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"Optimization, Cost and Health Benefits of Copper Tube Plate Fin Heat Exchangers," Presented by Optimized Thermal Systems. Live Discussion, Tuesday, January 26, 2021, 11am Eastern

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PUBLICATIONS

Yoram Shabtay and Kerry Song, "Smaller-Diameter Copper Tubes Support Three Trends in Ecofriendly Appliance Design," *Appliance & HVAC Report*, Vol.3, No. 1 (January 2021).
www.appliancehvacreport.com

Yoram Shabtay and Kerry Song, "Heat-Exchanger Simulations Fast-Track Adoption of MicroGroove Copper Tubes," *Appliance & HVAC Report*, Vol. 2, No. 4 (September / October 2020) pp. 14-21.

Yoram Shabtay, "Heat Exchanger Simulation Tools Help to Optimize the Use of Natural Refrigerants with MicroGroove Smaller-Diameter Copper Tubes," 2020 [ATMOsphere America Virtual Conference, Commercial Refrigeration Session](#).

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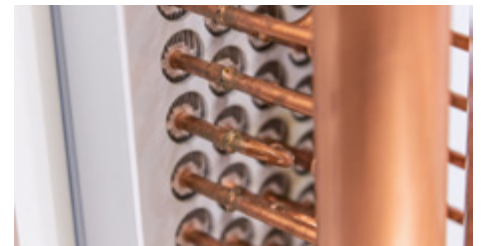
MICROGROOVE COILS SPAN THE GLOBE: EUROPE IS ECO-FRIENDLY

Considering its aggressive environmental policies, the European Union has emerged as a leader in innovative refrigeration technologies. In support of these policies, MicroGroove smaller-diameter copper tube technology has emerged as an enabling technology for increasing thermal efficiency of heat exchangers and accelerating the adoption eco-friendly refrigerants.

Although thermodynamics is well understood today, the development of refrigeration technology continues to march on. The introduction of MicroGroove smaller-diameter copper tubes in the past twenty years has allowed for a new generation of innovations in refrigeration and air conditioning.

MicroGroove technology is especially important today as Mankind seeks to improve the efficiency of refrigeration systems. MicroGroove technology offers improved thermal efficiencies and allows for the use of ecofriendly refrigerants by reducing the volume of refrigerant required for a given refrigeration capacity. The refrigeration cycle can be powered by clean electricity. Furthermore, heat pumps offer a much higher coefficient of performance (CoP) than could be obtained burning coal, oil or natural gas.

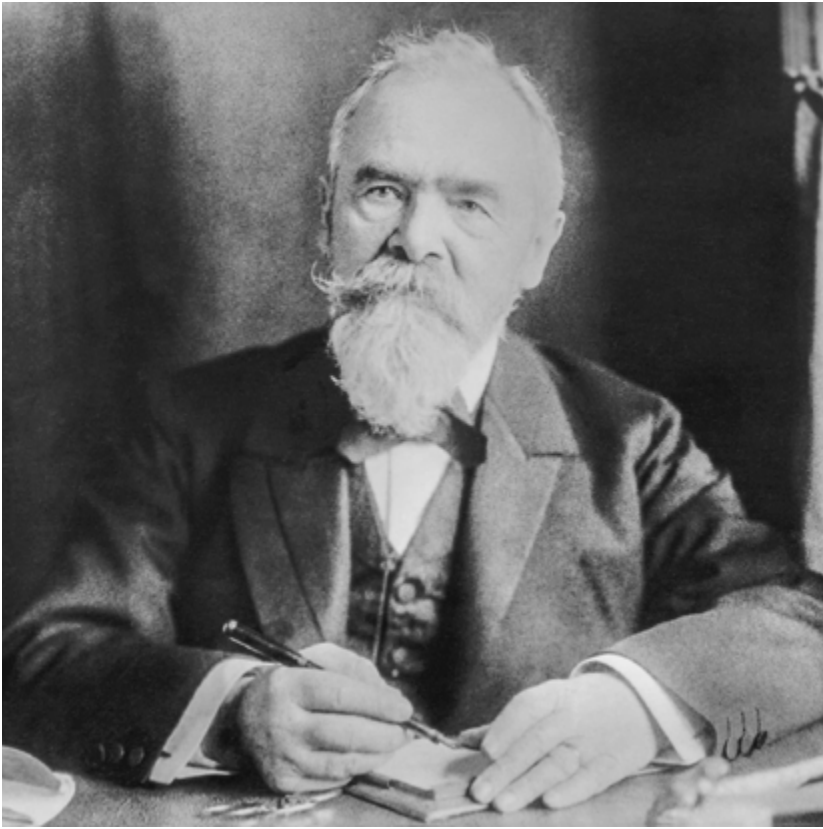
MicroGroove technology is being adopted at a rapid pace in Europe as well as other regions of the World as OEMs and end-users around the Globe seek to create a sustainable future through advanced technology. That future includes efficient refrigeration systems that will make the most of electrification and decarbonization of energy resources; as well as making the most of refrigerants



The trend for condensers and gas coolers in Europe is toward copper tubes with diameters of 5 mm. These smaller diameter tubes efficiently transfer heat and withstand the high temperatures and extreme pressures of hot compressed refrigerants such as carbon dioxide (R744). (Photograph courtesy of the LU-VE Group.)

with extremely low global warming potential (GWP). MicroGroove offers all of those advantages and more.

To better understand the state-of-the-art in refrigeration technology, it helps to understand a little of the history of thermodynamics and the development of refrigeration technology. After a glance backwards at the rich tradition of science and technology in Europe, this article surveys a few of the larger European companies who are continuing the march forward toward sustainable refrigeration systems with particular attention on the use of MicroGroove smaller diameter copper tubes in a new generation of commercial-sized heat exchangers.



Carl von Linde (1842-1934) was a scientist, inventor and entrepreneur.



Patent certificate for refrigeration machine, Professor Carl von Linde 1877.

A COPIOUS HISTORY OF INNOVATION

Unsurprisingly, perhaps, many important advances today in refrigeration technology are taking place in the birthplace of great scientific and technological revolutions of the past. It is an understatement to say that Europe is no stranger to scientific innovation. Many basic principles underlying refrigeration technology were laid bare by Europeans during the Scientific Revolution (*circa* 1543 to 1687); and the 19th century thermodynamics revolution.

Europeans also took the lead and applying these scientific principles to the development of refrigeration technology the past 150 years. In other words, today's refrigeration industry was built upon the thermodynamics revolution which itself was built upon the scientific revolution.

The refrigeration industry blossomed in the twentieth century. Notably, Carl von Linde (1842-1934) was a scientist, inventor and entrepreneur. He invented a continuous process of liquefying gases in large quantities and built a large plant for the liquefying air in 1895; and soon also a technology for separating pure liquid oxygen from liquid air [1]. The Linde Group officially merged with its American competitor Praxair in March 2019, forming the world's largest gas supplier [2] [3].

Separately, Linde founded a company originally called *Gesellschaft für Linde's Eismaschinen AG* (i.e., "the company for Linde's ice machines). This company later came to be known as Linde Kältetechnik and was acquired by Carrier Corporation in 2004. Now it is known as Carrier Commercial Refrigeration, a Carrier Company. In summary, the legacy of Carl von Linde is central to Europe's leadership position not only in industrial refrigeration but also in commercial refrigeration.

The Wikipedia page on the "Timeline of Heat Engine Technology" lists major contributors and their specific innovations [4]. Also a recent paper by Eckhard Groll reviews the history of refrigeration in the past 150 years [5].

A sprawling and complex refrigeration industry remains in Europe today and MicroGroove smaller-diameter copper tube suppliers are interwoven through that industry. The following survey presents a snapshot of the refrigeration industry in Europe today.

MICROGROOVE TECHNOLOGY LEADERS IN EUROPE

Smaller-diameter copper tubes are widely available to coil makers and suppliers of condensers and evaporators for applications from small to large, that is, from residential heat pumps and light commercial refrigeration systems to commercial- and industrial-sized condensers and gas coolers. There is a thriving

economy throughout Europe of companies large and small who supply heat-exchangers based on MicroGroove smaller-diameter copper tubes. There is also much research and development into the optimization of heat exchangers made with smaller diameter copper tubes, including research from renowned universities in Europe as well as corporate research laboratories.

Carrier Commercial Refrigeration

Carrier separated from United Technologies Corporation in 2020 and shares of its stock now trade under the symbol CARR on the NYSE. Carrier Kältetechnik Deutschland GmbH is a part of Carrier Commercial Refrigeration Europe, a leading supplier of high-efficiency refrigeration systems and services in the food retail industry. The rich history of this particular Carrier Company is described on the Carrier website [6] [7].

Carrier Commercial Refrigeration operates in more than 20 countries throughout Europe and has a significant presence in the Middle East and Asia. Its operations are supported by six European factories, two factories in Asia and world-class research and development centers in Germany and China.

Carrier Commercial Refrigeration offers its customers complete turnkey refrigeration systems as well as components for refrigeration systems. It can build its own heat exchangers for use in its own integrated systems; procure heat exchangers from suppliers outside of the company; and offer its own line of commercial condensers and gas coolers for use in refrigeration systems built by other companies. The objective is to provide and use heat exchangers that are best suited for any particular application.

QuietCO₂OL Transcritical CO₂ solutions for small stores.



Carrier Commercial Refrigeration boasted the highest number of R744 installations in Europe. The company has installed many thousands of R744 systems in supermarkets throughout Europe to date. Many of these R744 systems use smaller diameter copper tubes in the gas coolers and also use copper tubes in the evaporator units that are distributed throughout the supermarket to Low Temperature (LT) and Medium Temperature (MT) freezers and refrigerators.

Profroid

Profroid is a Carrier Company based in Aubagne in the Bouches du Rhône (Mouth of the Rhône River) department (*i.e.*, municipality) of the Provence-Alpes-Côte d'Azur (PACA) region of Southern France. It was founded in 1961 and its factory was built in 1987. It currently has about 320 employees engaged in the manufacture of packaged refrigeration units, bare units, housed condensing units, air coolers, air cooled condensers, gas coolers for CO₂, fluid coolers, refrigerating power packs and chillers as described in its catalogue [8].

Noteworthy for MicroGroove technology is the use of smaller-diameter copper tubes in its packaged refrigeration units, air-cooled condensers and gas coolers. The company is noted for its QuietCO₂OL Transcritical CO₂ solutions for small stores [9]. These systems typically use quarter-inch copper tubes as well as copper alloys (CuFe₂P). The units are designed for a maximum working pressure of 120 bars on the high pressure line, and for a maximum working pressure of 80 bars on the other lines.

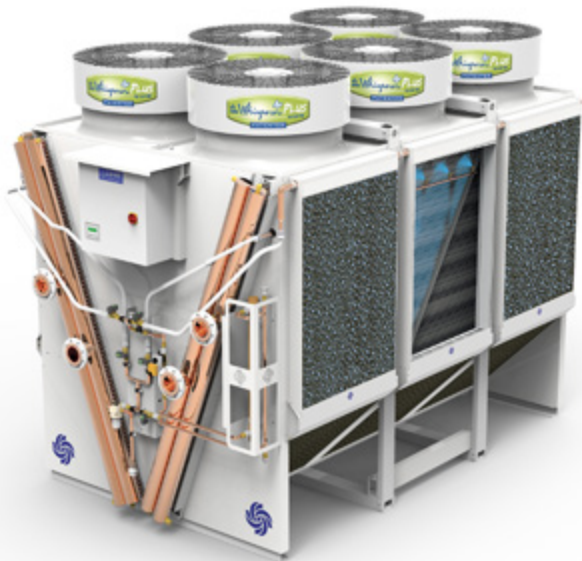
Profroid has named its air cooled condensers and gas coolers after musical terms. Air cooled condensers include the Adagio, Alto and Tenor; and the gas coolers include the Soprano CO₂, Alto CO₂ and Tenor CO₂. The air cooled condensers and CO₂ gas coolers cover a large range of capacity for commercial and industrial applications.

According to the latest product information (June 2020), the SOPRANO range, ALTO range and TENOR range of GasCO₂OL gas coolers are based on the association of aluminium fins and K65 copper tubes developed specifically for CO₂.



Profroid gas coolers for cooling R744 refrigerant include the Soprano, Alto and Tenor. The largest is the Tenor, which has a cooling capacity of 64 kW to 1208 kW.

Tubes and fins are intimately and definitively joined together per mechanical expansion of the tubes. Each manufacturing step is ensured by the latest generations of machines that help to produce high quality coils. The efficiency and compactness of these gas coolers are the result of technical choices in terms of materials and assembling technologies. Standard fin spacing is 2.12 mm. Alternative fins materials available upon request for saline or polluted atmospheres include copper tubes / aluminium fins with vinyl coating; and copper tubes / aluminium fins with "Blygold" coating.



The LU-VE Group pioneered the development of large condensers and gas coolers with 5 mm diameter copper tubes. Most recently the technology has been applied to R744 gas coolers such as the one shown here.

The LU-VE Group

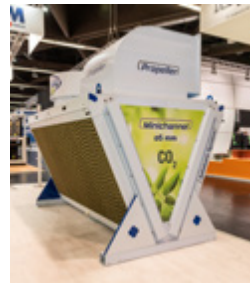
The LU-VE Group has emerged as a major player in the European refrigeration "ecosystem" and was the subject of a previous *MicroGroove Update* "In the Spotlight" column [10].

LU-VE was among the first to market with air-cooled condensers based on 5-mm copper tubes. Researchers at LU-VE understood the advantages of MicroGroove technology when smaller diameter copper tubes were designed into its NanoGiant line of air cooled condensers.

The company has been researching the use of smaller diameter copper tubes in gas coolers since at least 2012 when a paper on this topic was presented at the IIR International Congress of Refrigeration (ICR) in Prague. The 5-mm copper tube technology for CO₂ gas coolers was introduced into the market at Chillventa 2018 with much fanfare.

Stefano Fillipini of the LU-VE Group presented the latest research on gas coolers with smaller diameter copper tubes at the IIR ICR 2019 in Montreal in a paper titled "High efficiency air cooled heat

exchangers for CO₂ applications" (ID 326). A review of this paper and others from IIR ICR 2019 is given in a recent *MicroGroove Update* "In the Spotlight" column [11].



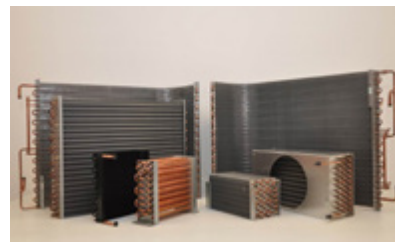
The LU-VE Group introduced a gas cooler made from 5 mm copper tubes at an industry event in October 2018.



Close-up of 5 mm copper tubes in gas cooler from the LU-VE Group.

It is noteworthy that LU-VE has developed a research laboratory capable of testing R744 gas coolers and unit coolers. A dedicated software program was developed in-house by LU-VE using LabView to monitor and acquire data. The maximum operating pressure for R744 gas coolers is 120 bar, while the maximum temperature is 120 °C.

According to LU-VE researchers, "The CO₂ gas cooler product can be considered proven technology in the refrigeration field. This achievement was made possible because of the design strategy adopted by the LU-VE Group, consisting of the utilization of high performance heat transfer surfaces and miniaturized geometries (small diameter tubes) even for large heat exchangers."



SPIROTECH was an earlier adopter of smaller-diameter copper tubes. The wide array of heat exchangers shown here all use 5 mm diameter copper tubes.

SPIROTECH Heat Exchangers (LU-VE Group) was among the first companies to adopt MicroGroove technology. Based in Bhiwadi, Rajasthan (about 60 km south of New Delhi), it makes MicroGroove heat exchangers for heat pumps, air conditioners and refrigeration systems, including MicroGroove heat exchangers for R744 systems. For more about SPIROTECH, see video [12]. The LU-VE Group acquired SPIROTECH in 2016 [13].

LU-VE SEST is another company within the LU-VE Group. It is a coil maker that supplies coils to other companies within the LU-VE Group as well as other OEMs. LU-VE SEST makes coils in Limana, Italy; Gliwice, Poland; Lipetsk, Russia; and Changshu, China.

SEST is the largest European company specializing in the production of heat exchangers and condensers for refrigerated cabinets. It has some of the most advanced coil manufacturing facilities in the world and is fully capable for processing smaller diameter copper tubes into coils for a wide range of applications [14].

MicroGroove technology is well established within the LU-VE Group. The Lu-VE Group acquired SPIROTECH, which makes a wide variety of heat exchangers based on 5-mm tube. Spirotech is a source for heat exchangers used in R290 light-commercial refrigeration systems. Its team of engineers designs and manufactures heat exchangers for a wide range of applications in Europe, the Middle East and India.



Modine's line of Eco coolers benefit from the use of smaller diameter copper tubes.

Modine and Eco

Modine established a formidable presence in Europe through its 2016 acquisition of Luvata, who had acquired Eco SpA, "the world's foremost manufacturer of heat-transfer coils and coolers," in 2007. Modine thereby became one of the largest manufacturers of heat exchangers in the world. Modine, of course, has its headquarters in Racine, Wisconsin in the USA but it also has a large footprint in Europe [15].

Modine's Commercial and Industrial Solutions (CIS) is an international Group, a worldwide leader in the production of heat exchangers, coils and coolers. It is organized into four Business Units (EMEA, NA, China and Coatings) across three continents. Modine CIS EMEA is located in Pocenica, Italy.

For more about how technology from Eco was shared globally within Modine, watch the 2018 video from shecco's ATMosphere America Conference, Long Beach, California [16].

A further development occurred in the Modine's marketing in 2020 whereby cooler and heat exchanger products are grouped under the Refrigeration markets webpage [17].

Modine's refrigeration markets page includes links to separate landing pages for Coolers www.modinecoolers.com; Coils www.modinecoils.com; and Coatings www.modinecoatings.com.

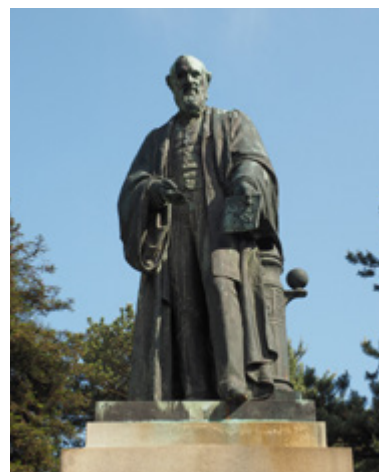
According to Modine's refrigeration page, the company selects only the highest quality, most technologically advanced materials for its ECO™ heat transfer coolers and Coiltech® industrial heat transfer products. The company combines these materials with its expertise in engineering and manufacturing with the results of unsurpassed quality, startling performance, and trusted reliability.

Eco is used as a trademark for Modine's line of Eco coolers. This branding has stuck and is readily visible on the website and throughout its Commercial Coolers General Catalog [18].

The product line of Eco heat transfer coolers can be found on the modinecoolers.com web page, following web page, along with new brochures and the general catalog [19].

As described in the general catalogue, smaller-diameter copper tubes are used in practically all of the Eco coolers, including inner-grooved tubes for conventional refrigerants and smooth tubes for R744 gas coolers. The latter is reported to use "special copper" in smaller diameter tubes with thicker walls, allowing maximum operating pressures of 130 bar.

There is an extensive product line of Eco Coolers, hence a selection software program has been developed to aid in the selection and specification of Eco Coolers [20].



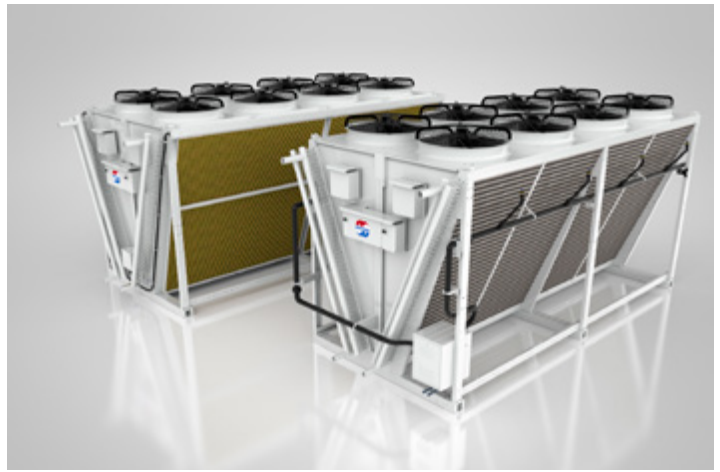
A statue of Kelvin greets visitors to the Botanic Gardens in Belfast. William Thomson, 1st Baron Kelvin was a mathematical physicist and engineer who formulated many of the basic laws of thermodynamics. He was born in Belfast in 1824 and was a Professor of Natural Philosophy at the University of Glasgow for 53 years.

Kelvion

Kelvion is 100 Years Old in 2020. Headquartered in Bochum, Germany, its origins go back to 1920, when Otto Happel founded the *Gesellschaft für Entstaubungsanlagen*, or GEA for short.

The GEA Heat Exchangers Segment of GEA spun off from GEA in 2014 and was renamed "Kelvion" in homage to Lord Kelvin who formulated the laws of thermodynamics [21]. Kelvion is an international manufacturer of industrial heat exchangers for a wide range of applications.

Kelvion's 2020 brochure on condensers and gas coolers describes Micro-Tube as a 5 mm coil innovation, which is the result of extensive R&D work, optimizing the geometry and surface enhancement to provide better fin surface utilization than ever before [22]. Micro-Tubes were announced in a 2016 press release at Chillventa. According to the release, the thin tubes – which are ideal for CO₂ as refrigerant, with its favorable thermal properties – allow cost-efficient cooler solutions for applications with high pressures. Kelvion developed its Micro Tubes with the aid of numerical flow simulation and optimized them in prototype tests in a wind tunnel.



Condensers and gas coolers in Güntner's new V-SHAPE Compact family occupy a remarkably small footprint. The efficiency of refrigerating plants can be improved through the adiabatic pre-cooling of ambient air by the optional humidification pad.



Kelvion's smallest heat exchanger uses its Micro-Tube coil technology. According to the company, this 5 mm coil is the result of extensive R&D work, optimizing the geometry and surface enhancement to provide better fin surface utilisation than ever before. The GF-D gas cooler for CO₂ refrigerant has a capacity of 1.8 kW to 39 kW.



Kelvion's Flatbed range uses its latest technology to reduce the footprint, lower the noise level, and improve capacity density. CO₂ gas coolers are available with capacities from 30.6 kW to 1424 kW.

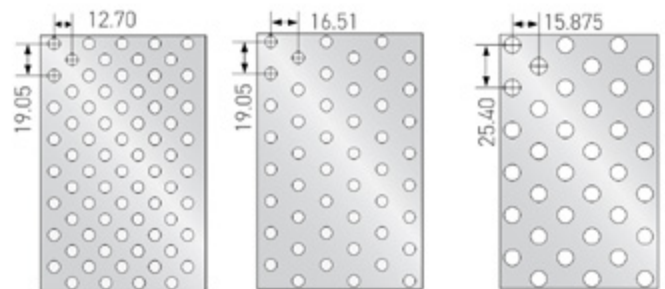


Fin patterns for Kelvion coils can be designed in 5, 8, 9.5 and 12 mm configurations with various protective coatings.

A wide variety of condenser and gas cooler configurations are available from Kelvion. With smaller tube diameters, heat exchangers can be made lighter, more compact and more cost effective. However, certain applications and working conditions may require larger tubes to handle the tube side pressure drop. Tubes can be bent to different shapes and could have smooth or grooved internal surfaces on the inside to enhance heat transfer.

Güntner

Güntner Group Europe GmbH is headquartered in Fürstfeldbruck, Germany. The company is a major supplier of condensers, gas coolers and air coolers and has an enormous global reach. Among other products, it makes flat, vertical or V-shaped condensers with capacities ranging from a few hundred watts to thousands of kilowatts. Standard designs typically use round copper tubes with aluminum fins although other special materials can be used depending on the application and the refrigerant. Güntner updated its selector software in 2020 [23]. Product brochures are available in many languages [24].



Holes can be spaced closer together for smaller diameter tubes. Shown from left to right are fin patterns for 5 mm, 7 mm and 9.5 mm (3/8 inch) tubes. (Illustration courtesy of Lordan.)

A BROAD FUTURE FOR SMALLER-DIAMETER COPPER TUBES

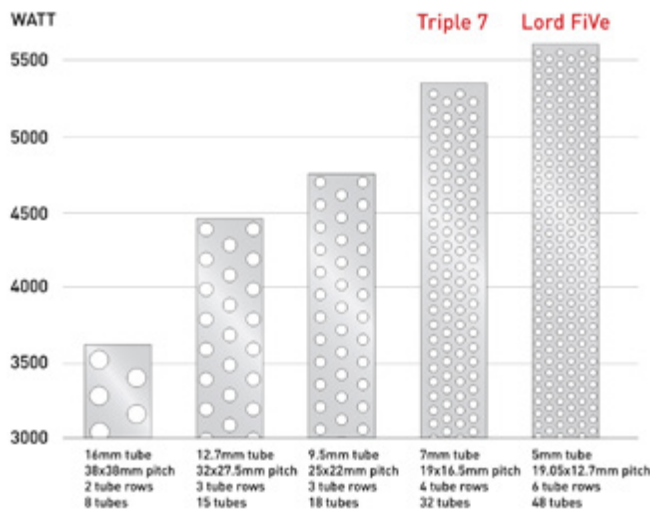
The above survey of major coil manufacturers reflects a dynamic and advanced refrigeration industry in Europe. Numerous innovative heat exchanger components are being installed in supermarkets, food-processing plants and industrial plants throughout Europe.

Many European manufacturers produce compact MicroGroove heat exchangers, including distributed evaporators for large refrigeration systems as well as evaporators and condensers for standalone systems for light-commercial refrigeration, including systems using eco-friendly R290 as a refrigerant. In most cases, these heat exchangers are made in Europe or nearby in the Middle East or India from smaller diameter copper tubes that are regionally sourced as well.

The refrigeration industry is notoriously segmented, which has the result of continual product innovation. Mid-sized coil makers working with MicroGroove smaller-diameter copper tube can be found throughout Europe. For example, Lordan (A.C.S.) headquarters in Kfar Szold, Israel, has production facilities in Israel and Wales; it was one of the early adopters of smaller-diameter copper tubes, which it markets as “Lord 5” 5 mm copper tube technology [25].

The company boasts that compared to 3/8 inch technology Lord 5 offers five advantages: volume saving, reduced weight, reduced refrigerants, energy savings, and ROHS Compliance. RoHS stands for Restriction of Hazardous Substances. It originated in the European Union and restricts the use of specific hazardous materials found in electrical and electronic products [26].

Eurocoil spa (Verona, Italy, www.eurocoil.eu) is another European company that makes heat exchangers with 5 mm diameter inner-grooved copper tubes, It currently offers a staggered 5-mm-diameter tube pattern with corrugated and louvered fin patterns from a minimum of 1.4 mm to a maximum of 4.0 mm [27].



Cooling capacity increases as tube size decreases. (Illustration courtesy of Lordan.)

RESEARCH FRONTIERS

The adoption of R744 technology by supermarkets continues in Europe. R744 systems are also being adopted by supermarkets in the USA, especially since the Dover Corporation acquired the Danish company Advansor, a leader in R744 refrigeration. Advansor is now part of Hill Phoenix, an operating company within Dover’s Engineered Systems segment; consequently, R744 installations in the USA and Europe are on the rise.

Europe has led the way in developing refrigeration systems that use R744 (carbon dioxide) as an eco-friendly natural refrigerant. Yoram Shabtay, a consultant expert to the ICA, has presented at the 2019 ATMO Europe conference in Warsaw, Poland. His presentation titled “Optimization of transcritical R744 gas coolers with Microgroove smaller diameter copper tubes” is available for viewing online or downloading [28].

Shabtay also presented a paper titled “Advanced round-tube, plate-fin (RTPF) heat-exchanger coils contribute to the high efficiency of heat pumps” at the Twelfth International Energy Agency Heat Pump Conference (IEA HPC), recently held in Rotterdam, The Netherlands [29].

The MicroGroove team coauthored a two-part paper titled “New Copper-Based Heat Exchangers for R744 Refrigerant,” which was presented at the Sixth IIR Conference: Ammonia and CO₂ Refrigeration Technologies, in Ohrid, Republic of Macedonia [30].

LOOKING AHEAD

There are many other companies across the countries of Europe meeting the robust demand for heat exchangers made with smaller diameter copper tubes; as well as the ever-increasing demand for eco-friendly refrigeration systems. Copper tube suppliers are just one part of the technologically innovative climate of the present day Europe, the United Kingdom and the Middle East.

ICA continues to support research projects leading to technical paper presentations at major conferences. Papers have been delivered on many topics, such as optimizing tube circuitry and fin design; software programs for developing heat exchangers; reducing refrigerant volume for use with new refrigerants and natural refrigerants; and the use of smaller diameter tubes in heat pump applications. The ICA supported the development of a heat exchanger simulation and optimization program specifically for small diameter tube designs

The countries of the European Union, the United Kingdom and the Middle East are certainly carrying on in their great traditions of scientific and technology revolution and rebirth. 🌐

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IN THE SPOTLIGHT

AN ADVOCATE FOR SUSTAINABILITY FOR TWO DECADES, SHECCO BRINGS TOGETHER OEMS, CONTRACTORS AND END USERS

ATMOSPHERE EUROPE PROMOTES SUCCESS IN THE USE OF NATURAL REFRIGERANTS

shecco describes itself as a global market accelerator helping its partners in the heat pump, air conditioning and refrigeration sectors bring their innovative solutions faster to the market. Its portfolio comprises activities in media, events and market development.

In a sense, shecco's history is linked to the environmental research that led to the Montreal Protocol of 1987. The Norwegian thermodynamic scientist Gustav Lorentzen rediscovered the benefits of CO₂ as a refrigerant in 1988; and introduced patented methods for regulating transcritical R744 refrigeration systems, or TC CO₂. shecco was established in 2000 within the Norwegian conglomerate Norsk Hydro for the purpose of developing sustainable heating and cooling with CO₂ (hence the quasi-acronym "shecco") as the technology continued to mature.

shecco was an important voice for the adoption of TC CO₂ since its inception in 2000. Along with Japanese partners, it facilitated the development of CO₂-based domestic water heating heat pumps (i.e., the EcoCute market in Japan). shecco and its partners also worked with automobile makers on CO₂-based mobile ACs and with refrigeration equipment companies.

A BROADER MISSION

shecco spun off from its parent company to become an independent company based in Belgium in 2007 [1]. Its marketing services were needed to support various technologies to address climate change [2]. The new shecco brand was launched in September 2008 [3]. It has been true to its mission to provide dedicated services to help its customers "Sustain our Atmosphere." Today shecco enjoys the freedom and flexibility of an open approach. For example, many of its publications and conference presentations are freely available online and its ATMOSphere conferences, which are held throughout the world, are friendly to end-users, contractors and OEMs as well as associations and media partners.

PARALLEL DEVELOPMENTS

Introducing game-changing technologies involves the parallel development of the supply chain, including components such as compressors and heat exchangers. The International Copper Association formed a consortium of OEMs, tube suppliers and universities more than a decade ago to develop smaller-diameter copper tube technology that would reduce material usage and increase the efficiency of air-conditioning and refrigeration systems. By 2010, the technology was ready for use. Hurdles in the manufacture of these copper tubes and their assembly into coils have been overcome. The superior performance of smaller-diameter tubes has been demonstrated not only in the laboratory but also in OEM-designed equipment. The MicroGroove campaign was launched at the AHR Expo in the USA in January 2011.

MicroGroove technology dovetailed with the adoption of natural refrigerants in refrigeration equipment. Small-diameter copper tubes are ideally suited for use with propane because of the reduced refrigerant charge requirements; and smaller diameters also provide a higher burst pressure in support of TC CO₂ applications, especially for the gas coolers as described in the main article of this issue.



Yoram Shabtay presents a MicroGroove R290 case study at an ATMOSphere America event.

IN THE SPOTLIGHT

MICROGROOVE AT ATMOSPHERE EUROPE

As shecco's twentieth anniversary approached, the 2019 ATMOsphere Europe event was held in Warsaw, Poland. The European Union leads the world in the phasedown of F-Gases, i.e., hydrofluorocarbons (HFCs), which are greenhouse gases (GHGs) with high global warming potential (GWP).

shecco advocates for a direct transition from HFC refrigerants to natural refrigerants, including CO₂ (R744), hydrocarbons (such as R290 or R600a) or ammonia (R717). Each of these natural refrigerants has a negligible GWP compared to hydrofluorocarbons (HFCs or F-Gases), which typically have GWPs that are hundreds or thousands of times higher.

As a consequence of aggressive policies of the European Union, ATMOsphere Europe conferences have grown in popularity among OEMs, end-users, contractors and component manufacturers. Many of the coil manufacturers mentioned in the main article of this issue have sponsored ATMOsphere Europe events. A sponsorship typically includes visibility in a modest-sized exhibit hall at these events. MicroGroove was a Bronze Sponsor in 2018 and 2019.

REFRIGERATION EQUIPMENT OEMS

Several Polish manufacturers of refrigeration equipment also sponsored ATMOsphere Europe in Warsaw. For example, representatives from ES Systems K (Wolbrum, Poland, www.essystemsk.pl) and JBG2 (Warsaw, Poland, www.jbg2.com) were in the exhibit hall.

ES Systems K boasts that almost 100 percent of its refrigeration appliances work with R290 or R744. Its product offerings include counters, multidecks with glass doors, islands and various coolboxes freezers, including plug-in appliances and remote equipment (with separate condensers).

JBG2 has an impressive large manufacturing facility in Warsaw as shown in an online video [4]. It ships remote and plug-in refrigeration products throughout Europe. Many of the applications benefit from heat exchangers made from smaller-diameter copper tubes [5]. JBG2 also has embraced natural refrigerants as it phases out F-Gas refrigerants. Interestingly, the company recently spun off JBG2PV, adding photovoltaic modules to its portfolio of environmentally friendly offerings [6].



Yoram Shabtay explains the trends towards smaller-diameter copper tubes for use with natural refrigerants such as R290 and R744.

R744 FOR SUPERMARKETS

A vitally important, ecofriendly, end-user application is TC CO₂ for supermarket refrigeration systems. Here copper is often used in the gas coolers, which must withstand high pressures; as well as in the evaporators, which may be distributed throughout the supermarkets, wholesale stores and distribution centers. Supply lines also benefit from copper by not requiring special welders for installation as described at 2019 ATMOsphere America event in Atlanta, Georgia [7].

Europe leads the world in the development of supermarket refrigeration and shecco tracks practically every new supermarket application. Thousands of R744 refrigeration systems already have been installed in supermarkets throughout Europe. ATMOsphere Europe events are characterized by enthusiastic end-users who make the business case for natural refrigerants. ATMOsphere Europe in Warsaw was no exception.

Tadeusz Plewa, Head of Technical Operations for Makro Cash & Carry Polska (a member of the METRO Group) participated in the end-user panel moderated by Michael Garry, Editor of shecco's *ACCELERATE* Magazine. Tadeusz has been with Makro for 25 years and has been involved in natural refrigerant projects for many of those years. He described his experiences with R744 in Makro Cash & Carry stores in Poland. These are wholesale supermarkets similar to Costco stores in the USA. New installations in Poland use state-of-the-art TC CO₂ refrigeration systems [8] [9].

IN THE SPOTLIGHT

For example, the Makro Cash & Carry store in Czestochowa has a total cooling capacity of 184.3 kW (52.4 TR). The gas coolers and unit coolers from LU-VE, including units with MicroGroove copper tubes, are integrated into a system that includes compressors from Bitzer, an ejector from Advansor, and controls by Carel. The TC CO₂ system in Czestochowa provides cooling for all of the store's refrigerated cabinets as well as cold rooms for dairy and meat [9].

Makro also operates a distribution center in the MLP Pruszków II logistics park outside of Warsaw. The distribution center has an area of 10,100 square meters and is equipped with an R744 refrigeration system larger than the TC CO₂ systems in Makro wholesale stores. The distribution center is a key link in the cold chain. Every day the warehouse is filled with refrigerated and frozen items from many food suppliers; in the early morning hours the cold products are loaded onto trucks for delivery to Makro warehouse stores as well as restaurants throughout Poland.

Several days after the conclusion of the ATMOSphere conference, Tadeusz cordially afforded an informative tour of the distribution center outside of Warsaw. He showed the two R744 refrigeration systems that serve the entire distribution center, including huge cold rooms, each cooled to a specific temperature depending on the product. The redundant design of the refrigeration system includes two independent R744 refrigeration systems (A and B), each with its own copper-tube gas cooler, so that one can be taken out of service for maintenance without affecting warehouse operations. See MLP website [10a] for more information about the Makro's cold storage distribution center [10b].



The Makro distribution center outside of Warsaw has an area of 10,100 square meters and is equipped with a dual R744 refrigeration systems for redundancy.

These Makro installations in Poland are part of the "F-Gas Exit Program" of its parent company METRO AG, whose aim is "to phase out f-gases in all METRO stores worldwide by 2030, replacing them with natural refrigerant systems where it is technically and economically feasible to do so." So far, METRO AG has 95 TC CO₂ stores as well as 108 R744 subcritical stores worldwide with rapid progress being seen recently internationally. METRO AG was the recipient of shecco's Accelerate Magazine Award/Europe in 2018 in the category of Best in Sector/Food retail for its F-Gas Exit Program [11].

TC CO₂ is not limited to wholesale stores. Biedronka, part of Jeronimo Martins Group, is one of the largest supermarket chains in Poland [12]. At the 2019 ATMO Europe event in Warsaw, Biedronka was the recipient of shecco's Accelerate Magazine Award/Europe in 2019 in the category of Best in Sector/Food retail [13].

"Biedronka" is the Polish word for "ladybug." Already about half of its 3,000 small-format stores in Poland are using TC CO₂ systems from Advansor and Carrier. As mentioned in the main article in this issue, Carrier typically specifies Profroid gas coolers, which benefit from small-diameter copper tubes, although these gas coolers may be procured from any manufacturer as suits the application. Retrofits and new openings began in 2017 and in just a few years about 900 existing stores were converted to TC R744 and 650 new stores were added with this technology. Biedronka is also converting its 16 distribution centers to R744 by 2025, and it expects to use zero HFCs.

SHECCO NOW MORE THAN EVER

This story of the accelerated adoption of TC CO₂ is repeated again and again for supermarket chains throughout Europe. A 2020 market study by shecco estimates that about 29,000 TC CO₂ systems have been installed in Europe compared to only 650 in the USA [14].

The race to phasedown HFCs in the cold chain is already underway in Europe and just getting started in the USA and other parts of the world. Consequently, shecco is busier than ever with its publications, events and market development. In 2020, in the face of the pandemic, shecco continued to hold events virtually.

IN THE SPOTLIGHT

CO₂ transcritical installations in the world

sheccoBase 



shecco's "World Guide to Transcritical CO₂" published in 2020 compares the number of installations in different regions of the World. Also see the related table from the same publication. (Courtesy of shecco.)

Noteworthy was the "Future of Air Conditioning" event jointly hosted by shecco and the Danish Technological Institute. This virtual event held in June 2020 focused on prospects for natural refrigerants in air conditioners. The complete program and slide presentations can be found online [15].

MicroGroove was a Bronze sponsor of the 2020 ATMOsphere America event [16]. The event platform allowed for each of the presentations to be recorded. Of special interest were the keynote address by Dan Hamza-Goodacre, Non-Executive Director, Kigali Cooling Efficiency Program, ClimateWorks Foundation [17]; and the Market Trends Report by Ilana Koegelenberg, Market Development Manager, shecco [18].

Yoram Shabtay, President, Heat Transfer Technologies, who is a consultant for the International Copper Association, delivered a presentation titled "Heat Exchanger Simulation Tools Help to Optimize the Use of Natural Refrigerants with MicroGroove Smaller-Diameter Copper Tube." The presentation can be found within the session on "Case Studies: Commercial Refrigeration" [19].

shecco recently announced that its next ATMOsphere Europe event will be held in Brussels in June 2021. The European Commission is expected to have the EU F-Gas 3 Proposal ready after Summer 2021. As it has for the past 20 years, shecco will continue to accelerate the adoption of ecofriendly cooling and refrigeration technologies.

For the sake of Earth's atmosphere, this acceleration towards adoption of low-GWP refrigerants cannot happen too soon! 🌍

Region	TC CO ₂ installations (Cumulative)			Percent Growth
	2008	2018	2020	2018 to 2020
Europe	140	>16,000	29,000	81%
U.S.		>370	650	76%
Canada		>245	340	39%
Japan		>3,530	5,000	42%
Australia		>20	95	375%
New Zealand		>40	100	150%
South Africa		>110	>220	100%

IN THE SPOTLIGHT

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