INTERNATIONAL JOURNAL OF REFRIGERATION 35 (2012) 278–289

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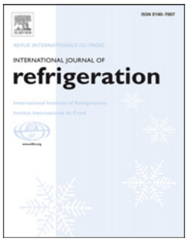

Performances of a split-type air conditioner employing a condenser with liquid–vapor separation baffles

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ARTICLE INFO

Article history:
Received 18 May 2011
Received in revised form
13 October 2011
Accepted 25 October 2011
Available online 10 November 2011

Keywords:
Air conditioning
Condenser
Refrigerant charge
Capillary tube
Performance

ABSTRACT

In this paper, a kind of heat exchanger with liquid–vapor separation baffles used as condenser was proposed for enhancing its thermal performance. Two HCFC22 air-conditioning units using the new heat exchanger and the traditional fin-and-tube heat exchanger respectively were constructed. The optimal system refrigerant charge amount and capillary tube length for both systems were experimentally investigated. The results showed that the enhanced condenser unit could supply the equivalent cooling capacity and energy efficiency ratio (*EER*) as those of the baseline one at the standard cooling condition when it had only 63.1% condenser heat transfer area and 80.3% charge amount of the baseline unit. Compared with the baseline unit, the cooling capacity and *EER* of the new unit were reduced more significantly at undercharge conditions, but their degradations were limited at overcharged conditions. Discharge and suction pressure, mass flow rate, subcooling and superheating degree were also investigated and discussed.

Performance d'un conditionneur d'air de type split utilisant un condenseur muni de chicanes pour la séparation liquide / vapeur

Mots clés : Conditionnement d'airl ; Condenseur ; Charge en frigorigène ; Tube capillaire ; Performance

1. Introduction

The thermal performance of condenser concerning energy, material and cost savings of air conditioner and refrigeration systems, consequently to environmental degradation, has led to the development of many heat transfer enhancement techniques in refrigeration industry. Air-cooled condensers of domestic air-conditioning units are widely domains of in-tube condensation. The condensation heat and momentum transfer inside tubes are strongly influenced by flow regimes. The heat transfer coefficient in annular flow increases with increasing mass flux, vapor quality and saturation

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doi:10.1016/j.ijrefrig.2011.10.014

Nomenclature

Q_r	cooling capacity, W
T	temperature, °C
DB	dry-bulb temperature, °C
WB	wet-bulb temperature, °C
OD	outer diameter, mm
ID	inner diameter, mm
k	coverage factor
Unit 1	air conditioner employing ordinary condenser
Unit 2	air conditioner employing liquid–vapor separation condenser
EER	energy efficiency ratio
EER *ratio*	ratio of EER value to 2.8
Cooling capacity ratio	ratio of cooling capacity to 2400
u	relative standard uncertainty
q_m	mass flow rate, kg s^{-1}
h_1	inlet enthalpy, kJ kg^{-1}
h_2	outlet enthalpy, kJ kg^{-1}
N	power consumption, W

temperature; but in the stratified regimes it is affected by temperature difference between saturation temperature and tube wall temperature (Dobson and Chato, 1998; Cavallini et al., 2001).

Using enhanced tubes is the most common technique to enhance condensation heat transfer in application. Enhanced tubes usually have special surface geometries, such as rough surface and extended surface. These surfaces can increase the effective exchange area, and induce turbulence in the liquid film as well as enhance surface tension effect on the condensate drainage. However, a distinct increase of pressure drop always companies with a heat transfer enhancement. The most used enhanced tubes are micro-fin, cross-grooved and herringbone tubes with inner tube diameter in the range of 7–9.5 mm, and up to 15 mm for large equipment. Micro-fin tubes show a heat transfer enhancement from 80 to 180% and over, with an increase in pressure loss from 20 to 80%, compared to equivalent smooth tubes under the same operating conditions. Cross-grooved tubes give a 25–30% higher heat transfer performance than micro-fin tubes with a 6–10% higher pressure drop (Cavallini et al., 2003; Han and Lee, 2005). Compared with an inner grooved tube at the same operative conditions, a herringbone tube was found to enhance heat transfer coefficient 200% and its pressure loss increased around 30%–50% (Ebisu and Torikoshi, 1998).

The use of flat extruded aluminum multi-port minichannel is another emerging technology for in-tube condensation in domestic units, which can be designed as channels with small hydraulic diameters down to 0.45 mm. The advantages of microchannel condensers over traditional fin-and-tube condensers are compactness, a reduced airside pressure drop and a reduced refrigerant charge (Cavallini et al., 2003). It was reported that the overall heat transfer coefficient of the microchannel heat exchanger was 62% higher than that of a plate-type condenser, even with 23% less refrigerant content (Fernando et al., 2008). To manage the excessive pressure drop by the small channel of the flat tube, multi-port design is necessary to reduce the mass flow rate inside tube for this kind of condenser. However, multi-port condenser raises the problem of ensuring uniform refrigerant distribution by the typical non-uniformities of two-phase flows in each microchannel. Otherwise, both thermal and fluid-dynamic performances deteriorated (Kim et al., 2011; Marchitto et al., 2008).

Peng et al. (2002, 2006) presented a novel method of enhancing in-tube condensation heat transfer. Its enhancement mechanism can be explained using the experimental results of R22 condensing inside a long horizontal tube presented by Dobson and Chato (1998), as seen in Fig. 1 At high flow rates, the flow regime of condensation were observed as annular-mist flow, followed sequentially by annular, wavy-annular and slug, as the quality decreased. The local heat transfer coefficient decreased with the condensation proceeding due to the thickness of liquid film increasing, especially in stratifying flow at the end of tubes. Fig. 1 shows the enhancement idea of Peng et al. (2002, 2006) that they divide a long condensing tube into several sections and set one liquid–vapor separator between each two adjacent sections. Liquid refrigerant was removed away by the liquid–vapor separator before coming into the next section and leave only vapor continuing condensing. When most vapor refrigerant condensed into liquid, all of them were collected together entering subcooling tubes. Because annular flow always occurs at high vapor quality along the entire tube even at low mass flux, a higher transfer coefficient of condensation would be expected (Boissieux et al., 2000; Islam and Miyara, 2007). Moreover, the uniform flow distribution within the whole condensation zone was easy to attain for the approximate single-phase vapor refrigerant. Additionally, each section should not be so long for keeping annular flow pattern, and the tube number or the flow passage area of each pass was designed to be reduced due to less and less vapors left with the flow process.

In this paper, we designed and manufactured a liquid–vapor separation condenser (LSC) according to the enhancement idea proposed by Peng et al. (2002, 2006). It has been

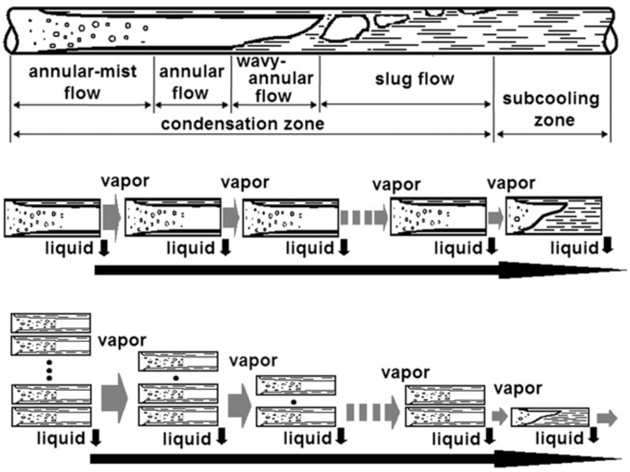

Fig. 1 – Schematics diagram of liquid–vapor separation condenser.