NATURAL CONVECTION HEAT EXCHANGERS FOR SOLAR WATER HEATING SYSTEMS

Technical Progress Report
October 1, 1995 to November 30, 1995

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Reporting Period: October 1, 1995 - November 30, 1995

Project Personnel: Jane H. Davidson
Scott Dahl, Graduate Research Assistant

Project Objectives:

The goals of this project are 1) to develop guidelines for the design and use of thermosyphon heat exchangers external to the storage tank in solar domestic water heating systems and 2) to establish appropriate modeling and testing criteria for evaluating the performance of systems using this type of heat exchanger.

Experimental Work

We are in the process of instrumenting the four tube-in-shell heat exchanger donated by Richard Lane of Public Energy Systems. A sketch of this heat exchanger is shown in Fig. 1. Planned experiments include measurement of the axial temperature distribution of the water in the center of the four tubes and wall temperature distribution on the outer surface of the shell. Testing protocol will remain identical to that used with the two-pass and finned tube-in-shell heat exchangers. Twenty additional temperature ports have been added to our data acquisition system to accommodate these measurements.

Model Development

In an effort to determine the impact of natural convection on heat transfer coefficients and pressure drop, we have completed a literature survey of the work in natural and mixed convection that may be useful in predicting thermal performance of these heat exchangers. We do not expect models which assume that either UA or effectiveness depend solely on flow rate to adequately predict performance.

The buoyancy parameter, Gr/Re^n, provides a measure of the influence of natural convection in comparison to forced convection. The power n depends on the flow geometry and surface heating conditions. Studies involving mixed convection in tubes, annuli, and rod bundles (e.g. Bernier and Baliga, 1992b; Bishop et al., 1980; Cebeci et al., 1982; El-Genk et al., 1993; Gau et al., 1992; Gruszczynski and Viskanta, 1983; Iannello et al., 1988; Jackson et al., 1989; Kemeny and Somers, 1962; Kim and El-Genk, 1989; Laouadi et al., 1994; Remizov and Kapinos, 1993; Shannon and Depew, 1968; Suh et al., 1989; Tsou and Gaus, 1992; Yao and Rogers, 1989) have found that buoyancy begins to affect the friction and heat transfer coefficients at Gr/Re values ranging between 300 and 800. Values of Gr/Re as high as 5000 are possible with the thermosyphon heat exchangers used in solar water heating applications. A 20% to 150% increase in the heat transfer coefficient and a 50% to 400% increase in the friction factor over laminar fully-developed forced flow correlations have been observed in the mixed convection studies, depending on the value of Gr/Re. Correctly assessing the influence of natural convection in the heat exchanger section is necessary to accurately predict the performance of natural circulation loops.
Fig. 1. Quad-Rod heat exchanger.

Other Activities

Mr. Sato Hirano, a visiting scientist from the National Institute for Resources and Environment, Tsukuba, Japan joined us September 1, 1995 and will work with us until April 1, 1996.

Future Activity

Continued fundamental analysis of the thermosyphon heat exchanger is underway and modeling efforts have begun. Scott Dahl is preparing his proposal for his doctoral dissertation.