Heat transfer probe details

A probe containing three thermocouples (Omega TMTSS-125U-12), measured the bulk temperature of the media in the column. Since this work studied the local heat transfer coefficient in the fully developed region, the thermocouple probe was installed close to the heat transfer probe (0.12 m in axial distance). The radial position of the three thermocouples in the thermocouple probe were r/R=-0.6, 0, +0.6, and the averaged value of the temperatures obtained by this probe was counted as the bulk temperature. The heat transfer probe, manufactured at Washington University, was a modified version of the probe proposed by Li and Prakash (1997). As shown in Figure 3-4, the heat transfer probe contains a Teflon tube, brass shell, heat flux sensor, heater, and Teflon cap. The diameter and the length of the brass shell are 11.4 mm and 38 mm, respectively. Inside the brass shell, a heater generates a temperature difference between the probe and the bulk media. On the outer surface of the shell, a micro-foil heat flux sensor (11mm × 14mm × 0.08mm) from RdF Corporation (No. 20453-1) was attached. The micro-foil sensor itself has two components: a heat flux sensor and thermocouple (Figure 3-4). Therefore, this micro-foil sensor can measure both the local heat flux from the probe to the bulk and the surface temperature of the probe simultaneously. The tube and fittings are Teflon, which reduces the heat loss transferred from the heater to the connections.

Since the purpose of this work was to investigate the heat transfer coefficient under mimicked FT conditions in the fully developed zone of the column, the heat transfer probe was vertically installed at an axial height (from the sparger to the heat flux sensor) to column diameter ratio (Z/D) equal to 5.5. This height was selected because it had previously been used in studying the time averaged phase distributions, hydrodynamics, turbulent parameters, and mass transfer coefficient by γ-ray CT, CARPT, and optical probe techniques in columns with the same dimensions (Ong, 2003; Rados, 2003; Shaikh, 2007; Han, 2007).

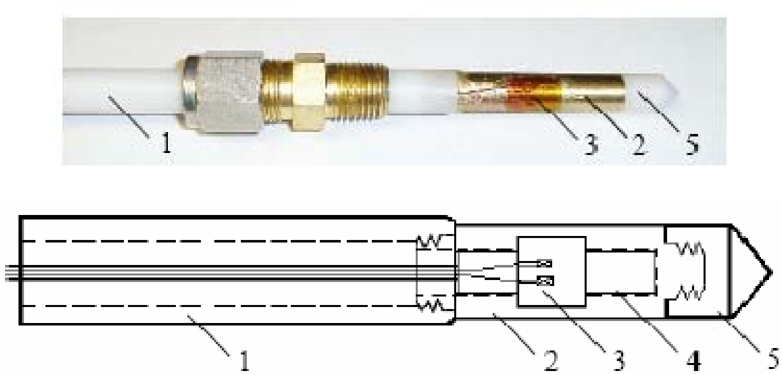

Figure 3-4. Photo and schematic diagram of the heat transfer probe

1. Teflon tube, 2. brass shell, 3. heat flux sensor, 4. heater, 5. Teflon cap.

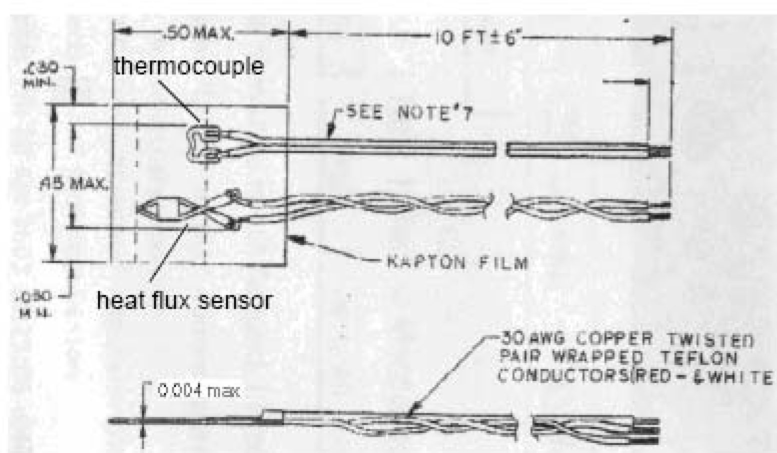

Figure 3-5. Schematic diagram of the heat flux sensor

(Provided by RdF Corpration, unit for the length is inch)

The measured signals of the heat flux, in the range of microvolts, need to be amplified before being sent to the data acquisition (DAQ) system. After being amplified, the heat flux signals, together with the signals from the thermocouples, were sampled at 50Hz for more than 40 seconds.

Since the heat flux, temperature of the probe surface, and the bulk media temperature could be directly measured, the local instantaneous and averaged heat transfer coefficient was estimated as follows:

$$h_i = \frac{q_i}{T_{si} - T_{bi}} \text{ , and}$$

$$h_{ave} = \frac{1}{n}\sum_{i=1}^{n}\frac{q_i}{T_{si} - T_{bi}} \text{ ,}$$

where h_i is the instantaneous local heat transfer coefficient, q_i is the heat flux across the sensor, T_{bi} is the instantaneous bulk temperature of the media, T_{si} is the instantaneous surface temperature of the probe, h_{ave} is the time averaged heat transfer coefficient, and n is the total number of the samples.