

SEPTEMBER 2017

ACCELERATE

ADVANCING HVAC&R NATURALLY

A M E R I C A

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Come to North America?

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UL Takes On
Hydrocarbons

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AAA Refrigeration's
CO₂ Training Program

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Aaron Sumida,
ALDI US

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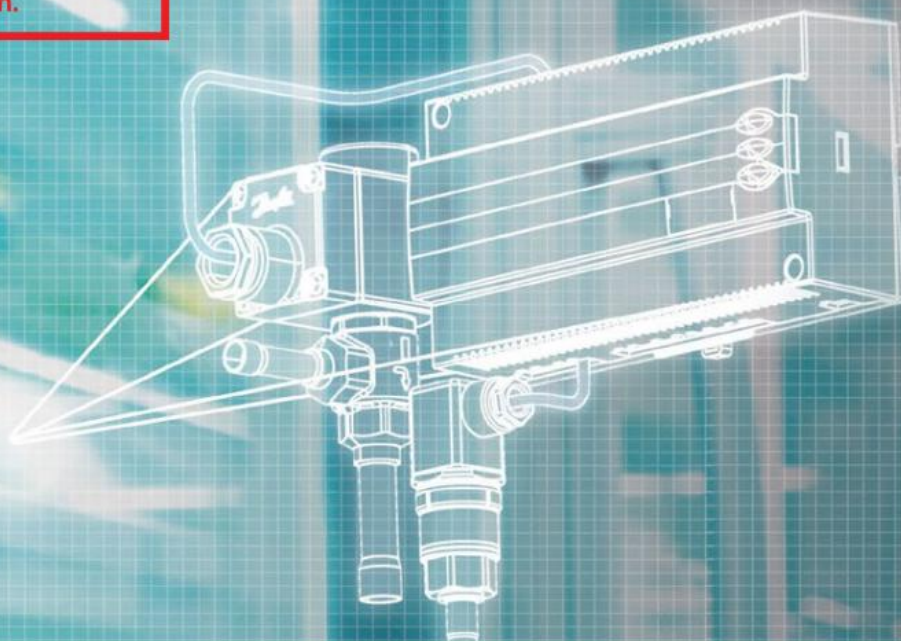
ALDI US

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ENGINEERING
TOMORROW

Danfoss

The Europe Effect

— By Michael Garry



As an employee of shecco, the Brussels, Belgium-based publisher of this magazine, for the past three years, I have developed a greater appreciation for all things European — especially Europe's leadership in the development and adoption of natural refrigerant technology.

The modern natural refrigerants movement began in Europe in the late 1980s when Norwegian scientist Gustav Lorentzen discovered a new way CO₂ could be used as a refrigerant. That set the stage for the emergence of cascade and later transcritical CO₂ systems across the European continent, where there are now more than 9,000 store installations of transcritical, according to sheccoBase data. Europe also leads the world in the development and application of technologies like ejectors that enhance the efficiency of transcritical systems in warm ambient climates. (See page 50.)

In North America, there are currently more than 450 transcritical store installations. Certainly, one key reason for the disparity between continents is the more aggressive regulation of HFCs in Europe, particularly the EU's F-Gas Regulation.

What's interesting is how Europe continues to influence the adoption of natural refrigerant technology in the U.S. Our cover story on ALDI US, the U.S. leader in transcritical store installations with 69, is prime evidence of that effect. (See page 36.) ALDI US, which started opening stores in 1976, is a member of parent company ALDI South (Sud), based in Mülheim, Germany; and while ALDI US is independently operated, it has followed the example of ALDI South stores in Europe. In February, ALDI South announced that it had installed its 1,000th store with a CO₂ system, representing 54% of its outlets. Clearly the experience of ALDI South has rubbed off on its U.S. member company.

"Some of the best examples for many of our environmental tests and initiatives begin with what other ALDI South group countries are doing," said ALDI VP Aaron Sumida in our article.

Europe's impact on the manufacturing side is also considerable. For example, ALDI's primary supplier of transcritical CO₂ systems, Hillphoenix, got its start with the technology after it acquired the Danish OEM Advansor — one of the leading producers of transcritical units in Europe — in 2011.

While it may be helpful to have a European connection, you don't need to have one to be successful with natural refrigerants in North America. Sobeys, in Canada, has certainly demonstrated that, as have U.S. retailers like Whole Foods and Roundy's. But you do need to share Europe's commitment to using refrigerants that are future-proof business investments and hugely beneficial to the environment. ■ MG



ACCELERATE

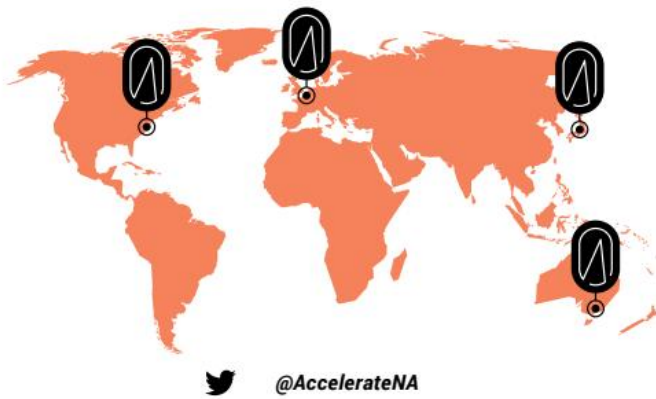
ADVANCING HVAC&R NATURALLY

AMERICA

About Accelerate America

Brought to you by shecco, the worldwide experts in natural refrigerant news, Accelerate America is the first news magazine written for and about the most progressive business leaders working with natural refrigerant solutions in all HVAC&R sectors.

<http://acceleratenews.com>



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Letters to *the Editor*

Let's Talk About Cost

I enjoyed participating in the 2017 ATMOSphere America conference in San Diego. Nice location, very well organized, relevant industry and regulatory speakers, and, most important, all key topics were covered. I liked the session on innovation and future environmentally friendly cooling technologies, and I hope this specific area will be more and more present in the upcoming conferences.

Another topic I would like to see emphasized more is cost – i.e. sessions to talk more in detail about the up-charge we see currently on technologies using natural refrigerants, especially CO₂.

Antoine Azar

Managing Director
Sustainable Solutions
Liège, Belgium



Tireless Sustainability Advocate

I was very happy to see that Bryan Beitler received the recognition that he deserves in your last issue. ("The Facilitator," *Accelerate America*, August 2017.) I know Bryan to be a tireless advocate for sustainability in the commercial refrigeration industry. His volunteer work as the president of the North American Sustainable Refrigeration Council brought the organization from its beginning just two years ago to its status now as a real powerhouse organization with over 80 members and a long list of accomplishments.

Bryan's low-key, collaborative style, though very effective in getting things done, usually results in others getting the credit for achievements. It is about time that his contributions were brought front and center. I enjoyed your article very much!

Keilly Witman

Owner
KW Refrigerant Management Strategy
Boise, Idaho

LETTERS ARE WELCOMED!

Accelerate America invites readers to submit letters to the editor at michael.garry@shecco.com. They can be about a recent article; anything related to the ATMOSphere America 2017 conference; an industry issue that readers would like us to cover in greater detail; or the value of *Accelerate America* and ATMOSphere America in educating the industry about natural refrigerants, including what we can do better. Letters may be edited for clarity or length.

Welcome to the world's largest
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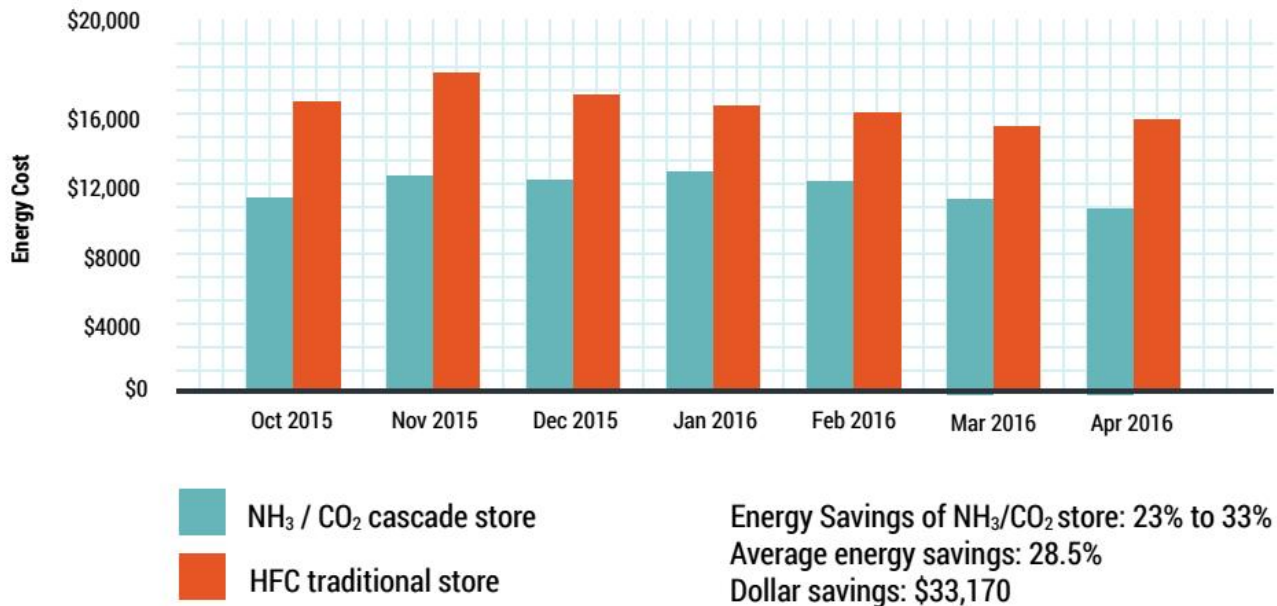
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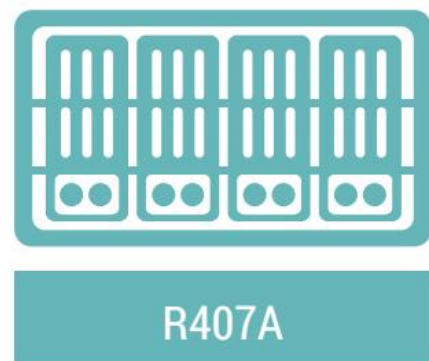
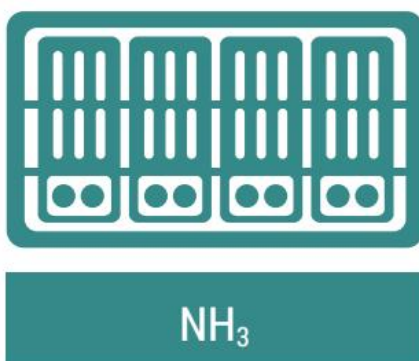
Energy Savings for NH₃/CO₂ Supermarket System

Comparison of NH₃/CO₂ cascade store and HFC store*



*Data supplied by JTM Corp. (Piggly Wiggly) based on power consumption at Columbus, Ga. store with NH₃/CO₂ system, compared to similar store with R407A normalized for store size. Refrigeration accounts for approximately 60% of energy savings.

Same-Store Energy Comparison of NH₃ Rack and R407A Rack**



Average daily energy consumption of NH₃ rack: 22% less than that of R407A rack.
Racks alternated every 1-2 weeks.

**Data based on Heatcraft study of NH₃ and CO₂ top-side racks (each connected to CO₂ rack) at Piggly Wiggly store, Columbus, Ga., from Feb. 2, 2016 to May 22, 2016. Energy savings of NH₃ rack varied from 18% to 25% based on ambient temperature.



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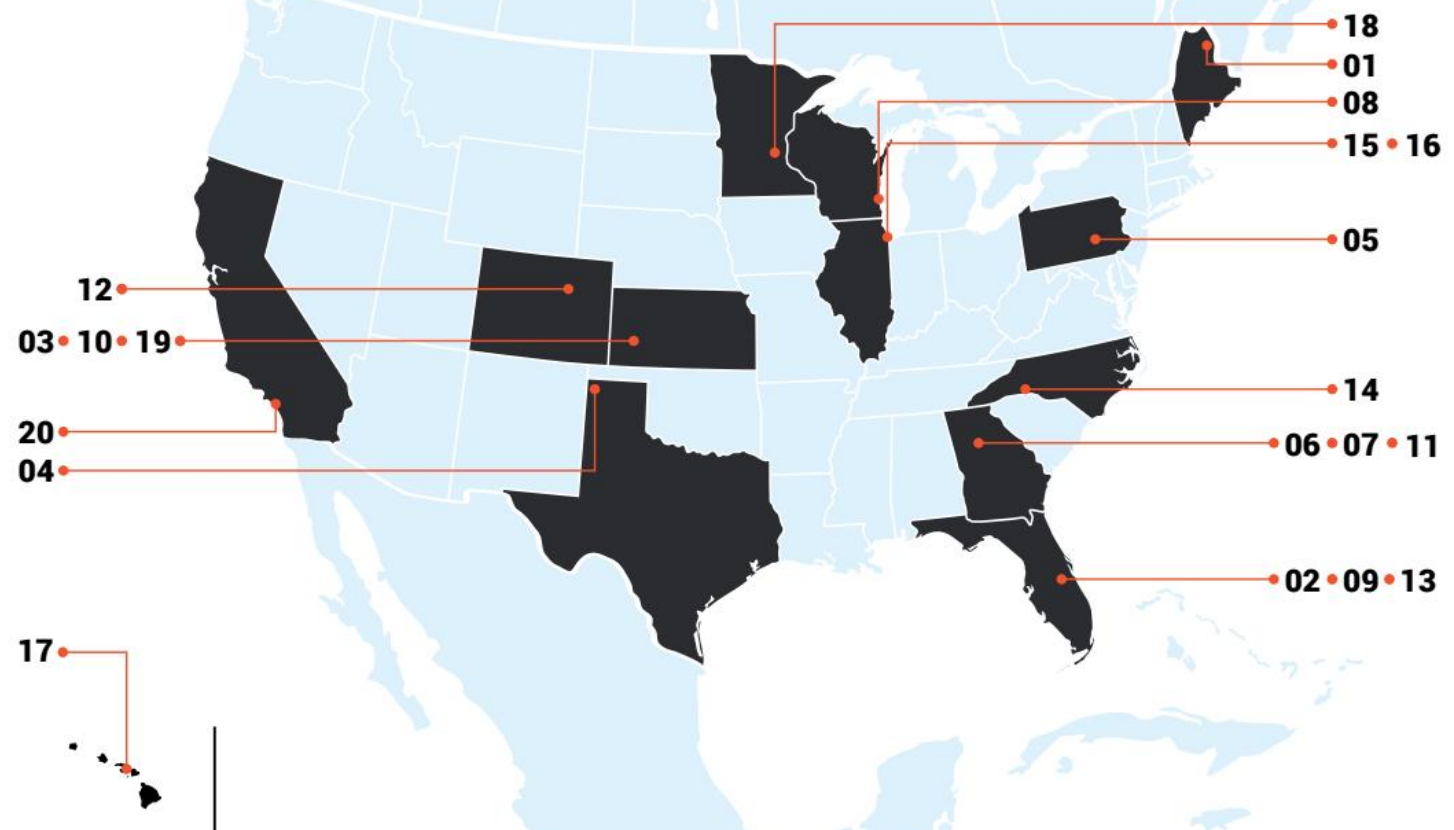
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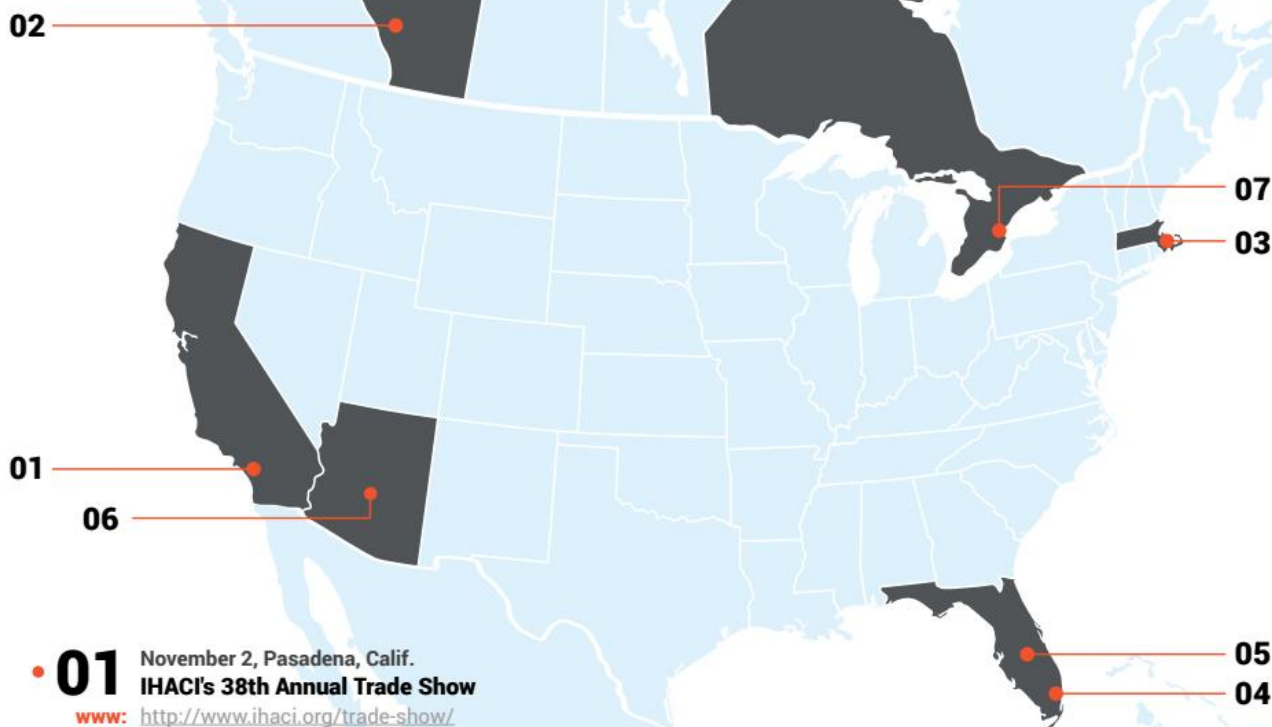
September 2017 / **October** 2017



- **01** September 23, Presque Isle, Maine
Presque Isle Ammonia Safety Day
www: <http://bit.ly/2t9kqNf>
- **02** September 24-26, Orlando, Fla.
Food Marketing Institute (FMI) Energy & Store Development Conference
www: <http://bit.ly/2sd8hmi>
twitter: @FMI_ORG #FMIEnergySD
- **03** September 25-28, Garden City, Kans.
Garden City Ammonia Program (GCAP) Implementation of Process Safety Management for Industrial Ammonia Systems
www: <http://bit.ly/2tMODzH>
- **04** September 26-27, Dalhart, Tex.
Ammonia Safety and Training Institute (ASTI) 8-Hour Refresher & 24-Hour Technician Training
www: <https://ammonia-safety.com/events/>
- **05** September 26-29, Hershey, Pa.
The Refrigerating Engineers and Technicians Association (RETA) Annual Conference (Heavy Equipment Show)
www: <http://www.reta-events.com/conference>
- **06** September 27-29, Atlanta, Ga.
ASHRAE 2017 Building Performance Analysis Conference
www: <http://bit.ly/2wKpkyS>
- **07** September 27-29, Atlanta, Ga.
World Energy Engineering Congress
www: www.energycongress.com
twitter: #weec
- **08** October 3-6, Milwaukee, Wis.
Plumbing-Heating-Cooling Contractors Association's Connect 2017
www: <http://bit.ly/2vHyGyr>
- **09** October 7-10, Orlando, Fla.
The National Frozen & Refrigerated Foods (NFRA) Convention
www: <https://nfraconvention.org/>
- **10** October 9-12, Garden City, Kans.
Garden City Ammonia Program (GCAP) Ammonia Operator Four-Day Course in Spanish
www: <http://bit.ly/2tMODzH>
- **11** October 10-12, Atlanta, Ga.
EEBA High Performance Home Summit
www: <http://summit.eeba.org/>
twitter: @GoEEBA
- **12** October 11, Aurora, Colo.
Ammonia Safety and Training Institute (ASTI) Aurora Safety Day
www: <https://ammonia-safety.com/events/>
- **13** October 11-13, Orlando, Fla.
2017 Florida Restaurant & Lodging Show
<http://www.flrestaurantandlodgingshow.com/125/florida-home.htm>
www: <http://www.flrestaurantandlodgingshow.com/125/florida-home.htm>
- **14** October 11-13, Charlotte, NC
21st Century Building Expo & Conference
www: <http://21buildingexpo.com/>
- **15** October 17-20, Chicago, Ill.
NACS Show 2017
www: <http://www.nacsonline.com/NACSShow/>
twitter: @NACSONline @NACSONline
- **16** October 18, Chicago, Ill.
Ammonia Safety and Training Institute (ASTI) Chicago Safety Day
www: <https://ammonia-safety.com/events/>
- **17** October 22-25, Maui, Hawaii
Sheet Metal & Air Conditioning Contractors' National Association (SMACNA) 2017 Convention
www: <https://www.smacna.org/annualconvention>
twitter: @SMACNA
- **18** October 23-25, Minneapolis, Minn.
Critical Facilities Summit 2017
www: <http://www.criticalfacilitiessummit.com/>
twitter: @CFSummit
- **19** October 23-26, Garden City, Kans.
Garden City Ammonia Program (GCAP) Ammonia Operator Four-Day Course
www: <http://bit.ly/2tMODzH>
- **20** October 24-26, Compton, Calif.
Ammonia Safety and Training Institute (ASTI) 24-Hour Technician & 8-Hour Refresher Training
www: <https://ammonia-safety.com/events/>
twitter: @SMACNA

EVENTS GUIDE

November 2017



- **01** November 2, Pasadena, Calif.
IHACI's 38th Annual Trade Show
www: <http://www.ihaci.org/trade-show/>

- **02** November 8-9, Calgary, Canada
BuilDEX Calgary
www: <http://builDEXcalgary.com/>
twitter: @BUILDEXshows

- **03** November 08-10, Boston, Mass.
Greenbuild International Conference and Expo
www: <https://www.greenbuildexpo.com/en/events.html>
twitter: @Greenbuild

- **04** November 12-14, Miami, Fla.
AHRI Annual Meeting
<http://www.ahrinet.org/News-Events/Meetings-and-Events.aspx>
www: [Meetings-and-Events.aspx](http://www.ahrinet.org/News-Events/Meetings-and-Events.aspx)
twitter: @AHRI_connect

- **05** November 14-15, Orlando, Fla..
NFMT Orlando 2017
www: <http://www.nfmt.com/orlando>
twitter: @nfmt_conference #NFMTOrlando17

- **06** November 28-29, Scottsdale, Ariz.
ICSC Retail Green Conference — Redefining Sustainability
<https://www.icsc.org/events-and-programs/details/>
www: [retailgreen-conference-sustainability-showcase1](https://www.icsc.org/events-and-programs/details/)
twitter: @ICSC

- **07** November 29-December 1, Toronto, Canada
The Buildings Show
www: <https://www.thebuildingsshow.com/en/home.html>

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Back to the Golden State

In 2018, ATMOsphere America will return to California – the epicenter of environmental leadership – for the third time, with expanded networking opportunities and more attendees

– By Elise Herron

With California playing an increasingly active role in advancing environmental initiatives, including those that impact natural refrigerants, ATMOsphere America will be held next year in Long Beach, Calif., June 11-13.

It will be the third time – and the second consecutive year – that the conference, hosted by shecco (publisher of *Accelerate America*), will take place in the Golden State. The event's hotel location is still being finalized.

New aspects of next year's event—which expects an unprecedented attendance of around 500 manufacturers, contractors, end users and other stakeholders from around the world – include increased networking opportunities, and the return of promotional “technomercial” sessions. As in the past, end users will be given complimentary full admission to the three-day conference.

Similar to last year's event in San Diego, ATMOsphere America 2018 will include key players in California who are driving policy decisions and incentive programs.

In San Diego, the California Air Resources Board (CARB) and California utilities like Southern California Edison and the Sacramento Municipal Utilities District used the forum to discuss programs affecting HFC reduction and natural refrigerant technology adoption. CARB, for example, solicited feedback from attendees about its HFC phase-down strategies. (See “CARB Asks for Help,” *Accelerate America*, June-July 2017.) Currently, CARB is considering an incentive program for the installation of natural refrigerants systems, and its eventual phase-down of HFCs may have national implications given the changing status of HFC regulation at the federal level.

In particular, the Environmental Protection Agency's management of HFCs was dealt a blow last month by a Court of Appeals ruling saying the agency couldn't require companies to replace HFCs via the Significant

New Alternatives Policy (SNAP) program. The EPA may appeal or find different avenues to regulate HFCs. (See “Industry Waits for EPA's Next Move Following Court Ruling on HFCs,” *Accelerate America*, August 2017.)

“Taking the event back to California is significant because of the uncertainty at the federal level with the HFC phase-down through the SNAP program,” said Derek Hamilton, vice president of business development for shecco America. “California's leadership in climate policy is more important than ever.”

New features

Beyond bringing cutting-edge natural refrigerant technology discussions to a climate-minded and economically robust location, ATMOsphere America 2018 has a number of new features in store for attendees.

The event format is being revamped to include a larger area where sponsors and attendees will be able to network. Breaks and meals will be situated in the sponsor area to maximize sponsor-attendee interaction. Also included in the program is a selection of pre-event workshops from top sponsors.

In a change of format from past years, the third annual Accelerate America Awards will be presented at a Tuesday evening networking dinner. The awards, which celebrate leaders in the natural refrigerant industry, have been moved to this highly attended slot in the program to recognize their growing importance in the industry. As in previous years, a post-event site tour of nearby facilities is planned.

“This isn't just another industry conference,” shecco's Hamilton said. “It's engaging; it's about community building and networking. We're bringing together the ATMO community to discuss the latest in technology and to work together to advance common goals.” ■ EH



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IN BRIEF

POLICY

MONTREAL PROTOCOL HELPED REDUCE U.S. GHG EMISSIONS

WASHINGTON, D.C. - The discovery that chlorofluorocarbons were causing the ozone layer to be depleted led to a global ban under the Montreal Protocol in 1987. The ban has not just led to the healing of the ozone layer as a recent study confirms that the international treaty has helped to reduce greenhouse gas emissions in the United States. The study shows that the reduction in ozone depleting substances from 2008 to 2014 eliminated 170 million tons of CO₂e emissions each year — roughly equivalent to 50% of the reduction in emissions of CO₂ and other greenhouse gases in the U.S. in the same period.

More information at:
<http://bit.ly/2xWmdEq>

AMMONIA

HENNINGSON OPENS LOW-CHARGE FACILITY

SALEM, Ore. — Henningsen Cold Storage Company recently opened its second facility in Salem, Oregon. The new facility represents Henningsen's biggest commitment yet to reducing the charge of ammonia in its warehouse. Its over six million cubic ft. of cold storage capacity operates with just 3,300 lbs. of NH₃ and can cool 25,000 pallets' worth of food in the warehouse. In 1993, Henningsen used as much as 52 lbs/TR of ammonia, which was reduced to 16 lbs/TR at the new plant in Salem Ore. (and to 12 lbs/TR at another Salem plant in 2014).

More information at:
<http://bit.ly/2fgdyWu>

CO₂

WHOLE FOODS MARKET ANALYZES CO₂ SYSTEMS

AUSTIN, TEXAS — In a webinar hosted by the Environmental Protection Agency's GreenChill Partnership on September 12, Tristram Coffin of Whole Foods Market, along with Michael Harvey and Tom Wolgamot of DC Engineering, compared five natural refrigeration systems installed in Whole Foods supermarkets in California. Their case study, "Comparing the Performance of Different Advanced System Types," looked at the way that transcritical CO₂ and cascade systems perform in variable climates and stores around California. Coffin said that building type and climate zone are the two most important considerations when deciding which type of natural refrigerant system to use.

More information at:
<http://bit.ly/2xsJ8ua>

HYDROCARBONS

GRENADA INAUGURATES HC AIR-CON SYSTEMS

SAINT-GEORGES, Grenada — On August 25, the small Caribbean island country of Grenada installed its first two air conditioning units to use hydrocarbons. The installation of the propane units is part of a regional demonstration project implemented by the United Nations Industrial Development Organization (UNIDO). Funding was provided by the Multilateral Fund for the Implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer. The two hydrocarbon-based AC units were installed at Grenada's pilot training center for low-GWP flammable refrigerants — open to students and local technicians — and were inaugurated by the country's National Ozone Unit and UNIDO.

More information at:
<http://bit.ly/2wkhb6K>

AMMONIA

STELLAR HIRES NEW SAFETY DIRECTOR

JACKSONVILLE, Fla. —Stellar, a designer, builder and installer of industrial ammonia systems, has hired Michael A. Chapman as its director of PSM (Process Safety Management) compliance and technological solutions. Chapman will lead Stellar's PSM team, which provides compliance solutions for clients, including audits, process hazard analyses, mechanical integrity inspections and corrective action support. To keep workplaces safe, the U.S. Occupational Safety & Health Administration (OSHA) issued the Process Safety Management of Highly Hazardous Chemicals standard, which contains requirements for the management of hazards associated with processes using hazardous chemicals. Chapman is also tasked with developing technology to enhance refrigeration operator/technician training.

More information at:
<http://bit.ly/2h2Wcwz>

EVENTS

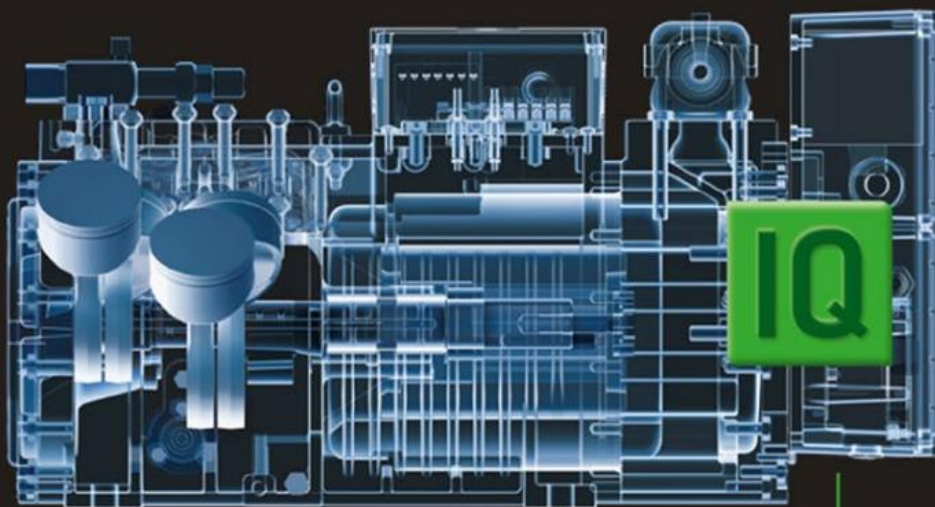
2018 AHR EXPO LISTS NEW PRODUCTS

CHICAGO — The 2018 AHR Expo (International Air-Conditioning, Heating, Refrigerating Exposition) has released information on new products and technologies that will be displayed at the conference, which will be held Jan. 22-24, 2018 at McCormick Place, Chicago, and is held concurrently with ASHRAE's Winter Conference. The 2018 event, co-sponsored by ASHRAE and AHRI, will feature 2,000+ exhibitors, 100+ seminars and product presentations, and more than 65,000 attendees, including contractors, engineers, facility managers, distributors, OEMs and other HVACR industry professionals. Upgraded Wi-Fi-connected thermostat technology, bionic impeller technology, and a self-contained HVAC system for hazardous locations are among the new exhibits.

More information at:
<http://bit.ly/2xgBNhe>



Bitzer

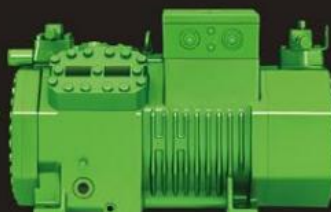


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Bitzer

Efficiency Secrets for Transcritical CO₂

Transcritical booster systems can run a lot more efficiently with direct heat reclaim, ECM fans for the gas cooler, and variable-capacity compressors, coupled with careful monitoring and analysis

— By Darren Cooper

Over the last several years my company has had the opportunity to do some detailed field analysis and study of a number of transcritical CO₂ booster systems from suppliers using equipment and components from several manufacturers.

The scope has mainly been to look at the operational efficiency of the systems with a focus on heat reclaim, gas cooler performance and variable capacity compressors. As an energy consultant our role is obviously operational efficiency, but efficiency must never compromise effectiveness (performance).

Depending on geographical region there are some variances that are needed in the system architecture or design. Initially, the use of transcritical CO₂ booster systems in North America was limited to more northern climates where the amount of time that a system would run transcritical was relatively low because of the cooler annual ambient temperatures. With the development of some new technologies such as ejectors, and improved knowledge of methods such as parallel compression and adiabatic gas coolers, we are starting to see CO₂ systems being installed in much warmer climate zones.

What have we learned? Generally speaking, my first comment is that many organizations are not practicing the total cost of ownership model, even though they may claim to. The reason for this is complex. In some instances it is a simple lack of knowledge or understanding. In others it is simply that their purchasing process is focused on a lowest-bid-wins model. This means that suppliers are producing an effective system to win the work but these systems are far from energy efficient. And compromising on efficiency often results in increased service and maintenance costs and a shortened life expectancy.

So, what should you do? First, get as much knowledge and information as you can that relates to the system you need and the environment and geographical location that you are putting it in. You can get this information from an experienced consultant, but don't be afraid to engage with manufacturers and the equipment suppliers — they have a lot of experience and knowledge that you can tap into.

Here are a few other considerations:

- Make sure that all the manufacturers you are considering are designing to the same conditions! This might sound obvious but sometimes the obvious gets missed and we have seen different design criteria used by manufacturers bidding for the same work. If the design conditions are different you are not comparing apples with apples!

- Make decisions in the design stage to help minimize costs. For example, if you plan to do heat reclaim for heating in your HVAC system using your transcritical refrigeration system, try to locate these as close together as possible to avoid extensive pipe runs. For example, try to place the rooftop HVAC unit close to the refrigeration plant. This is particularly important if you are doing direct heat reclaim where you are running refrigeration lines rather than the plumbing lines needed for a secondary heat reclaim system using glycol.

Consider what type of heat reclaim you are doing. Direct heat reclaim is more effective and therefore more efficient. It also requires less service and maintenance than secondary heat reclaim that has multiple heat exchangers and a circulation pump. In most jurisdictions, the use of a double wall heat exchanger means that direct CO₂ to domestic hot water is also possible.

- Consider your gas cooler operation and the fans and control strategy. Traditional staging of fans is simple and generally gets the job done but doesn't afford any energy efficiency. Adding VFDs to the first couple of fans improves the operation but you are likely to still be overusing the first part of the gas cooler and underutilizing the last section.

Solve this issue by considering ECM fans so that you can vary the speed of all the fans. This allows for full utilization of the gas cooler. This also means that the fouling of the gas cooler coils happens across the entire unit. Traditional staging means that the first section of the gas cooler will be fouled faster, which reduces performance and over time increases degradation of the fins of the coils in this area.



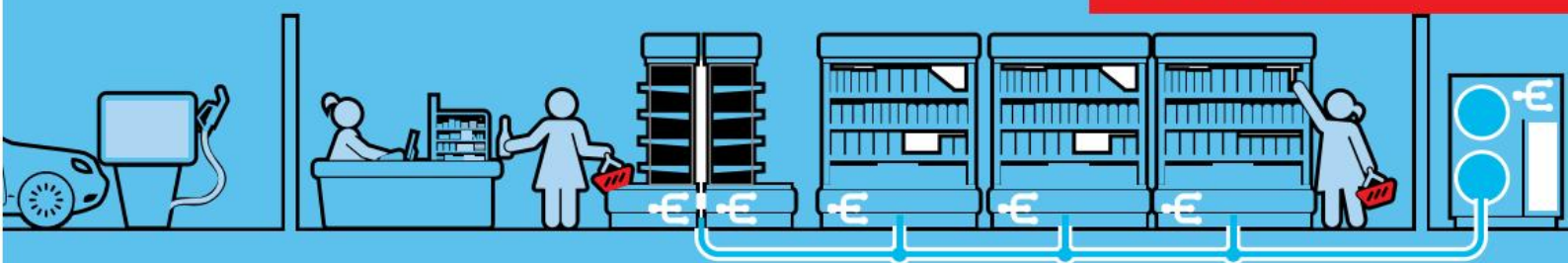
Real & Sustainable

RED'Y

when green becomes greener

The **Real & Sustainable condensing unit** capacity modulation control for **convenience stores**. The main feature of the CAREL system is the serial connection between the outdoor unit and the showcases. Real-time knowledge of individual showcase operating conditions means the condensing unit can implement advanced energy saving algorithms and at the same time increase overall system performance. This dynamic approach allows continuous variations in the set point, with positive results in terms of energy saving and food preservation.

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“The introduction of a variable speed drive or variable capacity compressor typically produces between 11% and 16% annual energy savings and simple payback of less than one year.”

- ▶ — The use of variable capacity compressors allows for a much smoother operation of the rack and thus the entire efficiency of the refrigeration system. They also avoid short cycling of compressors, which typically leads to premature failure.

From the studies we have performed, the introduction of a variable speed drive or variable capacity compressor typically produces between 11% and 16% annual energy savings and

simple payback of less than one year. The significant reduction in compressor short cycling that is facilitated by the variable capacity operation will help ensure that the maximum life expectancy of the rack is achieved without excessive repairs.

All of the analysis that we have performed has used the ClimaCheck Performance Analysis equipment and software. This allows for monitoring of the system in real-time and also the creation of weather-normalized power profiles that can be used to compare system operations over different ambient conditions, system architectures or upgrades and operational strategies.

In addition, the use of System Efficiency Index (SEI) allows for easy comparison of systems since it is a ratio of the theoretical coefficient of performance (COP), which assumes no energy losses, against the actual operating COP. This means that the SEI for a system that is operating well is unchanged across the entire range of ambient temperatures. This also means that systems in different geographical regions can be compared against each other.

The use of SEI is expanding as a method for undertaking performance-based maintenance and prediction of failures, since a degradation in SEI typically precedes these occurrences. SEI calculations are done at the subsystem level (compressor, condenser, evaporation and refrigerant cycle), which helps identify where within a refrigeration system the degradation in performance is occurring.

So regardless of where you run a transcritical CO₂ system, there are straightforward upgrades you can make to ensure an efficient operation, and some great tools to measure that efficiency.

Darren Cooper

President of Renteknik Group, Burlington, Ontario, Canada, a consultancy focused on energy optimization of HVAC&R systems.



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Ejectors: Solution to the CO₂-Equator Conundrum

Two-phase ejectors can bring about greater adoption of transcritical CO₂ systems, especially in high-ambient-temperature regions, but technical challenges remain

— By Stefan Elbel

Industry and academia have been working extensively on two-phase ejector cycles for close to two decades, but activities really picked up about five years ago.

It is interesting to note that the majority of the published ejector studies, especially those involving experimental results, are on systems using transcritical CO₂. On the other hand, that is maybe not too surprising given that CO₂ has inherently large throttling losses and ejectors represent a low-cost yet effective solution for increasing energy efficiency at high ambient temperatures.

Technologies like two-phase ejectors (which can pump two phases, gas and/or liquid) enable successful implementation of transcritical CO₂ systems on a larger scale, especially in regions that experience high ambient temperatures. While other cycle improvements, such as adiabatic gas coolers or parallel compression also help in that respect, it appears that the introduction of CO₂ ejectors could be the game-changing technology that will make it possible to move the CO₂-equator further south at reasonable cost.

The resulting performance gains are sufficiently high to make the performance of North American transcritical CO₂ installations comparable to synthetic low-GWP refrigerant options that are currently being discussed. Depending on the application and ambient temperatures (and the maturity of the baseline that is used for comparison), ejectors can easily bring COP improvements on the order of 20% to 30% in the most demanding outdoor conditions.

Numerous studies carried out at universities, such as the Air Conditioning and Refrigeration Center (ACRC) at the University of Illinois at Urbana-Champaign (UIUC), and also at independent third-party industry labs, such as Creative Thermal Solutions, Inc. (CTS), have confirmed these results.

In the case of supermarket refrigeration systems — one of the areas where CO₂ has recently gained traction in the southern climate zones of North America — the use

of ejectors resulted in measured yearly energy savings ranging from 10% to 15% (based on measurements taken in the warmer climate zones of Europe).

While CO₂ has made successful inroads in commercial refrigeration systems, numerous other applications exist for which ejectors could pave the road for successful introduction of transcritical CO₂ technology. In particular, these include applications where sustainable, non-flammable low-GWP options are sought, such as refrigeration and air conditioning in the transport and military sectors.

When considering reversible CO₂ heat pump systems, the use of two-phase ejectors could become a necessity, especially for systems having to operate at extremely low ambient temperatures. Examples include low-temperature heat pumps for commercial and residential applications, but also heat pumps for electric/hybrid electric vehicles.

In general, using an ejector instead of a conventional expansion valve makes most sense in systems that are operated at extreme heat rejection or heat absorption temperatures, or for systems that encounter both. In these situations, the throttling losses of refrigerants other than CO₂ can grow significantly as well, justifying R&D efforts also on low-pressure fluid ejector systems for various applications.

How ejectors work

Ejectors are such useful energy-saving devices because of their advantages over throttling devices such as capillary tubes, short tube orifices, and expansion valves.

To be sure, in transcritical CO₂ vapor-compression refrigeration cycles, these throttling devices can be used as robust and cost-effective solutions for expanding the refrigerant from the higher gas cooling pressure to the lower evaporation pressure.

However, the physical process during throttling is irreversible. Moreover, the isenthalpic pressure reduction

“CO₂ ejectors could be the game-changing technology that will make it possible to move the CO₂-equator further south at reasonable cost.”

inflicts a dual penalty on the system in the form of a reduction in cooling capacity as well as an increase in required compression work. This results in lower COP of the actual vapor-compression refrigeration cycle compared to an ideal Carnot refrigeration cycle.

COP reduction due to the isenthalpic process in the expansion valve can be lessened by many different methods. One of the simplest methods is internal heat exchange that reduces the generation of flash gas during expansion by introducing more subcooling at the inlet of the expansion device. However, methods that involve expansion work recovery – like an ejector – are known to be more beneficial in terms of cycle efficiency and cooling capacity.

A common feature of methods that involve work recovery is that they attempt to utilize the kinetic energy released during the pressure reduction of the fluid, as it passes from the high- to the low-pressure side, to save compressor work, instead of dissipating it in a throttling process. Meanwhile, an isentropic expansion process is approached rather than isenthalpic throttling. This increases cooling capacity because the specific enthalpy at the evaporator inlet is reduced. Therefore, devices that can approach expansion closer to an isentropic process are worth exploring.

Due to their ability to recover expansion work, two-phase ejectors are considered to be among the most promising candidates to achieve this goal. These refrigerant ejectors, very much like expanders, are able to (at least theoretically) approach isentropic instead of isenthalpic expansion, thereby reducing throttling losses that can be substantial depending on the choice of working fluid.

Ejectors, being robust and potentially inexpensive, are therefore seen as low-cost replacement for conventional expansion valves for many HVAC&R applications, especially those using transcritical CO₂, due to the substantial throttling loss of the fluid.

The ejector uses the expansion of a high-pressure (motive) fluid to transport and compress a low-pressure (suction) fluid by means of momentum transfer between the two fluid streams. The motive fluid is expanded through a usually converging-diverging (though sometimes converging-only) nozzle to high velocity and low pressure. This high velocity and low pressure is used to transport the suction fluid through the suction nozzle; the motive and suction fluids are then mixed in the mixing section. The high-speed mixed flow is then decelerated in the diffuser and static pressure is recovered, resulting in a pressure increase provided to the suction stream across the ejector.

Technical Challenges

In order to enable even more wide-spread commercialization of two-phase ejector technology, several technical hurdles need to be addressed. For example, in applications that count on compact system designs, ejector integration is key to avoid the introduction of additional system components.

Another focus area is the vapor-liquid separator that is required by many system architectures employing ejectors. Research carried out the ACRC labs at the University of Illinois has demonstrated that for the standard ejector cycle, separation efficiencies of more than 90% are required to translate the work recovery taking place in the ejector into actual energy savings of the cycle. In other words, it may not be sufficient to solely focus on optimizing the design of the ejector if the COP improvements cannot be fully harnessed due to imperfect separator design.

Another closely related challenge is the return of lubricant to the compressor, as some ejector cycle architectures create possible oil accumulation spots within the system (often in the vicinity of the evaporator). Proper cycle design is key, and it should be noted that a variety of cycle designs exist that have successfully resolved this problem through either the employment of designated liquid ejectors as a way to manage lubricant return or the elimination of a vapor-liquid separator altogether.

“Ejectors can easily bring COP improvements on the order of 20% to 30% in the most demanding outdoor conditions.”

► Current R&D efforts are also focused on controls of ejectors and ejector cycles. Being able to adjust the geometry of the ejector for various flow conditions reduces the performance loss at off-design conditions that is seen especially with fixed-geometry ejectors. The most popular approaches include control of the motive nozzle throat area by the insertion of a needle and the use of parallel, fixed-geometry ejectors that can be switched on as the system load requirements increase. Both of these approaches have advantages and disadvantages, and additional control options, such as vortex-based motive nozzle flow control, are the subject of ongoing research.

Closely related to system controls is the question of which ejector cycle is the best. Depending on the working fluid and the application, numerous ejector cycle layouts exist. The one receiving most attention is where the recovered expansion work is used to supplement compressor work; this is achieved by pre-compressing the flow, thereby reducing the pressure ratio of the compressor. Research at the University of Illinois has shown that this option is generally the best solution for transcritical CO₂.

Nevertheless, the same study has also shown that especially low-pressure refrigerants benefit more from so-called liquid overfeed systems, in which the work recovered by the ejector is used to provide more liquid to the evaporator than it can evaporate. The improvement comes from eliminating evaporator dryout, yet this cycle requires a careful optimization of the evaporator geometry to account for the sensitive trade-off between improved convective heat transfer coefficients and increased refrigerant-side pressure drop.

The substantial energy savings that can be realized due to the use of two-phase ejectors justify research and development efforts that will continue to facilitate the successful commercialization of this intriguing device.



Dr. Stefan Elbel

Chief engineer at Creative Thermal Solutions, Inc. (CTS) since 2007. He is also research assistant professor at the University of Illinois at Urbana-Champaign, where he and his students conduct research at the Air-Conditioning and Refrigeration Center (ACRC).

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Janos Maté, Greenpeace

Will GreenFreeze Come to **North America?**

Greenpeace's Janos Maté talks to *Accelerate America* about the success of domestic hydrocarbon refrigerators in Europe and Asia, and why the EPA should remove the charge-limit impediment to adoption in the U.S.

— By Charlotte McLaughlin and Michael Garry

In the early 1990s, Greenpeace, the environmental NGO, developed refrigeration technology dubbed "GreenFreeze," which uses hydrocarbons in domestic refrigeration rather than HCFCs and HFCs.

The concept quickly caught on and Greenpeace estimates that today there are between 900 million and 1 billion domestic hydrocarbon refrigerators in the world. This estimate is based on a 2016 UNEP (United Nations Environment Program) TEAP (Technology and Economic Assessment Panel) Progress Report that projects that by 2020, 75% of new refrigerator production will use R600a (isobutane), most of the rest will use R134a and a small share may apply unsaturated HFC refrigerants such as HFO-1234yf.

The markets that have been slowest to switch to hydrocarbons in domestic refrigeration are the U.S. and Canada. In the U.S., where the Environmental Protection Agency has allowed hydrocarbons in various refrigeration applications since 2011, the primary impediment has been the charge limit for hydrocarbons in domestic refrigeration, set by the EPA at 57 g. This is adequate for small units but not enough to support moderate-to-large size domestic refrigerators common in North America.

By contrast, in Europe, where GreenFreeze refrigerators have proliferated, the charge limit is 150 g, sufficient to support larger domestic refrigerators. (In both Europe and the U.S., the 150 g charge limit applies to commercial refrigeration, but by the end of 2017, the IEC – International

Electrotechnical Commission— may approve an increase to 500 g; that, in turn, could spark the EPA to raise the 150 g limit for commercial refrigeration, industry observers say.)

There has been some movement toward raising the domestic charge limit in the U.S. The Underwriters Laboratories (UL), this year adopted a new safety standard (UL 60335-2-24, Edition 2), which boosted the hydrocarbon charge allowed in U.S. domestic refrigerators from 57 g to 150 g. Several high-profile industry studies of the flammability of hydrocarbons and A2L refrigerants have been ongoing this year in order to build a case for charge increases.

However, the EPA still has to act before manufacturers can move to the higher standard. The EPA has already ruled that R134A, the most prevalent HFC used in domestic refrigeration, will be prohibited in domestic refrigerators beginning in 2021 (pending the EPA's reaction to a recent court ruling on HFCs; see ["Industry Waits for EPA's Next Move Following Court Ruling on HFCs," Accelerate America, August 2017](#)). Raising the charge would offer manufacturers a ready substitute for R134a in domestic units.

Janos Maté, a senior consultant in Greenpeace's political business unit, has been a campaigner for more environmentally friendly refrigerants since 1992. In 2010, he received the EPA Montreal Protocol Award for his work to protect the ozone layer and the climate. He is a passionate advocate for GreenFreeze technology, and *Accelerate America* talked to him about how it might come to North America.



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“North American charge limits should be immediately harmonized with international standards.”

▶ **Accelerate America: Why has the North American market been so slow to adopt hydrocarbons for domestic refrigeration?**

Janos Maté: The regulatory bodies – the U.S. EPA, UL, the Canadian Standards Association – for many years failed to approve hydrocarbons, and when they did they inexplicably set the charge limits significantly below international standards, making it more difficult for appliance manufacturers to market their standard products. Hydrocarbon refrigerator models that are allowed in all major markets around the world are disallowed in the United States. This retards the uptake of hydrocarbon refrigerators in the U.S. and Canada.

AA: What big suppliers have been slow to convert to hydrocarbons?

JM: All of the North American suppliers have been slow to convert to hydrocarbons. Manufacturers that sell hydrocarbon refrigerators in the European, Asian and Latin American markets have yet to make climate-friendly refrigerators available to North American consumers.

AA: How has the flammability issue slowed adoption?

JM: The fear of flammability has not been a consumer impediment to hydrocarbon fridges in Europe, Asia or Latin America. The hydrocarbon charge is contained in a hermetically sealed system. North Americans, with their cars, barbecue culture, natural gas kitchen ranges and home heating furnaces, are used to living with hydrocarbons.

The flammability issue is a bogey man deployed by the producers of fluorocarbons and their traditional commercial partners in the appliance manufacturing sector. The interest of the fluorocarbon industry to prolong the use of their products as long as possible, and then to replace them with a new generation of their products – for example HFOs – is obvious. They correctly view hydrocarbons as a main competition and a direct threat to their historical global monopoly in the refrigerant sector. Meanwhile, appliance manufacturers and dealers also have a short-term business rationale for holding onto the past. But eventually they shall have to bite the bullet and transition to sustainable technologies.

AA: Do you expect the EPA regulations to raise the charge limits soon?

JM: North American charge limits should be immediately harmonized with international standards. It makes sense. With nearly 1 billion hydrocarbon fridges in the world operating perfectly safely, why are North American consumers denied the right to purchase climate-friendly refrigerators? We believe, based on the success of the GreenFreeze technology in Europe and elsewhere, that North American consumers would welcome the opportunity to purchase environmentally and climate-safer refrigerators.

AA: Do you see Greenpeace's GreenFreeze project as a key element that led to the leapfrogging of HFCs straight to natural refrigerants?

JM: Greenpeace developed and promoted GreenFreeze, the hydrocarbon refrigerators, precisely to prove to the international community that contrary to the claims of the chemical industry – the producers of HFCs and HCFCs – it was possible to meet our cooling needs without the use of fluorocarbons. GreenFreeze was a major confidence builder in that regard, not only in the domestic refrigerator sector but in all cooling sectors.

AA: Would you say the GreenFreeze project is a key element that led to the development of light-commercial hydrocarbon-based fridges and freezers?

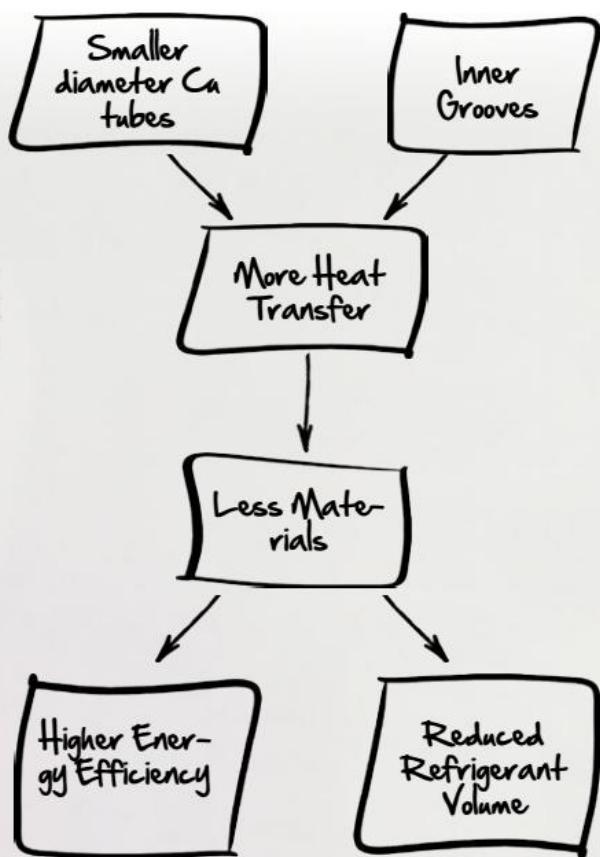
JM: The GreenFreeze Project led the way towards HFC-free cooling in both domestic and light-commercial cooling applications.

AA: Wolfgang Lohbeck, as the lead campaigner on ozone layer protection for Greenpeace Germany during the early 1990s, has been quite remarkable in contributing to the development of GreenFreeze. How would you describe his role?

JM: Wolfgang Lohbeck was instrumental in bringing about GreenFreeze. He played the pivotal role in the conceptualization and the technical development of GreenFreeze, the public promotion of the technology, securing regulatory approval for the technology and the uptake of the technology by major appliance manufacturers. He was the right person at the right time. The world is a better place because of his work.

■ CM & MG

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Transcritical rack at Emerson's Helix Innovation Center

Emerson Launches Phase-Down Calculator

The tool helps retailers transition to natural refrigerants by forecasting the life cycle climate performance (LCCP) of new systems

— By Michael Garry

St. Louis-based component manufacturer Emerson has launched a refrigerant calculator that helps retailers forecast the impacts of phasing down higher-GWP systems and phasing in new refrigerant architectures such as those based on natural refrigerants.

The web-based app helps a decision maker to forecast the life cycle climate performance (LCCP) in lbs of CO₂e per year of a chain or store based on preferred refrigeration architectures as well as preferred refrigerants.

By inputting key information about current and proposed system architectures, an end user can calculate the phase-down impacts and download charts that will help demonstrate those impacts. Input information includes store design temperatures, store counts of current and future architectures, leak rates and refrigerant choice.

"The calculator will be a valuable tool for retailers as they replace the common hydrofluorocarbons targeted for phase-down by the Environmental Protection Agency," said André Patenaude, director, CO₂ business development, Emerson's Commercial and Residential Solutions platform. "It provides a visual forecast of the impacts of phase-down and phase-in

of new refrigerants and system architectures, and assists retailers in the assessment of total carbon footprint impacts and LCCP in a single store and across an enterprise."

The calculator provides metrics that can be downloaded as charts, including total LCCP per franchise, total LCCP per store, weighted GWP per store and total weighted GWP.

The phase-down calculator can be found at: <http://bit.ly/2xu0sSw>.

CO₂ information tool

The phase-down calculator is the latest web-based app developed by Emerson to promote CO₂ systems. Last year the company launched a CO₂ information tool (<http://bit.ly/2xutSgc>) to provide details on Emerson-made CO₂ components available in North America, which was expanded this year to include equipment available in Europe. Emerson makes a wide range of CO₂ system components, such as compressors, oil separators, electronic controls and electronic expansion valves.

"We developed this with contractors and OEMs in mind," said Patenaude. "It's a one-stop area for technology details on CO₂ products."

In addition, Emerson has started running a series of tests at its Helix Innovation Center, in Dayton, Ohio, to measure the energy savings delivered by different transcritical CO₂ technologies. Patenaude said the data would help drive transcritical sales by boosting confidence in the efficiency of the system.

"What Emerson is trying to do this year is to take a CO₂ transcritical booster system and try to understand it better from an energy perspective," said Patenaude.

Emerson is starting with a basic booster system and "energy optimizing it as best as we can, running it at a gamut of temperatures and humidities," said Patenaude. In phase one of the project, launched in June and running through September, Emerson will compare the basic system to a system with: parallel compression; an adiabatic condenser; a combination of parallel compression and an adiabatic condenser; mechanical subcooling; and heat reclaim.

In phase two, running from October through December, Emerson will compare the basic system to one with: air conditioning and parallel compression, vapor ejectors and parallel compression; vapor ejectors, parallel compression and an adiabatic condenser, and other potential systems. ■ MG

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Mark Skierkiewicz, UL



UL Takes On Hydrocarbons

The safety certification group has updated charge-limit standards for hydrocarbon equipment and is engaged in industry research on the flammability of A3 refrigerants

“Once the codes allow for it, then we’ll start to see more adoption at the state and local level of these natural refrigerants.”

– By Michael Garry

Underwriters Laboratories (UL), the 124-year-old safety certification firm that helped usher in the modern electrical age, is contributing to the adoption of natural refrigerant technologies, most recently those based on flammable (A3) refrigerants like propane.

“Several [A3] refrigeration standards have recently been updated,” noted Mark Skierkiewicz, staff engineer for UL, who participated in the regulations and standards panel at ATMOSphere America in June.

In late April, UL adopted a new safety standard, UL 60335-2-24, Edition 2, which boosted the hydrocarbon charge allowed in U.S. domestic refrigerators to 150 g from 57 g, the amount previously allowed under UL 250.

The new standard is in line with the IEC’s international standard that allows 150 g of hydrocarbons propane and isobutane in domestic refrigerators. However, the Environmental Protection Agency has yet to change its own charge limit to 150 g from 57 g, holding back adoption of domestic refrigerators using hydrocarbons ([see page 26](#)).

In May, UL raised the charge limit for refrigerating appliances, ice cream appliances and ice makers to 150 g from 60 g under UL 60335-2-24; EPA’s limit for that equipment is also 150 g. Commercial refrigerators also have a 150 g limit under UL 471 (transitioning to UL 60335-2-89) and EPA. Water coolers, which EPA approved as an application for propane last year, has a limit of 60 g under both EPA and UL 399.

UL is an important player in industry research looking into the flammability risks of A3 and A2L (mildly flammable) refrigerants, including a \$5.2 million program launched last year by AHRI (Air-



Conditioning, Heating and Refrigeration Institute), ASHRAE, U.S. Department of Energy, and the California Air Resources Board.

UL's role is to examine "what the charge limit would be and hazards associated with that, refrigerant piping and joints, any source of ignition that might be inside the product—whether it be a sparking part or hot surface—and then any other mitigation means that we can use to prevent hazards," explained Skierkiewicz.

In June, AHRI released a report on A2Ls, the product of the AHRTI 9007 project. (AHRTI – the Air-Conditioning Heating and Refrigeration Technology Institute – is the research arm of AHRI.)

"The main objective of this project was to determine the severity of an event that could occur on behalf of a refrigerant leak," said Skierkiewicz. "We gathered data to determine what factors may impact the severity, such as the leak location, the temperature and humidity of the room, how the equipment was installed, and where it was installed." UL did some testing at the higher charge limit proposed by new IEC standards.

Having completed its flammability study of A2Ls, UL will use a similar approach to A3 refrigerants, he said.

UL is also involved in AHRTI-9008, which is looking at the hot-surface ignition temperature of A2L refrigerants, and AHRTI-9009, focused on leak detection for A2Ls.

Another UL flammability project – this one focused on propane – was sponsored by the Fire Protection Research Foundation, an affiliate of the National Fire Protection Association. "This is specifically looking at the fire hazard associated with R290 in refrigeration applications in retail sites, as well as commercial kitchens," said Skierkiewicz. "The charge limit for this project

was not limited to the current EPA SNAP [limit] of 150 grams; it went all the way up to 1 kg of A3 in each circuit. So that does provide the data points for future standards of refrigerant."

Skierkiewicz noted that whatever is decided on A3 safety standards will be reflected in ASHRAE-15 (the safety standard for refrigeration systems), which will then ultimately be reflected in the model codes, and from there filtered down to the states. "Once the codes allow for it, then we'll start to see more adoption at the state and local level of these natural refrigerants," he said.

ASHRAE-15, he added, is employed by the International Mechanical Code (IMC) and the Uniform Mechanical Code, the major building codes that are used in 48 states. (For ammonia, IAR-2 is becoming the go-to standard; see story, next page.)

The expected date to have final refrigerant requirements ready for codes is 2021, said Skierkiewicz; by 2023, they would start to filter down to the states. "I think at that point you'd probably have pretty good footing if it's been adopted by the state to really have a good conversation with local inspectors."

Any interested stakeholder can make a suggestion to UL regarding a standard for the North American market, Skierkiewicz noted. "If you know that there's a particular hazard that exists, let's address it for the whole industry and make the whole industry meet the minimum safety level that we have."

He added that there are some openings on the committee working groups for both HVAC and refrigeration. "The committee tries to pick manufacturers, installers and product users," he said. "I'm not guaranteeing that if you apply for membership you'll be on the committee, but there are openings on the committee for anybody that's interested in participating on the actual standards development process."

▶ IIAR: THE STANDARD-SETTER FOR AMMONIA REFRIGERATION

The IIAR (International Institute of Ammonia Refrigeration), a 2,900-member group founded in 1971, continues to set standards for the use of ammonia in industrial refrigeration – and increasingly, commercial refrigeration – that are followed by other standards and code organizations. (See timeline, this page.)

Last year, IIAR came out with an update to its IIAR-2 standard on safe design of ammonia refrigeration systems that included information on low-charge systems. Since then, IIAR-2 has been adopted by U.S. building codes for ammonia, noted Dave Rule, president of IIAR, at the ATMOSphere America conference in June. “This was a big undertaking and an important advancement for our industry.”

In addition, the ASHRAE committee for the ASHRAE-15 refrigeration safety standard voted to refer to IIAR-2 whenever ammonia is used; this change awaits final approval, which IIAR expects. “That’s an important change because it will help reduce the conflict in standards that are used in the U.S. and around the world,” said Rule. “That really makes IIAR-2 the de facto safety standard for ammonia in the U.S.”

IIAR standards are also recognized by the Environmental Protection Agency, Occupational Safety and Health Administration and Department of Homeland Security.

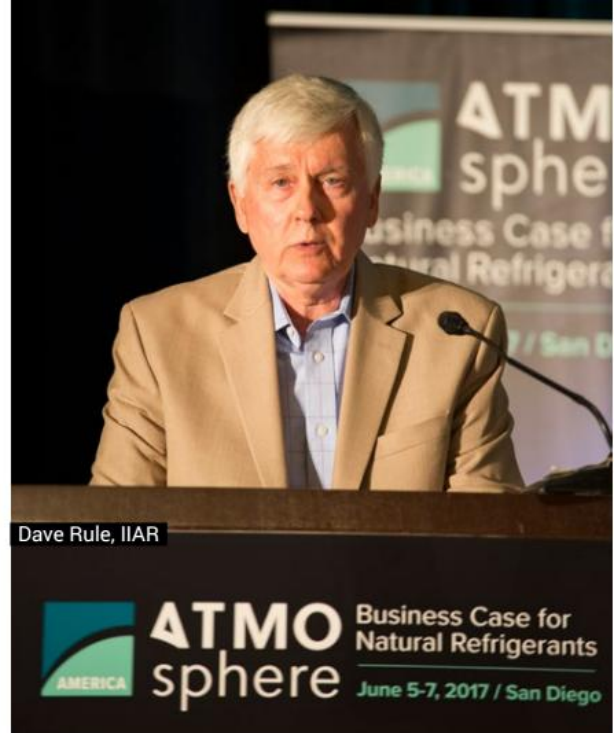
Standards under development include IIAR-6, a maintenance, testing and inspection standard. “This is important because it will address, for the first time, a lot of the regulatory questions and issues that our members deal with during their audits and inspections,” said Rule.

IIAR-9, another standard in draft process, covers RAGAGEP (Recognized and Generally Accepted Good Engineering Practices). “This again will be a very important standard because, for the first time, it will recognize the ‘grandfather’ issue – how often do you need to upgrade your systems? How do you go through the process of making those decisions, and how do you document that process so that you meet regulatory requirements?”

In a sign that it’s branching out to CO₂ refrigeration and more commercial applications, IIAR has developed in draft form IIAR C2, a CO₂ refrigeration system safety standard.

Meeting ANSI standards

Rule emphasized that IIAR is an ANSI (American National Standards Institute)-approved standards body. “ANSI comes into our office every five years and does a complete audit,” said Rule. “We are required to pull whatever standards they select at random.” ANSI completed its latest audit this year.



Dave Rule, IIAR

IIAR’s standards development starts with its standards committee, or a task force within IIAR that develops a scope for a standard. “That may be based on a need that we see through our membership, a safety issue that has developed or other maybe regulatory questions that need to be addressed,” Rule said. The standards are reviewed every five years.

Industry consensus is crucial to IIAR’s standards development. “As we are starting to draft a standard, we also go out into the industry and select groups from each of our sectors of membership to serve as a consensus body for that particular standard, or group of standards, that we are working on,” he said.

“A good standard really needs to be an industry-wide consensus process.” ■ MG

IIAR/ANSI Standards

IIAR-1 (2012):
Definitions and
Terminology Used in IIAR
Standards

2012

IIAR-3 (2012):
Ammonia Refrigeration Valves

IIAR-5 (2013):
Start-Up and Commissioning
of Closed-Circuit Ammonia
Refrigeration Systems

2013

IIAR-7 (2013):
Developing Operating Procedures
for Closed-Circuit Ammonia
Mechanical Refrigerating
Systems

IIAR-2 (2014):
Safe Design of
Closed-Circuit Ammonia
Refrigeration Systems

2014

IIAR-4 (2015):
Installation of Closed-Circuit
Ammonia Refrigeration
Systems

2015

IIAR-8 (2015):
Decommissioning of
Closed-Circuit Ammonia
Refrigeration Systems

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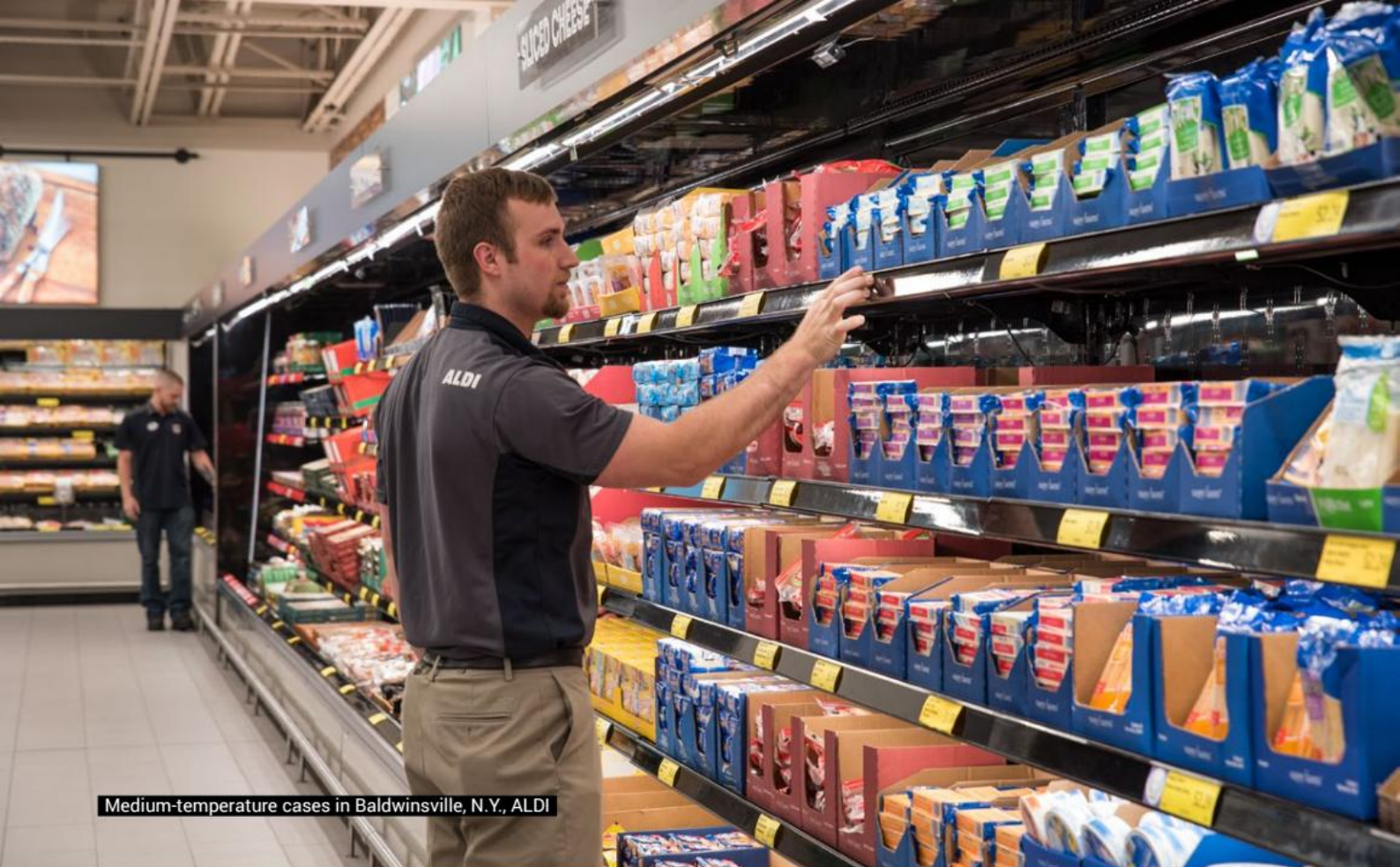
Leader of the Rack

With 69 installations, ALDI is the No. 1 user of transcritical CO₂ refrigeration systems in the U.S. supermarket industry, and its aggressive store expansion and remodeling plans call for even more

— By Michael Garry

New ALDI store with AdvansorFlex transcritical CO₂ system in Baldwinsville, N.Y.

Photography by Ben Cleeton



Medium-temperature cases in Baldwinsville, N.Y., ALDI

When Hillphoenix introduced the AdvansorFlex – a smaller capacity, less costly version of its Advansor transcritical CO₂ booster refrigeration system – in December 2015, the Conyers, Ga.-based OEM had in mind small-format stores as the primary end user.

Enter ALDI US, the fast-growing chain of nearly 1,700 value-oriented supermarkets in 35 U.S. states. The Batavia, Ill.-based company had already started installing Hillphoenix's Advansor system prior to the AdvansorFlex's release, but then switched to the smaller system.

"Hillphoenix engineered the AdvansorFlex specifically for ALDI stores, which have smaller footprints [about 20,000 sq ft]," said Aaron Sumida, an ALDI US vice president based in upstate New York. "The Advansor CO₂ booster system is better suited to traditional supermarkets."

As of August 11, 2017, ALDI had deployed a transcritical CO₂ system – the majority of them the AdvansorFlex – in 69 stores, with more installations coming. Hillphoenix supplied 66 of these stores, with the other three using transcritical

systems provided by a partnership between Hussmann and Canadian OEM Systemes LMP. More than 10 projects so far have been in remodeled stores, and the rest of the systems were installed in new locations. In stores without CO₂ refrigeration systems, ALDI currently uses R448A.

With 69 installations, ALDI is the No. 1 user of transcritical CO₂ refrigeration in the U.S. supermarket industry. In North America, it's second only to Sobeys, which has approximately 100 stores with a transcritical system.

Known for its low prices (up to 50% lower than those of traditional stores, the company says), private brands and no-frills, efficient operation, ALDI US is a 41-year-old independently operated member of Mülheim, German-based ALDI South (Süd). Facing growing competition in the U.S. from traditional grocers and other European-based retailers, ALDI has announced store development plans that are nothing if not ambitious. By the end of 2022, it expects to have nearly 2,500 stores, funded by a \$3.4 billion capital investment plan, putting it third in the U.S. in store count behind Walmart and Kroger.



Low-temperature cases in Baldwinsville, N.Y., ALDI



ALDI VP Aaron Sumida entering walk-in cold storage room at Baldwinsville, N.Y., store

In July, the chain opened a store in Baldwinsville, N.Y., overseen by Sumida that runs an AdvansorFlex system. (See photos in this article.)

Earlier this year, the company announced a \$1.6 billion plan to remodel and expand more than 1,300 existing U.S. stores by 2020. Remodeled stores will feature a modern design, open ceilings, natural lighting and environmentally friendly building features.

Immense impact of CO₂

As a parent company, ALDI South is dedicated to international carbon emissions reduction goals, setting the tone for its group countries. "We're committed to reducing, reusing and recycling waste, increasing energy efficiency, minimizing our carbon footprint and improving our green building standards across all of our stores and operations," said Sumida.

In the U.S., ALDI has set a corporate goal of reducing greenhouse gas emissions by 30% per square meter of sales floor by 2020 compared to 2012. Rooftop solar panels on many of its stores and distribution centers represent one avenue

“ We genuinely believe that natural refrigerants are the best long-term solution. ”



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▶ to reduced emissions, and equipping new and remodeled stores with all-LED lighting and efficient HVAC systems is another. In addition, the potential emissions-reducing impact of installing transcritical CO₂ systems “is immense,” said Sumida.

Replacing R404A, or even the lower GWP refrigerant R407A, with CO₂, he pointed out, means that the warming impact of a leak is reduced by 1/3,900th or 1/1,900th respectively. “Our stores are our primary source of emissions, so this can only help us meet our goal,” he said.

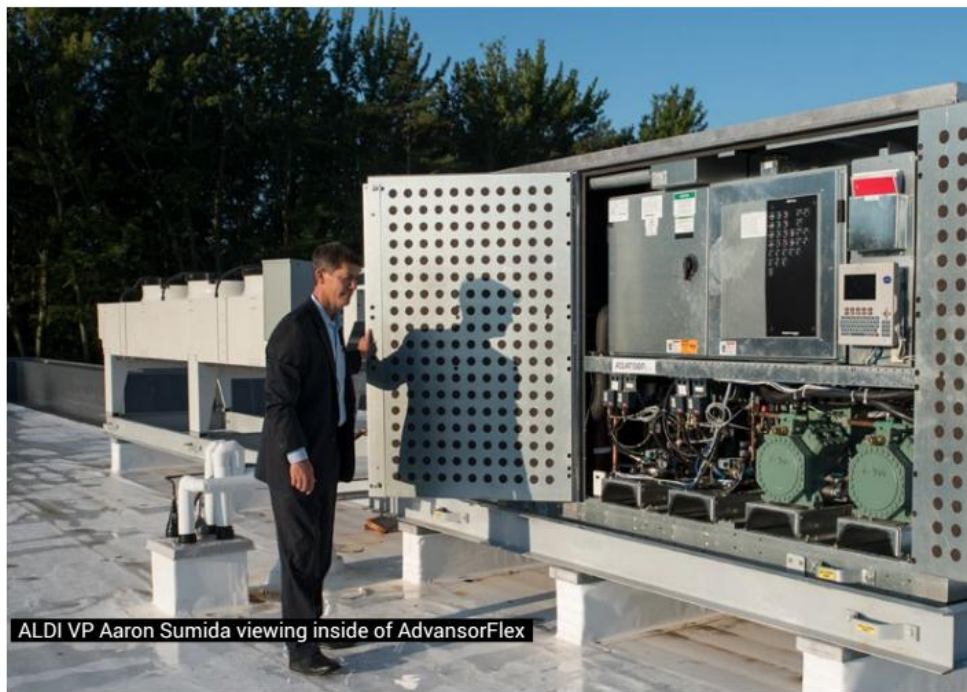
ALDI US started installing transcritical CO₂ systems in earnest when it entered the Southern California market in March 2016, and now uses them in new stores and major remodels in four of its 24 divisions – California, New England (Connecticut, Massachusetts, New Hampshire, Rhode Island and Vermont), New York and Virginia.

As of August 2017, 43 of ALDI’s 69 transcritical stores had been awarded GreenChill Platinum certification by the Environmental Protection Agency’s GreenChill Partnership, with more new and remodeled transcritical stores in the process of receiving this certification. Platinum is GreenChill’s highest level of certification, achieved in this case by using a refrigerant with a GWP of under 150. In 2015, ALDI joined GreenChill, which calls on supermarket members to set emission-reduction goals, report annual emissions and work to improve existing and future store refrigeration and HVAC equipment.

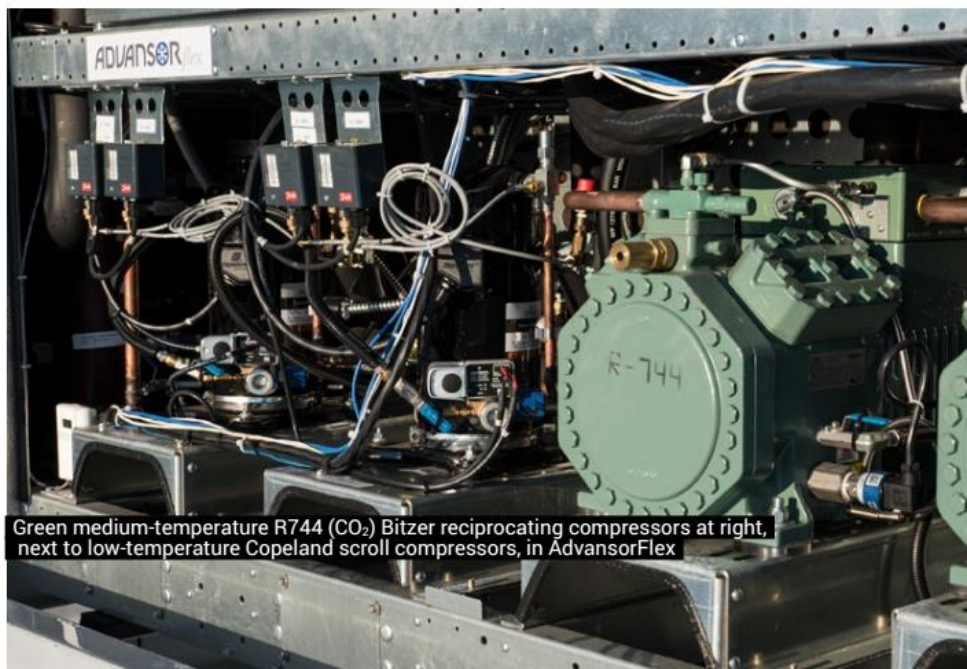
ALDI US has not set a deadline to fully commit to CO₂ transcritical refrigeration systems, but “it’s our long-term objective to standardize,” said Sumida. With about 800 new ALDI stores to open in the U.S. by 2022, each of the company’s 24 divisions will begin to phase in CO₂ transcritical systems – including the 18 not currently committed to it – “to ensure preparedness by the refrigeration installers and technicians,” he added.



AdvansorFlex unit (at right) and gas cooler on roof of ALDI store in Baldwinsville, N.Y.



ALDI VP Aaron Sumida viewing inside of AdvansorFlex



Green medium-temperature R744 (CO₂) Bitzer reciprocating compressors at right, next to low-temperature Copeland scroll compressors, in AdvansorFlex



Refrigerant-grade CO₂ stored at Baldwinsville, N.Y., ALDI

Beyond CO₂

CO₂ is not the only natural refrigerant in which ALDI has invested.

All spot merchandiser freezers purchased since 2015 in about 200 stores use propane as the refrigerant. "They have a very low refrigerant charge and are environmentally friendly," said Aaron Sumida, an ALDI US vice president based in upstate New York.

"We've thought about this concept and are open to considering it in the future," he added. "We're constantly exploring new natural refrigerant solutions to evaluate the right direction for our stores."

ALDI also employs an ammonia refrigeration system at each of its 24 distribution centers.

Does ALDI plan to use natural refrigerants in HVAC systems or in refrigerated trucking? "We've considered the use in these applications and will continue to explore our options as the technology develops" Sumida said.

ALDI's Primary Refrigeration System

The AdvansorFlex – the primary refrigeration system for new and remodeled stores in four of ALDI's 24 divisions – represents the latest chapter of Hillphoenix's natural refrigerants journey.

A longtime provider of secondary and cascade CO₂ systems, Hillphoenix entered the all-CO₂ transcritical refrigeration category in 2011 with the acquisition of Danish OEM Advansor, a major supplier of transcritical systems to the European marketplace. By 2012, Hillphoenix had begun manufacturing its own Advansor-branded transcritical racks at its Georgia headquarters. By mid-2017, Hillphoenix had installed close to 300 transcritical racks in North America – out of a total of about 410 – the most of any OEM.

Contributing significantly to that growth is the AdvansorFlex, a smaller capacity, less costly (by 20%-30%) version of the original Advansor system, designed for small-format stores (though it can be used in larger formats as well in multiples). Introduced in December 2015, the AdvansorFlex was specifically designed for the North American marketplace to meet stringent UL/cUL requirements and North American safety codes. Its rapid acceptance in the marketplace won Hillphoenix *Accelerate America's* Innovation of the Year award in 2017.

The AdvansorFlex's compact size enables it to be placed in a back room, on a mezzanine, on a rooftop or outside on the ground. Its sound-attenuating panels allow it to be installed near the sales floor. Two units are being considered as a replacement for an HFC system in an existing grocery store.

The AdvansorFlex was developed to be a "lower-cost alternative" that smaller-format stores would be able to afford, noted Scott Martin, Hillphoenix's director of business development and industry relations. In addition to small-footprint grocery stores, it is suited for convenience and dollar stores.

Hillphoenix was able to reduce the cost of the AdvansorFlex by redesigning elements like the oil system. "It doesn't require a traditional oil system that includes a separator and reservoir," said Martin.

While its first cost is still above that of an average HFC rack, the AdvansorFlex is designed to reduce installation and maintenance costs. For example, it uses smaller copper piping, less insulation and less expensive refrigerant than an HFC system. Its electrical installation only requires a single point of connection from case controllers, which lowers costs. "All of this has to be rolled into an ROI calculation, and we help people with that," said Martin.

Like all transcritical systems, the AdvansorFlex's efficiency depends on its location; it is up to 18% more efficient than an HFC unit in cooler climates, says Hillphoenix, but its efficiency decreases in warmer climates. However, Hillphoenix has installed AdvansorFlex units with efficiency-improving adiabatic gas coolers in southern U.S. locations, said Martin.



System Specs

The AdvansorFlex is available in 36 models. The following is summary of their specifications.

- Low-temperature (LT) load range: 50 kBTU/hr-125 kBTU/hr
- Medium-temperature (MT) load range: 100 kBTU/hr-425 kBTU/hr
- Standard low temperature: -25°F SST
- Standard medium temperature: 15°F SST (VFD in lead compressor)
- Gas cooler CO₂ outlet temperature: 85°F
- Gas cooler powered separately from the rack
- Approximate CO₂ charge: 350 lbs
- Chassis configuration for 100-230 kBTU/hr MT load models: two MT reciprocating compressors by two LT scroll compressors
- Chassis configuration for 425 kBTU/hr MT load model: three MT reciprocating compressors by two LT scroll compressors
- Height of 100-230 kBTU/hr MT-load models: 72 in
- Height of 425 kBTU/hr MT-load model: 74 in
- Weight of rack: 4,000-4,600 lbs

“ALDI stores in other countries also use CO₂ systems as a standard.”

► Why did ALDI US choose to install transcritical systems? “We genuinely believe that natural refrigerants are the best long-term solution,” said Sumida. And while ALDI US operates independently, it has also followed the example of ALDI South stores abroad, particularly in Europe. In February, ALDI South made public that the company had installed its 1,000th store with a CO₂ system, representing 54% of its outlets; the U.K. division of ALDI South announced that it would convert all of its roughly 700 stores to CO₂, starting with 100 by the end of 2018.

“ALDI stores in other countries also use CO₂ systems as a standard and have set a strong precedent in the natural refrigerants category,” Sumida noted, adding, “ALDI in other countries serves as a resource for us. Some of the best examples for many of our environmental tests and initiatives begin with what other ALDI South group countries are doing. This collaboration across countries continues to drive results.”

An energy benefit

Sumida acknowledged that there is a 20%-30% increase in upfront cost associated with the CO₂ transcritical systems compared to conventional HFC rack systems. However, ALDI anticipates a financial gain over the lifetime of the transcritical system considering “avoided refrigerant phase-outs and reduced cost of refrigerant,” he said. The company is still evaluating long-term maintenance costs and energy efficiency for transcritical, though “we’ve definitely seen an energy benefit in the cooler months.” To improve the energy efficiency of transcritical systems located in warmer climates like Southern California, ALDI employs an adiabatic condenser instead of a standard gas cooler.

In addition, as ALDI works to exceed national regulations related to refrigerant phase-outs, it expects to see additional savings from being able to avoid “increasing reporting regulations on non-natural refrigerants,” said Sumida.



Utility incentives haven’t covered any of ALDI transcritical equipment or installation costs, though the company is exploring available incentives in the divisions committed to CO₂.

Like many end users of transcritical CO₂ equipment, ALDI has been challenged by the shortage of refrigeration technicians trained on this technology. One resource tapped by the company is Hillphoenix’s Learning Center, which has trained at least 100 of the technicians providing service to ALDI.

Another challenge has been the availability of quality CO₂ refrigerant and system components, though with further adoption of CO₂ technology those items are now in greater supply.

ALDI shares its environmental accomplishments and progress in an environment section on its corporate responsibility website and on its social media channels. In Platinum-certified stores, said Sumida, “We also proudly display our EPA GreenChill Certification plaque” – representing its industry-leading investment in transcritical CO₂ refrigeration. ■ MG



Fear Strikes Out

AAA Refrigeration was able to move its technicians past their worries about the high pressures of CO₂ systems with an extensive training program

— By Michael Garry

“Once the techs were educated, they came to realize that the systems aren't much different than a standard DX or glycol system.”

When AAA Refrigeration Service, a Bronx, N.Y.-based contractor, found out in 2015 that it would be starting up and servicing a transcritical CO₂ system at a DeCicco & Sons store in Larchmont, N.Y., its technicians were a little taken aback.

“They said, ‘The pressures are too high, we don’t want to work on that,’” said Pete Savage, head of controls division (N.Y. office) and Long Island Zone service manager, for AAA Refrigeration, at a food retail session in June at the ATMOsphere America 2017 conference. He provided a contractor’s perspective for a panel otherwise populated by supermarket executives. (See [“Meeting the Retrofit Challenge,” Accelerate America, June-July 2017.](#))

But AAA Refrigeration addressed its technicians’ “fear of the high pressure,” with ample training on CO₂ technology, said Savage. “Once the techs were educated they came to realize that the systems aren’t much different than a standard DX or glycol system. They were able to embrace [CO₂].”

AAA Refrigeration has since then become one of the more proactive contractors with commercial CO₂ refrigeration systems, handling all of DeCicco & Sons new and retrofit stores as well as CO₂ systems used by other retailers.

Following its Larchmont store, DeCicco & Sons, a seven-store food retailer based in Pelham, N.Y., opened a second transcritical store in Millwood, N.Y., and retrofitted an existing store in Pelham with transcritical. The retailer is retrofitting another store in Harrison, N.Y., and plans to open another store with a transcritical system in Somers, N.Y. DeCicco & Sons uses an adiabatic condenser at all of his transcritical stores (as do other AAA Refrigeration customers), but is opting for a geothermal system instead for one of his upcoming projects, noted Savage.

In addition, AAA Refrigeration has worked on a transcritical store opened by Whole Foods Market in Closter, N.J., and a cascade CO₂ store operated by ShopRite, with plans to service an upcoming transcritical ShopRite store.

Education-oriented

Recognizing eight years ago that the tide was turning in the refrigeration industry, AAA Refrigeration launched what has become an annual Refrigeration Symposium; the most recent, hosted with CO₂ OEM Hillphoenix, was held in late March in Tarrytown, N.Y. The Symposium features presentations on CO₂ technology, energy efficiency and other related issues for an audience of contractors and food retailers.

“We’re a very education-oriented company,” said Savage. (See [“Shifting Gears,” Accelerate America, November 2015.](#))

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Eric Berman of Hillphoenix (at right) with AAA Refrigeration technicians

▶ To prepare for the DeCicco transcritical stores, AAA Refrigeration partnered with Hillphoenix (provider of the retailer's transcritical racks) and component manufacturer Emerson, supplier of its case and rack controllers. The manufacturers provided the contractor with "initial and ongoing education, both in a classroom setting and hands-on in the field," said Savage. "Suppliers have been integral to our ability to do this. They are all working together to make this technology viable and successful."

Case controllers represented another new technology for AAA Refrigeration's technicians, necessitating training on controller installation, start-up and troubleshooting. "This region of our territory had little to no case controller stores prior to the introduction of transcritical CO₂," Savage said.

Hillphoenix representatives were on hand when AAA Refrigeration technicians installed DeCicco's transcritical system in Larchmont, N.Y., in 2015. The smaller line sizes of CO₂ systems help expedite the installation process, noted Savage. Moreover, the use of Mueller XHP copper-iron piping eliminated the need for stainless-steel welders and helped "ease installation."

He recommended creating a start-up log of all measures and readings after the transcritical system has been commissioned. "It's important to document start-up readings and conditions, which can be used as a service tool down the road," he said, adding that accurate as-built drawings should be kept on-site.

He also suggested making sure that the CO₂ used is refrigerant grade. AAA Refrigeration gets CO₂ from a few suppliers, and keeps a full back-up of CO₂ charge in one store.

It's a good idea, he added, to include servicing technicians at a transcritical start-up "so they can familiarize themselves with the site."

Troubleshooting a transcritical CO₂ system is no different than doing so for a standard DX system, though "piping and controls are a little more complex," he said.

Retailers interested in transcritical CO₂ should "work with your prospective contractors, starting from the design phase," said Savage. "Make sure they are on board with new technologies and are willing to provide training." ■ MG

Energy Savings at DeCicco's

AAA Refrigeration has a bird's eye view of the energy savings made possible by transcritical CO₂ systems.

At the ATMOSphere America 2017 conference, Pete Savage, AAA Refrigeration's head of controls division (N.Y. office) and Long Island Zone service manager, shared the contractor's experience with the energy savings documented at DeCicco & Sons' first transcritical store in Larchmont, N.Y.

The 24,000-sq-ft store, with a total system capacity of 1.02M BTU and a CO₂ refrigerant charge of 1,000 lbs, used "anywhere from 7% to 37% less electricity than the baseline system," a store with an R404A DX system, during a 10-month period from January through October 2016, said Savage.

As expected with transcritical CO₂, efficiency gains were greatest in the winter, lowest in the summer. The total dollar savings from both reduced electricity use and lower demand was about \$75,000 on an annualized basis (based on a utility rate of 18.8 cents/kWh). He attributed the savings particularly to the case controllers and adiabatic condenser.

(John DeCicco, Jr., president of DeCicco & Sons, talked about the energy study at AAA Refrigeration's Symposium in March 2017. [See "Transcritical Cuts Energy Costs by \\$74,000 for DeCicco & Sons," Accelerate America, April 2017.](#))

Both the transcritical store and the HFC store employed other energy-saving equipment, such as LED lights, motion sensors, night curtains, anti-sweat heaters and variable-frequency drives.

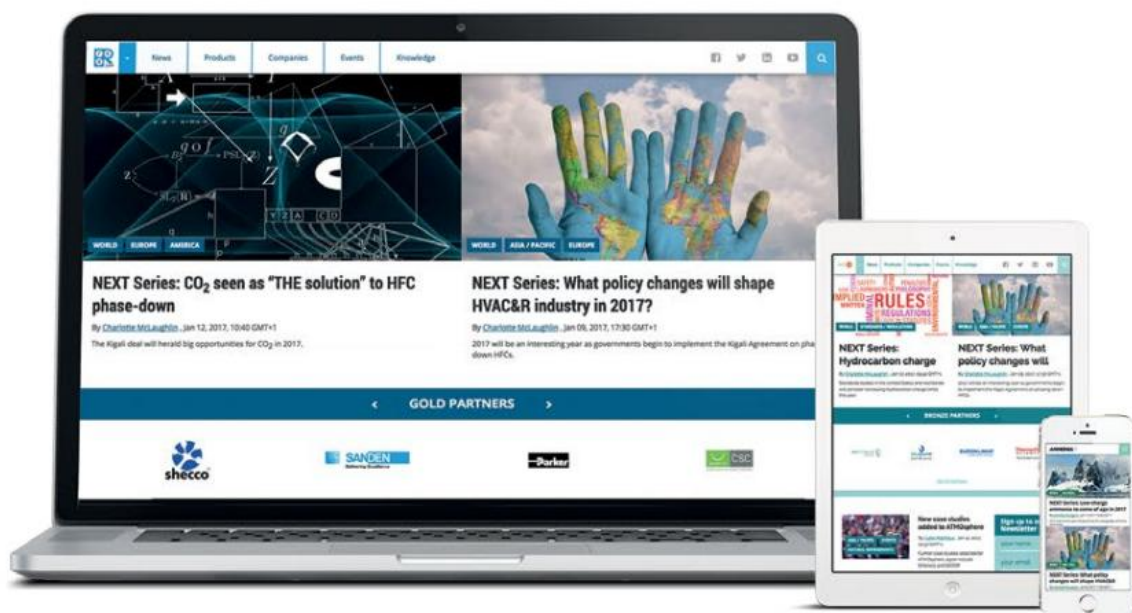
In addition to the savings in energy consumption and demand, the transcritical system offers 1.1 million BTUs in recovered heat, used for hot water, the entrance vestibule and in the kitchen.

DeCicco's latest transcritical store in Millwood, N.Y., also has five self-contained propane under-counter sandwich-prep units in the deli.

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Commercial case studies session, ATMosphere America

The Secret Sauce

Hillphoenix and Dorin explain how ejectors work with parallel compressors to make transcritical CO₂ work efficiently in warm climates

– By Michael Garry

Trancritical CO₂ refrigeration systems have steadily gained traction in the food retail industry in North America, with more than 450 installations to date, according to sheccoBase.

Most of these systems are operating in moderate climates, where their efficiency outdoes that of traditional HFC systems. But for transcritical to achieve broader adoption, particularly in the U.S. – and catch up with Europe, where there are 9,000 installations – it needs to be capable of operating with greater efficiency in warm ambient climates.

CO₂'s high critical point – 88°F – means that at high ambient temperatures CO₂ exists as a supercritical fluid (without distinct liquid and gas phases), and more energy is required in the vapor-compression cycle.

However, energy-enhancing technologies like adiabatic condensers, subcooling,

parallel comprehension and ejectors are able to increase the operating efficiency of transcritical systems, allowing them to break through the “CO₂ equator” that has constrained adoption in southern climates in the U.S. (See article on page 22.) In Europe, parallel compression in concert with ejectors has led to uptake of transcritical systems in warm countries like Spain and Italy.

At the ATMosphere America conference in June, representatives of OEM Hillphoenix and component maker Dorin spoke about the positive impact that ejectors and parallel compression can have on transcritical efficiency and how these technologies achieve this.

Flash gas problem

Hillphoenix's Danish subsidiary Advansor has placed 500 transcritical systems with parallel compression in Europe, and more than 20 with ejectors as well. In the U.S., Hillphoenix is just getting

started with these technologies, with a parallel compression system installed at a U.S. Navy commissary in Newport, R.I., and an ejector-parallel compression system operating at a Sprouts Farmers Market store in Woodstock, Ga.

At ATMosphere America 2017, Jeff Newel, director of research and development for Hillphoenix, described a study that Hillphoenix did at its lab in Covington, Ga., where the OEM compared the performance of a standard Advansor transcritical CO₂ booster system with the that of the same system equipped with parallel compression and a gas ejector.

The main problem faced by transcritical systems in warm climates is that the “flash gas” produced by the supercritical fluid as it enters the flash tank from the gas cooler does no useful work. The gas is essentially recycled through the system, initially at a reduced pressure, as it moves from the flash gas control (bypass)

valve through the medium-temperature compressors and back to the flash tank.

"That's where the energy issue arises," said Newel. "You've got this amount of flash gas, when you're in supercritical operation, that just goes around and around in a circle."

One way to address the flash gas problem is to eliminate, or at least minimize, the gas during supercritical operation. "That's where parallel compression comes in," Newel said.

Instead of going along its usual route to the medium-temperature compressors, the flash gas is redirected to an internal heat exchanger and then to the separate parallel compressor or compressors – a "satellite compressor group," said Newel. The sole purpose of the heat exchanger, he noted, is "to make sure there's enough super heat in the CO₂ as it goes back to the [parallel] compressor so that you're not going to cause a problem."

The key, he noted, is that the flash gas is now at a higher suction pressure (matching the pressure of the flash tank) as it heads to the parallel compressor than it would be in a conventional scenario. "You're not paying to take a 36-bar flash gas and pass it through the bypass valve, where

it drops down in pressure, and then re-compress it again," he explained. "That's what saves you money."

A gas ejector, inserted between the heat changer and the high-pressure control valve/flash tank, adds another layer of efficiency to the operation.

Ejectors "have been around a long time – or, at least, the concept has," Newel said.

The ejector receives not only supercritical fluid from the gas cooler but low-pressure CO₂ gas from the medium-temperature suction line, and channels both to the flash tank. From there the mix proceeds back up to the parallel compressor, just as simple parallel compression does. "It reduces energy further than even the parallel does and it gives that parallel compressor an opportunity to run for a longer time," said Newel. With the ejector, the energy-saving parallel compressor can run year-round, not just in warm ambients.

In effect, "the ejector really is just using energy that's been stored within the system," said Newel. "It's free energy."

Newel cited two types of ejectors, an adjustable-nozzle type made by Carel and Danfoss's multi-ejector with fixed ejector sizes applied in parallel. Hillphoenix is using the latter – "a little bit bigger than

an iPad, maybe an inch and a half thick," said Newel – in its year-old test system.

Newel described the transcritical test rack at its Georgia research facility as "a Frankenstein rack" because of all the enhancements that have been made. For its parallel compression-ejector test, the rack was set up with 50 MBTUH of low-temperature load at -20°F SST and 75 MBTUH of medium-temperature load at 20°F SST; the "interstage" (parallel compression) capacity ranged from 30-70 MBTUH at 39°F SST.

On a theoretical basis, Hillphoenix expected that, in a hot climate, parallel compression would produce annual energy savings in the 6% to 8% range, and that parallel compression with a gas ejector system would deliver an annual savings of 8%-10%. The company's Advansor subsidiary in Denmark tested "optimized systems" with similar results.

But in its lab, Hillphoenix tested a "non-optimized" system with a higher low-temperature load among other changes "because, believe it or not, systems out in the working world aren't always optimized," Newel said. The result was a 5.4% annual energy savings with parallel compression and 6.5% savings with parallel compression and an ejector. "This is still good savings," he added. ▶



Jeff Newel, Hillphoenix



Giacomo Pisano, Dorin

▶ Liquid ejector advantage

Giacomo Pisano, sales manager for Italian component manufacturer Dorin, described at ATMOsphere America how the company is enabling retailers like Carrefour to operate transcritical refrigeration efficiently in the warm climates of Italy. One way is with liquid ejectors.

In Europe, not only are manufacturers incorporating gas ejectors in transcritical systems, but liquid ejectors as well.

Liquid ejectors allow for a flooded evaporator design. Some liquid may come back from the evaporator, but would be collected into a low-pressure receiver and then pumped by a liquid ejector into an intermediate-pressure receiver. "By working in this way, you manage to raise the evaporating temperature by [as much as] six degrees Kelvin, which means a very high COP increase," said Pisano.

Pisano said a gas ejector works most efficiently in combination with a liquid ejector. "If you manage to raise your suction pressure with a liquid ejector, you will have a smaller differential pressure across the gas ejector—which will then be able to transfer more mass flow."

In Europe, there are about 100 transcritical systems running with gas and liquid ejectors, he said, especially in very warm areas like Italy or Greece. "This kind of system, using parallel compressors, liquid and gas ejectors, is managing to completely delete the so-called equator for CO₂ applications."

Pisano cited a Carrefour supermarket in Turin, Italy, as an example of where this enhanced transcritical system, with a rack from Italian OEM Enx and Dorin compressors, is running. The store has a medium-temperature capacity of 97 TR (340 kilowatts) and a low-temperature capacity of 19 TR (66 kilowatts), performs heat recovery for ambient heating and sanitary hot water usage, serves 160 evaporators, and is designed to work in ambient temperatures up to 113°F (45°C).

According to Pisano, by using a system with parallel compression combined with gas and liquid ejectors, Carrefour gains 28% in efficiency over a basic transcritical system. "You can easily understand how, with this technology, you manage to boost the efficiency of a CO₂ system in very warm climates," he said.

He acknowledged the higher cost of the enhanced system, but added that the ROI for the premium was calculated to be just two years. ■ MG

“You've got this amount of flash gas ... that just goes around and around in a circle.”

Efficiency through Modulation

Italian OEM Carel builds controllers that work not just on transcritical racks and cases but on a much smaller platform – single-temperature transcritical condensing units. These systems are in widespread use in Japan and Europe, but have not yet penetrated the U.S. marketplace; however, their potential for small-format supermarkets and convenience stores in the U.S. is considerable.

"We have to find a way to boost CO₂ in all applications possible, not just with higher and bigger compressor racks but also small units," said Nicola Pieretti, application manager for refrigeration at Carel's headquarters in Italy.

Carel's approach to efficiency enhancement in both large and small systems is through compressor modulation that enables the system to "adapt to the conditions – load and also climate," said Pieretti. This modulation can be achieved with brushless DC (BLDC) compressors.

Carel designs the controllers for these systems, such as the pRack100T, suitable for condensing units. Its larger rack controllers, such as the Hecu CO₂, manages a variable-speed BLDC compressor in the system, as well as high-pressure and flash valves; "Carel has just started incorporating it in the U.S.," said Brandon Marshall, U.S. application manager. Carel is collaborating with Zero Zone on developing the Hecu.

BLDC technology offers a 26% wider range of modulation, resulting in "higher efficiency at every load condition," said Pieretti. It can "make CO₂ efficient everywhere, available everywhere, no longer considering a climate barrier."

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EUROPE

europa@shecco.com

(+32) 2 230 3700

JAPAN

japan@shecco.com

(+81) 3 4243 7095

AMERICA

america@shecco.com

+1 503 737 5061

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VOLUME 3, ISSUE #28, SEPTEMBER 2017

ACCELERATE

ADVANCING HVAC&R NATURALLY

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Accelerate America is published 10 times per year by shecco America. All issues are available in digital form at AccelerateNA.com. Printed copies are mailed to end users and other key HVAC&R industry players, and are distributed at key industry events.*

Issue #27 August 2017

Focus: Contractor profile (Source Refrigeration & HVAC)

Issue #28 September 2017

Focus: Transcritical CO₂ system (ALDI US)

Issue #29 October 2017

Publication date: Oct. 24
Focus: HVAC: Progress in North America
Ad submission deadline: Oct. 20

Issue #30 (Vol. 4) November-December 2017

Publication date: Nov. 21
Focus: Top 25 Movers & Shakers
Ad submission deadline: Nov. 17

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- ▶ Research

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AHR Expo

January 22-24
Chicago
<https://ahrexpo.com>

IIAR Natural Refrigeration Conference & Expo

March 18-21
Colorado Springs, Colo.
<http://bit.ly/2yjQHsL>

NRA (National Restaurant Association) Show

May 19-22
Chicago
<https://show.restaurant.org/Home>

ATMOsphere America

June 11-13
Long Beach, Calif.
<http://www.atmo.org/events.details.php?eventid=66>

* The editorial calendar is subject to change.

Accelerate's network of offices stretches from New York and Brussels to Tokyo and Melbourne. Accelerate America is published monthly except for a mid-year and year-end double issue. The views expressed by the contributors are not necessarily those of the Publisher. Every care is taken to ensure the content of the magazine is accurate but we assume no responsibility for any effect from errors or omissions.

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ISSUE# 28

VOLUME 3

Publisher

Marc Chasserot
marc.chasserot@shecco.com
[@marcchasserot](https://twitter.com/marcchasserot)

Editor

Michael Garry
michael.garry@shecco.com
[@mgarrywriter](https://twitter.com/mgarrywriter)

Reporter

Elise Herron
elise.herron@shecco.com

VP-Business Development & Technical Editor

Derek Hamilton
derek.hamilton@shecco.com

Contributing Writers

Eda Isaksson
Charlotte McLaughlin
Andrew Williams
Devin Yoshimoto
Darren Cooper
Stefan Elbel

Ad Coordinator

Silvia Scaldaferrì

Art director

Anna Salhofer

Graphic Designer

Charlotte Georis
Juliana Gómez

Photographers

Ben Beech
Ben Cleeton
Anna Salhofer



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