The temperatures of refrigerant in a geothermal heat pump

QUESTION: In my home's geothermal heat pump, with a heat exchanger installed inside a borehole, I want to measure the temperatures of the incoming and outgoing refrigerant. Can I use a surface-mounted sensor or must I use thermowells? The tubing for the refrigerant has an outer diameter of 30 mm and is surrounded by thin metal netting. The insulation is 30 mm thick. The air temperature inside the room where the two sets of tubing enter the house is fairly high – about 25 °C.

Lasse S

ANSWER: The refrigerant's incoming temperature normally lies in the range of +5 °C down to a few degrees below 0. The return temperature is 2 –5 °C lower. The time of year and the installation's construction and operation determine what the temperatures will be. The difference between the fluid's incoming and outgoing temperatures is needed to calculate the installation's efficiency and energy supply. Under normal operation the refrigerant's temperature varies very slowly over time, and the measurement problem can therefore be regarded as stationary.

We can use an insulated sheathed thermocouple as a temperature sensor, lay the thermocouple on the outside of the metal netting and attach it with a cable tie or hose clamp. A thermocouple with an external diameter of 1.5 – 2 mm is easy to handle. The thermocouple should run about 25 mm in the axial direction on the outside of the metal netting before you let the thermocouple exit radially through the insulation. It is important that the thermocouple is calibrated and that the insulation is as good as possible when it is restored after the thermocouple installation, see the diagram. It is also important that the thermocouple installation is the same on both sets of tubing to reduce the error in the temperature difference.

Heat from the warm room will be added to the fluid and the temperature sensor will therefore measure a higher temperature than the temperature of the fluid. The heat transfer from the room to the outside of the insulation occurs via natural convection and radiation. Inside the insulation, the metal netting and the tubing wall, heat transfer occurs via thermal conduction. The heat transfer from the tubing wall to the fluid occurs via forced convection; see the diagram.

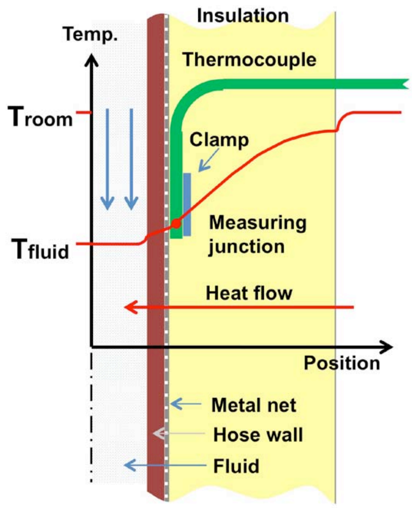
Estimate the measurement error

Based on the information given in the question plus some supplementary assumptions it is possible to estimate the measurement error. The total heat transfer coefficient on the outside of the insulation is 8 to 10 W/(m^{2}K) and this value includes both natural convection and radiation. The thermal conductivity for the insulation and tubing is assumed to be 0.04 W/(m^{2}K) and 0.4 W/(m^2 K) respectively. The thickness of the tubing wall is assumed to be 3 mm. The velocity of the fluid is estimated at 1 m/s, which gives a heat transfer coefficient of 1300 - 1700 W/(m^{2}K). The effect of the metal netting on the heat flux is neglected and the heat transfer is assumed to be one dimensional.

The measurement error can now be estimated at about 0.5 °C and the error becomes somewhat larger on the return tubing than on the incoming tubing even if you have the same type of installation. Based on the measurement and the added assumptions we can also calculate the actual temperatures of the fluid. The error with respect to the temperature difference will be very small but the temperature difference is also small. As usual, whether or not the measurement is acceptable must be decided from case to case.

The advantages of surface-mounted sensors are that they are fairly easy to install in an existing installation, they do not disrupt the fluid flow and they do not cause any pressure drop. One prerequisite is that there is good close contact between the sensor and the metal netting. It is therefore necessary to inspect the installation regularly.

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



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