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Refrigerant distribution in a parallel flow heat exchanger having vertical headers and heated horizontal tubes

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ABSTRACT

Refrigerant R-410a flow distribution is experimentally studied in a test section simulating a parallel flow heat exchanger having vertical headers with two pass configuration. Tubes are heated to yield a test section outlet superheat of 5 °C with inlet quality of 0.3. Mass flux is varied from 50 kg/m^2 s to 70 kg/m^2 s. Effects of inlet and outlet locations are investigated in a search for an optimum configuration. Results show that, significant liquid flows through bottom channels, and less liquid is supplied to top channels. As for the inlet location, better flow distribution (pressure drop as well) is obtained for top inlet as compared with middle inlet. As for the outlet location, top or bottom outlet is better than middle outlet. Correlations are developed for the fraction of liquid or gas taken off by downstream channel as a function of header gas Reynolds number at immediate upstream. The correlations may be used to predict the liquid or gas distribution in a parallel flow heat exchanger having vertical headers. A novel thermal performance evaluation method, which accounts for tube-side flow mal-distribution is proposed.

1. Introduction

Recent residential air conditioners are made to provide cool air during summer and warm air during winter. Such an operation is possible by use of a four-way valve, which reverses the refrigeration cycle. Then, an indoor heat exchanger, which acts as an evaporator during cooling season, becomes a condenser during heating season. Reverse is true for an outdoor heat exchanger. Thus, heat exchangers need to be designed with both evaporator and condenser operation in mind.

Round fin and tube heat exchangers are commonly used as condensers or evaporators of residential air conditioners. These heat exchangers, however, have inherent shortcomings due to usage of round tubes. The shortcomings include low thermal performance region behind round tubes, increased pressure drop due to round tubes, thermal contact resistance between fins and tubes. Such shortcomings may be alleviated by use of low profiled flat tubes. Brazed aluminum heat exchangers, which consist of flat tubes on the refrigerant-side and louver fins on the air-side, are seriously considered as indoor or outdoor heat exchangers in residential air conditioners.

In a brazed aluminum heat exchanger, a number of tubes are grouped to one pass using a header. This is necessary to manage the excessive pressure drop caused by the small channel size of the flat tube (typically $1 \sim 2$ mm). Due to such configuration, a brazed aluminum heat exchanger is also called a parallel flow heat exchanger. To use a parallel flow heat exchanger as a condenser, horizontal tube configuration is preferred (with headers in vertical position), because it ease the refrigerant flow. For evaporator usage, however, horizontal tube configuration has disadvantage on air-side condensate drainage. With conventional corrugated louver fins, air-side condensate flow is blocked by tubes. The situation may be improved if air-side condensate flow path is provided. Fig. 1 shows a conceptual drawing of a new fin, which may facilitate the air-side condensate drainage. Then, parallel flow heat exchanger with horizontal tube configuration may be used as an indoor heat exchanger (both evaporator and condenser) of a residential air conditioner. To use a parallel flow heat exchanger as an evaporator, it is very important to distribute the two-phase refrigerant (especially the liquid) evenly into each tube. Otherwise, the thermal performance is significantly deteriorated. According to Kulkarni et al. [1], the performance reduction by flow mal-distribution could be as large as 20%.

The literature reveals several studies on two-phase distribution in a header–branch tube configuration. In two-phase flow, many parameters – both geometric (header orientation, header size, tube size, tube protrusion depth, inlet orientation, etc.) and operating (mass flux, quality, heat load, etc.) – affect the flow distribution. Webb and Chung [2], Hrnjak [3], Lee [4], Ahmad et al. [5] provided

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