IS 12802 (1989): Temperature-Rise Measurements of Rotating Electrical Machines [ETD 15: Rotating Machinery]

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Indian Standard

TEMPERATURE-RISE MEASUREMENTS OF ROTATING ELECTRICAL MACHINES

भारतीय मानक

बिजली की घूर्णी मशीनों का ताप वृद्धि मापन

(Incorporating Amendment No. 1)

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Rotating Machinery Sectional Committee, ETDC 15

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards on 21 July 1989, after the draft finalized by the Rotating Machinery Sectional Committee had been approved by the Electrotechnical Division Council.

While revising IS 4722 : 1968, it was decided to prepare separate standards on the following subjects:

i) Specification for rotating electrical machines;

ii) Types of duty and classes of rating assigned to rotating electrical machines — IS 12824 : 1989; and

iii) Temperature-rise measurements of rotating electrical machines (this standard).

It is intended to use this standard as a reference standard in other specifications on rotating electrical machines.

The requirements in this standard have been aligned with the following:

i) IEC Pub 34 - 1 (1983) Rotating electrical machines : Part 1 Rating and performance. International Electrotechnical Commission.

ii) 85/22497 DC — Draft standard specification for general requirements for rotating electrical machines : Part 101 : Specification for rating and performance. British Standards Institution (UK).

This edition 1.1 incorporates Amendment No. 1 (June 1997). Side bar indicates modification of the text as the result of incorporation of the amendment.

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 or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

TEMPERATURE-RISE MEASUREMENTS OF ROTATING ELECTRICAL MACHINES

1 SCOPE

This standard specifies the methods of measurements and the limits of temperature-rise for rotating electrical machines of all types covered by IS 4722 : 1968.

2 REFERENCES

The standards given in Annex A are necessary adjuncts to this standard.

3 TERMINOLOGY

The definitions given in IS 1885 (Part 35) : 1973 and IS 4722 : 1968 shall be applicable.

4 CONDITIONS DURING TEMPERATURE-RISE TEST

4.1 Temperature of Coolant

A machine may be tested at any convenient value of coolant temperature. If the temperature of the coolant at the end of the temperature-rise tests differs by more than 30°C from that specified (or assumed from **6.3.5**) for operation on site, the corrections given in **6.4** shall be made.

4.2 Measurement of Coolant Temperature During Tests

The value to be adopted for the temperature of the coolant during a test shall be the mean of the readings of the temperature detectors or thermometers taken at equal intervals of time during the last quarter of the duration of the test.

In order to avoid errors due to the time-lag between the temperature of large machines and the variations in the temperature of the coolant, all reasonable precautions shall be taken to reduce these variations.

4.2.1 *Open Machines or Closed Machines Without Heat Exchangers* (*Cooled by Surrounding Ambient Air or Gas*)

The ambient air or gas temperature shall be measured by means of several temperature detectors or thermometers placed at different points around and half-way up-the machine at a distance from 1 m to 2 m from it and protected from all heat radiation and draughts.

4.2.2 *Machines Cooled by Air or Gas from a Remote Source Through Ventilation Ducts and Machines with Separately Mounted Heat Exchangers*

The temperature of the primary coolant shall be measured where it enters the machine.

4.2.3 *Closed Machines with Machine-Mounted or Internal-Heat Exchangers*

The temperature of the primary coolant shall be measured where it enters the machine. For machines having water-cooled or air-cooled heat exchangers, the temperature of the secondary coolant shall be measured where it enters the heat exchanger.

5 DETERMINATION OF TEMPERATURE-RISE

5.1 Temperature-Rise of a Part of a Machine

The temperature-rise of a part of a machine is the difference in temperature between that part of the machine measured by the appropriate method in accordance with **5.3**, and the coolant measured in accordance with **4.1** and **4.2**.

5.2 Method of Measurement of Temperature or Temperature-Rise

Four methods of determining the temperature of windings and other parts are recognized:

a) Resistance method,
b) Embedded temperature detector (ETD) method,
c) Thermometer method, and
d) Superposition method.

The different methods shall not be used as a check against each other.

5.2.1 *Resistance Method*

In this method, the temperature-rise of the windings is determined from the increase of the resistance of the windings.

5.2.2 *Embedded Temperature Detector* (*ETD*) *Method*

In this method, the temperature is determined by means of temperature detectors (for example, resistance thermometers, thermocouples or semiconductor negative coefficient detectors) which are built into the machines during construction, at points which are inaccessible after the machine is completed.

5.2.3 *Thermometer Method*

In this method, the temperature is determined by thermometers applied to the accessible surfaces of the completed machine. The term 'thermometer' also includes non-embedded thermocouples and resistance thermometers provided they are applied to the points accessible to the usual bulb thermometers. When bulb thermometers are used in places where there is a strong varying or moving magnetic field, alcohol thermometers shall be used in preference to mercury thermometers.

5.2.4 *Superposition Method*

In this method, the resistance measurements used for determination of temperature rises of ac windings in accordance with **5.3.1** are made without interruption of the ac load current by applying a small dc measuring current superposed upon the load current.

5.3 Choice of Methods of Measuring Temperatures of Windings

In general, for measuring the temperature of the windings of a machine, the resistance method in accordance with **5.2.1** shall be applied.

The embedded temperature detector (ETD) method shall be used for ac stator windings of machines having a rated output of 5 000 kW (or kVA) or more, unless otherwise agreed.

For ac machines having a rated output below 5 000 kW (or kVA) and above 200 kW (or kVA) the resistance method shall be used, unless the ETD method is agreed.

For ac machines having a rated output of 200 kW (or kVA) or less the resistance method shall be used, unless the superposition method is agreed.

For machines rated 600 kW (or kVA) or less, when the windings are non-uniform or severe complications are involved in making the necessary connections, the temperature-rise may be determined by means of thermometers (or nonembedded thermocouples). Temperature-rise limits in accordance with Table 1 shall apply.

For ac stator windings having only one coil-side per slot, the embedded detector method is not recognized and the resistance method shall be used (*see* also **5.3.2.2**).

NOTE — For checking the temperature of such windings in service, an embedded detector at the bottom of the slot is of little value because it gives mainly the temperature of the iron core. A detector placed between the coil and the wedge will follow the temperature of the winding much more closely and is, therefore, better for check tests, although the temperature there may be rather low. The relation between the temperature measured at that place and the temperature measured by the resistance method should be determined by a temperature-rise test.

For windings of armatures having commutators and for field windings, except for field windings in cylindrical rotors of synchronous machines, the resistance method and the thermometer method are recognized (*see* also **5.3.3**). The resistance method is preferred.

For stationary field windings of dc machines having more than one layer the ETD method may also be used.

5.3.1 *Determination of Temperature-Rise of Windings by the Resistance Method*

5.3.1.1 *Copper windings*

The temperature-rise $t_2 - t_a$ may be obtained from the ratio of the resistance by the formula:

$$\frac{t_2 + 235}{t_1 + 235} = \frac{R_2}{R_1}$$

where

t_2 = temperature (°C) of the winding at the end of the test,

t_a = temperature (°C) of coolant at the end of the test,

t_1 = temperature (°C) of the winding (cold) at the moment of the initial resistance measurement,

R_2 = resistance of the winding at the end of the test, and

R_1 = resistance of the winding at temperature t_1 (cold).

For practical purposes, the following alternative formula may be found convenient:

$$tr \text{ (Temperature-rise)} = t_2 - t_a = \frac{R_2 - R_1}{R_1} (235 + t_1) + t_1 - t_a$$

When the temperature of a winding is determined by resistance, the temperature of the winding before the test, measured by thermometer, shall be practically that of the coolant.

5.3.1.2 *Non-copper windings*

For materials other than copper, replace the number 235 in the above formula with the reciprocal of the temperature coefficient of resistance at 0°C of the material. For aluminium, unless otherwise specified, the number 225 shall be used.

5.3.2 *Determination of Temperature-Rise by the Embedded Temperature Detector (ETD) Method*

When the ETD method is used, the detectors shall be suitably distributed throughout the machine windings and the number of embedded detectors installed shall be not less than six.

All reasonable efforts, consistent with safety, shall be made to place the detectors at the various points at which the highest temperatures are likely to occur, in such a manner that they are effectively protected from contact with the primary coolant.

The highest reading of ETD elements shall be used to determine compliance with requirements for temperature-rise or temperature limits.

If there are two or more coil-sides per slot the detectors shall be installed in accordance with **5.3.2.1.** If there is only one coil-side per slot, or if it is desired to measure the end winding temperature, the recommended methods of installation are given in **5.3.2.2** and **5.3.2.3**, but in these cases, the ETD method of temperature measurement is not recognized method for determining temperature-rise or temperature limits in order to verify the compliance of the rating with this standard.

5.3.2.1 *Two coil-sides per slot or more than two coil-sides per slot*

When the winding has two coil-sides per slot or more than two coil-sides per slot, the temperature detectors shall be located between the insulated coil-side within the slot in positions at which the highest temperature are likely to occur.

5.3.2.2 *One coil-side per slot*

When the winding has one coil-side per slot, detectors that are embedded in the slots should be located between the wedge and the outside of the winding insulation in positions at which the highest temperature are likely to occur.

5.3.2.3 *End winding*

Where applicable, the temperature detectors should be located between two adjacent coil-sides within the external range of the end windings in positions at which the highest temperatures are likely to occur. The temperature sensing point of the temperature detector should be in close contact with the surface of the coil-side and be adequately insulated against the coolant influence.

5.3.3 *Determination of Temperature-Rise by the Thermometer Method*

The thermometer method is recognized in the cases in which neither the ETD method nor the resistance method is applicable.

Use of the thermometer method is also recognized in the following cases:

a) When it is not practicable to determine the temperature-rise by the resistance method as for example, with low resistance commutating coils and compensating windings and, in general in the case of low resistance windings, especially when the resistance of joints and connections forms a considerable proportion of the total resistance.

b) Single-layer windings, rotating or stationary.

c) The measurement of temperature-rise during routine tests on machines manufactured in large quantities.

If the purchaser wishes to have a thermometer reading in addition to the values determined by the resistance method or by the ETD method, the temperature-rise determined by thermometer, when placed at the hottest accessible slot, shall be the subject of agreement between manufacturer and purchaser, but shall not exceed:

65°C for Class A insulation of windings
80°C for Class E insulation of windings
90°C for Class B insulation of windings
115°C for Class F insulation of windings
140°C for Class H insulation of windings

NOTE — For the classification of the insulation, *see* IS 1271 : 1985.

5.4 Correction of Measurements Taken After the Machine has Come to Rest and is De-energized

5.4.1 The measurement of temperature after shutdown by the resistance method requires a quick shut-down of the machine at the end of the temperature test. A carefully planned procedure and an adequate number of people are required to obtain readings quickly enough to give reliable data.

If the initial resistance reading is obtained within, the time interval indicated below, this reading shall be accepted as the temperature measurement, and extrapolation of observed temperatures to the instant of switching off the power is unnecessary.

Rated Output (*P*) (kW)/(kVA)	*Time Delay After Switching Off Power* (*s*)
$P \leq 50$	30
$50 < P \leq 200$	90
$200 < P \leq 5\,000$	120
$5\,000 < P$	By agreement

5.4.2 If the initial resistance reading can not be made in the required length of time, it shall be made as soon as possible afterwards and additional resistance readings be taken at intervals of approximately 1 minute until these readings have begun a distinct decline from their maximum values. A curve of these readings shall be plotted as function of time and extrapolated to the time delay specified in the above table for the rated output of the machine. A semi-logarithmic plot is recommended where temperature is plotted on the logarithmic scale. The value of temperature thus obtained shall be considered as the temperature at shut-down. If successive measurements show increasing temperatures after shut-down, the highest value shall be taken.

5.4.3 For machines with one coil-side per slot, the resistance method may be used if the machine comes to a standstill within the time delay specified in the table above. If the machine takes longer than 90s to come to rest after switching off the power, the superposition method (*see* **5.2.4**) may be used if previously agreed between the manufacturer and the purchaser.

5.4.4 If the initial resistance reading cannot be made until after twice the time delay time specified in **5.4.1**, the method of **5.4.2** shall only be used by agreement between the manufacturer and the purchaser.

5.5 Duration of Temperature-Rise Test for Maximum Continuous Rating

For machines with maximum continuous rating (duty type S1), the temperature rise test shall be continued until thermal equilibrium has been reached. If possible, the temperature shall be measured both while running and after shut-down. The readings shall be taken at an interval of ½ hour or less. The temperature rise test shall be continued until there is 1°C or less charge in temperature-rise between two successive readings.

5.5.1 For machines with short time ratings, the duration of the test should correspond for the declared short time rating.

5.5.2 For machines (motors) for periodic duty and for continuous duty with intermittent lead the test shall be continued till thermal equilibrium has been achieved.

5.6 Temperature-Rise Tests for Classes of Rating Other than Maximum Continuous Rating

5.6.1 *Short-Time Rating* (*Duty Type S2*)

The duration of the test is that given in the rating.

At the beginning of the test, the temperature of the machine shall be within 5°C of the temperature of the coolant.

At the end of the test, the temperature-rise limits specified in **6.1.3** shall not be exceeded.

5.6.2 *Periodic Duty Type Ratings* (*Duty Types S3 to S8*)

For intermittent loads, the load cycle specified shall be applied and continued until practically identical temperature cycles are obtained. The criterion for this is that a straight line between the corresponding points of duty cycles has a gradient of less than 2°C per hour. If necessary, measurements should be taken at reasonable intervals over a period of time. At the middle of the period, causing the greatest heating in the last cycle of operation, the temperature-rise shall not exceed the limits specified in Table 1.

5.6.3 *Non-periodic Duty Type Rating* (*Duty Type S9*)

The temperature-rise test shall be carried out in accordance with **5.5** at the equivalent continuous rating assigned by the manufacturer on account of the rated load-speed variations and overload allowances, based on the duty specified by the purchaser in accordance with duty type S9 defined in **4.9** of IS 12824 : 1989.

NOTE — (Applicable to **5.6.2** and **5.6.3**) — For intermittent periodic duty types (S3 to S9), it may not be possible to conduct temperature-rise tests as per the exact duty cycle and it may be necessary to conduct the tests at equivalent duty rating. In such cases, the method of temperature-rise test shall be decided by agreements between the manufacturer and the user [*see* **11.4.6** of IS 12824 : 1989].

5.7 Determination of the Thermal Equivalent Time Constant for Machines for Duty Type S9

The thermal equivalent time constant (with ventilation as in normal operating conditions) suitable for approximate determination of the temperature course can be determined from the cooling curve plotted in accordance with **5.4.2.** Its amount is 1.44 times (that is, $\frac{10}{I_n 2}$ times) the delay between disconnecting the motor and reaching a temperature representing a point on the cooling curve corresponding to one half of the temperature-rise machine.

NOTE — In the case of a machine with more than one time constant, for example, a dc machine with different time constants for armature, field windings and commutating windings, all the time constants should be considered and the value likely to cause the most dangerous temperature should be used for determining temperature-rise.

5.8 Method of Bearing Temperature Measurement

For measuring the temperature of bearings, the thermometer method (*see* **5.2.3**) and the embedded temperature detector (ETD) method (*see* **5.2.2**) are recognized.

The measuring point for the determination of the temperature of bearings shall be located as nearly as possible to one of the two locations specified in the following table:

Type of Bearing	*Measuring Point*	*Location of Measuring Points*
Ball or roller	A	In the bearing housing and at a distance(1) of 10 to 55 mm from the outer ring of the bearing(2)
	B	Outer surface of the bearing housing as close as possible to the outer ring of the bearing
Sleeve	A	In the pressure zone of the bearing shell(3) and at a distance(1) not exceeding 40 mm from the oil-film gap(2)
	B	Elsewhere in the bearing shell

1)The distances 'measuring point to the outer ring' and 'measuring point to oil-film gap' are measured from the nearest point of the ETD or thermometer

2)In the unusual case of an 'inside-out' machine, print A will be in the stationary part not more than 10 mm from the inner ring of the bearing, and point B will be on the outer surface of the stationary part as close as possible to the inner ring of the bearing.

3)The bearing shell is the part supporting the bearing material which is pressed or otherwise secured in the housing. The pressure zone is the portion of the circumference which supports the combination of rotor weight and radial loads such as with belt drive.

For measuring the temperature of bearings, good heat transference between the temperature detector and the object to be measured shall be ensured, any air gaps, for instance, shall be packed with conducting paste.

NOTES

1 Between the measuring points A and B as well as between these points and the hottest point of the bearing, there are temperature differences which depend, among other things, on the bear size. For sleeve bearings with pressed-in bearing bushes and for ball or roller bearings with an inside diameter up to 150 mm, the temperature differences arising between the measuring points A and B may be presumed to be negligible. In the case of larger bearings, temperatures will arise at the measuring point A, higher by approximately 15°C than those arising at the measuring point B.

6 LIMITS OF TEMPERATURES AND TEMPERATURE-RISE

6.1 Tables of Temperatures and Temperature-Rise

Table 1 specifies the permissible limits of temperature-rise above the operating site ambient air temperature for machines cooled indirectly by air, when operating at rated output at the altitude and the maximum ambient temperature stated in IS 4722 : 1968. (that is, not exceeding 1 000 m above sea level and 40°C).

Table 2 specifies the permissible limits of temperature-rise above the hydrogen temperature at the outlet of the heat exchanger, for machines having windings indirectly cooled by hydrogen there the hydrogen temperature at the outlet of the heat exchanger does not exceed 40°C (*see also* **4.2.2** and **4.2.3**).

Table 3 specifies the permissible limits of temperature for machines having active parts directly cooled by gas or liquid.

6.1.1 *Machines with More than One Method of Cooling*

In the case of a machine where one winding is indirectly cooled and another winding is directly cooled, the limits of temperature-rise or of temperature of each winding shall be in accordance with the requirements of the appropriate table.

6.1.2 *Thermal Classifications*

The limits of temperature-rise or temperature given in Tables 1, 2 and 3 apply to the thermal classifications shown in these tables.

6.1.3 *Machines with Short-Time Rating*

For machines to which a short-time rating has been assigned (*see* **5.2** of IS 12824 : 1989) and which have a rated output of less than 5 000 kW (or kVA), the limits of temperature-rise specified in Table 1 increased by 10°C shall not be exceeded.

6.1.4 *Machines with Water-Cooled Heat Exchangers*

For a machine referred to in Table 1 or Table 2, having a water-cooled heat exchanger, the temperature rises shall be measured above the temperature of the primary coolant at the outlet from the heat exchangers (*see also* **4.2.2** and **4.2.3**), and shall apply with respect to this outlet coolant temperature providing this does not exceed 40°C.

However, the temperature-rises may, by agreement between the manufacturer and the purchaser, be measured with respect to the temperature of the water at intake to the heat exchanger and if this inlet water temperature does not exceed 25°C the temperature-rise limits of Tables 1 or 2 shall be increased by 10°C.

The adjustments of temperature-rise dependent on altitude and maximum coolant temperature, detailed in **6.3** shall be applied where they are relevant. Where, in the case of reference to the temperature of the water at intake, an adjustment in accordance with **6.3.4** has been agreed, this may be obtained by adding 15°C to the specified maximum water temperature and reading from the curve for this value and then increasing the adjustment by 10°C.

6.1.5 *Machines with Non-periodic Duty Type Rating*

It should be noted that, for machines to which a non-periodic duty type rating based on duty type S9 has been assigned, the limits of temperature-rise of Table 1 may be occasionally exceeded during operation of the machine.

6.2 Stator Windings for Rated Voltages in Excess of 11 000 V

6.2.1 *Machine Indirectly Cooled by Air*

For stator windings fully insulated for rated voltages in excess of 11 000 V, the limits of temperature-rise specified in Table 1 shall be reduced by the following amounts:

a) Each 1 000 V (or part thereof) above 11 000 V up to and including 17 000 V:

   1.5°C when measurements are made by thermometer,

   1°C when measurements are made by embedded temperature detector.

b) Each 1 000 V (or part thereof) above 17 000 V, additional 0.5°C when measurements are made by thermometer or embedded temperature detector.

6.2.2 *Machines Indirectly Cooled by Hydrogen*

For stator windings for rated voltages in excess of 11 000 V, the limits of temperature-rise specified in Table 2 shall be reduced by the following amounts:

a) 1°C per 1 000 V (or part thereof) above 11 000 V up to and including 17 000 V, and

b) additional 0.5°C per 1 000 V (or part thereof) above 17 000 V.

6.3 Adjustments to Limits of Temperature-Rise to Take Account of Operating Conditions

The adjustments detailed in this clause shall be made to the limits of temperature-rise for machines indirectly cooled by air specified in Table 1 to take account of specified conditions of altitude and/or maximum ambient temperature (or resulting conditions for maximum primary coolant temperature of a machine with water-cooled heat exchanger), at the operating site, differing from those specified in IS 4722 : 1968.

6.3.1 No adjustment is to be made to the temperature-rise limits specified in Table 1 when the maximum ambient temperature is 40°C and the altitude is between sea level and 1 000 m.

6.3.2 If the specified or resulting maximum coolant temperature exceeds 60°C or is less than 0°C, the limits of temperature-rise shall be agreed between the manufacturer and the purchaser.

6.3.3 If the specified or resulting maximum coolant temperature is between 40°C and 60°C, the limits of temperature-rise given in Table 1 shall be reduced by the amount by which the coolant temperature exceeds 40°C. This is illustrated in Fig. 1.

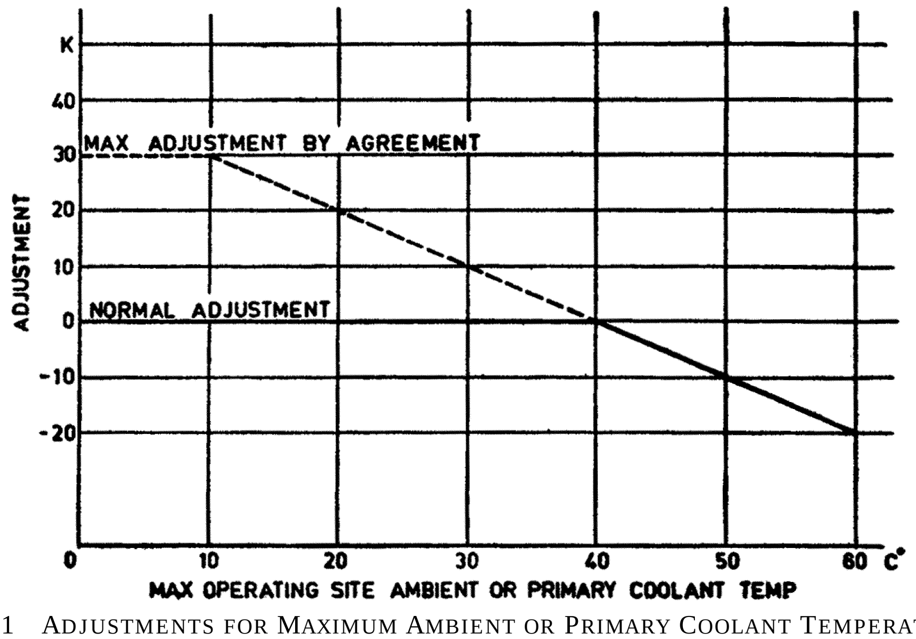

FIG. 1 ADJUSTMENTS FOR MAXIMUM AMBIENT OR PRIMARY COOLANT TEMPERATURE

Table 1 Limits of Temperature-Rise of Machines Indirectly Cooled by Air

(*Clause* 5.3, 5.6.2, 6.1, 6.1.2, 6.1.3, 6.1.5, 6.2.1, 6.3, 6.3.1, 6.3.3, 6.3.5, 6.4, 6.4.1 *and* 6.4.2)

Item No.	Part of Machine	Thermal Classification														
		A Method of Measurement			E Method of Measurement			B Method of Measurement			F Method of Measurement			H Method of Measurement		
		Thermo-meter (K)	Resist-ance (K)	ETD (K)	Thermo-meter (K)	Resist-ance (K)	ETD (K)	Thermo-meter (K)	Resist-ance (K)	ETD (K)	Thermo-meter (K)	Resist-ance (K)	ETD (K)	Thermo-meter (K)	Resist-ance (K)	ETD (K)
1 a)	A.C. windings of machines having outputs of 5 000 kW (or kVA) or more	—	60	65[1)]	—	—	—	—	80	85[1)]	—	100	105[1)]	—	125	130[1)]
b)	A.C. windings of machines having outputs above 200 kW (or kVA), but less than 5 000 kW (or kVA)	—	60	65[1)]	—	75	—	—	80	90[1)]	—	105	110[1)]	—	125	130[1)]
c)	A.C. windings of machines having outputs of 200 kW (or kVA) or less, other than those in Item No. 1 (d) or 1(e)[2)]	—	60	—	—	75	—	—	80	—	—	105	—	—	125	—
d)	A.C. windings of machines having rated outputs of less than 600 W (or VA)[2)]	—	65	—	—	75	—	—	85	—	—	110	—	—	130	—
e)	A.C. windings of machines which are self-cooled without fan (IC 40) and/or with encapsulation windings[2)]	—	65	—	—	75	—	—	85	—	—	110	—	—	130	—
2	Windings of armatures having commutators	50	60	—	65	75	—	70	80	—	85	105	—	105	125	—
3	Field windings of ac and dc machines having dc excitation other than those in Item 4	50	60	—	65	75	—	70	80	—	85	105	—	105	125	—
4 a)	Field windings of synchronous machines with cylindrical rotors having dc excitation winding embedded in slots except synchronous induction motors	—	—	—	—	—	—	—	90	—	—	110	—	—	135	—
b)	Stationary field windings of dc machines having more than one layer	50	60	—	65	75	—	70	80	90	85	105	110	105	125	135
c)	Low resistance field windings of ac and dc machines and compensating windings of dc machines having more than one layer	60	60	—	75	75	—	80	80	—	100	100	—	125	125	—
d)	Single-layer windings of ac and dc machines with exposed bare or varnished metal surfaces and single-layer compensating windings of dc machines[3)]	65	65	—	80	80	—	90	90	—	110	110	—	135	135	—
5	Permanently short-circuited windings	The temperature-rise of any part shall not be detrimental to the insulation of that part or to any other part adjacent to it.														

6	Commutators and slip-rings and their brushes and brushgear	The temperature-rise of any part shall not be detrimental to the insulation of that part or to any other part adjacent to it. Additionally the temperature-rise shall not exceed that at which the combination of brush grade and commutator/slip-ring material can handle the current over the complete operation range.
7	Magnetic cores and all structural components, whether or not in direct contact with insulation (excluding bearings)	The temperature-rise of any part shall not be detrimental to the insulation of that part or to any other part adjacent to it.

NOTES

1 Thermally sensitive test tapes may be used in place of thermometers.

2 Special precaution may be necessary in the choice of brush grades in using temperature-rise of 90°C and higher.

3 Temperature-rise by ETD method should be conducted if machine is fitted with ETD. Otherwise resistance method shall apply.

4 Temperature-rise of windings for machines given in Item 1(c), (d), (e) and fitted with ETD shall comply with limits given for machines in Item 1(a).

1) A correction for high-voltage ac windings may be applicable to these items (*see* **6.2**).

2) With application of the superposition test method to windings of machines rated 200 kW (or kVA) or less with insulation Classes A, E, B and F, the limits of temperature-rise given for the resistance method may be exceeded by 5°C

3) Also includes multiple layer windings provided that the under layers are each in contact with the circulating primary coolant.

Table 2 Limits of Temperature-Rise of Machines Indirectly Cooled by Hydrogen

(*Clauses* 5.3.2, 6.1, 6.1.2 *and* 6.2.2)

Item No.	Part of Machine	Thermal Classification							
		A Method of Measurement		E Method of Measurement		B Method of Measurement		F Method of Measurement	
		Resistance (K)	ETD (K)	Resistance (K)	ETD (K)	Resistance (K)	ETD (K)	Resistance (K)	ETD (K)
1	AC windings of machines having outputs of 5 000 kW (or kVA) or more, or having a core length of 1 m or more *Absolute hydrogen pressure*[1]								
	≤ 150 kPa (1.5 bar)	—	—	—	—	—	85[2]	—	105[2]
	> 150 kPa ≤ 200 kPa (2.0 bar)	—	—	—	—	—	80[2]	—	100[2]
	> 200 kPa ≤ 300 kPa (3.0 bar)	—	—	—	—	—	76[2]	—	96[2]
	> 300 kPa ≤ 400 kPa (4.0 bar)	—	—	—	—	—	73[2]	—	93[2]
	> 400 kPa (4.0 bar)	—	—	—	—	—	70[2]	—	90[2]
2 a)	AC windings of machines having output less than 5 000 kW (or kVA) and having a core length less than 1 m	60	65[2]	75	80[2]	80	85[2]	100	105[2]
b)	DC field windings of ac and dc machines other than those in items No. 3 and 4	60	—	75	—	80	—	105	—
3	Field windings of turbine-type machines having dc excitation	—	—	—	—	85	—	105	—
4 a)	Low-resistance field windings of more than one layer, and compensating windings	60	—	75	—	80	—	100	—
b)	Single-layer windings with exposed bare or varnished metal surfaces[3]	65	—	80	—	90	—	110	—
5	Permanently short-circuited windings	The temperature-rise of any part shall not be detrimental to the insulation of that part to any other part adjacent to it.							
6	Commutators and slip-rings and their brushes and brush holders	The temperature-rise of any part shall not be detrimental to the insulation of that part or to any other part adjacent to it. Additionally the temperature-rise shall not exceed that at which the combination of brush grade and commutator/slip-ring material can handle the current complete over the operation range.							
7	Magnetic cores and all structural components, whether or not in direct contact with insulation (excluding bearings)	The temperature-rise of any part shall not be detrimental to the insulation of that part or to any other part adjacent to it.							

NOTE — Special precaution may be necessary in the choice of brush/grades in using temperature-rises of 90°C and higher.

1) This is the only item where the permissible temperature-rise is dependent on hydrogen pressure.
2) A correction for high-voltage ac windings may be applicable to these items (*see* **6.2**).
3) Also includes multiple-layer field windings provided that the under layers are each in contact with the circulating primary coolant.

Table 3 Limits of Temperature of Directly Cooled Machines and Their Coolants

(*Clauses* 6.1 *and* 6.1.2)

Item No.	Part of Machine	Thermal Classification					
		B Method of Measurement			F Method of Measurement		
		Thermometer (K)	Resistance (K)	ETD (K)	Thermometer (K)	Resistance (K)	ETD (K)
1	Coolant at the outlet of directly-cooled ac windings. These temperature are perferred to the values given in Item No. 2 at the basis of rating						
a)	Gas (air, hydrogen, helium, etc.)	110	—	—	130	—	—
b)	Water	90	—	—	90	—	—
2	AC windings						
a)	Gas cooled	—	—	120	—	—	145
b)	Liquid cooled						
3	Field windings of turbine-type machines						
a)	Cooled by gas leaving the rotor through the following number of outlet regions[1]:						
	1 and 2	—	100	—	—	115	—
	3 and 4	—	105	—	—	120	—
	6	—	110	—	—	125	—
	8 - 14	—	115	—	—	130	—
	Above 14	—	120	—	—	135	—
b)	Liquid cooled	Observance of the maximum coolant temperatures given in Item No. 1 (b) will ensure that the hot-spot temperature of the winding is not excessive.					
4	Field windings of ac and dc machines having dc excitation other than that in Item No. 3						
a)	Gas cooled	—	130	—	—	150	—
b)	Liquid cooled	Observance of the maximum coolant temperature given in Item No. 1(b) will ensure that the hot-spot temperature of the winding is not excessive.					
5	Permanently short-circuited windings	The temperature of any part shall not be detrimental to the insulation of that part or to any other part adjacent to it.					
6	Commutators and slip-rings and their brushes and brush holders.	The temperature of any part shall not be detrimental to the insulation of that part or to any other part adjacent to it. Additionally the temperature shall not exceed that at which the combination of brush grade and commutator slip-ring material can handle the current over the complete operation range.					
7	Magnetic cores and all structural components, whether or not in direct contact with insulation (excluding bearings)	The temperature of any part shall not be detrimental to the insulation of that part or to any other part adjacent to it.					

Table 3 — *Contd*

NOTES

1 The rotor ventilation is classified by the number of radial outlet regions on the total length of the rotor. Special outlet regions for the coolant of the end windings are included as one outlet for each end. The common outlets of two axially opposed cooling flows are to be counted as two regions.

2 Special precautions may be necessary in the choice of the brush grades in using a temperature of 130°C and higher.

1) It is important to note that the temperature measured by ETD is no indication of the hot-spot temperature of the stator winding. Observance of maximum coolant temperatures given is Item 1 will ensure that the hot-spot temperature of the winding is not excessive. The limit of permissible temperature of the stator windings, however, is intended to be a safeguard against excessive heating of the insulation from the core. The readings of the ETD temperatures may be used to monitor the operation of the cooling system of the stator winding.

6.3.4 If the specified or resulting maximum coolant temperature is between 0°C and 40°C, no increase in the limits of temperature-rise shall normally be made by agreement between the manufacturer and the purchaser, however, an increase may be made, but this shall not exceed the difference between this maximum coolant temperature and 40°C, with a maximum of 30°C. This is illustrated in Fig. 1.

6.3.5 If the machine is to operate at an altitude exceeding 1 000 m but not exceeding 4 000 m and the maximum coolant temperature is not specified, it shall be assumed that the reduced cooling resulting from altitude is compensated by a reduction of maximum ambient temperature below 40°C and that the limiting total temperatures will therefore not exceed 40°C plus the Table 1 temperature rises. The specified altitude and assumed maximum ambient temperature shall be marked on the rating plate in accordance with IS 4722 : 1968.

NOTE — Assuming the necesssary decrease in ambient temperature is 1 percent of the limiting rise for every 100 m of altitude above 1000 m, the assumed maximum ambient temperature at operating site based on a 40°C maximum ambient temperature for altitudes up to 1 000 m will be as shown in Table 4 [based on the limiting rises for Item 1 (b) and 1 (c) of Table 1].

6.3.6 If the machine is to operate at an altitude exceeding 4 000-m the maximum limits of temperature rise shall be agreed between the manufacturer and the purchaser.

Table 4 Assumed Maximum Ambient Temperatures

(*Clause* 6.3.5, *Note*)

Altitude (m)	Temperature (°C) Class of Insulation				
	A	E	B	F	H
(1)	(2)	(3)	(4)	(5)	(6)
1 000	40	40	40	40	40
2 000	34	33	32	30	28
3 000	28	26	24	19	15
4 000	22	19	16	9	3

6.4 Adjustments to Limits of Temperature-Rise to Take Account of Altitude or Ambient Temperature of Test Site

The adjustments detailed in this clause shall be made to the limits of temperature rise for machines indirectly cooled by air specified in Table 1 to take account of difference in altitude between the test site and the operating site, or difference between the specified on resulting maximum coolant temperature at the operating site and the coolant temperature on the test.

6.4.1 *Adjustments to Limits of Temperature-Rise at the Test Site on Account of Difference in Altitude*

If the operating site is higher than the test site, but is not higher than 4 000 m, the limits of temperature-rise on test shall be as in Table 1 (corrected, if appropriate, in accordance with **6.2** and **6.3**) minus an adjustment calculated on the basis of a one percent change in the permitted temperature-rise in Table 1 per 100 m of difference between the altitudes of the test site and the operating site. For purposes of this calculation, altitude below 1 000 m shall be assumed to be equal to 1 000 m.

If the test site is higher than the operating site but is not higher than 4 000 m the corresponding adjustment shall be added, not subtracted. If this positive temperature-rise adjustment when added to the ambient temperature at the test site, results in a total temperature considered excessive by the manufacturer, the testing procedure shall be agreed between the manufacturer and the purchaser.

6.4.2 *Adjustments for Difference in Coolant Temperatures*

When the actual coolant temperature at the inlet to the machine at the completion of the temperature-rise test differs by less than 30°C from the maximum temperature at the operating site or that assumed from **6.3.5**, no further adjustment shall be made to the limits of temperature-rise on test.

When the actual coolant temperature at the inlet to the machine at the completion of the temperature-rise test is lower by 30°C or more than the maximum temperature at the operating site or that assumed from **6.3.5**, the limits of temperature-rise on test shall be those specified in Table 1 adjusted in accordance with **6.1.3**, **6.1.4**, **6.2**, **6.3.3** and **6.3.4** as relevant and then reduced by a percentage numerically equal to one-fifth of the difference between the maximum coolant temperature for the operating site and the coolant temperature on test.

When the actual coolant temperature at the inlet to the machine at the completion of the temperature-rise test is higher by 30°C or more than the maximum temperature at the operating site or that assumed from **6.3.5**, the limits of temperature-rise on test shall be those specified in Table 1 adjusted in accordance with **6.1.3**, **6.1.4**, **6.2**, **6.3.3** and **6.3.4** as relevant and then increased by a percentage numerically equal to one-fifth of the difference between the maximum coolant temperature for the operating site and the coolant temperature on test.

6.5 Corrections to Take Account of Hydrogen Purity on Test

For machines indirectly cooled or directly cooled by hydrogen, if the purity of the hydrogen during test differs from the 98 percent specified in **5** of IS 4722 : 1968, no corrections shall be made to the permissible temperature rises or limits of temperature if the proportion of hydrogen lies between 95 percent and 100 percent.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
IS 1271 : 1985	Thermal evaluation and classification of electrical insulation (*first revision*)
IS 1885 (Part 35) : 1973	Electrotechnical vocabulary: Part 35 Rotating machines
IS 4722 : 1968	Rotating electrical machines
IS 12824 : 1989	Types of duty and classes of rating assigned to rotating electrical machines.

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