ISOTECH

Whitepaper

Careful consideration should be given to the measuring current in order to minimise the self-heating effect

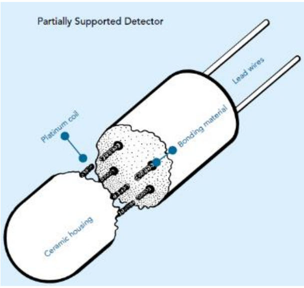
- 0.5mA or 1 mA for 100 Ohm thermometers
- 1mA for 25 Ohm thermometers
- 5mA to 10mA for 0.25 Ohm thermometers

Platinum Resistance Thermometer: Self Heating

Construction

Conventional platinum resistance thermometers have a sensing element situated at the tip of the thermometer sheath.

The body of these sensing elements is ceramic and can vary in length and diameter depending upon the application.



Within the sensing element is a coil(s) of fine platinum wire that are either partially or fully supported within the body of the sensing element. This support prevents the individual coils from shorting together during heating/cooling – expansion/contraction.

These types of sensing elements are referred to as ‘wire wound’.

How to measure resistance?

During normal use a platinum resistance thermometer would be connected to some form of temperature measurement device.

The device passes a known current, I through the sensing element of the thermometer and a Voltage, V is developed across the sensing element which is measured. Then using ohms law the resistance R, would be calculated.

$$V = IR$$

transposing,

$$R = V/I$$

This is done automatically by most temperature measurement devices.

What is self-heating?

When a current is passed through a resistive element (in the same way as an electrical heater) Power, P is generated and is dissipated as heat;

$$P = I^2R$$

This heat due to the current from the measuring device is known as Self Heating.

The self-heating effect is in addition to the temperature of the thermometers environment it is trying to measure.

where,
t_E is the temperature of the thermometer due to the environment being measured
Δt_{SH} is the additional temperature increase of the thermometer due to the self-heating effect

This can be re-written in terms of resistances.

The measured resistance from the thermometer, R_t;

$$R_t = R_E + \Delta R_{SH}$$

where,
R_E is the resistance of the thermometer due to the environment being measured
Δt_{SH} is the additional resistance increase of the thermometer due to the self-heating effect

How to measure the self-heating effect of a platinum resistance thermometer (ΔR_{SH})?

Problem: It is impossible to make measurements with platinum resistance thermometers without passing a current through, therefore the self-heating effect is always present. From a single measurement it is impossible to differentiate what proportion of the measurement is attributable to self-heating and what proportion is attributable to the actual environment the thermometer is trying to measure.

Solution: To make two measurements;
one with the normal measuring current
one with a current that either halves or doubles the power

From this the self-heating effect (ΔR_{SH}) can be calculated along with the zero-power resistance (i.e. resistance with no self-heating effect).

From earlier it can be seen that the power dissipated as heat in the sensing element during a measurement is described by,

$$P = I^2R$$

To halve the power the current can be changed to a value of: $I \times 1/\sqrt{2}$ or ($I \times 0.7071$)
To double the power the current can be changed to a value of: $I \times \sqrt{2}$ or ($I \times 1.4142$)

If we take the resistances measured at each of these currents as;

normal power	R_{P1}
half power	$R_{P0.5}$
double power	R_{P2}

Then to calculate the self-heating effect ΔR_{SH}, one of the following can be used;

$$\Delta R_{SH} = R_{P2} - R_{P1}$$

or

$$\Delta R_{SH} = R_{P1} - (R_{P0.5} \times 2)$$

From this, the zero-power resistance, R_{ZP} can be calculated;

$$R_{ZP} = R_{P1} - \Delta R_{SH}$$

Note: Precision instruments such as the microK and milliK can make self-heating measurements automatically.

The magnitude of self-heating of a thermometer is dependent on a number of factors;

- the size of the current passed through the sensing element
- the nominal resistance of the sensing element
- the construction of the thermometer
- the thermal contact the thermometer has with the environment it is measuring

In order to make sensible temperature measurements all of these must be considered.

With industrial thermometers measuring air temperatures the self-heating effect can be significant, tenths of a degree or larger and even with SPRTs in liquid baths there will be some effect, typically > 1 mK.

Why measure the self-hearing value and calculate zero power resistance?

Example Application: Measurements in Fixed Point Cells

When making high accuracy measurements in fixed point cells, every time a SPRT is inserted into a cell (possibly the same cell) its thermal bond to the cell will be different and consequently it’s self-heating value will be different.

Also, when an SPRT is used on different measuring systems they will deliver nominally the same measuring current but there will be some very small differences due to the specification of the devices, again giving a different self-heating effect.

Therefore, to compare measurements at the highest level of accuracy this self-heating effect must be corrected for.

For further information relevant for primary metrology please see,

The optimization of self-heating corrections in resistance thermometry

J V Pearce, R L Rusby, P M Harris and L Wright Metrologia 50 (2013) 345–353

Online at stacks.iop.org/Met/50/345

Help and Advice

If you need low uncertainty measuring systems we can help, contact us for free advice and consultation. We have proven solutions at all levels in temperature metrology, from high accuracy cost effective industrial measurements systems to the lowest uncertainty systems for primary metrology used by the world’s leading National Metrology Institutes.

If you have any questions, if you need any advice, if you would like a free consultation then please get in touch