MicroGroove Contributes to the Success of Propane in Refrigeration Appliances

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The marriage of smaller-diameter copper tubes with low-GWP refrigerants has given birth to a new generation of eco-friendly, economical, high-efficiency appliances for commercial refrigeration.

Bottle coolers, cold-vending machines and "reach in" cold-food display cases are widely used in corner stores, bodegas, delicatessens, grocery markets, ice-cream shops, restaurants and supermarkets around the globe. These appliances represent a significant portion of the refrigeration marketplace.

Remarkably, a major paradigm shift has occurred with respect to these products. In recent years, since 2011, the regulatory environment has been warming up to the use of propane as a refrigerant while imposing limits on the allowed refrigerant charge due to its flammability. These quantity restrictions as well as other safe-design measures are needed to allay concerns about the flammability of propane.

Concurrently, the technology of smaller-diameter copper tubes matured as manufacturers and regulators signaled that propane would be allowed in light commercial applications. The renewed interest in propane and the parallel development of heat exchangers made with smaller-diameter copper tubes is a fascinating story. Albeit propane was used as a refrigerant in the early days of refrigeration and air-conditioners; but never before has it been used in refrigeration equipment made with smaller-diameter copper tubes, enabling low-charge refrigerant systems!

That is something completely new and the marketplace is responding accordingly.

This article examines the regulatory environment with respect to the ozone depletion potential (ODP) and global warming potential (GWP) of candidate refrigerants. It reviews the history of refrigerants up to and including the current state of regulations around the globe; and the current battle of the refrigerants within industry. Issues relating to the flammability of refrigerants and charge limits are then reviewed along with a discussion of how these issues have been resolved in favor of propane.

Next the properties of smaller-diameter microgroove copper tubes are addressed with particular attention on how the smaller-diameter tubes affect the refrigerant volume and the heat transfer coefficients for typical heat exchangers charged with 150 grams of flammable refrigerant. It is shown how the technology of smaller-diameter MicroGroove copper tubes and heat exchangers contributed to the successful development of a new generation of eco-friendly, energy efficient and economical appliances.

Design principles and simulation software allow OEMs to rapidly prototype heat exchangers with propane as a refrigerant.

Next a case study is presented for MTL Cool, whose engineers designed a whole new line of cold display cases and constructed a new manufacturing plant for the production of these units.

Finally, prospects for the union of propane and MicroGroove in other types of appliances are discussed.

Finished Oasis 36 units ready for shipping. (Courtesy of MTL Technologies)

This article concludes with a look at what is possible for the progeny of the marriage of propane and MicroGroove. What products are candidates for conversion to ultralow GWP refrigerants? How will the use of flammable refrigerants impact the operations of grocery stores and refrigeration technology? What opportunities exist for the use of propane in other applications such as heat pumps and air conditioners?

Refrigerant Wars

Ozone Depletion by CFCs and HCFCs

For their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone, Paul Crutzen (Max-Planck-Institute for Chemistry), Mario Molina (MIT) and F. Sherwood Rowland (University of California, Irvine) were awarded the 1995 Nobel Prize in Chemistry. *[1]*

CFCs are the worst refrigerants in terms of ODP. CFC molecules do not break down or wash out in the troposphere (lower atmosphere) but transport destructive chlorine atoms all the way to the stratosphere, where the chlorine atoms deplete the ozone layer. The culprit in ozone depletion typically is the chlorine atom, a halogen, which tends to interact with ozone in a catalytic manner and remain in the atmosphere for very long periods of time. One chlorine atom can destroy tens of thousands of ozone molecules before it is finally removed from the ozone layer.

Hydrochlorofluorocarbons (HCFCs) such as R22 are also ozone-depleting substances (ODS). They are not as harmful as CFCs because they are not very stable in the troposphere; only a small percentage of HCFC molecules actually reach the ozone layer. Nonetheless HCFCs still contain chlorine and their use is being phased out as well.

CFCs were invented in the 1920s and 1930s as safe alternatives to toxic refrigerants such as ammonia and flammable refrigerants such as propane. As man-made materials, they never existed in nature before. Their adverse effects on the atmosphere were not quantified until the 1970s and beyond.

Ironically and unfortunately, these “safe” refrigerants proved disastrous for the global environment. Their high ODP was recognized in 1972 and, after a long regulatory battle, the use of CFCs was banned according to a legally enforceable schedule for phasing out their manufacture and distribution.

As the result of the phasedown under the Montreal Protocol, the use of the worst of these gases has been largely eliminated and the ozone layer has begun to heal itself.

Allowable substitutes have included F-gases, such as R414 and R410a, but these require higher pressures and do not perform as well as the refrigerants that they replaced. Also, as fate would have it, they too are not eco-friendly.

Global Warming by F-Gases

The current array of substitutes for R12 and R22 are molecules which contain fluorine. The problem with fluorine is its capacity to reflect infrared radiation back into the atmosphere rather than allowing it to radiate out into space. The GWPs of F-gases are remarkable. A single molecule of R414a for example reflects 2000 times more photons than a molecule of carbon dioxide and, what’s more, R414a remains in the atmosphere for decades once it is released.

Hence, hydrofluorcarbons (HFCs) such as R134a and R410a are also being targeted for phase out — not because of their ODP but rather because of their GWP. In other words, fluorinated gases (also known as F-gases) that contain no chlorine are not a threat to the ozone layer, but they will be eliminated from most applications because of their very high GWP values.

Worldwide Resolve

The United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty signed in 1992. The aim of “the Convention” is to contain anthropogenic greenhouse gas emissions (caused by human activity) in order to avoid a major disruption of the planet’s climate system.

In alignment with these aims, the Conference of the Parties (COP) is the supreme decision-making body of the UNFCCC. The 196 Parties (195 countries and the European Union) have met every year since 1995. COP21 in Paris was especially significant because it resulted in the Paris Agreement, which is scheduled to go into effect in the year 2020. A small group of countries including India, Pakistan and some Gulf states, pushed for and secured an even later start in 2028, saying their economies need more time to grow. Environmental groups had hoped that the deal could reduce global warming by half a degree Celsius before the end of this century.

COP21 was held in Paris in December 2015. COP22 was held in Marrakech from November 7 to 18, 2016. Of the 197 Parties to the Convention, the number of those that who have ratified the Paris Agreement can be viewed online here: http://unfccc.int/2860.php

Meanwhile, delegates met in Rwanda, in its capital city Kigali, in October 2016 for talks on hydrofluorocarbons, or HFCs. Agreement was reached by more than 150 countries to limit the use of harmful F-gases. More than 100 developing countries, including China, will start taking action by 2024 and developed countries including the United States agreed to a gradual process beginning in 2019. The Kigali deal is perhaps more significant that the Paris Agreement since it is legally binding as an amendment to the Montreal Protocol. *[2]*

The 200 nations who signed off on the Kigali amendment to the Montreal Protocol agree that a ban on F-Gases makes sense from an environmental point of view.

A detailed list of substances with their ODPs and GWPs and CAS (Chemical Abstract Service Registry Number) is available online (www.epa.gov/ozone/science/ods/index.html).

Remaining Refrigerant Options

R32 is an HFC similar to methane

Safety classification	Flammability level,% in air by volume	Heat of combustion, J/kg	Flame propagation
1			No flame propagation
2L, lower flammability	> 3.5	< 19,000	Flame propagation with maximum burning velocity of ≤ 10 cm/s.
2, flammable	> 3.5	< 19,000	Flame propagation
3, higher flammability	≤ 3.5	≥ 19,000	Flame propagation

except that two of the four hydrogen atoms have been replaced by fluorine atoms. Its GWP of 675 is still quite high but relatively low compared to other HFCs still in use. By comparison, HFC 134a has a GWP of 1300; HFC 410a has a GWP of 2088; and, in the extreme, HFC 23 has a GWP of 14,800. *[3]*

Hydrofluoroolefins (HFOs) are also compounds of hydrogen, fluorine and carbon but are distinguished from HFCs by being derivatives of alkenes (olefins) rather than alkanes. Researchers are already seeking to understand how R32, HFOs and blends of these refrigerants behave.

Various MicroGroove heat exchangers in storage. (Courtesy of MTL Technologies)

Here is where the refrigerant cost versus low GWP comes to a climax. The HFOs have ultralow GWPs and factually are less flammable than R32; for example, R1234ze has a GWP of 7; however, HFOs are currently more costly because production of these compounds has not been scaled up. Meanwhile, R32 is cheaper and more widely available, but it is more flammable and has a much higher GWP.

Propane has a safety classification of A3. The letter "A" refers to its toxicity and the digit "3" refers to its flammability. As indicated in Table 1, Class 3 designates highly flammable; Class 2 mildly flammable; and Class 2L mildly flammable with relatively low burning velocity.

Applications that use R290 as a refrigerant typically use smaller-diameter copper tubes to allow for the reduction of the refrigerant charge, thus complying with regulations.

Propane on Top

It is not enough just to ban refrigerants. The cold chain is essential to modern civilization so alternatives must be found. Yet there are very few gases that have the thermo-physical properties suitable for refrigeration equipment. The properties of every gas known to mankind have been carefully examined with respect to their suitability as refrigerants. Chemical journals have been scoured for data on every known molecule. Only a few gases have thermophysical properties suitable for refrigeration equipment as well as low GWP and ODP.

One of these gases is propane.

The propane story demonstrates how the enlightened use of government regulations can be used to boost the adoption of a technology that is beneficial to all stakeholders. It is fundamentally misleading to call propane a "new" alternative. The truth is that propane is not "new" as a refrigerant. It was among the original refrigerants; it was in use well before the invention of nonflammable synthetic refrigerants such as R12 and R22.

The U.S. Environmental Protection Agency's Significant New Alternatives Policy (SNAP) program is based on the amended Clean Air Act of 1990. The SNAP program listed propane as "acceptable,

REFRIGERANT	Molecular Weight	Normal Boiling Point	Critical Temperature	Critical Pressure
	[kg/kmole]	[˚C]	[˚C]	[MPa]
R22	86.5	- 40.8	96	4.07
R410A	72.6	- 52.7	72.5	4.95
R290	44.1	- 42.1	96.8	4.25

subject to use conditions" as a substitute for CFC–12, HCFC–22, and R–502 in retail food refrigerators and freezers (standalone units only) in a Final Rule titled "Protection of Stratospheric Ozone: Listing of Substitutes for Ozone Depleting Substances—Hydrocarbon Refrigerants," which was published in December 2011.

One of the "use conditions" limits the refrigerant charge in this end-use to 150 grams (5.3 ounces) or less.

The SNAP program generates lists of acceptable and unacceptable substitutes for each of the major industrial use sectors as well as specific products categories. Once it was established that propane was an acceptable substitute, the EPA proceeded to change the status of environmentally undesirable F-Gases from acceptable to unacceptable. For example, see "Final Rule 21 - Protection of Stratospheric Ozone: Significant New Alternatives Policy Program New and Changed Listings" published in December 2016.

In this manner, propane has emerged victorious in the "refrigerant war" in several key product categories. Its success in retail refrigeration has been widely recognized and indeed 2017 could be called a watershed year for propane. Scores of companies have jumped in the propane bandwagon, so to speak, and they are now offering low-refrigerant-charge refrigeration equipment, a large market segment for appliances. It may be only a matter of time before F-gases are phased out and propane becomes the industry standard.

Less widely acknowledged is the vital role played by smaller-diameter copper tubes in the battle of refrigerants. Yet propane-based refrigeration equipment would be a non-starter without smaller diameter copper tubes. If not for the possibility of reducing refrigerant charge values using smaller-diameter copper tubes, this success might never have occurred. "R290 and MicroGroove" opened the door to the comeback of propane as a refrigerant. So in this sense, what was old becomes new.

The thermodynamic properties of propane as a refrigerant are well suited for retail refrigeration applications. Its thermodynamic properties typically are superior to HCFCs and closer to CFCs.

In this "back to the future" scenario, the industry is adopting a familiar refrigerant with excellent properties. The only caveat is the flammability of the refrigerant and the related "use condition" that the refrigerant charge be limited to 150 grams or less. The thermodynamic properties of propane are similar to those of R22. It has low back pressure, high volumetric capacity and contributes to higher coefficients of performance.

MicroGroove Reduces Refrigerant Charge

The core benefits of MicroGroove are energy efficiency, less material usage and reduced refrigerant charge. Tube-diameter reduction results in more effective heat transfer and consequently smaller, lighter coils with less refrigerant charge.

Pound for pound, smaller diameter tubes provide much more heat transfer than larger diameter tubes. A dramatic reduction in refrigerant volume is a further benefit of economical, eco-friendly copper tubes. The smaller internal volume of the coils means that less refrigerant is necessary to charge the coil. The need for less refrigerant results in other design advantages including a further reduction in overall system weight. For propane systems, the smaller refrigerant volume allows for the desired cooling capacities to be reached without exceeding the charge limits imposed by the regulatory authorities.

How it Works

Smaller diameter tubes allow for more effective heat transfer. The same or better performance can be achieved with less tube and fin material and less refrigerant. In other words, more heat can be dissipated with less material. A coil made with smaller diameter tubes has a higher "heat transfer coefficient" compared to a coil made with larger diameter tubes thus it is capable of transferring more heat to the air per coil area.

The overall heat transfer coefficient has many parts including 1) the convection of the fluid inside the tube to the tube wall; 2) conduction through the tube wall; and 3) dissipation through the fins by forced convection (fan). Among other things, the first part is a function of the flow stream inside the tube as well as the thermal conductivity of the fluid and the tube geometry. As an approximation, the first part is inversely proportional to the diameter of the tube. In other words, a smaller diameter tube transfers heat more efficiently than a large diameter tube.

Technically speaking, heat-transfer engineers talk about the "convective cooling of fluids in turbulent flow" as described by, for example, the Dittus–Boelter heat-transfer correlation. Briefly, the differential flow-stream volumes are closer on average to the tube wall as the diameter of the tube decreases. In other words, convective heat-transfer from the flow stream (refrigerant) to the tube wall is more efficient for flow streams that are closer to the tube wall.

The purpose of a refrigeration system is to transfer heat from the cooled space to the evaporator. The condenser removes the heat from the compressed refrigerant and causes the refrigerant to condense to a liquid (hence "condenser"). The use of smaller-diameter tubes allows heat to be transferred more efficiently in each of these heat exchangers in the system. Another great benefit is that the amount of refrigerant needed can be reduced without incurring a penalty in cooling capacity.

High-pressure polyurethane foam injection system, showing the two tanks for two foam components. (Courtesy of MTL Technologies)

Simulation Software

The International Copper Association, Inc. (ICA) and Optimized Thermal Systems, Inc. (OTS) are working with OEMs to develop eco-friendly MicroGroove heat exchangers using MicroGroove smaller-diameter copper tubes.

It has been demonstrated time and again that the use of MicroGroove smaller-diameter copper tubes in air conditioning systems results in higher coefficients of performance (COPs), less materials usage and reduced refrigerant volumes. Currently, the supply chain for the manufacture of high efficiency MicroGroove coils is well established. OEMs today have many options available as they strive to make the transition from conventional copper tubes to smaller-diameter copper tubes.

Several years ago, in cooperation with ICA, OTS implemented additional MicroGroove tube correlations into the renowned CoilDesigner® software package, developed and maintained by the Center for Environmental Energy Engineering (CEEE) at the University of Maryland. This critical development allowed for the full power of the industry-leading heat exchanger design software to be applied to the design of heat exchangers using smaller-diameter copper tubes.

CoilDesigner includes the ability to design with MicroGroove tubes. In other words, the correlations for both the airside and tube side performance have been programmed into the simulation software, allowing for accurate simulations to be performed for a wide range of tube sizes as well as for a wide range of fin designs.

The International Copper Association, Inc. (ICA) and Optimized Thermal Systems, Inc. (OTS) have simulated the performance of MicroGroove heat exchangers for major OEM clients. More recently, these simulations have been performed for heat exchangers using hydrocarbons refrigerants, including propane and isobutane.

Educational Outreach Program

Many OEMs are interested in simulations of refrigeration systems that use MicroGroove with propane. Academic literature presently is lacking in studies on the behavior of propane as a refrigerant inside smaller-diameter tubes. To bridge this knowledge gap and to facilitate the adoption of eco-friendly propane in refrigeration systems, OTS and ICA presented three technical webinars that provide an in-depth exploration of MicroGroove technology.

Segments included 1) the science behind the advantages of smaller diameter copper tube-fin heat exchangers; 2) the manufacturing technology for the construction of RTPF (Round Tube Plate Fin) heat exchangers; and 3) effective design practices, including use of simulation software tools for the design of heat exchangers using smaller diameter copper tubes. The webinars and slideshows can be accessed via microgroove.net by selecting OTS-ICA from the menu on the home page.

www.microgroove.net/ots-ica-educational-outreach

Anyone can view the webinars and download the slideshows with no registration required. Interested parties are also encouraged to participate in OTS-ICA initiatives aimed at engineering students, academic researchers and industry professionals.

Viewing the three webinars and completing a survey for each is a prerequisite to gain access to the demonstration and trial versions of CoilDesigner®, software developed by the University of Maryland's Center for Environmental Energy Engineering (CEEE).

Interested participants can also request a sample 5-mm heat exchanger for use in instruction or for laboratory testing. Participants who conduct performance tests in their own facilities will be encouraged to share their findings. See the registration OTS-ICA registration page, or contact OTS directly at info@optimizedthermalsystems.com.

The purpose of this hands-on introduction to MGHX (MicroGroove Heat Exchanger) technology is to engage people from various institutions and different backgrounds and encourage them to collaborate in advancing the state-of-the-art of round tube, plate fin (RTPF) heat exchangers. Participants will learn how MicroGroove heat exchangers in HVAC&R equipment contribute to sustainable development of the global built environment.

Typical Simulation Results for Appliances

A recent success story involves collaborating with Friedrich in the design of a drop-in replacement for one of its major AC products. Although this application does not use propane as a refrigerant, it serves as an illustration of the results that can be obtained using simulations.

Friedrich engaged Optimized Thermal Systems, Inc. (OTS) to explore the design space for a drop-in replacement coil for an existing 1.5-ton air-conditioning unit. Using the new MicroGroove correlations available for CoilDesigner, they began tackling the problem of how to improve the COP of existing products. A drop-in replacement was desirable so that the system COP could be rapidly improved without redesigning the whole system.

Friedrich wanted to determine which designs made the most sense in terms of lowering materials costs and increasing COP for a drop-in replacement coil. The existing design for the window-type air conditioner used conventional copper tubes with outer diameters (ODs) of 5/16 inch (7.93 mm). Friedrich needed to increase the EER of the baseline unit in order to meet the regulatory requirement for this type of air conditioning system. Simulations and experiments showed that a quick solution would be to add another row of conventional tubes, which would increase the EER by 3.5 percent. But the mass of copper tubes (excluding u-bends and connecting tubes) would be increased from 3.97 pounds to 5.29 pounds (1.80 kg to 2.40 kg). That's a 33 percent increase in the amount of copper in the system! The mass of the coil, including copper plus aluminum, was increased from 9.5 pounds to 12.7 pounds (4.3 kg to 5.7 kg, an increase of 34 percent).

As a result, OTS proposed a number of configurations made with 5-mm OD MicroGroove tubes, which were simulated in CoilDesigner. Friedrich had access to suppliers who could make the coils with either slit fins or louver fins. Working with OTS and supported in part by the International Copper Association (ICA), many coils were simulated and several of the best candidates were built to confirm the performance through laboratory testing.

The MicroGroove coils typically had four rows of tubes with 25 tubes per row for a total of 100 tubes. Compared to the baseline design, one configuration reduced the total internal volume of the tubes from 0.041 cubic feet to 0.032 cubic feet (1.16 liters to 0.91 liters) while pushing the COP up by 4 percent; and, at the same time, the total mass of the coil was reduced from 3.97 pounds to 3.21 pounds (reduction of 19 percent). The total mass of the coil (including aluminum plus copper) was reduced from 11.01 pounds to 6.98 pounds (4.50 kg to 3.16 kg, a reduction of 36 percent).

The upshot is that the smaller diameter tubes reached the target COP while decreasing the amount of copper by nearly one-fifth; rather than increasing the amount of copper by one-third. The simulation software also compared louver-fin designs with slit-fin designs and variations of fin pitches. The final choice of fin design will be dictated by manufacturing considerations and discussions with suppliers. Also, the simulations favored circuitry with five circuits rather than four.

The final design choice will be made by Friedrich. Using the CoilDesigner software, this choice can be made with confidence that the final product will meet the desired performance criteria.

MTL Cool Product Line

A few years ago, the engineers at MTL Cool recognized that high efficiency, low-GWP cooling systems could be made using MicroGroove smaller diameter copper tubes with propane as a refrigerant. They recognized two important trends in the refrigeration sector:

- Progression to smaller-diameter tubes for higher efficiency and low charge
- The use of low-GWP natural refrigerants.

Once the EPA SNAP rules that allowed for 150 grams of propane went into effect, the playing field was wide open. The engineers got to work designing refrigeration systems for supermarket and convenience store applications. They developed a complete line of refrigerated cabinets from scratch, including "reach-in" coolers, with or without glass doors. These cooling cabinets are sometimes sold to the store owners; and sometimes branded and sold to the companies that make packaged goods products.
Smaller diameter copper tubes were already being used in the manufacture of residential air conditioning systems. Could the same technology be adapted for use in refrigeration systems using natural refrigerants? MTL Cool had a lot of know-how in the design of process cooling systems, including various types of industrial cooling systems. When its engineers saw the growing market demand for a new generation of commercial refrigeration systems, they began developing a completely new line of products.

Electrical box assemblies. (Courtesy of MTL Technologies)

The small self-contained coolers from MTL Cool are easy to install and use as bottle coolers or for displaying deli meats, sandwiches and other refrigerated food products. They typically maintain temperatures between 36 ˚F and 41 ˚F (that is, –1 ˚C to 5 ˚C).
According to Mark Bedard, CEO of MTL Cool, the manufacture of the MicroGroove system with propane as a refrigerant is not much different than any other system. There are certain nuances with regard to the cabinet design for enclosing a propane-based refrigeration system. For example, metal-bladed fans or electrical components that could generate sparks cannot be used in the system. Since metal-blade fans are rarely used nowadays anyways, that was an easy requirement to meet.

MTL Cool approached Super Radiator Coils for the coil design and SRC was able to provide prototype heat exchangers for both the evaporator and the condenser. When the system is charged with refrigerant, it has to be sealed using a (flameless) ultrasonic welding system. Also, the heat exchangers must be thoroughly leak tested. Various other standards must be followed in the cabinet design as outlined in industry standards. While cost of materials was not a driver in the selection of coil materials, Bedard notes that smaller diameter tubes result in a less consumption of materials. Also, reliability was improved because smaller-diameter tubes are stronger tubes for a given tube wall thickness.

Initially, there was a shortage of refrigeration technicians and contractors who could service propane-based coolers. This issue has now been remedied and qualified technicians can be found in the field in most regions of the world. Furthermore, propane can be vented to the air. It does not have to be recycled because it has a very low GWP and low cost.

The engineers at MTL Cool looked at microchannel aluminum for use as a coil material. However, among other drawbacks, the tendency for lubricant oil to become entrapped in the channels was a major issue. Overall, MTL Cool has more familiarity with copper and its engineers were more comfortable with its track record for reliability.

MTL Cool is rapidly expanding to meet the demand for its propane-based MicroGroove cooling systems. A new factory under construction in Chambly, Quebec, outside of Montreal, is slated to go into production in 2017. As the volumes increase, the company may consider bringing the coil manufacturing inside. “For now, we are content with buying our coils from trusted suppliers, including Super Radiator Coils,” says Bedard.

There may be a point where production volumes are high enough to consider investing in coil manufacturing equipment and so build the coils as well as the refrigeration systems.

According to Bedard, the 150 gram limit still allows for the use of propane-based refrigeration systems in a wide range of applications. This amount is sufficient for most of the refrigeration needs in convenience stores, which is a huge market, and many grocery store applications, where individual cabinets each with its own compressor can be installed. If the propane weight limit is increased to 500 grams, then a vast array of refrigeration products could be manufactured with MicroGroove technology.

Looking Ahead

The phasedown of HFCs by such regulations as the F-Gas regulations of the European Union, the SNAP process of the EPA and the Kigali Amendment to the Montreal Protocol contributed to the interest in low-GWP hydrocarbons such as propane.

Yet it is the attractive physical properties of propane that have led to its quick adoption, once the regulatory hurdles in favor of propane and against HFCs were in place. Its excellent thermodynamic properties and the fact that it is readily available and affordable are important factors. Refrigeration systems that use propane as a refrigerant have high-efficiency and high-performance.

Although propane is classified as an A3 flammable refrigerant, it is safe to use when proper protocols are followed. Propane is not a drop-in replacement. The refrigeration systems must be specifically designed for R290 and comply with the charge limit of 150 grams. The low-charge limit restricts the use of propane to refrigeration systems with fractional horsepower compressors. This is okay for convenience store applications; but multiple independent refrigeration circuits must be used for large applications. Also, it is not permitted for use in split systems.

Currently, a working group within the International Electrotechnical Commission (IEC) is developing a standard that would allow for 500 grams of propane to be used in refrigeration systems. If accepted, the new standard could be published in 2018 and as a reference standard it could influence standards issued in the U.S. for example by the EPA and Underwriters Laboratories (UL).

It is expected that propane will play a key role in refrigeration systems for many years to come. As MicroGroove tubes and coils are uniquely suited for use with propane, particularly with respect to reduced refrigerant charge, the upsurge in the use of propane will also establish smaller diameter copper tubes in the supply chain and contribute to broader use of MicroGroove technology in all types of refrigeration, air-conditioning and heat pump applications. **IAM**

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