

RESPONSE TIME WHEN MEASURING THE TEMPERATURE OF LIQUIDS AND GASES

QUESTION: Why is the response time always shorter when I measure the temperature of liquids than of gases? I use the same type of sheathed thermocouple.

Bengt D

ANSWER: To answer this question we can study the measurement installation shown in the figure below. The temperature of the flowing fluid is measured using a sheathed thermocouple that has the diameter d m and is mounted at a right angle to

the pipe wall. For the thermocouple, we disregard the heat flow to/from the wall by conduction and by radiation exchange with the wall if the fluid is a gas. We also disregard any temperature differences inside the thermocouple. If the temperature of the fluid changes over time, the thermocouple's temperature, T °C, can be described with the aid of the differential equation

$$\rho c_p (dT/dt) + hA(T - T_{\text{fluid}}) = 0$$

QUESTION



ANSWER

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

where, ρ is the sheathed thermocouple's density in kg/m^3 , c_p the specific heat capacity in Ws/(kgK) , V the volume in m^3 , τ the time in s, α the heat transfer coefficient in $\text{W/(m}^2\text{K)}$, h the heat transferring area in m^2 and T_{fluid} the fluid temperature in °C. The sheathed thermocouple contains various materials, and for the quantities ρ and c_p we must therefore use the mean values.

We now assume that the fluid temperature changes in the form of a step, ΔT °C. The time it takes for the thermocouple to reach 63% of the temperature difference ΔT is a quantity – the time constant τ in s – which can be used to determine the thermocouple's response time. For τ the relevant equation here is

$$\tau = (\rho c_p V)/(hA)$$

For a specific sheathed thermocouple, the time constant is inversely proportional to the heat transfer coefficient h , which in its turn is determined by such factors as the thermocouple's diameter, the fluid's velocity, and the physical properties of the fluid in question, which are determined by the temperature.

We now consider a type K sheathed thermocouple with the diameter $d = 0.004$ m plus a fluid with the velocity $w = 1$ m/s and the temperature 20 °C. For air, the heat transfer coefficient is $h = 51$ $\text{W/(m}^2\text{K)}$ and for water $h = 9400$ $\text{W/(m}^2\text{K)}$. The time constant for air is 89 s and for water 0.48 s. In this case, the time constant for water is approximately 0.5% of the time constant for air.

The calculation applies to a specific measurement situation and is based on a number of conditions. However, the response time is almost always considerably shorter when measuring liquids rather than gases.

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