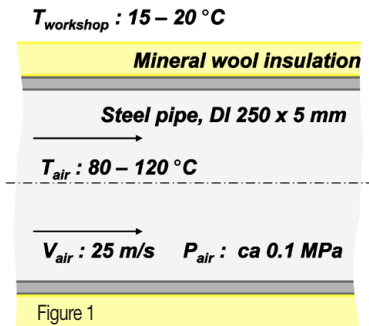


# Surface-mounted sensors as good as those in thermowells?

**QUESTION:** We want to measure the air temperature inside a steel pipe where the air velocity is high. We would prefer to avoid using thermowells inside the pipe because the air contains sharp particles that would perforate the thermowells. Can we use surface-mounted temperature sensors instead? The pipe's dimensions and current measurement data are given in Figure 1.

Staffan L



**ANSWER:** Unfortunately your question cannot be answered with a simple yes or no. The answer depends partly on the measurement requirements that must be met. Two factors that influence the answer to your question are the required accuracy and response time.

If the air temperature is fairly constant and any temperature variations occur slowly, the measurement problem can be regarded as being essentially stationary. The heat flux from the air inside the pipe out to the workshop occurs as follows: Between the air in the pipe and the pipe's inside surface, the heat transfer occurs by means of forced convection; inside the pipe wall the heat transfer occurs by means of conduction, and this also applies to the insulation. On the outside of the insulation, the heat transfer to the workshop occurs by means of natural convection

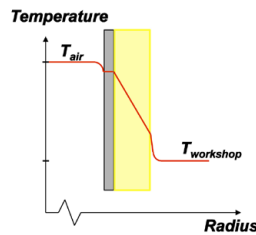


Figure 2

and radiation. See Figure 2. Let us assume that the air temperature inside the pipe is  $100 \text{ °C}$  and the temperature inside the workshop is  $15 \text{ °C}$ . If the insulation's thickness is  $40 \text{ mm}$  we can calculate the temperature on the pipe's outside surface to be  $98.7 \text{ °C}$  and if the insulation's thickness is  $80 \text{ mm}$  the corresponding temperature is  $99.3 \text{ °C}$ . When the temperature sensor is placed on the outside of the pipe, the measurement error is just over  $1 \text{ °C}$  and just under  $1 \text{ °C}$  respectively. Whether or not the measurement error is acceptable must be decided from case to case. Note that even a sensor inside a thermowell will produce some measurement error and that a thermowell will always disrupt the flow.

With an uninsulated pipe, the temperature on the pipe's external wall will be  $84 \text{ °C}$  and the measurement error will be  $16 \text{ °C}$ . The insulation's thickness is thus decisive to the size of the measurement error. During installation it is essential to achieve a good close contact between the sensor and the pipe wall. A poor contact increases the measurement error, as does an oxide layer between the pipe and the sensor. Regular inspection of the installation is therefore necessary.

At a rough estimate, given a stepwise temperature reduction of  $10 \text{ °C}$  of the air inside the pipe, almost four minutes will pass before the sensor displays the temperature of  $95 \text{ °C}$ . One reason for the long response time is the limited heat transfer coefficient between the air and the pipe wall in combination with the thickness of the steel pipe.

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

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

An external surface-mounted sensor has several advantages. One is that it is easy to install. Another is that it does not disrupt the flow inside the pipe. In the case of a fairly stationary measurement problem, we can often accept the measurement error. In this case the sensor's weak point is its long response time.

If you have questions or comments, contact Dan Loyd, LiU, [dan.loyd@liu.se](mailto:dan.loyd@liu.se)