CAN A THERMOCOUPLE BE USED AS A FLOW METER?

QUESTION ? ANSWER

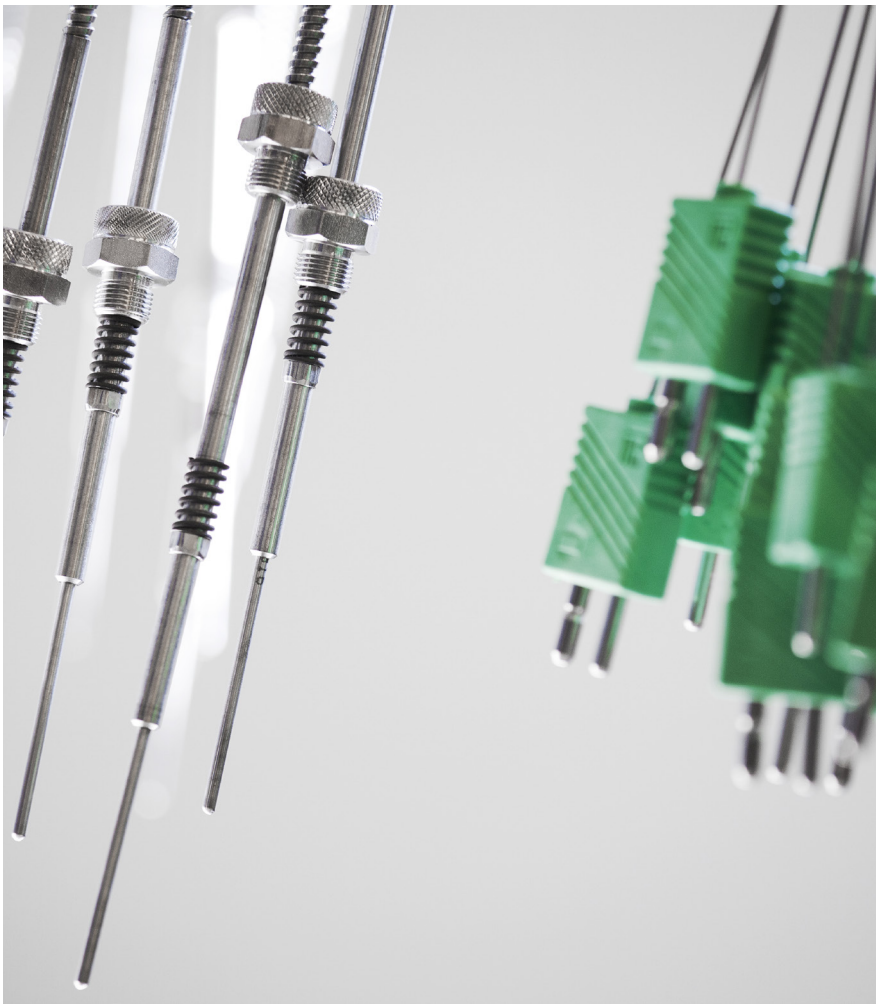
Questions should be of general interest and be about temperature measurement techniques and/or heat transfer.

QUESTION: We have an air intake that consists of a long pipe with an inner diameter of 200 mm plus an intake opening that is covered by a grating. About 300 mm from the grating, we measure the temperature at the centre of the pipe with a sheathed thermocouple that has a diameter of 4 mm. When our machinery is operating, the pipe is heated up and after an hour or so it has a temperature of about 50 °C. The air flow in the pipe is about 600 m^3 per hour but for a half hour or so it can be 500 or 700 m^3 per hour. It seems as if the thermocouple's temperature changes slightly when the air flow changes. The outdoor temperature remains the same. Is there any technical explanation for this small temperature change or is it a coincidence?

Kevin O

ANSWER: The air flow is constant for lengthy periods of time and we can therefore content ourselves with regarding this as a stationary process in which the air flow velocity inside the pipe is constant. The outdoor temperature is constant and we assume that the thermocouple is calibrated and correctly installed. If the pipe has the same temperature as the air that has been taken in, the thermocouple will measure the air temperature. In this case, the air flow velocity has no influence on the temperature being measured.

We now assume that the pipe has a higher temperature than the air in the air intake. The temperature being measured by the thermocouple will now be influenced partly by radiation from the hot pipe wall to the thermocouple, and partly by thermal conduction inside the thermocouple resulting from its attachment to the hot pipe. As a result of the radiation and thermal conduction from the pipe, the thermocouple's temperature will be higher than the air temperature, and heat will be transfered to the air via convection. When the heat flow to the thermocouple becomes equal to the heat flow from the thermocouple, an equilibrium occurs and thereby an equilibrium temperature is reached.



We assume now that the pipe and the grating have a constant temperature, T_{pipe}, the air temperature is T_{air} and the thermocouple's temperature T_{meas}. All temperatures must be given in Kelvin. We now disregard the heat flow via conduction to the thermocouple and assume that it has a constant temperature. The heat flow Q W from the thermocouple to the air can be written as

$$Q = A\,h\,(T_{meas} - T_{air}) = \varepsilon\,\sigma\,A\,(T_{pipe}^{4} - T_{meas}^{4})$$

where A is the thermocouple's heat transferring area in m^2, h the convective heat transfer coefficient in $W/(m^2K)$, ε the resulting emission coefficient and σ the Stefan-Boltzmann constant, $5.67\ 10^{-8}\ W/(m^2K^4)$.

The thermocouple's temperature (the equilibrium temperature) is somewhat higher than the air temperature but it is lower than the pipe wall temperature. If the air flow and thereby the air flow velocity increases, the convective heat transfer coefficient h between the thermocouple and the air will increase. This means that the thermocouple's temperature will decrease somewhat. If the air flow decreases, the heat transfer coefficient will decrease, which means that the thermocouple's temperature will increase somewhat.

When the pipe and the air have different temperatures, the measured temperature is affected by the air flow. The thermocouple becomes a type of flow meter. Unfortunately, given the low temperatures involved in this case, the temperature change will be very small, 0.1 – 0.2 °C. There are also many other error sources, which means the measurement result can be very difficult to interpret. See also www.pentronic.se > News > Technical information > Properties and sources of error by thermocouples > 2019-1 p6 Read more.

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