Method for spark testing of cables

The European Standard EN 50356:2002 has the status of a British Standard

ICS 29.060.20

British Standards

National foreword

This British Standard is the official English language version of EN 50356:2002. It partially supersedes BS 5099:1992.

The UK participation in its preparation was entrusted by Technical Committee GEL/20, Electric cables, to Subcommittee GEL/20/17, Low voltage cables, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

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ICS 29.060.20

English version

Method for spark testing of cables

Essai diélectrique au défilement à sec des câbles électriques

Durchlaufspannungsprüfung an elektrischen Kabeln und Leitungen

This European Standard was approved by CENELEC on 2002-03-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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CENELEC

European Committee for Electrotechnical Standardization

Comité Européen de Normalisation Electrotechnique

Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

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Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 20, Electric cables.

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- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2003-03-01

- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 2005-03-01

Contents

Introduction

The practice of using spark-testers to detect defects in the insulation or sheathing layers of electric cables has been developed over many years of practical experience.

The operation of the equipment using the verification method described in this document has proved to be satisfactory. This method employs an artificial fault simulator and its performance has been shown to be comparable to that using operational efficacy tests involving the detection of artificially prepared defects (i.e. faults in the insulation/sheathing material) in lengths of cable.

1 Scope

The spark-test method specified in this standard is intended for the detection of defects in the insulation or sheathing layers of electric cables. For single core cables with no outer metallic layer, the general process is accepted as being equivalent to subjecting samples of those cables to a voltage test in water.

This standard specifies the operational requirements for the spark-test equipment, as well as the principal characteristics, functional parameters and calibration procedures for each type of test equipment.

2 Types of voltage waveform

For the purposes of this standard, the types of voltage waveform used for spark-testing are divided into the following groups:

a.c. an alternating current (a.c.) voltage of approximately sine-wave form, at the industrial frequency of 40 Hz to 62 Hz;

d.c. a direct current (d.c.) voltage;

h.f. an alternating current (a.c.) voltage of approximately sine-wave form, at frequencies between 500 Hz and 1 MHz;

pulsed a voltage waveform comprising a fast rise time and highly damped wave-tail, as defined in 4.2.

NOTE Provided the manufacturer can demonstrate equivalent effectiveness, h.f. voltages at frequencies below 500 Hz may be used.

3 Procedure

The insulated conductor or sheathed cable shall be passed through an electrode energised at the test voltage. The method detailed in this standard provides for the application of a.c., d.c., h.f. and pulsed voltages.

The requirements for voltage waveform, frequency and test voltage are given in 4.2 and clause 5. The maximum speed at which the cable shall pass through the electrode is determined by the minimum residence time specified in 4.6.

When used as an alternative to a voltage test in water, it is recommended that the test be restricted to layer thicknesses not greater than 2,0 mm and to a.c. and d.c. test voltages.

The requirements are not applicable to cable insulation having a rated voltage (U_0) greater than 3 kV.

Annex A provides recommended voltages for each voltage waveform, to be used in the absence of any alternative voltages in the relevant cable standard.

4 Equipment

4.1 Safety

To limit the effect of electrical shock to personnel, for all types of voltage source, the equipment shall be constructed such that the short-circuit current is limited to less than 10 mA r.m.s. or equivalent.

This requirement is additional to, or may be superseded by, any national regulation that prevails at the time.

NOTE Guidance on the limiting of shock currents can be found in IEC 60479-1 and IEC 60479-2.

Further aspects of operational safety are given in Annex C.

4.2 High voltage source

The high voltage electrode shall be supplied in one of the following forms, as defined in clause 2: a.c., d.c., h.f. or pulsed.

For a d.c. test, connection to the test electrode shall be by means of a low capacitance unscreened lead. For d.c. and pulsed voltage testing, the test electrode may be either positive or negative polarity, the other pole being earthed.

The requirements for pulsed waveforms are presented in Figures 1, 2 and 3.

For pulsed waveforms, the rise time of the wave front shall reach 90 % of the specified peak value in less than 75 μs – see Figure 1. Fluctuations of the actual peak value, due to variations of input power into the generator, shall not exceed ± 2 % of the specified peak value – see Figure 2. The peak value shall not show more than 5 % reduction in the event of an increase of capacitive load of 50 pF, during the operation, from an initial load of 25 pF between electrode and instrument ground. The time that each pulse remains at a voltage greater than 80 % of the specified peak voltage shall be between 20 μs and 100 μs – see Figure 3. The pulse repetition frequency shall be greater than 170 per second and less than 500 per second. This corresponds to pulse separations between 2 000 μs and 5 880 μs. Visible or audible corona shall be evident in the electrode structure when operating at the specified voltage.

4.3 Voltage monitoring equipment

For a.c., d.c. and h.f. sources, the voltage between electrode and earth shall be displayed on a meter either by connection directly to the output terminal of the high voltage source or by any suitable equivalent arrangement. The measurement system shall have an accuracy of ± 5 % of the indicated value.

For a pulse source there shall be a peak reading instrument voltmeter connected directly to the electrode, continually indicating the voltage at the electrode, with or without a grounded test wire in the test chamber. The peak reading voltmeter shall indicate full deflection at a peak value not exceeding 25 kV and with a precision level of ± 5 % of the indicated value.

NOTE If the spark-tester is to be controlled remotely, it should be noted that the current drawn by the cable under test can cause variation of the test voltage. In this situation, the regulation of the voltage source needs to be sufficient to maintain the voltage within the 5 % accuracy limit.

4.4 Fault indicator

There shall be a detection circuit to provide a visible and/or audible indication of failure of the insulation or sheath to maintain the specified voltage. The fault detector shall be arranged to operate a digital display counter such that one count per discrete fault is registered. It shall also be of a totalizer type and cumulative to the end of the cable run. The counter shall maintain the indication until either the next succeeding fault is registered or until the indication is manually cancelled.

4.5 Electrodes

An appropriate choice of electrode shall be made in order to obtain the maximum effective rate of detection.

Types of cable to be tested (construction, materials, etc.) and the test conditions (linear speed, voltage source mode, etc.) form some of the parameters to be considered.

Examples of electrode types are

- contact types:
  bead chain, spring loaded hyperbola, brushes (rotating or fixed),
- non-contact types:
  metallic tube, rings.

4.6 Design of electrodes

4.6.1 Contact type

The electrode shall be of metallic construction and its length shall be such that every point of the insulated conductor or non-metallic sheath under test is in electrical contact with the electrode for times not less than the following:

a) for a.c. supply to the electrode: 0,05 s

NOTE 1 This time represents a maximum linear throughput speed of 1,2 m/min per millimetre of electrode. The minimum length of the electrode (mm) is therefore given by 0,833 *v*, where *v* is the linear throughput speed in m/min.

b) for d.c. supply to the electrode : 0,001 s

NOTE 2 This time represents a maximum linear throughput speed of 60 m/min per millimetre of electrode. The minimum length of the electrode (mm) is therefore given by 0,017 *v*, where *v* is the linear throughput speed in m/min.

c) for h.f. supply to the electrode: $\frac{0{,}002\ 5}{f}$ s

where *f* is the supply frequency in kHz.

NOTE 3 This time represents a maximum linear throughput speed of 24 *f* m/min per millimetre of electrode. The minimum length of the electrode (mm) is therefore given by 0,042 *v*/*f*, where *v* is the linear throughput speed in m/min.

d) for pulse supply to the electrode: $\frac{2{,}5}{p}$ s

where *p* is the pulse repetition rate in pulses per second.

NOTE 4 This time represents a maximum linear throughput speed of 24 *p* m/min per millimetre of electrode. The minimum length of the electrode (mm) is therefore given by 0,042 *v*/*p*, where *v* is the linear throughput speed in m/min.

4.6.2 Non-contact type (d.c. test only)

The electrode shall consist of a cylindrical metal tube or series of metallic rings. In either case the internal diameter(s) shall not be greater than 15 mm. In the case of the ring type, the number of rings shall be such that a uniform electric field is formed. These electrodes shall only be used with a d.c. source and their length shall be such that every point of the insulated conductor or non-metallic sheath is in the electrode for not less than 0,001 s.

NOTE This time represents a maximum linear throughput speed of 60 m/min per millimetre of electrode. The minimum length of the electrode (mm) is therefore given by 0,017 *v*, where *v* is the linear throughput speed in m/min.

The design of the non-contact electrode shall be such that the cable under test is guided by any suitable means along the central axis and be maintained in that position without undue deviation for the duration of the test run.

The maximum recommended overall diameter of the core or cable to be tested using the non-contact electrode system is 3,0 mm.

The use of this type of electrode shall be restricted to a test voltage of 18 kV.

5 Test voltages

The test voltage depends upon the type of electrode used and the voltage waveform applied.

The voltage is related to the total layer thickness being subjected to the test. This may be an insulation layer, a sheath over a metallic layer, or a combination of insulation and sheath with no intermediate metallic layer.

The conductor of the cable under test, or the metallic layer underlying the sheath under test, shall be continuously earthed throughout the test, such that the full test voltage is applied between the test electrode and this earthed component of the cable.

The magnitude of the test voltages are to be found in the cable standard. In the absence of such specified voltages, use can be made of the recommended test voltages given in Annex A.

6 Sensitivity

6.1 a.c., d.c. and h.f. voltages

The sensitivity of the spark test equipment shall be such that the fault detector will operate when an artificial fault is connected between the electrode and earth. The method is given in 6.3.

The performance requirement for each type of voltage source is given below:

a.c. and h.f.

The typical fault is defined as a fault current

a) between 0,5 mA and 10 mA in conformity with the technical characteristics of the test equipment,

b) at a minimum repetition frequency of 1 pulse per second,

c) with a minimum current duration of 0,025 s,

d) with a minimum series of 20 pulses.

d.c.

The typical fault is defined as a fault current as above for a.c. and h.f. conditions except that the minimum current duration shall be 0,000 5 s and at a level between 0,1 mA and 10 mA.

6.2 Pulsed voltages

The sensitivity shall be such that the fault detector will operate when a typical fault is present between electrode and earth.

The typical fault is defined as that generated through a 0,5 MΩ resistor by one pulse over its operating voltage range.

6.3 Method of assessment

NOTE 1 To check the absence of interference on fault detection through the corona effect it is necessary to test a number of lengths of fault free cable at the maximum voltage. No single fault should be detected.

The no-load electrode voltage shall be set initially at 3 kV r.m.s. (a.c. and h.f. systems) or 5 kV for d.c. systems or the minimum test level if greater. When the artificial fault device is connected to the electrode, with the spark gap temporarily short circuited, the steady state current shall not exceed 600 μA. In order to limit the current to a suitable value an impedance may be added in series with the artificial fault device.

NOTE 2 Where the test is to be used as an in-process check in addition to the final voltage test on the cable, the sensitivity test at 3 kV r.m.s. or 5 kV d.c. may be carried out at a steady state current of 1,5 mA. This would be appropriate if the normal operating conditions are such that a sensitivity setting of less than 1,5 mA during production would lead to spurious tripping of the detector.

The artificial fault device shall be set to produce a spark having a maximum duration of 0,025 s for a.c. and h.f., or 0,000 5 s for d.c., for each simulated fault.

A succession of not less than 20 sparks (as specified above) shall be effected, with consecutive sparks being no more than 1 s apart and, if required, with the current-limiting impedance in series with the gap. The fault indicator shall register neither more nor less than one count per spark.

The current-limiting impedance, if any, shall then be short circuited. A fault-free length of cable, presenting the largest capacitive load with which the spark tester is to be used, shall be inserted into the electrode. Alternatively, a high voltage capacitor having the equivalent capacitance shall be connected across the gap. The electrode voltage shall be increased to the maximum required test voltage.

The test shall then be repeated in order to establish that 20 further sparks (no more than 1 s apart) cause the fault indicator to register neither more nor less than one count per spark.

NOTE 3 Separate artificial fault devices may be used for the two tests, in order to limit damage caused by the high energy sparks, for example by erosion of spark gaps.

NOTE 4 Details of one common type of artificial fault device are given in Annex B.

7 Calibration

7.1 General

Verification of the performance of the equipment for a.c., d.c. and h.f. voltage sources shall be carried out using the sensitivity determination specified in 6.3 for a.c., d.c. and h.f. voltage sources.

The pulse type equipment shall be calibrated by means of a peak detecting electronic voltmeter connected directly between the electrode head and ground. The pulse generator shall be energized and the voltage control of the pulse generator shall be adjusted until the reading on the calibration voltmeter is the specified voltage, at which point the reading on the instrument voltmeter shall be observed and recorded. This calibration shall be repeated at each specified peak voltage. The pulse waveform shall be monitored by means of an oscilloscope connected to the electrode head at suitable test points.

NOTE Calibration may be accomplished without a test cable in the electrode, in which case the voltage control on the pulse generator may require a different setting for each cable size in order to give the desired reading on the instrument voltmeter; or the calibration may be made with a load of 20 pF to 60 pF. The equipment may also be calibrated against an oscilloscope with a calibrated and compensated attenuator. The chosen method should have an accuracy of ± 2 %.

7.2 Verification frequency

The test system may be demonstrated to be effective by carrying out the sensitivity assessment in clause 6. It is recommended that the verification is carried out at least once a year, upon initial installation and after any repairs or major adjustments to the equipment.

The accuracy of voltage measurement specified in 4.3 shall be verified at least once a year and after any repairs or major adjustments to the equipment.

The user shall verify that the following functions operate efficiently on a regular basis:

a) fault registration system;

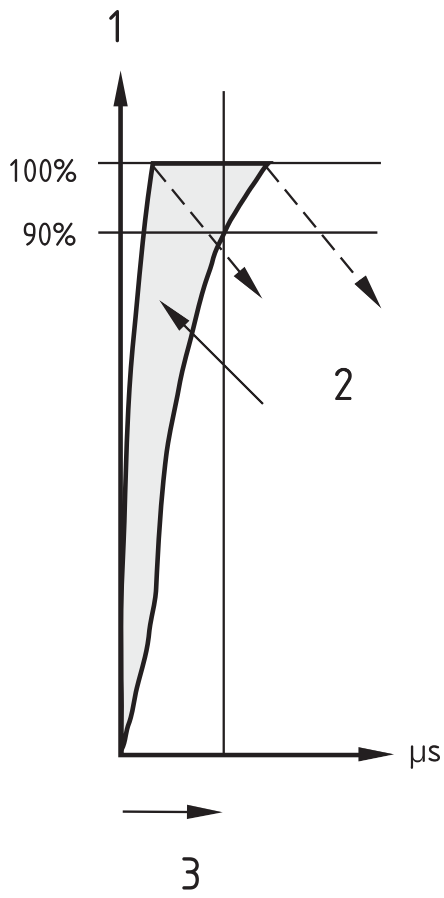
b) fault alarm system;

c) in-line controls operated by fault detection;

d) mechanical state and cleanliness of the electrode assembly;

e) safety interlocks;

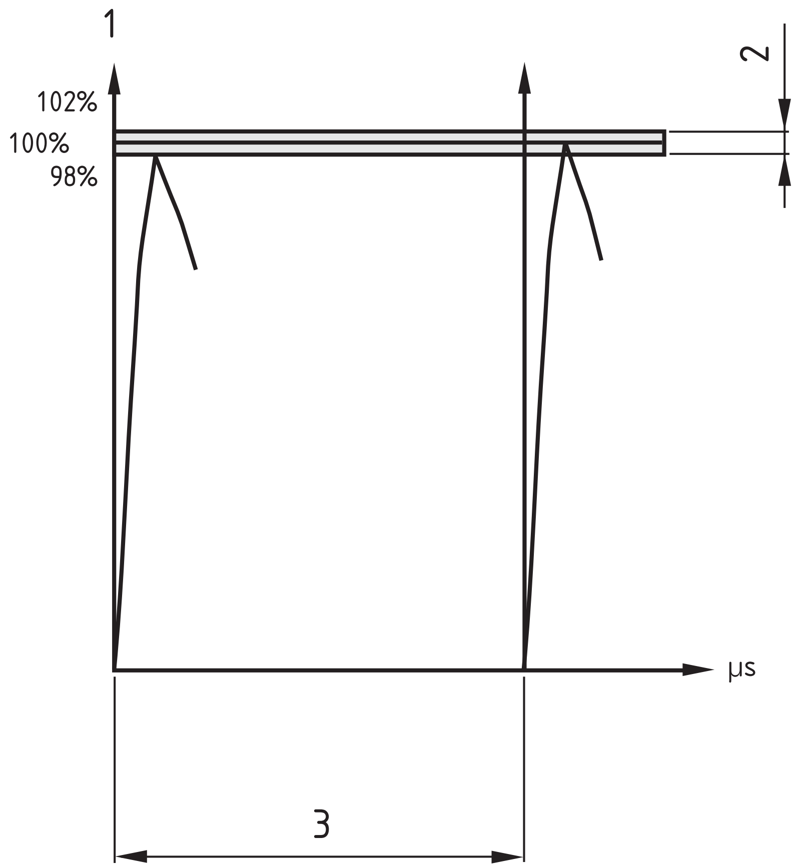
f) maximum short circuit levels.



Key

1 Actual voltage
2 Range of rise time of wavefront
3 Maximum 75 μs

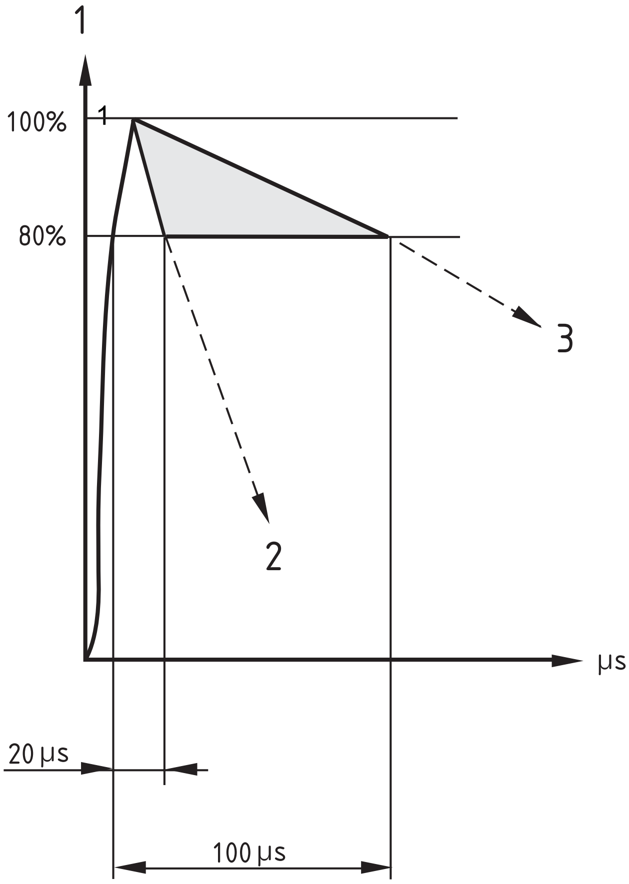
Figure 1 — Requirements for pulsed waveforms - Rise time



Key

1 Actual voltage
2 Fluctuation range
3 Pulse repetition from 2 000 µs to 5 880 µs

Figure 2 — Requirements for pulsed waveforms – Fluctuation of peak value and pulse repetition rate



Key

1 Actual voltage
2 Pulse duration - minimum
3 Pulse duration - maximum

Figure 3 — Requirements for pulsed waveforms - Pulse duration

Annex A
(informative)

Recommended minimum voltage levels

A.1 General

The levels of test voltages given below are those for use where no alternative voltages are specified in the cable standard.

The details of the test method are as given in the main section of this standard.

A.2 Test voltages

A.2.1 General

The voltages given in this annex are recommended as the minimum levels to be used to locate defects in the layer under test. The applicability of these levels should be confirmed by the manufacturer, and will depend upon the type of material being tested.

NOTE Some countries have established higher test levels in their national standards.

A.2.2 Contact electrodes

The high voltage supply to the test electrode may be a.c., d.c., h.f. or pulsed voltage, as specified in clause 2 and 4.2.

Table A.1 gives test voltages which are recommended for cables having a rated voltage (U_0) between 300 V and 3 000 V.

Table A.1 — Recommended minimum spark-test voltages for cables having rated voltage (U_0) between 300 V and 3 000 V

Tabulated radial thickness of layer under test mm		Test voltage kV			
from	up to	a.c.	d.c.	h.f.	pulse
0	0,25	3	5	4	5
0,26	0,50	5	7	6	7
0,51	0,75	6	9	7	9
0,76	1,00	7	11	8	11
1,01	1,25	9	13	10 [a]	13
1,26	1,50	10	15	11 [a]	15
1,51	1,75	12	17	13 [a]	17
1,76	2,00	13	20	14 [a]	20
2,01	2,25	14	22	15 [a]	
2,26	2,50	16	24	17 [a]	
2,51	2,75	17	26	18 [a]	
2,76	3,00	19	28	20 [a]	

[a] h.f. voltage testing for layer thicknesses greater than 1,0 mm should be limited to frequencies between 500 Hz and 4 kHz.

Pulsed voltage testing is not recommended for layer thicknesses greater than 2,0 mm.

As a test to replace the traditional voltage test in water for single core cables without any outer metallic layer, the recommendations in Table A.1 only apply for thicknesses up to 2,0 mm and for a.c. or d.c. waveforms.

When testing laid-up core assemblies, i.e. cables without sheath, the test voltage level shall be that for the lowest individual insulation thickness in the assembly.

NOTE Particular cable standards may, in exceptional circumstances (e.g. for sheathing materials known to exhibit low insulation resistance characteristics, i.e. K_i less than 100 MΩ·km), recommend or require a reduction in the test voltage to ensure that excessive leakage current does not flow and give rise to spurious faults. In no instance shall the reduction be in excess of a factor of two and the fault detection system shall be verified under the alternative test conditions.

A.2.3 Non-contact electrodes

The high voltage supply to the test electrode shall be d.c. only, as defined in 4.2. The conductor of the core or the metallic layer under the sheath shall be continuously earthed and the potential difference between the electrode and the conductor or the metallic layer shall be 18 kV.

Annex B
(informative)

Example of an artificial fault device

One common type of artificial fault device comprises a needle point and a metal plate or shoe. One of these elements is mounted on a rotating spindle, while the other element is fixed, such that a spark gap is created between the two at one point during each revolution of the spindle.

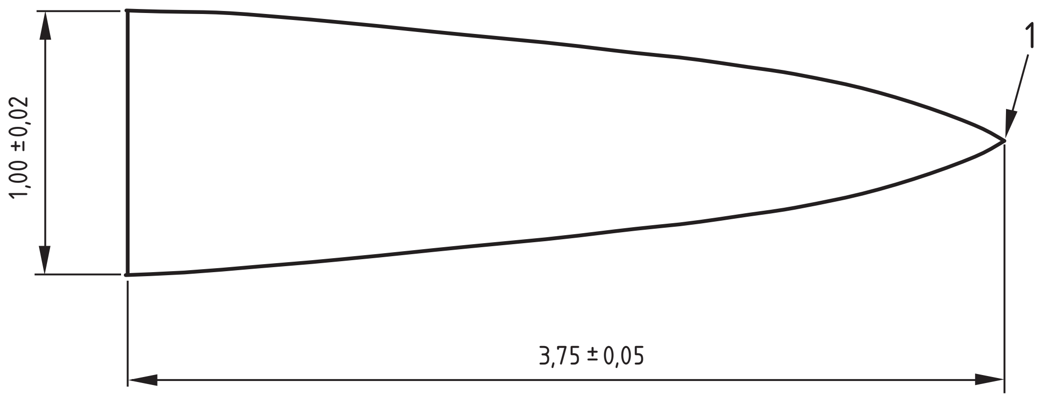
The spark gap between needle and plate is set to (0,25 ± 0,05) mm.

The dimensions of the plate and the rotational speed are such that the spark is maintained for the required maximum duration of 0,025 s (for a.c. and h.f.) or 0,000 5 s (for d.c.) with a maximum repetition rate of 1 s.

The point of the needle is formed from a 1,0 mm chrome finished steel element over a distance of 3,75 mm along the axis as illustrated in Figure B.1. The radius of the point is less than or equal to 0,03 mm. The angle of the point is not greater than 16°.

A suitable point may be obtained from the end portion of a needle widely available from commercial sources.[1)]

The needle should be discarded after a maximum of 400 repetitive sparks.



Dimensions in millimetres

Key

1 Radius of point ≤ 0,03

Figure B.1 - Needle for use in the artificial fault device

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1) For information on the availability of suitable needles, contact national standards organisations.

Annex C
(informative)

Notes on the use of spark testing machines

C.1 General

It is recommended that, when spark testing is being carried out, any safety guidance provided by the equipment manufacturer is strictly observed. In the absence of contrary advice from the equipment manufacturer, the following precautions should be observed, as well as any supplementary guidance from site safety officers.

C.2 Access to electrode systems

To avoid the risk of operator shock when access is desired to the electrode systems, it is advisable to check regularly that the automatic switch-off mechanisms on the shielded enclosure for the electrodes are functioning correctly.

C.3 Conductor earthing

Unless the conductor, metallic sheath, screen or armour underlying the non-metallic covering under test is effectively and continuously earthed, faults may not be located. Continuous earthing or other suitable means should be provided for the prevention of electrical shock. It is particularly important with pulsed voltages, for both operational and safety reasons, that this connection provides a very low impedance to earth.

C.4 Leakage currents

Precautions are necessary to ensure the satisfactory operation of spark testing equipment by restricting leakage currents to a minimum level, e.g. by removing surface moisture from the core or cable under test before it enters the spark testing electrode. The removal of surface moisture is particularly important for d.c. spark-testers, to avoid false registering of faults.

C.5 Charge removal

A length of core or cable which has been subjected to d.c. spark testing may retain a high potential static charge for a certain period after the test. To avoid the possibility of operator shock, care should be taken to ensure that a means of removing the charge from the cable surface is provided, e.g. by allowing the core or cable to run over or through an earthed metallic electrode immediately on emerging from the test electrode.

C.6 Ozone production

Corona discharges within the spark-tester will convert oxygen in the air into ozone. The design of the equipment, its maximum operating voltage and operating procedures should be such as to limit ozone concentrations to an acceptable level. Users are advised to check that this is the case.

Bibliography

IEC/TR2 60479-1, *Effects of current on human beings and livestock — Part 1: General aspects*

IEC/TR 60479-2, *Effects of current passing through the human body — Part 2: Special aspects — Chapter 4: Effects of alternating current with frequencies above 100 Hz — Chapter 5: Effects of special waveforms of current — Chapter 6: Effects of unidirectional single impulse currents of short duration*

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