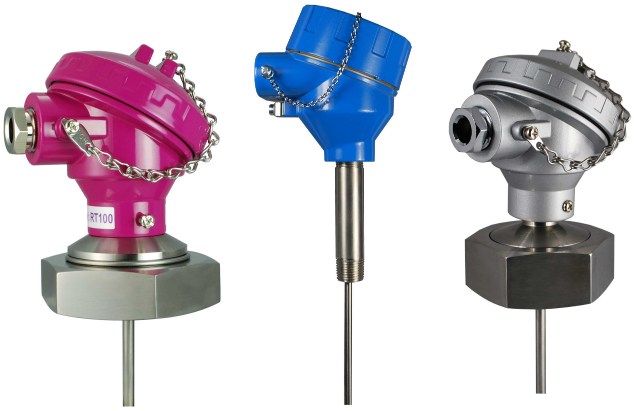
GENERAL INFORMATION ABOUT RESISTANCE THERMOMETERS



WORKING PRINCIPLE

The working principle for metal resistance thermometers, normally called thermo resistances, is based on the variation of the electrical resistance of a metal with variations in the surrounding temperature. In the industrial field the materials most frequently used are platinum and nickel which, due to their high resistivity and stability, permit the production of thermo elements which are highly reproducible, small and with excellent dynamic characteristics. The temperature measurements carried out with thermo resistances are far more precise and reliable than those carried out with other types of sensor such as thermocouples. Normally resistance thermometers are identified with the code of the material used to construct them (platinum = Pt, nickel = Ni etc.) followed by their nominal resistance at a temperature of 0°C. The range of use for industrial resistance thermometers is between -200 and +850°C.

PLATINUM (Pt) RESISTANCE THERMOMETERS

PCI platinum resistance thermometers comply with the international standard IEC 751; sensitive elements which conform to other standards, for example JIS C 1604 etc., may be supplied on request. According to standard IEC 751 the platinum used for the manufacture of resistance thermometers should have a temperature coefficient of alpha = 3,85x10-3 Standard IEC 751 allows for thermo resistances with a nominal value at 0 °C (Ro) of between 5 and 1000 ohm; however, the values most commonly used are 100 ohm, 500 ohm and 1000 ohm. The equation linking resistance at temperature t° (Rt) and resistance at 0° (Ro) is a follows:

in the range -200°C / 0 °C

$$Rt = Ro\,[\,1+At+Bt^2+C\,(\,t-100\,)\,t^3\,]$$

in the range 0 °C / 850 °C

$$Rt = Ro\,(\,1+At+Bt^2\,)$$

Where the coefficients A, B and C have the following values:

$A = 3{,}9083 \times 10^{-3}$

$B = -5{,}775 \times 10^{-7}$

$C = -4{,}183 \times 10^{-12}$

The classes of precision for platinum resistance thermometers refer to temperature and are standardized as follows:

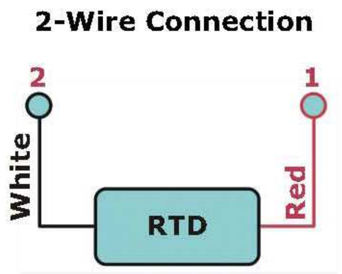
Class A = 0,15+0,002 | t | (°C)
Class B = 0,3+0,005 | t | (°C)

Class A covers up to a maximum temperature of 650°C and thermometers connected to three or four wires. It is, however, possible to have more precise thermo resistances which are classified as a fraction of class B, for example class 1/3B equals 1/3 (0.3+0.005 | t |).

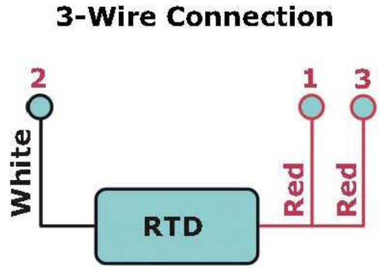
RESISTANCE THERMOMETER TYPES

There are different methods for connecting the resistance thermometers to the measuring devices; the choice of one method rather than another basically depends on the precision required in the measurement

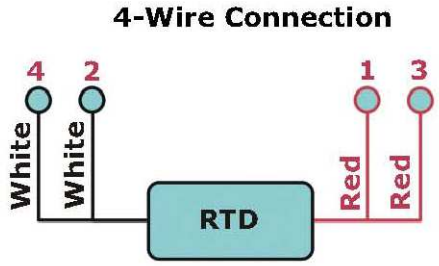
Resistances thermometers connection techniques



- The two-wire technique is the least precise and is used only in cases where the connection of the thermo resistance is carried out with short and low resistivity wires; indeed testing the equivalent electrical circuit, it can be noted that the electrical resistance measured is the sum of that of the sensitive element (and, therefore, dependent on the temperature being measured) and the resistance of the leads used for the connection. The error introduced with this type of measurement is not constant: it depends on temperature. Resistance = (1 + 2 + RTD)



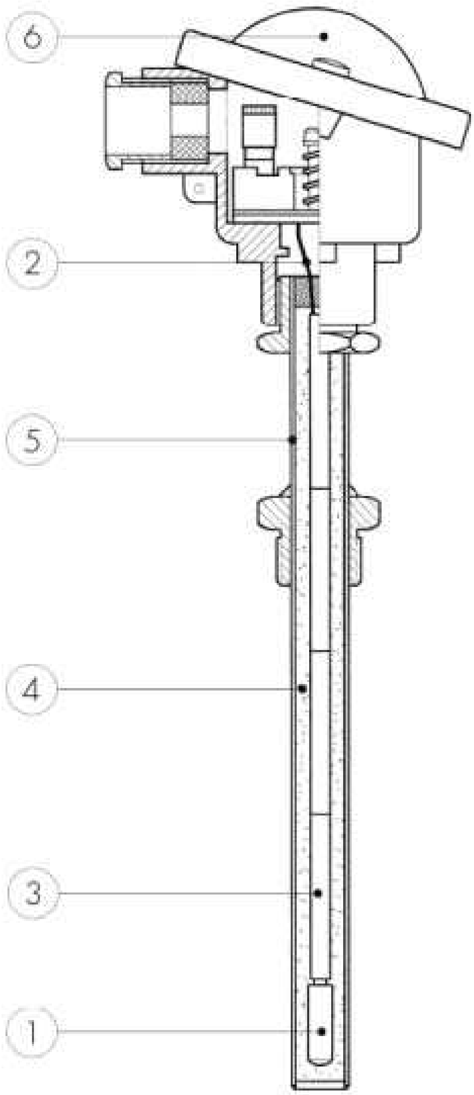
- Due to the good degree of precision obtainable in measurements, the three-wire technique is the most used in the industrial field. With this measurement technique the errors caused by the resistance of the leads used for the connection of the thermo resistance are mostly eliminated. Lead wire 3 acts as a sense lead and is part of both halves of the bridge and therefore Resistance = (1 - 2 + RTD). Therefore now the lead wire error is no longer part of the total resistance (1 + 2), but only the difference (up to 10%) between their resistances (1 - 2).



- The technique of four wires is little used in the industrial field, it is almost exclusively used in laboratory applications.

TRADITIONAL INSULATION THERMORESISTANCES

Traditional insulation thermo resistances comprise:



1. Sensitive element

The sensitive element is the most important part of the thermo resistance, a poor quality sensitive element would jeopardize the correct functioning of the entire sensor. Once connected with the connection wires, it is placed inside the protective sheath. Sensitive elements with different degrees of precision and with double winding are available.

2. Connection wires

The connection of the sensitive element can be carried out using 2, 3 or 4 wires; the wire material depends on the conditions of use of the probe.

3. Ceramic insulators

Ceramic insulators prevent short circuits and insulate the connection wires from the protective sheath.

4. Filler

The filler is composed of extremely fine alumina powder, dried and vibrated, which fills any gaps so as to protect the sensor from vibrations.

5. Protective sheath

The protective sheath protects the sensitive element and the connection wires. Since it is in direct contact with the process it is important that it is made of the right material and has the right dimensions. In certain conditions it is advisable to cover the sheath with additional casing (thermowell).

6. Connection head

The connection head contains the terminal board made of insulating material (normally ceramic) which permits the electrical connection of the thermo resistance. Depending on the conditions of use explosion proof casing may be used. A 4-20mA converter can be installed instead of the terminal board

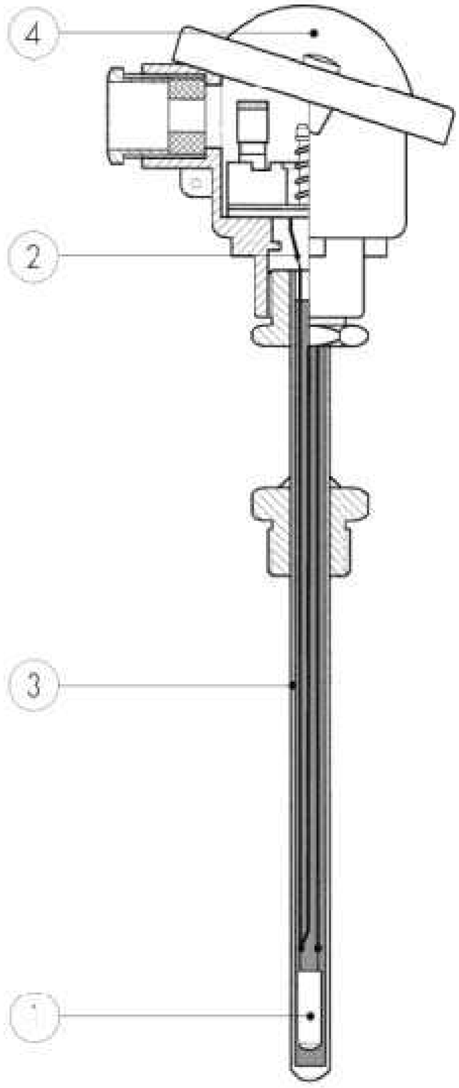
CONSTRUCTION OF RESISTANCE THERMOMETERS

There are two construction types of thermo resistances: with traditional insulation or mineral Mao insulation. The following table shows the main characteristics of the two types:

	Response speed	Electrical insulation	Vibration resistance	Pressure resistance
Traditional insulation	Good	Excellent	Good	Good
Mineral (Mao) insulation	Excellent	Good	Excellent	Excellent

MINERAL MgO INSULATION THERMORESISTANCES

This particular construction type permits the manufacture of high performance thermo resistances with excellent mechanical characteristics. The main characteristics which differentiate this type of construction from the traditional type, in addition to those already described, are: the possibility of bending the sheath with a sharp bending radius, the possibility of soldering the sheath upon installation and the possibility of creating very long probes.



1. Sensitive element

With the use of particular techniques, the sensitive element is connected to the conductors of the cable insulated in mineral oxide. To meet different requirements, it is possible to use double sensitive elements or elements with different degrees of precision.

2. Connection wires

The sensitive element can be connected using 2, 3 or 4 wires.

3. Mineral insulation sheath

This comprises an external metal sheath with the conductors insulated inside from one another and the sheath using extremely pure and highly compressed metal oxides; the standard insulator is magnesium oxide (MgO).

4. Connection head

The connection head contains the terminal board made of insulating material (normally ceramic) which permits the electrical connection of the thermo resistance. Depending on the conditions of use explosion proof casing may be used. A 4-20mA converter can be installed instead of the terminal board.

MAIN CAUSES OF ERRORS IN MEASUREMENTS WITH RESISTANNCE THERMOMETERS

Measuring temperature with thermo resistances is quite simple to carry out compared to that using other types of sensors, however certain steps should be taken to remedy any measurement errors. There are three main causes of errors introduced into temperature measurements with thermo resistances: - Error due to the self heating of the sensing element - Error due to the poor electrical insulation of the sensitive element - Error due to the sensitive element not being immersed at sufficient depth.

The sensitive element heats up by itself during measuring when it is crossed by a current which is too high which, due to the Joule effect, increases the temperature of the element. The increase in temperature depends both on the type of sensitive element used and the measuring conditions. At the same temperature, the same thermo resistance will heat up by itself less if placed in water rather than air; this is due to the fact that water has a higher dispersion coefficient than air. Normally all measuring devices which use thermo resistances as sensors have an extremely low measuring current, however it is advisable never to exceed a measuring current of 1 mA (IEC 751).

For the correct measurement with thermo resistances it is very important that the electrical insulation between the conductors and the external sheath is sufficiently great, particularly at high temperatures. The insulation resistance may be seen as an electrical resistance positioned parallel to those of the sensitive element. It is, therefore, at a constant temperature, should the electrical insulation diminish, the voltage measured across the sensitive element will also diminish thus introducing an error into the measurement. Insulation resistance can fall when the probe is used at temperatures which are too high, when there are strong vibrations or because of the influence of physical or chemical agents.

The immersion depth of the sensitive element is also extremely important for correct measurements; unlike in thermocouples where measurements can be considered punctiform, if the depth is not sufficient it can cause errors in the measurement of as much as several degrees °C. This is due to the fact that the sheath, usually metallic, with which the sensitive element is protected, disperses heat in proportion to the difference in temperature between the hot and cold areas; we, therefore, have a thermal gradient along part of the sheath's length. The immersion depth must, therefore, be sufficient so that the sensitive element inside the sheath is not subjected to this thermal gradient. The minimum depth will depend on the physical measuring conditions and the dimensions of the thermo resistance (length of the element etc.).

REFERENCE TABLES

RES. THERMOMETER TYPE Ni100 ohm 0°C ACCORDING TO DIN 43760 (IPTS 68)

°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	°C
					Ohm - Ohm						
0	100,0	94,6	89,3	84,2	79,1	74,3	69,5				**0**
°C	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**-60**	**-70**	**-80**	**-90**	**°C**
°C	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**°C**
					Ohm - Ohm						
0	100,0	105,6	111,2	117,1	123,0	129,1	135,3	141,7	148,3	154,9	**0**
100	161,8	168,8	176,0	183,3	190,9	198,7	206,6	214,8	223,2		**100**
°C	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**°C**

Reference junction at 0°C

RES. THERMOMETER TYPE Pt100 ohm 0°C ACCORDING TO IEC 751 (ITS 90)

°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	°C
					Ohm - Ohm						
-200	18,49	14,45	10,49	6,99	4,26	2,51					**-200**
-100	60,26	56,19	52,11	48,00	43,88	39,72	35,54	31,34	27,10	22,83	**-100**
0	100,00	96,09	92,16	88,22	84,27	80,31	76,33	72,33	68,33	64,30	**0**
°C	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**-60**	**-70**	**-80**	**-90**	**°C**
°C	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**°C**
					Ohm - Ohm						
0	100,00	103,90	107,79	111,67	115,54	119,40	123,24	127,08	130,90	134,71	**0**
100	138,51	142,29	146,07	149,83	153,58	157,33	161,05	164,77	168,48	172,17	**100**
200	175,86	179,53	183,19	186,84	190,47	194,10	197,71	201,31	204,90	208,48	**200**
300	212,05	215,61	219,15	222,68	226,21	229,72	233,21	236,70	240,18	243,64	**300**
400	247,09	250,53	253,96	257,38	260,78	264,18	267,56	270,93	274,29	277,64	**400**
500	280,98	284,30	287,62	290,92	294,21	297,49	300,75	304,01	307,25	310,49	**500**
600	313,71	316,92	320,12	323,30	326,48	329,64	332,79	335,93	339,06	342,18	**600**
700	345,28	348,38	351,46	354,53	357,59	360,64	363,67	366,70	369,71	372,71	**700**
800	375,70	378,68	381,65	384,60	387,55	390,48					**800**
°C	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**°C**

STANDARD TOLERANCES FOR THERMORESISTANCES

<table>
<tr><th>Temp. °C</th><th colspan="2">Class B Class B 0,30+0,005*| t | (°C)</th><th colspan="2">>Class A Class A 0,15+0,002*| t | (°C)</th><th colspan="2">>Class 1/3B Class 1/3B 1/3*(Class B) (°C)</th><th colspan="2">>Class 1/10B Class 1/10B 1/10*(Class B) (°C)</th></tr>
<tr><td></td><td>>Ohm</td><td>>°C</td><td>>Ohm</td><td>>°C</td><td>>Ohm</td><td>>°C</td><td>>Ohm</td><td>>°C</td></tr>
<tr><td>>-200</td><td>±0,56</td><td>±1,30</td><td>±0,24</td><td>±0,55</td><td>±0,19</td><td>±0,43</td><td>±0,06</td><td>±0, 13</td></tr>
<tr><td>>-100</td><td>±0,32</td><td>±0,80</td><td>±0,14</td><td>±0,35</td><td>±0,11</td><td>±0,27</td><td>±0,03</td><td>±0, 08</td></tr>
<tr><td>>0</td><td>±0,12</td><td>±0,30</td><td>±0,06</td><td>±0,15</td><td>±0,04</td><td>±0,10</td><td>±0,01</td><td>±0, 03</td></tr>
<tr><td>>100</td><td>±0,30</td><td>±0,80</td><td>±0,13</td><td>±0,35</td><td>±0,10</td><td>±0,27</td><td>±0,03</td><td>±0, 08</td></tr>
<tr><td>>200</td><td>±0,48</td><td>±1,30</td><td>±0,20</td><td>±0,55</td><td>±0,16</td><td>±0,43</td><td>±0,05</td><td>±0, 13</td></tr>
<tr><td>>300</td><td>±0,64</td><td>±1,80</td><td>±0,27</td><td>±0,75</td><td>±0,21</td><td>±0,60</td><td>±0,06</td><td>±0, 18</td></tr>
<tr><td>>400</td><td>±0,79</td><td>±2,30</td><td>±0,33</td><td>±0,95</td><td>±0,26</td><td>±0,77</td><td>±0,08</td><td>±0, 23</td></tr>
<tr><td>>500</td><td>±0,93</td><td>±2,80</td><td>±0,38</td><td>±1,15</td><td>±0,31</td><td>±0,93</td><td>±0,09</td><td>±0, 28</td></tr>
<tr><td>>600</td><td>±1,06</td><td>±3,30</td><td>±0,43</td><td>±1,25</td><td></td><td></td><td></td><td></td></tr>
<tr><td>>650</td><td>±1,13</td><td>±3,55</td><td>±0,46</td><td>±1,45</td><td></td><td></td><td></td><td></td></tr>
<tr><td>>700</td><td>±1,17</td><td>±3,80</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>>800</td><td>±1,28</td><td>±4,30</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>>850</td><td>±1,34</td><td>±4,60</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

t = Temperature (°C)

<table>
<tr><th>>Temp. °C</th><th>>0,4+0,07*| t | (°C) 0 °C<t<180 °C</th><th>0,4+0,028*| t | (°C) -60 °C<t<0 °C</th></tr>
<tr><td></td><td>>Ohm</td><td>>°C</td></tr>
<tr><td>>-60</td><td>±1,00</td><td>±2,10</td></tr>
<tr><td>>0</td><td>±0,20</td><td>±0,40</td></tr>
<tr><td>>100</td><td>±0,80</td><td>±1,10</td></tr>
<tr><td>>180</td><td>±1,30</td><td>±1,70</td></tr>
</table>

t = Temperature (°C)