**6. The Effect of Thermal Stress on Heat Exchanger Tube Natural Frequencies**

Typically a heat exchanger operates such that the tubes are at one temperature and the shell at another. This temperature mismatch can result in significant thermally induced stresses in the tubes. This investigation should establish the effect of these thermal stresses on the natural frequency of vibration of the heat-exchanger tubes.

The frequency of vibration is important because the flow of the heat exchanger fluids *across* the tubes can excite vibration of the tubes. Adjoining tubes can hit, fret, and fail, or a tube can vibrate enough so that it is cut by the baffles. To prevent this from happening, the tube must be designed so that the natural frequency of the tube does not correspond to an important forcing frequency in the cross flow.

An apparatus has been constructed in the laboratory which allows the temperature of a tube to be varied while the length of the tube is maintained constant by a large outer pipe at room temperature. This apparatus has been welded as well as mechanically fastened and therefore it has ***not*** been assembled at room temperature. As a matter of fact, the tube is in tension at room temperature. Your job is to develop a theoretical model to predict the natural frequency of the tube, including the effect of thermal stress. You should use the experimental results from the apparatus to guide the development of the model and to confirm in detail the accuracy of the model. The resulting model of the natural frequency of the tube would be used by a heat-exchanger designer who would also have a model to predict the characteristic frequency of flow-induced vibration--this latter part of the problem is not your responsibility.