

External measurement of internal temperature

The temperature of flows in pipes, tubes and hoses can be measured in various ways. Usually a temperature sensor is placed directly in the flow. Another alternative is to measure the temperature of the outside of the tube and thereby discover the temperature of the flow. What conditions apply to the use of the external measurement method?

External contact temperature sensors have the distinct advantage that no hole needs to be bored in the pipe, tube or other container. For hygienic applications like those in the pharmaceutical and food industries, it is a great advantage to have as few interventions as possible, especially when it is temporarily necessary to take test readings at several places in the process.

There are several different main types of surface temperature sensors for the external measurement of pipe systems. Figure 1 shows some examples. The simplest is a thermocouple wire (A) with a welded measuring junction that can be attached with tape or cable ties. In order to use the more stable and therefore more accurate Pt100 sensor, model (B) can be used with a heat-transferring and protective brass body. The sides that serve as contact surfaces can be flat or milled with one or several radii. The sensor is clamped securely to the pipe, e.g. with a cable tie or hose clamp. Model (C) surrounds the pipe with two halves of a plastic housing that contains a Pt100 sensor. The housing serves as the required insulation. The sensor is in contact with the pipe via copper components, which transfer the heat to the sensor. The two halves of the housing are held together with two screws, which make it possible to easily move the sensor along straight sections of the pipe by loosening the housing slightly.

What are we measuring?

In case (D) in Figure 2 the pipe is surrounded by air, which can have a low or high velocity depending on the surroundings and can thereby draw off heat via varying convection. Radiation from the pipe's surface also contributes to the heat flow. Inside the pipe a fluid of some kind is flowing. The sensor models (A) and (B) in Figure 1 then show the pipe's surface temperature T_3 , which is indicated by (D) in Figure 2. The inside


of the pipe wall has the temperature T_2 and the centre of the flow has T_1 . The average temperature, which is often what we want to measure, lies somewhere between T_1 and T_2 . As Figure 2 shows, the difference between that temperature and the measured T_3 is considerable.

Insulating the pipe surface with a mounted sensor considerably improves the measuring situation. See Figure 2 and (E). The thermal insulation means that the heat flow from the fluid in the pipe, via the pipe wall and the insulation, is greatly reduced compared to when there is no insulation at all. Because the temperature difference between T_1 and T_5 is still just as great, the lower heat flow will reduce the temperature drop ($T_1 - T_3$). However, the insulation, with its by definition low thermal conductivity, absorbs most of the temperature drop ($T_3 - T_5$). The purpose of the insulation is to restrict the heat flow to the surroundings so much that the temperature drop through the pipe wall becomes small enough for the reading from the sensor (S) to become acceptable. It is important to extend the insulation in an axial direction considerably farther than the actual measuring position. Otherwise some of the heat flow escapes out the sides of the insulation and

the flow is not restricted enough to produce the intended effect.

Contact resistance

There are other circumstances that can increase the difference between the measured temperature and the desired one. One example is the contact between the sensor and the pipe's external surface. Using contact paste and ensuring a good fit are recommended. For pipe diameters from 100 mm and up, sensors with a flat surface usually suffice. Deficiencies in the conductivity between the surfaces have the greatest consequence in the case of dynamic processes, that is, when a rapid response time is a priority. One example would be the detection of rapid temperature changes in fluid flows. For very slow changes the contact properties are less important.

The circumstances on the inside of the pipe wall also affect the measurement process. The heat transfer from the fluid to the wall is affected by the flow velocity, other flow conditions, the type of fluid, and the inner surface of the wall material (e.g. dirt deposits). If the fluid in the pipe is not a liquid but a gas or a gas + liquid, external contact sensors should be used with caution because the measurement error can be large. 

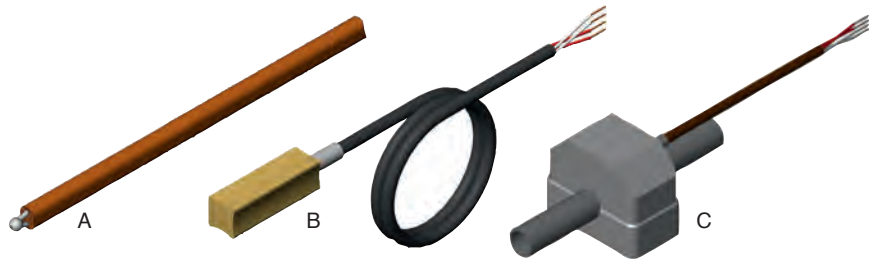


Figure 1. Different models of surface temperature sensors. A) Thermocouple wire. B) Pt100 in a brass body with various radii. C) Pt100 sensor built into an insulating housing. NB! Not comparable sizes.

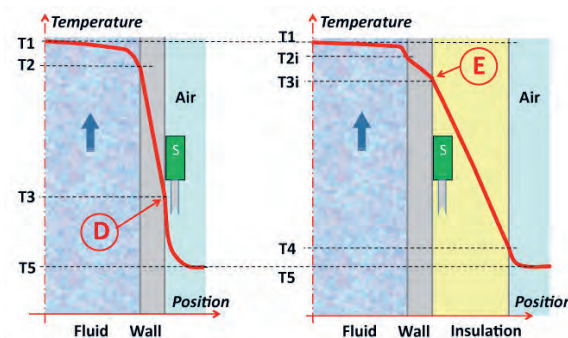


Figure 2. The diagrams show what a surface temperature sensor (S) senses first without and then with insulation against the surroundings. Both sensors measure the pipe's surface temperature. Position E corresponds more or less to the temperature of the fluid.

References see www.pentronic.se > News > Pentronic News > Pentronic News Archive
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If you have questions or comments, contact Hans Wenegård: hans.wenegard@pentronic.se