Copper Development Association Inc.

A Copper Alliance Member

Small-Diameter Copper Tube's Role in Maximizing Dehumidifier Performance: A Case Study with AprilAire

OTS R&D, Inc., in collaboration with the Copper Development Association (CDA), provides design support to optimize copper tube aluminum fin heat exchangers for commercial dehumidification.

Problem

In collaboration with the Copper Development Association (CDA) and OTS R&D, Inc. (OTS), AprilAire, a manufacturer of dehumidification equipment, sought to maximize the performance of their products in both standard and low-temperature operating conditions while avoiding frost accumulation on the evaporator.

Traditional dehumidifiers often lose efficiency as frost accumulates, leading to disruptions in conditioning and temporary spikes in humidity. The question was whether small-diameter copper tube fin heat exchangers could maintain or increase efficiency while preventing frost accumulation in these unique operating conditions.

OTS is a CDA partner that provides crucial heat transfer and system integration expertise to the industry, specifically in air conditioning, heat pumping, refrigeration, and energy conversion. Having roots with faculty and research at the University of Maryland, OTS supports innovation and next-generation product development using industry-leading software.

Solution

Through extensive research and simulation using the CoilDesigner® tool, the OTS project team explored various heat exchanger designs and airflow rates to identify optimal configurations. The study focused on reducing the outside diameter of the copper tubes from conventional values to 5mm and selecting copper as the tube material.

The optimization study considered seven different tube fin geometries, ranging from 5mm OD options to 7.94mm OD tubes. Various parameters such as fin density, coil height, number of tubes, circuitry, and airflow rates were analyzed to maximize dehumidification rate, efficiency, and frost avoidance while minimizing material consumption and refrigerant charge.

Using small-diameter copper tubes (5mm) provides several benefits for heat exchangers and overall advantages for original equipment manufacturers (OEMs).

Reducing the diameter of copper tubes within coils offers a cost-effective avenue for enhancing system energy efficiency. While alternative methods might bolster system energy efficiency by increasing the number of conventional tubes, this approach incurs penalties such as augmented weight in tube and fin materials and heightened refrigerant volume. Conversely, reducing tube diameter fosters more efficient heat transfer and yields smaller, lighter coils. This reduction in materials can maintain or even enhance heat transfer efficiency while enabling smaller overall product dimensions, facilitating easier storage, transport, and installation, and ultimately reducing the footprint at the point of use.

Moreover, small-diameter copper tubes present a significant advantage in reducing refrigerant volume within systems. The diminished internal volume of the coils necessitates less refrigerant to charge, leading to further benefits in system design, including a notable decrease in overall system weight. Coils constructed with copper tubes and aluminum fins (CTAF) or copper tubes and copper fins (CTCF) stand as enduring and reliable solutions within the industry, setting the standard for corrosion resistance and long-term service life.

With a high level of familiarity across the supply chain, from tube suppliers to HVAC/R contractors, the transition to these innovative copper tubes ensures continuity in fabrication, assembly, installation, service, repair, and recyclability processes, maintaining efficiency and reliability throughout.

Results

At the conclusion of the project, the team identified 13 candidate designs meeting the product requirements, with seven using 5mm OD tubes and six using 7.94mm tubes. The optimized 5mm design showcased significant improvements over conventional designs, with a 5% increase in dehumidification rate and efficiency, a 15% reduction in material mass, and a 60% reduction in internal volume (refrigerant charge). The predicted efficiency at the standard rating condition exceeded the target requirement by 4%.

Comparing the 5mm and 7.94mm designs, the former offered substantial advantages in terms of material consumption, material cost, and internal volume reduction while maintaining performance, achieving reductions of 42%, 48%, and 50%, respectively,. Moreover, the 5mm condenser variant was approximately 31% less deep in the airflow direction, allowing for a larger evaporator depth and surface area.

Cara Martin, CEO of OTS R&D, Inc., shares her insights on the project, stating:

"The project utilized advanced simulation tools to identify viable heat exchanger combinations that unlock a new level of dehumidification performance in challenging conditions. AprilAire will further review the wide range of design options for prototyping and testing, with the expectation that this effort will significantly cut down experimental trial and error in the product development process."

In conclusion, optimizing copper tube aluminum fin heat exchangers for commercial dehumidification applications represents a significant advancement in HVAC/R technology. By reducing tube diameter and selecting appropriate materials, manufacturers can achieve higher efficiency, lower material consumption, and improved performance in challenging operating conditions, ultimately enhancing user experience and satisfaction.

Marcus Elmer, CDA Director of Tube and Fittings, adds:

“At CDA, we understand that every project is unique and requires specialized guidance and expertise. That's why we work closely with our established partner network to provide customized design, simulation, testing, or evaluation support to OEMs like AprilAire.

“By collaborating with CDA and our expert partners,” he continues, “you gain access to a wealth of resources, state-of-the-art facilities, and a deep understanding of the latest trends and technologies.”

Get in touch with the Copper Development Association to partner on researching and developing air conditioning, refrigeration, and heat pump systems and components; in particular, design, analysis, and optimization of tube-fin, small-diameter copper tubes, and brazed plate heat exchangers.