Designing with platinum resistance thermometers (PRTs)

Temperature measurement using PRTs can be confusing, with different models, resistance values, temperature ranges and number of electrical connections.

The electrical resistance of a metal will change as a function of its temperature. In theory, any metal could be used. However the metal should have a high melting point and an ability to withstand the effects of corrosion. Platinum has become the metal of choice for RTDs. The relationship between temperature and resistance can be expressed in the following equation:

Rt = Ro (1 + aT - bT2 - cT3 (T-100))

where Rt = Resistance at a certain temperature T
Ro = Resistance at 0˚C
a, b, c are co-efficients (refer to tables below)

Co-efficients for TCR = 3,850ppm/˚C (IEC 751 Standard)

Temperature	a	b	c
T < 0˚C	3.90802 x 10-3	5.80195 x 10-7	4.27351 x 10-12
T > 0˚C	3.90802 x 10-3	5.80195 x 10-7	0

Co-efficients for TCR = 3,750ppm/˚C

Temperature	a	b	c
T < 0˚C	0.81019 x 10-3	6.01875 x 10-7	6.14500 x 10-12
T > 0˚C	0.81019 x 10-3	6.01875 x 10-7	0

RTD types

RTDs will usually take one of two forms, either wirewound or thin film. Wirewound elements are made by winding a strand of platinum wire into a coil. These are usually more expensive than thin film devices, but the design is strain free.

Thin film elements are made by depositing a thin layer of platinum onto a ceramic substrate. One of the advantages of this type of sensor is the higher resistance value that can be achieved. Sensors up to 1,000Ω are available in thin film. However, thin film sensors are more susceptible to strain.

Wiring configuration

As with low ohmic resistors, errors can be introduced by the resistance of the lead wire. Added to this is the temperature co-efficient of the lead wire, which at 3,600ppm/˚C can also be significant. Two wire RTDs should be used only with short lead wires or with a 1,000Ω device (see figure 1 - lead resistance is represented by L1 and L2).

In the three wire configuration there are three wires connected to the RTD. L1 and L3 carry the measuring current to the element and therefore cancel each other out in the bridge circuit shown in figure 2.

The optimum form of connection is the four wire kelvin connected RTD. This removes the error caused by the wires. This design is the best choice for accuracy, especially when using 100Ω devices (see figure 3).

Figure 1

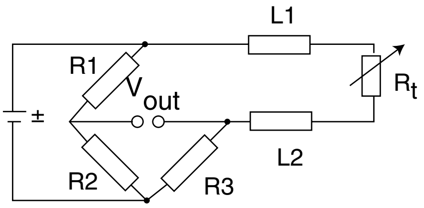


Figure 2

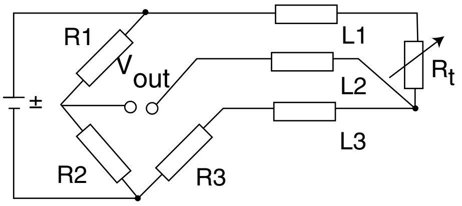
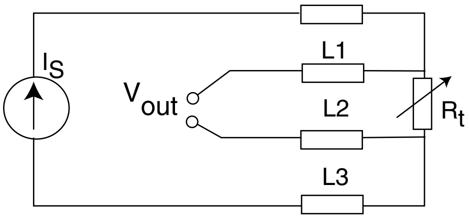


Figure 3



Self heating

Heat energy is generated when applying current to the RTD. This self heating effect can cause errors in the temperature measurement. The amount of self heating can be calculated from the dissipation constant, usually expressed in mW/˚C. The amount of self heating is dependant on the medium in which the RTD is located. Though the general rule is to use as little current as possible.

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Accuracy

RTDs are categorised as class A, B, C or D depending on their resistance tolerance and temperature deviation. Resistance tolerance and deviation are listed below.

Class	Resistance tolerance at 0˚C	Temperature deviation (˚C)
A	±0.06 %	±(0.15 + 0.002 |T|)
B	±0.12 %	±(0.3 + 0.005 |T|)
C	±0.24 %	±(0.6 + 0.007 |T|)
D	±0.48%	±(1.33 + 0.0184 |T|)

Repeatability

Repeatability is the ability of the sensor to give the same output under repeated identical conditions.

Stability

This is the ability of the sensor to maintain a constant output when a constant input is applied. Chemical changes can cause drift as will physical effects such as expansion and contraction of the substrate the element is wound or sputtered onto. Drift rates are typically 0.05˚C per year.

Theory of heat flux sensors

To measure thermal transfer or movement RdF has a unique line of heat flux sensors to meet a broad range of measurement applications. Specifically, the RdF heat flux sensor is designed to obtain a precise direct reading of thermal transfer through a surface in terms of energy per unit time per unit area.

Heat flux vs. surface temperature measurement

The techniques of surface temperature measurement and their instruments are well known. Surface temperature measurements are perfectly satisfactory for applications in which only the immediate, single surface temperature data is required. However, the temperature of a single or outer surface is almost always the result of a thermal condition acting upon an inner surface as well as the thermal properties of the total material thickness.

Heat flux sensing devices are the only practical way of accurately measuring the thermal properties of a surface material and the thermal characteristics affecting both sides of that metal.

Easy to use

Applications for RdF Micro-Foil heat flux sensors are practically unlimited, not only because of their high performance and reliability but also because of their ease of installation.

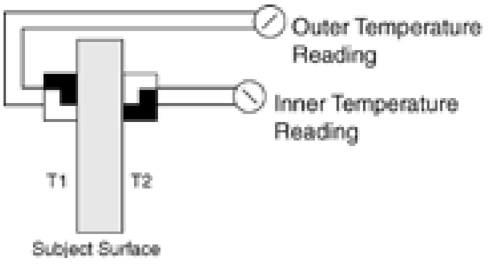
The sensors are very thin and flexible and can be attached to flat or curved surfaces without damage to those surfaces. They require no special wiring, reference junctions or signal conditioning. Readout is accomplished by connecting the sensors to any direct reading micro volt meter or recorder. Upon connecting the sensor leads to the meter or recorder, one is provided with a direct measurement of the heating or cooling transfer rate through a material in BTU's or other units. This is made possible because there is a direct relationship or calibration factor between the micro voltage change and heat flux rate.

How heat flux sensors work

The function of a heat flux sensor is to measure heat transfer (loss or gain) through a surface. It does this by differentiating temperature between opposite sides of certain rigid materials thereby allowing a direct measurement of the heat loss or gain through the material surface.

Before heat flux sensors were developed, the typical method for determining heat/loss transfer was to install two temperature measuring devices, one on either side or the rigid material to be measured. (See figure A.)

Figure A



Theory of heat flow sensors (continued)

The differential or change between the readings could then be mathematically calculated to show heat loss or gain through the surface provided the thermal characteristics of the material were known.

In a great many situations, however, it is neither desirable nor possible to install temperature measuring devices on both sides of a rigid material, even if the thermal characteristics of the material are known. Also, instantaneous direct reading measurements are not practical. The heat flux sensor allows these same heat transfer measurements to be made from a single, convenient surface with instantaneous readout. And nothing need be known about the properties of the surface materials.

By way of simplified explanation, the heat flux (see figure B) is constructed much like the example shown in figure A, with two temperature measuring elements physically separated by a thermal insulating material. When the heat begins to 'transfer' through surface (T1), the thermal energy at junction (J1) generates a small voltage.

As the heat passes through the material (I1) to reach thermocouple junction (J2), it generates the differential voltage. In other words, as the temperature of J1 is warmer or cooler than the temperature at J2, that temperature differential, in turn, creates a similar differential in voltage. Since the temperature differential is proportional to the voltage differential, the heat (or cooling) transfer rate can be directly read out as a function of voltage.

If such a heat flux device were to be embedded within a subject material, it would tend to become an integral part of that material, duplicating and reading out the heat/loss transfer characteristics of the composite material.

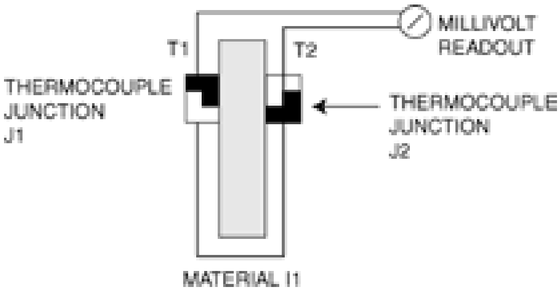


Figure B

Due to the unique design of the RdF Micro-Foil heat flux sensors it is not necessary to implant or in any way damage or invade the subject surface in order to achieve highly reliable and precise readings (see figure C).

The RdF heat flux sensors are extremely thin and flexible so that when properly mounted they become virtually a 'component' of the subject surface. The RdF heat flux sensor faithfully simulates the action and reaction of the temperature changes (transfer of heat) through the subject surface.

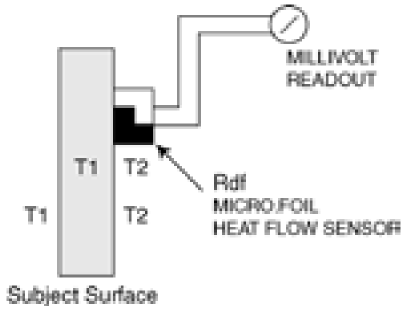


Figure C

Unique construction

Conventional heat flux sensors are usually fabricated with wire and electroplated junctions, which tend to create excessive thermal losses within the sensor as well as giving a bulky configuration.

The unique RdF Micro-Foil heat flux sensors (patented) are fabricated with special homogeneous alloys and extremely thin foil legs between junctions. This greatly reduces thermal loss due to leg conduction. Equally important is that the formation of RdF sensor junctions is achieved by a unique bonding process which joins dissimilar metals without degradation of physical or thermal properties. Moreover, the overall fabrication results in a very thin, strong and flexible sensor unit.

Calibration

RdF Micro-Foil heat flux sensors are individually calibrated at a base temperature of 70˚F (21˚C). Generally they are calibrated conductively for low levels. Calibration is a constant EMF output for a constant heat transfer rate. Each sensor is individually packaged with its calibration data.