

## Heat Transfer Workshop 12 – Building Heat Transfer Coefficients

Name \_\_\_\_\_

**Read about heat transfer coefficients**

A heat transfer coefficient is used to relate the heat flux between a surface and a fluid. For heat flux that is defined as positive from the surface

$$h = \frac{q''}{T_s - T_{fluid}}$$

where  $T_s$  is the surface temperature and  $T_{fluid}$  is the temperature of the bulk fluid. Note that if the temperature difference is zero, the value of  $h$  is undefined. Therefore, heat transfer has to be provided into or out of the surface for  $h$  to have meaning. If there is no heat transfer occurring naturally, a heater may be added to provide the heat flux. The temptation might be, however, to assume that all of the heat flux from the heater goes into the air by convection. This is generally not a good assumption because some of the energy will always go into the substrate material. Therefore, it is useful to have a heat flux sensor to measure the heat flux that goes directly from the surface to the fluid to give an accurate measure of the heat transfer coefficient.

There is one additional problem, though. Placing a heater behind the heat flux sensor creates an artificial “hot spot” where the sensor is. This disruption of the surface temperature is known to increase the heat transfer coefficient at the location of the sensor and results in measurement errors that can be quite large. The following reference gives additional details. There is also guidance on using heat flux sensors in the two ASTM standards that are listed.

Diller, T. E., “Practical Heat Flux Measurement, Ch. 12, in The Art of Measuring in the Thermal Sciences, Eds. Josua Meyer and Michel De Paepe, CRC Press, Boca Ratan, 2021.

ASTM E2684-17, Standard Test Method for Measuring Heat Flux Using Surface-Mounted One-Dimensional Flat Gages. Ann. Book ASTM Standards, 15.03, 2017.

ASTM E2683-17, Standard Test Method for Measuring Heat Flux Using Flush-Mounted Insert Temperature-Gradient Gages. Ann. Book ASTM Standards, 15.03, 2017.

## Heat Transfer Workshop 12 Results

Name \_\_\_\_\_

### Read about heat transfer coefficients

Normally the heat flux through building walls is very small. Consequently, to measure the convective heat transfer coefficient on the outside of the wall, add the heater provided in the sensor kit to give a more measurable heat flux. Place it between the heat flux sensor and the wall of a building. Put the side of the sensor with the thermocouple away from the building to get a positive heat flux when the heater is operating. Turn on the data acquisition for at least 10 seconds and then activate the heater. Let it run for at least 30 seconds. Then find the average values before and after turning on the heater.

Outside Building Wall	$q''$ (W/m <sup>2</sup> )	$T_s$ (C)	$T_{air}$ (C)	$h$ (W/m <sup>2</sup> -K)
Before Heater				
After Heater				

1. Plot the temperatures, heat flux and heat transfer coefficient as a function of time. Attach the three graphs to the workshop results. Do the values of temperature and heat flux before the heater is turned on make sense?

2. Show the calculations for the heat transfer coefficients.

3. The heater increases the temperature of the sensor and the resulting convective heat flux, which makes it easier to determine the heat transfer coefficient. However, this increased surface temperature locally disrupts the thermal boundary layer, increasing the local heat transfer coefficient. Based on your measurements, how much does the  $h$  value increase for this case?

4. What happens to the heat transfer coefficient under transient conditions when the direction of the temperature difference changes from positive to negative?

5. What can you conclude about the limitations of heat transfer coefficients and how they are defined?