BRITISH STANDARD

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Incorporating Amendment No. 1

Method for the

Measurement of voltage with sphere-gaps —

(One sphere earthed)

UDC 621.317.32:621.316.933

Co-operating organizations

The Electrical Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

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This British Standard, having been approved by the Electrical Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 16 November 1960

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Contents

Foreword

This standard makes reference to the following British Standard:

BS 923, *Impulse-voltage testing*.

This British Standard, prepared under the authority of the Electrical Industry Standards Committee, revises and supersedes the 1939 edition.

This edition has been drafted concurrently with the Recommendations for voltage measurement with sphere-gaps prepared by the International Electrotechnical Commission and is in technical agreement with the IEC Recommendations.

The revision gives a method of checking the spheres for surface irregularities and also more detailed information regarding the irradiation of the sphere-gaps.

Appendix A gives a bibliography of experimental calibrations, and Appendix B indicates the procedure by which the flashover voltage values have been derived.

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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 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.

1 Scope

This publication contains rules and recommendations for the construction and use of sphere-gaps for voltage measurement where one sphere is earthed. The rules apply to the measurement of the peak value of:

a) alternating voltages,

b) full standard impulses (as defined in BS 923[1]) and impulses with longer tails,

c) direct voltages.

The peak flashover voltages in air for various spacings between the spheres are given in Table 3 and Table 4.

Appendix A gives the limits of voltage and frequency over which the tables have been derived from experiment and can be presumed to be accurate within the limits specified in Clause **11**.

Appendix B gives the procedure by which the values in the tables have been derived from previous National Standards and other sources.

2 Standard sphere-gap

The standard sphere-gap is a peak voltage measuring device constructed and arranged in accordance with the rules in this document. It consists of two metal spheres of the same nominal diameter (*D*) and their shanks, operating gear, insulating supports, supporting frame and leads for connection to the points between which the voltage is to be measured. Standard values of *D*, in centimetres, are 2, 5, 6.25, 10, 12.5, 15, 25, 50, 75, 100, 150 and 200. The spacing between the spheres is designated *S*.

The points on the two spheres which are closest to each other are called the sparking points.

Figure 1 and Figure 2 show two arrangements, one of which is typical of sphere-gaps with a vertical axis and the other of sphere-gaps with a horizontal axis.

3 Requirements for the spheres

The spheres shall be carefully made so that their surfaces are smooth and their curvature is as uniform as possible.

They shall meet the following requirements:

a) *General shape.* The diameter of each sphere shall nowhere differ from the nominal value by more than two per cent.

b) *Freedom from surface irregularities.* The spheres shall be reasonably free from surface irregularities in the region of the sparking point. This region is defined by a circle such as would be drawn on the spheres by a pair of dividers set to an opening of 0.3 *D* and centred on the sparking point.

The freedom from surface irregularities shall be checked by a spherometer of which the feet are between 0.125 *D* and 0.25 *D* apart.

A spherometer measures the distance *h* of its central point from the plane passing through the three feet of the instrument, which form an equilateral triangle of side *a*.

When the three feet and the central point are in contact with a perfectly spherical surface of radius *D*/2, a value for *h* is obtained as follows:

$$h = \frac{D}{2} - \frac{1}{2}\sqrt{D^2 - \frac{4a^2}{3}}$$

$$= \frac{D}{3}\left[\left(\frac{a}{D}\right)^2 + \frac{1}{3}\left(\frac{a}{D}\right)^4\right] \text{with adequate accuracy.}$$

[1] BS 923, "*Impulse-voltage testing*".

When the feet of the spherometer are placed on the spheres in various positions in the region defined above, the difference between the measured values of *h* and the value given in the formula shall nowhere exceed:

0.1 per cent of the nominal diameter (*D*) if this is less than or equal to 100 cm.

0.2 per cent of the nominal diameter (*D*) if this is greater than 100 cm.

If a spherometer is not available, a flat circular gauge may be used for an approximate evaluation of surface irregularities.

NOTE The tolerances on size and shape need usually only be checked in the manner described above when the spheres are first supplied. It will normally be sufficient to make subsequent examinations by feeling the spheres or inspecting them visually.

c) *State of the surfaces*. In the neighbourhood of the sparking points the spheres shall be free from any trace of varnish, grease or other protective coating.

They shall be clean and dry but need not be polished.

If the spheres become excessively roughened or pitted in use they shall be reburnished or replaced.

NOTE If the relative humidity of the air exceeds about 90 per cent, moisture may condense on to the surface and the measurements will then cease to be accurate.

4 Construction and mounting of the spheres

a) *Vertical gap*. When the spheres are mounted vertically, the shank of the high-voltage sphere shall be free from sharp edges or corners and its diameter shall not exceed 0.2 *D* over a length *D*. This requirement is made in order to reduce the influence of the high-voltage shank on the flashover voltage. If a stress distributor is used at the end of the shank, its greatest dimensions, perpendicular to the axis of the spheres, shall not exceed 0.5 *D*. Such stress distributors shall be at least 2 *D* from the sparking point of the high-voltage sphere.

The earthed shank and the operating gear have a smaller effect and their dimensions are therefore less important.

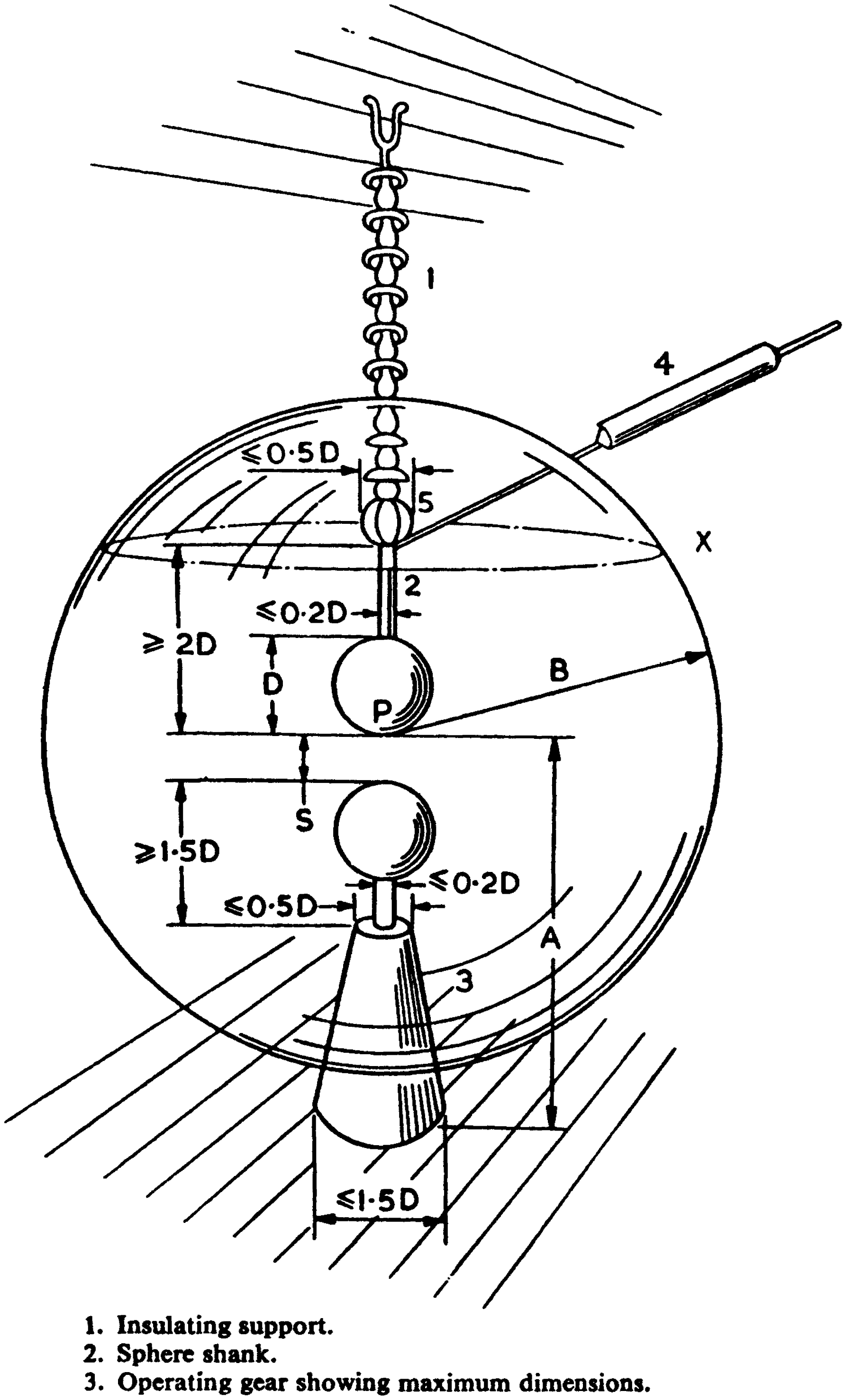
Figure 1 gives the limits of size of the components of a typical vertical sphere-gap.

b) *Horizontal gap*. The limiting dimensions of a typical sphere-gap for horizontally mounted spheres are given in Figure 2. They are the same for both sides of the gap.

NOTE The sphere shanks shall be reasonably in line, whichever form of gap is used.

5 Height of the spheres above the horizontal earth plane

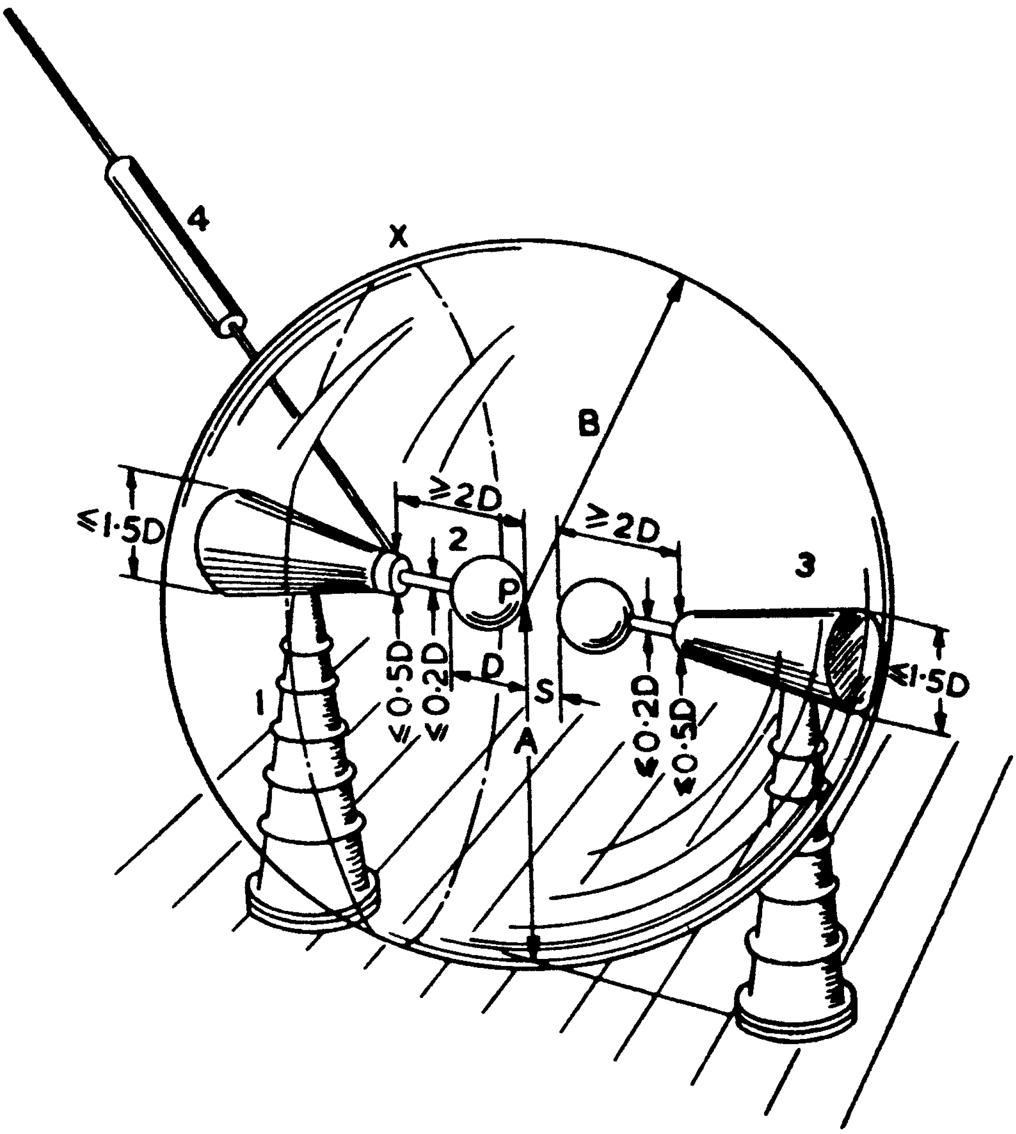
The sphere-gap should be used with the sparking point at a distance *A* from an earthed plane, such as a conducting network in or on the floor of the laboratory, or some other large conducting surface; the distance *A* shall be within the limits given in Table 1. This requirement applies whether the axis of the gap is parallel or normal to the earthed plane.



1. Insulating support.
2. Sphere shank.
3. Operating gear showing maximum dimensions.
4. High voltage connection with series resistance.
5. Stress distributor showing maximum dimensions.

P = Sparking point of high voltage sphere.
A = Distance of *P* to earth plane.
B = Radius of space free from external structures.
X = Item 4 not to pass through this plane within a distance *B* from *P*.

Figure 1 — Typical vertical sphere-gap



1. Insulating support.
2. Sphere shank.
3. Operating gear showing maximum dimensions.
4. High voltage connection with series resistance.

P = Sparking point of high voltage sphere.
A = Distance of *P* to earth plane.
B = Radius of space free from external structures.
X = Item 4 not to pass through this plane within a distance *B* from *P*.

Figure 2 — Typical horizontal sphere-gap

6 Clearance around the spheres

The distance from the sparking point of the high-voltage sphere to any extraneous objects (such as walls, a ceiling, transformer tanks, bushings, impulse generators, etc.) and also to the supporting framework for the spheres if this is made of conducting material, shall not be less than the value for *B* given in Table 1. Except as permitted below, *B* shall not be less than 2 *D* regardless of the value of *S*.

When made of insulating material, supporting frameworks for the spheres are exempt from this stipulation provided that they are clean and dry and that the spheres are used for the measurement of alternating or impulse voltages only. The distance *B* between the sparking point of the high voltage sphere and the framework may then be less than is prescribed in Table 1, but it must not be below 1.6 *D*.

Table 1 — Clearances round the spheres

Sphere diameter, *D*	Minimum value of *A*	Maximum value of *A*	Minimum value of *B*
cm			
Up to 6.25	7 *D*	9 *D*	14 *S*
10 – 15	6 *D*	8 *D*	12 *S*
25	5 *D*	7 *D*	10 *S*
50	4 *D*	6 *D*	8 *S*
75	4 *D*	6 *D*	8 *S*
100	3.5 *D*	5 *D*	7 *S*
150	3 *D*	4 *D*	6 *S*
200	3 *D*	4 *D*	6 *S*

NOTE 1 The test conditions may make it impossible for the values of *A* and *B* to meet the requirements in the table. In such cases the sphere-gap may nevertheless be regarded as satisfactory if the sphere-gap readings corresponding to some value of a related parameter, e.g. transformer primary voltage with the specified and with the test clearances, do not differ significantly.

Small earthed or live objects at less than the distance *B* from the sparking point of the high-voltage sphere do not affect the results appreciably if the sphere-gap spacing is low. When, however, the spacing approaches 0.5 *D* the presence, even at the distance *B*, of large conducting surfaces such as walls has an important effect.

Table 3 and Table 4 have been derived from experimental calibrations made in open laboratories with not more than one wall at the distance *B* and the other walls at greater distances. If, therefore, the sphere-gap is placed in an earthed cylindrical container of radius *B* the calibrations in this document will no longer apply, except at very small sphere-gap spacings.

NOTE 2 For the measurement of the very highest voltages it may be necessary to increase *A* and *B* above the minimum values given in Table 1, as these are not always sufficient to prevent flashover to earthed objects, especially those with sharp edges or corners.

7 Connection of the sphere-gap

a) *Earthing*. One sphere shall be connected directly to earth, but, for special purposes, it may be connected through resisters. In the interests of personal safety, however, such resistors shall be of very low value.

b) *High-voltage conductor*. The high-voltage conductor, including any series resistor not in the shank itself, shall be connected to a point on the shank at least 2 *D* away from the sparking point of the high-voltage sphere.

Within the region where the distance to the sparking point of the high-voltage sphere is less than *B*, the live conductor, including the series resistor, if any, shall not pass through a plane normal to the axis of the sphere-gap and situated at a distance 2 *D* from the sparking point of the high-voltage sphere (see Figure 1 and Figure 2 where the plane is shown).

c) *Protective series resistance in the measurement of alternating and direct voltages*. Precautions should be taken to minimize pitting of the spheres and to prevent superimposed oscillations which may cause erratic flashovers. For this purpose a resistance of 100 kilohms to 1 megohm should be inserted in series with the sphere-gap. This range of resistance values applies to measurements of direct voltages and of alternating voltages at power frequencies. For alternating voltages of higher frequencies, where the effect of the voltage drop in the resistance due to the charging current of the gap may become appreciable, the resistance should be suitably reduced.

The resistor is to be placed as near as possible to the gap, usually in series with the high-voltage sphere. It should not be placed in the common connection from the voltage source to the sphere-gap and to the test object.

When brush discharges are present in the test circuit, series resistance is especially important in order to reduce the effect of the consequent transient over-voltages on the operation of the sphere-gap. When these discharges are not present either in the test circuit or in the test specimen, the resistance may be reduced (within the limits given above) to a value fixed by the permissible burning of the spheres by flashover.

d) *Protective series resistance in the measurement of impulse voltages.* The purpose of the series resistance when measuring impulse voltages is to reduce the rate of voltage chopping, which may introduce undesirable stresses in the test object. Another purpose, which is especially relevant to spheres of large diameters, is to eliminate oscillations in the sphere-gap circuit which may cause a higher voltage to occur between the spheres than on the test specimen. For spheres of smaller diameter this phenomenon is usually of minor importance.

The value of the resistance should not exceed 500 ohms. It is essential for the reduction of oscillations that it should be of low inductance (not more than 30 μH).

8 Irradiation of the sphere-gap

The time delay of flashover, and, to some extent, the flashover voltage, of a sphere-gap, are influenced by the ionization existing in the gap between the spheres at the moment of application of voltage. The flashover voltages given in the tables apply to measurements made without ionizing irradiation, apart from any random irradiation already present, except for:

i) the measurement of voltages below 50 kV peak, whatever the sphere diameter,

ii) the measurement of voltage with spheres of 12.5 cm diameter and less, whatever the voltage.

For measurements under conditions i) and ii) extra irradiation is recommended, and is sometimes essential if accurate and consistent results are to be obtained. This is of especial importance in the measurement of impulse voltages, and for all types of voltage when very small gap spacings are used.

The effects of various types of irradiation are still under investigation. Those obtained from a high intensity source of ultra-violet light, or from a capsule of radium or of certain other radioactive materials of adequate gamma ray activity are, however, known to be effective. Pending the availability of fuller information it is recommended that one of the following irradiation sources should be used:

a) A capsule of radium or of a radium salt of activity not less than 0.2 mc and preferably about 0.6 mc placed inside the high-voltage sphere close to the sparking point with the minimum metal thickness intervening.

b) An equivalent quantity of a suitable gamma-active artificially radioactive isotope of long half-life, similarly used: examples of isotopes which may be suitable are:

Isotope		Required activity[a] mc	Half life years
Caesium	137	1.4	33
Cobalt	60	0.3	5.25
Sodium	22	0.4	2.6
Manganese	54	0.9	0.8

[a] to give the equivalent of 0.5 mc of radium (see Note 2 on page 7).

c) Irradiation by ultra-violet light from another spark gap — usually the trigger gap of an impulse generator — placed as close as practicable to the measuring gap.

d) Irradiation by a quartz mercury vapour lamp, having a minimum rating of 35 watts and a current of at least 1 ampere, placed at approximately the distance *B* given in Table 1, so as to illuminate the sparking points of the spheres.

NOTE 1 Although radioactive sources used for sphere-gap irradiation should not be of sufficient activity to be dangerous when properly used, it is important that the recognized precautions in their handling and storage should be observed. It is equally important to avoid damage to the eyesight from unshielded ultra-violet lamps. Excessive irradiation is to be avoided, as, apart from any risks involved, this may actually reduce the accuracy of measurement.

NOTE 2 For equal ionizing effect, sources of equal gamma ray activity are required. Different isotopes, however, give appreciably different gamma energy emission for each disintegration; hence sources of different strengths in millicuries (defining the number of disintegrations per second) should be used as indicated above. One millicurie is the activity of 1 mg of radium, i.e. 3.7×10^7 atom disintegrations per second.

NOTE 3 Ultra-violet lamps have been found to lose effectiveness with time, because of the formation of an absorbing deposit on the outside of the quartz tube.

NOTE 4 The effectiveness of an irradiation source may be ascertained by the sharpness of the transition from 0 to 100 per cent flashover when used for impulse voltage tests [see Clause **9** b)]; or by the consistency of the flashover values for other types of voltage.

9 Voltage measurements

The procedure usually consists of establishing a relation between a high voltage as measured by the sphere-gap and the indication of a voltmeter, an oscillograph or other device connected in the control circuit of the equipment.

Unless the contrary can be shown, this relation ceases to be valid if the circuit is altered in any respect other than by a slight change of the spacing of the spheres. The voltage measured by the sphere-gap is derived from the sparking distance.

The procedure in establishing the relation varies with the type of voltage to be measured, as follows:

a) *Measurement of direct and alternating voltage.* The voltage shall be applied with an amplitude low enough not to cause flashover during the switching transient and it is then raised sufficiently slowly for the low voltage indicator to be read accurately at the instant of flashover of the gap.

Alternatively, a constant voltage may be applied across the gap and the spacing between the spheres slowly reduced until flashover occurs.

If there is dust or fibrous material in the air, numerous low and erratic flashovers may occur, especially when direct voltages are being measured, and it may be necessary to carry out a larger number of tests before consistent results can be obtained.

The final measurement should be the mean of three successive readings agreeing within 3 per cent.

b) *Measurement of impulse voltages.* In order to obtain the 50 per cent flashover voltage of a sphere-gap, the spacing of the gap or the charging voltage of the impulse generator shall be adjusted in steps corresponding to not more than 2 per cent of the expected flashover value of the sphere-gap, several applications of the impulse voltage being made at each setting. (The interval between applications shall be not less than 5 seconds.) The value giving nominally 50 per cent probability of flashover shall preferably be determined by establishing two limit settings, differing by not more than 2 per cent, at one of which flashover shall occur on not more than 2 out of 10 applications and at the other on not less than 8 out of 10. Alternatively, counts of 1 out of 6, and 5 out of 6, are acceptable. The 50 per cent flashover setting is regarded as the mean of these two limit settings. In either case a number of preliminary flashover tests shall be made before readings are taken.

The sharpness of transition from 0 to 100 per cent flashover which is established by this method affords a valuable check on the probable accuracy of measurement given by the sphere-gap, provided of course that the other requirements in the specification regarding clearances, condition of surfaces, etc., are met.

10 Sphere-gap flashover values

Numerical values in the tables. The flashover voltages for various distances between the spheres are given in Table 3 and Table 4.

Table 3 gives flashover voltages (50 per cent values in impulse tests) in kilovolts peak at 20 °C and 1 013 millibars for:

Table 3 gives flashover voltages (50 per cent values in impulse tests) in kilovolts peak at 20 °C and 1 013 millibars for:

a) alternating voltages,

b) direct voltages of both polarities,

c) full negative standard impulses (as defined in BS 923[2)]) and impulses with longer tails.

This table is not valid for the measurement of impulses below about 10 kV.

[2)] BS 923, "*Impulse-voltage testing*".

Table 4 gives 50 per cent flashover voltages in kilovolts peak at 20 °C and 1 013 millibars for full positive standard impulses (as defined in BS 923[3]) and impulses with longer tails.

NOTE 1 Appendix A gives the range of voltages over which the values in the tables have been derived from experiment and can be presumed to be accurate within the limits given in Clause **11**.

NOTE 2 The tables may be used without appreciable additional error for the measurement of impulses having front times longer than the standard.

NOTE 3 The impulse flashover voltage of a sphere-gap increases as the tail length of the impulse decreases and when this is very short, the exact wave shape becomes important. For a 1/5 micro-second wave (as defined in BS 923[3]), the increase above the tabulated values is unlikely to exceed 5 per cent.

11 Accuracy of the tables

a) *Alternating and impulse voltages.* For spacings up to 0.5 *D* the tables are considered to be accurate within ± 3 per cent. Values in the tables for spacings between 0.5 *D* and 0.75 *D* are regarded as being of doubtful accuracy and for that reason are put in brackets.

b) *Direct voltage.* The measurement of direct voltages is generally subject to larger errors than that of alternating or impulse voltages. Such errors are usually caused by dust or fibres in the air. There is also a tendency for abnormally low flashover values to be obtained if the voltage is applied for a long time. It is considered that in the absence of excessive dust the results will be accurate within ± 5 per cent provided that the spacing is not greater than about 0.4 *D*.

NOTE As it may be difficult to adjust and measure the gap with sufficient accuracy if the ratio of spacing to diameter is very small, it is recommended that the spacing should not be less than 0.05 *D*.

12 Influence of atmospheric conditions

a) *Atmospheric conditions valid for the tabulated values.* The tabulated values are valid for:

an ambient temperature of 20 °C

an atmospheric pressure of 1 013 millibars.

NOTE 1 1 013 millibars correspond to 760 mmHg with the column at 0 °C.
The height *b* to be used in Clause **12** b) below should therefore be adjusted for the temperature of the mercury. For every 6 degC by which this exceeds 0 °C, 0.1 per cent should be subtracted from the measured height of the column. This adjustment is usually too small to be significant.

NOTE 2 If the height of the mercury barometer is *h* mm and the ambient temperature is *t* °C, then the atmospheric pressure is:

$$\frac{1013h}{760}(1 - 1{\cdot}7 \times 10^{-4}t) \text{ millibars}$$

b) *Correction for air density,* Flashover voltages corresponding to a given spacing under atmospheric conditions other than those specified above are obtained by multiplying the values in Table 3 and Table 4 by a correction factor *k*. This factor is a function of the relative air density *d*, defined by:

$$d = \frac{b}{1013} \cdot \frac{273 + 20}{273 + t} = 0{\cdot}289 \cdot \frac{b}{273 + t}$$

where *b* is the atmospheric pressure in millibars, and *t* the temperature in degrees Celsius (centigrade).

The relation between the air density and the correction factor is given in Table 2. The correction factor is equal to the relative air density (i.e. *k* = *d*) for values of *d* between 0.95 and 1.05.

[3] BS 923, "*Impulse-voltage testing*".

Table 2 — Air density correction factor

Relative air density d	Correction factor k
0.70	0.72
0.75	0.77
0.80	0.82
0.85	0.86
0.90	0.91
0.95	0.95
1.00	1.00
1.05	1.05
1.10	1.09
1.15	1.13

c) *Humidity*. The flashover voltage of a sphere-gap increases with increasing humidity of the air. The numerical value of the effect is uncertain but it is unlikely to be more than 2 or 3 per cent over the range of humidities normally encountered in laboratories. Because of this uncertainty, no correction factor for humidity can be given at present. In any case, the humidity of the air in the various laboratories where the experimental calibrations were made was not usually recorded.

See Clause **3** c) for a note on the danger from condensation of moisture on the surface of the spheres.

Appendix A Range of experimental calibrations

Indicated below are the highest voltages used in the derivation, by experiment, of the values in Table 3 and Table 4. Up to these voltages, the tables can be presumed to be accurate within the limits given in Clause **11**.

Experimental calibrations of the sphere-gap

Kind of voltage	Highest voltage kV peak	Reference
Alternating voltage of power frequency	1 700	*Transactions A.I.E.E.*, (3), **71**, 1952, 455
	1 400	*J.I.E.E.*, **82**, June 1938, 655
Direct voltage +	800	*Zeit. tech. Phys.*, **18**, 1937, 209
Direct voltage −	1 300	*Zeit. tech. Phys.*, **18**, 1937, 209
Impulse voltage +	2 580	*Transactions A.I.E.E.*, (3), **71**, 1952, 455
Impulse voltage −	2 410	*Transactions A.I.E.E.*, (3), **71**, 1952, 455
Alternating voltage of high frequency		*E.T.Z.*, **60**, 1939, 92 (see Note 1 below)
Undamped alternating voltage of high frequency	See Note 2 at foot of table	*J.A.I.E.E.*, **46**, 1927, 1314 *Arch. Elektr.*, **14**, 1924, 491 *Arch. Elektr.*, **24**, 1930, 525 *Arch. Elektr.*, **25**, 1931, 322 *Arch. Elektr.*, **26**, 1932, 123
Damped alternating voltage of high frequency	See Note 2 at foot of table	*Ann. Phys.*, **19**, 1906, 1016 *Arch. Elektr.*, **16**, 1926, 496 *Arch. Elektr.*, **20**, 1928, 99

NOTE 1 This reference contains a summary of calibrations with damped and undamped high frequency voltages made up to 1939 over a range of voltages and frequencies. The other references in the list give the details of most of these individual calibrations.

NOTE 2 From the information in the references, which is incomplete and sometimes conflicting, it appears that Table 3 can be used without serious error for the measurement of undamped alternating voltages at frequencies up to 20 kc/sec, but only up to about 15 kV peak. At higher frequencies this voltage is reduced.

The references also show that Table 3 can be used for the measurement of damped alternating voltages at frequencies up to 500 kc/sec, but again with the restriction that the voltage should not exceed 15 kV peak.

Appendix B Procedure by which the values in Table 3 and Table 4 have been derived from national standards and other sources

Apart from certain exceptions which are noted below, the flashover voltages in the tables are the mean of:

the values in a draft revision of Publication No. 52, which were provisionally accepted by the IEC in July, 1939, and

the values in A.S.A Standard C 68.1 (1953) (after adjustment for temperature).

However, the calculation of the mean resulted in a few anomalies: in particular the breakdown voltages of small gaps varied rather irregularly as the sphere diameter was increased.

These anomalies have been removed as far as is possible without introducing other anomalies.

The exceptions mentioned above are listed below:

a) No data are given in the A.S.A Standard for 2, 5, 10 and 15 cm spheres.

The IEC figures of 1939 for 5, 10 and 15 cm spheres have therefore been included in the present tables without any changes other than the minor adjustments referred to above.

b) The figures for a 2 cm gap in the IEC Document of 1939 (none was given for positive impulses) were later found to be inaccurate at spacings up to 1 cm. New figures are given but these are not applicable to the measurement of impulses of either polarity below 10 kV. See *Proc. I.E.E.* (2), 101, August 1954, 438, for evidence on this point.

c) The IEC data of 1939 for impulse voltages above 1 400 kV are regarded as being less reliable than the most recent measured values in the USA. and these latter have therefore been adopted. [See *ASA C* 68.1 (1953) and *Transactions, A.I.E.E.* (3), **71**, 1952, 455].

The figures in the tables have been rounded off as follows:

Up to	50 kV	to the nearest 0.1 kV
over	50 and up to 100 kV	to the nearest 0.5 kV
over	100 and up to 500 kV	to the nearest 1 kV
over	500 and up to 1 000 kV	to the nearest 5 kV
over	1 000 kV	to the nearest 10 kV

Table 3 — Flashover voltages (50 per cent values in impulse tests) for alternating voltages, for direct voltages of either polarity, and for full negative standard impulses and impulses with longer tails: one sphere earthed

Sphere-gap spacing, cm	Kilovolts peak at 20 °C: 1 013 millibars											
	Sphere diameter, cm											
	2	5	6.25	10	12.5	15	25	50	75	100	150	200
0.05	2.8											
0.10	4.7											
0.15	6.4											
0.20	8.0	8.0										
0.25	9.6	9.6										
0.30	11.2	11.2										
0.40	14.4	14.3	14.2									
0.50	17.4	17.4	17.2	16.8	16.8	16.8						
0.60	20.4	20.4	20.2	19.9	19.9	19.9						
0.70	23.2	23.4	23.2	23.0	23.0	23.0						
0.80	25.8	26.3	26.2	26.0	26.0	26.0						
0.90	28.3	29.2	29.1	28.9	28.9	28.9						
1.0	30.7	32.0	31.9	31.7	31.7	31.7	31.7					
1.2	(35.1)	37.6	37.5	37.4	37.4	37.4	37.4					
1.4	(38.5)	42.9	42.9	42.9	42.9	42.9	42.9					
1.5	(40.0)	45.5	45.5	45.5	45.5	45.5	45.5					
1.6		48.1	48.1	48.1	48.1	48.1	48.1					
1.8		53.0	53.5	53.5	53.5	53.5	53.5					
2.0		57.5	58.5	59.0	59.0	59.0	59.0	59.0	59.0			
2.2		61.5	63.0	64.5	64.5	64.5	64.5	64.5	64.5			
2.4		65.5	67.5	69.5	70.0	70.0	70.0	70.0	70.0			
2.6		(69.0)	72.0	74.5	75.0	75.5	75.5	75.5	75.5			
2.8		(72.5)	76.0	79.5	80.0	80.5	81.0	81.0	81.0			
3.0		(75.5)	79.5	84.0	85.0	85.5	86.0	86.0	86.0	86.0		
3.5		(82.5)	(87.5)	95.0	97.0	98.0	99.0	99.0	99.0	99.0		

NOTE 1 This table is not valid for the measurement of impulse voltages below about 10 kV.
NOTE 2 The figures in brackets, which are for spacings of more than 0.5 *D*, are of doubtful accuracy [see Sub-clause **11** a)]. See Sub-clause **11** b), for restrictions on the use of this table for the measurement of direct voltages.

Table 3 — Flashover voltages (50 per cent values in impulse tests) for alternating voltages, for direct voltages of either polarity, and for full negative standard impulses and impulses with longer tails: one sphere earthed

Sphere-gap spacing, cm	Kilovolts peak at 20 °C: 1 013 millibars											
	Sphere diameter, cm											
	2	5	6.25	10	12.5	15	25	50	75	100	150	200
4.0		(88.5)	(95.0)	105	108	110	112	112	112	112		
4.5			(101)	115	119	122	125	125	125	125		
5.0			(107)	123	129	133	137	138	138	138	138	
5.5				(131)	138	143	149	151	151	151	151	
6.0				(138)	146	152	161	164	164	164	164	
6.5				(144)	(154)	161	173	177	177	177	177	
7.0				(150)	(161)	169	184	189	190	190	190	
7.5				(155)	(168)	177	195	202	203	203	203	
8.0					(174)	(185)	206	214	215	215	215	
9.0					(185)	(198)	226	239	240	241	241	
10					(195)	(209)	244	263	265	266	266	266
11						(219)	261	286	290	292	292	292
12						(229)	275	309	315	318	318	318
13							(289)	331	339	342	342	342
14							(302)	353	363	366	366	366
15							(314)	373	387	390	390	390
16							(326)	392	410	414	414	414
17							(337)	411	432	438	438	438
18							(347)	429	453	462	462	462
19							(357)	445	473	486	486	486
20							(366)	460	492	510	510	510
22								489	530	555	560	560
24								515	565	595	610	610
26								(540)	600	635	655	660
28								(565)	635	675	700	705

Table 3 — Flashover voltages (50 per cent values in impulse tests) for alternating voltages, for direct voltages of either polarity, and for full negative standard impulses and impulses with longer tails: one sphere earthed

Sphere-gap spacing, cm	Kilovolts peak at 20 °C: 1 013 millibars											
	Sphere diameter, cm											
	2	5	6.25	10	12.5	15	25	50	75	100	150	200
30								(585)	665	710	745	750
32								(605)	695	745	790	790
34								(625)	725	780	835	840
36								(640)	750	815	875	885
38								(655)	(775)	845	915	930
40								(670)	(800)	875	955	975
45									(850)	945	1 050	1 080
50									(895)	1 010	1 130	1 180
55									(935)	(1 060)	1 210	1 260
60									(970)	(1 110)	1 280	1 340
65										(1 160)	1 340	1 410
70										(1 200)	1 390	1 480
75										(1 230)	1 440	1 540
80											(1 490)	1 600
85											(1 540)	1 660
90											(1 580)	1 720
100											(1 660)	1 840
110											(1 730)	(1 940)
120											(1 800)	(2 020)
130												(2 100)
140												(2 180)
150												(2 250)

Table 4 — 50 per cent flashover voltages for full positive standard impulses and impulses with longer tails: one sphere earthed

Sphere-gap spacing, cm	Kilovolts peak at 20 °C: 1 013 millibars											
	Sphere diameter, cm											
	2	5	6.25	10	12.5	15	25	50	75	100	150	200
0.05												
0.10												
0.15												
0.20												
0.25												
0.30	11.2	11.2										
0.40	14.4	14.3	14.2									
0.50	17.4	17.4	17.2	16.8	16.8	16.8						
0.60	20.4	20.4	20.2	19.9	19.9	19.9						
0.70	23.2	23.4	23.2	23.0	23.0	23.0						
0.80	25.8	26.3	26.2	26.0	26.0	26.0						
0.90	28.3	29.2	29.1	28.9	28.9	28.9						
1.0	30.7	32.0	31.9	31.7	31.7	31.7	31.7					
1.2	(35.1)	37.8	37.6	37.4	37.4	37.4	37.4					
1.4	(38.5)	43.3	43.2	42.9	42.9	42.9	42.9					
1.5	(40.0)	46.2	45.9	45.5	45.5	45.5	45.5					
1.6		49.2	48.6	48.1	48.1	48.1	48.1					
1.8		54.5	54.0	53.5	53.5	53.5	53.5					
2.0		59.5	59.0	59.0	59.0	59.0	59.0	59.0	59.0			
2.2		64.0	64.0	64.5	64.5	64.5	64.5	64.5	64.5			
2.4		69.0	69.0	70.0	70.0	70.0	70.0	70.0	70.0			
2.6		(73.0)	73.5	75.5	75.5	75.5	75.5	75.5	75.5			
2.8		(77.0)	78.0	80.5	80.5	80.5	81.0	81.0	81.0			
3.0		(81.0)	82.0	85.5	85.5	85.5	86.0	86.0	86.0	86.0		
3.5		(90.0)	(91.5)	97.5	98.0	98.5	99.0	99.0	99.0	99.0		

NOTE The figures in brackets, which are for spacings of more than 0.5 D, are of doubtful accuracy [see Clause **11** a)].

Table 4 — 50 per cent flashover voltages for full positive standard impulses and impulses with longer tails: one sphere earthed

Sphere-gap spacing, cm	Kilovolts peak at 20 °C: 1 013 millibars											
	Sphere diameter, cm											
	2	5	6.25	10	12.5	15	25	50	75	100	150	200
4.0		(97.5)	(101)	109	110	111	112	112	112	112		
4.5			(108)	120	122	124	125	125	125	125		
5.0			(115)	130	134	136	138	138	138	138	138	
5.5				(139)	145	147	151	151	151	151	151	
6.0				(148)	155	158	163	164	164	164	164	
6.5				(156)	(164)	168	175	177	177	177	177	
7.0				(163)	(173)	178	187	189	190	190	190	
7.5				(170)	(181)	187	199	202	203	203	203	
8.0					(189)	(196)	211	214	215	215	215	
9.0					(203)	(212)	233	239	240	241	241	
10					(215)	(226)	254	263	265	266	266	266
11						(238)	273	287	290	292	292	292
12						(249)	291	311	315	318	318	318
13							(308)	334	339	342	342	342
14							(323)	357	363	366	366	366
15							(337)	380	387	390	390	390
16							(350)	402	411	414	414	414
17							(362)	422	435	438	438	438
18							(374)	442	458	462	462	462
19							(385)	461	482	486	486	486
20							(395)	480	505	510	510	510
22								510	545	555	560	560
24								540	585	600	610	610
26								570	620	645	655	660
28								(595)	660	685	700	705

Table 4 — 50 per cent flashover voltages for full positive standard impulses and impulses with longer tails: one sphere earthed

Sphere-gap spacing, cm	Kilovolts peak at 20 °C: 1 013 millibars											
	Sphere diameter, cm											
	2	5	6.25	10	12.5	15	25	50	75	100	150	200
30								(620)	695	725	745	750
32								(640)	725	760	790	795
34								(660)	755	795	835	840
36								(680)	785	830	880	885
38								(700)	(810)	865	925	935
40								(715)	(835)	900	965	980
45									(890)	980	1 060	1 090
50									(940)	1 040	1 150	1 190
55									(985)	(1 100)	1 240	1 290
60									(1 020)	(1 150)	1 310	1 380
65										(1 200)	1 380	1 470
70										(1 240)	1 430	1 550
75										(1 280)	1 480	1 620
80											(1 530)	1 690
85											(1 580)	1 760
90											(1 630)	1 820
100											(1 720)	1 930
110											(1 790)	(2 030)
120											(1 860)	(2 120)
130												(2 200)
140												(2 280)
150												(2 350)

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