

## R600a Appliances Benefit from the MicroGroove Advantage, Says ICA

*Smaller Diameter Copper Tubes Allow for Smaller Volumes of Flammable Refrigerant*

**New York, New York (15 January 2018)** – According to the International Copper Association, Inc. (ICA), MicroGroove is playing an essential role in the development of refrigeration systems made with isobutane (R600a). Already most products in this category use copper tubes with outer diameters of five-sixteenths inch (7.9 mm) or one-quarter inch (6.35 mm). Copper tube diameters smaller than conventional three-eighths inch copper tubes (9.525 mm) are considered to be MicroGroove.

### MicroGroove and R600a

International regulations have placed limits on the allowable refrigerant charge for isobutane because of its flammability. That limit is 150 grams in Europe and it has been 57 grams in the USA for residential applications. If the use conditions are 150 grams then there is no need to further reduce refrigerant charge.

A leading manufacturer of high-quality residential refrigerators and freezers, Sub-Zero recently considered adopting even smaller diameter MicroGroove tubes. The company initially was motivated to meet the 57-gram “use conditions” on isobutane, a flammable refrigerant. The 57-gram limit would be challenging to meet and drastic measures would be necessary as F-Gases are phased out by the year 2021. That led Sub-Zero to explore the advantages of MicroGroove tubes with copper tube outer diameters of 5 mm.

### Collaboration with OTS

Optimized Thermal Systems, Inc. (OTS) offers customized software and services for the design and optimization of thermal systems. Engineers from Sub-Zero approached OTS for assistance in using CoilDesigner®, a proprietary heat exchanger design and simulation software tool. The primary objective was to design a condenser coil that would equal the performance of the existing (baseline) coil while lowering the refrigerant charge. Secondary objectives were to reduce the total footprint of the coil and the total tube-and-fin material mass.

### Baseline Condenser

The baseline condenser coil uses quarter-inch copper tubing, flat plate fins and a low fin density. The condenser has two refrigerant circuits, with each circuit serving an independent vapor compression cycle for the refrigerator and freezer compartments. A CoilDesigner® model of the condenser was developed and validated against experimental data.

Prior to evaluating potential small diameter replacements, a study was conducted to evaluate the effect of refrigerant circuitry on the existing coil performance. Three operation modes were evaluated: only the refrigerator circuit running, only the freezer circuit running, and both circuits running.

It was found that by extending both refrigerant circuits to cover the entire face area of the coil instead of half of the face area, the thermal performance of the circuit improved during single circuit operation; that is, the heat load and refrigerant sub-cooling increased for both refrigerator and freezer circuits.

From this initial review, the best circuitry design was selected and used as the baseline reference for the optimization study.

### **Smaller Diameter Tubes**

The optimization study was conducted to identify condenser designs that could reduce the internal volume and lower the refrigerant charge. Five millimeter tube designs were evaluated and compared to the baseline design and significant reductions were found in internal tube volume. The best 5-mm design reduced the internal tube volume by as much as 41 percent as compared to the baseline, along with a 57 percent reduction in coil footprint.

The new designs used wavy-herringbone fins with a reduced fin thickness as compared to the baseline. Other variables included the horizontal and vertical spacing of the tubes; number of tubes per bank; fin density; wavy fin pattern depth; tube circuitry; and tube length. The design criteria are as follows.

- Heat rejection greater than or equal to the heat rejection of the baseline design;
- Sub-cooling equal to or greater than sub-cooling of the baseline coil; and
- Saturation temperature drop kept within one degree of the baseline.

### **Airside Pressure Drop**

Multiple factors contributed to an increase in airside pressure drop with the smaller diameter tube coils, including fin type, face area of the coils, and fin density. The baseline system used flat fins, yet all of the optimized designs used wavy fins, which inherently contribute to higher pressure drops. The face area was reduced for all coils to maintain the tube spacing ratio; yet, for a fixed airflow volume, reduced face area increases the air velocity.

Nonetheless, for this application, reduced internal volume was considered to be more important than the airside pressure drop. The fan motors used in this system can overcome the increased resistance and compensate for the increase in airside pressure drop.

### **Conclusions**

In summary, OTS identified several new condenser designs with significant potential to reduce internal volume while maintaining performance, and thereby reducing total system charge. The increased airside pressure drop of the designs can be accommodated by the existing fan motors. The reduced footprint of the coils allows for a smaller enclosure.

This study is a starting point for the development of high performance condenser coils for this application. With a high-performance condenser, condenser fan speed can be reduced, resulting in a quieter refrigerator unit. Also, less fouling could be useful in the condenser, requiring less maintenance.

“R600a will play a key role in refrigeration systems for many years to come,” said Nigel Cotton, MicroGroove Team Leader for the International Copper Association. “As MicroGroove tubes and coils are uniquely suited for use with propane, so they are also well suited for isobutane. The Sub-Zero study has set a benchmark for the use of MicroGroove with R600a.”

The website [www.microgroove.net](http://www.microgroove.net) includes additional data relating to heat exchanger design and manufacturing technology. It also includes links to the MicroGroove series of webinars. A technical literature section provides links to technical papers relating to laboratory experiments, tube circuitry optimization, fin design and manufacturing equipment.

### **About ICA**

ICA brings together the global copper industry to develop and defend markets for copper and to make a positive contribution to society’s sustainable-development goals. Headquartered in New York, the organization has offices in four primary regions: Asia, Europe and Africa, Latin America and North America. Copper Alliance® programs and initiatives are executed in nearly 60 countries through its regional offices. For additional information please visit [copperalliance.org](http://copperalliance.org).

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