ≥ √2	Actual: ≥ √2

10.8.9.3 Mounting of the test sample

Replacement of Subclause 8.9.3:

For a base-mounted arrester, the mounting arrangement is shown in Figure 9. The distance to the ground from the insulating platform and the conductors shall be as indicated in this figure.

Dimensions in metres



NOTE All leads and venting systems in the same plane.

Figure 9 – Short-circuit test setup for polymer-housed arresters

For non-base-mounted arresters (for example, pole-mounted arresters), the test sample shall be mounted on a non-metallic pole using mounting brackets and 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. In cases where the foregoing is at variance with the manufacturer's instructions, the arrester shall be mounted in accordance with the installation recommendations of the manufacturer. The entire lead between the base and the current sensor shall be insulated for at least 1 000 V. The top end of the test sample shall be fitted with the base assembly of the same design of an arrester or with the top cap.

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 9. 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 grounded), except for the base of the arrester, shall be at least 1,6 times 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 Equation (1) below. The enclosure shall not be permitted to open or move during the test.

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

where

H is the height of tested arrester unit;

D_{arr} is the diameter of tested arrester unit.

In the event that physical space limitations of the laboratory do not permit an enclosure of the specified size, the manufacturer may choose to use an enclosure of lesser diameter.

Test samples shall be mounted vertically unless agreed upon otherwise between the manufacturer and the user.

The mounting of the arrester during the short-circuit test and, more specifically, the routing of the conductors shall represent the most unfavourable condition in service. For all polymer-housed arresters, the ground conductor shall be directed to the opposite direction as the incoming conductor, as described in Figure 9. In this way, the arc will stay close to the arrester during the entire duration of the short-circuit current, thus creating the most unfavourable conditions with regards to the fire hazard.

10.8.9.4.3 High-current test at less than 77 % of rated voltage

Replacement of Subclause 8.9.4.3:

When tests are made with a test circuit voltage $<$ 77 % of the rated voltage of the test samples, the test circuit parameters shall be adjusted in such a way that the RMS value of the symmetrical component of the actual arrester test current shall equal or exceed the required test current level selected from Table 7.

For “Design B” arresters tested at rated short-circuit current, the peak value of the first half-cycle of the actual arrester test current shall be at least $\sqrt{2}$ times the RMS value of the rated short circuit current.

For all the reduced short-circuit currents the RMS value shall be in accordance with Table 7 and the peak value of the first half-cycle of the actual arrester test current shall be at least $\sqrt{2}$ times the RMS value of this current.

Especially for tall arresters that are tested at a low percentage of their rated voltage, the first asymmetric peak current of 2,5 is not easily achieved unless special test possibilities are considered. It is thus possible to increase the test RMS voltage or reduce the impedance so that, for the rated short-circuit current, the peak value of the first half-cycle of the test current is equal to, or greater than, 2,5 times the required test current level. In case of testing with a generator, the first peak of 2,5 times the required test current can also be achieved by varying the generator’s excitation. The current should then be reduced, not less than 2,5 cycles after initiation, to the required symmetrical value. The actual peak value of the test current, divided by 2,5, should be quoted as the test current, even though the RMS value of the symmetrical component of the actual arrester test current may be higher. Because of the higher test current, the sample arrester may be subjected to more severe duty and, therefore, tests at X/R ratio lower than 15 should only be carried out with the manufacturer’s consent.

For “Design B” polymer-housed arresters, even the first current peak of $\sqrt{2}$ may not be easily achieved unless special test facilities are considered. Pre-failed arresters can build up considerable arc resistance, which limits the symmetrical 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 pre-failing, or similar, circuit during a maximum of 2 s immediately before applying the short-circuit test current (see Figure 10). It is acceptable to increase the short-circuit current of the pre-applied circuit up to 300 A (RMS). If so, its maximum duration, which depends on the current magnitude, shall not exceed the following value:

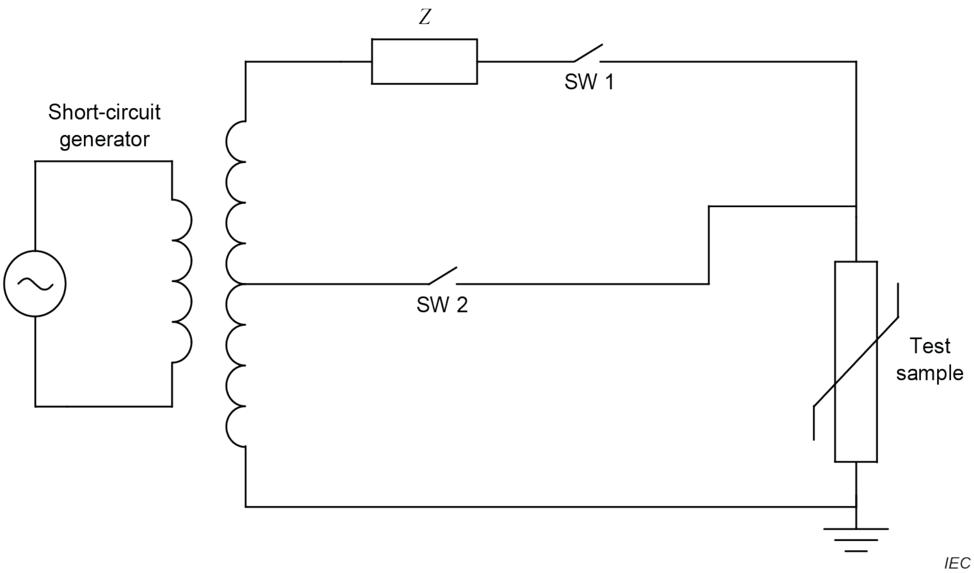
$$t_{rpf} \leq Q_{rpf} / I_{rpf}$$

where

t_{rpf} is the re-pre-failing time in s;

Q_{rpf} is the re-pre-failing charge = 60 As;

I_{rpf} is the re-pre-failing current in A (RMS).



NOTE SW 1 is closed and SW 2 is opened to apply pre-failing level of current (maximum of 30 A, limited by impedance Z). After a maximum of 2 s, SW 2 is closed to cause the specified short-circuit current to flow through the test sample.

Figure 10 – Example of a test circuit for re-applying pre-failing circuit immediately before applying the short-circuit test current

10.8.10 Test of the bending moment

Replacement of Subclause 8.10:

This test applies to polymer (except cast-resin) housed arresters (with and without enclosed gas volume) for which the manufacturer claims cantilever strength. The test shall be performed on the arrester without insulating base or mounting bracket.

Cast-resin housed arresters shall be tested according to 8.10. Arresters that have no declared cantilever strength shall be submitted to the terminal torque preconditioning according to 10.8.10.3.1, the thermal preconditioning according to 10.8.10.3.2 and the water immersion test according to 10.8.10.3.3.

The complete test procedure is shown by the flow chart in Annex C.

10.8.10.1 General

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 arrester units with the highest rated voltage of the unit. For single-unit arrester designs, the test shall be performed on the longest unit with the highest rated voltage of that unit of the design. Where an arrester contains more than one unit or where the arrester has different specified bending moments in both ends, the test shall be performed on the longest unit of each different specified bending moment, with loads determined according to C.1. However, if the length of the longest unit is greater than 800 mm, a shorter length unit may be used, provided the following requirements are met:

- the length is at least as long as the greater of
  - 800 mm
  - three times the outside diameter of the housing (excluding the sheds) at the point it enters the end fittings;
- the unit is one of the normal assortment of units used in the design, and is not specially made for the test;
- the unit has the highest rated voltage of that unit of the design.

A two–step test shall be performed one after the other on three samples as follows:

- On two of the samples a static bending moment test with the test load equal to the specified short-term load (SSL), i.e. the 100 % value of C.2 and on the 3rd sample a mechanical preconditioning test as per 10.8.10.3;
- on all three samples a water immersion test as per 10.8.10.3.3.

Tolerance on specified loads shall be $^{+5}_{-0}\%$.

10.8.10.2 Sample preparation

The test samples shall contain the internal parts.

Prior to the test, each test sample shall be subjected to the following tests:

- electrical tests made in the following sequence:
  - watt losses measured at Uc and at an ambient temperature of 20 °C ± 15 K;
  - internal partial discharge test according to item c) of 9.1;
  - residual voltage test at (0,01 to 1) times the nominal discharge current; the current wave shape shall be in the range of T_1/T_2 = (4 to 10)/(10 to 25) μs;
- leakage tests in accordance with item d) of 9.1 for arresters with enclosed gas volume and separate sealing system.

If the partial discharge test according to item c) of 9.1 and the leakage test according to item d) of 9.1 have been performed as routine tests they need not be repeated at this time.

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.

10.8.10.2.1 Test procedure

The test shall be performed on three samples.

Step 1.1:

Subject two samples to a bending moment test. The bending load shall be increased smoothly to specified short-term load (SSL) within 30 s to 90 s. When the test load is reached, it shall be maintained for 60 s to 90 s. During this time the deflection shall be measured. Then the load shall be released smoothly.

The maximum deflection during the test and any 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.

Step 1.2:

Subject a third sample to mechanical/thermal preconditioning according to 10.8.10.3.

Step 2:

Subject all three samples to the water immersion test according to 10.8.10.3.3.

10.8.10.3 Mechanical/thermal preconditioning

This preconditioning constitutes part of the test procedure of 10.8.10.2.1 and shall be performed on one of the test samples as defined in 10.8.10.2.1.

10.8.10.3.1 Terminal torque preconditioning

The arrester terminal torque specified by the manufacturer shall be applied to the test sample for a duration of 30 s.

10.8.10.3.2 Thermo-mechanical preconditioning

This portion of the test applies only to arresters for which a cantilever strength is declared.

The sample is submitted to the specified long-term load (SLL) in four directions and in thermal variations as described in Figure 11 and Figure 12.

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

The thermal variations consist of two 48 h cycles of heating and cooling as described in Figure 11. The temperature shall be measured in the air surrounding the arrester in the test chamber. The temperature of the hot and cold periods shall be maintained for at least 16 h. The test 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 at any temperature in the transition from hot to cold, or from cold to hot, as defined in Figure 11.

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

Any residual deflection measured from the initial no-load position shall be reported. The residual deflection shall be measured within 1 min to 10 min after the release of the load.

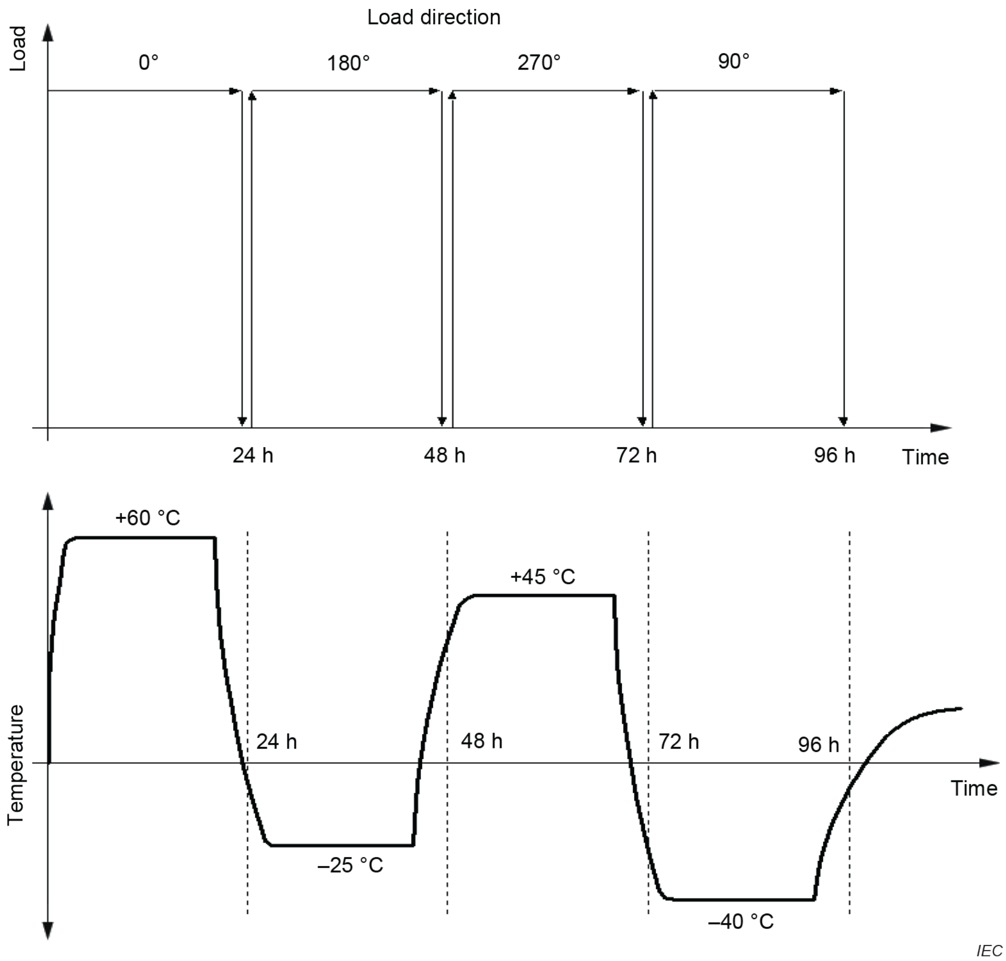


Figure 11 – Thermomechanical test

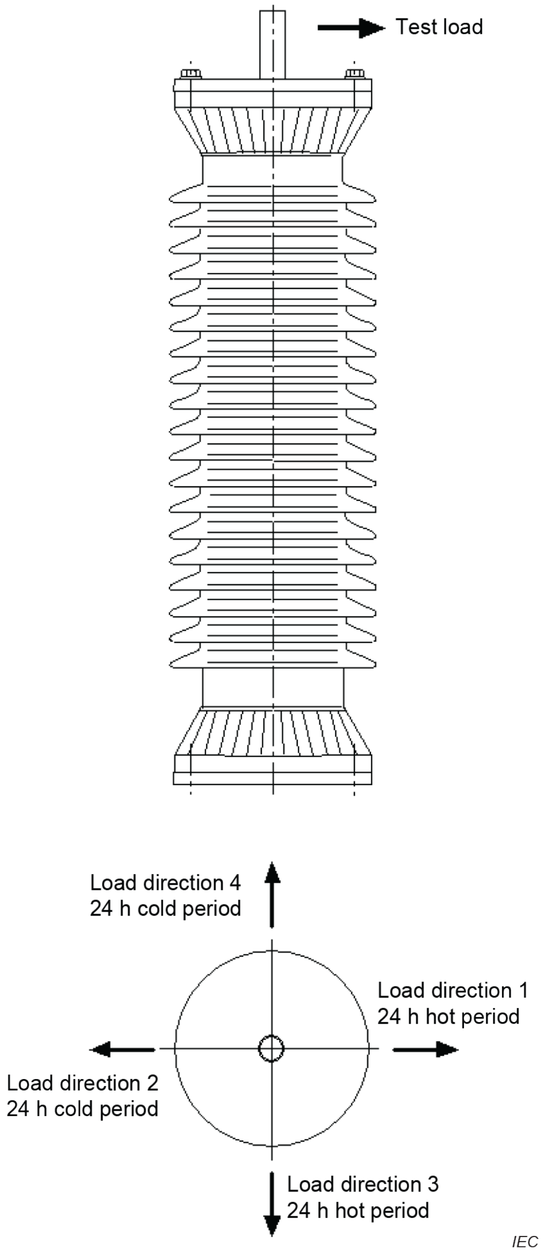


Figure 12 – Example of the test arrangement for the thermomechanical test and direction of the cantilever load

10.8.10.3.2.1 Thermal preconditioning

This portion of the test applies only to arresters for which no cantilever strength is declared.

The sample is submitted to the thermal variations as described in Figure 11 without any load applied.

The thermal variations consist of two 48 h cycles of heating and cooling as described in Figure 11. The temperature of the hot and cold periods shall be maintained for at least 16 h. The test shall be conducted in air.

10.8.10.3.3 Water immersion test

The test samples shall be kept immersed in a vessel, in boiling deionised water with 1 kg/m^3 of NaCl, for 42 h.

NOTE 1 The characteristics of the water described above are those measured at the beginning of the test.

NOTE 2 This temperature (boiling water) can be reduced to 80 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 can be expanded up to 168 h (i.e. one week) after agreement between the manufacturer and the user.

At the end of the boiling, the arrester shall remain in the vessel until the water cools to approximately 50 °C and shall be maintained in the water at this temperature until verification tests can be performed. The arrester shall be removed from the water and cooled to ambient temperature for not longer than three thermal time constants of the sample (as derived from the cooling curves of 10.8.5). The 50 °C holding temperature is necessary only if it is necessary to delay the verification tests after the end of the water immersion test as shown in Figure 13. Evaluation tests shall be made within the time specified in 10.8.10.4. After removing the sample from the water it may be washed with tap water.

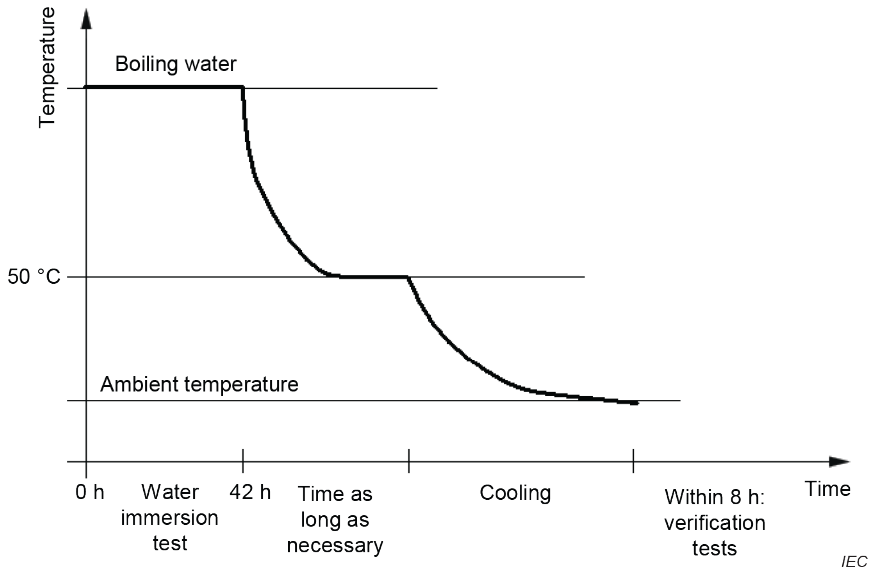


Figure 13 – Water immersion

10.8.10.4 Test evaluation

Tests according to 10.8.11.2 shall be repeated on each test sample.

The arrester shall have passed the test if the following is demonstrated:

After step 1:

- there is no visible damage;
- for step 1.1, 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 s^{-1}. The cut-off frequency of the measuring equipment shall be not less than 5 Hz.

  Maximum deflection during step 1 and any remaining permanent deflection after the test shall be reported.

After step 2:

- within 8 h after cooling as defined in Figure 13:
  - the increase in watt losses, measured at U_c 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 U_c (measured at U_c) or 20 %;

  - the internal partial discharge measured at 1,05 times U_c does not exceed 10 pC;
- at any time after the above watt losses and partial discharge measurements:
  - for arresters with enclosed gas volume and separate sealing system, the samples pass the leakage test in accordance with item d) of 9.1;
  - the residual voltage measured at the same current value and wave shape as the initial measurement is not more than 5 % different from the initial measurement;
  - the difference in voltage between two successive impulses at nominal discharge current does not exceed 2 %, and the oscillograms of voltage and current do not reveal any partial or full breakdown of the test sample. The current wave shape shall be in the range of T_1/T_2 = (4 to 10)/(10 to 25) μs and the impulses shall be administered 50 to 60 s apart.

NOTE 2 In case of extra-long arresters where the blocks can be dismantled, the residual voltage test can be performed on individual blocks or stacks of blocks. If the blocks cannot be dismantled, a possible procedure would be to drill a hole in the arrester insulation to make contact with the internal stack at a metal spacer and in this way be able to test shorter arrester sections.

10.8.11 Environmental tests

Subclause 8.11 does not apply.

10.8.12 Seal leak rate test

Subclause 8.12 applies, except as follows:

Replacement of Subclause 8.12.1:

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

10.8.13 Test to verify the dielectric withstand of internal components

Subclause 8.13 applies without modification.

10.8.14 Test of internal grading components

Subclause 8.14 applies without modification.

Addition:

10.8.15 Weather ageing test

10.8.15.1 General

This test has two parts. One evaluates the effect of exposure of the arrester to salt fog. The other evaluates the effect of exposure of the housing material to ultra-violet (UV) light.

10.8.15.2 Salt fog test

10.8.15.2.1 Test specimens

This test shall be performed on the longest electrical unit with the minimum specific creepage distance and the highest rated voltage recommended by the manufacturer for this unit.

10.8.15.2.2 Test procedure

The test is a time-limited continuous test under salt fog at constant power-frequency voltage equal to U_c. The test is carried out in a moisture-sealed corrosion-proof chamber. An aperture of not more than 80 cm^2 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 power-frequency test voltage shall be obtained with a test transformer. The test circuit, when loaded with a resistive current of 250 mA (RMS) during 1 s on the high-voltage side, shall experience a maximum voltage drop of 5 %.

The protection level shall be set at 1 A (RMS). 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 enough 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 $l/h/m^3 \pm 0,1\ l/h/m^3$
- Size of droplets 5 μm to 10 μm
- Temperature 20 °C ± 5 K
- NaCl content of water between 1 kg/m^3 to 10 kg/m^3

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 recirculate 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 re-started 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 noted. The number of overcurrent trip-outs shall be noted and taken into account in the evaluation of the duration of the test.

NOTE 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.

10.8.15.2.3 Evaluation of the test

The test is regarded as passed, if no tracking occurs (see IEC 62217), if erosion does not occur through the entire thickness of any shed or other part of the external coating up to the next layer of material, if the sheds and housing are not punctured, if the Power frequency sparkover voltage test measured before and after the test at the same ambient temperature within ± 3 K has not decreased by more than 10 %, and if the partial discharge measurement performed before and after the test is satisfactory, i.e. the partial discharge level shall not exceed 10 pC as measured according to the procedure of 9.1 c).

10.8.15.3 UV light test

10.8.15.3.1 Test procedure

Select three specimens of shed and housing materials for this test (with markings included, if applicable). The insulator housing material 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: ISO 4892-1 and ISO 4892-2, using method A without dark periods, standard spray cycle, black-standard/black panel temperatures of 65 °C, an irradiance of around 550 W/m^2.
- Fluorescent UV method: ISO 4892-1 and ISO 4892-3, using type I fluorescent UV lamp, exposure method 1 or 2.

10.8.15.3.2 Evaluation of the test

After the test, markings on shed or housing material shall be legible; surface degradations such as cracks and raised areas are not permitted. In case of doubt concerning such degradation, two surface roughness measurements shall be made on each of the three specimens. The roughness, R_z as defined in ISO 4287, shall be measured along a sampling length of at least 2,5 mm. R_z shall not exceed 0,1 mm.

NOTE ISO 3274 gives details of surface roughness measurement instruments.

10.9 Routine tests

Clause 9 applies without modification.

Annex A
(normative)

Special Environmental 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.

1) Temperature in excess of +40 °C or below –40 °C.
2) Application at altitudes higher than 1 000 m.
3) Fumes or vapours which may cause deterioration of insulating surface or mounting hardware.
4) Excessive contamination by smoke, dirt, salt spray or other conducting materials.
5) Excessive exposure to moisture, humidity, dropping water or steam.
6) Live washing of arrester.
7) Explosive mixtures of dust, gases or fumes.
8) Abnormal mechanical conditions (earthquakes, vibrations, high wind velocities, high ice loads, high cantilever stresses).
9) Unusual transportation or storage.
10) Nominal frequencies below 48 Hz and above 62 Hz.
11) Heat sources near the arrester (see 5.4 b)).
12) Wind speed > 34 m/s.
13) Non-vertical erection and suspended erection.
14) Torsional loading of the arrester
15) Tensile loading of the arrester
16) Use of the arrester as a mechanical support.

Annex B
(normative)

Typical information given with enquiries and tenders

B.1 Information given with enquiry

B.1.1 System data

- –Highest system voltage.
- Frequency.
- Maximum voltage to earth under system fault conditions (earth fault factor or system of neutral earthing).
- Maximum duration of the earth fault.
- Maximum value of temporary overvoltages and their maximum duration (earth fault, loss of load, ferro-resonance).
- Insulation level of equipment to be protected.
- Short-circuit current of the system at the arrester location.

B.1.2 Service conditions

For normal conditions, see 5.4.1.

Special environmental conditions:

a) For ambient conditions, see 5.4.2 and Annex A:
   - for the natural pollution level, see IEC 60071-2.

b) System:
   - possibility of generator overspeeding (voltage-versus-time characteristics);
   - nominal power frequency other than 48 Hz to 62 Hz;
   - load rejection and simultaneous earth faults. Formation during faults of a part of the system with an insulated neutral in a normally effectively earthed neutral system;
   - incorrect compensation of the earth fault current.

Any other special requirements with respect to service conditions shall be specified and quantified as far as possible.

B.1.3 Arrester duty

a) Connection to system:
   - phase to earth;
   - neutral to earth;
   - phase to phase.

b) Type of equipment being protected:
   - transformers (directly connected to a line or via cables);
   - rotating machines (directly connected to a line or via transformers);
   - reactors;
   - HF-reactors;
   - other equipment of substations;
   - gas-insulated substations (GIS);

- capacitor banks;
- cables (type and length), etc.

Maximum length of high-voltage conductor between arrester and equipment to be protected (protection distance).

B.1.4 Characteristics of arrester

Continuous operating voltage.

Rated voltage.

Steep current impulse residual voltage.

Standard nominal discharge current and residual voltages.

Switching current impulses and residual voltages.

For 10 kA and 20 kA arresters, repetitive charge transfer rating and thermal energy rating.

Short circuit rating.

Length and shape of creepage distance of arrester housing. Selected on the basis of service experience with surge arresters and/or other types of equipment in the actual area.

B.1.5 Additional equipment and fittings

Metal-enclosed arrester.

Type of mounting: pedestal, bracket, hanging (in what position) etc. and if insulating base is required for connection of surge counters. For bracket-mounted arresters, whether bracket is to be earthed or not.

Mounting orientation if other than vertical.

Earth lead disconnector/fault indicator if required.

Cross-section of connection lead.

B.1.6 Any special abnormal conditions

Any other special requirements in respect to service conditions shall be specified and quantified as far as possible.

B.2 Information given with tender

All items from B.1.4 and B.1.5.

In addition:

- reference current and voltage at ambient temperature;
- power-frequency voltage versus time characteristics (see 8.6);
- lightning impulse residual voltage at 0,5, 1 and 2 times the nominal discharge current. If the complete arrester acceptance test cannot be carried out at one of those currents, the

residual voltage shall in addition be specified for current in the range of 0,01 to 0,25 times the nominal discharge current, see 6.3 and 8.3;

- pressure-relief function;
- clearances;
- mounting specifications;
- possibilities of mounting, drilling plans, insulating base, bracket;
- type of arrester terminals and permissible conductor size;
- maximum permissible length of lead between arrester and surge counter, and between surge counter and earth;
- dimensions and weights;
- cantilever strength.

Annex C
(normative)

Mechanical considerations

C.1 Test of bending moment

In the case of a multi-unit arrester, each unit shall be tested with the bending moment according to Figure C.1. If the units differ only in length, but are otherwise identical from material and design, it is not necessary to test each unit.

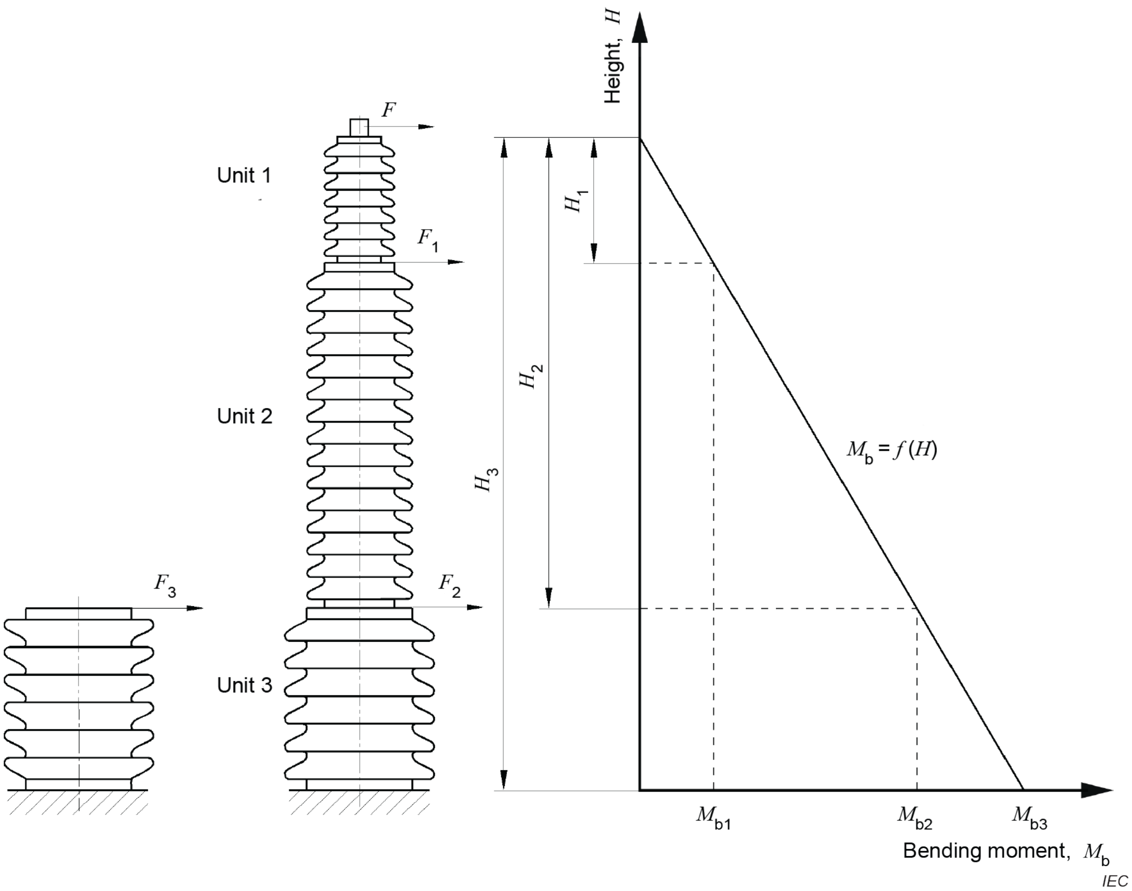


Figure C.1 – Bending moment – multi-unit surge arrester

Testing the complete arrester, the moment affecting the bottom flange is $M_{b3} = F \times H_3$.

The moment affecting the top flange of the bottom unit is $M_{b2} = F \times H_2$.

If one unit is tested separately (example for unit 3), the test force F_2 for the test of the bottom flange of unit 3 is as follows:

$$F_2 \times (H_3 - H_2) = F \times H_3;$$

$$F_2 = \frac{F \times H_3}{(H_3 - H_2)}$$

The test of the top flange of unit 3 shall be performed with the unit in reversed position. Test force F_3 for the test of the top flange of unit 3 is as follows:

$$F_3 \times (H_3 - H_2) = F \times H_2$$

$$F_3 = \frac{F \times H_2}{(H_3 - H_2)}$$

C.2 Definition of mechanical loads

Figure C.2 indicates the relationships between mechanical load ratings.

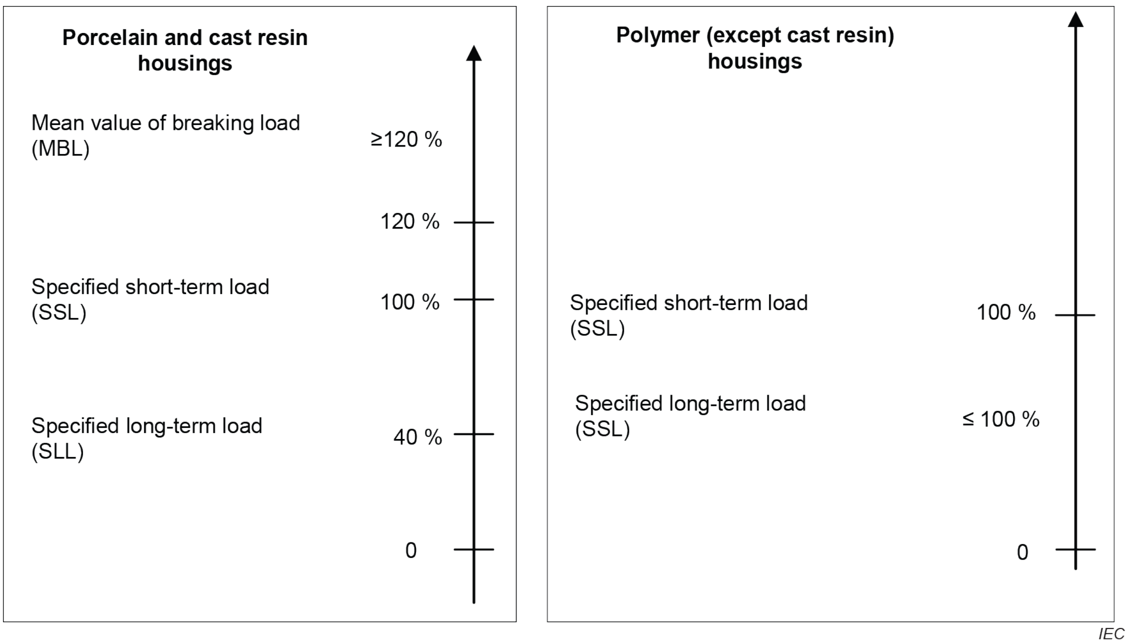


Figure C.2 – Definition of mechanical loads

C.3 Definition of seal leak rate

Figure C.3 schematically represents an arrester unit.

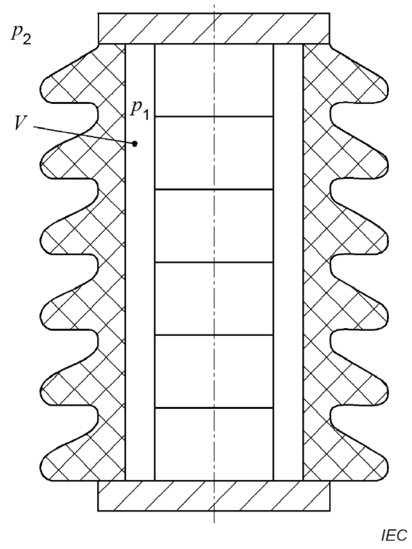


Figure C.3 – Surge arrester unit

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 $|p_1 - p_2| \geq 70\ \text{kPa}$ and at a temperature of +20 °C ± 15 K,

where

$\Delta p_1 =$ $p_1(t_2) - p_1(t_1)$;

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

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

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

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

$\Delta t =$ $t_2 - t_1$;

V is the internal gas volume of the arrester (m^3).

C.4 Calculation of wind-bending-moment

Figure C.4 schematically represents an assembled arrester.

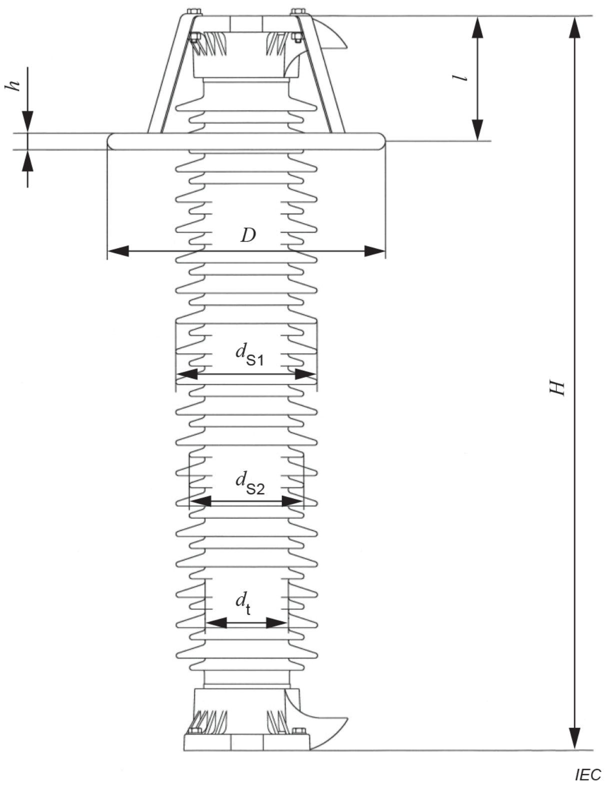


Figure C.4 – Surge-arrester dimensions

The wind-bending moment is given by

$$M_w = P \times H \times d_a \times C \times H/2 + P \times D \times h \times (H - l)$$

where

P = $(P_1/2) \times V^2$;

d_a = $(2d_t + d_{s1} + d_{s2})/4$ as per IEC 60815-2 ($d_{s1} = d_{s2}$ for non-alternating sheds)

M_w is the bending moment caused by the wind (Nm);

H is the height of the arrester (m);

d_a is the mean value of the insulator diameter (m);

h is the thickness of the grading ring (m);

D is the diameter of the grading ring (m);

l is the grading ring distance to the top (m);

C is the coefficient of drag for cylindrical parts; equal to 0,8;

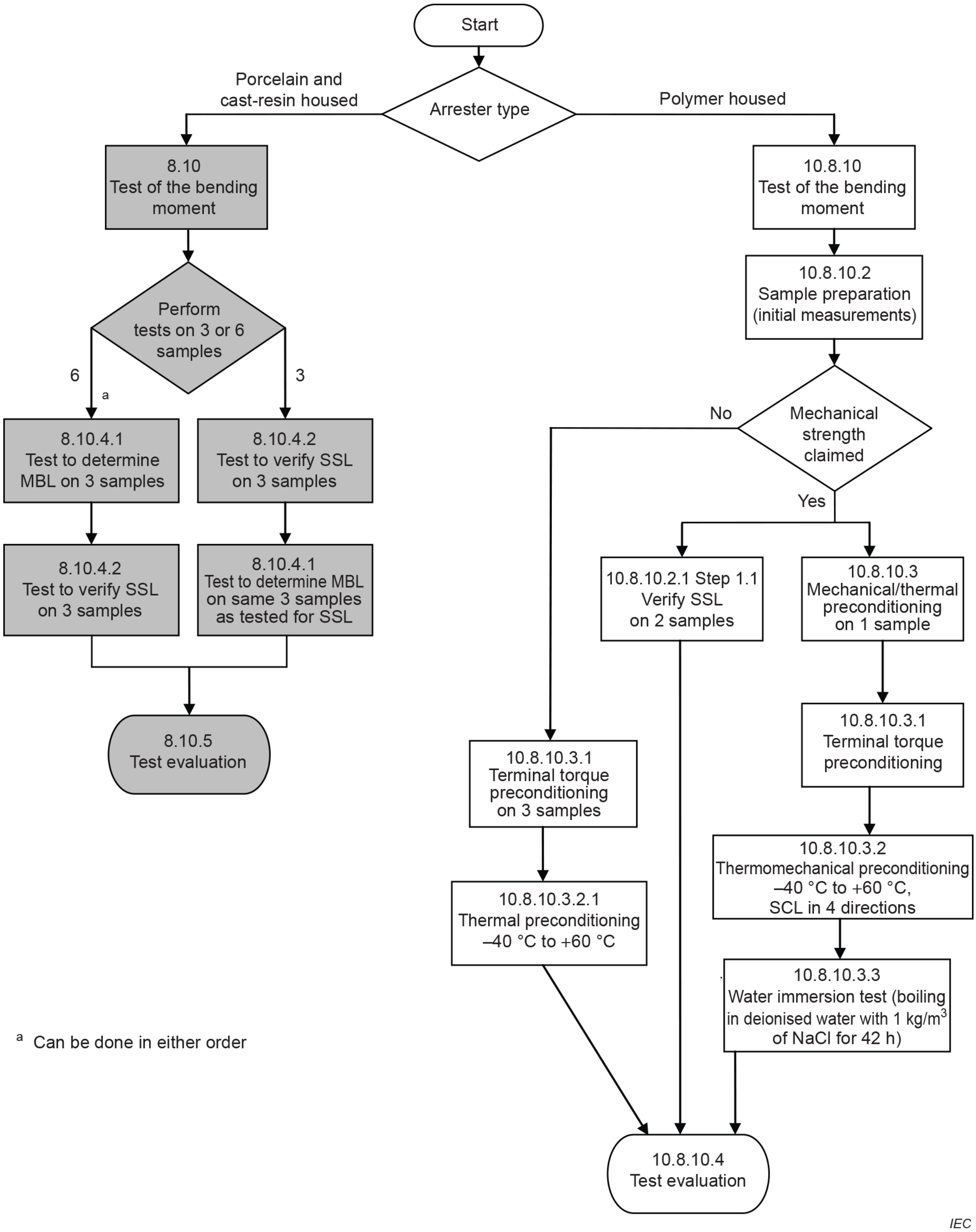
P is the dynamic pressure of the wind (N/m^2);

P_1 is the density of air at 1,013 bar and 0 °C; equal to 1,29 kg/m^3;

V is the wind velocity (m/s).

C.5 Procedures of tests of bending moment for porcelain/cast resin and polymer-housed arresters

A flow chart of the procedures is shown in Figure C.5.



[a] Can be done in either order

Figure C.5 – Flow chart of bending moment test procedures

____