भारतीय मानक

Indian Standard

IS 6792 : 2023
IEC 60156 : 2018

विद्युत रोधक द्रव्य — पॉवर आवर्ती पर भंजन वोल्टता का निर्धारण — परीक्षण विधि

(तीसरा पुनरीक्षण)

Insulating Liquids — Determination of the Breakdown Voltage at Power Frequency — Test Method

(Third Revision)

ICS 29.040

भारतीय मानक ब्यूरो
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Fluids for Electrotechnical Applications Sectional Committee, ETD 03

NATIONAL FOREWORD

This Indian Standard (Third Revision) which is identical IEC 60156 : 2018 ‘Insulating liquids — Determination of the breakdown voltage at power frequency — Test method’ issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Fluids for Electrotechnical Applications Sectional Committee and approval of the Electrotechnical Division Council.

This standard was originally published in 1972. The first revision of this standard was brought out in1992 subsequently second revision in 2017. The third revision has been undertaken to align it with the latest version of IEC 60156 : 2018.

The text of the IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards.Attention is particularly drawn to the following:

a) Wherever the words ‘International Standard’ appears referring to this standard, they should be read as ‘Indian Standard’.
b) Comma (,) has been used as a decimal marker, while in Indian Standards the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60475 Method of sampling insulating liquids	IS 6855 : 2023 Method of sampling insulating liquids (*third revision)*	Identical with IEC 60475 : 2022

Only the English language text has been retained while adopting it in this Indian Standard, and as such, the page numbers given here are not the same as in the IEC Publication.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

CONTENTS

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].

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1 Numbers in square brackets refer to the Bibliography.

Indian Standard

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

(Third Revision)

1 Scope

This document specifies the method for determining the dielectric breakdown voltage of insulating liquids at power frequency. The test procedure is performed in a specified apparatus, where the oil sample is subjected to an increasing AC electrical field until breakdown occurs. The method applies to all types of insulating liquids of nominal viscosity up to 350 mm^2/s 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 60475, *Method of sampling insulating liquids*

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) current-limiting resistors,
5) measuring device.

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

4.2 Voltage regulator

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

4.4 Switching system

The circuit shall be opened automatically if 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 sensitivity of the current or voltage sensing element depends on the energy-limiting device employed and only approximate guidance can be given.

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.

4.5 Current-limiting resistors

To protect the equipment and to avoid excessive decomposition at the instant of breakdown of liquids such as silicone or ester liquids, a resistance limiting the breakdown current 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 system

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

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 an impedance similar to the one of the sample liquid. The auxiliary device is separately calibrated against a primary standard [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.

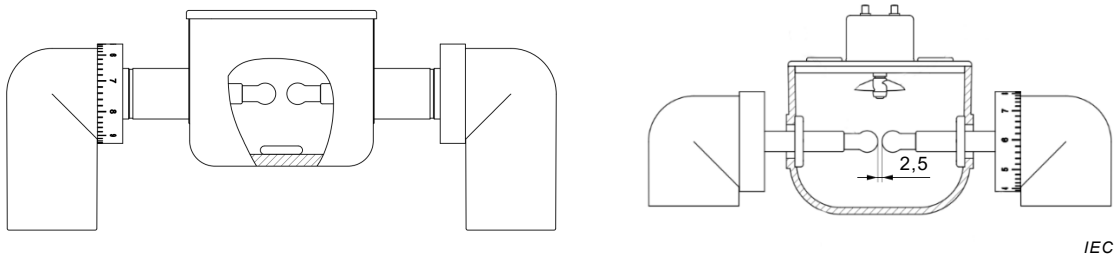
The cell shall be made from electrically insulating materials, that are not hygroscopic. The cell shall be transparent and chemically inert, resistant to the insulating liquid and to the cleaning agent that shall be used. A glass cell is the preferred option.

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.

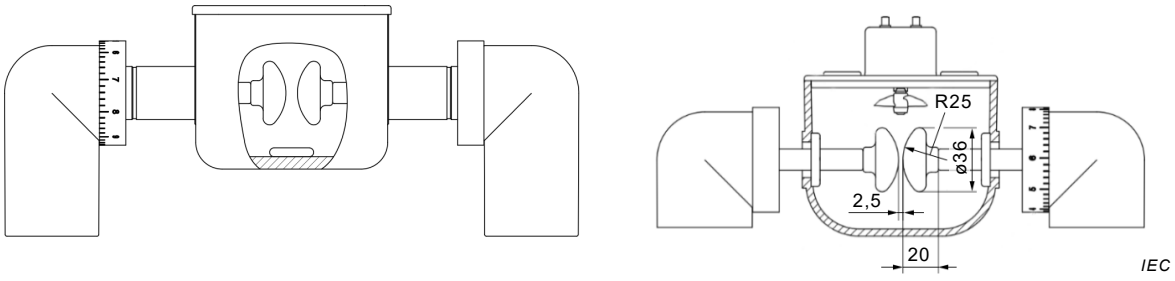
Dimensions in millimetres



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. 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

The use of an automatic stirring device is recommended, to be used at all times throughout the test.

The stirrer shall be mounted in the test cell in order to maximize the homogenization of the liquid. It shall be designed so that it is easily cleaned. Stirring shall be achieved by means of a two-bladed or appropriate stirrer of effective diameter 25 mm to 35 mm, axial depth 5 mm to 10 mm, rotating at a speed of 200 r/min to 300 r/min. The stirrer shall not produce air bubbles. It shall be fully immersed in the liquid sample. Examples of stirring systems mounted in test cells are reported in Figures 1 and 2.

NOTE 1 To avoid bubbles between the electrodes the stirrer can rotate preferably in such a direction that bubbles can be removed [5].

NOTE 2 The stirring device can be mounted on the top or on the bottom. In Figures 1 and 2, the stirring device position is reported only as reference.

NOTE 3 A magnetic stirring device can be also used.

6 Preparation of electrodes

New electrodes shall be cleaned and fulfil the requirements of 5.3. Preparation of the electrodes shall be according to the following procedure:

– clean all surfaces with a suitable volatile solvent and allow the solvent to evaporate;
– polish with fine abrasive powder (for example, jeweller’s rouge) or abrasive paper or cloth, for example crocus cloth (see 5.3);
– after polishing, clean with petroleum spirit (reagent quality: boiling range of about 40 °C to 80 °C) followed by acetone (reagent quality);
– assemble the electrodes in the cell, fill with a clean, unused insulating liquid of the type to be tested;
– before the first breakdown test, raise the voltage until breakdown 24 times.

This procedure shall be repeated after each cleaning or change of electrodes.

7 Test assembly preparation

It is recommended that a separate test cell assembly be reserved for different insulating liquid types.

Test assemblies shall be stored in a dry place, covered and filled with dry insulating liquid of the type in regular use in the cell.

On change of the type of liquid under test, remove all residues of the previous liquid with an appropriate solvent, rinse the assembly with a clean, dry liquid of the same type as the one to be tested, drain and refill.

8 Sampling

Sampling shall be carried out in accordance with IEC 60475.

NOTE Breakdown voltage is extremely sensitive to the slightest contamination of the sample by water and particulate matter. Special precautions can be implemented to avoid contamination of the sample and the need for trained personnel and experienced supervision. Unless otherwise required, the sample is taken where the liquid is likely to be most contaminated, usually at the lowest point of the container holding it.

The test is carried out, unless otherwise specified, on the sample as received without drying or degassing.

9 Test procedure

9.1 Sample preparation

Immediately before filling the test cell, the sample container is gently agitated and turned over several times in such a way as to ensure, as far as possible, a homogeneous distribution of the impurities contained in the liquid without causing the formation of air bubbles.

A possible method is an automatic rotation of the sample container horizontally for 1 min with a recommended speed of 30 r/min.

Equilibrate the sample to room temperature. Unnecessary exposure to the ambient air of the sample shall be avoided.

9.2 Filling of the cell

Immediately before commencing the test, drain the test cell and rinse the walls, electrodes and other component parts, with the test liquid. Drain and slowly fill with the test liquid avoiding the formation of air bubbles.

Measure and record the temperature of the liquid.

10 Application of the voltage

At the time of test, the temperatures shall be maintained at room temperature (20 °C ± 5 °C).

Adjust the electrode gap distance to 2,5 mm ± 0,05 mm with a vernier or other system and start the stirrer. The stirrer, if used, shall run continuously throughout the test.

Metallic gauges can damage the surface of the electrodes; hence, they have to be avoided.

The first application of voltage is started approximately 5 min after completion of filling and checking that no air bubbles are visible in the electrode gap. Apply voltage to the electrodes and uniformly increase voltage from zero at the rate of 2,0 kV/s ± 0,2 kV/s until breakdown occurs.

The breakdown voltage is the maximum voltage reached at the time the circuit is opened either automatically (established arc) or manually (visible or audible discharge detected).

Record the value in kilovolts.

Carry out six breakdowns on the same cell filling allowing a pause of at least 2 min after each breakdown before re-application of voltage. Check that no gas bubbles are present within the electrode gap.

Calculate the mean value of the six breakdowns, standard deviation and related coefficient of variation (ratio between standard deviation and mean breakdown voltage).

For insulating liquids having a nominal viscosity higher than 15 mm^2/s (40°C), the resting time before application of the voltage shall be increased in the range of 15 min to 30 min. In addition, the resting time between two consecutive shots shall also be increased accordingly.

11 Report

The report shall include:

– sample identification, possibly including the type of insulating liquids;
– value of each individual breakdown in kilovolts;
– mean breakdown value;
– type of electrodes used;
– temperature of the liquid (in the test cell);
– coefficient of variation (%) (optional);
– frequency of the test voltage (optional);
– stirring arrangement (optional).

In the case where the individual breakdown voltage is above the maximum equipment voltage capability, the result shall be reported as greater than the maximum voltage capability (example: > 80 kV).

12 Test data dispersion and reproducibility

12.1 Test data dispersion

The graphical representation of Figure 3 indicates the values of the coefficient of variation and its mean value which have been found in a large body of test data in several laboratories using transformer liquids. The solid line in the graph shows the distribution of the coefficient of variation as a function of the mean breakdown value. The dotted lines indicate the expected 2,5 % (0,025) to 97,5 % (0,975) range of values of standard deviation (SD)/mean as a function of the value of the mean.

Typical coefficients of variation reported in Figure 3 are for information only and do not represent an acceptance criteria for the obtained results.

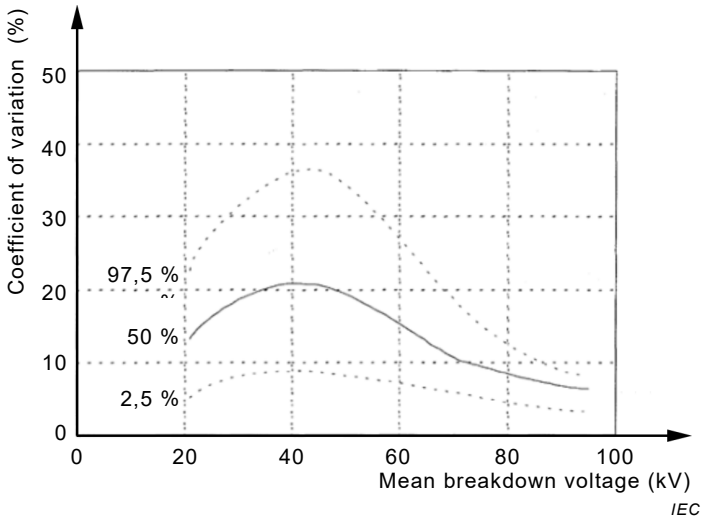


Figure 3 – Graphical representation of coefficient of variation versus mean breakdown voltage

12.2 Reproducibility

Experience has shown that the reproducibility of individual dielectric breakdown values is in the range of ±30 %.

Annex A
(informative)

Improved test method

A.1 Test procedure for improved test method

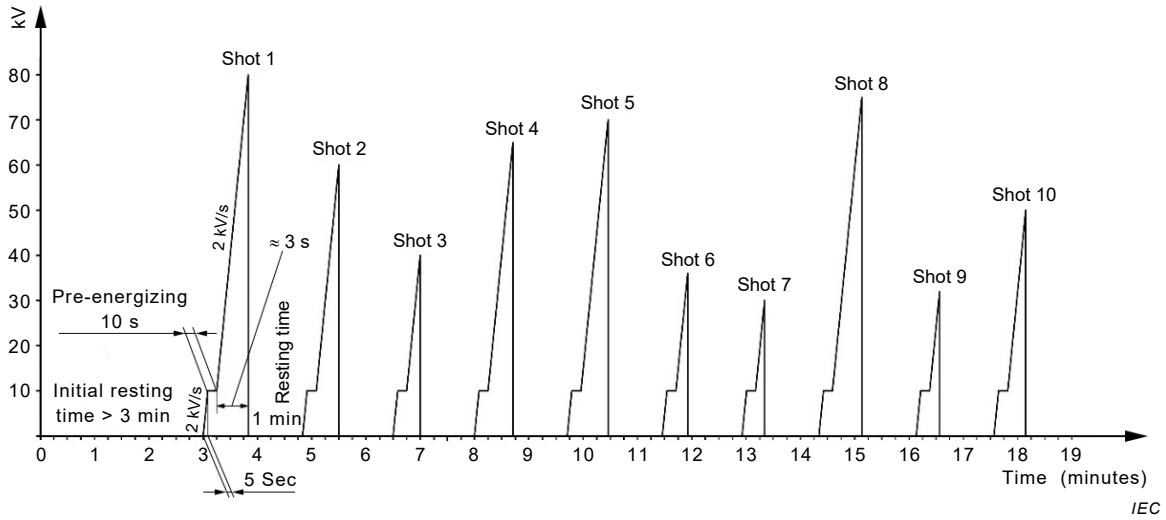
Annex A describes an improved test method, believed to be able to reduce the scatter of the results of breakdown voltage, which may be used [5],[6],[7]. The results obtained using both methods around the world during the following years will assist in a future choice when this document is revised.

Use the same instrument and prepare the test according to Clauses 4 to 9. Instead of the procedure described in Clause 10, follow the procedure described hereafter (Figure A.1):

NOTE The software of the device can be aligned with the procedure described in Annex A.

1) The first application of voltage is started at least 5 min after completion of filling and after checking that the liquid under test is free from air bubbles.
2) Apply voltage to the electrodes uniformly and increase the voltage from zero at the rate of 2 kV/s ± 0,2 kV/s until 10 kV is reached.
3) Maintain the 10 kV level for 10 s, then continue with a rate of voltage rise of 2 kV/s ± 0,2 kV/s until a breakdown occurs.
4) The breakdown voltage shall be recorded at the maximum voltage reached.
5) Carry out 10 breakdowns on the same filling, allowing a pause of at least 1 min after each breakdown before re-application of the test voltage. Record each single breakdown. Calculate the test results as the average and coefficient of variation (ratio between standard deviation and mean breakdown voltage) of the remaining six results after disregarding the two highest and two lowest results.
6) When the coefficient of variation of the test result (mean breakdown voltage) exceeds the upper limit (Figure 3), the test procedure should proceed for the other 10 breakdowns, repeating the procedure from 2) to 6) with the same sample liquid. Record also the results of these additional breakdowns. Calculate the test results as the average and coefficient of variation of the remaining 12 results after disregarding the four highest and four lowest results.

For insulating liquids having a nominal viscosity higher than 15 mm^2/s (40°C), the resting time before application of the voltage shall be increased in the range of 15 min to 30 min. In addition, the resting time between two consecutive shots shall also be increased accordingly.



In the average calculation, the results of four outliers (two highest and two lowest values) have to be discarded (in this example, shots 1 and 8 are the highest and shots 7 and 9 are the lowest).

Figure A.1 – Example of a sequence of breakdown shots for determination of the breakdown voltage

A.2 Report

See Clause 11.

Annex B
(informative)

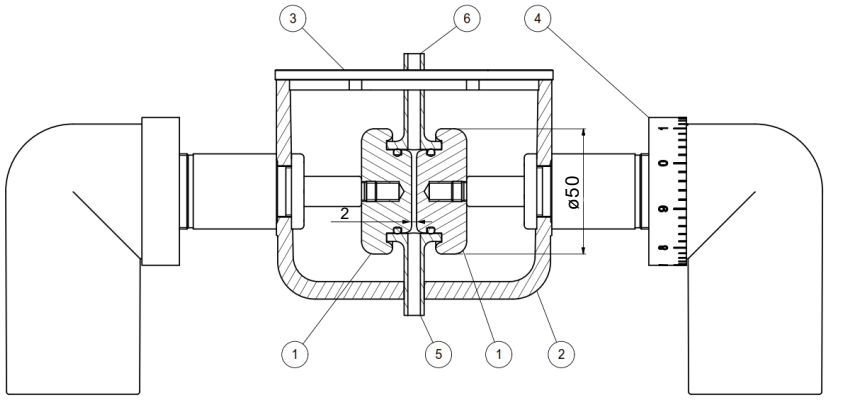
Special test methods for low volume samples

B.1 Low volume sample test

The special test method reported in this annex is suggested for use with low sample volumes. A limited body of data has shown that the results obtained are comparable to the results obtained from the method described in the main body of this document. Examples of the reduced volume test cell are shown in Figures B.1 and B.2.

A fast test on-site may require small portable testers, able to measure the breakdown voltage of insulating liquids (in either direct current or alternating current). An example of such instruments is a Cockcroft-Walton generator, which utilizes a small electrode gap cell and measuring instrumentation. The cell in such an instrument also requires very small quantities of test liquid.

NOTE The results obtained with such portable instruments cannot be used for diagnostic purposes. Results can differ significantly unless comparability has been established.



Key

1 partially spherical electrodes, rounded disk electrode, 50 mm diameter, 2 mm gap
2 oil filled cup, test cell HV insulation
3 cover
4 electrode distance control
5 sample inlet
6 sample outlet

Figure B.1 – Example of low volume test cell, fixed electrode distance of 2 mm with 2 ml active volume under dielectric stress

Dimensions in millimetres

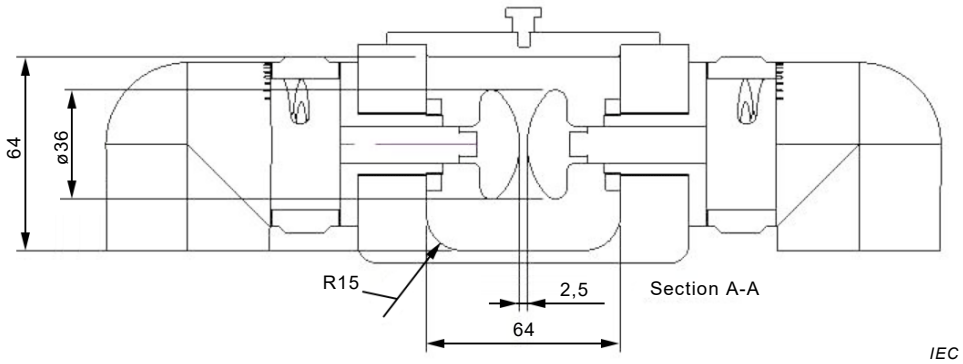


Figure B.2 – Example of low volume test cell, fixed electrode distance of 2,5 mm (150 ml to 200 ml)

Annex C
(informative)

Representative material for a performance test

The reference analysis may be used as a performance check to prove that the test system is fit for use according to IEC 60060-3.

The representative material shall be unused, filtered and degassed mineral, silicone or ester liquids. The minimum quality requirement of the liquid shall be according to IEC relevant standards.

If the test result does not reach the required > 70 kV value, check the functionality of the equipment, or prepare a fresh representative material sample and carry out a new performance check.

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