BRITISH STANDARD

BS 5000 :
Part 16 : 1997

Rotating electrical machines of particular types or for particular applications

Part 16. Rotating electrical machines with type of protection 'N'

ICS 29.160.01; 29.260.20

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee PEL/2, Rotating electrical machinery, upon which the following bodies were represented:

Association of Consulting Engineers
Association of Electrical Machinery Trades
Association of Manufacturers of Power Generating Systems
ERA Technology Ltd.
Electricity Association
Health and Safety Executive
Institution of Incorporated Executive Engineers
Institution of Plant Engineers
Ministry of Defence
Power Generation Contractors Association (PGCA (BEAMA Ltd.))
Rotating Electrical Machines Association (BEAMA Ltd.)
United Kingdom Offshore Operators Association

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Contents

Foreword

This Part of BS 5000 has been prepared by Technical Committee PEL/2. It supersedes BS 5000 : Part 16 : 1985 which is withdrawn. It applies to rotating electrical machines up to and including 15 kV.

This Part of BS 5000 sets out minimum requirements for rotating electrical machines with type of protection 'N', i.e. non-sparking rotating electrical machines with surface temperature limitations for use in hazardous areas designated zone 2 as defined in BS 5345 : Part 1.

This edition introduces technical changes but it does not reflect a full review or revision of the standard, which will be undertaken in due course. The additional technical change now incorporated principally relates to raising the upper voltage of low voltage machines from 660 V to 690 V.

At present there is no corresponding international standard. International work has been completed on document IEC 79-15 : 1987 *Electrical apparatus for explosive gas atmospheres Part 15: Electrical apparatus with type of protection 'N'*, but this only has the status of a report.

Certification. Attention is drawn to the Health and Safety at Work, etc. Act 1974 [1], the Factories Act 1961 [2], the Mines and Quarries Act 1954 [3], the Regulations made under these Acts, and also any other appropriate statutory requirements or Byelaws. These place responsibility for complying with specific safety requirements on the manufacturer and the user. Further information relating to the requirements for certification of apparatus used in applications other than Group I (mining) or explosive processing and manufacture, is provided in BS 5345 : Part 1. BS 5345 : Part 7 is the appropriate standard for the installation and maintenance of type 'N' apparatus.

Users of this British Standard are advised to consider the desirability of third party certification of product conformity with this British Standard based on testing and continuing product surveillance which may be coupled with assessment of a supplier's quality systems against the appropriate standard in the BS EN ISO 9000 series.

Enquiries as to the availability of third party certification schemes are forwarded by BSI to the Association of British Certification Bodies. If a third party certification scheme does not already exist, users should consider approaching an appropriate body from the list of Association members.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 6, an inside back cover and a back cover.

Specification

1 Scope

This Part of BS 5000 specifies design and construction requirements for rotating electrical machines with type of protection 'N', i.e. those which are non-sparking in normal operation and which have surface temperature limitations. Machines having parts which may produce arcs or sparks are not excluded if such parts are protected for use in the appropriate potentially explosive atmosphere.

This standard applies to rotating electrical machines for use on systems operating at voltages up to and including 15 kV.

NOTE. Information recommended to be given with enquiry and order is listed in annex A.

2 References

2.1 Normative references

This Part of BS 5000 incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on the inside back cover. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this Part of BS 5000 only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

2.2 Informative references

This Part of BS 5000 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definition

For the purposes of this Part of BS 5000, the following definition applies.

3.1 normal operation

A rotating electrical machine is in normal operation when it conforms electrically and mechanically with its design specification and is used within the limits specified by the manufacturer.

NOTE. The limits specified by the manufacturer may include persistent operational conditions such as stalled rotors and overloads.

4 General

In addition to the requirements specified in other clauses of this standard rotating electrical machines with type of protection 'N' shall conform to BS EN 60034-1 and all other relevant Parts of BS EN 60034, except for marking of the rating plate which shall be as specified in clause **14** of this standard.

NOTE. If certification is sought, it is not intended that the certifying authority should check compliance with BS EN 60034, but the manufacturer should declare that the machine does conform to the requirements of that standard.

5 Enclosures

5.1 Degree of protection

Enclosures containing bare live metal shall provide a degree of protection not less than IP54 as classified in BS 4999 : Part 105. Other enclosures shall provide a degree of protection not less than IP10.

NOTE 1. Attention is drawn to the fact that certain applications necessitate more stringent requirements. For example, it is known that high voltage windings which are heavily contaminated by conducting substances can exhibit electrical discharge under certain conditions.

It is essential that the user makes known the operating environmental conditions to the manufacturer who will advise which enclosure is appropriate and what, if any, special precautions need to be taken by the user.

NOTE 2. It is essential that the design of joint faces and the details of gaskets, if any, take into account the fact that the long term effectiveness of the enclosure is of particular importance.

It is essential that gasket materials have adequate life for the application and the environment and that they adhere to one of the mating surfaces only. The information supplied by the manufacturer regarding maintenance should include the recommendation that if gaskets are damaged at any time they should be replaced.

5.2 Mechanical strength

The mechanical strength of the enclosure shall conform to **23.4.3** of BS EN 50014 : 1993 with the exception that the tests on parts made of plastics material shall be carried out at (20 ± 5) °C.

NOTE. Attention is drawn to the fact that certain applications may necessitate more stringent requirements.

5.3 Circulating currents

Precautions shall be taken where necessary to guard against the occurrence of sparks due to the presence of circulating currents caused by stray magnetic fields.

NOTE. Precautions may include the provision of bonding between parts of the enclosure and the provision of an adequate number of bolts for bolted parts of enclosures.

6 Terminal arrangement

6.1 Terminal boxes

6.1.1 *Rotating electrical machines for operation at voltages up to and including 690 V*

Where fitted, terminal boxes shall provide a degree of protection not less than IP54 as classified in BS 4999 : Part 105. Terminal boxes for machines having a degree of protection less than IP41 shall not be open to the interior of the machine. Terminal boxes for machines having a degree of protection of IP41 or higher may be open to the interior of the machine, but the degree of protection of the terminal box shall not be reduced below IP54 with respect to the exterior of the machine.

6.1.2 *Rotating electrical machines for operation at voltages above 690 V*

Where fitted, terminal boxes, including removable covers, shall be made of steel and shall provide a degree of protection not less than IP54 as classified in BS 4999 : Part 105, and shall be one of the following types, as defined in BS 4999 : Part 145:

a) phase insulated;

b) phase separated;

c) phase segregated;

d) air insulated.

6.2 Form of terminations

Terminations shall accept external connections readily with one of the following arrangements.

a) Conductors clamped to the terminals without reducing the conductor cross-sectional area, in such a manner that they are permanently gripped and secured against loosening and twisting and that the contact pressure is maintained permanently.

b) Terminals suitable for cable lugs, provided that the lugs can be secured against loosening and that the arrangement is such that the contact pressure will be maintained permanently. Where this type of termination is used, means shall be provided for preventing accidental reduction of clearances.

NOTE. This may be achieved by insulating the shanks of the lugs or by the use of insulating barriers at least as high as the terminals and of sufficient length to ensure maintenance of the required clearances and creepage distances when the lugs are in the least favourable position.

6.3 Clearances and creepage distances

Electrical clearances and creepage distances, with the correct terminations in position, shall conform to BS 4999 : Part 145 except for the following.

a) Until BS 4999 : Part 145 is amended the values for clearance and creepage distance given in tables 2 and 3 of BS 4999 : Part 145 : 1987 for 660 V shall apply for voltages up to 690 V.

b) When pressure-containing terminal boxes are fitted no reduction in the clearances or creepage distances shall be permitted[1)].

These clearances and creepage distances shall apply independently of any insulation which may be added and which is disturbed when the connection is broken. For voltage ratings in excess of 1100 V, in the case of air insulated terminal boxes, the comparative tracking index of the insulation material shall be not less than 175, as defined in BS 5901.

NOTE. Clearances and creepage distances are specified in **6.4** for cable sealing and dividing boxes, and in **6.7** for auxiliary terminal arrangements.

6.4 Cable sealing and dividing boxes

Where cable sealing and dividing boxes are fitted, the clearances and creepage distances in air shall be in accordance with the dimensions given in the appropriate tables in BS 4999 : Part 145, and the boxes shall provide a degree of protection not less than IP54 as classified in BS 4999 : Part 105. When the cable sealing and dividing box is filled with compound, the clearances and creepage distances shall conform to the values given in table 1.

For rotating electrical machines for operation at voltages above 690 V, the cable sealing and dividing boxes shall be made of steel.

6.5 Cable entries

For all forms of cable connection, it shall be possible to remove the rotating electrical machines without stressing the cable or breaking any cable seal provided.

6.6 Rotating electrical machines with loose leads

Where machines are provided with loose leads, sufficient length of loose lead shall be provided to permit more than one reconnection to be made.

NOTE. The form of connection used with loose leads, the provision of any necessary insulation and the maintenance of clearances and creepage distances required by **6.3** are the responsibility of the installer of the machine.

Table 1. Minimum clearances and creepage distances for compound filled cable sealing and dividing boxes for voltages above 690 V

Rated voltage not exceeding	Clearances		Creepage distances	
	Between phases	Between phase and earth	Between phases	Between phase and earth
kV	mm	mm	mm	mm
1.1	12.5	12.5	19.0	19.0
3.3	19.0	12.5	37.5	25.0
6.6	25.0	19.0	63.0	31.5
11.0	37.5	25.0	90.0	45.0
13.8	45.0	31.5	110.0	55.0
15.0	50.0	35.0	120.0	60.0

[1)] BS 4999 : Part 145 normally allows a reduction when agreed between manufacturer and purchaser.

6.7 Auxiliary terminal arrangement

Heater or other additional connections, where provided, shall have rated voltages not exceeding 690 V and shall be clearly identified. For rotating electrical machines for operation voltages above 690 V the auxiliary connections shall be brought out to a separate terminal box.

NOTE 1. For machines for operation at voltages up to and including 690 V, the connections may be brought out to the main terminal box.

Heater terminals in the same terminal box as the main terminals shall be shielded in such a manner that it shall be safe to connect or disconnect the main cables or other auxiliary cables while the heater circuit is energized.

NOTE 2. This requires a minimum degree of protection of IP20, as classified in BS 4999 : Part 105, for the heater circuit with the box open, together with any additional protection necessary to prevent accidental contact with the heater circuit by tools or loose cable tails.

For stud terminals, the minimum clearance and creepage distance shall be 6.3 mm and 11.2 mm respectively. For terminals other than stud terminals, the rated voltage of the auxiliary circuit and the comparative tracking index of the terminal insulation material, as specified in BS 5901 and given in table 2, shall be used in assessing clearances and creepage distances.

NOTE 3. In order to reduce the possibility of an ignition hazard in the event of supply voltage breakthrough from a monitoring instrument, which may be of unspecified quality, it is recommended that terminals for embedded temperature detectors and other similar low voltage sensing devices should be rated at not less than 250 V.

6.8 Neutral point connections

In the case of neutral point connections which are not intended for use as an alternative supply connection to the machine, the creepage and clearance requirements shall be determined from the assumed voltage ratings given in table 3.

Table 3. Assumed voltage ratings of neutral points

Supply voltage	Assumed voltage rating of neutral point
kV	kV
15	11
13.8	11
11	6.6
6.6	3.3
3.3	1.1

In the case of neutral point connections within the main enclosure of the machine, the neutral connection shall be fully insulated unless the ingress protection is IP41 or greater and the machine is not intended to be connected to an earthed line supply.

Table 2. Minimum clearances and creepage distances for auxiliary terminals other than stud terminals

Rated auxiliary circuit voltage not exceeding	Minimum clearance in air	Minimum creepage distance			
		Minimum comparative tracking index			
		500	250	175	125
V	mm	mm	mm	mm	mm
13	0.4	1	1	1	1
33	0.8	1	1	1	1
66	1.3	1.3	1.3	1.3	1.3
143	1.4	1.4	1.7	2	2.5
275	2	2.3	2.8	3.4	4
418	2.8	3.7	4.3	5.1	6.7
550	3.4	4.4	5.1	6	7.1
690	5	6.5	7.5	9	11

7 Radial air gap

The minimum radial air gap between stator and rotor (in millimetres), when the rotating electrical machine is at rest, shall be not less than the value calculated using the equation:

$$\text{minimum radial air gap} = \left[0.15 + \left(\frac{D - 50}{780}\right)\left(0.25 + 0.75\,\frac{n}{1000}\right)\right] rb$$

where

D = 75 (for rotor diameters less than 75 mm);
or
D = rotor diameter in mm (for values between 75 and 750);
or
D = 750 (for rotor diameters greater than 750 mm);

n = 1000 (for maximum rated speeds below 1000 r/min);
or
n = maximum rated speed (for values above 1000 r/min);

r = 1 (where the ratio of core length to rotor diameter is less than 1.75);
or

$$r = \frac{\text{core length}}{1.75 \times \text{rotor diameter}}$$

(when the value of the expression is greater than 1);

b = 1 (for machines with rolling bearings);
or
b = 1.5 (for machines with plain bearings).

8 Cage windings

8.1 Rotor cage built from conductors connected to end rings

Precautions shall be taken to guard against incendive arcs or sparks during normal operation of the rotating electrical machine. In particular the joints between conductors and short-circuiting rings shall be brazed or welded and compatible materials shall be used to enable high quality joints to be made. Potentially incendive sparks or arcs due to intermittent contact between live bare conductors and other metal parts shall be prevented during normal operation.

NOTE. The following recommendations should be observed.

a) The conductors throughout the length of the rotor core should be mechanically tight with respect to adjacent stampings.

b) The whole rotor construction should be such as to minimize the risk of fracture of conductors, joints or short-circuiting rings.

c) Where the type of construction employs impregnating varnish to provide the necessary degree of tightness, the manufacturer should employ a method achieving full penetration of the varnish, and should ensure that the grade of varnish is suitable for the design temperature and operating conditions.

8.2 Cast rotor cages

Cast rotor cages shall be pressure die or centrifugal castings.

9 Bearing seals and shaft seals

9.1 Non-rubbing seals and labyrinths

The minimum radial or axial clearance between the stationary and rotating parts of any non-rubbing seal or labyrinth shall be not less than 0.1 mm. This minimum clearance shall apply for all possible positions of the shaft within the bearings

NOTE. The axial movement in a typical ball bearing is likely to be up to 10 times the radial movement.

9.2 Rubbing seals

Where rubbing seals are incorporated they shall be either lubricated or made of material having a low coefficient of friction, e.g. PTFE. In the former case, the design of the bearing shall be such that a supply of lubricant to the seal is maintained.

Rubbing seals shall be assessed in accordance with clause **11**.

NOTE. In order that excess temperatures are not generated in service, information on any maintenance required to ensure continued conformity to the requirements of **9.1** and **9.2** should be provided by the manufacturer.

10 Ventilation systems

10.1 Ventilation openings for external fans

The degree of protection of ventilation openings for external fans shall be at least IP20 on the air inlet side and IP10 on the air outlet side as classified in BS 4999 : Part 105. For vertical (shaft down) machines it shall not be possible for a foreign body falling vertically to enter directly into a ventilation opening.

10.2 Construction and mounting of fans

Fans, fan hoods, ventilation screens, etc. shall be constructed and fixed so as to prevent distortion and displacement which could cause impact or friction of rotating parts against stationary parts.

10.3 Clearances for ventilating systems

In normal operation the clearance distance between a fan and any stationary part, unless both are machined, shall be not less than the values given in table 4.

Table 4. Clearances between fan and stationary parts (unless both machined)

Maximum diameter of fan mm	Clearance mm
≤ 100	1
> 100 and ≤ 500	0.01 × maximum diameter of fan
> 500	5

If both opposing parts are machined, the clearance distance shall be not less than 1 mm. In the case of fan covers which may be deformed during the mechanical strength test specified in clause **5** no rubbing shall occur after the test.

10.4 Materials used for fans

Fans manufactured in plastics material with a designed peripheral speed exceeding 50 m/s shall have an electrical resistance not exceeding 1 GΩ when measured by the test described in **23.4.7.8** of BS EN 50014 : 1993.

Fans manufactured in light alloy shall contain not more than 6 % of magnesium by mass.

11 Surface temperature limitation

11.1 Prevention of thermal ignition

To prevent thermal ignition, the temperature of any external or internal surface to which the potentially explosive atmosphere has access shall not, under normal operating conditions and excluding starting, exceed the limiting temperature of any specified temperature class chosen in accordance with clause **5** of BS EN 50014 : 1993.

NOTE 1. A full description of the temperature class system and a list of gases and vapours allocated to each class are given in BS 5345 : Part 1.

NOTE 2. Unless otherwise specified at the time of ordering, a rotating electrical machine should be supplied and marked for temperature class T3 (limiting temperature 200 °C).

11.2 Operation with a non-sinusoidal supply

Where a rotating electrical machine is intended to operate with a non-sinusoidal supply, e.g. a motor fed from a static frequency converter or a generator supplying a thyristor load, the temperature class of the machine shall be determined either by test or, in exceptional cases where it is not practicable to carry out the test, by calculation.

NOTE 1. The determination of the temperature class by calculation should be agreed between the manufacturer, the purchaser and the certifying authority, as appropriate.

NOTE 2. The temperature differential between stator and rotor of a machine operating with a non-sinusoidal supply may vary greatly from the temperature differential that would occur on the same machine operating with a sinusoidal supply and therefore special attention needs to be paid to the rotor temperature, which, particularly in the case of rotor cage windings, may be a limiting feature of the machine.

11.3 Operation on a duty cycle or with frequent starts

Where a rotating electrical machine is intended to operate on a duty cycle or to be started frequently, the temperature rise during starting shall be one of the factors used when determining the temperature class and the machine shall be marked accordingly (see clause **14**e).

NOTE 1. The exclusion of the consideration of starting conditions in assigning temperature class is appropriate for machines that start infrequently as the statistical probability of an explosive gas mixture being present in a zone 2 area during the starting sequence is considered acceptable.

NOTE 2. The manufacturer's calculations or tests may be accepted as evidence of compliance with **11.1**, **11.2** and **11.3**.

12 Auxiliary devices

Capacitors and other auxiliary devices mounted on a rotating electrical machine for protective, alarm or other purposes shall conform to the relevant requirements of the appropriate British Standard for any type of protection for electrical equipment for use in hazardous atmospheres.

NOTE 1. The use of flameproof or intrinsically safe (Ex d or Ex i, see BS 5345 : Part 1) auxiliary equipment in conjunction with a machine having type of protection 'N' will restrict the use of the whole combination to zone 2 areas containing gases for which the Ex d or Ex i apparatus group is appropriate.

NOTE 2. If current transformers are fitted, it should be noted that under open circuit secondary conditions they may be capable of producing voltages which are significantly in excess of the voltage rating of the terminals employed in the current transformer circuit. Dependent on the circumstances of a particular installation, it may be appropriate to take precautions to ensure that dangerous open circuit voltages cannot occur. For machines having current transformers connected to matching transformers in the switchgear (e.g. a differential protection system), consideration should be given to the effect at the machine of any possible disconnection of either set of transformers.

13 Earth terminals

Earth terminals shall be provided both inside and outside the terminal box for connection of protective or earth conductors and shall be clearly identified by the symbols ⏚ and ⏚ respectively. The minimum connection capacity of each earth terminal shall be as shown in table 5.

Table 5. Minimum connection capacity of earth terminals

Live conductor mm^2	Internal earth conductor mm^2	External earth conductor mm^2
≤ 4	Equal to that of live conductor	4
> 4 ≤ 25	Equal to that of live conductor	
> 25 ≤ 50	25	
> 50	0.5 × that of live conductor	

To ensure good electrical contact, the earth terminals shall be effectively protected against corrosion. They shall also be so designed that the conductors can be secured against loosening and twisting and that permanent contact pressure can be maintained.

14 Marking

The rating plate shall carry the following information:

a) the information required by BS EN 60034-1, the appropriate BS number, Part number and date being BS 5000 : Part 16 : 1997[2)];

b) the symbol for the type of protection 'N', the apparatus group and the temperature class in accordance with clause **11**, e.g. Ex N II T3;

c) a reference to the duty cycle or frequency of starting (using the format detailed in BS EN 60034-1, if appropriate) if this forms part of the temperature classification;

d) the relevant certification mark and certification number, where certification has been obtained;

e) the symbol X if there are any special conditions of installation and use relevant to the safety of the machine. These shall be specified in the documents for the machine.

If any auxiliary item fitted to the rotating electrical machine reduces the utility of the machine by virtue of a restrictive apparatus group or temperature classification, then the code of that item shall appear as part of the machine code (see item b)). In each case the code shall represent the most restrictive apparatus group and the most restrictive temperature classification.

NOTE. A full explanation of hazardous area codes is given in BS 5345 : Part 1.

Annex A (informative)

Information recommended to be given with enquiry and order

When enquiring about, or ordering, rotating electrical machines conforming to this standard, it is recommended that the following particulars should be supplied:

a) the number and Part of this British Standard, i.e. BS 5000 : Part 16;

b) for machines rated above 690 V, the maximum fault level in MVA or kA and the fault withstand level required;

c) type of switching device and circuit protective devices to be used in conjunction with the machine;

d) type of cable entry, cable terminations and cable size required;

e) the maximum temperature class for which the machine is required, if other than class T3, or if a duty cycle or frequent starting conditions is to be included;

f) for motors which are to be fed from a static frequency convertor, the manufacturer and type of frequency convertor, the load torque/speed curve and the speed range for which the drive is required;

g) for generators supplying a non-sinusoidal load, appropriate information regarding the resulting harmonics should be stated.

[2)] Marking BS 5000/16/1997 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

List of references (see clause 2)

Normative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 4999 :	*General requirements for rotating electrical machines*
BS 4999 : Part 105 : 1988	*Classification of degrees of protection provided by enclosures for rotating machinery*
BS 4999 : Part 145 : 1987	*Specification for winding terminations*
BS 5901 : 1980	*Method of test for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions*
BS EN 60034 :	*Rotating electrical machines*
BS EN 60034-1 : 1995	*Rating and performance*
BS EN 50014 : 1993	*Electrical apparatus for potentially explosive atmospheres. General requirements*

Informative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 5345 :	*Code of practice for the selection, installation and maintenance of electrical apparatus for use in potentially explosive atmospheres (other than mining applications or explosive processing and manufacture)*
BS 5345 : Part 1 : 1989	*General recommendations*
BS 5345 : Part 7 : 1979[3)]	*Installation and maintenance requirements for electrical apparatus with type of protection N*

Other references

[1] GREAT BRITAIN. Health and Safety at Work etc. Act 1974. London HMSO[3)].
[2] GREAT BRITAIN. Factories Act 1961. London HMSO[3)].
[3] GREAT BRITAIN. Mines and Quarries Act 1954. London HMSO[3)].

[3)] Referred to in the foreword only.

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