ENVIRONMENTAL AND MECHANICAL ENGINEERING LABORATORY
Heat Transfer –Week 1.
INITIAL SET UP AND CALIBRATION

General description

The experiment consists of heated plate in an air flow. Heat is supplied to the plate to maintain it at a given temperature. By measuring the power required to maintain the plate temperature the heat flux is determined. The aim is to measure the *heat transfer coefficient* for a range of temperatures and air flow rates, covering *free convection, laminar and turbulent forced convection*. The labview VI controls the heater so that the temperature rapidly reached the set value. Once this is reached the system is set to manual and the heater is maintained at a fixed power. The heat transfer coefficients and the Nusselt number are determined from the measurements of the power and the temperatures if the air and the plate.

Objectives

1. To calibrate the heat flux meter
2. To measure the velocity profile across the duct

Procedures

1. The calibrate the heat flux meter

*****The heater will switch off if the temperature read-out on the power supply reaches 100^{o}C. Run the fan during the calibration to avoid this.**

Manually adjust the power to the heater using the control knob on the front of the power supply. Adjust the power knob from 0 – 20W in increments of 5W then in steps of 10W from 20 - 120W. Then in reverse back down to 5W in the same order of increments. Using the multimeters record the measure voltage and current to the heater unit. Fit the measured power from the heater to the meter reading using equation (1). Note that the V and I meter reading are peak values and have to be converted to rms values prior to calculating P. Then plot the data (Power Measured vs. Power Calculated) and determine the least squares fit to the data.

2. Measure the velocity profile

The probe measures the airflow by the rate of cooling of a heated thermistor. Set the flow speed to zero and check the zero on the meter reading. Set the flow speed to 0.6 ms^{-1} and measure the flow speed at increments of 2 cm across the duct. Repeat the measurements with the speeds of 1.0 and 2.0 ms^{-1}. Plot the resulting velocity profiles (Position vs. Velocity) across the duct.

Then determine which flow speeds are laminar and which are turbulent. Measure area and perimeter of the duct to calculate the range of Reynolds numbers (*Re*) that can be achieved in the duct. The transition from laminar to turbulent flow takes place at Re ≈ 10^6.

Error analysis

1. Calculate any systematic errors in the measurements you take.
2. Determine random errors from repeated samples.
3. Plot all data with appropriate error bars.

Definitions

The power *P* to the heater is given by

$$P = IV, \tag{1}$$

where *P* is in Watts, *V* is the voltage and *I* is the current.

The Reynolds number (*Re*) is

$$\mathrm{Re} = \frac{UD}{v}, \tag{2}$$

where *U* is the flow speed, *D* is the hydraulic radius of the channel and *v* is the kinematic viscosity of air. The hydraulic radius *D* is defined by

$$D \equiv \frac{4A}{p}, \tag{3}$$

where *A* is the cross-sectional area of the duct and *p* is its perimeter. The kinematic viscosity for air is $v \approx 19.4\mathrm{x}10^{-6}$ m^2 s^{-1}. The convective heat transfer coefficient (h_c) is defined as

$$h_c = \frac{H}{(A_p)(\Delta T)}, \tag{4}$$

where *H* is the heat flux in Watts, A_p is the area of the plate and ΔT is the temperature difference between the plate and the air. The units of h_c are W m^{-2} (°C)$^{-1}$. The Nusselt number *Nu* is defined as

$$Nu = \frac{h_c L}{\lambda}, \tag{5}$$

where $\lambda \approx 0.0279$ W m^{-1} (°C)$^{-1}$ is the thermal conductivity of air and *L* is the length of the plate in the streamwise direction.