microgroove™ Update

Attain High Energy Efficiency with Less Materials Using Smaller-Diameter, Inner-Grooved Copper Tubes

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SMALLER DIAMETER COPPER TUBES EXPAND INTO DIVERSE APPLICATIONS

Not many years ago there were just a handful of MicroGroove applications but that's no longer the case. MicroGroove smaller-diameter copper tubes can be found in a myriad of products, from small to very large, with tube lengths ranging from a few inches to several meters; and capacities ranging from hundreds of watts to hundreds of kilowatts.

Today MicroGroove heat exchangers are enabling high efficiency in diverse and dissimilar products, from cold vending machines and cold display cases to clothes drying heat pumps and mobile refrigeration systems. And that's not even mentioning the broad array of air conditioning systems such as window units, central AC, split systems, VRF systems and packaged systems, which benefit from materials savings and reduced refrigerant volumes.

Large commercial and industrial systems, too, are built using MicroGroove tubes. Once the small diameter tubes are interlaced with aluminum fin plates and mechanically expanded, the ruggedness of the round tube plate fin (RTPF) heat exchangers is remarkable. Such are highly valued for their corrosion resistance. Consequently, there is scant chance of a leak even under harsh environmental conditions. That means MicroGroove designs are favored in outdoor condensers and process cooling equipment.

Let's take a closer look at the advantage of MicroGroove in select products from these broad classes. Of course, there will be some overlap between arbitrary classifications but for the purpose of this article we can group the coil sizes into small, midsize and large. Within each of these size classes, one could find evaporators and condensers working with many types of refrigerants in an array of applications.

SMALL MICROGROOVE COILS

Perhaps amongst the smallest-sized applications are the condensers and evaporators for bottle coolers and cold display cases, especially those using R290 as a refrigerant. R290's ultralow Global Warming Potential value (GWP of 3) makes it highly desirable as a refrigerant. However, R290 is flammable and so EPA regulations currently limit the mass of R290 refrigerant to 150 grams (which is about 5.3 ounces). The smaller diameter tubes increase the heat transfer efficiency, making it not only possible but also economical to use propane in eco-friendly applications. Recently True Manufacturing produced videos relating to its R290 products. One describes ecofriendly products in a general way (Hydrocarbon Now) and the other is a training resource for technicians, showing how to replace the refrigerant in the heat exchangers that are actually used in these products (R-290 Service Training).

PRESENTATIONS

UPCOMING EVENTS

2016 ATMO America Conference
Jun 16 2016 - Jun 17 2016
The Westin Michigan Ave, Chicago, Illinois

Purdue Conference on Refrigeration and Air Conditioning
Jul 11 2016 - Jul 14 2016
Stewart Center, Purdue University

IIR 12th Gustav Lorentzen Natural Working Fluid Conference
Aug 21 2016 - Aug 24 2016
Edinburgh, Scotland

FEATURE ARTICLE

Yoram Shabtay and Nigel Cotton, "Trends in the Design and Manufacture of Round-Tube Plate-Fin Coils from Smaller Diameter Copper Tubes," *International Appliance Manufacturing magazine, October 2015.*

www.microgroove.net/sites/default/files/microgroove_reprint-final.pdf

RECENT WEBINARS

"A Practical Update on Advanced Copper Alloys and On-Site Joining Methods for HVACR Systems"
Sponsored by the Copper Development Association
Speaker: John Hipchen, Exel Consulting
Moderated by Lori Schiavo, Publisher of the RSES Journal
www.microgroove.net/practical-update-advanced-copper-alloys-and-site-joining-methods-hvacr-systems

For more information, see the MicroGroove "Webinars" webpage
www.microgroove.net/webinars

Also see MicroGrooveTech YouTube channel for archive of past webinars
www.youtube.com/user/MicroGrooveTech

Figure 1: Cutaway view of outdoor condenser which uses 5 mm copper tubes. (*Image Courtesy of Goodman)*

MIDSIZE MICROGROOVE COILS

Goodman was an early adopter of MicroGroove tubes for air-conditioning. **(See Figure 1.)** How Goodman (now Daikin) came to develop the 5 mm diameter copper SmartCoil for residential central AC is described in the October 2013 issue of *International Appliance Manufacturing* magazine as well as in the January 2014 issue of *MicroGroove Update* (MGU).

Another maker of AC condensers is Spirotech. **Figure 2** shows a residential condenser for a two refrigeration-ton (RT) split system. (Note that 2 RT = 7.03 kilowatts.) **Figure 3** shows a 1.5 RT (i.e., 5.28 kW) window unit. Spirotech established its MicroGroove processing line in 2012 and has been producing diverse heat exchangers ever since. **Figure 4** shows a condenser from Spirotech that serves as a heater for clothes dryer. Other outstanding MicroGroove products from Spirotech are an R744 gas cooler **(Figure 5)** and a finless copper heat exchanger **(Figure 6)**.

Lordan is a coil-maker with expertise in various and sundry heat exchanger designs using MicroGroove copper tubes. Lordan was one of the first companies to adopt 7-mm copper tube technology and it continues to set trends for product development with its Lord-Five (5-mm copper tube) product line. **(See Figure 7.)** The company designs and builds coils of all sizes from the small to midsize to very large. One remarkable and interesting application is a mobile refrigeration system. These coils are used in trucks and vans that deliver ice cream

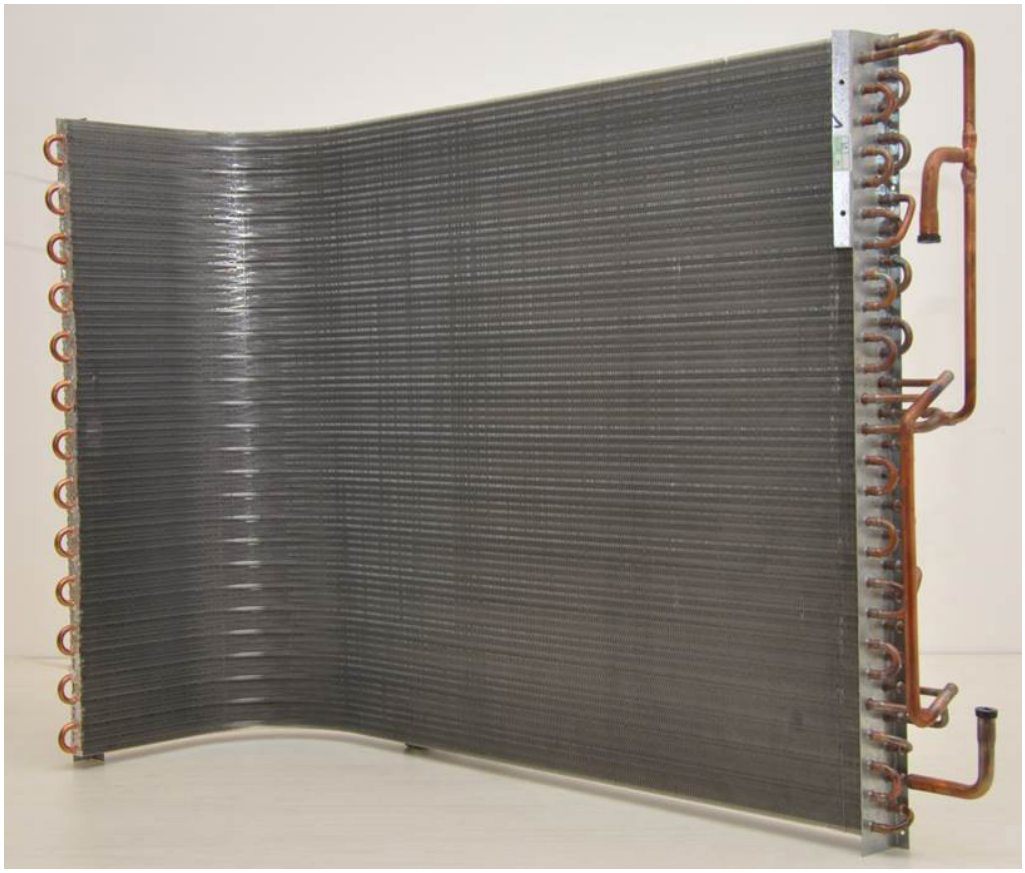

Figure 2: MicroGroove coil for 2 RT condenser split system. (*Courtesy of Spirotech*)

Figure 3: MicroGroove coil for 1.5 RT condenser. (*Courtesy of Spirotech)*

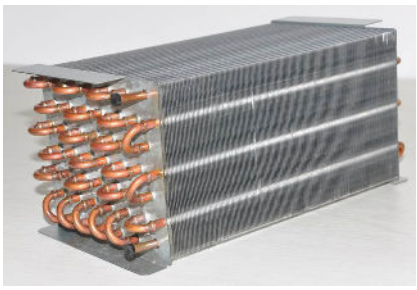

Figure 4: A MicroGroove condensing coil provides heat for clothes dryers. (*Courtesy of Spirotech)*

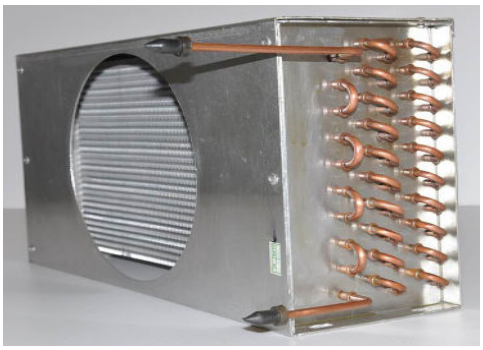

Figure 5: R744 Gas Cooler. (*Courtesy of Spirotech*)

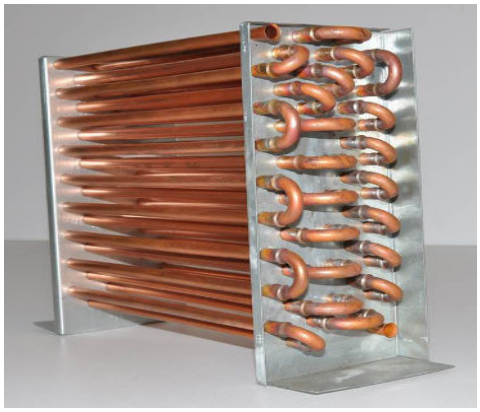

Figure 6: A finless copper heat exchanger. (*Courtesy of Spirotech*)

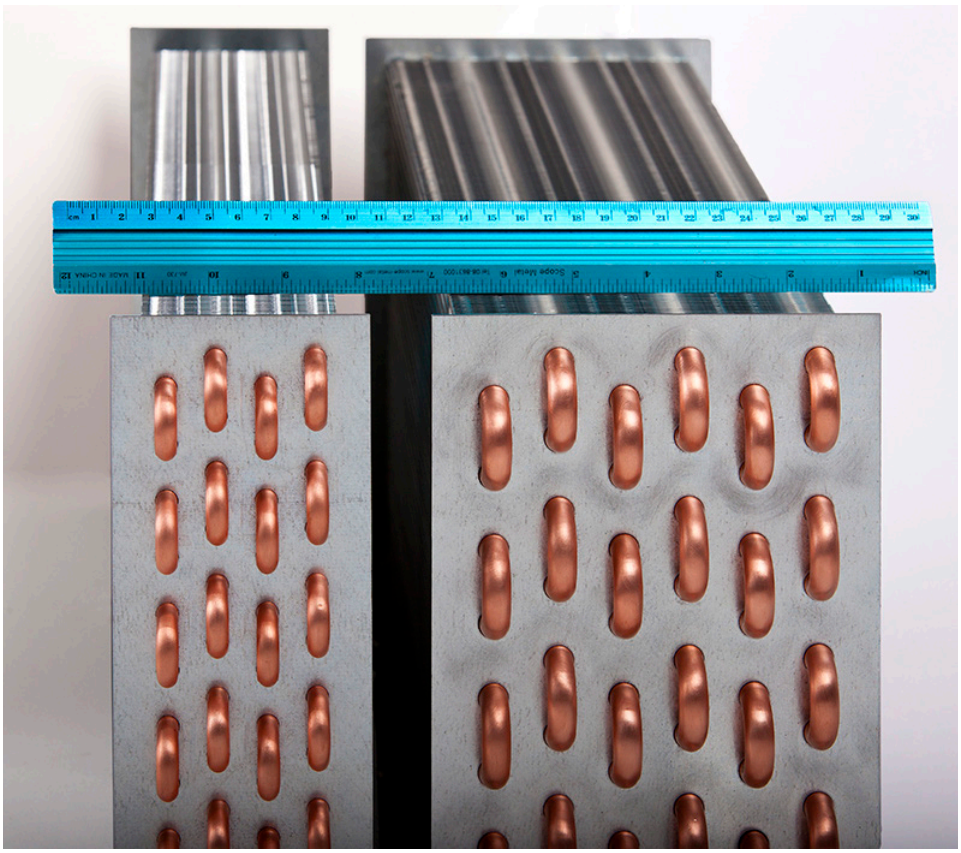

Figure 7: Two coils, comparing 5-mm and 7-mm MicroGroove copper tubes. (*Courtesy of Lordan.*)

to resorts along the coast of the Dead Sea where temperatures often climb above 100 °F. Lordan heat transfer engineer Peter Mostovoy reports that smaller diameter copper tubes outperform microchannel aluminum tubes because the efficiency of the latter drops off rapidly at ambient temperature above the narrow range of temperatures for which the microchannel coil has been optimized. The same is not true for MicroGroove coils which continue to perform satisfactorily even at the high ambient temperatures.

Heat Transfer Solutions, one of the largest producers of condenser and evaporator coils in the world, uses heavy-wall 5 mm, 7 mm, 1/4" and 5/16" diameter copper tubes in coils for countless refrigeration applications of all sizes. An example is the UL-approved Heatcraft coil for use with R744 as a refrigerant as described in the July 2015 issue of MGU.

Super Radiator Coils also builds all sizes of heat exchangers with MicroGroove copper tubes for use with a variety of refrigerants, including propane (R290) and CO2 (R744). Case studies of several of these coils were presented at ATMO America 2015 and new case studies will be presented at ATMO America 2016 in Chicago (See MicroGroove Events webpage.) Most recently, for an R290 air-conditioner condenser application with a capacity of 1.38 kW, copper usage was reduced up to 26 percent while increasing capacity up to 6.5 percent by using smaller diameter copper tubes.

LARGE MICROGROOVE COILS

Companies such as Lordan, LU-VE, Spirotech and Super Radiator Coils have developed expertise in the manufacture of large condenser coils. These coils typically function as outdoor condensers for the air conditioning of commercial buildings or they can be used for process cooling.

LU-VE for example offers a standard line of condensers made from 5 mm coils, including three basic classes based on fan diameters of 350 mm, 500 mm and 630 mm. The NanoGiant LCM 350 uses one to four fans for capacities from 9.3 to 44.0 kilowatts; LCM 500 uses one to three fans for 17.5 to 105.9 kW; and LCM 630 uses one to four fans for 24.8 to 247.2 kW.

"Prospects are unlimited for the construction of heat exchangers for outdoor condensers using MicroGroove copper tubes," says Nigel Cotton. "In other words, heat exchanger designers have just begun to tap into the potential of MicroGroove for such applications."

Supermarket cooling is one area where outdoor condensers can provide an added boost to cascaded CO2 systems. See MicroGroove technical literature pertaining to the 2015 Ohrid Conference on ammonia and CO2.

Reduced refrigerant volume is a very important factor considering the flammability of low-GWP refrigerants. MicroGroove helps to

Figure 8: Large condenser coil made using 5 mm copper tubes. (*Courtesy of Super Radiator Coils*)

meet the safety codes that may be developed for such systems while not compromising on the cooling capacity. Candidate refrigerants include low Global Warming Potential (GWP) hydrofluorocarbons (HFCs) such as HFC-32, which has a GWP of 675; and ultra-low GWP hydrofluoroolefins (HFOs), such as HFO-1234yf and HFO-1234-ze, which have GWPs of 4 and 6, respectively. Scores of refrigerants that are blends of HFCs are HFOs are also under consideration for various applications. Such refrigerant blends can be tailored to the application by making tradeoffs between performance, cost, GWP and flammability

MANUFACTURING AND DESIGN BREAKTHROUGHS

The handling of small diameter tubes was a challenge for early adopters but many of the hurdles have been overcome with the invention of new equipment for bending and lacing tubes and expanding the small round tubes into the aluminum plate fins. Bullet expansion can be used to expand the tubes and also new techniques such as pneumatic expansion and hydraulic expansion are also effective. In fact, noninvasive pressure expansion may actually increase the yield of coils because the tubes are not prone to buckling during pressure expansion.

WHAT'S NEXT FOR MICROGROOVE?

The question "What's next?" is often asked. There are rumors of an R744 air conditioning system being developed for residential applications. Furthermore, manufacturing techniques will continue to be improved so that hydraulic pressure expansion can be automated as well as the brazing of return loops. Noninvasive tube expansion will allow for the development of more intricate patterns of inside-the-tube surface enhancement. Ever smaller diameter tubes are also a prospect; at some point fins may be discarded as the heat can be dispersed directly from the tube surface to the ambient air. Coil design software such as CoilDesigner from Optimized Thermal Solutions will speed up product development, allowing for highly accurate and precise simulations of coil performance without building a single coil.

See the "Presentations" section for conferences and exhibits as well as paper presentations about MicroGroove.

BREWERS REAP THE BENEFITS OF THE MICROGROOVE ADVANTAGE

The next time you enjoy a "cold brew" consider whether or not the condensers used for process cooling at the brewery are made with MicroGroove smaller-diameter copper tubes.

PRO Refrigeration is now offering turnkey refrigeration systems that use smaller diameter copper tubes in the condenser. These chiller systems are used to cool wort, control fermentation and chill conditioning tanks. They offer improved performance in a smaller footprint compared to coils made with larger diameter copper tubes or aluminum microchannel.

A GAME-CHANGING CONDENSER

Tommy Gaubatz of Innovative Cooling & Equipment Inc. (ICE) recognized that MicroGroove could easily become a game changer for the large condensers used in process cooling and commercial refrigeration. Having spent much of his career at Carrier in various marketing and engineering roles, he witnessed the move toward smaller-diameter copper tubes in both residential air conditioning as well as refrigerated transport. He realized that smaller-diameter copper tubes could be a game changer in the design of process cooling equipment, too.

Gaubatz teamed up with PRO Refrigeration, a company with extensive experience in building industrial-sized refrigeration equipment. Along with the engineers at PRO Refrigeration, Gaubatz helped to apply ICE's new condenser constructed with smaller diameter copper tubes. This condenser turned out to be a perfect fit for the process cooling systems that PRO Refrigeration builds for breweries.

Meanwhile, the manufacture of high-quality copper tubes with smaller diameters was mastered by the copper industry, initially for use in the highly competitive residential air conditioning market; and more recently, coil makers began developing large heat exchanger coils made with smaller-diameter copper tubes.

According to Gaubatz, the advantages of smaller-diameter tubes would apply equally as well for large outdoor condensers as for smaller systems. The copper tubes offer better corrosion resistance compared to aluminum microchannel. Customers could reap the benefits of reliability and familiarity, as well as high efficiency and reduced refrigerant charge.

PERFECTING THE DESIGN

The development was a success and the refrigeration system went on display at the 2016 AHR Expo in Chicago. ICE designed and assembled the condenser module with 5 mm copper tubes for PRO Refrigeration's process chiller. Already the first PRO Refrigeration system using MicroGroove tubes has been installed and more are being built for breweries across the country.

While it is true that a large cooling system requires a large surface area to exchange heat with the ambient air, the refrigerant tubes need not have a large diameter. In fact, smaller diameter tubes allow for a more compact design. The higher heat-transfer coefficients of the smaller diameter tubes allow for heat to be transferred more efficiently from inside-the-tube refrigerant through the tube wall and ultimately to the fins on the airside of the condenser.

Gaubatz designed the condenser to minimize pressure drop with shorter overall circuit lengths. The design also alleviates most of the stress due to thermal expansion. Another advantage is that the heat exchanger modules are flexible, lighter, more compact, and easier to install.

Using this atypical design configuration, the condenser system could be perfectly fitted to the high side of the air-cooled process chiller. The result was a smaller footprint than could otherwise be achieved with large diameter tube condenser configurations.

LESS REFRIGERANT

The unique design of the condenser also resulted in less refrigerant. For a brewer the cost of refrigerant could be a significant fraction of the total system cost, says Gaubatz. This factor becomes even more important as new, more costly refrigerants are developed. The use of smaller-diameter copper tubes can reduce the amount of refrigerant in the system by several hundred pounds. A system using large diameter copper tubes might require 700 pounds of refrigerant, for example, while a system using smaller-diameter tubes might use only 200 or 300 pounds of refrigerant. "When refrigerant sold for a few dollars per pound, these costs were manageable," explains Gaubatz, "but as the price of new refrigerants climbs to ten dollars or more per pound, it becomes a big deal."

ALUMINUM NOT UP TO TASK

Gaubatz preferred MicroGroove copper over aluminum microchannel coils for a number of reasons. One reason was that none of the microchannel coils available would fit his design requirements. Also, he preferred copper tubes because they are proven technology and contribute to better system reliability.

According to Gaubatz, corrosion in microchannel coils could result in a catastrophic system failure. Such failures are especially troublesome because the coils cannot be easily repaired in the field. Ultimately corrosion-resistant coatings were developed but these added heavy costs to the coils. In nearly all applications where microchannel is used, and especially in mission critical process cooling applications, such coatings are mandatory when using aluminum only coils.

MEETING THE NEEDS OF BREWERS

Process cooling at the brewery is mainly needed for rapid cooling of the "wort." As every zymurgist knows, wort is a key intermediate ingredient obtained from boiling crushed hops in a malt extract. The carb-rich wort is cooled rapidly and precisely held at various temperatures. Yeast is added and fermentation occurs at these set temperatures.

Temperature control is paramount to successful brewing!

Process cooling is accomplished using a chilled mixture of glycol and water. A stainless steel sanitary heat exchanger employs a counter-flow of chilled coolant to cool the wort.

Coolant can be pumped to cool the wort in a precisely regulated process. Once it picks up heat from the wort, it is pumped to the outdoor refrigeration system and then stored in tanks that typically hold 2000 gallons.

PRO Refrigeration makes turnkey refrigeration systems specifically for breweries. The outdoor system is a complete package; the condenser rests atop the evaporator. This system functions more or less as a chiller except that the circulated liquid is a glycol-water mixture rather than just water.

DESIGN OPTIMIZATION

Gaubatz cooperated with coil makers in the optimization of the coil designs. Typically coil makers assist in the design of the coils. ICE has used heat exchangers coils from Super Radiator Coils as well as Lordan. "The technical service offered by both companies has been excellent," says Gaubatz. "I would not have been able to develop these condensers without a robust supply chain in place."

The ICE design incorporates many features that Gaubatz feels will provide superior performance not only in refrigeration systems for breweries but also in many other commercial refrigeration and process cooling applications. "Right now, the ICE condenser can outperform any microchannel condenser," he says. "With further optimization of the coil design and improvements in manufacturing, I believe that smaller diameter copper tubes will be the winning technology for most process cooling applications that rely on an outdoor condenser."