

SEPTEMBER 2017

ACCELERATE

ADVANCING HVAC&R NATURALLY

C O R P O R A T E



Natural Refrigerants: Taking Root

in North America – and Around the World



ABOUT ACCELERATE CORPORATE

Accelerate Corporate captures the efforts of market leaders in advancing the use of natural refrigerants across different applications, industry sectors and continents.

Each issue of the magazine is prepared in partnership with an influential corporation, organization or group of entities striving to accelerate the uptake of climate-friendly, natural refrigerant-based technologies.

Accelerate Corporate seeks to showcase end users' experiences working with natural refrigerants and to highlight the underlying market, policy and technology trends driving their uptake.

This issue of *Accelerate Corporate* has been produced with support from:



A Wave of Innovation

— By Michael Garry



In the first issue of *Accelerate America*, published in November of 2014, publisher and shecco CEO Marc Chasserot wrote: "Natural refrigerant-based technologies are disrupting the HVAC&R industry in North America. Behind this wave of innovation are people with brilliant and creative ideas who are designing and using functioning technologies in brand new ways to meet exciting business opportunities."

That description applies equally to this edition of *Accelerate Corporate*. Natural refrigerant technologies, like the transcritical CO₂ and ammonia/CO₂ cascade systems that are the focus of this issue, are continuing to disrupt the business-as-usual approach to refrigeration in the food retail sector, giving supermarkets a truly future-proof alternative to high-GWP HFC systems. And the company whose support has made this issue possible — Heatcraft, a division of Lennox International Inc. — is a prime example of an innovator that is facilitating the transition to natural refrigerant systems.

The cover illustration, which continues on the inside cover and back cover,

aptly captures the message of this publication. Natural refrigerant equipment — represented by trees, which also make productive use of CO₂ — is indeed taking root in many parts of the world. The most fertile regions include Europe and Japan, where government regulation and incentives have enriched the soil for climate-friendly refrigeration. But North America is catching up, with a growing field of possibilities.

The map also shows the global presence of Heatcraft, with locations in the U.S., South America, Europe, China and Australia. The OEM's far-flung manufacturing and R&D divisions allow it to leverage the best talent from all parts of the globe to design and manufacture leading-edge technologies that are helping to drive worldwide adoption of natural refrigerant solutions. (See [page 7](#).)

Moreover, Heatcraft's worldwide resources have enabled it to create

global platforms for its transcritical CO₂ and ammonia/CO₂ systems, which are then commercialized in individual markets. Each market, in turn, offers learnings about regulations, technology, implementation and adoption that help enhance the global design. Retail case studies showing how this works in the marketplace in the U.S. (Piggly Wiggly) and Europe (Carrefour) can be found on [page 17](#) and [page 20](#), respectively.

Training is another major theme of this issue. Heatcraft's "Sleep Well" training program ([page 23](#)) is designed to give retailers the reassurance that knowledgeable contractors and technicians are prepared to take care of their natural refrigerant systems day or night.

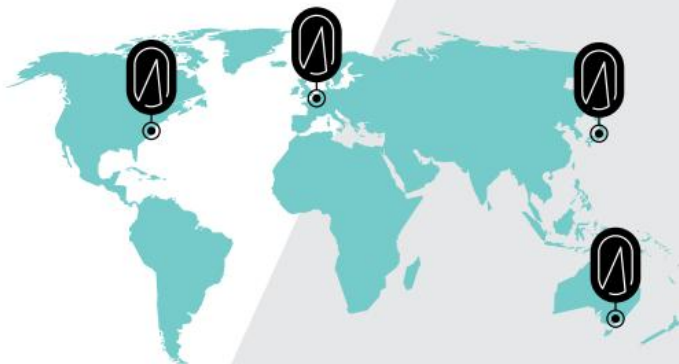
If you are one of those people interested in designing and using functioning natural refrigerant technologies in brand new ways to meet exciting business opportunities, I think you will enjoy this special issue. ■ MG

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ACCELERATE

ADVANCING HVAC&R NATURALLY

C O R P O R A T E



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Impact of Natural Refrigerants

R407A system

ENVIRONMENTAL IMPACT

Conventional supermarket's greenhouse gas impact from leaks*

Annual CO₂e of R407A leaked:

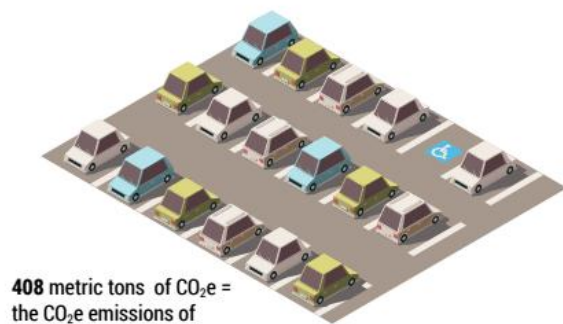
408 metrics tons



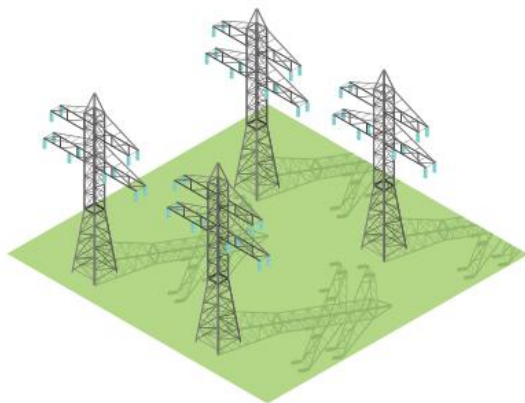
REFRIGERANT COST IMPACT***

Annual replacement cost of R407A: \$3,150

Initial charge cost of R407A: \$21,000



408 metric tons of CO₂e =
the CO₂e emissions of
87 cars in one year**



ENERGY IMPACT****

Annual energy consumption: 1.5M kWh

Annual energy cost: \$225,000

vs. R717/R744 system

ENVIRONMENTAL IMPACT

Greenhouse gas impact of R717/R744 system from leaks*

Annual CO₂e of R717 and R744 leaked:

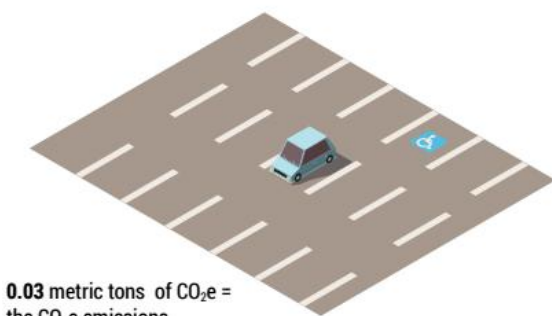
0.03 metrics tons (99.9% less)



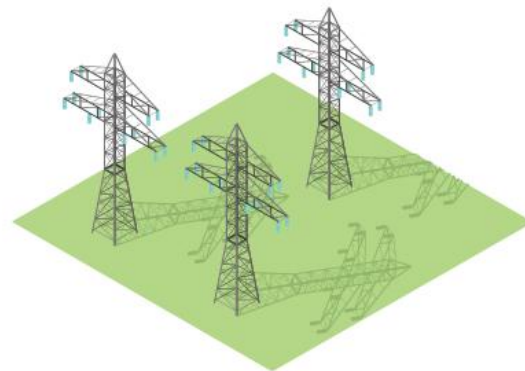
REFRIGERANT COST IMPACT***

Annual replacement cost of R717 and R744: \$362 (89% less)

Initial charge cost of R717 and R744: \$2,480 (88% less)



0.03 metric tons of CO₂e =
the CO₂e emissions
of **1 car in 2.3 days****



ENERGY IMPACT****

Annual energy consumption: 1.17M kWh (22% less)

Annual energy cost: \$175,000 (22% less)

*Based on 3,000 lbs of R407A charge, 15% leak rate; 53 lbs of R717 (ammonia) charge, 2% leak rate; 1,600 lbs of R744 (CO₂), 15% leak rate.

**Based on EPA estimate of average annual emissions of one car (4.7 metric tons of CO₂e).

***Based on \$7/lb for R407A, \$1.50/lb for R717 and R744.

****Heatcraft estimate based on measured data from study of R717 and R407A top-side racks at Piggly Wiggly store in Columbus, Ga.



Heatcraft headquarters, Stone Mountain, Ga.

Global Advantage

Heatcraft leverages its worldwide installation experience and research capabilities to develop state-of-the-art natural refrigerant solutions

— By Mark Hamstra

Think Global, Act Local is more than just a mantra for Heatcraft Worldwide Refrigeration.

Part of a global heating, air conditioning and refrigeration equipment-manufacturing enterprise, Heatcraft is able to capitalize on learnings from around the world to execute solutions on a local level.

The company hails from America, with its parent company, Lennox International, based in Richardson, Texas. Lennox focuses primarily on the residential heating, ventilation and air conditioning (HVAC) business, which accounts for 55% of its sales volume. Lennox also has a commercial HVAC segment serving what's known as the "rooftop" market, which includes office buildings and other commercial and public structures that require comfort cooling and heating.

As Lennox's third segment, Heatcraft Worldwide Refrigeration makes commercial refrigeration equipment, both conventional and natural refrigerant systems for four markets: cold storage, food processing, foodservice and grocery retail. In the U.S., it operates manufacturing facilities in Columbus, Tifton and Stone Mountain, Ga.

In all of its refrigeration manufacturing endeavors, "the core of our business is food preservation and food safety," said Bala Ekambaram, vice president of marketing and product management at Heatcraft Worldwide Refrigeration.

Heatcraft Refrigerated Products (HRP) is the umbrella name for a family of brands that manufacture unit coolers, condensers, compressor racks, condensing units, refrigeration systems and supermarket display cases. Its six U.S. sub-brands are Bohn, Larkin, Climate Control, Chandler, Kysor/Warren and InterLink.

The Kysor/Warren brand, which Heatcraft acquired in 2010, builds refrigeration systems and display cases for the supermarket industry, while the other brands manufacture components for a variety of industries, including the convenience store, food distribution and foodservice markets. The supermarket channel accounts for about 40% of Heatcraft's revenues globally.

The brands offer their products both independently and in tandem with each other as part of overall refrigeration solutions, so that products from different brand divisions end up reaching the

same customer. One large food retailer, for example, uses display cases and a back-end refrigeration system from Kysor/Warren, but another HRP brand, Bohn, for a large cold storage room.

The HRP brands offer their products through a network of more than 3,400 distributors worldwide, including 2,300 in North America, who in turn sell them to contractors.

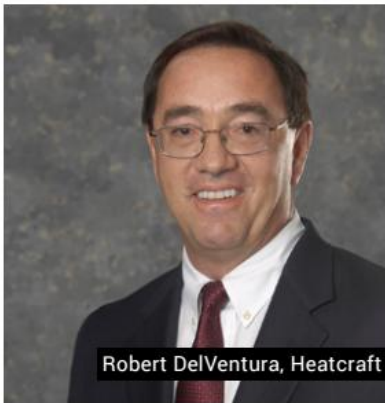
The Heatcraft umbrella brand is used for refrigeration systems in Asia, Australia and North and South America, while the HK Refrigeration and Friga-Bohn brands are employed for refrigeration in Europe.

Driving global platform designs

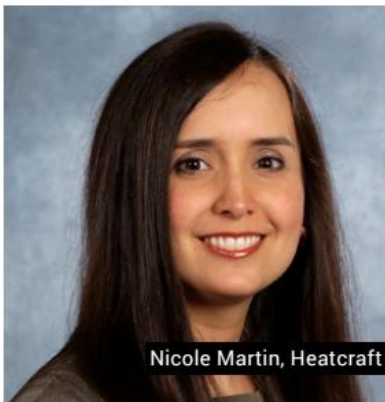
The international experience of Lennox has been an important component of the company's success, particularly in the area of natural refrigerants. Alternative refrigerant systems, primarily HFC/CO₂ cascade and secondary refrigeration installations — along with a growing number of transcritical CO₂ installations — have been rolled out extensively in Europe, North America and Australia. This experience with alternative systems



Bala Ekambaram, Heatcraft
Worldwide Refrigeration



Robert DelVentura, Heatcraft



Nicole Martin, Heatcraft

became the benchmark used by the industry to promote natural refrigerants. Recognizing the global trend toward natural refrigerants, Heatcraft developed its transcritical CO₂ platform to be global from the outset, leveraging the maturity of the market and supplier base. The global platform is a core development of the company's Alternative Systems Center of Excellence (COE).

"We developed a global platform for CO₂ systems, and commercialized it in Europe first," said Ekambaram. "We customized the global design for local markets, including the U.S. We took our learnings on regulations, technology deployment, execution challenges, and customer adoption from each of these markets, and used these to continue to evolve the design. This strengthened our value proposition compared to HFC systems and improved our cost position."

Consistent with its approach to CO₂ systems, Heatcraft developed another global platform for ultra-low-charge ammonia/CO₂ cascade systems with a launch customer in the U.S., Ekambaram explained.

The ammonia/CO₂ system "was designed to serve the global market, and commercialized first for the U.S. market," he said.

That installation is seen as a successful use of low-charge ammonia in a supermarket refrigeration system in warmer climates, where basic transcritical booster CO₂ systems are less efficient. The knowledge and experience from development of the ultra-low-charge ammonia cascade system allowed Heatcraft to apply these lessons to other HRP businesses, including cold storage.

Global research network

The Global Innovation group drives new technology platform developments for Heatcraft Worldwide Refrigeration. That organization is comprised of three teams: a Global Research team that explores potential future refrigeration technologies, the Alternative Systems COE that commercializes

the technologies, and the Global Laboratories group that conducts performance and compliance testing for all WWR products. All three teams work in a coordinated fashion to develop technologies and systems for the global marketplace, with a focus on systems that use refrigerants with a GWP of 150 or lower. (Ammonia has a GWP of zero, and CO₂ has a GWP of one.)

The Global Research team, led by Dr. Nicole Martin, is investigating technologies with an eye toward deployments that are three to seven years in the future, based largely on market trends and the regulatory landscape.

"We like to be ahead of the game if possible," said Martin. "We like to get together with regulators and understand what they are doing, before the regulations are put in place."

All of the Heatcraft divisions around the world "look to us as being the advanced-technology arm of the company," she said. "We serve as a team to solve their most difficult technical challenges."

Heatcraft's Alternative Systems COE, led by Dr. Augusto Zimmermann, is focused on natural and other low-GWP refrigeration technologies that are expected to be available for deployment within the next three years.

"The COE is the team who starts to commercialize the new technology that the Research team has developed, or alternative technologies, such as transcritical CO₂, cascades, and hydrocarbons," said Robert DelVentura, vice president of global innovations at Heatcraft, who oversees all three global innovation groups.

Both COE and the Global research team work with the Global Laboratories to put their research findings to the test in labs in Wuxi, China; Lyon, France; Columbus, Ga.; and Stone Mountain, Ga. The U.S. labs are led by Michael Kojak. Heatcraft also accesses the Lennox India Technology Centre, a team of engineers specializing in areas like finite element analysis

continues to grow and be shared throughout the company – with the help of the global platform design. Worldwide, Heatcraft has nearly 300 natural refrigerant installations, and this number is growing.

Europe became an early adopter of natural refrigerant systems. As a result, basic designs evolved into the more sophisticated systems existing today. Those systems

(FEA), computational fluid dynamics (CFD) and advanced solid modeling.

Coordinated testing of new products through the global network reduces time to market for new technologies and products, Zimmermann added.

"This enables quicker product prototyping and reduced prototype testing while increasing the robustness and performance of our products," Zimmermann said. "Our global team network is a key differentiator in our ability to produce world-class technology and to constantly assess emerging technologies. They are a key building block in our technology leadership position."

'Glocalization' process

Zimmermann said the teams seek to develop flexible solutions that can be adapted across multiple markets. As the products are being guided toward their launch in specific regions, the design undergoes what Heatcraft calls a "glocalization" process, he said.

"We take a global design and we localize it for the specific electrical safety standards, mechanical safety standards and other needs as required for certain markets," Zimmermann added.

While previously each region employed its own design variations for conventional refrigeration systems, the emergence of various natural and alternative refrigeration systems has led to more standardization around the world.

In addition to the ammonia/CO₂ cascade system, Heatcraft has also been developing other technologies that can make CO₂ a viable alternative in higher ambient temperature conditions. These technologies include ejector-enhanced parallel compression systems, air-cooled gas coolers and adiabatic gas coolers. The company will continue to test these and other emerging technologies in the years to come to ensure that Heatcraft delivers the energy and environmental benefits that its customers expect.

Heatcraft is also investigating and preparing its facilities for what Zimmermann described as "the next level of innovation in liquid ejectors." He said the company has already recorded some promising results — a significant reduction in energy use with ejectors, compared with standard booster systems in high ambient temperatures.

The company has been working closely with suppliers of ejectors to remain on top of the latest innovations in these systems, Zimmermann said.

DelVentura said Heatcraft has developed a significant amount of intellectual property in the last few years related to these innovative technologies and "we expect this trend to continue."

The company's natural refrigerant technologies have been meeting Heatcraft's objectives for energy savings, according to Zimmermann.

He cited the ammonia/CO₂ cascade refrigeration system at the Piggly Wiggly in Georgia as an example. In that installation, Kysor/Warren also put in place a duplicate HFC refrigeration system to enable real-world comparisons in identical conditions. The test results — certified by a third-party engineering firm — revealed an average energy savings of 22% from using the ammonia/CO₂ system, compared with the conventional HFC system.

"That was pretty much in line with our expectations when we designed the systems," said Zimmermann, who noted that the COE remotely monitors all of its installations to ensure a high level of performance.

"For instance, at Piggly Wiggly, we have been monitoring and optimizing the approach temperatures in the heat exchangers," he said. "For the transcritical installations, we are perfecting and optimizing the high-pressure side controls and the gas cooler controls, to optimize the efficiency." ■ MH



Innovation Center at Heatcraft's Stone Mountain, Ga., headquarters, which encompasses a showroom, training facility and lab. From left: Bobby Austin, Keith Chester and Brendan Bannister.

Innovation Meets Responsibility

Lennox's companies are saving energy and cutting greenhouse gas emissions in its internal processes, reflecting the innovation and sustainability of its HVAC&R products

— By Mark Yohman

Our sustainability theme at Lennox International Inc. (LII) is "Innovation Meets Responsibility." This embodies our commitment to the environment as we produce the industry's most innovative and energy-efficient products in our Residential, Commercial and Refrigeration (Heatcraft and Kysor/Warren in the U.S.) businesses.

We are a 100+ year old company, and product innovation has always been our lifeblood. Our sustainability approach has been to apply our culture of product innovation to environmental improvements throughout our operations. We are industry leaders with our broad portfolio of energy-efficient and innovative products, and we want to walk the talk by producing these products with operations that are environmentally progressive.

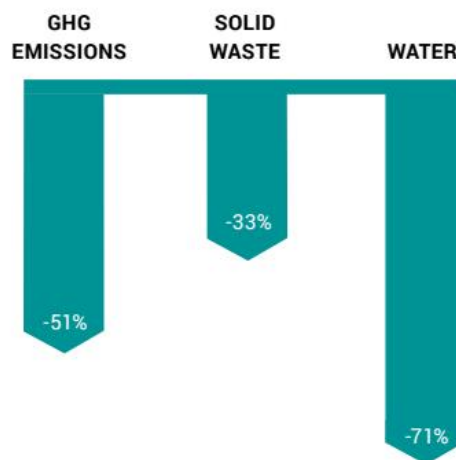
I oversee worldwide environmental regulatory compliance and environmental sustainability for operations. Our sustainability program includes metrics for reducing energy use, greenhouse gas (GHG) emissions, solid waste and water use at our 19 manufacturing and research locations worldwide and our 200+ distribution and retail stores in the U.S. and Canada.

We have a five-person corporate environmental department that sets the tone in driving environmental initiatives, but we really depend on the business units to get things done, and on each plant manager's sustainability leadership.

We're very fortunate that Todd Bluedorn, LII's CEO, decided in 2009 to create a sustainability capital budget to drive GHG reductions. Since then, we have had dedicated funding and do not have to compete with other projects in order to complete worthy sustainability initiatives. The availability of project funding has been a big part of how we've made environmental progress. Most of our capital projects have

LENNOX INTERNATIONAL

Absolute Sustainability Performance, 2009-2016,
Accompanying 44% Sales Growth



focused on reducing GHG emissions with energy-saving projects and reducing refrigerant loss to the atmosphere.

For example, to improve energy consumption, we've done a lot of lighting projects – first with fluorescents and now with LEDs. A capital project was recently approved for an LED retrofit at the Kysor/Warren plant in Columbus, Ga. We've also completed many other energy-efficiency projects, including compressed air and HVAC upgrades company-wide that have reduced energy consumption. Between 2009 and 2014 we implemented over 80 energy-saving capital projects. We have also improved employee awareness around energy consumption.

We have significant initiatives to reduce refrigerant loss, including implementing tighter controls when charging, testing and evacuating refrigerant in our products. These projects have helped drive down refrigerant loss by 85% in our manufacturing plants, and as a result we have realized significant GHG emission reductions from our operations.

As a result of these initiatives, Lennox met its energy and GHG emissions reduction goals for 2014 and reduced its energy usage and GHG emissions by 25% from 2009 baselines. Additionally, we have achieved a 31% reduction in energy use and a 67% reduction in GHG emissions (revenue normalized) between 2009 and 2016. In 2014, we established our new 10-year goals, which are to reduce energy use and GHG emissions by an additional 25% compared to 2014 levels.

On an absolute basis between 2009 and 2016, we were able to reduce GHG emissions, landfilled solid waste and water use by 51%, 33% and 71%, respectively, despite 44% revenue growth.

Engaging employees

Employee engagement is an important part of our sustainability program. We engage employees in several ways:

- ▶ We have quarterly conference calls with all worldwide plant managers in which best practices are shared.

- ▶ Lennox has annual awards to recognize successfully implemented sustainability initiatives. There's a lot of pride in winning this award and a friendly sense of competition among all of our business units to compete for an annual LII Sustainability Pacesetter Award.

- ▶ We also have a separate LII program, the Sqaure Melon, that recognizes and rewards individuals for identifying and completing projects that improve our products and reduce the impact on the environment.

- ▶ Beyond the corporate initiatives, business units and plant managers drive their own local awareness efforts and foster conservation-minded behaviors.

Here are some examples of ideas that were recognized by the LII sustainability recognition program:

- ▶ At our Orangeburg, S.C., and Saltillo, Mexico, plants, an automatic refrigerant leak detection system using a sealed chamber replaced a manual and laborious process, delivering more consistent leak detection.

- ▶ Kysor/Warren replaced two steel brackets in a Stratus multi-deck display case with one piece, cutting structural steel by 31% and weight by 28 lbs, while still maintaining the structural stability of the case. This reduced CO₂e emissions in the manufacturing process, since approximately one ton of emissions is generated for every ton of new steel made from melting scrap metal.

- ▶ A Lennox residential team worked with transportation carriers to improve parts delivery from Lennox Distribution Centers

to Lennox Parts Plus stores. This resulted in significantly fewer miles traveled and reduced our diesel GHG emissions.

- ▶ Our Tifton, Ga., Heatcraft plant built an in-house control mechanism to turn off idling air compressors, resulting in energy savings and a reduction in GHG emissions. The change also had a positive business impact by reducing oil changes and maintenance frequency. Often good environmental initiatives and positive business impact go hand-in-hand.

Lennox companies have been commended by outside entities for our sustainability achievements. We were recognized in 2014 by the U.S. Department of Energy as part of their Better Plants Program for meeting the 25% energy intensity commitment that we made. We also received an "A-" climate score for our voluntary reporting of climate change awareness and reduction programs. We are very proud of this recognition.

Additionally, seven of our U.S. regional distribution centers and our LII headquarters have received ENERGY STAR certification from the U.S. Environmental Protection Agency for performing in the top 25% of energy use relative to similar buildings. Our Saltillo, Mexico, facility received energy management certification from the International Organization for Standardization (ISO) last year. We have six factories that have achieved ISO's environmental management certification in Mions, Longvic and Genas, France; Burgos, Spain; Krunkel, Germany; and Saltillo, Mexico.

As our company continues to produce industry-leading, energy-efficient HVAC&R products – including products using climate-friendly natural refrigerants – we will continue to ensure that we do so with sustainability as a priority. ■ MY



Mark Yohman is director of environmental affairs for Lennox International, based in Richardson, Texas. A 25-year employee at Lennox, he has worldwide responsibility for environmental regulatory compliance and operations environmental sustainability.

Global Transcritical CO₂ Installations

Why Natural Refrigerants?

Regulation is the underlying driver, but the industry is diligently making the business case for these technologies by addressing efficiency, capital cost, total cost of ownership and the availability of trained maintenance staff

— Derek Hamilton and Michael Garry

The market for CO₂-based refrigeration in North America began more than a decade ago with the installation of secondary and cascade systems at food retailers like Food Lion and Price Chopper. The regulatory push against R22 was underway – with a ban on the production or import of the refrigerant slated for January 1, 2020 – and forward-thinking businesses were looking for reliable alternatives.

Since then, progress in North America with CO₂ systems has been gradual, well below European standards. Still, a growing number of regulations by the Environmental Protection Agency's Significant New Alternatives Program, including the delisting of HFC refrigerants that began in 2015, planted the seed for further growth of natural systems. And even if recent developments have added some uncertainty to the situation at the federal level, the industry remains positive about the prospects for growth. ([See policy article on page 15.](#))

By 2015, there were over 200 CO₂ secondary and cascade stores in North America, most of them in the U.S. These systems typically used an HFC refrigerant on the high side with CO₂ in pumped overfeed for medium-temperature cases and DX for low-temperature cases.

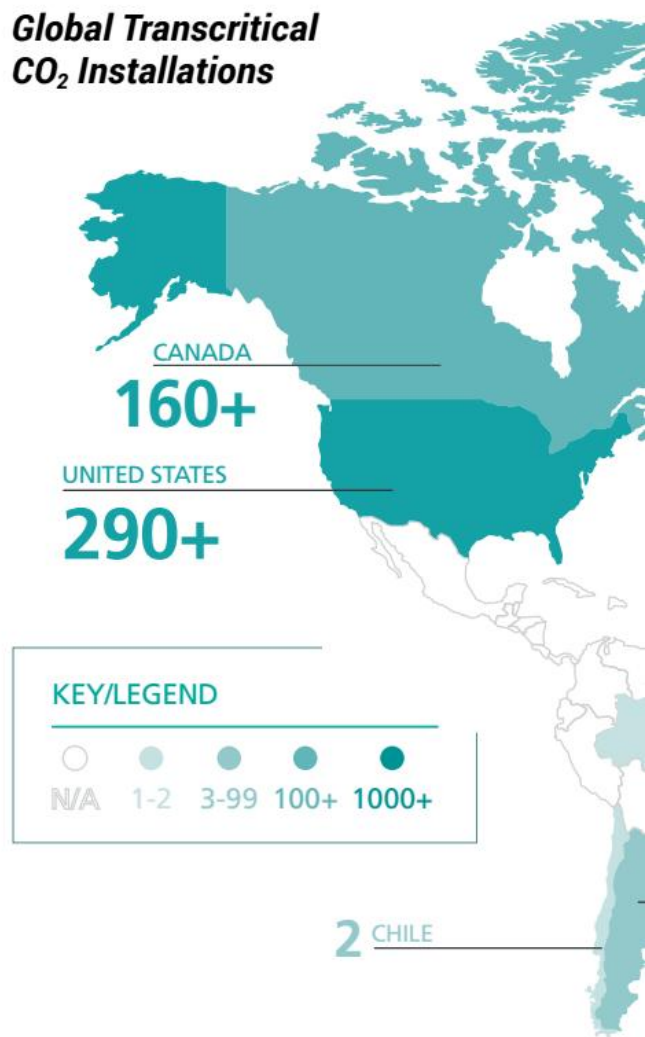
Canada, with its own regulatory schemes often patterned after the EPA's, decided to go in a different direction, opting for all-CO₂ transcritical systems. Sobeys, the country's second largest grocery chain, installed its first transcritical system in 2009, and soon thereafter it became the standard for new stores and retrofits. By last

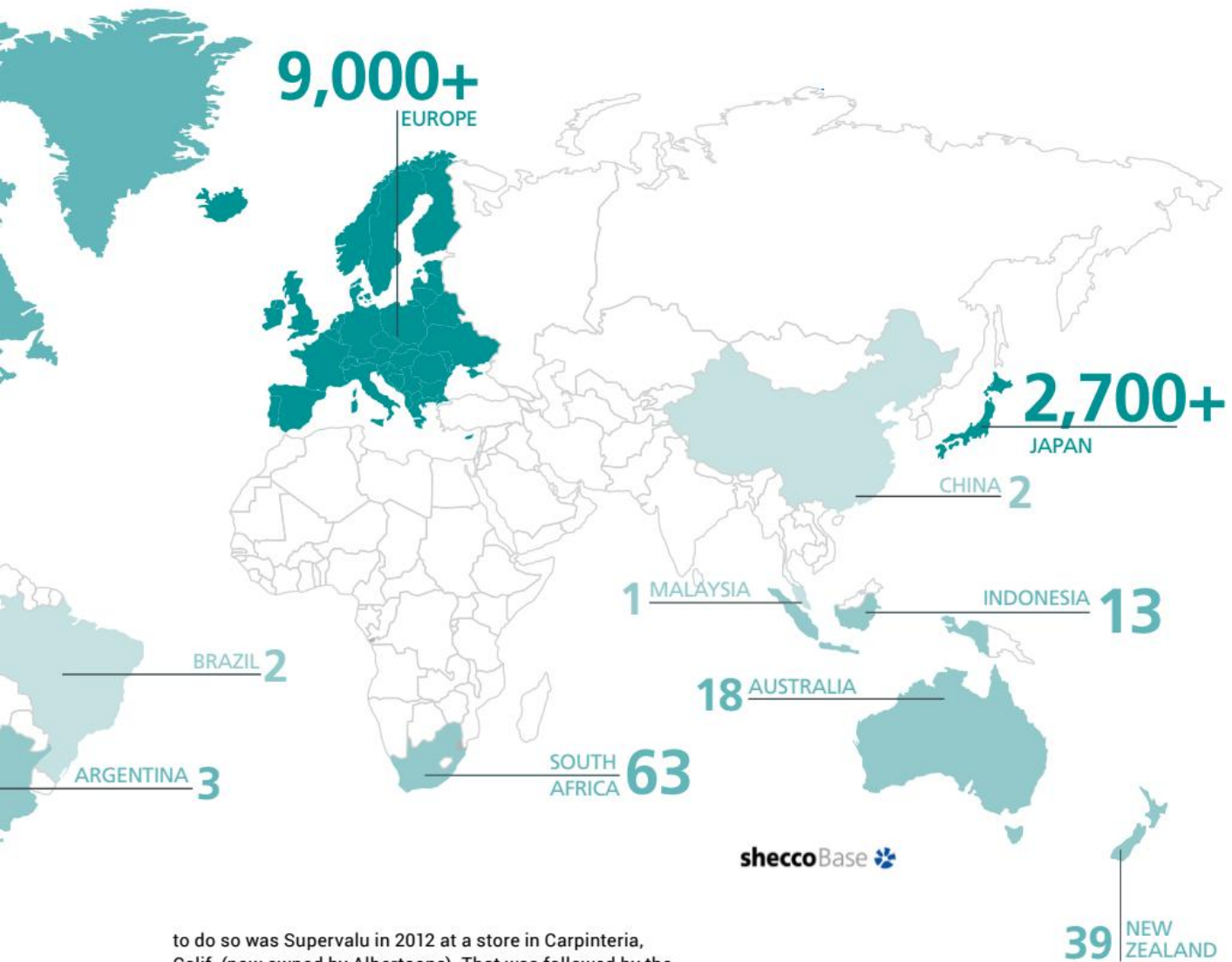
year, Sobeys had 82 transcritical stores, the most by far of any food retailer in North America, with plans to add transcritical to 15-20 new and remodeled stores each year.

The first transcritical installation in the U.S. took place in 2013 at a new Hannaford Supermarket in Turner, Maine. Since then, chains like ALDI, Roundy's, Whole Foods Markets, Target and Sprouts Farmers Market have opted for transcritical in some stores, along with a number of smaller retail operators like DeCicco & Sons in New York. By June of this year, more than 250 U.S. stores were using transcritical systems, along with more than 160 Canadian outlets.

While this still accounts for a relatively small percentage of the total number of North American supermarkets, the proportion of new-build stores using transcritical technology is growing all time. A notable recent development is that transcritical systems are increasingly being considered as retrofits in stores with aging equipment, a development that will further boost the uptake of the technology.

Most CO₂ cascade systems installed in the U.S. use an HFC on the high side, but four innovative retailers have installed cascade systems using another natural refrigerant – ammonia – on the high side in rooftop units. The first





to do so was Supervalu in 2012 at a store in Carpinteria, Calif. (now owned by Albertsons). That was followed by the Defense Commissary Agency (DeCA) at a commissary at the Lackland Air Force Base in San Antonio, Texas; Whole Foods Market in Dublin, Calif.; and JTM Corp. at a Piggly Wiggly store in Columbus, Ga. Last year, at a store in Santa Clara, Calif., Whole Foods employed a different natural refrigerant – propane – in rooftop high-side units.

Speaking of propane, it has become an increasingly popular substitute for HFCs in self-contained display cases in North America, with hundreds of stores deploying these units as an add-on to central refrigeration systems.

Early adopters of CO₂ and ammonia/CO₂ systems have faced a number of challenges – ranging from relatively high capital costs, to a lack of availability of properly trained technicians, to a range of negative perceptions surrounding the safety of ammonia and CO₂ as a refrigerant. There were a number of initial barriers to overcome, so why has the industry persisted in going down this route?

A reduced regulatory burden, and the removal of any uncertainty relating to future refrigerant regulations, has been an important part of any decision to choose natural

refrigerants. However, this was only part of the story - any decision also had to be supported by a strong business case based on efficiency, capital cost, total cost of ownership and the availability of trained maintenance staff. The industry, driven by increasing demand and greater competition, has been diligently addressing each of these challenges.

Design improvements

Most transcritical systems in North America have been installed in relatively moderate climates like those in Canada and the Northern U.S., where they have been found to be more efficient in many cases than HFC systems. By contrast, in climates that more often exceed CO₂'s critical point, 88°F, the refrigerant exists in a supercritical state that makes it harder to condense and therefore less energy efficient. So, in warm climates like the southern U.S., basic transcritical booster systems may not perform as efficiently as their HFC DX counterparts.

However, transcritical systems have benefited from a number of recent design improvements. These include the addition of parallel compression systems, commercially

“Transcritical systems are increasingly being considered as retrofits in stores with aging equipment.”

▶ viable ejectors, subcoolers and adiabatic gas coolers, which have all led to incremental increases in system efficiency. The net result is that a modern transcritical CO₂ system can be as much as 30% more efficient when measured against an early equivalent.

In the U.S., Sprouts recently opened a store in Woodstock, Ga., equipped with a transcritical system that includes an ejector and parallel compression. In Canada, Sobeys and Costco stores have started to use transcritical systems with these efficiency-enhancing add-ons. (Canada still gets hot in the summer.)

Cascade systems don't experience an efficiency challenge in warmer climates. In fact, the Piggly Wiggly store with an ammonia/CO₂ cascade system in Georgia (see article on [page 17](#)), has found that its ammonia rack operates 22% more efficiently than an HFC rack also used at the store for comparison purposes.

That efficiency advantage for ammonia/CO₂ would seem to make it a slam dunk in warmer geographies, except that ammonia's toxicity and pungent odor give some food retailers pause, even though it is safely locked away on rooftops. That perception may ease over time, especially as retailers like Piggly Wiggly demonstrate the safety of the system; in two years of operation, the Columbus, Ga., store has yet to leak any ammonia, and even if it did, the lighter-than-air gas would either dissipate into the atmosphere (where it would have zero impact on the climate) or be captured by a water diffusion tank.

And, of course, much is known about ammonia refrigeration, which has been a mainstay of the cold-storage industry for decades. This means that the technology and technician know-how supporting ammonia are much more robust than those supporting more recently adopted natural refrigerants like CO₂ and propane (in the modern era).

Clearing the cost hurdle

Perhaps the biggest obstacle to the uptake of natural refrigerant systems is their cost premium over traditional systems. Though energy efficiencies and lower installation and maintenance costs can deliver a lower total cost of ownership for a natural refrigerant system over the 15-20-year lifetime of the system, margin-pressed food retailers may still balk at the sticker price, which can be as much as 30%-60% higher than their legacy systems.

But there are mitigating factors that over time will ultimately bring the cost premium down to zero or close to it, as the more mature European market is finding. Most importantly, capital equipment costs are coming down as more systems are being built, and as more system manufacturers begin to add natural refrigerant options to their product portfolios.

The growing availability of utility incentives to switch to more efficient, lower-GWP refrigerants is another important market driver easing some first-cost burden. In California, utilities such as Southern California Edison and the Sacramento Municipal Utility District (SMUD) are already providing incentives to food retailers and cold storage operators installing energy-efficient natural refrigerant systems. SMUD has gone one step further, launching a first-of-its-kind incentive for reducing greenhouse gas emissions through the installation of natural refrigerant systems.

Still there is a need for more industry collaboration with utilities to educate them about natural refrigerants

and demonstrate the efficiencies and positive environmental impact they make possible.

The availability of properly trained technicians is also consistently highlighted as one of the main obstacles to increased adoption of natural refrigerant technologies. Here again, progress is being made as many OEMs are stepping forward with aggressive training programs, particularly for contractors and technicians engaged in the installation and maintenance of their natural refrigerant systems. Specialized training organizations, like the Garden City Ammonia Program (GCAP) and associations like RETA and RSES, are also filling the void with robust training opportunities.

And some leading contractors, like Source Refrigeration & HVAC, Climate Pros and AAA Refrigeration, are proactively training their technicians on the art and science of natural refrigerant technology. Source, for example, has opened a training facility at its headquarters in Anaheim, Calif., that uses a simulated grocery store equipped with a CO₂ cascade system; Climate Pros is in the process of building such a center at its Chicago headquarters, while AAA holds an annual symposium that brings together natural refrigerant experts to train its technicians.

While the market for natural refrigerants in North America is still in its early stages of development, a confluence of forces is ensuring that this technology is here to stay and will provide an increasingly important option for retailers seeking a future-proof solution to their refrigeration needs. ■ **DH & MG**



Former Secretary of State John Kerry

A Volatile Landscape

Uncertainty at the federal level is raising questions about HFC regulations in the U.S., but natural refrigerant technologies are expected to continue making inroads in North America nonetheless

— By Marie Battesti and Michael Garry

Probably the biggest driver of natural refrigerant technologies throughout the world is government policy that either regulates high-GWP synthetic refrigerants or outright supports low-GWP alternatives like naturals.

In Europe, for example, the advanced adoption of natural refrigerants stems from the F-Gas Regulation, which calls for the phase-down of HFCs in the coming years, as well as from aggressive bans and taxes applied to synthetic refrigerants. In Japan, the generous subsidies from the Ministry of the Environment have covered as much as one-third the installed cost of natural refrigerant-based systems, leading to more than 2,400 mostly convenience stores using transcritical CO₂ condensing units at the end of February 2017.

In North America, where natural refrigerants uptake has grown but still lags behind Europe and Japan, the federal government has been less of a factor. Still, the Canadian government last year announced an HFC reduction plan. In the U.S., the Environmental Protection Agency and the Department of Energy have both implemented policies that have affected the refrigerants marketplace, while the most populous U.S. state, California, is independently and actively addressing the issue.

As a developing country, Mexico has done less to address HFCs, though it has set up a program that targets short-lived climate pollutants including HFCs.

► The Kigali factor

The refrigerant policy landscape for all three countries, along with that of the world, changed last October with the passage of the Kigali Amendment to the Montreal Protocol, which calls for a global phase-down of high-GWP HFCs as a follow-up to the phase-down of ozone-depleting CFCs and HCFCs.

In North America, Canada proposed its HFC-reduction plan shortly after the passage of the Kigali Amendment, combining an HFC consumption phase-down with controls on specific products that contain HFCs, including refrigeration and air conditioning equipment. The plan, which could go into effect next year, ensures that Canada would meet its obligations under Kigali to cut HFC emissions by 85% by 2036. Mexico will be seeking funding from the Montreal Protocol's Multilateral Fund to support an HFC phasedown under the Kigali program established for developing (A5) countries.

Under the Obama administration the U.S. was on course to ratify and pursue an HFC phase-down as prescribed by Kigali. However, there is some uncertainty now about how the Trump administration will deal with refrigerants following its decision to exit the Paris climate change accord. The situation was further complicated last month when a three-judge panel in the Court of Appeals for the District of Columbia Circuit ruled 2-1 that the EPA cannot require companies to replace HFCs with low-GWP substances under its Significant New Alternatives (SNAP) program.

Even so, there is so much industry momentum behind the replacement of high-GWP HFC refrigerants with natural refrigerant alternatives, that most observers believe the U.S. will continue to move in that direction.

In the long-term, U.S. end users and their suppliers are seeking a future-proof solution immune to the political vagaries of the moment and supported by a favorable business case that includes improved energy efficiency. Organizations in the U.S. responsible for standards like Underwriters Laboratories (UL) and ASHRAE will continue to propel the market as well.

And the continuing impact of climate change further underscores the need to reduce emissions of greenhouse gases like HFCs.

Challenge to SNAP

The EPA, through its SNAP program, is charged with evaluating and regulating substitutes for ozone depleting substances (ODS). Over the last several years, the SNAP program has incentivized the transition to climate-friendly refrigerants by approving the use of CO₂ and hydrocarbons in a variety of applications while delisting the use of HFCs in those applications. In both 2015 and 2016, the EPA set into motion the removal of HFCs like R404A and R407A in commercial and industrial systems.

However, the Court of Appeals panel in the case *Mexichem Fluor, Inc. vs. EPA* ruled on August 8 that the EPA, by delisting HFCs, had overstepped its authority under



Section 612 of the Clean Air Act, which was designed to regulate only ozone-depleting substances (ODS).

While the ruling would appear to be a setback for low-GWP HFC replacements like natural refrigerants, several industry players said it was too soon to know its ultimate effect given the different directions the EPA can still take. The EPA could appeal the ruling to the full Court of Appeals for the District of Columbia Circuit, considered more liberal than the three-judge panel. Or the EPA could follow the court's suggestions on how it could still regulate HFCs.

The EPA's regulatory authority over HFCs may ultimately depend on U.S. action on Kigali. If the Senate approves the amendment, and Congress follows suit with an adjustment to the Clean Air Act, then EPA's authority would be confirmed.

Another important factor in the U.S. are the efforts underway in California to reduce emissions of short-lived climate pollutants (SLCPs), including HFCs. California has solidified its position as a leader in the U.S. for climate action, and this trend is set to continue with a planned HFC phase-down. In contrast with the position at the federal level, the state plan approved in March 2017 aims to reduce HFCs by 25% below business-as-usual emissions by 2020, and by 40% below 2013 levels by 2030.

Similar to the EU with its F-Gas Regulation, the California Air Resources Board (CARB) is proposing a combination of measures to reduce HFC emissions that could be implemented next year. These include a prohibition on refrigerants with a GWP over 150 in new refrigeration equipment and over 750 in new air conditioning equipment, and a ban on refrigerants with a GWP over 2,500, lowered later to 1,500. These restrictions would have a national impact on manufacturers and could ultimately drive the adoption of federal changes – an effect California has had in the past on environmental standards.

So, despite some uncertainty fostered by the current U.S. political climate, natural refrigerant technologies should continue to make inroads in North America, backed by a strong business case, industry support for future-proof solutions, and the expectations generated by Kigali and California. ■ MB & MG

Saving Energy with Ammonia and CO₂

A Piggly Wiggly store in Columbus, Ga., has saved almost \$125,000 in energy costs in about two years, thanks largely to the superior efficiency of its NH₃/CO₂ cascade system

— By Michael Garry



The iconic Mr. Pig mascot

When Keith Milligan received the first utility bill for his new 36,000-square-foot Piggly Wiggly store in Columbus, Ga., in 2015, he was flabbergasted at how low it was.

"I called the lady at the power company [Georgia Power] and said, 'I just want to make sure you got this right,'" said Milligan, CIO for the JTM Corp., Phenix City, Ala., a family-owned retailer that operates 19 Piggly Wiggly stores along the border separating central Alabama and Georgia. He chuckled at the memory. "I didn't want her to come back in two years and say, 'I billed you wrong and you owe us \$200,000.' But she checked it, and it was correct."

The linchpin of this Piggly Wiggly — and the biggest contributor to its energy-saving capacity — is an ammonia (NH₃)/CO₂ cascade system made by Kysor/Warren, a division of Heatcraft Worldwide Refrigeration, at its plant in Columbus, about 1.5 miles from the store.

The store, opened in September 2015, is just the fourth in the U.S. to use an NH₃/CO₂ refrigeration system, along with some installations at European supermarkets. But its superior energy efficiency, even in a warm climate like central Georgia, makes NH₃/CO₂ one of the more promising natural refrigerant technologies in the world. "We're excited about being one of the first stores to do this," said Milligan.

The Piggly Wiggly store uses an ultra-low charge (53 lbs) of ammonia — less than any of the other NH₃/CO₂ stores — which is confined to the roof in the ammonia rack. The ammonia condenses the CO₂, which circulates throughout the store, cooling low-temperature cases via direct expansion and medium-temperature cases through pumped liquid overfeed.

At the ATMosphere America conference in June 2016, Milligan presented data on the Columbus store's power

consumption compared with one of his company's R407A stores in La Grange, Ga., normalized for store size. For the period ranging from October 2015 to April 2016 (six months), the new Piggly Wiggly consumed 23% to 33% less energy than the conventional outlet, for an average energy savings of 28.5% (\$33,170 in total).

The new store was equipped with a number of other energy-saving elements, including LED lights, skylights, occupancy and daylight controls, doors on display cases, Lennox rooftop HVAC units, external Dryvit insulation, a white roof, and heat reclaim for hot water. But the NH₃/CO₂ system, which accounts for 60% of the store's electricity consumption, was by far the most impactful on efficiency.

In a webinar sponsored by the Environmental Protection Agency's GreenChill program in December 2016, Milligan provided updated energy comparison numbers. Over a 13-month period – October 2015 to October 2016 – the store cut its energy consumption by 33% on average – for a total of \$74,640 in savings – compared to using HFC refrigeration.

Milligan recently supplied an update showing the continuation of his energy savings: From October 2015 through July 2017, the NH₃/CO₂ store used an average of 27% less energy than the HFC store, saving \$124,800. "I'm really pleased with the savings," he said.

At the ATMosphere America conference, Kysor/Warren offered energy data on the ammonia rack compared with that of an HFC (R407A) rack; these top-side

racks alternate about every two weeks, each separately working in tandem with the CO₂ rack. To compensate for potential variations in ambient weather and case loads under which each rack operated, the loads and ambient temperatures were "normalized."

Between February 2, 2016, and May 22, 2016, CTA Architects and Engineers performed an independent third-party audit to certify that the system was built as designed and that the comparison methodology being used was appropriate. It was shown that the NH₃ rack consumed 22% less energy on average than the HFC rack, ranging between 18% and 25% depending on ambient temperature.

"This was done with the intent of taking the ambiguity out of the energy comparison and getting really solid numbers," said Robert Delventura, vice president of global innovation for Heatcraft.

A lower TCO

While the NH₃/CO₂ system has demonstrated significant energy savings – crucial in a small-margin business like food retailing – it does, at present, come with a higher price tag than a conventional HFC system. Would its total cost of ownership (TCO), factoring in operating costs, make it a worthwhile investment for Piggly Wiggly?

Time will tell, though Milligan is optimistic. In addition to the energy savings, he points to the rising costs of synthetic refrigerants like R407A and R22, used in his other stores, and the low cost of CO₂ and ammonia.



Keith Milligan, JTM Corp. (Piggly Wiggly)

"We really feel like natural refrigerants are the end game," he said. "We won't have to worry about their costs going up." Nor will there be any concern about regulations banning or phasing out high-GWP refrigerants. "I wish all of our stores were that way."

At ATMosphere America, Kysor/Warren presented a slide on the estimated total cost of ownership (TCO) of an NH₃/CO₂ system modeled for a store in San Diego, Calif. Again using a traditional HFC system as a baseline, Heatcraft found a 15% to 20% lower TCO for the ammonia system. This calculation factored in a 15%–23% lower energy cost, a 50%–70% higher first (capital) cost (now more in the range of 30–40%), and a 0–5% higher maintenance cost.

In regard to first costs, because Milligan allowed Heatcraft to use the Columbus store as a "test lab" that included the redundant HFC system, "they gave us a really good deal [on the NH₃/CO₂ system]," he said. "It's been a really good partnership with Heatcraft."

If Milligan had paid the full cost of the system – and presuming a 30% premium above the cost of a conventional HFC DX system, a number that is coming down significantly – he estimated a four-to-seven-year ROI, based mainly on energy and refrigerant savings.

He was able to secure a "sizable" energy-efficiency incentive for the Columbus store from the Georgia Power Co., though not for the refrigeration



Columbus, Ga., store with NH₃/CO₂ system

system. The incentive covered other standard energy savers like LED lighting and glass case doors. With the NH_3/CO_2 in place, and proving to be energy efficient, future stores in Georgia would be eligible for incentives for this equipment.

Milligan recently said that he has found the maintenance costs on the NH_3/CO_2 system to be about the same as those for his conventional systems at other stores. The only additional cost is "a few hundred [dollars] a month" to maintain the evaporative condenser. And the installation cost (not including the HFC system) was also comparable to that of other systems.

Ammonia poses some challenges, notably its toxicity in certain concentrations and its pungent odor. "I asked a lot of questions about that," said Milligan. "But because there is such a small amount [53 lbs] I didn't see much danger. I'm very comfortable with it." The Piggly Wiggly distribution center in Bessemer, Ala., he noted, uses thousands of pounds of ammonia.

Almost two years into the NH_3/CO_2 system's operation, there have been no ammonia leaks, Milligan said. If there were a leak, "ammonia is lighter than air, and it's above the store," he added. "So it stays outside." There have been only minor CO_2 leaks – which don't need to be reported to the EPA – since the store opened.

And with its self-alarming odor, "ammonia lets you know you have a leak and you can leave the area. So I don't think there's any danger at all for our techs."

Environmental benefit

Beyond its impact on energy consumption, the NH_3/CO_2 system offers a tremendous reduction in direct greenhouse gas emissions due to refrigerant leaks. That's because of the virtually non-existent combined GWP of ammonia (zero) and CO_2 (one). Based on a 15-year life, a 15% leak rate, a refrigeration load of 535KW, among other factors, an NH_3/CO_2 system in San Diego would cut direct emissions by 99% compared to an HFC DX system; including indirect emissions from power consumption, the NH_3/CO_2 system's life cycle climate performance (LCCP) would be reduced by 64%, according to Heatcraft.

The environmental benefits of his Columbus store are aligned with Milligan's values. "I have grandkids and I want to leave a good place for them," he said. "As a nation and a world we are making progress, but we still have a long way to go."

Milligan intends to use an NH_3/CO_2 system in future stores. As for existing outlets, he is open to exploring a retrofit solution that encompasses natural refrigerants.

Now he would like to see more supermarkets follow his lead. "Every store you change makes a big difference." To that end, he allows other retailers, including competitors, to tour his Columbus store and see the system in operation. "Lots of people from all over the world come in regularly," he said. ■ MG



The NH_3/CO_2 system's rooftop ammonia rack

System Specs

The NH_3/CO_2 cascade refrigeration system at the Piggly Wiggly store in Columbus, Ga., has the following characteristics:

- ▶ Refrigeration capacity, medium temperature cases: 462.1 MBH (38.5 TR)
- ▶ Refrigeration capacity: low temperature cases: 221.7 MBH (18.5 TR)
- ▶ Total capacity of the ammonia cycle: 70 TR
- ▶ NH_3 rack: three Bitzer open-drive reciprocating compressors
- ▶ CO_2 rack: two Bitzer reciprocating compressors
- ▶ HFC rack (for energy comparison with NH_3 rack): five Copeland semi hermetic compressors
- ▶ NH_3 charge: 53 lbs (0.75 lbs/TR)
- ▶ CO_2 charge: 1,400 lbs
- ▶ HFC (R407A) charge: 300 lbs
- ▶ Automatic oil recovery system
- ▶ Water diffusion tank
- ▶ Stratus display cases with electronic expansion valves
- ▶ Danfoss case and rack controls
- ▶ BAC evaporative fluid cooler
- ▶ Variable frequency drives
- ▶ Heat reclaim for hot water
- ▶ Defrost, low temperature: electric
- ▶ Defrost, medium temperature: off-cycle



CO_2

A Breakthrough Technology for Carrefour

The global retailer is one of the leading users of transcritical CO_2 refrigeration, which is delivering energy savings compared to traditional systems, even in warm climates

— By Mark Hamstra and Michael Garry

One of the world's largest retailers is focused on leaving a much smaller environmental footprint.

As of June 2017, Boulogne-Billancourt, France-based Carrefour Group encompassed 12,052 corporate and franchised stores, including hypermarkets, supermarkets, convenience stores and cash-and-carry outlets in more than 30 countries. It's also one of the world's leading operators of natural refrigerant technologies.

The company has committed to reducing its carbon emissions by 40% by 2025

and by 70% by 2050, compared with 2010 levels. It is doing so through both a reduction in energy consumption and a reduction in CO_2e emissions from refrigeration and transportation.

As part of its effort to achieve those goals, Carrefour is replacing its HFC refrigeration systems with natural refrigerant technologies. Going forward, this will focus on transcritical CO_2 systems, said Jean Michel Fleury, director of international support at Carrefour, where he oversees innovation in energy efficiencies for all 10 Carrefour subsidiaries around the

world. His team also supports energy efficiency efforts among Carrefour's franchise partners, which operate Carrefour stores in some regions.

"The policy is to go to 100% natural stores [using transcritical CO_2]," he said.

On its website, the company states that transcritical CO_2 refrigeration is "a breakthrough technology that has been tested and approved by Carrefour."

As of Sept. 1, Carrefour operated approximately 418 stores using natural refrigerants, about 90% of which use CO_2 ,

including 179 stores in seven countries that feature transcritical CO₂ systems. Three of Carrefour's transcritical CO₂ systems are in Brazil, and the rest are in Europe. The company is also eyeing China for potential future installations, Fleury said, as that country has begun to embrace sustainability initiatives.

The other 239 CO₂ stores have subcritical, or "hybrid" systems, which use HFCs on the high side along with the natural refrigerant. The company also uses self-contained hydrocarbon systems, another natural refrigerant technology, in plug-in refrigeration units.

Carrefour has primarily been focused on installing CO₂ systems in supermarkets and hypermarkets, but it has employed CO₂ in a handful of its cash-and-carry stores, and has also begun installing CO₂ systems in a small number of convenience stores in Spain and France, according to Fleury.

Although Carrefour has deployed ammonia refrigeration systems in some of its distribution facilities, the company's focus is on shifting toward transcritical CO₂ systems in those locations as well, Fleury said, citing the additional regulatory and safety issues involved with the use of ammonia.

"Ammonia is excellent from an energy efficiency point of view, and for the environment, but it has its own challenges," he said.

Europe is currently experiencing a boom in the sale of HFOs because of the ease with which they can replace the increasingly regulated HFCs, but Fleury said Carrefour is committed to CO₂ technologies.

"Carrefour has a very cautious policy regarding the use of HFOs," he said, citing uncertainty around their impact on public health and noting that the ingredients used in HFOs "take centuries to degrade."

Fleury acknowledged that HFOs have a low global warming potential (GWP), but Carrefour's position is that natural refrigerants provide a better solution, even if converting to the technology requires a refrigeration system retrofit.

Although the recent F-Gas Regulation in the European Union accelerated the deployment of natural refrigerants in France, Spain and other EU countries where Carrefour operates stores, Fleury noted that Carrefour had already been proactive in its adoption of such systems.

"We did not wait for the EU F-Gas Regulation," he said, noting that the company's commitment to reduce carbon emissions — part of its corporate social responsibility goals — already existed before the regulations.

Carrefour prioritized the installation of CO₂ systems in Europe because of the F-Gas Regulation, but Fleury pointed out that the installations in Brazil, where no such regulations exist, demonstrate the company's environmental commitment.

Auxiliary Technologies

In order to increase the efficiency of transcritical CO₂ installations in warmer climates, including Brazil and Spain, Carrefour has deployed auxiliary technologies, including adiabatic gas coolers, parallel compressors, and ejector technology, Fleury said.

"It is true that we lose a bit of efficiency according to the climate," he said. "But we have applications such as parallel compression to maintain the equivalent performance." Other than the auxiliary equipment, the basic technology used in each of the regions is the same, Fleury explained.

Using transcritical CO₂ systems instead of conventional HFC systems, Carrefour achieves energy savings of 8% to 12% in warmer-climate regions, such as in southern Spain, and savings of 18%

to 20% in areas with more temperate climates such as Brussels and Paris, according to Fleury. In regions that experience sharp variations in temperature, with hot summers and very cold winters, such as Poland, the energy savings range from 15% to 20%, he said.

According to Carrefour's website, the energy savings provided by transcritical CO₂ technology has helped the company earn ISO 50001 certification for its energy management system, becoming the first French retailer to do so.

Fleury estimated that return on investment for the additional technologies required to make CO₂ more efficient in warmer climates is between one and three years.

Although transcritical systems may require a larger upfront cost than conventional HFC refrigeration systems, Fleury said the CO₂ systems require less maintenance if they are operated and maintained properly.

"Transcritical installations have particular characteristics, such as thicker pipes, which reduce the costs of maintenance," he said, although he added that costs can vary according to the constraints of each location and the brand of equipment used. Remote monitoring via digital technologies also helps reduce maintenance costs, he said.

In assessing the cost of a transcritical system, Carrefour looks at the total cost of ownership and overall ROI, factoring in equipment, installation, maintenance and energy, over a period of 10-15 years, Fleury said.

Carrefour hypermarket in Spain.





Philippe Fauchon, Lennox EMEA

A CO₂ Pioneer

Lennox EMEA, the European subsidiary of Lennox International responsible for Europe, the Middle East and Africa, got an early start with CO₂ refrigeration through its HK Refrigeration brand. "We were one of the first to be talking about CO₂," said Philippe Fauchon, sales manager, HK Refrigeration.

The company, based in Lyon (Genas), France, began manufacturing secondary pumped CO₂ refrigeration systems for Europe in 2003. At that time, however — before Europe implemented the current restrictions on HFCs — there were few incentives for supermarket operators to adopt CO₂.

So, after its initial foray into CO₂ technologies, the company shifted its focus back to conventional installations until about four years ago, when it began installing subcritical CO₂ systems, followed by transcritical systems about a year later. Since that time, the company has installed hundreds of CO₂ systems, both subcritical and transcritical.

In Europe, Lennox EMEA, through HK Refrigeration, is a major provider of these CO₂ systems, supplying them to such major retailers as Carrefour franchises, Auchan and Intermarché.

The HK Refrigeration brand works with other Heatcraft divisions around the world on CO₂ technologies through the Center of Excellence, or COE, which refines the innovations developed through its global research team to create equipment specific to the needs of each market.

"It's the same basic technology [for each market]," said Fauchon, with product differences seen in optional features based on market needs.

Although CO₂ systems are more complex than conventional systems, installers competing against each other have been driving down the price for end users so that basic CO₂ systems have reached price parity with traditional systems in Europe, relative to equipment and installation costs.

"Now you can get [natural] solutions installed for exactly the same price as for all other solutions," said Fauchon.

Fauchon said HK Refrigeration has installed transcritical CO₂ systems in moderately warm climates, such as those found in Portugal and Southern France, but not in extremely hot places such as the Middle East.

Lennox EMEA has deployed auxiliary technologies to make warm-weather CO₂ more efficient, including adiabatic coolers, but the company tries to be conscious of when to apply them because of water-usage requirements, according to Fauchon. Other technologies, such as parallel compression and ejectors, have been deployed, and HK Refrigeration is refining them as well as other high-temperature equipment.

HK Refrigeration is also doing its part to bring technicians up to speed on installing and maintaining CO₂ refrigeration systems.

The company offers two levels of training. One is called Lennox University, which is conducted in Lennox EMEA offices and provides basic information about how CO₂ refrigeration works and the challenges of CO₂ systems. The second level provides after-sale training at customers' store locations on the actual systems that are being installed.

"We show them how it works on their own installation," said Fauchon. ■ **MH & MG**



HK Refrigeration eCO₂ Boost transcritical system

► Technician Shortage

The biggest challenge Carrefour has encountered with CO₂ transcritical refrigeration is the shortage of trained technicians relative to the number of installations, according to Fleury. Although he said Europe had an abundance of trained technicians in the early years of its CO₂ deployments, it has recently started to become more challenging to find these individuals.

"There is a boom of demand for CO₂-based equipment, and good installers and technicians are increasingly rare," Fleury said. "It is a real problem that will increase over the years."

He said it is up to manufacturers and the industry to train more technicians and work with schools to support their training programs. It is a problem that needs to be addressed at the public policy level as well, Fleury added, noting that — at least in France — students are not permitted to touch transcritical systems because of the danger associated with the higher pressures in these systems.

He suggested that special certifications should be established for technicians who have been trained to work on transcritical refrigeration systems.

"I am not sure that exists in all countries," said Fleury.

Sweet Dreams

Kysor/Warren makes a 'Sleep Well' promise to natural refrigerant systems end users, pledging that trained technicians will be ready to address any issue, at any time

— By Mark Hamstra

One of the well-known barriers to the adoption of natural refrigerant technologies is uneasiness about technicians' degree of experience with the systems.

"If you are a retailer looking at a new alternative [system], support is the one area you are the most concerned about," said Michael Lehtinen, director of marketing for Heatcraft Worldwide Refrigeration, in a presentation at the ATMOsphere America conference in June.

"You want to know, 'Will I be able to get help when I need it?'"

In order to put its customers at ease, Columbus, Ga.-based refrigeration equipment manufacturer Kysor/Warren, a brand owned by Lennox International's Heatcraft division, offers what it calls the "Sleep Well" promise. This is a pledge that professional maintenance and emergency service by trained technicians will be available for the end users of these systems.

"We really want to make sure the end users are comfortable, that they are being taken care of and that they can sleep well at night," said Augusto Zimmermann, group senior manager at Heatcraft's Alternative Systems Center of Excellence (COE), during the presentation at ATMOsphere America.

Heatcraft's experience installing and maintaining nearly 300 systems using natural refrigeration technologies — transcritical CO₂ systems, HFC/CO₂ cascade systems, and, most recently, a cascade ammonia/CO₂ system — around the



Dan Roehl, Market Mechanical

world has given the company the background and experience to handle any situation that arises, said Zimmermann.

"We have a global design platform to ensure reliability for our customers," he said. "It is repeatable — what you get in Europe is the same thing you get in the U.S., and there are a lot of benefits from that. There's a lot of technology and knowledge transfer between regions, so we use best practices from all of the different parts of the world."

Ongoing training and support

A significant element of Kysor/Warren's Sleep Well promise is the ongoing training and support it provides to its contractors, its customers and their technicians. To that end, Kysor/Warren has developed a comprehensive suite of training tools for contractors that includes classroom sessions, online media and hands-on support before, during and after installation.

"We partner with our customers to train their contractors of preference to be proficient with our systems," said Zimmermann. "We really provide a lot of support to them during the installation, and even before that, during the store planning, and during the commissioning and post-commissioning operation, making sure everything is running smoothly."

In providing support for customers and contractors, Kysor/Warren also leverages the knowledge of the global team of experts within Heatcraft's Alternative Systems COE, whose engineers designed the systems.

► Doug Norton, project manager at Trenton, N.J.-based Capitol Refrigeration, which installed a Kysor/Warren-designed transcritical CO₂ refrigeration system at a supermarket in Towson, Md., said the manufacturer was “very thorough and supportive.” Although Capitol had installed transcritical CO₂ booster systems before, the Towson installation was the company’s first with Kysor/Warren.

“They brought the training to us,” Norton said. “The class they gave us really helped.”

Kysor/Warren also provided high-quality drawings of the system, which Norton said can be helpful when it comes to obtaining permitting from local jurisdictions.

Capitol Refrigeration, which has a contract with the supermarket operator to provide ongoing maintenance at the location, has had “no issues” with that aspect of its responsibilities, despite the higher operating pressures of the CO₂ system.

“Once you get through the first one, they are pretty straightforward,” said Norton. “They are just like any other system. You just have to be aware of the higher pressures. You need to keep safety in mind.”

Technical sales support, too

Kysor/Warren also has about 20 technical sales support (TSS) professionals around the country who work closely with contractors and customers throughout the installation process.

Mark Stansbury, one of Kysor Warren’s TSS professionals, said he and his colleagues are always ready to assist customers and their contractors.

“Most of us will jump on an airplane and be on site within six hours if need be,” he said. “We are there for the end user, and to help the contractor get through any issues.”

At one recent natural refrigeration installation — a CO₂ transcritical system

“We really want to make sure the end users are comfortable, that they are being taken care of and that they can sleep well at night.”

— Augusto Zimmermann, Heatcraft

at a supermarket in Boston — Kysor/Warren flew in several team members from around the country to make sure the contractor had the necessary support. Although the contractor had previous experience installing a CO₂ refrigeration system, that system was not one of Kysor/Warren’s designs, and Stansbury said Kysor/Warren wanted to ensure that everything went smoothly with the Kysor/Warren CO₂ system.

Stansbury agreed that the main concerns for contractors installing CO₂ systems revolve around the higher gas pressures, which call for the use of special, steel-reinforced copper piping that is rated for 120 bar of pressure (about 1,740 psig), compared with 45 bar for conventional systems. The special piping comprises about 15%-20% of the total piping in the system where the CO₂ exerts the most extreme pressure.

“The pressures that we deal with on hot days are probably three to four times what anyone has worked on over the years,” he said. “Instead of seeing 300 pounds of pressure on a bad day on the high side, we are looking at 1,300 pounds.”

Technicians who have some experience in the industry tend to pick up on the transcritical technology easily, he said.

“With CO₂, you want to try to refrain from making dry ice out of it by releasing the liquid CO₂ into the atmosphere,” said Stansbury. “Other than that variable, and some higher pressures, it’s basically the same thing they’ve always worked on.”

Safety is always a key consideration with high-pressure systems, but Kysor/Warren builds safety features into the systems and trains technicians how to

use them. A typical DX system might have two relief valves, for example, while a transcritical system might have nine, Stansbury explained.

A level of familiarity

Dan Roehl, project manager at Brooklyn Park, Minn.-based Market Mechanical, a contractor that counts several supermarket operators among its clients, said training around natural refrigerant technologies is welcomed in the industry.

Market Mechanical recently partnered with Kysor/Warren to co-sponsor a training class in Minneapolis for about 75 refrigeration industry professionals, including local technical college instructors and labor union training personnel. Kysor/Warren sent six of its engineers to lead the training

“The idea is to build a level of familiarity and comfort with the use of CO₂ in refrigeration,” said Roehl. “Everyone is excited to learn about the new technology.”

Because there are still relatively few deployments of CO₂ systems in supermarkets in the U.S., few technicians have had hands-on experience, he pointed out.

“I think there are more [installations] coming up in the future, and I think it helps make the end customer aware that we are trying to be more familiar with the product,” said Roehl. “Sometimes customers hesitate because it’s new, and they wonder whether or not we can handle it. The more we train our technicians, the more our customers are going to feel confident that they have a capable contractor.” ■ MH



Heatcraft R&D lab

Developing New Products at Heatcraft

The company's global R&D prowess keeps its customers on the cutting edge of natural refrigerant technology and ahead of regulatory pressures

– By Robert DelVentura, Augusto Zimmermann and Nicole Martin

Robust new product development capability – of which innovation is the lifeblood – is critical to a company's success, and Heatcraft Worldwide Refrigeration (WWR) is no exception.

At Heatcraft, our research and development (R&D) teams focus on developing new and emerging technologies to provide the best possible Life Cycle Climate Performance (LCCP) for our customers.

Our innovation capability creates new opportunities to provide timely market-based solutions. It also drives product lifecycles – today's innovation quickly becomes tomorrow's standard – and it continuously raises the bar for new product development.

Our role as environmental stewards requires that we push the boundaries of technology in order to meet constantly changing market requirements and regulatory performance standards. This must be done in a controlled process that demonstrates engineering rigor and best practices. The methodology uses a gated process that takes innovation step-by-step from proof of concept to commercialization.

Heatcraft Global Research and Development manages this pipeline through our global research and advanced alternative systems teams as well as through our regional engineering teams residing in all of our global businesses. We leverage our company's global laboratories network located in North America, Europe and Asia as well as our





Augusto Zimmermann, Heatcraft

“With a track record of hundreds of successful CO₂ installations and strong partnerships with contractors all over the globe, we are quickly overcoming the early misconceptions and reluctance about alternative refrigerants.”

► Lennox International Technology Center in India to provide state-of-the-art testing and research capability.

Being able to bring all of these resources together in order to focus on new product development allows us to leverage advanced analytics that include finite-element analysis, computational fluid dynamics and sophisticated 3D solid-modeling techniques. Combined with actual product testing, these tools enable us to meet or exceed various global standards and international codes reducing time to market while developing robust products.

The latest in alternative refrigerants technology

A great example of this global effort is the transcritical CO₂ booster rack platform design that has been manufactured for Europe, North America and Australia with the same design standards, layouts, and manufacturing principles. This platform not only delivers the basic CO₂ booster system design but also offers the latest technology developments in parallel compression and ejector refrigeration cycles. The latter is the result of strategic partnerships with component suppliers to engage in early in-house testing and validation of the energy benefit of the technology, as well as its reliability and control system.

As a solutions portfolio provider, Heatcraft has been deploying CO₂-based systems for about a decade, starting with liquid-overfeed secondary loop systems and hybrid cascade systems with medium-temperature liquid overfeed and low-temperature direct expansion. With a track record of hundreds of successful CO₂ installations and strong partnerships with contractors all over the globe, we are quickly overcoming the early misconceptions and reluctance about alternative refrigerants.

Heatcraft WWR has also been a pioneer in dispelling myths about the use of ammonia as a refrigerant in the food retail segment by providing an ultra-low-charge ammonia cascade system at a Georgia grocery store that uses CO₂ in the bottom cycle and ammonia in the top cycle. The system uses only 12 oz of ammonia per ton of refrigeration, and has a total charge of just 53 lbs. ([See article on page 17.](#))

At this store, a third-party firm certified 22% average energy savings for the ammonia rack as compared to the HFC rack installed at the same location for research purposes. Moreover, this innovative cascade system design demonstrated that oil recovery, one of the greatest challenges with ammonia systems, can be completely automated, thus eliminating the need for service technicians to manually

perform this task and helping to reduce site maintenance costs.

The U.S. Environmental Protection Agency's GreenChill Partnership not only awarded the store a Platinum designation, it recognized the store as the "Best of the Best" in 2016 for its innovative ammonia refrigeration system. This served to demonstrate that Heatcraft is a solutions provider with a broad product portfolio that can cater to customers' needs based on what they are trying to accomplish.

Scouting technologies

Research in the Heatcraft Global Research and Development organization encompasses advanced technology projects that are three years or longer from commercialization, nearer term open innovation projects, and global regulation tracking. This forward-looking arm of Global R&D is responsible for the cutting-edge developments that characterize Heatcraft's innovation focus.

The research team scouts technologies within and outside the HVAC&R industry and via involvement with industry groups, consortia, and universities. Heatcraft R&D maintains active interests in alternative refrigeration cycles, efficient defrost technologies, fan and motor improvements, and novel heat-transfer

technologies. We take great pride in having been chosen to serve as the commercial partner on several advanced technology projects in the government sector; in fact, we are becoming a sought-after partner for these projects.

Open innovation allows ideas and advancement in another industry to serve as a rich source of innovation within one's own industry. As an early adopter of innovation from outside the traditional HVAC&R industry, Heatcraft boasts many open-innovation successes, including some of the first electrically commutated motors for refrigeration applications.

Key to our innovation strategy is the continual tracking of worldwide regulations to ensure Heatcraft is ahead of developments that may impact our customers now and in the future. With manufacturing facilities and sales around the world, Heatcraft is poised to observe international treaties such as the Kigali Amendment to the Montreal Protocol, to learn from progressive environmental stances in Europe, and to assist developing countries such as Brazil and Mexico in their aspirations to leapfrog into natural alternatives. The societal trend towards increased energy efficiency and a reduced environmental footprint is universal, and Heatcraft will continue to develop and launch innovative products to assist our customers, around the world, in meeting and exceeding their environmental and energy requirements.

Center of Excellence

Natural refrigerant systems are commercialized by the Alternative Systems Center of Excellence (COE) team, which focuses on emerging technologies that are up to three years out, and are still in the maturation stage, requiring development prior to incorporation into commercial products.

Emerging technologies are identified from the research pipeline and from other sources such as strategic partnerships with suppliers, research entities and/or start-ups. A significant amount of innovation may happen at this stage, since this is where "the rubber meets the road" in terms of design for operational performance.

Commercialization may involve a proof-of-concept or pilot unit that will serve as the basis for developing a

product for any continent. The pilot tests are designed to establish real-world conditions while reducing time to market and mitigating new-technology risk for the customer. In this process, the team also leverages best practices from manufacturing, product design, marketing, and supply chain to deliver an optimized product to the end user.

Heatcraft Global Laboratories not only enables the COE team to validate technologies but, by virtue of UL Client Test Data Program participation, has allowed UL 1995 listing of our transcritical CO₂ eCO₂Boost racks and NTC air cooled gas coolers in North America from the first unit shipped. The Global Laboratories also enables COE to test new ideas and generate intellectual property to incorporate into our products..

The Global Innovation team at Heatcraft has an aggressive global patent filing strategy. It stems from a unique team approach to ideation and streamlined vetting that creates an optimal

environment for our engineers to apply and test their creativity. The level of innovation evidenced also serves as a testament to the investment and commitment by Lennox and Heatcraft WWR to provide market leadership in commercial refrigeration.

At the center of Heatcraft technology development and innovation strategy is the customer. All of Heatcraft's development efforts to deliver energy-efficient, reliable products with reduced maintenance costs are focused around the customer. And we believe that what Heatcraft truly delivers to its customers is the freedom to "sleep well."

Robert DelVentura, P.E., is vice president, global innovations at Heatcraft Worldwide Refrigeration; **Augusto J. P. Zimmermann, Ph.D.**, is global sr. manager, Alternative Systems Center of Excellence, at Heatcraft Worldwide Refrigeration; and **Nicole Z. Martin, Ph.D.** is global research manager at Heatcraft Worldwide Refrigeration.

■ RD, AZ & NM



North America



Europe



Australia

Heatcraft's transcritical CO₂ racks for the North American, European and Australian markets based on the global platform.

Heatcraft Talks NatRefs

Executives Parke Adamson and Michael Lehtinen describe the company's efforts to expand the commercial market for transcritical CO₂ and ammonia/CO₂ cascade refrigeration

— By Elise Herron



Parke Adamson, Kysor/Warren

Parke Adamson, vice president and general manager of Heatcraft's Kysor/Warren subsidiary, and Michael Lehtinen, Kysor/Warren's marketing director, recognize that natural refrigerant technology has to be both cost-effective and environmentally beneficial to be adopted worldwide.

To that end, Heatcraft's efforts to upgrade the North American commercial market with climate-friendly transcritical CO₂ and ammonia/CO₂ cascade refrigeration systems include developing state-of-the-art technology, educating end users and monitoring global regulations. R&D investments the company has made are starting to pay dividends, its natural refrigerant installation count is growing, and its "Sleep Well" training program is demystifying natural refrigerant technology for contractors and end users.

In an interview with *Accelerate Corporate*, Adamson and Lehtinen talk about Heatcraft's commitment to, and leadership in, natural commercial refrigeration.

Accelerate Corporate: Why has Heatcraft gone in this direction?

Parke Adamson: The short answer is we see natural refrigerants as the end game for commercial refrigeration. Using natural gases minimizes the impact on the environment. They are compliant with any proposed regulations that we see coming in the future.

AC: How do natural refrigerant solutions fit into Heatcraft's broader goals as a company, from a business and environmental perspective?

PA: Natural refrigerants are key products for Kysor/Warren. We continue innovating, expanding our technology leadership position, and we continue to file patents to extend our intellectual property lead in this market. Customers can count on us to design, produce and deliver products that exceed their expectations.

AC: How much potential does Heatcraft see for natural refrigerant-based systems in North American supermarkets in the next five or 10 years?

Michael Lehtinen: Over the last 18 months we saw substantial growth in the natural refrigerant marketplace. Over the next five years we'll see double-digit growth if everything continues the way it is in the supermarket industry.

AC: In reference to regulation, how much will the Environmental Protection Agency continue to drive changes in refrigerant usage, beyond what is already in place? Will the U.S. Senate ratify the Kigali Amendment?

ML: I think that if we want to see further domestic regulation on refrigerants [the Senate] has to ratify it. The reason I say that is because of what's going on right now [in the courts] with the EPA's SNAP [Significant New Alternatives Policy] rule. Meanwhile, each state has the option to take a more stringent approach, which we see some states like California and others doing. I think state implementation of more protective measures points to the momentum currently behind sustainable refrigerants.

Some very exciting technology is being developed in the industry today with both transcritical and ammonia cascade systems. You are seeing real-world application of it in pilot studies and commercial installations. I believe that we will continue to see the technology being refined and evolving over time. As the industry does this, alternative refrigerant technology will become very cost competitive and exceedingly mainstream.

Initially, some retailers may be hesitant when they first hear about an ammonia system in a grocery store application. But, when we make them aware that all the ammonia is outside the store on the rooftop, that the quantity is less than 53 lbs and that any leak would be directed to a water diffusion tank, then they become much more comfortable and we can start talking about all the long-term savings with this system. We are really educating the market on the design and advantages of ultra-low-charge ammonia systems

AC: Is that enough to persuade retailers?

ML: We are making headway by getting the word out through ATMOSphere America, case studies and meetings with key market influencers. We've demonstrated that you can successfully design, install and operate an ammonia cascade system and derive significant energy savings, trouble-free operation, reduced operational costs and effective servicing of the system over a two-year period. As this type of success continues, I think you will see more of these systems deployed within the industry.

“We see natural refrigerants as the end game for commercial refrigeration.”

- Parke Adamson, Kysor/Warren

AC: Do you see most of the installations of naturals in new stores? What about existing stores with aging systems?

ML: While I am seeing primarily new store installations for natural refrigerants, we know that the trend for natural retrofits is growing globally and we envision this coming to the U.S. market in the not-too-distant future. It is certainly something that is being discussed in the industry – I know that at FMI Energy there is a session devoted to a CO₂ transcritical retrofit – and these types of studies and workshops are usually the first steps as the market grows.

AC: Has Heatcraft's experience with ammonia/CO₂ cascade at Piggly Wiggly set it apart from other OEMs?

PA: I'm biased but I think the answer is yes, certainly. You're talking about an ammonia charge in the 50-pound range at that Piggly Wiggly store. No other installation around the country has that ratio of ammonia charge to refrigeration tonnage. The system's been running for two years now with an ultra-low charge, exceptional reliability and efficiency, and there have been zero major operational events at that store. It's been remarkably successful for a pilot store and I think people know this. It's been a bit of a beacon. Today we are unique in our ability to deliver a system with that kind of charge.

AC: Piggly Wiggly saved 22% in a comparison of the ammonia rack and the HFC rack.

ML: Yes, we achieved 22% reduction at Piggly Wiggly. We know that this number will vary depending on the location of the installation, but energy is just one part of the overall long-term savings with an ammonia cascade system. Ammonia is well established in terms of operation and components. With its superior refrigeration properties, it is poised for some significant innovation focus.

AC: How does Heatcraft make sure that contractors and technicians are trained on natural refrigerants in order to make its "Sleep Well" offer to retailers?

ML: We engage with the retailer up front, and show them a commitment as an OEM that the training will benefit them financially – both in the installation and the long-term maintenance of the system. Typically, the retailer will strongly encourage participation from the contractors and technicians to learn the technology.

AC: Can you quantify how much first costs are starting to drop for natural refrigerant equipment?

ML: First costs are starting to drop, but they haven't come down quite enough to reach cost parity. There is still some premium associated with CO₂ and ammonia technology. Do we see in the distance a point where CO₂ technology and HFCs reach cost parity on equipment? I believe we can say yes to that at this point. When is hard to say – optimistically, in the next two to five years.

AC: Retailers are looking for a two-year ROI, but if you take in energy and other savings, you're going to end up with a lower total cost of ownership. Are they open to a TCO evaluation?

ML: Some retailers absolutely get the TCO, as well as the intangible benefits of a natural refrigerant system – you never have to worry about phase-out or replacement since it is the end game. Others are more focused on the ROIC, return on invested capital, and the shorter term payback schedule. I would say those who have adopted CO₂ and other natural refrigerant technology throughout their operations, and have moved beyond the pilot stage, are ones that use TCO as part of their evaluations.

AC: Does Heatcraft help retailers obtain energy incentives or rebates from utilities for natural refrigerant equipment?

ML: We do have an active rebate assistance program with personnel that support the application process. Kysor/Warren also talks with consultants that specialize in this type of work to provide us with guidance on the latest evaluations and rewards with rebates. These certainly help the ROI and help to enhance adoption of alternatives by incentivizing the energy and environmental benefits of the technology.



Michael Lehtinen, Kysor/Warren

“We engage with the retailer up front, and show them a commitment as an OEM that the training will benefit them financially.”

— Michael Lehtinen, Kysor/Warren

AC: How do you personally view the company's commitment to natural refrigerants? What about the Heatcraft board?

PA: I have worked for Lennox international for 13 years, in various capacities, and I believe that Lennox International's commitment is really deeply rooted, and it's growing. Natural refrigerants make sense from a business standpoint and a sustainability standpoint. Lennox leadership is committed to sustainability. It makes good business sense, but it also makes good environmental sense.

Personally, I'm the GM but I'm an engineer by training and I find it very interesting. You're running a business and you're doing the right thing at the same time and I like that. ■ **EH**

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