Copper Development Association Inc.

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# Improving Heat Pump System Performance through Small-Diameter Copper Tube and Design Optimization: A Case Study with Whirlpool Corporation

***OTS R&D, Inc., in collaboration with the Copper Development Association (CDA), provides design support to evaluate alternative evaporator and condenser designs for a Whirlpool laundry appliance heat pump transitioning from refrigerant R134a to a low-GWP alternative.***

## Problem

In collaboration with the Copper Development Association (CDA) and OTS R&D, Inc. (OTS), Whirlpool Corporation, a global leader in kitchen and laundry appliances, sought to optimize the performance of a heat pump laundry appliance. Facing the challenge of transitioning from refrigerant R134a to a low global warming potential (GWP) alternative, OTS provided design support to evaluate alternative evaporator and condenser designs. The goal was not only to comply with new refrigerant regulations, but also to improve product performance.

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.

The existing Whirlpool heat pump system utilized 8mm aluminum tubes with aluminum dog-bone fins in both the evaporator and condenser, using refrigerant R134a. However, with the need to transition to a new refrigerant, Whirlpool had to identify design changes to enhance performance. The study's primary objectives were to increase heat exchanger capacity, decrease material weight, and reduce air-side pressure drop to lower fan power consumption.

## Solution

OTS conducted an exhaustive analysis of the evaporator and condenser to identify new designs that met the desired parameters and goals. The evaporator analysis focused on identifying designs that considered the change in refrigerant and targeted goals for the next-generation evaporator. More than 55,700 candidate models were generated, with 1,149 designs meeting the criteria for further evaluation.

OTS implemented several changes in the proposed designs, including reducing the outer tube diameter (O.D.) from 8mm to 5 mm, changing from aluminum to copper tubes, and replacing dog-bone fins with regular flat fins. These design changes resulted in compact, lightweight designs that offered increased secondary heat transfer area, reduced tube-fin contact resistance, and improved thermal conductivity.

The use of small-diameter copper tubes provides several benefits for heat exchangers and overall advantages for original equipment manufacturers (OEMs). Copper tubes offer high thermal conductivity, ensuring efficient and rapid heat transfer in the wall of the tube. Copper is also highly durable, with excellent resistance to corrosion and biofouling.

Copper offers a predictable metal that's easy to manufacture due to its precise temper, allowing for inner grooving maximization that improves the heat transfer properties of the tube.

Small-diameter copper tubes have superior strength, allowing for thinner walls and resulting in smaller diameters while maintaining the same strength level as larger tubes. As a result, less material is needed to manufacture the tubes, reducing cost and making the tubes an economical choice. Manufacturing and repair costs are important considerations, and copper tubes in heat exchanger coils can offer significant cost savings while providing superior performance and durability.

## Results

The analysis of the evaporator designs revealed a set of Pareto optimal designs with the most preferred options outperforming the baseline coil in terms of weight reduction, air-side pressure drop, internal volume (refrigerant charge reduction), and latent load.

The new 5 mm evaporator designs can achieve a weight reduction between 9% to 76%, a reduction in air-side pressure drop between 2% to 79%, and up to a 6% increase in latent load as compared to the 8 mm baseline design using the alternative refrigerant. These compact designs were made possible by the change from dog-bone to regular flat fins, the increased thermal conductivity of the copper tubes, and reduced tube diameter, which allows tighter tube packing.

Similarly, the analysis of the condenser designs resulted in a set of selected designs that surpassed the performance of the baseline coil. The new 5 mm condenser designs can achieve a weight reduction between 21% to 27%, a reduction in air-side pressure drop between 2% to 7%, and up to a 3% increase in heat load as compared with the 8 mm design using the alternative refrigerant. These improvements were attributed to the increased secondary heat transfer area, reduced tube-fin contact resistance, and reduced number of tube banks in the airflow direction.

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

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“Through our collaboration with Whirlpool and the Copper Development Association, we identified compact heat exchanger designs that significantly improved product performance. The switch to copper tubes, combined with the reduced diameter and flat fins, allowed for higher heat transfer efficiency and reduced weight.”

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 Whirlpool.

“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 the research and development of 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.