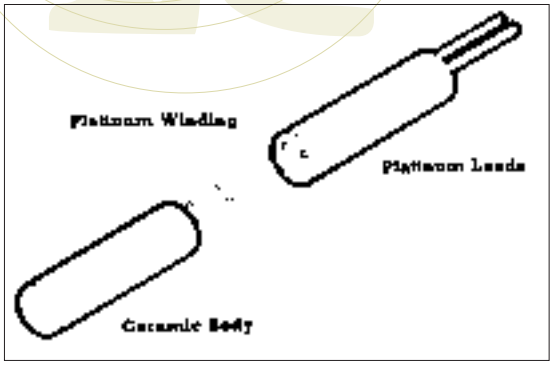
section 12

platinum resistance temperature detectors



The sophistication of modern process control and monitoring equipment, for industrial and laboratory usage, requires a temperature measurement capability having the highest repeatability and stability.

For precise temperature measurement the Platinum Resistance Thermometer (P.R.T.) offers the best overall advantage of any device and the ceramic bodied wire-wound platinum resistance temperature detector (R.T.D.) has the highest performance, when compared against “film” and “glassed” types of detectors.

Detectors supplied by **Sensing Devices** are of the wire-wound type, in which the platinum winding is partially supported by a high temperature glass adhesive, inside a ceramic tube. This construction provides a detector in which stability, repeatability and accuracy are of the highest available for most industrial and scientific applications.

By concentrating on this detector type, **Sensing Devices** has been able to offer the largest possible selection of sizes to suit all types of requirements. Also, the unique company organisation allows standard and special detector designs to be delivered with an unrivalled service.

It is possible that we have in stock the detectors you need.

This brochure details only the most popular detector, i.e. PT100 Series. For other detectors as mentioned, please enquire.

To cover the manufacture of P.R.T. detectors certain national and international standards exist.

The three best known are:-

British BS1904: 1964

German DIN43760: 1968

American RC21-4: 1966

Of these three standards, BS1904 is the most demanding. Sensors complying with BS1904 will also satisfy DIN43760 and RC21-4.

Basically the three standards are equivalent one to the other.

Within this section reference will be made frequently to BS1904 for which the Pt100 range is basically applicable.

platinum resistance – temperature detectors

THE INTERNATIONAL PRACTICAL TEMPERATURE SCALE

The IPTS-68 is based on the assigned values of the temperatures of a number of reproducible equilibrium states (defining fixed points) and standard instruments calibrated at these temperatures. The standard instrument used from 13.81K to 630.74˚C is the Platinum Resistance Thermometer. This was chosen because of its extremely high standards of reproducibility of measurement.

The unit of the fundamental physical quantity known as thermodynamic temperature, symbol *T*, is the kelvin, symbol K, defined as the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

For historical reasons, related to the way temperature scales were originally defined, it is common practice to express a temperature in terms of its difference from that of a thermal state 0.01 kelvins lower than the triple point of water. A thermodynamic temperature, *T*, expressed in this way is known as a Celsius temperature, symbol *t*, defined by $t = T - 273.15K$.

The unit of Celsius temperature is the degree Celsius, symbol ˚C, which by definition, is equal in magnitude to the kelvin. A difference of temperature may be expressed in kelvins or degrees Celsius.

The International Practical Temperature Scale of 1968 (IPTS-68) has been constituted in such a way that any temperature measured on it is a close approximation to the numerically corresponding thermodynamic temperature. Moreover, such measurements are easily made and are highly reproducible; in contrast, direct measurements of thermodynamic temperatures are both difficult to make and imprecise. The IPTS-68 uses both International Practical Kelvin Temperatures, symbol T_{68}, and International Practical Celsius Temperatures, symbol t_{68}. The relation between T_{68} and t_{68} is the same as that between *T* and *t*, for example: $t_{68} = T_{68} - 273.15K$

The units T_{68} and t_{68} are the kelvin, symbol K and the degree Celsius, symbol ˚C; that is; the names of the units are the same as those used for the thermodynamic temperature *T* and *T*.

All temperatures referred to in this section relate to IPTS-68.

Where more detailed information about IPTS-68 is required, it is recommended that a study be made of "The International Practical Temperature Scale of 1968".

TEMPERATURE/RESISTANCE RELATIONSHIP

This section details the most commonly used detector specification in general use throughout Europe, USA and many other parts of the world.

Pt100

The Temperature/Resistance Relationship for platinum resistance thermometers can be obtained from the Callendar-van Dusen equation.

For the range -200˚C to 0˚C:

$R_t = R_o \{ 1 + At + Bt^2 + Ct^3 (t - 100)\}$ ..... (1)

For the range 0˚C to 630˚C:

$R_t = R_o \{1 + At' + Bt'^2\}$ ..... (2)

The constants A, B and C are determined by the properties of the platinum wire used in the construction. Platinum is specially selected to give nominal values of the constants below. The nominal values for Alpha, Delta and Beta are also listed.

DETECTOR CONSTANTS	Pt100
A	3,908 02
B	-5,801 95
C	-4,273 50
Alpha	3,850
Delta	1,50700
Beta	0,111

The constants A, B and C can be written:

$A = \text{Alpha} \{1 + \frac{\text{Delta}}{100_1}\}$ ˚C⁻ –

$B = \text{Alpha} \times \text{Delta} \times 10^{-4}$ ˚C^{-2}

$C = \text{Alpha} \times \text{Beta} \times 10^{-8}$ ˚C^{-4}

Alpha (α) is the temperature coefficient of resistance (obtained by measurement of the detector resistance R_o at ˚C and R_{100} at 100˚C) and is defined as:

$$\text{Alpha} = \frac{R_{100} - R_O}{100 \times R_O}$$

Delta (δ) is obtained by calibration at a high temperature, for example, at the Freezing Point of Zinc (419.58˚C)

Beta (β) is obtained by calibration at a negative temperature.

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Using Alpha, Delta and Beta and Callendar-van Dusen equation can alternatively be written:

$R_t = R_o \{1 + [t - (\ ^t\ )(\ ^t\ -1) - (\ t\ )^3 (\ t\ -1)]\}$

The temperature/resistance scale obtained by using the Callendar-van Dusen equation provides a resistance value as a function of temperature *t'*. In order to equate this temperature to the values defined by the International Practical Temperature Scale – 1968 (IPTS-68) a correction procedure is designated in order that the scale conforms exactly with International Practical Celsius Temperatures, displayed as t_{68}. For temperatures from 0°C to 630°C, Figure 1 illustrates the approximate correction necessary. For temperatures below 0°C the correction procedure is much more complex and reference should be made to "International Practical Temperature Scale of 1968" for further details.

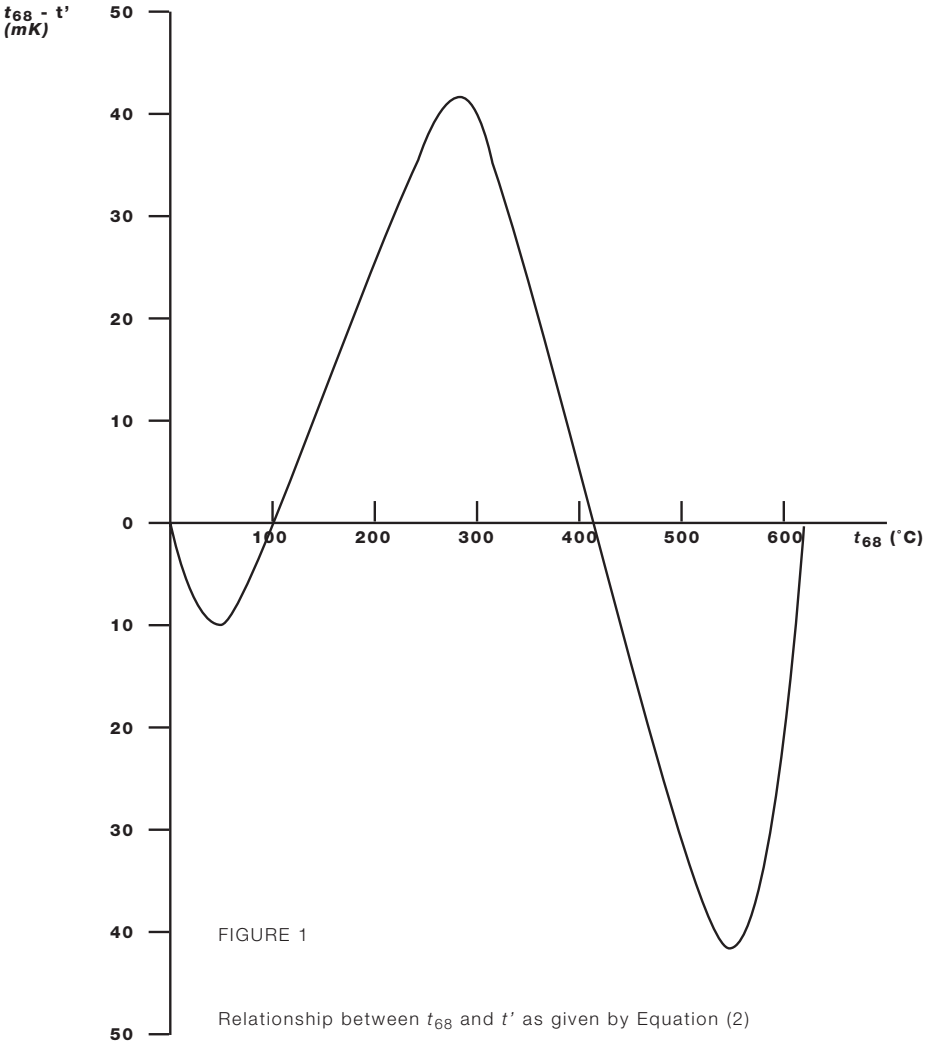

FIGURE 1

Relationship between t_{68} and *t'* as given by Equation (2)

platinum resistance – temperature detectors

The temperature *t'* is obtained from Equation (2) and t_{68} is derived from it by using the correction shown in Figure 1.

In order to provide a more practical approach for users of platinum thermometers, tables of temperature against resistance values are listed in 1˚C steps. A reduced table is shown on page 12-7. The full table can be provided on request.

DETECTOR TOLERANCE AND ACCURACY

The two most important factors affecting detector tolerance are deviation from the nominal resistance value at 0˚C and variation in the temperature coefficient (Alpha) of the platinum wire. The first factor, deviation from R_o, is a direct result of the manufacturing method and a tolerance of±0,01% is readily achievable. In the case of Alpha variation, the wire manufacturer dictates to a larger extent the final values obtained. However, manufacturing processes do cause changes in the metal and it is essential to have complete control of every stage of production in order to guarantee minimum deviation from specification.

Detectors supplied by **Sensing Devices** have close control of manufacturing techniques and critical selection of materials resulting in typical Alpha deviation of less than ±0.000003˚C^{-1}. This ensures the very highest conformance to the temperature/resistance characteristics thus giving full confidence in detector interchangeability and allowing critical measurements, such as determination of small temperature differentials, to be made with accuracy, stability and repeatability.

The most typical tolerance band for industrial usage, specifically chosen by **Sensing Devices** as their standard, is ±0.1% of resistance at 0˚C (R_o). However, closer tolerance detectors are available in quantity in the following tolerance bands.

BAND	TOLERANCE (% of R_o)
1	0.1 (Standard)
2	0.05
3	0.03
4	0.02
5	0.01

Again with regard Pt100 range detectors are available in tolerance **Bands 1 to 5** and in tolerance grades **Class A** and **Class B** of specifications **DIN 43760 – 1980, BS 1904: 1984** and **IEC 751: 1983.**

However, it should be appreciated that originally DIN 43760 and BS 1904: 1964 specified a tolerance at 0˚C of 100 ±0.1 ohms and it is still widely accepted that 1/2, 1/3 1/5 and 1/10 DIN refer to these respective fractions of 0.1 ohms. In 1979 DIN 43760 was revised and the current DIN 43760 – 1980 now has tolerance bands of ±0.12 ohms (Class B) and ±0.06 ohms (Class A). The current situation in Europe is that specifications BS 1904: 1984, DIN 43760: 1980 and IEC 751: 1983 now completely conform on all tolerance values and characteristics.

For 100 ohm detectors the tolerance values at any temperature (*t*˚C) for these specifications are given by:

±0.3 + (0.005 x *t*)˚C for Class B

± 0.15 + (0.002 x *t*)˚C for Class A

These tolerance values include deviations in R_o and Alpha, but when using these allowed deviations the values for Alpha can vary from 0.003837 to 0.003863 for Class B and from 0.003845 to 0.003855 for Class A detectors.

OTHER DETECTOR RANGES MANUFACTURED BY S.D.L.:

In addition to Pt100, **Sensing Devices** currently manufacture a range of detectors with characteristics not detailed in this section. Some types are:

1. 100 ohm at 0˚C; Alpha = .003916˚C^{-1}.
   D 100 series, JIS C 1604.
2. 130 ohm at 0˚C; Alpha = .003900˚C^{-1}.
   F 130 series BS 2G. 148
3. 10 ohm platinum at 25˚C.
4. 10 ohm platinum at 20˚C.
5. 100 ohm at 0˚C; Alpha = .003900˚C^{-1} (F100)
6. 100 ohm at 0°C; Alpha = .003923°C^{-1}.
7. SAMA 100 ohm nominal; R_o = 98.129 ohms
8. SAMA 10 ohm platinum at 0˚C

We would be pleased to quote for supplying any size of detector with other characteristics.

One special detector manufactured is R 25.5/50P which is specially designed for inclusion into Precision Temperature Standards for calibration purposes. The resistance at 0˚C is 25.5 ohms and the minimum Alpha value is .003925˚C^{-1}. Full technical information will gladly be forwarded on request.

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TEMPERATURE RANGE

The **Sensing Devices** range of temperature detectors are designed for use over the temperature span from -200˚C to + 800˚C. However, to avoid contamination special care should be taken when using detectors above 300˚C, particularly when using metal sheaths.

CALIBRATION

For all detectors the calibration point is 5mm from the ceramic body and at the customer's request (with extra cost) detectors can be supplied with calibration values at 0˚C and 100˚C, or at other temperatures.

Normally two leads, of platinum or platinum group metals, exit from the ceramic body (four leads for duplex units) and have a standard length of 10mm. Longer lead lengths are available to special order.

Lead resistance values are:

Detector Diameter mm	Lead Diameter mm	Lead Resistance ohms/mm/lead
2.4 to 5.0	0.45	0.0007
1.6	0.27	0.0019
1.2	0.25	0.0023
0.9	0.15	0.0063

STABILITY

Sensing Devices detectors are automatically aged as part of the manufacturing process, thus ensuring the highest levels of stability. Detectors operated over the range -50˚C to +450˚C will have stability levels not attainable by any other type of detectors. Typically the resistance at 0˚C will not change by more than 0.04% after 10 consecutive shocks from -200˚C to + 600˚C.

SELF HEATING

When tested in a well stirred ice bath, the rise in temperature will not exceed 0.3˚C, with 10 milliwatts dissipated in the detector.

THERMAL RESPONSE TIME

The following values are given for general guidance only, for 50% and 90% response to a step change or 10˚C from an ambient temperature, in water flowing 0.4 metres/second.

Detector Diameter mm	Response Time in Seconds	
	50%	90%
3.0 & 3.2	0.6	2.2
2.4 & 2.8	0.35	1.8
1.6	0.3	1.6
1.2	0.25	1.3
0.9	0.15	0.7

VIBRATION

When properly supported detectors will withstand a vibration level of 30g over the frequency range of 10Hz to 1kHz.

PRESSURE

The construction of **Sensing Devices** ceramic bodied detectors ensures that they are insensitive to large changes of pressure. However, it should be realised that since **the detectors are not hermetically sealed,** they should be protected from contamination by liquids or gases by the use of suitable protection sheaths.

IMMERSION DEPTH

Depth of immersion is recommended to be three times the sensing length; under these conditions the requirements of BS1904; 1964 will generally be met.

INSULATION RESISTANCE

At 240 V DC and at ambient temperature the insulation resistance between leads and sheath is greater than 10 Megohms.

THERMOELECTRIC EFFECT

When tested in accordance with Section 3.18 of BS1904: 1964 any thermoelectric potentials present will not cause the measurement to shift outside the application tolerance band.

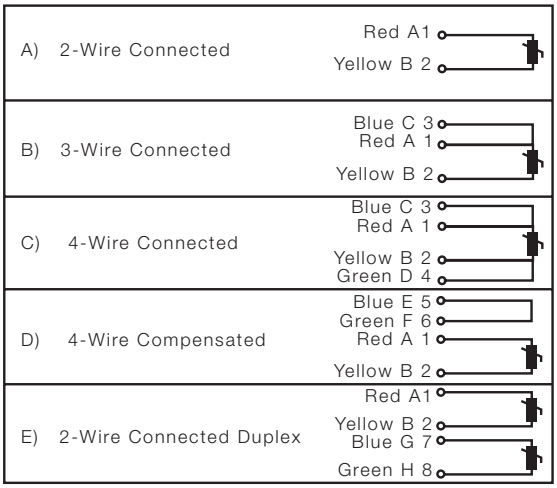
LIMITING TEMPERATURES

When subjected to the upper and lower limits of the temperature range for a total period of 250 hours at each temperature, the insulation resistance shall not have fallen below that required by Section 2.6 and the resistance accuracy shall be within the tolerance specified at 0°C.

MAXIMUM CURRENT

Typical values of currents recommended for sensors for minimal self heating are between 1 and 5mA.

CONNECTION METHOD & SDL COLOUR CODE



Other colour codes may sometimes have to be adopted dependent on the availability of material.

INDUSTRIAL RESISTANCE THERMOMETER TO BS 1904 TABLE 1
1970 REVISION
-200˚C TO 629˚C 10˚C INCREMENTS

t_{68}(˚C)	-0	-10	-20	-30	-40	-50	-60	-70	-80	-90
	Resistance – Ohm									
-200	18.49									
-100	60.25	56.19	52.11	48.00	43.87	39.71	35.53	31.32	27.08	22.80
- 0	100.0	96.09	92.16	88.22	84.27	80.31	76.33	72.33	68.33	64.30
	+0	**+10**	**+20**	**+30**	**+40**	**+50**	**+60**	**+70**	**+80**	**+90**
	Resistance – Ohm									
+ 0	100.0	103.90	107.79	111.67	115.54	119.40	124.24	127.07	130.89	134.70
100	138.50	142.29	146.06	149.82	153.58	157.31	161.04	164.76	168.46	172.16
200	175.84	179.51	183.17	186.82	190.45	194.07	197.69	201.29	204.88	208.45
300	212.02	215.57	219.12	222.65	226.17	229.67	233.17	236.65	240.13	243.59
400	247.04	250.48	253.90	257.32	260.72	264.11	267.49	270.86	274.22	277.56
500	280.90	284.22	287.53	290.83	294.11	297.39	300.65	303.91	307.15	310.38
600	313.59	316.80								