

Australian Standard[®]

Surge arresters

Part 2: Metal-oxide surge arresters without gaps for a.c. systems

This Australian Standard was prepared by Committee EL/7, Power Switchgear. It was approved on behalf of the Council of Standards Australia on 12 August 1996 and published on 5 December 1996.

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Electricity Supply Association of Australia
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Part 2: Metal-oxide surge arresters without gaps for a.c. systems

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PREFACE

This Standard was prepared by the Standards Australia Committee EL/7 on Power Switchgear to supersede AS 1307.2, *Surge arresters (diverters)*, Part 2: *Metal-oxide type for a.c. systems*.

This Standard is Part 2 of a series which when completed will consist of the following:

AS

1307 Surge arresters

Part 1: Silicon carbide type for a.c. systems

Part 2: Metal-oxide surge arresters without gaps for a.c. systems

Part 3: Distribution type metal-oxide surge arresters with gaps for a.c. systems

Part 4: Application guide

This Standard is based on and contains the full text of IEC 99-4, *Surge arresters*, Part 4: *Metal-oxide surge arresters without gaps for a.c. systems* and includes changes for Australian conditions. The IEC text being amended has been retained and is shown boxed. The changes and additions are indicated by a marginal bar.

The objective of this Standard is to adopt IEC 99-4 where possible, and add requirements for—

- (a) tests for verification of spark production class;
- (b) seal leak and seal ageing tests;
- (c) polymer housing tests; and
- (d) multiple lightning surge operating duty test.

This Standard presents the minimum criteria for the requirements and testing of gapless metal-oxide surge arresters that are applied to a.c. power systems.

Arresters covered by this Standard are commonly applied to live/front overhead installations in place of the non-linear resistor type gapped arresters covered in AS 1307.1. Protection of low-voltage circuits, below 1 kV, is under consideration.

An accelerated ageing procedure is incorporated in the Standard to simulate the long-term effects of voltage and temperature on the metal-oxide arrester. This is necessary since the metal-oxide resistors will have system power frequency voltage across them during the time the arrester is in service.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

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STANDARDS AUSTRALIA

Australian Standard

Surge arresters

Part 2: Metal-oxide surge arresters without gaps for a.c. systems

SECTION 1 GENERAL

1.1 SCOPE This Standard applies to non-linear metal-oxide resistor type surge arresters without spark gaps designed to limit voltage surges on a.c. power circuits.

This standard basically applies to all metal-oxide surge arresters; however, polymeric housed, GIS, liquid immersed and other special designs may require special consideration in design, test and application.

This Standard basically applies to all metal-oxide surge arresters; however, polymeric housed arresters above 36 kV, GIS, liquid immersed and other special designs may require special consideration in design, test and application.

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

IEC 60-1: 1989, *High-voltage test techniques. Part 1: General definitions and test requirements.*

IEC 71: *Insulation co-ordination.*

IEC 71-2: 1976, *Insulation co-ordination. Part 2: Application guide.*

IEC 99-1: 1991, *Surge arresters. Part 1: Non-linear resistor type gapped arresters for a.c. systems.*

IEC 99-3: 1990, *Surge arresters. Part 3: Artificial pollution testing of surge arresters.*

IEC 270: 1981, *Partial discharge measurements.*

IEC 815: 1986, *Guide for the selection of insulators in respect of polluted conditions.*

1.2 REFERENCES The following Standards contain provisions which, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the Standards indicated below. Standards Australia maintains a register of currently valid International Standards.

AS

1018 Partial discharge measurements

1033 High voltage fuses (for rated voltages exceeding 1000 V)

1033.1 Part 1: Expulsion type

AS	
1307	Surge arresters (diverters)
1307.1	Part 1: Silicon carbide type for a.c. systems
1824	Insulation co-ordination (phase-to-earth and phase-to-phase, above 1 kV)
1824.2	Part 2: Application guide
1931	High voltage testing techniques
1931.1	Part 1: General definitions, test requirements, test procedures and measuring devices
2650	High voltage a.c. switchgear and controlgear—Common requirements
IEC	
507	Artificial pollution tests on high-voltage insulators to be used on a.c. systems
99	Surge arresters
99-3	Part 3: Artificial pollution testing of surge arresters
815	Guide for the selection of insulators in respect of polluted conditions
1109	Composite insulators for a.c. overhead lines with a nominal voltage greater than 1000V—Definitions, test methods and acceptance criteria
ASTM	
D2000	Classification system for rubber products in automotive applications (SAE recommended practice J200)
ENEL	
DY1009	Regulations for the testing of metal-oxide arresters without spark gaps and organic material casing for medium voltage grid

SECTION 2 DEFINITIONS

For the purpose of this Standard, the following definitions apply.

2.1 METAL-OXIDE SURGE ARRESTER WITHOUT GAPS An arrester having non-linear metal-oxide resistors connected in series and/or in parallel without any integrated series or parallel spark gaps.

2.2 NON-LINEAR METAL-OXIDE RESISTOR The 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.

2.3 INTERNAL GRADING SYSTEM OF AN ARRESTER Grading impedances, in particular grading capacitors connected in parallel to one single or to a group of non-linear metal-oxide resistors, to control the voltage distribution along the metal-oxide resistor stack.

2.4 GRADING RING OF AN ARRESTER A metal part, usually circular in shape, mounted to modify electrostatically the voltage distribution along the arrester.

2.5 SECTION OF AN ARRESTER A complete, suitably assembled part of an arrester necessary to represent the behaviour of a complete arrester with respect to a particular test. A section of an arrester is not necessarily a unit of an arrester.

2.6 UNIT OF AN ARRESTER A 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. A unit of an arrester is not necessarily a section of an arrester.

2.7 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.

2.7 PRESSURE RELIEF DEVICE OF AN ARRESTER A design or mechanism for relieving excessive internal pressure in an arrester housing (this includes an arrester housing which ruptures or vents to act as a pressure relief device e.g. a polymer housing) under conditions of either a sustained power follow current or fault current due to an internal fault.

2.8 RATED VOLTAGE OF AN ARRESTER (U_r) The maximum permissible r.m.s. value of power frequency voltage between its terminals at which it is designed to operate correctly under temporary overvoltage conditions as established in the operating duty tests (see Clause 7.5). The rated voltage is used as a reference parameter for the specification of operating characteristics.

NOTE: The rated voltage as defined in this document is the 10 s power frequency voltage used in the operating duty test after high current or long duration impulses. Tests used to establish the voltage rating in AS 1307.1 as well as some National Standards involve the application of repetitive impulses at nominal current with power frequency voltage applied. Attention is drawn to the fact that these two methods used to establish rating do not necessarily produce equivalent values. (A resolution to this discrepancy is under consideration).

2.9 CONTINUOUS OPERATING VOLTAGE OF AN ARRESTER (U_0) The continuous operating voltage is the designated permissible r.m.s. value of power frequency voltage that may be applied continuously between the arrester terminals in accordance with Clause 7.5.

2.10 RATED FREQUENCY OF AN ARRESTER The frequency of the power system on which the arrester is designed to be used.

2.11 DISRUPTIVE DISCHARGE The phenomena associated with the failure of insulation under electric stress, which include a collapse of voltage and the passage of current. The term applies to electrical breakdowns in solid, liquid and gaseous dielectric, and combinations of these.

NOTE: 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.

2.12 PUNCTURE (BREAKDOWN) A disruptive discharge through a solid.

2.13 FLASHOVER A disruptive discharge over a solid surface.

2.14 IMPULSE A 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.

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

2.15 DESIGNATION OF AN IMPULSE SHAPE A 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). It is written as T_1/T_2 , both in microseconds, the sign '/' having no mathematical meaning.

2.16 STEEP CURRENT IMPULSE A 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 . The virtual time to half value on the tail shall be not longer than 20 μs .

NOTE: The time to half on the tail is not critical and may have any tolerance during the residual voltage type tests (see Clause 7.3).

2.17 LIGHTNING CURRENT IMPULSE An 8/20 current impulse with limits on the adjustment of equipment such that the measured values are from 7 μs to 9 μs for the virtual front time and from 18 μs to 22 μs for the time to half value on the tail.

NOTE: The time to half value on the tail is not critical and may have any tolerance during the residual voltage type tests (see Clause 7.3).

2.18 LONG DURATION CURRENT IMPULSE A rectangular impulse which rises rapidly to maximum value, remains substantially constant for a specified period and then falls rapidly to zero. The parameters which define a rectangular impulse are polarity, peak value, virtual duration of the peak and virtual total duration.

2.19 PEAK (CREST) VALUE OF AN IMPULSE The maximum value of a voltage or current impulse. Superimposed oscillations may be disregarded (see Clauses 7.4.2 (c) and 7.5.4.2 (e)).

2.20 FRONT OF AN IMPULSE The part of an impulse which occurs prior to the peak.

2.21 TAIL OF AN IMPULSE The part of an impulse which occurs after the peak.

2.22 VIRTUAL ORIGIN OF AN IMPULSE The 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. For current impulses the reference points shall be 10% and 90% of the peak value.

NOTES:

- 1 This definition applies only when scales of both ordinate and abscissa are linear.
- 2 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.

2.23 VIRTUAL FRONT TIME OF A CURRENT IMPULSE (T_1) The 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: 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.

2.24 VIRTUAL STEEPNESS OF THE FRONT OF AN IMPULSE The quotient of the peak value and the virtual front time of an impulse.

2.25 VIRTUAL TIME TO HALF VALUE ON THE TAIL OF AN IMPULSE (T_2) The time interval between the virtual origin and the instant when the voltage or current has decreased to half its peak value. This time is expressed in microseconds.

2.26 VIRTUAL DURATION OF THE PEAK OF A RECTANGULAR IMPULSE The time during which the amplitude of the impulse is greater than 90% of its peak value.

2.27 VIRTUAL TOTAL DURATION OF A RECTANGULAR IMPULSE The time during which the amplitude of the impulse is greater than 10% of its peak value. If small oscillations are present on the front, a mean curve should be drawn in order to determine the time at which the 10% value is reached.

2.28 PEAK (CREST) VALUE OF OPPOSITE POLARITY OF AN IMPULSE The maximum amplitude of opposite polarity reached by a voltage or current impulse when it oscillates about zero before attaining a permanent zero value.

2.29 DISCHARGE CURRENT OF AN ARRESTER The impulse current which flows through the arrester.

2.30 NOMINAL DISCHARGE CURRENT OF AN ARRESTER (I_n) The peak value of lightning current impulse (see Clause 2.17) which is used to classify an arrester.

2.31 HIGH CURRENT IMPULSE OF AN ARRESTER The 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.

2.32 SWITCHING CURRENT IMPULSE OF AN ARRESTER The peak value of discharge current having a virtual front time greater than 30 μs but less than 100 μs and a virtual time to half value on the tail of roughly twice the virtual front time.

2.33 CONTINUOUS CURRENT OF AN ARRESTER The continuous current is the current flowing through the arrester when energized at the continuous operating voltage.

NOTE: The continuous current, which consists of a resistive and a capacitive component, may vary with temperature, stray capacitance and external pollution effects. The continuous current of a test sample may, therefore, not be the same as the continuous current of a complete arrester.

The continuous current is, for comparison purposes, expressed either by its r.m.s. or peak value.

2.34 REFERENCE CURRENT OF AN ARRESTER The reference current is the peak value (the higher peak value of the two polarities if the current is symmetrical) of the resistive component of a power frequency current used to determine the reference voltage of the arrester. The reference current shall be high enough to make the effects of stray capacitances at the measured reference voltage of the arrester units (with designed grading system) negligible and shall be specified by the manufacturer.

NOTE: Depending on the nominal discharge current and/or line discharge class of the arrester, the reference current will be typically in the range of 0.05 mA to 1.0 mA per square centimetre of disc area for single column arresters.

2.35 REFERENCE VOLTAGE OF AN ARRESTER (U_{ref}) The peak value of power frequency voltage divided by $\sqrt{2}$ which shall be applied to the arrester to obtain the reference current. The reference voltage of a multi-unit arrester is the sum of the reference voltages of the individual units.

NOTE: Measurement of reference voltage is necessary for the selection of a correct test sample in the operating duty test (see Clause 7.5).

2.36 RESIDUAL VOLTAGE OF AN ARRESTER (U_{res}) The peak value of voltage that appears between the terminals of an arrester during the passage of discharge current.

NOTE: The term 'discharge voltage' is used in some countries.

2.37 POWER FREQUENCY WITHSTAND VOLTAGE VERSUS TIME CHARACTERISTIC OF AN ARRESTER The power frequency withstand voltage versus time characteristic shows the 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 Clause 5.10.

2.38 PROSPECTIVE CURRENT OF A CIRCUIT The current which would flow at a given location in a circuit if it were short-circuited at that location by a link of negligible impedance.

2.39 PROTECTIVE CHARACTERISTICS OF AN ARRESTER The combination of the following:

- (a) Residual voltage for steep current impulse according to Clause 7.3.1.
- (b) Residual voltage versus discharge current characteristic for lightning impulses according to Clause 7.3.2.

The lightning impulse protection level of the arrester is the maximum residual voltage for the nominal discharge current.

- (c) Residual voltage for switching impulse according to Clause 7.3.3.

The switching impulse protection level of the arrester is the maximum residual voltage at the specified switching impulse currents.

2.40 THERMAL RUNAWAY OF AN ARRESTER The term ‘thermal runaway’ is used to describe a situation when the sustained power loss of an arrester exceeds the thermal dissipation capability of the housing and connections, leading to a cumulative increase in the temperature of the resistor elements culminating in failure.

2.41 THERMAL STABILITY OF AN ARRESTER An arrester is thermally stable if, after an operating duty causing temperature rise, the temperature of the resistor elements decreases with time when the arrester is energized at specified continuous operating voltage and at specified ambient conditions.

2.42 ARRESTER DISCONNECTOR A 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: Clearing of the fault current through the arrester during disconnection generally is not a function of the device.

2.43 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. 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.

2.44 ROUTINE TESTS Tests made on each arrester, or on parts and materials, as required, to ensure that the product meets the design specifications.

2.45 ACCEPTANCE TESTS Tests which are made when it has been agreed between the manufacturer and the purchaser that the arresters or representative samples of an order are to be tested.

2.46 SPARK An incandescent particle capable of igniting a suitable fire ignition bed to the point of actual flame or to a smouldering condition that can be fanned to a flame or to visible incandescence in an illumination of 200 lx.

NOTE: Research has been carried out on the fire ignition probability of various ignition bed materials related to the diameter of molten copper particles at a temperature just above their melting point (see AS 1033.1). For the test requirements of this Standard, a minimum spark is taken as the thermal equivalent of a 1.1 mm diameter molten copper particle (see Paragraph L2 in Appendix L).

The 1.1 mm molten copper particle is used to calibrate ground papers. Much smaller particles of materials which burn may constitute a spark, e.g. aluminium, steel and organic substances (see Paragraphs L2 and L4 in Appendix L).

2.47 DISTRIBUTION TYPE ARRESTER An arrester which has no assigned line discharge class and is used for distribution line application at ≤ 36 kV rms.

2.48 SIGNIFICANT INTERNAL GAS VOLUME A gas volume which can be removed by evacuation and replaced by a tracer gas.

2.49 HIGHEST VOLTAGE FOR EQUIPMENT (U_m) The highest r.m.s. value of phase-to-phase voltage for which the equipment is designed in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment Standards.

2.50 ARRESTER INTERRUPTOR A device designed either as a part of the arrester construction, or which may be fitted to an arrester, which will interrupt the flow of earth fault current through a failing arrester and thereby prevent shattering and/or spark production at currents equal to and below its maximum fault clearing current (I_f) in the arrester failure mode test.

2.51 ARRESTER INDICATOR A device which may be fitted to an arrester to indicate that the arrester has failed but which does not electrically disconnect the arrester.

SECTION 3 IDENTIFICATION AND CLASSIFICATION

3.1 ARRESTER IDENTIFICATION Metal-oxide surge arresters shall be identified by the following minimum information which shall appear on a nameplate permanently attached to the arrester:

- (a) continuous operating voltage;
- (b) rated voltage;
- (c) rated frequency, if other than one of the standard frequencies (see Clause 4.2);
- (d) nominal discharge current;
- (e) pressure relief rated current in kA r.m.s. (for arresters fitted with pressure relief devices) (see Clause 5.11), and whether S or NS;
- (f) spark production class, if A or B or C;
- (g) the manufacturer's name or trade mark, type and identification of the complete arrester;
- (h) identification of the assembling position of the unit (for multi-unit arresters only);
- (i) the year of the manufacture;
- (j) serial number (at least for arresters with rated voltage above 60 kV).

NOTE: If sufficient space is available the nameplate should also contain:

- (a) Line discharge class or high lightning duty type (see Appendix C);
- (b) Contamination withstand level of the enclosure (see IEC 815).

3.2 ARRESTER CLASSIFICATION Surge arresters are classified by their standard nominal discharge currents and they shall meet at least the test requirements and performance characteristics specified in Table 3.2.

NOTE: For the 10 000 A and 20 000 A arresters there are five types differentiated by the amplitude and the duration of the long duration current which they are capable of withstanding (see Table 7.2 in Clause 7.4.2).

3.2 ARRESTER CLASSIFICATION Surge arresters are classified by their standard nominal discharge currents and they shall meet at least the test requirements and performance characteristics specified in Table 3.2 except those listed as informative.

NOTES:

- 1 For the 10 000 A and 20 000 A line discharge class arresters there are five types differentiated by the amplitude and the duration of the long duration current which they are capable of withstanding (see Table 7.2 in Clause 7.4.2).
- 2 The test requirements of this Standard do not necessarily correspond with other National or International Standards.

3.3 VERIFICATION OF SPARK PRODUCTION Distribution type surge arresters shall be classified according to the maximum number of sparks produced when the pressure relief tests (see Clause 7.8) are being performed as shown in Table 3.1 and as follows:

The test samples shall be the longest unit of a homogeneous series of arresters, having the same nominal discharge current, in which the different voltage ratings are obtained by the assembly from metal-oxide resistors having the same cross-section and essentially the electrical and thermal characteristics proportional to the voltage rating. The cross-sectional dimensions within the housing shall be constant and the housing shall be of the same material, have the same housing barrel cross-sectional dimensions and the same general shed configuration. The design of the housing end terminations and internal components, except resistors and spacers, shall be the same.

The test shall be regarded as demonstrating compliance of arresters made of units of the same series as defined above provided that if the arrester incorporates units having different designs of porcelain housing i.e. the base unit being of larger dimensions, the longest units of each design shall be tested.

The tests shall be deemed to prove all voltage ratings of the same series of arrester of lower voltage than the tested arrester.

The sparks are to be detected in accordance with Appendix L.

TABLE 3.1
SPARK PRODUCTION CLASS

Class	Max. number of sparks during a test shot	Average number of sparks per test at each test current
A	0	0
B	3	≤1
C	Unrestricted	Unrestricted

NOTES:

- 1 *Class A* Surge arresters shall be spark-free.
- 2 *Class B* Surge arresters shall produce not more than an average of one spark per test for each test current and a maximum of three sparks for any one test. The average number of sparks produced shall be reported for class B arresters for each test current. In proving performance to class B a minimum of three tests shall be performed at each current level.
- 3 *Class C* May produce an unrestricted number of sparks.

TABLE 3.2
ARRESTER CLASSIFICATION AND TEST REQUIREMENTS ¹

	Standard nominal discharge current ²				
	20 000 A	10 000 A	5 000 A	2 500 A	1 500 A
1 Rated voltage U_r (kV _{rms})	$360 < U_r \leq 756$	$3 \leq U_r \leq 360$	$U_r \leq 132$	$U_r \leq 36$	See Note 3
2 Insulation withstand tests on the arrester housing	7.2.6, 7.2.7	7.2.6, 7.2.7, 7.2.8	7.2.6, 7.2.8	7.2.6, 7.2.8	7.2.6, 7.2.8
3 Residual voltage test	Table K1	Table K1	Table K2	Table K2	Table K2
(a) Steep current impulse residual voltage test	7.3.1	7.3.1	7.3.1	7.3.1	7.3.1
(b) Lightning impulse residual voltage test	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
(c) Switching impulse residual voltage test	7.3.3	7.3.3	Not required	Not required	Not required
4 Long duration current impulse withstand test	7.4.2	7.4.2	7.4.3	7.4.3	Not required
5 Operating duty test					
(a) High current impulse operating duty test	Not required	7.5.4 Table 7.4	7.5.4 Table 7.4	7.5.4 Table 7.4	7.5.4 Table 7.4
(b) Switching surge operating duty test	7.5.5 Table 7.2	7.5.5 Table 7.2	Not required	Not required	Not required
6 Power frequency voltage versus time curve	5.10	5.10	5.10	5.10	5.10
7 Pressure relief (when fitted with relief device)	5.11	5.11	5.11	Not required	Not required
8 Arrester disconnector (when fitted)	5.12	5.12	5.12	5.12	5.12
9 Polluted housing test	Appendix F				

¹ Numbers in rows 2-8 refer to clauses and subclauses in this Standard.

² In some countries it is customary to classify arresters as:

- (a) station for 10 000 A arresters;
- (b) intermediate or distribution for 5000 A arresters;
- (c) secondary for 1500 A arresters.

³ This low voltage range is under consideration.

TABLE 3.2
ARRESTER CLASSIFICATION AND TEST REQUIREMENTS

	10 000 A LDC 1	10 000 A LDC 2-3	20 000 A LDC 4-5	20 000 A HL	10 000 A DT	5 000 A DT
1 Rated voltage kV rms	$3 \leq U_r \leq 100$	$3 \leq U_r \leq 362$	$3 \leq U_r \leq 765$	$3 \leq U_r \leq 36$	$U_r \leq 36$	$U_r \leq 36$
2 Insulation withstand test	7.2.6 7.2.7 7.2.8	7.2.6 7.2.7 7.2.8	7.2.6 7.2.7 7.2.8	7.2.6 7.2.6 7.2.8	7.2.6 7.2.6 7.2.8	7.2.6 7.2.6 7.2.8
3 Residual voltage test	Table K1	Table K1	Table K1	Table K2	Table K2	Table K2
(a) Steep current impulse residual voltage	7.3.1	7.3.1	7.3.1.	7.3.1	7.3.1	7.3.1
(b) Lightning impulse residual voltage test	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2	7.3.2
(c) Switching impulse residual voltage test	7.3.3	7.3.3	7.3.3	Not required	Not required	Not required
4 Long duration impulse withstand test	7.4.2 Table 7.2	7.4.2 Table 7.2	7.4.2 Table 7.2	7.4.3 Table 7.3	7.4.3 Table 7.3	7.4.3 Table 7.3
5 Operating duty						
(a) High current impulse operating duty test	7.5.4 Table 7.4	Not required	Not required	7.5.4 Appendix C Figure C1	7.5.4 Table 7.4	7.5.4 Table 7.4
(b) Switching surge operating duty test	Not required	7.5.5 Table 7.2	7.5.5 Table 7.2	Not required	Not required	Not required
6 Power frequency vs time curve	5.10	5.10	5.10	5.10	5.10	5.10
7 Pressure relief (failure mode)	5.11	5.11	5.11	5.11	5.11	5.11
8 Arrester disconnecter, interruptors and indicators	5.12	5.12	5.12	5.12	5.12	5.12
9 Arrester seal leak rate	5.5	5.5	5.5	5.5	5.5	5.5
10 Verification of spark production class	5.14 See Note 4	Not required	Not required	5.14	5.14	5.14
11 Polluted housing test	Appendix F (Informative)					
12 Polymer housed arrester environmental test	Appendix M (Informative)					
13 Multipulse lightning impulse current operating duty test	Appendix O (Informative)					

NOTES:

- 1 Numbers in rows 2 to 13 refer to Clauses and Appendices in this Standard.
- 2 LDC 1 indicates line discharge Class 1.
LDC 2-3 indicates line discharge Classes 2 and 3.
LDC 4-5 indicates line discharge Classes 4 and 5.

HL indicates high lightning
DT indicates distribution type.

3 Practical system voltage application are

LDC 1 3 to 72 kV
LDC 2 3 to 245 kV
LDC 3 3 to 362 kV
LDC 4 3 to 550 kV
LDC 5 3 to 765 kV

4 Where a LDC 1 arrester is used for distribution applications it should meet the requirements as specified for a 10 000 A DT arrester.

3.4 HAZARD OF OPERATION OF DISCONNECTOR, INTERRUPTOR OR INDICATOR DEVICE Where an arrester is fitted with a disconnector, interruptor or indicator device that contains an explosive charge to power the operation of the device and which, when operating, is capable of being a hazard to adjacent personnel or equipment, a warning shall be shown clearly on the carton. The installation instructions shall detail any appropriate instructions to ensure safety in handling and in service operation.

SECTION 4 STANDARD RATINGS

4.1 STANDARD RATED VOLTAGES Standard values of rated voltages for arresters (in kilovolts r.m.s.) are specified in Table 4.1 in equal voltage steps within specified voltage ranges:

TABLE 4.1
STEPS OF RATED VOLTAGES

Range of rated voltage kV r.m.s.	Steps of rated voltage kV r.m.s.
<3	Under consideration
3 – 30	1
30 – 54	3
54 – 96	6
96 – 288	12
288 – 396	18
396 – 756	24

NOTE: Other values of rated voltage may be accepted, provided they are multiples of 6.

4.2 STANDARD RATED FREQUENCIES The standard rated frequencies are 50 Hz and 60 Hz.

4.3 STANDARD NOMINAL DISCHARGE CURRENTS The standard nominal 8/20 discharge currents are: 20 000 A, 10 000 A, 5000 A, 2500 A and 1500 A (see Clause 2.30).

4.3 STANDARD NOMINAL DISCHARGE CURRENTS The standard nominal 8/20 discharge currents are: 20 000 A, 10 000 A and 5000 A (see Clause 2.30).

4.4 SERVICE CONDITIONS

4.4.1 Normal service conditions Surge arresters which conform to this standard shall be suitable for normal operation under the following normal service conditions:

(a) Ambient air temperature within the range of -40°C to $+40^{\circ}\text{C}$.

(a) Ambient temperature within the range of -10°C to $+50^{\circ}\text{C}$.

(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 test. If there are other heat sources near the arrester, the application of the arrester shall be subject to an agreement between the manufacturer and the purchaser.

(b) Maximum solar radiation does not exceed 1.1 kW/m (equivalent to a black body temperature of 80°C).

(c) Altitude not exceeding 1 000 m.

(d) Frequency of the a.c. power supply not less than 48 Hz and not exceeding 62 Hz.

- (d) Frequency of the a.c. power supply not less than 48 Hz and not greater than 52 Hz.
- (e) Power frequency voltage applied continuously between the terminals of the arrester not exceeding its continuous operating voltage.
- (f) Mechanical conditions (under consideration).

(g) Pollution conditions (no requirement at this time).

- (g) Pollution conditions (under consideration).
- (h) Localized external surface temperature due to adjacent heat sources, such as transformers, shall not exceed 60°C. This maximum external temperature shall not occur continuously.
- (i) Wind pressure does not exceed 1.2 kPa
NOTE: This wind pressure is the free stream dynamic pressure and corresponds to a wind velocity of 45 m/s (on a projected flat surface).

4.4.2 Abnormal service 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 standard in case of abnormal service conditions is subject to agreement between the manufacturer and the purchaser. A list of possible abnormal service conditions is given in Appendix A.

SECTION 5 REQUIREMENTS

5.1 INSULATION WITHSTAND OF THE ARRESTER HOUSING The arrester housing shall withstand the following voltages when tested according to Clause 7.2:

5.1 INSULATION WITHSTAND The arrester housing shall withstand the following voltages when tested according to Clause 7.2:

- (a) The lightning impulse protection level of the arresters (see Clause 2.39) multiplied by 1.3.

NOTE: The 1.3 factor covers variations in atmospheric conditions and discharge currents higher than nominal.

- (b) For 10 000 A and 20 000 A arresters with rated voltages of 200 kV and above, switching impulse protection level of the arrester (see Clause 2.39) multiplied by 1.25.

NOTE: The 1.25 factor covers variations in atmospheric conditions and discharge currents higher than the maximum values of Table 7.1 (see Clause 7.3.3).

- (c) Power frequency voltage in wet conditions for arrester housings for outdoor use and in dry conditions for arrester housings for indoor use.

Housings of 1500 A, 2500 A and 5000 A arresters and high lightning duty arresters (see Appendix C) 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.

Housings of 5000 A and 10 000 A distribution type and high lightning duty arresters (see Appendix C) 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.

Housings of 10 000 A and 20 000 A LDC arresters with rated voltages less than 200 kV, shall withstand a power frequency voltage with a peak value equal to the switching impulse protection level multiplied by 1.06 for a duration of 1 minute.

For arresters fitted with disconnectors or interruptors, a 1 min. wet withstand test on one test sample shall be carried out at $1.5 U_r$ applied from the earthed terminal of the arrester to earth with the disconnector or interruptor operated.

5.2 REFERENCE VOLTAGE The reference voltage of each arrester shall be measured by the manufacturer at the reference current selected by the manufacturer (see Clause 6.2). The minimum reference voltage of the arrester at the reference current used for routine tests shall be specified and published in the manufacturer's data.

5.3 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 waveshapes. These are derived from the type test data and from the maximum residual voltage at a lightning impulse current used for routine tests as specified and published by the manufacturer.

The maximum residual voltage of a given arrester design for any current and waveshape 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 waveshape.

NOTE: For some arresters with a rated voltage less than 38 kV (see Clause 8.1 (b)) the reference voltage may be used for this calculation instead of the residual voltage.

5.4 PARTIAL DISCHARGES When required, the partial discharges in the arrester energized at 1.05 times its continuous operating voltage shall not exceed 50 pC (see Clauses 8.1 (c) and 8.2.1 (c)).

5.4 PARTIAL DISCHARGES When required, the partial discharges in the arrester energized at 1.05 times its continuous operating voltage shall not exceed 10 pC (see Clauses 8.1 (c) and Clause 8.2.1 (c)).

5.5 SEAL LEAKAGE Arrester units with sealed housings shall exhibit no measurable leakage (see Clause 8.1 (d)).

5.5 SEAL TEST Arrester units shall comply with the seal test (see Clause 7.7).

5.6 CURRENT DISTRIBUTION IN A MULTI-COLUMN ARRESTER The manufacturer shall specify the highest value of the current in a column of a multi-column arrester (see Clause 8.1 (e)).

5.7 THERMAL STABILITY When agreed between manufacturer and purchaser, a special thermal stability test may be performed according to Clause 8.2.2.

5.8 LONG DURATION CURRENT IMPULSE WITHSTAND Arresters shall withstand long duration currents as checked during type tests (see Clause 7.4).

For 20 000 A and 10 000 A arresters the long duration withstand is demonstrated by a line discharge test (see Clause 7.4.2) with the line discharge class specified by the user.

For 5000 A and 2500 A arresters the long duration withstand is demonstrated by a long duration impulse test (see Clause 7.4.3).

The two paragraphs above are void.

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

The residual voltage measured before and after the long duration current test shall not have changed by more than 5%.

5.9 OPERATING DUTY Arresters shall be able to withstand the combination of stresses arising in service as demonstrated by the operating duty tests (see Clause 7.5). These stresses shall not cause damage or thermal runaway.

For 1500 A, 2500 A, 5000 A and 10 000 A line discharge Class 1 arresters and High Lightning Duty arresters (see Appendix C), this is demonstrated by the high current impulse operating duty test (see Clause 7.5.4 and Figure 8.1 or C1).

For 5000 A and 10 000 A distribution type, 10 000 A line discharge Class 1 arresters and High Lightning Duty arresters (see Appendix C), this is demonstrated by the high current impulse operating duty test (see Clause 7.5.4 and Figure 8.1 or C1).

For 10 000 A line discharge Classes 2 and 3 and 20 000 A line discharge Classes 4 and 5 arresters, this is demonstrated by the switching surge operating duty test (see Clause 7.5.5 and Figure 8.2).

The arrester has passed the test if thermal stability is achieved, if the residual voltage measured before and after the test is not changed by more than 5%, and if examination of the test samples after the test reveals no evidence of puncture, flashover or cracking of the non-linear metal-oxide resistors.

5.10 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 60°C and subjected to the high current or line discharge class energy duty respectively, without damage or thermal runaway.

This information shall be presented as power frequency voltage versus time curves with the impulse energy consumption prior to this power frequency voltage application stated on the above mentioned curve.

NOTES:

- 1 Such curves are necessary for the selection of the arrester rated voltage depending on local system conditions, such as lightning, switching and temporary overvoltages.
- 2 The curves may be established by calculation.
- 3 The temporary overvoltage curve should cover the time range from 0.1 s to 20 min. For arresters to be used in isolated neutral or resonant earthed systems without earth fault clearing, the time should be extended to 24 h.

If verification of the power frequency voltage versus time curve is agreed upon by the manufacturer and the purchaser, the procedure described in Appendix D shall be used.

5.11 PRESSURE RELIEF When an arrester is fitted with a pressure relief device, the failure of the arrester shall not cause explosive shattering of the housing. This is verified by the test described in Clause 8.7 of IEC 99-1. Other test conditions are under consideration.

The test sample is deemed to have passed the test if the housing remains intact or if it breaks non-explosively and if all parts of the sample are contained within the required enclosure.

5.11 PRESSURE RELIEF When an arrester is fitted with pressure relief (this includes an arrester housing which ruptures or vents to act as a pressure relief e.g. a polymer housing) the arrester shall be tested according to Clause 7.8.

5.12 DISCONNECTORS

5.12 DISCONNECTORS, INTERRUPTORS AND INDICATORS

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

- (a) Long duration current impulse test (see Clause 7.6.2.1).
- (b) Operating duty test (see Clause 7.6.2.2).

5.12.1 Disconnecter, interruptor and indicator withstand When an arrester is fitted or associated with a disconnector, interruptor or indicator, these devices shall withstand, without operating, each of the following tests:

- (a) Long duration current impulse test (see Clause 7.6.2.1).
- (b) Operating duty test (see Clause 7.6.2.2).

These tests may be repeated after environmental ageing, if agreed between the purchaser and the manufacturer.

These devices shall operate at each pressure relief test, where performed.

These devices shall be fitted during all spark production tests.

5.12.2 Disconnecter operation The time delay for the operation of the disconnector is determined for three values of current according to Clause 7.6.3. There shall be clear evidence of effective and permanent disconnection by the device.

5.12.3 Interruptors When an arrester is fitted with an interruptor, this device shall be tested according to Clause 7.6.

5.12.4 Indicators When an arrester is fitted with an indicator, this device shall operate at and above a minimum test current as agreed between the purchaser and the manufacturer.

5.13 REQUIREMENTS FOR AUXILIARY EQUIPMENT SUCH AS GRADING COMPONENTS No requirement at this time.

5.13 REQUIREMENTS FOR ALL EXTERNAL AUXILIARY EQUIPMENT No requirements at this time.

5.14 VERIFICATION OF SPARK PRODUCTION CLASS When required, arresters shall be classified for spark production class in accordance with Appendix L.

SECTION 6 GENERAL TESTING PROCEDURE

6.1 MEASURING EQUIPMENT AND ACCURACY The measuring equipment shall meet the requirements of AS 1931.1. 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.

6.2 REFERENCE VOLTAGE MEASUREMENTS The reference voltage of an arrester (see Clause 2.35) is measured at the reference current (see Clause 2.34) on sections and units when required. The measurement shall be performed at an ambient temperature of $20^{\circ}\text{C} \pm 15^{\circ}\text{C}$ and this temperature shall be recorded.

NOTE: As an acceptable approximation, the peak value of the resistive component of current may be taken to correspond to the momentary value of the current at the instant of voltage peak.

6.3 TEST SAMPLES Unless otherwise specified all tests shall be made on the same arresters, arrester sections or arrester units. They shall be new, clean, completely assembled (e.g. with grading rings if applicable) and arranged as nearly as possible to simulate the conditions in service.

When tests are made on sections it is necessary that the sections represent the behaviour of all possible arresters within the manufacturer's tolerances with respect to a specific test.

The samples to be chosen for the line discharge test (see Clause 7.4.2) and operating duty test (see Clause 7.5) shall have a reference voltage value at the lowest end of the variation range declared by the manufacturer. Furthermore, in case of multi-column arresters the highest value of uneven current distribution shall be considered. In order to comply with this demand the following shall be fulfilled:

- (a) The ratio between rated voltage of the complete arrester to the rated voltage of the section is defined as n . The volume of the resistor elements used as test samples shall not be greater than the minimum volume of all resistor elements used in the complete arrester divided by n .
- (b) The reference voltage of the test section should be equal to $k U_r/n$ where k is the ratio between the minimum reference voltage of the arrester and its rated voltage. In case $U_{\text{ref}} > k U_r/n$ for an available test sample, the factor n has to be reduced correspondingly. (In case $U_{\text{ref}} < k U_r/n$ the arrester may absorb too much energy. Such a section can be used only after agreement from the manufacturer.)
- (c) For multi-column arresters the distribution of the current between the columns shall be measured at the impulse current used for current distribution test (see Clause 8.1 (e)). The highest current value shall not be higher than an upper limit specified by the manufacturer.

6.4 PROTECTION DURING TESTS Arresters fitted with disconnectors, interruptors and indicator devices may have explosive charges to cause their operation. Such devices may operate during the tests in which heat is applied (e.g. seal tests, operating duty tests etc), or as heat is generated by the test (e.g. long duration current impulse test, high current withstand test etc). Such devices may also operate if handled roughly. Care should, therefore, be exercised to ensure that, if the device operates, appropriate protection to personnel and equipment is maintained.

SECTION 7 TYPE TESTS (DESIGN TESTS)

7.1 GENERAL The following type tests shall be made as far as required in Table 3.2 and Table C1 of Appendix C:

- (a) *Insulation withstand tests (see Clauses 5.1 and 7.2)* These tests demonstrate the ability of the arrester housing to withstand voltage stresses under dry and wet conditions.
- (b) *Residual voltage tests (see Clauses 5.3 and 7.3)* These tests demonstrate the protective levels of the arrester.
- (c) *Long duration current impulse withstand test (see Clauses 5.8 and 7.4)* These tests demonstrate the ability of the resistor elements to withstand possible dielectric and energy stresses without puncture or flashover.
- (d) *Operating duty tests (see Clauses 5.9 and 7.5)* These tests demonstrate the thermal stability of the arrester under defined conditions.
- (e) *Pressure relief test (see Clause 5.11)* For arresters fitted with pressure relief devices these tests demonstrate the ability of the arrester housing to withstand short-circuit currents without violent shattering of the housing under specified test conditions.
- (f) *Tests of arrester disconnectors (see Clauses 5.12 and 7.6)* For arresters fitted with disconnectors these tests demonstrate the correct operation of the disconnector.
- (g) *Artificial pollution test (see Appendix F, not yet established)* This test is made to show that the internal parts of the arrester including its grading system, are able to withstand pollution without any damage and that the external insulation does not flashover.
- (h) *Partial discharge test (see Clause 5.4)* This test measures the internal partial discharges.

- (i) *Seal leakage test (not yet established)* This test determines the integrity of the arrester seals.

- (i) *Seal test (see Clause 5.5)* This test determines the integrity of the arrester seals.
- (j) *Current distribution test for multi-column arrester (see Clauses 5.6 and 8.1 (e))* This test determines the current through each column of parallel resistors when there is no electrical connection between columns.
- (k) *Verification of spark production (see Clause 5.14)* For distribution type arresters which have reduced spark production, these tests demonstrate the ability of the arresters to limit sparks produced under pressure relief test conditions.

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