

Guide to

Insulators of ceramic material or glass for overhead-lines with a nominal voltage greater than 1000 V, puncture testing

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee PEL/36, Insulators for power systems, upon which the following bodies were represented:

- Association of Consulting Engineers
- Association of Manufacturers Allied to the Electrical and Electronic Industry (BEAMA Ltd.)
- British Industrial Ceramic Manufacturers' Association
- British Railways Board
- Electrical and Electronic Insulation Association (BEAMA Ltd.)
- Electricity Association
- Transmission and Distribution Association (BEAMA Ltd.)

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National foreword

This British Standard has been prepared by Technical Committee PEL/36. It is identical with IEC Technical Report 1211:1994 *Insulators of ceramic material or glass for overhead lines with a nominal voltage greater than 1 000 V — Puncture testing* published by the International Electrotechnical Commission (IEC).

It is being published as a guide at the request of BSI Technical Committee PEL/36 as there is a need for a prospective standard for provisional application in the field of puncture testing of ceramic and glass insulator units of class B and because there is an urgent requirement for guidance on how standards in this field should be used to meet an identified need.

The International Standard (IEC 1211) is a technical report type 2 and will be reviewed before June 1997 with the option of either authorizing the extension of this publication for a further 3 years or conversion to a full standard or withdrawal.

If any recipient of this document has constructive technical comments and/or suggestions on how it can be improved could they inform the secretary of PEL/36 by letter or fax at the address on the back page.

Additional information. The text refers to IEC 381-1:1993 *Insulators for overhead lines with a nominal voltage above 1 000 V — Part 1: Ceramic or glass insulator units for a.c. systems — definitions, test methods and acceptance criteria* which is currently being studied by the European Committee for Electrotechnical Standardization (CENELEC) as a potential European Standard (EN). Copies of this standard are available from BSI Customer Services (see back cover for details).

Cross-references

Publications referred to	Corresponding British Standard
Normative	
IEC 60-1:1989	BS 923 <i>Guide on high-voltage testing techniques</i> Part 1:1990 <i>General</i>
IEC 790:1984	BS 6647:1985 <i>Guide to oscilloscopes and peak voltmeters for impulse tests</i>
Informative	
IEC 305	BS 137 <i>Insulators of ceramic material or glass for overhead lines with a nominal voltage greater than 1 000 V</i> Part 2:1973 <i>Requirements</i> (Technically equivalent) BS 3939 <i>Graphic symbols for electric power, telecommunications and electronic diagrams</i>
IEC 617-1	Part 1:1986 <i>General information, general index</i> (Related)
IEC 617-2	Part 2:1985 <i>Symbol elements, qualifying symbols and other symbols having general application</i> (Identical)

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 16, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Introduction

A power frequency puncture test on insulators in oil was specified in IEC 383: *Insulators for overhead lines with a nominal voltage above 1 000 V*. An impulse overvoltage test is given as an alternative, without specification of method or acceptance criteria. Sub-committee 36B has considered questions related to puncture testing already for a long time. The opinions and experience of National Committees have also been requested and collated.

In time, interest in an impulse voltage puncture test on insulators in air has increased considerably.

This report contains a proposal for a standard impulse voltage puncture test. This test is intended to be the impulse overvoltage test given in **15.2** of IEC 383-1.

The main problems in introducing an impulse voltage puncture test appeared to be relevant stress in the test and, secondly, the doubt about reproducibility of this test in general and its feasibility, especially in insulator manufacturers' laboratories. In studying these questions, considerable support has been received from several working groups of CIGRÉ Study Committee 33, Insulation co-ordination. Annex A to Annex E summarize the findings of the sub-committee and the studies behind the conclusions. For more detailed information, reference is made to *Electra*, Report by Aro, M. *and al.*: Puncture testing of ceramic and glass insulators. Final report of CIGRÉ task force 33.07.01 published in *Electra* **136**, June 1991. This is shown in the text by [E].

The impulse voltage puncture test on insulators in air is reproducible if voltage amplitude of the test impulse is specified instead of steepness. In addition to amplitude, the test procedure has to be specified in detail. Special attention has to be paid to the measurement.

The choice of specification of amplitude instead of steepness derives mainly from the following two facts. It is easier and more accurate to measure peak value than steepness. The stress does not depend on the test circuit and the other test conditions when referring to the peak value.

This report assumes that the manufacturer specifies the impulse puncture withstand voltage as a characteristic of the insulator unit. This voltage is defined as peak value of the measured voltage across the insulator in the actual test. For more general specification of test voltage of different types of insulator units, it is useful to apply per unit (p.u.) values (see Annex A). It is recommended to obtain this information, together with the puncture test results for further consideration of the specification of the test voltage.

The purchaser may adopt the amplitude specification for an insulator by taking into consideration the overvoltage calculations on one hand, as well as test and service experience, on the other hand. This experience, especially and most clearly in Canada, supports the introduction of an impulse voltage puncture test. For consideration of the test specification, results of a large series of measurements in many laboratories have been used for transforming the steepness criteria to amplitude criteria [E]. It is considered that, for the moment, the specification for the amplitude has to be kept within the range of the stress applied in tests of current practice.

As to the test procedure, polarity of the impulse related to the pin, starting polarity, possible polarity reversals and time interval between consecutive impulses may affect the severity of the test and hence have to be specified.

It is realized that measurement of these short impulse voltages needs special attention to achieve an acceptable accuracy. Even the revision of IEC 60 will not fully support this topic. Consequently, special requirements and guidance for measurements are necessary. In this, it is recommended to keep a little on the safe side, because of new considerations. Annex B gives some guidance.

In limited conditions, it is possible to use fixed circuits in tests without measurements. However, this requires considerable calibration work from time to time. Nevertheless, some conditions lead to high dispersion. Thus, this seems not to be a very practical method.

The puncture strength of insulators depends on both design and quality of manufacturing and a sample test is needed to confirm the type test result. It is recognized that this test may be expensive and time-consuming. Annex D gives some guidance.

Annex E indicates the problems found in the reproducibility of power frequency puncture tests on insulators in oil. During the test series, the reproducibility of this test was very poor, because initially the importance of the oil characteristics was not fully appreciated.

The results are mainly influenced by the characteristics of the oil, particularly by the resistivity, which varied over a large range during the tests, and possibly by the dielectric strength. The tests, however, indicated that the reproducibility could, in principle, be improved, e.g. by specifying a narrower range for the resistivity and dielectric strength of the oil. Modifying the oil used in the test by specifying tighter tolerances for the oil characteristics is very difficult. It may even be necessary to specify different characteristics of oils for different dielectric materials of the insulators. The manufacturer is in the best position to define the necessary characteristics of oil for his insulators.

It is recommended to retain the power frequency puncture test in oil without modification until wider experience of impulse voltage puncture testing has been gained. The puncture test in oil is designed to check the head of the insulator, and applies the power frequency voltage suitably higher than the dry power frequency flashover voltage in air between the pin and the cap. The oil allows this voltage to be applied by increasing the breakdown value above that of the air flashover path. Providing this voltage is applied without puncturing the head of the insulator at the specified voltage, there is a high degree of assurance that the test result and the insulator are satisfactory. It is important, however, that the oil is selected to ensure that pre-discharges, flashover, or puncture of the outer sheds do not occur below the specified withstand voltage.

1 Scope and object

This technical report deals with puncture testing of ceramic and glass insulator units of class B only. Although there is little or no experience of testing class B long-rod and line-post insulators, the experience already gained with cap and pin, and pin insulators, permits their mounting arrangements and test procedures to be specified for use in future tests to gain experience.

This report may be applied also in tests on insulators of other materials (e.g. polymers and composites). However, it may be useful to consider the possible need to adjust the test procedure accordingly.

An impulse voltage puncture test on insulators in air is required and applied in more and more countries, and by a growing number of users. The applied test procedures differ from each other considerably. This report is published with the object of specifying a standard procedure for impulse voltage puncture test on insulators in air, so that experience with this test may be obtained on a common basis.

It is recommended that wider manufacturer and user experience with the impulse test be obtained in order to establish the practicability of including it in a future standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this technical report. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this technical report are encouraged to investigate the possibility of applying the most recent edition of the normative documents 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 383-1:1993, *Insulators for overhead lines with a nominal voltage above 1 000 V — Part 1: Ceramic or glass insulator units for a.c. systems — Definitions, test methods and acceptance criteria*.

IEC 790:1984, *Oscilloscopes and peak voltmeters for impulse tests*.

3 Classification of the puncture test on insulators

The puncture characteristics of insulators depend both on the design, and manufacturing conditions, and on the materials used. IEC 383-1 specifies the puncture test as a sample test, and allows for an impulse overvoltage puncture test as an alternative by agreement. It is recommended to apply this report in the case where this alternative is chosen.

It is realized that impulse voltage puncture tests take more time than power frequency tests. Thus, the procedure for the sample test is given for guidance, to be used as desired for both research and specification for supply of insulators, and to gain more information on the costs of the sample test.

The costs can be reduced by automation.

4 Impulse voltage puncture test on insulators in air

4.1 General requirements for the test

Except if otherwise specified, IEC 60-1 and IEC 383-1 are applicable. The test specimen shall be clean, dry, and in thermal equilibrium with surroundings before starting the test.

4.2 Mounting arrangements

The mounting arrangement depends on the type of the insulator unit and on its possible integral metallic parts.

The **cap and pin insulator** (Figure 1) shall be mounted cap side down on an earthed plate whose smallest dimension is at least twice the diameter of the insulator tested. The distance from this plate to the insulator dielectric shall be as small as possible but sufficient to avoid direct flashover to the plate. On the pin side, a ball socket having approximately the same dimension as the actual cap of the insulator shall be mounted to avoid electrical over-stress in the critical area at the level of the cement around the pin. The divider (D) and generator (G) shall be connected on the upper side of this ball socket. A similar method shall be used for clevis and tongue-type fittings.

The **long-rod insulator** (Figure 1) shall be mounted vertically accordingly on an earthed plate. Rounded clevises, having approximately the same diameter as the end fittings, shall be mounted on both end fittings of the insulator to avoid electrical over-stress in the critical area at the level of the cement around the fitting. The divider and generator shall be connected accordingly.

The **pin insulator** (Figure 2) shall be mounted on a supporting cross-arm, which shall be a horizontal, straight, smooth, earthed, metallic tube or structural member having a horizontal width not less than 76 mm, and not more than 152 mm. It shall be placed on the ground.

Depending on the type of **pin insulator**, two mounting arrangements on the supporting cross-arm are used:

a) *For pin insulators with the insulating component in service being supported without contact with the supporting structure:*

The test specimen shall be mounted vertically on a metal pin of approximately 25 mm diameter of such length that the shortest dry-arcing distance from the upper electrode and connected metallic parts to the supporting cross arm shall be 25 % to 50 % greater than the similar distance to the pin. The pin shall be coaxial with the test specimen. If the insulator has an integral pin, this shall be used.

b) *For pin insulators with the insulating component in service being in contact with the supporting structure:*

The test specimen shall be attached vertically directly to the supporting cross-arm.

The **line-post insulator** (Figure 2) shall be mounted in an upright position at the centre of a horizontal earthed metallic structure made from an inverted U-channel. This metallic structure shall have a width approximately equal to the diameter of the base of the insulator under test and shall have a length at least equal to twice the insulator height. It shall be placed on the ground.

For the top connection of pin and line-post insulators without metallic clamp, a circular metallic spring of 18 mm in diameter shall be placed in the side groove. A suitable plate with smooth connections in the side groove shall be mounted over the top or in the top groove, if any. This plate shall be provided with two connectors, one for the generator (G) circuit, and the other for the divider (D).

If the pin and line-post insulator is provided with a means of clamping, the connectors for the generator (G) circuit and for the divider (D) shall be placed in a clamp.

The ground return conductor between the insulator and the divider shall be a plate. It is advisable to use plate also in other parts of the ground return circuit. The test voltage shall be applied between the generator connector and earth.

4.3 Number of insulators to be tested

- *for the type test:* five;
- *for the sample test:* as in IEC 383-1, clause 8.2, sample size E2.

For time saving, in the case where this test is used as an alternative to the puncture test in oil as described in IEC 383-1, the test may be carried out on a separate sample from the same batch. In this case, there is no need to carry out the previous tests of the sample test sequence of IEC 383-1.

4.4 Measurement of test voltage

It is recommended to use a fast small-size low resistance, or other type of small and fast special divider. The ratio of the divider shall be known with an error not exceeding $\pm 2\%$. The measuring system shall be calibrated and approved in accordance with IEC 60. The oscilloscope shall comply with IEC 790. Minimum requirements for the response of the measuring system are:

- *oscilloscope:* rise time (0 % – 100 %) ≤ 12 ns;
- *measuring system without oscilloscope:* first partial response time $T_a \leq 3$ ns

Figure 3 gives an example for a recommendable configuration of a small-size solid-type voltage divider.