Summary of Recent Technical Literature from China on Small Diameter Copper Tubes for Air-conditioning Applications

Current research results from the Chinese small-diameter copper tube research consortium as well as Chinese OEMs form a foundation for the development of residential air conditioning (RAC) products that use less material and are more economical than RAC products made with conventional tubes.

Wenson Zheng, Frank Gao and Kerry Song from the Shanghai Office of the International Copper Association Ltd. coauthored four research papers relating to small-diameter copper tubes in cooperation with two Chinese Universities [1-4]. They collaborated with the School of Energy & Power Engineering at Xi'an Jiaotong University on heat-exchanger design projects [1, 2]; and they collaborated with the Institute of Refrigeration and Cryogenics at Shanghai Jiaotong University, Shanghai, China, on the condensation of refrigerant-oil mixtures in small diameter tubes [3, 4].

Also, Chinese air-conditioner OEMs recently published three papers on small-diameter copper tubes [5-7]. Researchers from Guangdong Chigo Air Conditioning reported on the performance of small-diameter copper tubes in an evaporator for residential air conditioners [5]; and researchers from Guangdong Midea Refrigeration Appliances reported on small-diameter inner-grooved copper tubes in a split air-conditioning system [6]. Finally, researchers from Shanghai Golden Dragon Refrigeration Technology Company presented detailed performance data and a cost analysis for heat exchangers made from small-diameter copper tubes [7].

These university research results and OEM investigations relating to small diameter copper tubes are summarized below.

Tube Circuitry and Fin Design

The performance of condensers made from small diameter tubes was modeled and simulated at the School of Energy & Power Engineering, Xi'an Jiaotong University, Xi'an. Separate papers were published on the tube circuitry [1] and the other on fin design [2].

The tube-circuitry research compared conventional-diameter (Φ7mm) tubes with small-diameter (Φ5mm) tubes [1]. Simulations predict higher refrigerant pressure drops for small-diameter tubes. Nonetheless, by increasing the number of circuit branches, decreasing the single branch length and adding more tubes in the circuit design, refrigerant pressure drop could be kept within a factor of two for almost the same heat exchange rate and a significant saving in tube materials. Further reducing the refrigerant pressure drop remains a key issue for practical applications.

Researchers at Xi’an also studied fin designs for heat exchangers made with small-diameter (Φ4mm) tubes [2]. Firstly, for reference, numerical simulations were conducted on reference fins with conventional-diameter (Φ7mm) tubes, including various louvered and slotted-fin heat transfer surfaces. Then, based on nearly optimized values, new louvered-fin and slotted-fin structures were proposed and simulated for small-diameter (Φ4mm) tubes. The fin designs with the small-diameter tubes matched the heat transfer requirements for the reference louvered fin while greatly reducing the copper tube material in the new heat exchanger.

Heat Transfer Coefficients

The condensation heat-transfer characteristics of an R410A-oil mixture inside small-diameter smooth copper tubes was investigated experimentally by researchers from the Institute of Refrigeration and Cryogenics at Shanghai Jiaotong University, Shanghai [3,4].

In one study, the heat-transfer coefficient (HTC) was found to decrease with the increasing oil concentration [3]. For small diameter smooth tubes, it decreased by a maximum of 28.5 percent at an oil concentration of five percent. A correlation was proposed between the heat transfer coefficient and oil concentration for R410A-oil mixture flow condensation inside smooth copper tubes. The proposed correlation agreed with all experimental data within a deviation of –30 percent to +20 percent.

In another study, the two-phase heat transfer characteristics for flow condensation of an R410A-oil mixture inside small diameter microfin copper tubes were investigated experimentally [4]. Effects on heat transfer were negligible at one percent nominal oil concentration but the heat transfer coefficient deteriorated by 25.1 percent at five percent nominal oil concentration. The correlation of Yu and Koyama is recommended to predict the local condensation heat transfer coefficient of R410A-oil mixture inside small diameter microfin tubes.

Materials Reduction in Evaporator Application

Researchers at the Guangdong Chigo Air Conditioning in Foshan, Guangdong, compared the performance of conventional diameter (Φ7mm) and small-diameter (Φ5mm) inner-grooved copper tubes in an evaporator application for a residential air conditioner [5]. Heat-transfer coefficients, fluid pressure drops and system performance were compared. For the Φ5mm tube, copper usage was lowered by more than 43 percent and cost reduced by around 40 percent while increasing the cooling capacity, energy efficiency ratio (EER) and air volume.

Refrigerant Charge Reduction

Researchers at the Refrigeration Research Institute of Guangdong Midea Refrigeration Appliances Group in Shunde, China conducted R410A and R290 performance experiments on split air conditioners with small diameter (Φ4mm) heat exchanger tubes [6]. Without sacrificing any performance, the 4mm tubes reduced the volume and cost of the heat exchanger and significantly lowered the refrigerant charge.

Performance and Cost Analysis

Researchers at the Shanghai Golden Dragon Refrigeration Technology Co., Ltd. Shanghai reported performance results and a cost analysis for conventional diameter (Φ9.52mm) and small diameter (Φ5mm) inner-grooved copper tubes as well as heat exchangers made with these two tube types [7]. For the same experimental conditions and volume flow, the heat exchange coefficient is about 15% higher for the Φ5mm inner-grooved copper tube than the Φ9.52mm inner-grooved copper tube. For the same operating conditions the same windward dimensions, comparing a Φ5mm copper tube heat exchanger with a Φ9.52mm copper tube heat exchanger, the former uses 41.8 percent less copper material for the tubes and 50 percent less aluminum foil material in the fins.

References

1. Wei-kun Ding *et al.* (Xi'an and ICA) "Development of Small-diameter Tube Heat Exchanger: Circuit Design and Performance Simulation," presented at the Conference on Thermal and Environmental Issues in Energy Systems, Sorrento, Italy, May 2010 (CTEI-ES 2010).

2. Ju-fang Fan *et al.* (Xi'an and ICA) "Development of Small-diameter Tube Heat Exchanger: Fin Design and Performance Research," presented at CTEI-ES 2010.

3. Guoliang Ding *et al.* (Shanghai and ICA) "Condensation heat transfer characteristic of R410A-oil mixture inside small diameter smooth copper tubes," presented at CTEI-ES 2010.

4. Guoliang Ding *et al.* (Shanghai and ICA) "Two-phase heat transfer characteristics of R410A-oil mixture flow condensation inside small diameter microfin copper tubes," presented at presented at CTEI-ES 2010.

5. You Shunyi *et al.* (Guangdong Chigo Air Conditioning Co.) "Application of Small Diameter Inner-Grooved Copper Tubes in Air-Conditioning Systems," presented at Second IIR Workshop on Refrigerant Charge Reduction, Stockholm Sweden, June 2010 (RCR 2010).

6. Jia Qingxian *et al.* (Guangdong Midea Refrigeration Appliances Group) "Experimental Research for Lowering Refrigerant Charge with 4mm Tube Heat Exchanger," presented at RCR 2010.

7. Wu Yang *et al.* (Shanghai Golden Dragon Refrigeration Technology Co.) "Performance and Cost Analysis and Research of Air-Cooled Heat Exchanger Using Small Diameter Copper Tubes," presented at RCR 2010.