MEASURING AIR TEMPERATURE WITH A SHEATHED THERMOCOUPLE

QUESTION: I've read that we can use a thin thermocouple to measure the air temperature inside a workshop or factory and achieve acceptable accuracy. Is this always the case at a normal room temperature?

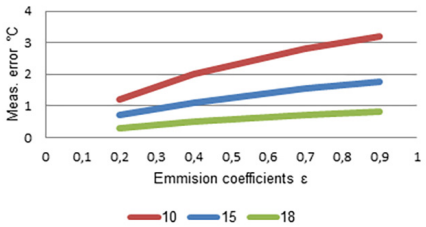
Ali M

ANSWER: Unfortunately your question cannot be answered with a simple yes or no, as the answer is considerably more complex. To illustrate the problem, we will take a simplified case and study an empty workshop where the stationary air has the constant temperature of 20.0 °C. We assume that the surface temperature of the walls, floor and ceiling – the wall temperature – is lower than 20 °C. We will measure the air temperature at about the centre of the workshop using a horizontally oriented sheathed thermocouple whose outer diameter is within the range of 0.5 mm to 3.0 mm.

Because the wall temperature is lower than the air temperature, the radiation from the thermocouple to the walls means that the thermocouple's temperature will fall below the air temperature. Heat is now transferred to the thermocouple from the air via convection. In the case of a stationary condition, we achieve an equilibrium whereby the heat flow from the thermocouple to the walls is equal to the heat flow from the air to the thermocouple. The heat transfer from the stationary air to the thermocouple occurs via natural convection.

Diagram 1 shows how the measurement error (the difference between the air temperature and the measured temperature) for a sheathed thermocouple with an outer diameter of 1.0 mm depends on the parameters of the thermocouple's emissivity and the wall temperature. We assume that the emissivity of 0.2 - 0.4 apply for a new thermocouple and the emissivity of 0.7 - 0.9 for a dirty thermocouple. The wall temperatures shown in the diagram are 18 °C, 15 °C and 10 °C.

Diagram 1.



Measurement errors depending on different emissivity at wall temps. 10, 15 and 18 °C. Outside diameter 1.0 mm.

The diagram shows that the difference between the air temperature and the wall temperature has a major influence on the measurement error. The smaller the temperature difference, the smaller the measurement error. The thermocouple's emissivity also has a major influence on the measurement result. The lower the emissivity, the lower the measurement error. Among other things, this means that a dirty thermocouple produces a bigger measurement error than a new one.

Diagram 2 shows how the thermocouple's outer diameter influences the measurement error. The diameters studied have the standard values of 0.5 mm, 1.0 mm, 2.0 mm and 3.0 mm. The two curves shown correspond to the wall temperatures of 18 °C and 15 °C respectively and in both cases the emissivity is 0.2. The thermocouple's outer diameter indirectly influences the measurement error via the heat transfer coefficient, which increases as the diameter decreases. Diagram 2 shows that the smaller the outer diameter of the thermocouple, the smaller the measurement error becomes.

In conclusion, the two parameters – the thermocouple's emissivity and the temperature difference between the air and the wall – have a greater influence on the measurement error than the third parameter -the thermocouple's outer diameter. The

QUESTION ? ANSWER

Questions should be of general interest and be about temperature measurement techniques and/or heat transfer.

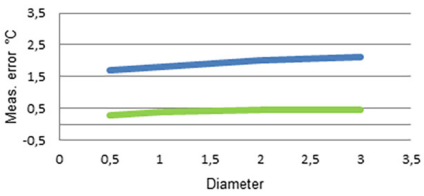


Diagram 2.

Measurement errors depending on the thermocouple diameter at wall temps. 15 and 18 °C. Emissivity 0.2.

calculation of the measurement error depends on a number of conditions and simplifications. Other conditions and simplifications will produce other results, but the three parameters that have been discussed here still have the same type of influence on the measurement error. Whether the measurement error is acceptable or not must be decided from case to case.

The answer to the question is: Yes, in some cases it is possible to measure the air temperature with acceptable accuracy using a thermocouple if it is new, thin, and the temperature difference between the wall and the air is small. However, this is not always the case. In each measurement situation, don't forget to check the conditions and the required accuracy.

If you have questions or comments, contact professor Dan Loyd, LiU, dan.loyd@liu.se