Heat Transfer Workshop 1 Introduction to Heat Flux Sensors

Name _____

This series of workshops is designed to help you understand heat transfer and temperature. Temperature is what most people measure, but heat transfer is equally important for engineering applications. The workshops use a combination of thermocouples and heat flux sensors to measure both of these quantities simultaneously. The sensor output is read by a data acquisition board (DAQ) that is connected through a USB port to a laptop computer. A program is loaded on the computer to graphically display results and provide a control panel.

Heat transfer (q) is the movement of thermal energy as a function of time. Typical units are watts, the same as power, which is the movement of mechanical energy as a function time. Heat flux is heat transfer per surface area (q''), with units of watts per square meter. This is analogous to a power density. It is measured across a thin, flat sensor that is encapsulated in a plastic cover. It outputs a voltage (E), which is directly proportional to the heat flux according to a supplied calibration (S), typically given as microvolts per watt per square meter, $q'' = E/S$. The computer program automatically does this conversion when supplied with the sensor's calibration value.

To measure temperature two thermocouples are provided. One is attached as part of the heat flux sensor. The other is a separate set of wires, welded together at one end to form the thermocouple junction. Thermocouples measure the difference in temperature from this junction to the connection point of the other end of the wires. The DAQ automatically measures the connection temperature and adjusts the voltage output to give absolute temperature values.

Together, this allows direct measurement of both individual temperatures and temperature difference. Heat transfer is driven by temperature difference. There is always a source of thermal energy at a higher temperature that moves to an energy sink at a lower temperature. Consequently, it is important to know the source and sink temperatures and the resulting heat flux in an engineering system.

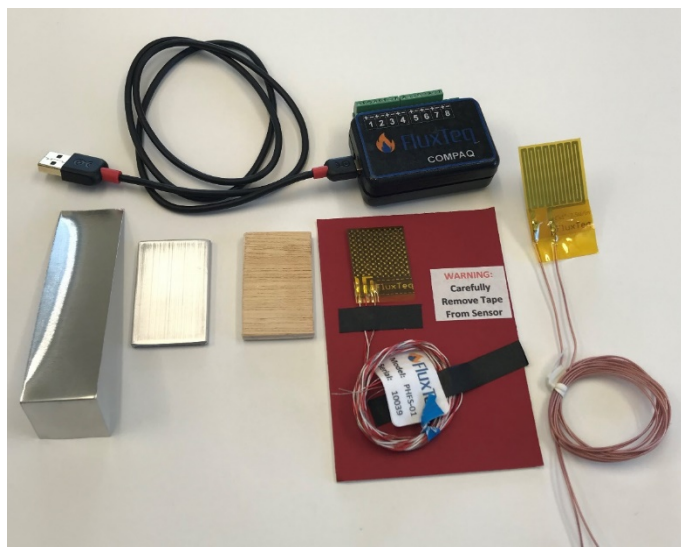

Fig. 1 Heat Flux Sensor Kit Components

The heat flux sensor kit provides the components as shown in Fig. 1. Included is a heat flux sensor with a thermocouple, a second separate thermocouple, a DAQ, an aluminum coupon, an aluminum fin, a small piece of wood, a thin heater and a small piece of cloth. The heater is designed to take power either from the DAQ or from a separate battery pack. It is used to provide a source of heat for some of the workshops. Many of the workshops use the human body as a heat source, which allows you to feel the thermal process while measuring the results.

To make the measurements put the heat flux sensor between a heat source and a heat sink. This can be as simple as a desk and your hand or your arm and the surrounding air. The heat flux sensor can be taped to a surface or placed between two objects to hold it in place. Single-sided tape can be used over top of the sensor or double-sided tape can be used between the sensor and a surface. In either case the goal is to create good contact between the entire sensor and the surface to obtain a good reading.

Heat Transfer Workshop 1 Introduction Assignment

Name _____

1. Watch the introductory video on Heat and Temperature. https://youtu.be/1SX8u3qXo0A
2. Assemble your system. Make sure the wiring is correct. The placement of the colored wires is important. Starting from the left, the first two wires are the heat flux sensor (white then red). The next two wires are the thermocouple (blue then red). The next two are for the second thermocouple (blue then red). The last two wires are black in either order to the power supply – either the battery pack or the last two positions on the DAQ.
3. Make sure the proper computer programs are installed on your computer.
4. Plug in the DAQ to a USB port (at least 2.0 or higher).
5. Start the program and enter the proper heat flux sensor sensitivity. A screen should appear with graphs for the heat flux and two temperatures.
6. Record the heat flux and sensor temperature from a source to a sink. Note that the output from the heat flux sensor is directional. In one direction the heat flux should read positive and if the sensor is flipped over the output should be negative. The thermocouple, however, only measures a temperature at a location. It does not have positive and negative values. In all cases, if a wire is broken or disconnected, the output will be very large and unresponsive. Save the data as an Excel or MatLab file. This file will have four columns beginning with time in seconds, followed by the heat flux in W/m^2, the third column is the sensor temperature (°C), and the fourth is the second temperature (°C).

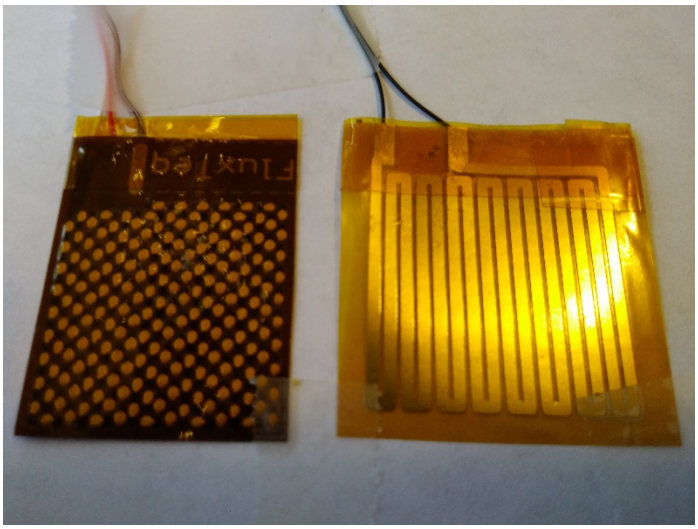

Figure 2 The heat flux sensor is picture on the left. The heater is pictured on the right (sizes may vary).

<u>Measurement Description:</u>

q" = _____ T = _____

Are these values what you expected (including sign and direction)?
Explain why.