

## Is a surface probe reliable?

**QUESTION:** In order to better monitor our district heating network we plan to install new temperature sensors, especially in a large pipe (DN 1000 size with an outer diameter of 1016 mm and a wall thickness of 11 mm). The average velocity of the water in the pipe is 0.8 – 4.0 m/s and the temperature is 75 – 110 °C. Can we use a surface probe instead of an insert probe to measure the water temperature with less than 1 °C measurement error and little delay?

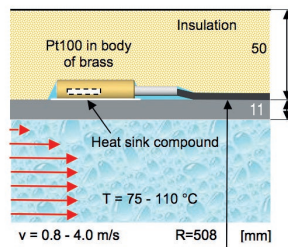
Sören A

**ANSWER:** A surface probe measures the temperature on the outside of the pipe. The heat flow from the water to the pipe's surroundings will deviate from the water temperature. In a stationary situation the measured temperature will be lower. There is no general answer regarding the size of this measurement error. However, if we make a number of assumptions we can estimate the measurement error and the dynamic behaviour of the measurement system.

Let us assume that the pipe is insulated. The heat is transferred from the water to the surroundings of the pipe via convection

between the water and the inside of the pipe, plus heat conduction within the pipe wall and within the insulation. If the pipe is surrounded by air, the heat is transferred from the outside of the insulation via convection and radiation to the surrounding air. If the pipe is buried underground, the heat is transferred to the surrounding earth via conduction. Our model assumes natural convection on the outside of the pipe and a temperature of 10 °C.

The water flow in the pipe is turbulent and we assume that the turbulence is fully developed. We further assume that the water temperature is constant across the pipe. The lower the flow velocity, the greater the measurement error. If we assume that the pipe is not insulated, these conditions



*It is crucial that the temperature sensor is in good contact with the pipe, e.g. by means of a spring clip. Heat sink compound facilitates the heat transfer.*

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

**QUESTIONS?**  
**ANSWERS!**

will result in a measurement error of about 0.5 °C. If the pipe is insulated with the equivalent of 5 cm of mineral wool, the measurement error will be less than 0.05 °C. Both of these readings meet the requirements for measurement error.

In the case of the insulated pipe with the assumptions stated above, we can estimate the response time of the measurement system. If we calculate the step response time,  $t_{0.5}$ , for a temperature reduction of the water of 10 °C, the sensor will measure a temperature change of 5 °C after less than 15 seconds. Flow velocities higher than 0.8 m/s will decrease response time even more. A response time ( $t_{0.5}$ ) of 15 seconds should be acceptable for monitoring a district heating system. There are Pt100 sensors specially designed to take surface measurements. It is important to install them under the insulation and with good thermal contact with the pipe. You must inspect the sensor installation regularly because poor surface contact seriously impact the measurement readings. 📷

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