BS EN 60751:2008

BSI Standards Publication

Industrial platinum resistance thermometers and platinum temperature sensors

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National foreword

This British Standard is the UK implementation of EN 60751:2008. It is identical to IEC 60751:2008. It supersedes BS EN 60751:1996 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GEL/65, Measurement and control, to Subcommittee GEL/65/2, Elements of systems.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 60751

September 2008

ICS 17.200.20

Supersedes EN 60751:1995 + A2:1995

English version

Industrial platinum resistance thermometers and platinum temperature sensors
(IEC 60751:2008)

Thermomètres à résistance
de platine industriels
et capteurs thermométriques en platine
(CEI 60751:2008)

Industrielle
Platin-Widerstandsthermometer
und Platin-Sensoren
(IEC 60751:2008)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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

Ref. No. EN 60751:2008 E

Foreword

The text of document 65B/664/FDIS, future edition 2 of IEC 60751, prepared by SC 65B, Devices & process analysis, of IEC TC 65, Industrial-process measurement, control and automation, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60751 on 2008-08-01.

This European Standard supersedes EN 60751:1995 + A2:1995.

The significant technical changes with respect to EN 60751:1995 are as follows:

While the temperature/resistance relationship in 4.2 remains unchanged, there are several changes in the other chapters. Most important are:

– tolerance classes follow a new scheme;

– tolerance acceptance test is included;

– hysteresis test is included;

– several changes in the individual tests;

– appendices are deleted.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2009-05-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2011-08-01

Annex ZA has been added by CENELEC.

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Endorsement notice

The text of the International Standard IEC 60751:2008 was approved by CENELEC as a European Standard without any modification.

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 61152 (mod)	- [1)]	Dimensions of metal-sheathed thermometer elements	EN 61152	1994 [2)]
IEC 61298-1	- [1)]	Process measurement and control devices - General methods and procedures for evaluating performance - Part 1: General considerations	EN 61298-1	1995 [2)]

[1)] Undated reference.

[2)] Valid edition at date of issue.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INDUSTRIAL PLATINUM RESISTANCE THERMOMETERS AND PLATINUM TEMPERATURE SENSORS

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60751 has been prepared by subcommittee 65B: Devices and process analysis, of IEC technical committee 65: Industrial-process measurement, control and automation.

This second edition cancels and replaces the first edition published in 1983, amendment 1 (1986) and amendment 2 (1995). This edition constitutes a technical revision.

The significant technical changes with respect to the previous edition are as follows:

While the temperature/resistance relationship in 4.2 remains unchanged, there are several changes in the other chapters. Most important are:

– tolerance classes follow a new scheme;
– tolerance acceptance test is included;
– hysteresis test is included;
– several changes in the individual tests;
– appendices are deleted.

The text of this standard is based on the following documents:

FDIS	Report on voting
65B/664/FDIS	65B/683/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INDUSTRIAL PLATINUM RESISTANCE THERMOMETERS AND PLATINUM TEMPERATURE SENSORS

1 Scope

This standard specifies the requirements and temperature/resistance relationship for industrial platinum resistance temperature sensors later referred to as “platinum resistors” or "resistors" and industrial platinum resistance thermometers later referred to as "thermometers" whose electrical resistance is a defined function of temperature.

The International Standard applies to platinum resistors whose temperature coefficient α, defined as

$$\alpha = \frac{R_{100} - R_0}{R_0 \cdot 100\,°\mathrm{C}}$$

is conventionally written as α = 3.851 x 10^{-3} °C^{-1}, where R_{100} is the resistance at t = 100 °C and R_0 is the resistance at t = 0 °C.

Values of temperature in this standard are in terms of the International Temperature Scale of 1990, ITS-90. Temperatures in degrees Celsius are denoted by the symbol t, except in Table 1 where the full nomenclature t_{90}/°C is used.

The standard covers resistors or thermometers for all or part of the temperature range -200 °C to +850 °C with different tolerance classes, which may cover restricted temperature ranges.

For temperature/resistance relationships with uncertainties <0,1 °C, which are possible only for resistors or thermometers with exceptionally high stability and individual calibration, a more complex interpolation equation than is presented in this standard may be necessary. The specification of such equations is outside the scope of this standard.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies:.

IEC 61152, *Dimensions of metal-sheathed thermometer elements*

IEC 61298-1, *Process Measurement and Control devices – General Methods and Procedures for Evaluating Performance – Part 1: General considerations*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
dielectric strength
maximum voltage between all parts of the electric circuit and the sheath of the thermometer or, in the case of a thermometer with two or more sensing circuits, between two individual

circuits which the thermometer can withstand without damage. The measurement conditions for d.c and a.c (with frequency) have to be specified.

3.2
insulation resistance
electrical resistance measured between any part of the electric circuit and the sheath at ambient or elevated temperatures and with a specified measuring voltage (a.c or d.c)

3.3
minimum immersion depth
immersion depth at which the change from the calibration at full immersion does not exceed 0.1 °C

3.4
nominal resistance
expected resistance R_0 of a resistor or resistance thermometer at 0 °C, declared by the manufacturer and shown in the thermometer marking, usually rounded to the nearest ohm. Platinum resistors are often characterized by their nominal: A Pt-100 resistor is a resistor with R_0 = 100 Ω

3.5
platinum resistance thermometer
PRT
temperature responsive device consisting of one or more sensing platinum resistors within a protective sheath, internal connecting wires and external terminals to permit connection of electrical measurement instruments. Mounting means and connection heads may be included. Not included is any separable protection tube or thermowell

3.6
temperature sensitive length
length of the thermometer whose temperature directly influences the resistance measured. Usually the temperature sensitive length is related to the length of the resistor

3.7
platinum resistor
resistor made from a platinum wire or film with defined electrical characteristics, embedded in an insulator (in most cases glass or ceramic), designed to be assembled into a resistance thermometer or into an integrated circuit

3.8
self-heating
increase of the temperature of the resistor or of the resistor in a thermometer caused by the dissipated energy of the measuring current

3.9
self-heating coefficient
coefficient with the dimension °C/mW is characteristic for a resistor/thermometer and describes the temperature increase of the resistor per unit power dissipated. This coefficient is evaluated under specified operating conditions of the resistor or thermometer. The medium, its flow conditions and temperature should be specified

3.10
terminals
termination of the connections supplied with the resistance thermometer

NOTE Typical types of terminals are:

– screws or clamps on the terminal socket;

– pins of fixed connectors;

– open ends of fixed cables, or equivalents.

3.11
thermal response time
time a thermometer takes to respond at a specified percentage to a step change in temperature. To specify the response time, it is necessary to declare the percentage of response, usually $\tau_{0.9}$, $\tau_{0.5}$, or $\tau_{0.1}$, which gives the time for 90 %, 50 % or 10 % of the response. The test medium and its flow conditions have to be specified (usually flowing water and/or flowing air)

3.12
thermoelectric effect
effect of inducing the electro-motive force (EMF) caused by different metals used in the electric circuit of the thermometer and by thermoelectric inhomogeneity of the internal leads at the conditions of temperature gradients along the leads. The induced EMF is measured across the terminals of the thermometer while the thermometer is subjected to a specified temperature

3.13
tolerance
initial[1] maximum allowable deviation expressed as $\Delta t(t)$ in °C from the nominal temperature/resistance relationship $R(t)$

3.14
hysteresis
property of a device or instrument whereby it gives different output values in relation to its input values depending on the directional sequence in which the input values have been applied

[IEC 61298-1, 3.13]

NOTE Hysteresis as defined in IEC 61298-1 can be applied to thermometers by the method described in 6.5.6 of this standard

4 Characteristics

The temperature/resistance relationships and tolerances in this chapter are valid for the sensing resistors at its connecting points. For thermometers, they are valid for the complete thermometer at its terminals.

In the case of two-wire connections, the resistance values of the leads between the connecting point of the resistor and the terminals shall be considered. They may be indicated on the thermometer and shall be subtracted from measured resistances. In some cases, it also may be advisable to consider the temperature coefficient of the lead wires, the geometrical characteristics of the wires and the temperature distribution along their length.

4.1 Temperature/resistance relationships

The temperature/resistance relationships used in this standard are as follows:

For the range –200 °C to 0 °C:

$$R_t = R_0[1 + At + Bt^2 + C(t - 100°C)\, t^3]$$

For the range of 0 °C to 850 °C:

[1] First calibration before any use of the resistor or thermometer.

$$R_t = R_0(1 + At + Bt^2)$$

where

R_t is the resistance at the temperature t;

R_0 is the resistance at t = 0 °C.

The constants in these equations are:

$A = 3.9083 \times 10^{-3}\ °C^{-1}$

$B = -5.775 \times 10^{-7}\ °C^{-2}$

$C = -4.183 \times 10^{-12}\ °C^{-4}$

These equations and coefficients have been used to derive the table of resistance values, Table 1, for a platinum resistor of nominal resistance R_0 = 100 Ω .

4.2 Resistance values

The temperature/resistance relationship in Table 1 is given for a resistor with nominal resistance of 100 Ω. For other nominal resistances R_0, such as; 10 Ω, 500 Ω or 1 000 Ω, the table can be used by multiplying the table values with the factor R_0 /100 Ω.

Table 1 – Temperature/resistance relationship, R_0 = 100.00 Ω

t_{90}/°C	Resistance at the temperature t_{90}/°C Ω										t_{90}/°C
	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	
-200	18.52										-200
-190	22.83	22.40	21.97	21.54	21.11	20.68	20.25	19.82	19.38	18.95	-190
-180	27.10	26.67	26.24	25.82	25.39	24.97	24.54	24.11	23.68	23.25	-180
-170	31.34	30.91	30.49	30.07	29.64	29.22	28.80	28.37	27.95	27.52	-170
-160	35.54	35.12	34.70	34.28	33.86	33.44	33.02	32.60	32.18	31.76	-160
-150	39.72	39.31	38.89	38.47	38.05	37.64	37.22	36.80	36.38	35.96	-150
-140	43.88	43.46	43.05	42.63	42.22	41.80	41.39	40.97	40.56	40.14	-140
-130	48.00	47.59	47.18	46.77	46.36	45.94	45.53	45.12	44.70	44.29	-130
-120	52.11	51.70	51.29	50.88	50.47	50.06	49.65	49.24	48.83	48.42	-120
-110	56.19	55.79	55.38	54.97	54.56	54.15	53.75	53.34	52.93	52.52	-110
-100	60.26	59.85	59.44	59.04	58.63	58.23	57.82	57.41	57.01	56.60	-100
-90	64.30	63.90	63.49	63.09	62.68	62.28	61.88	61.47	61.07	60.66	-90
-80	68.33	67.92	67.52	67.12	66.72	66.31	65.91	65.51	65.11	64.70	-80
-70	72.33	71.93	71.53	71.13	70.73	70.33	69.93	69.53	69.13	68.73	-70
-60	76.33	75.93	75.53	75.13	74.73	74.33	73.93	73.53	73.13	72.73	-60
-50	80.31	79.91	79.51	79.11	78.72	78.32	77.92	77.52	77.12	76.73	-50
-40	84.27	83.87	83.48	83.08	82.69	82.29	81.89	81.50	81.10	80.70	-40
-30	88.22	87.83	87.43	87.04	86.64	86.25	85.85	85.46	85.06	84.67	-30
-20	92.16	91.77	91.37	90.98	90.59	90.19	89.80	89.40	89.01	88.62	-20
-10	96.09	95.69	95.30	94.91	94.52	94.12	93.73	93.34	92.95	92.55	-10
0	100.00	99.61	99.22	98.83	98.44	98.04	97.65	97.26	96.87	96.48	0
t_{90}/°C	0	1	2	3	4	5	6	7	8	9	t_{90}/°C
0	100.00	100.39	100.78	101.17	101.56	101.95	102.34	102.73	103.12	103.51	0
10	103.90	104.29	104.68	105.07	105.46	105.85	106.24	106.63	107.02	107.40	10
20	107.79	108.18	108.57	108.96	109.35	109.73	110.12	110.51	110.90	111.29	20
30	111.67	112.06	112.45	112.83	113.22	113.61	114.00	114.38	114.77	115.15	30
40	115.54	115.93	116.31	116.70	117.08	117.47	117.86	118.24	118.63	119.01	40
50	119.40	119.78	120.17	120.55	120.94	121.32	121.71	122.09	122.47	122.86	50
60	123.24	123.63	124.01	124.39	124.78	125.16	125.54	125.93	126.31	126.69	60
70	127.08	127.46	127.84	128.22	128.61	128.99	129.37	129.75	130.13	130.52	70
80	130.90	131.28	131.66	132.04	132.42	132.80	133.18	133.57	133.95	134.33	80
90	134.71	135.09	135.47	135.85	136.23	136.61	136.99	137.37	137.75	138.13	90
100	138.51	138.88	139.26	139.64	140.02	140.40	140.78	141.16	141.54	141.91	100
110	142.29	142.67	143.05	143.43	143.80	144.18	144.56	144.94	145.31	145.69	110
120	146.07	146.44	146.82	147.20	147.57	147.95	148.33	148.70	149.08	149.46	120
130	149.83	150.21	150.58	150.96	151.33	151.71	152.08	152.46	152.83	153.21	130
140	153.58	153.96	154.33	154.71	155.08	155.46	155.83	156.20	156.58	156.95	140
150	157.33	157.70	158.07	158.45	158.82	159.19	159.56	159.94	160.31	160.68	150
160	161.05	161.43	161.80	162.17	162.54	162.91	163.29	163.66	164.03	164.40	160
170	164.77	165.14	165.51	165.89	166.26	166.63	167.00	167.37	167.74	168.11	170
180	168.48	168.85	169.22	169.59	169.96	170.33	170.70	171.07	171.43	171.80	180
190	172.17	172.54	172.91	173.28	173.65	174.02	174.38	174.75	175.12	175.49	190
200	175.86	176.22	176.59	176.96	177.33	177.69	178.06	178.43	178.79	179.16	200
210	179.53	179.89	180.26	180.63	180.99	181.36	181.72	182.09	182.46	182.82	210
220	183.19	183.55	183.92	184.28	184.65	185.01	185.38	185.74	186.11	186.47	220
230	186.84	187.20	187.56	187.93	188.29	188.66	189.02	189.38	189.75	190.11	230
240	190.47	190.84	191.20	191.56	191.92	192.29	192.65	193.01	193.37	193.74	240
250	194.10	194.46	194.82	195.18	195.55	195.91	196.27	196.63	196.99	197.35	250
260	197.71	198.07	198.43	198.79	199.15	199.51	199.87	200.23	200.59	200.95	260
270	201.31	201.67	202.03	202.39	202.75	203.11	203.47	203.83	204.19	204.55	270
280	204.90	205.26	205.62	205.98	206.34	206.70	207.05	207.41	207.77	208.13	280
290	208.48	208.84	209.20	209.56	209.91	210.27	210.63	210.98	211.34	211.70	290
300	212.05	212.41	212.76	213.12	213.48	213.83	214.19	214.54	214.90	215.25	300
310	215.61	215.96	216.32	216.67	217.03	217.38	217.74	218.09	218.44	218.80	310
320	219.15	219.51	219.86	220.21	220.57	220.92	221.27	221.63	221.98	222.33	320

Table 1 *(continued)*

t_{90}/°C	Resistance at the temperature t_{90}/°C Ω										t_{90}/°C
	0	1	2	3	4	5	6	7	8	9	
330	222.68	223.04	223.39	223.74	224.09	224.45	224.80	225.15	225.50	225.85	330
340	226.21	226.56	226.91	227.26	227.61	227.96	228.31	228.66	229.02	229.37	340
350	229.72	230.07	230.42	230.77	231.12	231.47	231.82	232.17	232.52	232.87	350
360	233.21	233.56	233.91	234.26	234.61	234.96	235.31	235.66	236.00	236.35	360
370	236.70	237.05	237.40	237.74	238.09	238.44	238.79	239.13	239.48	239.83	370
380	240.18	240.52	240.87	241.22	241.56	241.91	242.26	242.60	242.95	243.29	380
390	243.64	243.99	244.33	244.68	245.02	245.37	245.71	246.06	246.40	246.75	390
400	247.09	247.44	247.78	248.13	248.47	248.81	249.16	249.50	249.85	250.19	400
410	250.53	250.88	251.22	251.56	251.91	252.25	252.59	252.93	253.28	253.62	410
420	253.96	254.30	254.65	254.99	255.33	255.67	256.01	256.35	256.70	257.04	420
430	257.38	257.72	258.06	258.40	258.74	259.08	259.42	259.76	260.10	260.44	430
440	260.78	261.12	261.46	261.80	262.14	262.48	262.82	263.16	263.50	263.84	440
450	264.18	264.52	264.86	265.20	265.53	265.87	266.21	266.55	266.89	267.22	450
460	267.56	267.90	268.24	268.57	268.91	269.25	269.59	269.92	270.26	270.60	460
470	270.93	271.27	271.61	271.94	272.28	272.61	272.95	273.29	273.62	273.96	470
480	274.29	274.63	274.96	275.30	275.63	275.97	276.30	276.64	276.97	277.31	480
490	277.64	277.98	278.31	278.64	278.98	279.31	279.64	279.98	280.31	280.64	490
500	280.98	281.31	281.64	281.98	282.31	282.64	282.97	283.31	283.64	283.97	500
510	284.30	284.63	284.97	285.30	285.63	285.96	286.29	286.62	286.95	287.29	510
520	287.62	287.95	288.28	288.61	288.94	289.27	289.60	289.93	290.26	290.59	520
530	290.92	291.25	291.58	291.91	292.24	292.56	292.89	293.22	293.55	293.88	530
540	294.21	294.54	294.86	295.19	295.52	295.85	296.18	296.50	296.83	297.16	540
550	297.49	297.81	298.14	298.47	298.80	299.12	299.45	299.78	300.10	300.43	550
560	300.75	301.08	301.41	301.73	302.06	302.38	302.71	303.03	303.36	303.69	560
570	304.01	304.34	304.66	304.98	305.31	305.63	305.96	306.28	306.61	306.93	570
580	307.25	307.58	307.90	308.23	308.55	308.87	309.20	309.52	309.84	310.16	580
590	310.49	310.81	311.13	311.45	311.78	312.10	312.42	312.74	313.06	313.39	590
600	313.71	314.03	314.35	314.67	314.99	315.31	315.64	315.96	316.28	316.60	600
610	316.92	317.24	317.56	317.88	318.20	318.52	318.84	319.16	319.48	319.80	610
620	320.12	320.43	320.75	321.07	321.39	321.71	322.03	322.35	322.67	322.98	620
630	323.30	323.62	323.94	324.26	324.57	324.89	325.21	325.53	325.84	326.16	630
640	326.48	326.79	327.11	327.43	327.74	328.06	328.38	328.69	329.01	329.32	640
650	329.64	329.96	330.27	330.59	330.90	331.22	331.53	331.85	332.16	332.48	650
660	332.79	333.11	333.42	333.74	334.05	334.36	334.68	334.99	335.31	335.62	660
670	335.93	336.25	336.56	336.87	337.18	337.50	337.81	338.12	338.44	338.75	670
680	339.06	339.37	339.69	340.00	340.31	340.62	340.93	341.24	341.56	341.87	680
690	342.18	342.49	342.80	343.11	343.42	343.73	344.04	344.35	344.66	344.97	690
700	345.28	345.59	345.90	346.21	346.52	346.83	347.14	347.45	347.76	348.07	700
710	348.38	348.69	348.99	349.30	349.61	349.92	350.23	350.54	350.84	351.15	710
720	351.46	351.77	352.08	352.38	352.69	353.00	353.30	353.61	353.92	354.22	720
730	354.53	354.84	355.14	355.45	355.76	356.06	356.37	356.67	356.98	357.28	730
740	357.59	357.90	358.20	358.51	358.81	359.12	359.42	359.72	360.03	360.33	740
750	360.64	360.94	361.25	361.55	361.85	362.16	362.46	362.76	363.07	363.37	750
760	363.67	363.98	364.28	364.58	364.89	365.19	365.49	365.79	366.10	366.40	760
770	366.70	367.00	367.30	367.60	367.91	368.21	368.51	368.81	369.11	369.41	770
780	369.71	370.01	370.31	370.61	370.91	371.21	371.51	371.81	372.11	372.41	780
790	372.71	373.01	373.31	373.61	373.91	374.21	374.51	374.81	375.11	375.41	790
800	375.70	376.00	376.30	376.60	376.90	377.19	377.49	377.79	378.09	378.39	800
810	378.68	378.98	379.28	379.57	379.87	380.17	380.46	380.76	381.06	381.35	810
820	381.65	381.95	382.24	382.54	382.83	383.13	383.42	383.72	384.01	384.31	820
830	384.60	384.90	385.19	385.49	385.78	386.08	386.37	386.67	386.96	387.25	830
840	387.55	387.84	388.14	388.43	388.72	389.02	389.31	389.60	389.90	390.19	840
850	390.48										850

5 General requirements

5.1 Tolerance classes

5.1.1 Temperature range of validity

The temperature ranges of validity of tolerance classes for resistors given in Table 2 are based on the working experience with film and wire resistors showing that in these ranges most resistors can maintain their tolerances and other performance characteristics. The value of –196 °C was chosen as being close to the boiling point of liquid nitrogen.

5.1.2 Resistors

The tolerance values of resistors are classified in Table 2. These tolerances apply for resistors of any value of R_0. Where the specified temperature range of a particular resistor is smaller than in this table, this shall be stated.

Table 2 – Tolerance classes for resistors

For wire wound resistors		For film resistors		Tolerance value[a]
Tolerance class	Temperature range of validity °C	Tolerance class	Temperature range of validity °C	°C
W 0.1	–100 to +350	F 0.1	0 to +150	± (0.1 + 0.0017 | t |)
W 0.15	–100 to +450	F 0.15	–30 to +300	± (0.15 + 0.002 | t |)
W 0.3	–196 to +660	F 0.3	–50 to +500	± (0.3 + 0.005 | t |)
W 0.6	–196 to +660	F 0.6	–50 to +600	± (0.6 + 0.01 | t |)

[a] \| t \| = modulus of temperature in °C without regard to sign.

5.1.3 Thermometers

The tolerance values of resistance thermometers are classified in Table 3. These tolerances apply for thermometers of any value of R_0. Where the specified temperature range of a particular thermometer is smaller than in this table, this shall be stated.

Table 3 – Tolerance classes for thermometers

Tolerance class	Temperature range of validity °C		Tolerance values[a]
	Wire wound resistors	Film resistors	°C
AA	–50 to +250	0 to +150	± (0.1 + 0.0017 | t |)
A	–100 to +450	–30 to +300	± (0.15 + 0.002 | t |)
B	–196 to +600	–50 to +500	± (0.3 + 0.005 | t |)
C	–196 to +600	–50 to +600	± (0.6 + 0.01 | t |)

[a] \| t \| = modulus of temperature in °C without regard to sign.

5.1.4 Special tolerance classes and special temperature ranges of validity

Tolerances and ranges of validity which differ from values given in Table 2 and Table 3 shall be agreed between manufacturer and user. Recommended special tolerance classes are constructed as multiples or fractions of class B tolerance values. A special tolerance class

without specification of the temperature range of validity is not permissible. It is left to the manufacturers and users to establish tolerances for their thermometers or resistors at temperatures outside the ranges in Table 2 and Table 3.

Special tolerance classes may also be defined for restricted or extended temperature ranges, e.g. for the ranges –196 °C to 850 °C or –200 °C to 660 °C.

5.2 Measuring current

The measuring current to the resistor shall be limited to a value at which the self-heating of the thermometer under conditions as specified in 6.4.3 does not exceed 25 % of the tolerance value of the declared tolerance class. The measuring current is usually not more than 1 mA for a 100 Ω wire wound resistor.

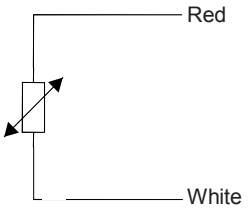
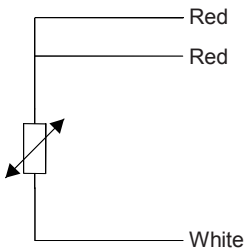
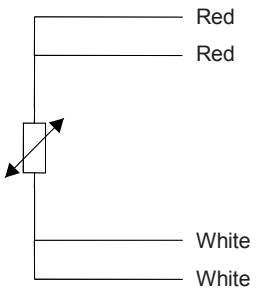
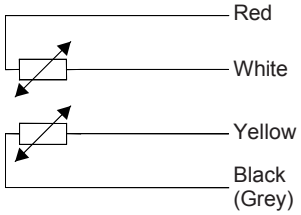
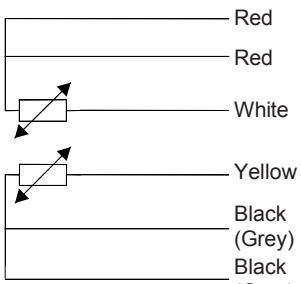
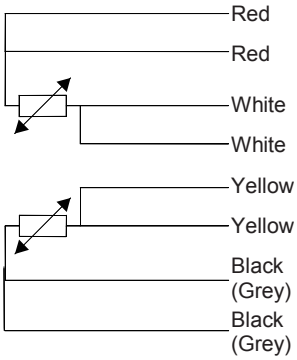
5.3 Electrical supply

Resistors and thermometers shall be constructed so that they are suitable for use in measuring systems using direct current or alternating current at frequencies up to 100 Hz. Some measuring systems may require operation at higher frequencies.

5.4 Connecting wire configuration

All thermometers of tolerance class better than class B shall have 3 wire or 4 wire configuration.

Thermometers may be constructed with one or two resistors and a variety of internal connecting wire configurations. Identification and/or designation of the terminals is shown in Figure 1.

	2-wire-configuration	3-wire-configuration	4-wire-configuration
1 resistor			
2 resistors			

IEC 870/08

Figure 1 – Connecting configurations

6 Tests

6.1 General

Tests shall be carried out to prove that resistors or thermometers comply with the requirements of this standard.

It is not intended or recommended that all tests should be carried out on every resistor or thermometer supplied. Different kinds of tests are therefore described in this clause.

6.1.1 Routine production tests

Routine production tests shall be carried out on every resistor or thermometer manufactured in accordance with this standard. These tests are also included in the specified type tests.

6.1.2 Type tests

Type tests shall be carried out on samples of each particular design and range of resistor or thermometer. These are subdivided into tests for all forms of resistors or thermometers.

6.1.3 Additional type tests

Additional type tests may be required by other regulations or be agreed between manufacturer and user for special applications. If not stated otherwise, there are no fixed specifications for these test items. The results of the tests shall be made available on request.

6.2 Routine production tests for resistors

6.2.1 Tolerance acceptance test

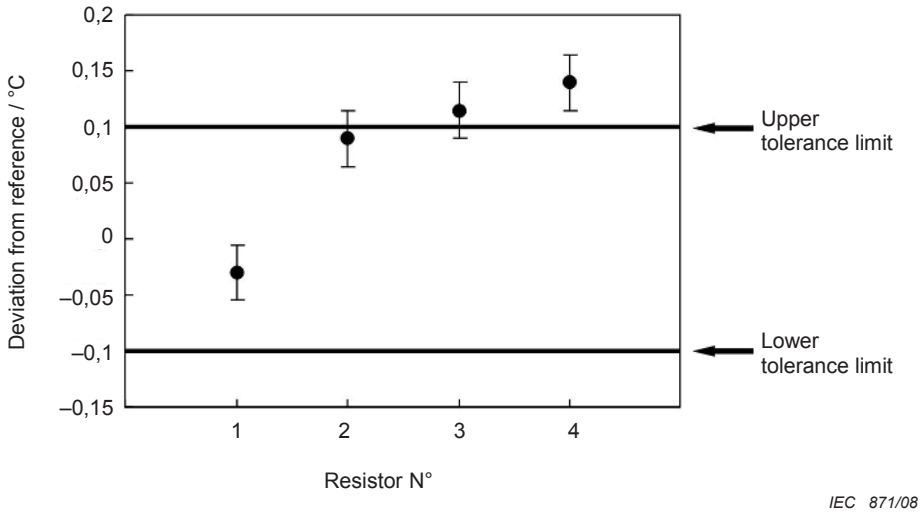
All types of resistors shall be tested at one temperature at least. The test temperature shall be in the range from –5 °C to +30 °C, preferably 0 °C.

Resistors of the tolerance classes 0.15 or better shall be tested at one additional temperature at least. This test temperature shall be the upper or lower temperature limit of the resistor, or spaced from the first test temperature by a minimum of 90 °C, whichever is less.

The manufacturer shall guarantee that resistances are within the specified tolerance class. When selecting the resistors, the measurement uncertainty of the test has to be taken into account. An example is given in Figure 2: if measured by the manufacturer, only resistor No. 1 is within the tolerance class. If measured by the customer, only resistor No. 4 can be rejected.

Therefore, the selection criteria for the manufacturer to use are as follows: the result of the test, expressed as a temperature deviation, when added to the corresponding expanded uncertainty, shall be totally included within the tolerance band.

The rejection criteria for the user are as follows: the tolerance value is not met if the result of the test, expressed as a temperature deviation, when added to the corresponding expanded uncertainty, is totally outside the tolerance band.



NOTE At each test result the expanded uncertainty (k=2) is indicated. Measurement uncertainty of manufacturer and user are assumed to be the same.

Figure 2 – Examples of test results for selecting or rejecting resistors..

6.3 Routine production tests for thermometers

6.3.1 Insulation resistance at ambient temperature

The insulation resistance between each terminal and the sheath shall be tested with a test voltage at minimum 100 V d.c.

The insulation resistance shall be not less than 100 MΩ.

6.3.2 Sheath integrity test

The integrity of the sheath and all closure weldings shall be tested by suitable means, for example the following tests:

6.3.2.1 Water quench test

The thermometer shall be subjected to a minimum temperature of 300 °C for a minimum time of 5 min and then immediately plunged into water at room temperature. Then the insulation resistance shall be measured while the thermometer is immersed. The insulation resistance shall meet the requirements of 6.5.1.

6.3.2.2 Nitrogen pressure test

The thermometer shall be externally pressurized for approximately 30 s at a minimum pressure of 2.5 MPa in a nitrogen gas, after which the thermometer shall be immediately immersed in water or alcohol. There shall be no bubbling from the weld.

6.3.2.3 Liquid nitrogen test

The thermometer shall be immersed in liquid nitrogen until the temperature is stabilized, after which the thermometer shall be immediately immersed in water or alcohol. There shall be no bubbling from the weld.

The integrity of the sheath may also be tested by other suitable means. For particular applications, sheath integrity tests may be agreed between user and manufacturer.

This test is only recommended for thermometers that can be used at temperatures down to -196 °C.

6.3.3 Dimensional test

In the case for which the thermometer manufactured is covered by the scope of IEC 61152, the outside diameter and the straightness shall be tested to be in accordance with the requirements of the above-mentioned standard.

6.3.4 Tolerance acceptance test

The manufacturer has to assure that resistors of the appropriate tolerance class have been used. Thermometers of tolerance classes A and better (see 5.1 of this standard) shall be tested for resistance accuracy at one temperature in the range of –5 °C to +30 °C. Acceptance and rejection criteria are the same as described in 6.2.1 of this standard.

6.4 Type tests for resistors

6.4.1 Tolerances

The tolerance values for the specified tolerance class shall be met for the whole temperature range of validity. The number of necessary measurements for this test depends on the temperature range and the tolerance class and shall include temperatures close to the upper and lower limits of the declared temperature range.

6.4.2 Stability at upper temperature limit

The resistor shall be subjected to its declared upper temperature limit in air for 1 000 hours. The drift of the resistance value of the thermometer at 0 °C after the test shall not be more than the tolerance value of the declared tolerance class.

6.4.3 Self-heating

The self-heating coefficient expressed in °C/mW shall be evaluated at a temperature between 0 °C and 30 °C in flowing air with a velocity of (3 ± 0.3) m/s and/or in flowing water with a velocity >0.2 m/s. The self-heating under the above mentioned conditions shall not exceed 25 % of the tolerance value of the declared tolerance class at the declared maximum measuring current.

6.5 Type tests for thermometers

6.5.1 Insulation resistance at elevated temperatures

The insulation resistance shall be tested with the thermometer being at the rated maximum temperature over at least the minimum immersion depth and a test voltage minimum of 10 V d.c. The insulation resistance between each terminal and the sheath shall not be less than indicated in Table 4.

Table 4 – Minimum insulation resistance of thermometers at maximum temperature

Rated maximum temperature	Minimum insulation resistance
°C	MΩ

up to 250	20
251 to 450	2
451 to 650	0.5
651 to 850	0.2

6.5.2 Thermal response time

The thermal response time $\tau_{0.5}$ in flowing water with a velocity >0.2 m/s and/or in flowing air with a velocity (3 ± 0.3) m/s shall be recorded. If requested the response times $\tau_{0.9}$ and/or $\tau_{0.1}$ may also be recorded.

6.5.3 Stability at upper temperature limit

After a minimum of 4 weeks (672 h) continuously maintained at the specified upper temperature limit, the drift of the resistance value of the thermometer at 0 °C shall be not more than the tolerance value of the declared tolerance class. The insulation resistance shall not be less than specified in 6.5.1.

6.5.4 Thermoelectric effect

The thermometer shall be heated to the declared maximum temperature with the thermometer terminals close to the ambient temperature. The immersion depth of the thermometer shall be varied until the EMF is at its maximum. Set the direct measuring current to the maximum permissible value and obtain resistance readings with the normal and reversed polarity of the current. The temperature equivalent of the difference between the resistance of the thermometer measured with the normal and reversed polarity of the current shall not exceed the tolerance value of the declared tolerance class.

6.5.5 Effect of temperature cycling

The thermometer shall be brought carefully to the upper limit of its temperature range and then exposed to air at room temperature. It shall next be brought slowly to the lower limit of its temperature range and then exposed to air at room temperature. At each limit, the thermometer shall be immersed to at least its declared minimum immersion depth and shall be maintained at the temperature for sufficient time to reach equilibrium.

After 10 cycles between the upper and the lower temperature limits, the calibration at 0 °C shall not drift by more than the tolerance value at 0 °C for the respective tolerance class.

6.5.6 Effect of hysteresis

The resistance of the thermometer shall be measured in the middle of the temperature range after exposure to a temperature at the lower limit of the temperature range. Then the resistance should be measured again at the same temperature in the middle of the temperature range after exposure of the thermometer to a temperature at the upper limit of the temperature range. The difference between these two measurements shall not be larger than the calculated tolerance value at the test temperature for the respective tolerance class. It is important for both measurements that the thermometer goes directly from the ends of the temperature range to the temperature in the middle of range.

EXAMPLE: If the range of the thermometer is 0 °C to 400 °C, the thermometer shall go from 0 °C to 200 °C, then from 200 °C to 400 °C, and finally from 400 °C to 200 °C without cooling below 200 °C during this last step.

6.5.7 Self-heating

The self-heating coefficient expressed in °C/mW shall be evaluated at a temperature between 0 °C and 30 °C in flowing water with a velocity >0.2 m/s and/or in flowing air with a velocity of (3 ± 0.3) m/s. The self-heating under the above mentioned conditions shall not exceed 25 % of the tolerance value of the declared tolerance class at the declared maximum measuring current.

6.5.8 Minimum immersion depth

The thermometer shall be immersed into water with a temperature of at least 85 °C to the same depth as used for the tolerance acceptance test and with the thermometer terminals close to the ambient temperature. The thermometer shall then be extracted step by step out of the medium until the resistance changes by an amount which corresponds to a temperature change of 0.1 °C. This immersion depth shall be declared as minimum immersion depth.

6.6 Additional type tests for special applications of thermometers

For particular applications, special type tests may be agreed between user and manufacturer, for example:

6.6.1 Capacitance

The capacitance between one terminal and the sheath at a frequency of 1 kHz is to be reported.

6.6.2 Inductance

The inductance of each resistor circuit at a frequency of 1 kHz is to be reported.

6.6.3 Dielectric strength

A test voltage of 500 V a.c. shall be applied between one measuring circuit and the sheath of the thermometer for a duration of 1 min. During this time no breakdown shall occur. For thermometers with two or more measuring circuits, the same test shall be made between the individual circuits.

6.6.4 Vibration test

This test should be conducted if possible with the thermometer mounted in the same manner as that in which it is to be used. The thermometer shall be vibrated over the frequency range of 10 Hz to 500 Hz with a forcing acceleration of 20 m/s^2 to 30 m/s^2. The frequency range shall be swept at a rate of one octave per minute for a total period of 150 h. The vibrations shall be applied to the thermometer in axial and transverse directions each for one-half of the total period. The frequency and nature of any resonance shall be noted and limited to the first harmonic. The electrical continuity shall be monitored continuously.

At the conclusion of this test, the thermometer shall be tested to ensure the continued compliance with the insulation resistance requirements of 6.3.1. The thermometer shall also be tested to verify that the resistance at 0 °C shall not have changed by more than the equivalent of 0.1 °C.

6.6.5 Drop test

This test is intended to reveal any weakness of construction. The thermometer, complete with head, if any, shall be held with its longitudinal axis horizontal and then be dropped ten times from the height of 250 mm on to a 6 mm thick steel plate on a rigid floor. The thermometer shall be inspected for mechanical damage. It shall also be tested to ensure continued compliance with the insulation resistance requirements of 6.3.1 and the maintenance of electrical continuity.

6.7 Summary of tests

The tests described in this international standard are summarized in Table 5, with reference to the clause where details of the test are given.

Table 5 – Table of tests described in this standard

	Routine production tests		Type tests		Additional type tests
	Resistors	Thermometers	Resistors	Thermometers	
Resistance tolerance	6.2.1	6.3.4	6.4.1	6.3.4	
Insulation resistance at ambient temperature		6.3.1		6.3.1	
Sheath integrity test		6.3.2		6.3.2	
Dimensional test		6.3.3		6.3.3	
Stability at upper temperature limit			6.4.2	6.5.3	
Thermoelectric effect				6.5.4	
Self-heating			6.4.3	6.5.7	
Insulation resistance at elevated temperatures				6.5.1	
Thermal response time				6.5.2	
Effect of temperature cycling				6.5.5	
Hysteresis				6.5.6	
Minimum immersion depth				6.5.8	
Capacitance					6.6.1
Inductance					6.6.2
Dielectric strength					6.6.3
Vibration test					6.6.4
Drop test					6.6.5

7 Information to be made available by the manufacturer

7.1 For resistors only

Leads of resistors:

- length of the leads;
- linear resistance in Ω/mm;
- temperature coefficient of resistance;
- material.

7.2 For resistors and/or thermometers

- results of all specified type tests;
- temperature sensitive length and position of resistor;
- ohmic resistance of internal connection wires and their temperature coefficient shall be available for 2-wire configurations, where the resistance of internal connection wires is equal to or greater than the tolerance value at the maximum rated temperature in the respective tolerance class.

8 Thermometer identification and marking

Each thermometer shall be marked or labelled so that the user may determine either directly or indirectly the number of resistors, nominal resistance, tolerance class, connecting wire configuration and temperature limits.

Example:

$1 \times$ Pt 100 / A / 4 / –150 / +500

meaning:

- one resistor;
- nominal resistance: R_0 = 100 Ω;
- tolerance class A (range of validity: –100 °C to 450 °C);
- four-wire connection;
- lower temperature limit of the thermometer: –150 °C;
- upper temperature limit of the thermometer: +500 °C.

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