TEMPERATURE MEASUREMENT THROUGH OBSTACLES

QUESTION ? ANSWER

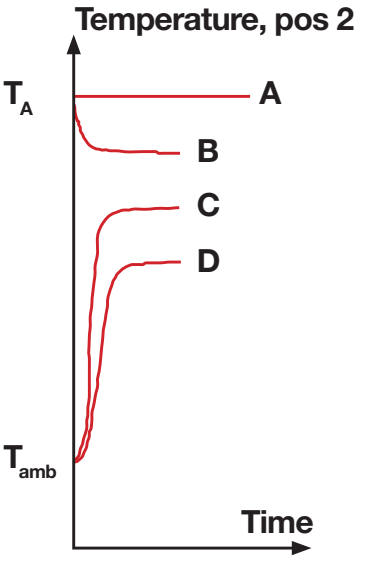
Questions should be of general interest and be about temperature measurement techniques and/or heat transfer.

QUESTION: When we inspect hot water pipes, we sometimes have to estimate the water temperature. Usually there is no sensor installed where we have to measure. By measuring the pipe's surface temperature, we can estimate the water temperature. However, company policy does not permit us to remove the insulation and measure the pipe's surface temperature. To take our measurements, we therefore usually use a handheld indicator with a sheathed thermocouple, which we insert in through the insulation. How good is this measuring method in practice?

Elis B

ANSWER: It is always complicated to measure the temperature of a surface, and the difficulty increases if you must use handheld sensors. In this case, it is even more complicated because you cannot see where and how the sensor touches the pipe. The total heat transfer coefficient on the pipe's inside surface is very high and the pipe wall is made of steel. This means that when the water velocity is normal and the pipe is well insulated, the difference between the temperature of the hot water and that of the pipe's surface is very small.

The pipe's undisturbed surface temperature is assumed to be T_A. When the sensor comes into contact with the pipe, the temperature of the point of contact changes in theory according to curve B shown in the figure. This temperature change normally happens very rapidly. Heat travels from the pipe to the sensor by conduction and from the sensor to the surrounding insulation by conduction. The heat transfer in the steel pipe and the sensor also occurs by conduction.



The temperature as a function of time at the different positions shown in Figure 2. Note that initially the sensor's point of contact (B) very briefly adopts the surface temperature T_A.

The temperature reduction of the pipe's surface is caused by the thermal load resulting from the sensor. The change is due to factors such as the geometry and thermal properties of the pipe and the sensor. Curves C and D in the figure show the temperature at the corresponding points in the sensor. Accordingly, the temperature measured by the sensor depends on where the temperature detector is located inside the sensor body and what the physical contact is like between the sensor and the pipe's surface. The measurement error resulting from Pos 2 is greater than that from Pos 1. The design of the sensor tip is one of the factors influencing the measurement error. Special sensors are available for measuring surface temperatures. One complication in this particular case is that you cannot see the measuring position when you insert the sensor in through the insulation.

In some cases, there is also a contact resistance, for example an oxide layer, between the sensor and the pipe. The contact resistance influences the heat flow to the sensor and thereby the surface temperature reading. The contact resistance depends on factors such as how you hold the sensor and the pressure between the sensor and the pipe. If the pressure and point of contact

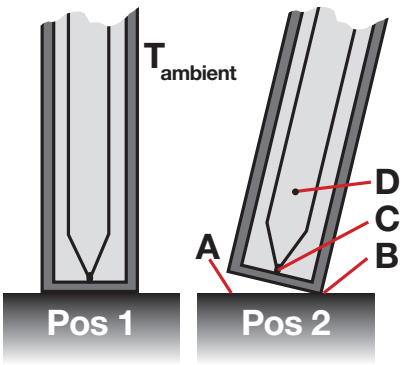
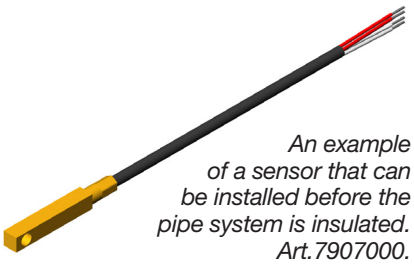


Figure 2. Pos 1. The correct perpendicular application of the surface temperature sensor. Pos 2. Other angles than the perpendicular cause the sensor's point of contact (B) to briefly adopt the surface temperature T_A. The measuring junction (C) remains colder than (B).



An example of a sensor that can be installed before the pipe system is insulated. Art.7907000.

vary then the temperature will also vary. The reason for the temperature variations you mention can therefore depend on both the measurement method used and the person taking the readings.

In summary, when you use a handheld sensor to measure a surface temperature you must always expect to get a measurement error. The error is caused mainly by the measuring method but also by how the measuring is done. During signal processing, damping functions are usually used, which normally suppress the initial temperature variation. In most cases the instrument therefore indicates the situation after the brief transient state.

This measuring method is useable when you have to do a "rush" job and do not have very high demands for accuracy. In most cases, you also know what the approximate temperature should be. When measuring at several positions along the pipe, it should be the same person who does the measurement. You thereby avoid having the measurement result vary according to who is doing the measuring.

Many factors influence the measurement error, and it is therefore difficult to comment on the size of the error. With this type of measurement, you must therefore always be very careful when assessing the measurement result. If the water temperature varies rapidly, this method should be avoided. When higher accuracy is required, you must build a conventional sensor installation. If it is difficult to remove the insulation to install a temporary sensor, you can install some surface sensors (such as Pt100s) before the pipe system is insulated. You can then connect the sensors at a later date to mobile measurement equipment in order to measure the temperature.

If you have questions or comments, contact Professor Emeritus Dan Loyd, LiU, dan.loyd@liu.se