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colour inside

Insulating liquids – Determination of the breakdown voltage at power frequency – Test method

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

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

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INTERNATIONAL
ELECTROTECHNICAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INSULATING LIQUIDS – DETERMINATION OF THE BREAKDOWN VOLTAGE AT POWER FREQUENCY – TEST METHOD

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 60156 has been prepared by IEC technical committee TC 10: Fluids for electrotechnical applications.

This third edition cancels and replaces the second edition published in 1995. This edition constitutes a technical revision and, mainly, confirms the content of the previous edition even if some advances are included. The test method has not been changed for practical reason due to the very large number of instrumentation disseminated around the world, although the use of stirring is now recommended.

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

FDIS	Report on voting
10/1061/FDIS	10/1065/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.

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.

IMPORTANT – The “colour inside” logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

INTRODUCTION

As normally applied, breakdown voltage of insulating liquids is not a basic material property but an empirical test procedure intended to indicate the presence of contaminants such as water and solid suspended matter and the advisability of carrying out a drying and filtration treatment.

The AC breakdown voltage value of insulating liquids strongly depends on the particular set of conditions used in its measurement. Therefore, standardized testing procedures and equipment are essential for the unambiguous interpretation of test results.

The method described in this document applies to either acceptance tests on new deliveries of insulating liquids, or testing of treated liquids prior to or during filling into electrical equipment, or to the monitoring and maintenance of oil-filled apparatus in service. It specifies rigorous sample-handling procedures and temperature control that should be adhered to when certified results are required. For routine tests, especially in the field, less stringent procedures may be practicable and it is the responsibility of the user to determine their effect on the results.

Annex A (informative) describes, for comparison, an alternative test method which could be introduced in the future. Annex B (informative) describes special test methods, using cells which may include low volume samples. Annex C (informative) describes a reference material for a performance test and check according to IEC 60060-3[1][1].

1 Numbers in square brackets refer to the Bibliography.

INSULATING LIQUIDS – DETERMINATION OF THE BREAKDOWN VOLTAGE AT POWER FREQUENCY – TEST METHOD

1 Scope

This document specifies the method for determining the dielectric breakdown voltage of insulating liquids at power frequency. The test ~~portion, contained~~ procedure is performed in a specified apparatus, where the oil sample is subjected to an increasing AC electrical field ~~by means of a constant rate of voltage rise~~ until breakdown occurs. The method applies to all types of insulating liquids of nominal viscosity up to 350 mm^2/s~~$^{-1}$~~ at 40 °C. It is appropriate both for acceptance testing on unused liquids at the time of their delivery and for establishing the condition of samples taken in monitoring and maintenance of equipment.

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 60052: 1960, *Recommendations for voltage measurement by means of sphere-gaps (one sphere earthed)*~~

~~IEC 60060, *High-voltage test techniques*~~

IEC 60475~~:1974~~, *Method of sampling insulating liquids ~~dielectrics~~*

3 Terms and definitions

No terms and definitions are listed in this document.

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

4 Electrical apparatus

4.1 General

The electrical apparatus consists of the following units:

1) voltage regulator,
2) step-up transformer,
3) switching system,
~~4) energy limiting devices.~~
4) current-limiting resistors,
5) measuring device.

Two or more of these units may be integrated in any equipment system.

4.2 Voltage regulator

~~Uniform increase of voltage with time by manual means is difficult and, for this reason, automatic control is essential.~~

~~Voltage control may be achieved by one of the following methods:~~

~~a) Variable ratio auto-transformer~~

~~b) Electronic regulator~~

~~c) Generator-field regulation~~

~~d) Induction regulator~~

~~e) Resistive type voltage divider~~

The test voltage shall be increased with an automatic control of the required uniform voltage rate of rise. The device should not introduce harmonics disturbances (< 3%) and the AC source should be free from harmonics.

4.3 Step-up transformer

The test voltage is obtained by using a step-up or resonant transformer supplied from an AC source using ~~(~~ 48 Hz to 62 Hz~~)~~ (sinusoidal waveform) ~~voltage source whose value is gradually increased~~. The voltage source value is constantly increased. The controls of the variable low-voltage source shall be capable of varying the test voltage smoothly, uniformly and without overshoots or transients. Incremental increases (produced, for example, by a variable auto-transformer or an amplifier) shall not exceed 2 % of the expected breakdown voltage.

~~The voltage applied to the electrodes of the liquid-filled cell shall have an approximately sinusoidal waveform, such that the peak factor is within the following limits: 1,41 ± 0,07.~~

The centre-point of the secondary winding of the transformer should be connected to earth.

4.4 Switching system

~~3.4.1 Basic requirements~~

The circuit shall be opened automatically if ~~an established~~ a sustained arc between the electrodes occurs and the voltage between the electrodes collapses to a voltage less than 500 V. The primary circuit of the step-up transformer shall be fitted with a circuit-breaker operated by the current sensing device, resulting from the breakdown of the sample and shall break the voltage within 10 ms. ~~The circuit may be opened manually if a transient spark (audible or visible) occurs between the electrodes.~~

~~NOTE~~ The sensitivity of the current or voltage sensing element depends on the energy-limiting device employed and only approximate guidance can be given. ~~Normally, triggering of cut-off by a current of 4 mA maintained for 5 ms is acceptable, while fast energy-limiting (see 3.4.2) triggering by a transient current of 1 A maintained for 1 µs has been found satisfactory.~~

A cut-off time of < 100 µs, as given in the previous edition of this document, is needed to perform multiple breakdowns on silicone liquids.

~~3.4.2 Special requirements for silicone liquids~~

~~Silicone liquids can give rise to solid decomposition products through the action of electric discharges, which may cause gross errors in the observed results. In such cases, all feasible steps shall be taken to minimize the energy available for dissipation in the breakdown discharge.~~

~~Whilst current limiting as above, combined with isolation of the step-up transformer primary within 10 ms, is adequate for hydrocarbons. More satisfactory performance for silicone liquids is obtained by short circuiting of the primary circuit of the transformer by a low-impedance or by use of a low-voltage device for detection of breakdown acting within a few microseconds. This device may be of either analogue (for example, modulating amplifier) or switching (for example, thyristor) type. By the use of this device, the output voltage of the step-up transformer shall be reduced to zero within 1 ms of detection of breakdown, and shall not thereafter increase again until the next step of the test sequence is commenced.~~

4.5 Current-limiting resistors

To protect the equipment and to avoid excessive decomposition ~~of the liquid~~ at the instant of breakdown of liquids such as silicone or ester liquids, a resistance limiting the breakdown current ~~may~~ shall be inserted in series with the test cell.

The short-circuit current of the transformer and associated circuits shall be within the range of 10 mA to 25 mA for all voltages higher than 15 kV. This may be achieved by a combination of resistors in either or both the primary and secondary circuits of the high-voltage transformer.

4.6 Measuring ~~device~~ system

For the purposes of this document, the magnitude of the test voltage is defined as its peak value divided by $\sqrt{2}$.

~~This voltage may be measured by means of a peak-voltmeter or by means of another type of voltmeter connected to the input or output side of the testing transformer, or to a special winding provided thereon; the instrument then used shall be calibrated against a standard up to the full voltage which it is desired to measure.~~

The output voltage of the step-up transformer may be measured by means of a measuring system consisting of a voltage divider or a measuring winding of the step-up transformer coupled with a peak-voltmeter. The measuring system shall be calibrated up to the upper scale voltage to be measured. A method of calibration which has been found satisfactory is the use of a transfer standard. This is an auxiliary measuring device which is connected in place of the test cell between the high-voltage terminals to which it presents ~~the same~~ an impedance ~~as the filled test cell~~ similar to the one of the sample liquid. The auxiliary device is separately calibrated against a primary standard~~, for example, a sphere gap in accordance with IEC 52 (see also IEC 60)~~ [2],[3].

5 Test assembly

5.1 General

The breakdown voltage test is performed following the method described herewith as a routine test.

5.2 Test cell

The volume of the cell shall be between 350 ml and 600 ml.

The cell shall be made from electrically insulating materials, that are not hygroscopic. The cell shall be transparent and chemically inert, resistant to the insulating liquid and to the cleaning agent~~s~~ that ~~may~~ shall be used. A glass cell is the preferred option.

The cell shall be provided with a cover and shall be designed to permit easy removal of the electrodes for cleaning and maintenance. To improve homogenization of the test liquid, a rounded bottom shape of the cell is recommended. Containers and covers shall be cleaned by washing with a suitable solvent or clean insulating liquid to remove residues of an earlier sample. After cleaning, containers shall be immediately capped and kept closed until used again. Electrodes shall be stored in clean insulating liquids.

NOTE It is preferable, in the case of esters, to use similar liquid to store the electrodes.

Examples of suitable cell designs are given in Figures 1 and 2.

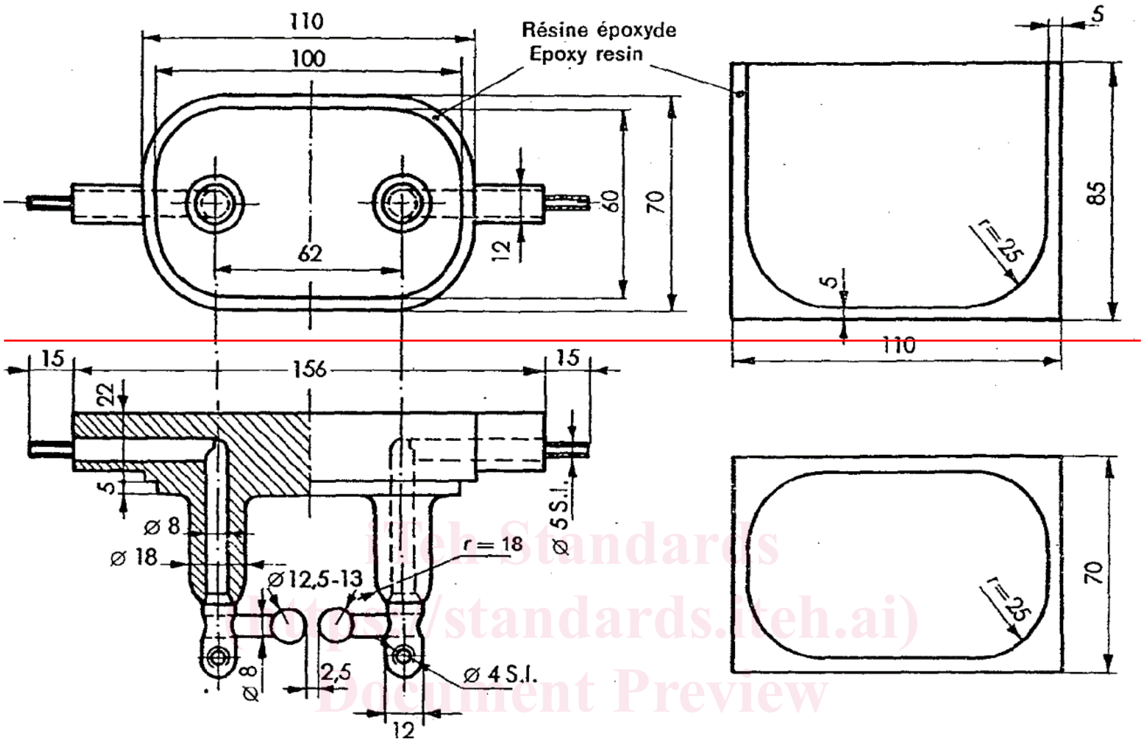


Figure 1 – Example of suitable cell and spherical electrodes

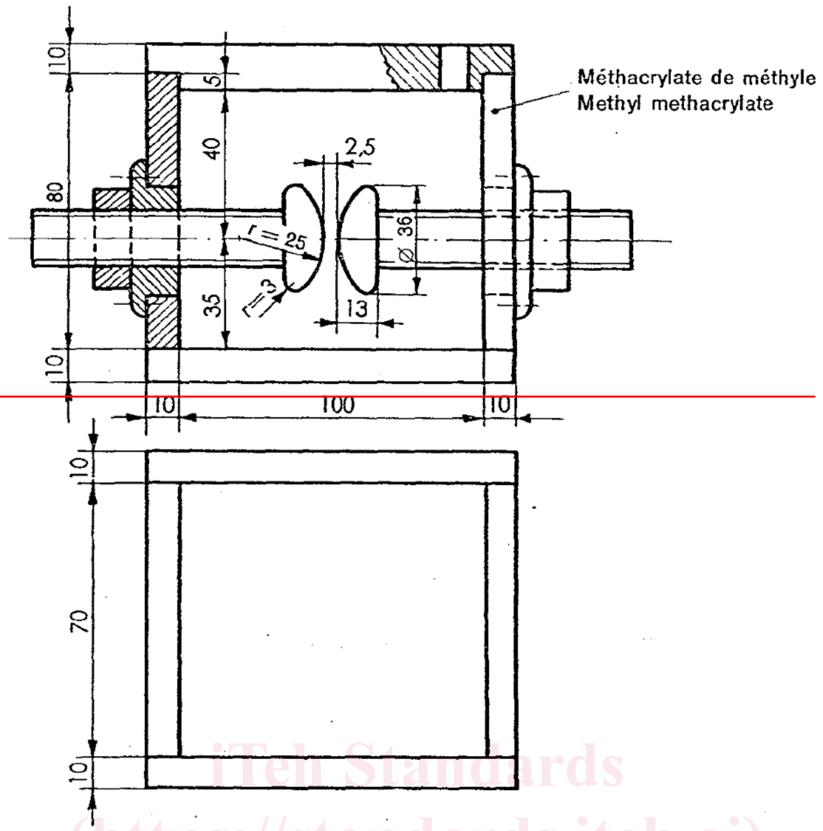
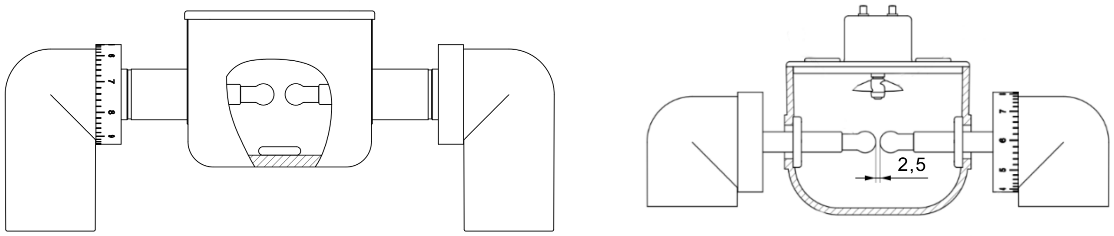


Figure 2 – Example of suitable cell and partially spherical electrodes

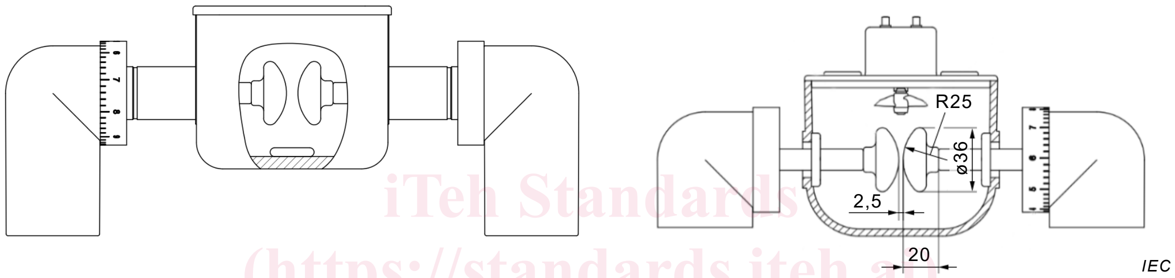
Dimensions in millimetres



NOTE The stirring device can be mounted on the top (right side figure) or on the bottom (left side figure). The stirring device position and Vernier shifter are reported only as reference.

Figure 1 – Examples of test cells with spherical electrodes 12,5 mm to 13,0 mm diameter

Dimensions in millimetres



NOTE The stirring device can be mounted on the top (right side figure) or on the bottom (left side figure). The stirring device position and Vernier shifter are reported only as reference.

Figure 2 – Examples of test cells with partially spherical electrodes with 25 mm radius and diameter of 36 mm

5.3 Electrodes

The electrodes shall be made either of brass, bronze or austenitic stainless steel. They shall be polished and, in shape, either spherical (12,5 mm to 13,0 mm diameter) as shown in Figure 1 or in partially spherical shape (25 mm ± 0,25 mm radius) as shown in Figure 2. The axis of the electrode system shall be horizontal and shall be at least 40 mm below the surface of the test liquid. ~~No part of the electrode shall be closer than 12 mm to the cell wall or stirrer.~~ Any part of the cell or stirrer shall not influence the electric field between the electrodes. The gap between the electrodes shall be 2,50 mm ± 0,05 mm.

The electrodes shall be examined frequently for pitting or other damage and shall be maintained or replaced as soon as such damage is observed.

NOTE The electrodes can be replaced or refurbished typically after 5 000 single breakdowns. The surface of the electrodes can be polished with a maximum grain diameter of 10 µm. The limit of the arithmetical mean deviation of the roughness profile of the electrodes can be Ra ≤ 0,5 µm, according to ISO 4287[4].

5.4 Stirring device ~~(optional)~~

~~The test may be conducted with or without stirring. Differences between tests with or without stirring have not been found statistically significant. A stirrer, however, may be convenient especially with apparatus capable of automatic operation.~~

~~Stirring may be achieved by means of a two-bladed impeller of effective diameter 20 mm to 25 mm, axial depth 5 mm to 10 mm, rotating at a speed of 250 r.p.m to 300 r.p.m. The impeller~~