Different ways to measure surface temperature

We can measure the temperature of a surface by using contact thermometers such as thermocouples and Pt100 detectors or with non-contact IR pyrometry. The methods have their advantages and disadvantages, which we will discuss in this article.

A sensor that is in direct contact with a warm surface transfers extra heat to the surroundings. See figures 1 and 2.This phenomenon is called thermal load and it influences the sensor readings. In contrast, the surface temperature is not influenced by a pyrometer, which measures from a distance.

The thermal load is most evident when hand-held measuring probes are held against the surface. Thermal load occurs wherever the sensor is placed. The degree of influence depends on e.g. the temperature difference between the surface and its surroundings, the geometry, and the heat-conducting properties of the probe and the surface.

The temperature difference drives the heat flow to the surroundings. In any given set of circumstances involving a sensor and a measurement object, the influence on the reading increases in almost direct proportion to the temperature difference. A measurement object that is in the form of a copper plate is an excellent heat conductor, and heat losses will easily be compensated for with heat conduction from adjacent parts of the plate. In contrast, a wooden board is a poor heat conductor and the heat losses will be almost permanent.

Measure along the isotherm

In the case of fixed installations, we can avoid the varying pressure force associated with the hand-held probe by locating the measuring position at a distance from where the sensor leaves the surface (see Figure 2). It is important that between these two points the sensor is in as good contact as possible with the surface. In this way, the surface of the measurement object is very little disrupted at the measuring position, but only at the spot where the probe or thermocouple wire leaves the surface. The distance that the sensor needs to be in contact with the surface depends on such factors as the heat conduction properties of both the sensor and the measurement object.

As the examples given in Figures 1 and 2 indicate, we should measure along an isotherm (a curve that has constant temperature) and not across it. The latter path constitutes a temperature gradient, which shows how the temperature is distributed along a line. (Compare figure 3). There is no heat flow between two points that have equal temperatures. The points along a gradient normally have different temperatures, and therefore a heat flux can exist there.

Figure 3 shows the measurement of surface temperature by using a thermocouple wire on the outside of a vessel that contains a hot liquid flow. In the first case, the surface has no insulation, and in the second case the surface is insulated. The insulation strongly limits the heat flow out from the vessel. This in turn means that the temperature drop over the insulation dominates over that of the steel wall and that in the fluid. The outside of the steel almost acquires the temperature of the liquid. Adding external insulation is therefore a way to approximately measure the temperature of a vessel's contents from the outside surface of the vessel. [Ref 1]

IR creates no thermal load

The major advantage of infrared pyrometry is that it does not create a thermal load on the measurement object. In addition, the response time is considerably shorter than when using thermocouples and Pt100 detectors in corresponding installations. This makes IR pyrometry suitable for use with e.g. moving measurement objects. However, some warnings are in order (see Figure 4):

- The pyrometer's measuring spot size must be less than that of the measurement object or the background temperature will disrupt the readings.
- Heat radiation can be reflected via the measurement object into the pyrometer and disrupt the readings. The proportion of radiation reflected from a measurement object depends on the emission coefficient ε (epsilon), which is $0 < \varepsilon < 1$. High values lead to a small disruption by reflections whilst shiny metals give a low ε and a large measurement error. The coefficient ε is hard to determine and varies according to the material, surface structure, measurement angle, wavelength and temperature.
- The major advantage of pyrometry is comparative measurement because it offers good repeatability. However, it is difficult to measure absolute temperature and the resulting measurement error is often several degrees in size. [Ref 2]

Understanding the underlying theory helps us to better assess the uncertainty involved in measuring surface temperature.

References: see www.pentronic.se >> Pentronic News >> Pentronic News archive
[Ref 1] See Pentronic News 2009-5 p 3.
[Ref 2] See Pentronic News 2008-2 p 4.

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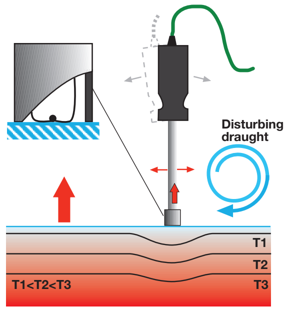

Figure 1. A hand-held sensor lowers the temperature of warm surfaces wherever it is placed. See the T1, T2 and T3 isotherms. The sensor's angle and degree of pressure varies, as does the air draught and thereby also the heat transfer. The result is uncertain measurement!

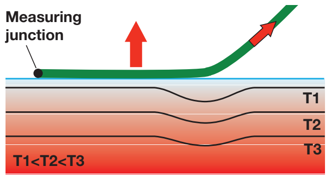

Figure 2. Fixing the probe to the surface reduces the measurement error. The distance between the measuring position and the spot at which the probe leaves the measurement surface reduces the thermal load error. Result: far more certain measurement.

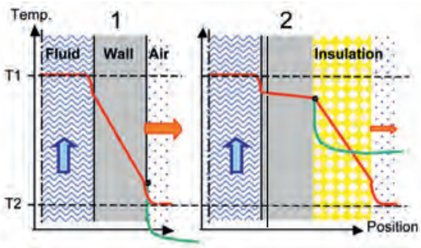

Figure 3. The size of the heat flow out from the steel vessel (red arrow) determines the slope of the temperature gradient (red curve). Case 1: Uninsulated vessel wall that absorbs most of the temperature drop from T1 to T2. A thermocouple (green) measures the wall's outer temperature. Case 2: The addition of external insulation reduces the heat flow, and most of the temperature drop is absorbed by the insulation. The sensor measures a temperature that is more or less the same as that of the fluid (≈T1).

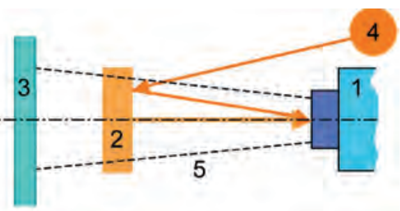

Figure 4. 1) IR pyrometer, (2) measurement object, (3) background, (4) another heat source, (5) the pyrometer's "field of vision". The measurement object must be larger than this field of vision. The emission coefficient ε determines how much extraneous radiation is reflected into the pyrometer. Knowledge of IR pyrometry is important for achieving correct measurement results.