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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Industrial platinum resistance thermometers and platinum temperature sensors

Thermomètres à résistance de platine industriels et capteurs thermométriques en platine

IEC 60751:2008

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INDUSTRIAL PLATINUM RESISTANCE THERMOMETERS AND PLATINUM TEMPERATURE SENSORS

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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.

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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

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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

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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;

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– 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.

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

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.

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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

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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

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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] °C
Tolerance class	Temperature range of validity °C	Tolerance class	Temperature range of validity °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] °C
	Wire wound resistors	Film resistors	
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

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