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CONDENSER

NH_3 | CO_2 TAKE GOLD

ICE RINKS ANSWER HFC PHASE OUT WITH NATURAL REFRIGERANTS

MARCH 2018

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president's MESSAGE

BY DAVE RULE

It's that time of year again, and I'm happy to welcome all IIAR members back to our most important event – the IIAR annual conference and exhibition. Before I get into the exciting things we've got in store for you as an organization this year, I'd like to take a minute to recognize all our sponsors and exhibitors. It is their support that provides the backbone for this annual event, sponsoring food and coffee breaks, not to mention our exhibit hall – and everything else that makes this one of the premier events in our industry.

And I'd also like to thank you, as an IIAR member or attendee. Our technical program is the most central element of our work as an industry, and your participation is crucial. Special thanks go out to all our tech paper authors, workshop and panel contributors. Your leadership and enthusiasm has made the IIAR annual conference the top notch technical event it is today.

I'd also like to encourage everyone to take advantage of the opportunities to participate in IIAR's continuing education here in Colorado Springs this year. It's a great chance to expand your technical knowledge and grow your professional credentials while making our industry a safer place to work. And finally, don't forget to attend the Monday night event and other social gatherings to network and catch up with old friends!

IIAR will be stepping up a focus on regulatory initiatives in recognition that it's time for our organization to take a leadership role in addressing several specific regulations this year.

Now that I've given a proper welcome, I'd like to highlight a few initiatives and projects that IIAR is moving forward over the next year – through the strength of its membership, committee volunteer program and sound direction from the executive committee and board of directors.

First, IIAR's new and updated major publications will be made available over the next six months, so stay tuned for news of their release. Next, IIAR has implemented new technology through the IIAR learning management system to make education and training more accessible.

We've got a new focus on electronic access for IIAR members with multiple facilities. And to that end, we'll be announcing some exciting opportunities coming soon through the Academy of Natural Refrigerants, where we'll provide a more comprehensive program to expand continuing education and professional credentials for all membership sectors of our industry.

Meanwhile, IIAR will be stepping up a focus on regulatory initiatives in recognition that it's time for our organization to take a leadership role in addressing several specific regulations this year.

IIAR has determined that these regulations are overly burdensome and reduce safety both in our facilities and for the public. Our focus will be on the definition associated with IDLH for ammonia required reporting levels and the limited time allowed in executing a release report to EPA.

Our goal will be to define these regulations on sound information and modify existing regulations to provide guidance that is fair to our members and offers greater safety for our industry.

In closing, this advocacy and these programs that I've mentioned here in my column this month represent the future of our industry, and your support of them is essential. Every IIAR program and initiative is made possible by your membership, and additionally, by your leadership as a volunteer.

I'd like to encourage everyone to use this conference to get involved in the work of your organization. Or if you couldn't join us this year, be sure to renew your membership. It's the best way to make sure you connect with this ever-growing community of friends and colleagues who are passionate about natural refrigerants.


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chairman's MESSAGE

WALTER TEETER

It's amazing how quickly a year can go by. Our 2018 annual conference is here already, and while that means this is the last annual meeting during my term as Chairman, this year's conference represents just the beginning of many exciting developments for IIAR and its members.

Each opportunity for sharing knowledge and information, such as this conference, and our international seminars, is a chance for us to build and strengthen the resources we have available for our members.

In each membership year, the annual conference is the place to kick off new programs and initiatives for the year ahead. In 2017, we met several important goals, and we will now build on those achievements in the months ahead.

As IIAR members, the programs we support are made possible by the hard work of our Committees and the volunteer members who run them. IIAR continues to focus on providing our members with the safety standards, regulatory support, industry technology and other member services that are necessary to operate an ammonia system in today's environment.

Each opportunity for sharing knowledge and information, such as this conference, and our international seminars, is a chance for us to build and strengthen the resources we have available for our members.

We are constantly at work, developing the world's largest and best information resource for our membership and the industry in general. One of the best parts of being IIAR's Chairman over the past year has been the opportunity to be part of this work, and now, to showcase it at our annual conference.

Our exhibit hall this year is packed with the best in technology and expertise from across our industry. I hope you'll take advantage of the opportunity to see the best your colleagues and business partners have to offer in the latest equipment, products and services available in natural refrigeration.

I'd also like to highlight the 2.5-day technical program consisting of peer-reviewed technical papers, experimental workshops and engaging panels on topics including emergency response in an ammonia refrigeration facility, hot gas defrost, use of water as a refrigerant, and stainless-steel piping in industrial refrigeration.

The IIAR tech program is an essential part of the work we do. It's the best way to engage in the ongoing conversation about new ways of doing things with other professional engineers. I hope you'll make it a priority to read the work of your peers or stop in to a live presentation and take part in a technical paper discussion.

Meanwhile, two other important technical resources will be available at this year's event. Exclusive to the 2018 IIAR Conference is the Sunday afternoon Mechanical Integrity for Ammonia Refrigeration Systems Education Program. This education program provides a comprehensive outline of compliance regarding mechanical integrity for ammonia refrigeration systems with information on the basic components of a mechanical integrity program, minimum requirements of inspection, testing and maintenance as well as preventative maintenance, audits, training and quality assurance.

And in addition to that event, attendees will also be able to sit for certificate program testing at the show. The IIAR Academy of Natural Refrigerants Certificate Program is meant to help refrigeration professionals develop their skills and further their careers. Two certificate programs are currently available for testing, the IIAR 2 Certificate Course and the IIAR 4,5 and 8 Certificate Course.

As your outgoing Chairman, I would like to encourage you to join in as many of these conference events as possible. It has truly been an honor to serve as your Chairman. I am looking forward to seeing many of you at the conference. And beyond that, I'm looking forward to seeing where the achievements of the past few years take us as we move towards the future of our industry.

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ICE RINKS ANSWER HFC PHASE OUT WITH NATURAL REFRIGERANTS

BY MINDY LONG

Ice rinks from community recreation facilities to the National Hockey League are moving to natural refrigerants such as ammonia and carbon dioxide as they replace aging facilities and deal with the mandatory phase out of R-22, a hydrochlorofluorocarbon that has been widely used at ice rinks across North America.

John Collins, industrial sales manager for Zero Zone, said the lifespan of refrigeration systems at hockey rinks can be between 15 years and 50 years. “As ice rinks replace equipment, they’re looking at either low-global-warming-potential HFCs, ammonia or CO_2,” Collins said, adding that Zero Zone makes equipment using all three refrigerants.

One factor pressing change will be the dwindling supply of R-22. Beginning on Jan.1, 2020, U.S. production and import of R-22 will end, making the refrigerant more expensive and difficult to obtain.

Benoit Rodier, director of business development for Cimco Refrigeration, estimates that about 50 to 60 percent of ice rinks in Quebec and the U.S. utilize R-22. The rest of Canada is roughly 90 percent ammonia. Roughly 70 to 80 percent of those ice rinks were installed 15 to 30 years ago.

Cimco is a leading provider for the National Hockey League and has installed equipment in more than 4,500 arenas, including new NHL rinks in Miami, Chicago, Montreal, Boston, St Louis and Ottawa. The company recently installed refrigeration systems at the Boston Bruins practice facility and the joint amphitheater and practice rink for the Knights in Las Vegas. Cimco also co-authored the NHL’s minimum refrigeration specifications for new NHL arenas.

Azane, part of the Star Refrigeration group of companies, has also seen interest from ice rinks looking to replace R-22. “Most of the systems I see are old and leaking, which can be painful when you consider the increasing costs of R-22,” said Caleb Nelson, vice president of business development for Azane Inc.

Over the past 50 years, ice rinks have traditionally used ammonia or R-22. New systems using R-22 ceased several years ago but there are still a lot of R22 systems out there, Collins said. Many rinks that made the transition from R-22 moved to R-404 or R-507, he added. Now the use of these refrigerants is a concern due to their high global warming potential.

Although synthetic refrigerants may seem to cost less initially, that may change as regulations on environment change. “Rinks that may have opted for synthetic refrigerants in the past are looking towards natural refrigerants as they are ‘future proof’ and will still be viable options as our regulations on environmental change evolve,” Rodier said.


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Operators with a long-term vision look at natural refrigerants because it is a better choice for the environment and energy efficiency. "Ammonia and CO_2 will be better in terms of efficiency than any synthetic refrigerant," Rodier added.

you're a skater, the ice quality is most certainly your highest concern," Rodier said. "If you're a five-year-old playing hockey, you don't notice it. If you're a highly trained athlete, ice quality is a major concern."

"Rinks that may have opted for synthetic refrigerants in the past are looking towards natural refrigerants as they are 'future proof' and will still be viable options as our regulations on environmental change evolve."

–Benoit Rodier, director of business development for Cimco Refrigeration

HOW ICE IS MADE

Most ice rinks have a refrigeration system in the mechanical room and pump a secondary fluid, glycol or brine, into the floor, which keeps the refrigerant in the mechanical room. But, with glycol or brine, the temperature changes from one end of the ice to the other. "When

Some rinks opt for a primary refrigerant, such as R-22, that is pushed through the floor. "When you're doing this with a refrigerant you don't have a change in temperature, you just have a change in state going from liquid to gas," Rodier said, adding that Cimco offers a direct CO_2 floor.

A MESSAGE ON SAFETY FROM IIAR

The recent accident at the Fernie Ice Rink in British Columbia serves to remind us all of the importance of design safety, utilizing good operating and maintenance standards and proper safety training when working with ammonia refrigeration systems. The safe design, maintenance and operation of ammonia refrigeration systems is of paramount importance to the International Institute of Ammonia Refrigeration, International Association of Refrigerated Warehouses, Ammonia Safety Training Institute, and the Refrigerating Engineers and Technicians Association.

As advocates for natural refrigerants, our industry will continue its work to investigate and learn from an incident like Fernie – and refocus the attention of regulators, our facility owners and operators and those new to ammonia – on our industry's strong commitment to education and standards and our long history of safety.

Ammonia and other natural refrigerants provide significant benefits to ensure an economical and safe food chain while also protecting our environment, and those benefits will only grow stronger as new technology makes our industry safer and more accessible than ever before.

IIAR, IARW, ASTI and RETA take refrigeration safety very seriously and we remain committed to developing and disseminating ammonia resources to help prevent tragedies like the one that occurred in Fernie.

Additional information concerning the use of ammonia and other natural refrigerants may be found on the IIAR website at www.iiar.org.

INTEREST IN CO_2

CO_2 is gaining in popularity and more and more rinks are being built using the refrigerant. "Now we're up to a point that a lot of people know more about it and tons have adapted equipment capable of using CO_2. Scandinavia is moving mainly to CO_2 in the supermarket and ice-rink industries. It has been the same thing out east in Canada and it is moving to the west. In the U.S., it is starting in the supermarket industry," Rodier said.

Swapping out systems may be possible, but that depends on the building and mechanical room. "If you want to switch from R22 to ammonia, you might have major constraints in the building configuration to do that," Rodier said. "If you're going to CO_2, you could probably keep your same room and you don't have the same architectural constraints as going to ammonia."

And CO_2 tends to perform better in colder climates. "The energy efficiency of CO_2 is highly dependent upon the climate - CO_2 excels in colder climates. For example, a CO_2 ice rink is much more efficient than ammonia ice rinks in cold climates such as Canada. Conversely, ammonia ice rinks are more efficient than CO_2 in warmer climates such as the southern United States, Rodier said.

ADVANCES IN AMMONIA

Ammonia as a refrigerant has been around for a long time, but the equipment has changed. "We have a newer approach. Now we focus more on safety and reliability as well as less maintenance, less investment in repairs, reducing the ammonia charge and keeping it in the mechanical room," Rodier said.

Increased use of new technologies in systems allows the size of the equipment to be smaller in general, Collins said. "Some of the things allowing that are the heat exchanger designs on both the chiller/evaporator and the condensing side. There are a lot more options today," he said, adding that Zero Zone is using more water-cooled condensers and plate heat exchangers because they allow the charge to be reduced."

Ammonia is also very efficient. "So the systems have a very long lifespan with no threat of phase-out which means the life-cycle costs savings can be huge," Nelson said.

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room system piped to an evaporative condenser, Nelson said. "You only have to install one piece of equipment and you avoid water costs, sewer costs, and water treatment costs and maintenance," he said.

With the availability of packaged air-cooled ammonia chillers that offer remote monitoring, the changeover to a new plant from an old one can be managed with minimal or even no downtime and there is no need to rip out the old plant before the new equipment goes into the same place, said Alan Walkinshaw, sales director at Star Refrigeration.

Meanwhile, because ammonia has been a common technology for ice rinks for so long, it's also time for facility owners and managers to take a renewed interest in the technology their facilities employ.

AMMONIA SAFETY

Ammonia has traditionally been a popular choice for ice rinks, but a recent release at an ice rink in Vancouver has shaken confidence in that choice – leading to questions about ammonia's sustainability for ice rinks and commercial applications where the public is in close proximity to installations.

As ammonia and other natural refrigerants move into new environments, the industry's strong commitment to safety will be ever more important to highlight.

To promote that goal, IIAR is working to create guidance documents to help ice-rink managers ensure that a system is operating properly and craft an appropriate plan and documentation, Collins said. And a new IIAR CO_2 standard, currently under development, will help pave the way for wider adoption of CO_2, he added.

"Most ice rinks fall in the 500 to 1,500-pound charge range. They're not technically covered by the PSM standard, but the general-duty clause requires that operators and owners of these systems provide a safe working environment for the people working at the rinks, the fans and the skaters," Collins said.

While safety has always been a top priority, rinks can also improve safety by reducing the charge needed in equipment, which is possible with today's technology. There has been an ongoing effort in the refrigeration industry for decades to reduce the amount of refrigeration charge required. "That is definitely something ice rinks have to do," Collins said.

Meanwhile, because ammonia has been a common technology for ice rinks for so long, it's also time for facility owners and managers to take a renewed interest in the technology their facilities employ. When many ammonia rinks were installed decades ago, there weren't the same safety requirements in place, said Collins. "There are many features now that are mandated by current codes, but a lot of systems are 20 or 30 to 40 years old. If the industry is going to avoid safety questions with legacy systems, upgrading the older facilities even if they aren't changing refrigerants, is not only necessary, but essential" he said.

VALUE-ADDED BENEFITS OF NEW REFRIGERATION SYSTEMS

At the same time, the ease of installation, lower cost, maintenance and safety measures of new technology using natural refrigerants will renew interest in ammonia and CO_2 for ice rinks.

Newer equipment, such as that from Cimco, Hillphoenix, Zero Zone, and others, allows the temperature of the ice to be precisely controlled and adjusted. "That wasn't given much attention in the past at your typical rinks," Collins said. "We're including more sophisticated controls now with variable pump flow and adaptable operating modes to allow rink managers to optimize for their changing schedules.

That can help attract skaters and meet the needs of different types of athletes. For example, figure skaters like ice that is slightly softer than what hockey players prefer.

Many of today's systems can also take the heat they are removing from the surface of the ice and put it back into the building, creating a more comfortable experience for fans in the stands. "We can put tubing in the seats to have radiant indoor heating. And it's all free, because it comes from the heat taken out of the system," Rodier said.

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Europe's F-Gas Phase-Out, Price Increases, Leave the Industry Looking for Solutions

BY MONIKA WITT

In Europe, the phase out of fluorinated gases with high global warming potential, known as F-gases in Europe and HFCs in the U.S., is resulting in severe shortages, causing prices to skyrocket and creating challenges for those that operate and maintain the systems.

The first HFC supply reduction of seven percent took place from 2016 to 2017, and demand is already exceeding supply. The European Union's HFC phase-out regulations took effect in 2015, but there are still approximately 4,000 systems in use that rely on R404A, mainly because alternatives were not available.

Because of the tightened supply, prices had increased nearly every month during 2017, and by the end of the year were eight times higher than at the end of 2016.

From 2018 to 2020, the EU will cut the use of HFCs by 44 percent and then by 60 percent until 2022. After Jan. 1, 2018, large manufacturers, such as Chemours and Honeywell, no longer offered R404A, making R404A for maintenance even more difficult to get.

Part of the challenge has been that replacement refrigerants from the HFO series were not yet available, partially since public authorities would not approve storage vessels for these fluids. HFOs not only burn but create hazardous substances and require additional safety precautions that are not yet fully defined.

There are numerous HFC mixtures currently available, but all have a global warming potential that prohibits long-term use. The HFC mixtures currently offered for R404A have mostly a GWP above 1500 respective 1000, which means they need to be phased out after 2018 and 2024, respectively.

Old systems will have to rely on drop-in replacement refrigerants, but for a limited time. What's more, most of the available HFC replacements are not suitable as drop-ins, which means they need system modifications.

In the long-term, older systems will need to be replaced and it is still open as to whether they will use HFOs or natural refrigerants, such as carbon dioxide or hydrocarbons such as propane. Going forward, it is likely that small systems will use hydrocarbons with limited charge, whereas larger commercial systems will head towards CO_2 and, in some cases, indirect ammonia or ammonia-blend systems.

Another option, besides using ammonia for smaller application, is an ammonia-dimethylether blend, an azeotropic mixture that enables small capacities with air-cooled condensers even in warmer climates. In order to achieve wider acceptance, ammonia-dimethylether would require an ASHRAE classification.

Moving to natural refrigerants would create a long-term, sustainable solution with better efficiency.

THE F-GAS PHASE-OUT

The European Union is gradually reducing the permitted total quantity of F-gases, known in the U.S. as HFCs. The first F-gas regulation, which was designed to make systems leak-tight and spur more frequent checks, was adopted in 2006. That initial measure was replaced in 2014 by a new regulation, which took effect on Jan. 1, 2015.

Core elements of the actual F-gas regulation are:

- Phase-down: The supply of F-gases available on the market will be gradually reduced. The reference point consists of the average available quantity of F-gases available on the market from 2009 to 2012.
- Restrictions on use: F-gases that are particularly harmful to the climate will be gradually prohibited completely.
- Quota system: F-gas quotas will be allocated to the manufacturers and importers to control the actual consumption of F-gases.
- Leak tests: To avoid leakages, stricter regulations will apply in future to leak tests on refrigeration and air-conditioning systems.
- Extended operator obligations: Operators are responsible for ensuring that installation, maintenance, servicing, repairs or decommissioning is performed only by certified personnel.

A SUCCESSFUL AMMONIA-DIMETHYLETHER INSTALLATION

There is great potential for ammonia-dimethylether to serve as a replacement of F-gases, and WITT has had a successful installation of an ammonia-dimethylether refrigerant system in the old city of Cologne.

In the Cologne application, the challenge was not only to install the system without interrupting operation, but also to install the container in a very tight space on the roof top of an existing building. The goal was to reduce the refrigerant cost and cut the energy bill. At the same time the system needed to be maintenance-free.

WITT turned to a system that was charged with a blend of 60 percent ammonia and 40 percent dimethylether. Dimethylether had already been mixed into ammonia in former East-Germany to reduce the compressor end-temperature, particularly when using air-cooled condensers.

The azeotropic blend of 60 percent ammonia and 40 percent dimethylether was patented until 2016 and commonly sold under the name "R723." However, the mixture was never classified by ASHRAE and as such has no safety-class assignment in either AHRAE or EN378.

For the risk analysis, the content of EN378 was adhered to and the highest safety standards of B3 refrigerants (compared to B2 for ammonia) were used for electrical equipment. In addition, the low charge of less than 0.25 kg per KW minimized the risk even in the unlikely event of a leakage.

The mixture of ammonia and dimethylether has similar properties of ammonia, including the same pungent typical smell to easily detect the smallest leakages, but with an approximate 10- to 20-degree lower compressor end temperature.

The customer has experienced notable savings, particularly because the cost of R134a and R404a, which the new system eliminated, have increased dramatically, if it would have even been possible to get it. Additionally, it has created a reliable operation and low electrical bill.

Welcome to Colorado and the 2018 Natural Refrigeration Conference & Expo

Special thanks to every company who provided important financial support for IIAR through their conference participation

It's the beginning of a new annual conference for all of us at IIAR, and that means it's time to meet new colleagues, network, and catch up with friends and business partners at our industry's largest event. Welcome to the 2018 IIAR Natural Refrigeration Conference & Exhibition!

The work of our committees is really the cornerstone of our institute and activities. I'd like to use this message to not only welcome you to this year's conference, but also to encourage you to find a committee whose work you can participate in and become passionate about.

As always there's a lot going on both in our business environment and within our organization, and so I would like to take this opportunity to talk about how this event and your membership in this organization is making an important contribution to our everyday lives and the lives of others. Our great mission together is one of safety - making the world a safer place!

Having the privilege of serving on your Executive Committee has made me increasingly aware of this mission – to address climate change by promoting the use of natural refrigerants in ways that are energy efficient, and to develop safety standards and training programs that insure the safe application of natural refrigerants.

Embracing the many applications of natural refrigerants means we're making the environment safer for ourselves and our future generations. Because of their low environmental impact and high efficiency, natural refrigerants are the best answer for doing what we do – making things cold.

Another part of our mission is to extend the reach of natural refrigerants to all sorts of refrigeration applications. That's a goal that our membership and our board is really embracing, as evidenced by our focus on producing safety standards for not only ammonia but now carbon dioxide and soon to be hydrocarbons.

We have active committees and task forces that are currently working on producing CO_2 safety standards, and a task group investigating how we can begin to develop best practice documents for hydrocarbon refrigerants.

Our industry has a long record of safety to be proud of, and our standards activity is at the core of that. We're making refrigeration facilities safer through the development of PSM, RMP programs, education and training.

All of that work starts here, at our annual conference through the hard work and dedication of our committee members. So how can you participate in this great mission of ours? Two words . . . get involved!

The work of our committees is really the cornerstone of our institute and activities. I'd like to use this message to not only welcome you to this year's conference, but also to encourage you to find a committee whose work you can participate in and become passionate about.

That sense of volunteer leadership just keeps growing every year. If you're a longtime IIAR member, welcome back. And if you're new here, I hope you enjoy the energy and enthusiasm of your colleagues. Welcome to Colorado Springs and enjoy the conference!

Best Regards,

Bruce Nelson
2018 Conference Chair


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news

LOIS STIREWALT O'CONNOR
EXECUTIVE DIRECTOR, AMMONIA REFRIGERATION FOUNDATION

Foundation-Led Apprenticeship Program Takes Off

The International Institute of Ammonia Refrigeration, in partnership with other industry leaders — including The Foundation, RETA, IIAR, GCCA, Lanier Technical College, and Fastport — has created an apprentice program for mechanics and technicians to help bolster the refrigeration workforce. The program is designed to train ammonia refrigeration technicians in all phases of their careers and combines well-developed on-the-job learning with related instruction.

The Refrigeration Engineers Technicians Association's (RETA) leadership was instrumental in bringing the apprenticeship program to fruition. Not only is this an opportunity to strengthen the industry's workforce, but it's an exciting opportunity to strengthen relationships between these organizations.

It's simple for employers to participate in the apprenticeship program. "The major paperwork element has been taken care of already," says Dave Harrison, executive director of the national apprenticeship program for Fastport, said. "All you have to do to have a registered apprenticeship program is to fill out and sign the employer acceptance agreement saying you're going to participate in the apprenticeship in a fair and equitable manner. Employers are required to submit their individual training processes they'll use with apprentices, and although there are minimum training standards that must be met, there is no one-size-fits-all approach or specific requirements to participate in the program.

Although it was only announced recently, the Foundation is thrilled to announce that seven companies so far have begun implementing apprenticeships and several more have inquired for further information.

There are multiple benefits of implementing apprenticeship programs, and the process doesn't need to be overly complicated. Dave Harrison, our subject matter expert, is ready to help the process. He can be reached at Dave.Harrison@fastport.com.

Join Us in Welcoming Our Military Personnel and Veterans

On Tuesday, March 20, 2018, the Foundation will welcome and host military service members and veterans from the Colorado Springs area to the IIAR Conference and Expo. They will be briefed on the industry and learn about many exciting career opportunities that are available.

Volunteers from IIAR membership, who are also veterans, will act as "tour guides" for this group. The group will be met and escorted to the trade show floor by the tour guides where they will engage with exhibitors and attendees throughout the entirety of the conference. As part of the program, companies will have the opportunity to interview individuals from this group.

This personal touch is important. To further our mission of training transitioning military personnel, these individuals have to understand what the industry is, what the opportunities are and how they would fit. By inviting veterans to our conference and facilitating their involvement, they will have the opportunity to understand how a career in this industry would benefit them.

By attending the conference, these veterans and others will have the opportunity to interact with and learn about the most cutting-edge equipment, products, services and technologies available in the industry today. With over 1,900 industry professionals in attendance, this conference is the best opportunity to network with key decision makers from across the country and around the world. For more information on the conference, visit www.iiar.org.


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The Ammonia Refrigeration Foundation Recognizes the Kahlert Foundation

The Ammonia Refrigeration Foundation is pleased to announce that The Kahlert Foundation, in an ongoing gesture of faith and support in the mission to address issues of talent development in the refrigeration industry, has given $125,000 to support military recruitment, training and hiring initiatives.

"The Foundation's goal to recruit and train transitioning military and bring them into the refrigeration industry aligns with one of the areas of focus for the Kahlert Foundation," Greg Kahlert, President of the Kahlert Foundation, said. "We want to expand our reach into this sector in the mid-Atlantic region, and by investing into the Foundation's mission it allows us to do that."

The Kahlert Foundations' generous gift will be used to help fill the approximately 40,000 open positions in the refrigeration industry with our nation's returning heroes. There is an immediate need to fill these positions, and many industry leaders have expressed they would like to hire veterans, but they are unsure of how to cut through the red tape to accomplish this goal.

Through the Foundation's partnerships with various government agencies and with the support of groups like the Kahlert Foundation, we are now poised to recruit, train and hire qualified transitioning military personnel into our industry. It is the position of the Foundation that this effort not only makes sense, but it's the right thing to do.

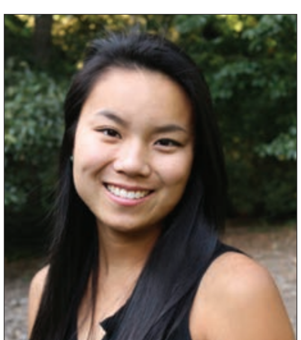
This investment has also allowed the Ammonia Refrigeration Foundation to partner with the U.S. Chamber of Commerce Hiring our Heroes program and to hold a seat on the prestigious Veterans Employment Advisory Council. Through this partnership, the Foundation will be sponsoring an upcoming Hiring Summit in Dover, Delaware on April 12, and another hiring event to be held in another city at a later date.

"With its support of Hiring Our Heroes, the Ammonia Refrigeration Foundation is taking its commitment to military families to the next level," Eric Eversole, president of Hiring Our Heroes and vice president at the U.S. Chamber of Commerce said. "The [Foundation's] support will help us continue to bring free employment events and resources to veterans, transitioning service members, and military spouses around the country."

At this Summit, The Foundation – as the 501c3 for the industry – will be representing IIAR and other industry groups like RETA and GCCA. Volunteers are needed that can participate and speak about the variety of skill sets and opportunities. Please contact the Executive Director at Lois_Oconnor@NH_3foundation.org for more information.

Foundation Welcomes Founders Scholarship Recipients

The Foundation is pleased to host three of our Founder's Scholars at this year's IIAR Conference and Expo in Colorado Springs, Rachel Sealover, James Schubert, and Connor Wheeler. These outstanding individuals are exemplary reflections of the skills and character we are trying to recruit into our industry. These Junior members will have an exciting opportunity to meet with industry professionals to discuss potential internships and career possibilities. Please take a moment to meet them during your time at the conference.


Rachel Sealove


James Schubert


Connor Wheeler

The Foundation awards scholarships to engineering students and annually develops a specific student track in coordination with the IIAR conference each year. Additionally, relationships are developed with academic institutions to include trade and technical programs in order to encourage the best skills for the refrigeration industry and demonstrate the many employment opportunities available.

Interested in learning more about this scholarship program? Applications are now open for the 2018 class, and the deadline for submitting materials is May 28. Please encourage colleagues, family, friends and interns to apply for this outstanding opportunity. More information can be found online at www.NH_3foundation.org/education.

From Threat Assessment to Employee Engagement: IIAR Tech Papers Unveil Research, Analyze Data

Utilizing bow-tie graphics to assess and prevent potential threats to an industrial ammonia refrigeration system, the importance of employee engagement and building relationships with first responders, and the benefits of ammonia scrubbing with C02 are among the technical papers and workshops that will be presented at this year's annual IIAR Natural Refrigeration Conference and Expo. Other papers will focus on practical design and low charge systems.

The meeting is scheduled for March 18-21 in Colorado Springs, Colorado.

Martin Timm, a process safety manager at Praxair, Inc., will discuss how bow-tie graphics can be used to summarize findings in process hazard analysis studies, as well as for refresher training on hazards and barriers.

Timm's presentation explains that the term "bow tie" refers to the graphical appearance of a diagram in which a "top event" is arranged in the center of a graphic, with a "fault tree" feeding in from the left and an "event tree" spreading to the right.

"A process hazard analysis is often quite lengthy," Timm says. "The bow tie graphic is a nice way of showing key information in a concise fashion."

Bow-tie diagrams can be used to explain to workers how unwanted scenarios develop, and how they can be prevented, or the consequences mitigated. "For example, one of the consequences of an ammonia leak is it could lead to a fire, and one of the barriers to that could be adequate ventilation, which would prevent ammonia concentration from rising to the lower flammable limit," Timm says.

A technical paper providing an energy and function analysis of hot-gas defrost in ammonia refrigeration systems will be presented by Niels Vestergaard and Morten Skovrup, global industrial refrigeration applications experts at Danfoss.

The Vestergaard- Skovrup paper will discuss results from a research project that assessed energy savings potential in ammonia refrigeration systems with the focus on hot-gas defrost and minimum condensing pressure. For the project, an industrial refrigeration system was built at the Danish Technological Institute; it consisted of a pump-circulation ammonia system and a climate chamber, and equipment to measure data and to analyze frost efficiency.

The project studied how hot gas pressure affects defrost time and efficiency and determined the lowest required pressure; the difference in savings when using the liquid drain method vs. pressure control; and how the defrost duration affected the savings potential.

"Based on this project, it has become possible to conduct detailed operation and energy analysis and propose design requirements for safe, efficient and reliable defrost systems," Vestergaard says.

Dr. Faris Hussain, a teaching associate in the food-science department at Kansas State University, will explore the benefit of scrubbing ammonia with CO2 following a release to decontaminate food products. "This is a very effective way to do it," he says. "By scrubbing with CO2, you neutralize the ammonia, so you can't smell or taste it, and the product is fine."

The process involves locking down and sealing the facility, spraying with CO2 gas and waiting 12 to 24 hours. "The CO2 is inexpensive, and you could save the product," he says. "In case of an insurance claim against the product instead, you could win in court and the product might stay in your facility."

Stephanie Smith, a senior engineer at Risk Management Professionals, will present a workshop on how California's ARP Program 4 and Occupational Safety and Health Administration regulation 5189.1 could ultimately affect the ammonia refrigeration industry across the country.

A paper from Craig Slininger, operating engineer at Nestle, will explore ways to develop relationships with local first responders that can be beneficial in the event of an ammonia incident. Slininger will cite a recent situation in which a fire marshal took possession of a facility for three days, shutting down production and costing the company millions of dollars.

"You don't ever want to be sitting on the bench when the future of your facility is on the line," Slininger says. "You want to maintain control over your facility. For that to happen, you need to develop a relationship so first responders have absolute confidence that you're not just saying something for monetary reasons."

Slininger will recommend steps that create a bond with first responders. "Invite them to your facility several times, not just once a year for required drills," he says. "Know their names, titles and positions. Create a relationship where they come not because they are obligated, but because they want to."

The paper will explore steps to consider prior to an emergency incident, such as informal tours of the facility that build trust with first responders. "You don't want to give up a say in the process. As long as you're on the team, you're still the subject matter expert for what's going on," he says.

Meanwhile, two more technical papers will focus on practical design. One will examine stainless steel piping while another delivers a case study on low charge systems.

Karthick Kuppasamy, a refrigeration design engineer for Heatcraft Worldwide Refrigeration, will present a case study focused on ultra-low charge ammonia refrigeration in food retail. The session will describe the design, installation, commissioning, and certification of energy savings for a me-dium size supermarket in southeastern USA.

Eric Teale, director, refrigeration engineer at Corval Group, Inc. will present a technical paper fo-cused on stainless steel piping in industrial refrigeration. The session will provide an in-depth examination of stainless steel: the history of stainless steels, properties of stainless steel, corrosion of stainless steel, welding of stainless steel, and QA/QC issues associated with the installation pro-cess of stainless steel.

Efficiency Can be Just Another Controllable Cost

Energy efficiency can be achieved in ways other than with new technology. It can also prove to be a controllable cost, just as with labor and equipment. By developing an energy management system that establishes clear, measurable goals for energy performance, end users of industrial refrigeration facilities can realize a significant reduction in energy consumption, delivering cost savings that fall straight to the bottom line.

"There is an opportunity to save energy at these facilities beyond capital investment," says Josh Bachman, a senior engineer at Cascade Energy.

"Warehouses and food processors can save anywhere from five to 15 percent energy by doing a better job with what they have. It's really about training their people to focus on energy efficiency."

–Josh Bachman, a senior engineer at Cascade Energy

"Warehouses and food processors can save anywhere from five to 15 percent energy by doing a better job with what they have. It's really about training their people to focus on energy efficiency."

The key to a successful energy management system is executive support and employee engagement, Bachman says.

"The people who operate the equipment and make decisions every day on how to run the equipment have a huge impact on energy. They are your greatest asset for saving energy," he says. "It's important to address energy from an employee perspective rather than just with projects and installing technology. Training is one element of that but installing a management system surrounding energy is the biggest factor."

An energy management system begins with setting policy, goals and responsibilities. The system should communicate long-range energy performance objectives and assign responsibility for reaching those goals to an individual energy "champion" or an energy team.

The next step is the planning and implementation. Current energy management practices can be assessed by using a performance scorecard. An energy map then displays a breakdown of energy usage and costs across the company. Planning also includes listing the actions to be undertaken over one or more years, such as improvements to operations and maintenance practices. It is critical to engage employees in this process and to empower individuals to look for areas where energy consumption can be reduced. Managers of this process need to periodically review energy performance by comparing actual to expected energy consumption.

Finally, there should be a system in place to regularly collect, store and analyze data so that performance relative to baseline is tracked on an ongoing basis.

Through this process, it is important that the leadership team supports and engages employees, and that energy goals are clearly defined. "Saying you're going to cut energy by 20 percent in 10 years with no plan or budget to do so is a common stumbling block to success," Bachman says.

Here are five ways an energy management program can train employees to reduce energy consumption:

Reduce system lift by raising suction pressure and lowering condensing pressure. "How far you can increase suction pressure is generally limited by space and product temperature requirements," Bachman says. "Condensing pressure is limited by outdoor ambient weather conditions, coupled with the minimum pressure requirements unique to each facility's refrigeration system. So, no one size fits all."

Ensure that operations and maintenance include tuning setpoints and control strategies, calibrating sensors, cleaning evaporator coils, condenser coils and condenser spray nozzles, and staying on top of repairs.

Improve part-load performance of the big energy users on refrigeration systems: compressor, condensers, and evaporators. This equipment is designed for peak load conditions. The drawback is that peak load conditions occur rarely; most of the year the system is oversized for the job. Utilizing speed control with variable frequency drives (VFDs), by cycling evaporator fans in the absence of speed control, and by controlling evaporators, condensers and compressors as a group helps to maximize part-load efficiency. "Ideally, if you only need 50 percent of the full capacity of a compressor, it would only require 50 percent of full power," Bachman says.

Optimize defrosts by defrosting only when necessary and for only as long as necessary. With hot-gas defrosts, minimize false loading from uncondensed hot gas flowing to the suction side. "Defrosting an evaporator is an energy-intensive activity," Bachman says. "You're adding heat to a cold space, and whatever heat doesn't go towards melting the frost runs down the drain and winds up in a space that must be removed by the refrigeration system. Because evaporators are out of sight and out of mind and icing up a coil is a huge headache, the tendency is to be safe and over-defrost.

Reduce refrigeration loads. There are several ways to accomplish this, including maintaining good door practices, cycling evaporator fans, and minimizing lighting use in refrigerated spaces.

"In the end, this is about recognizing that energy efficiency is about people and not technology," Bachman says.

Little Details Add Up

BY KEM RUSSELL

When big things happen they really draw our attention, but in most cases it's the little things we miss that can result in unexpected and sometimes undesirable results. We might breeze along taking account of larger items, not realizing or taking time to think that little details can make a big difference. As engineers, contractors, owners and operators, and educators we each have to pay attention to the little details to make the whole (the big thing) work correctly. Here are some examples of how little details can make a big difference . . .

A large freezing processing facility had been shut down for several weeks as new pieces of equipment were installed. Along with the new equipment, a much needed upgrade in the control assemblies for the new equipment was also done. One thing that was especially needed was new insulation.

In the past when I had visited this facility, all of the control valve assemblies for the freezing equipment had been extremely iced up. In almost all cases you could not operate a hand valve, or even find the hand valve under the ice. Any adjustment to control valves required ice removal before adjustments could be made. Newly assigned personnel to the refrigeration department were given the task of carefully removing the ice from the valve assemblies, which was a continual job since the freezing process did not shutdown.

With correctly applied new insulation and vapor barrier the control assemblies would be kept frost free. In addition the low pressure receiver (LPR) was also completely re-insulated. This included not only the vessel, but the ammonia pumps, float column, and associated piping.

The day I arrived at this facility just happened to be the day the system was started back up. At first all seemed to be going well, then one of the new operators noticed they were low on ammonia in their three (3) high pressure receivers. The Chief Engineer said "We can't be low on ammonia. We had it all when we shut down and we haven't had any leaks or releases. So, go find where it went!"

A clue to where the ammonia was – came when the single operating screw compressor used for the initial pull down started to unusually frost up. Fortunately, it was shutdown prior to any serious damage happening. Why was the ammonia flooding back?

At the LPR, an operator climbed up a ladder to check the operating floats. The make-up float appeared to be closed, which when closed would de-energize the LPR liquid make-up solenoid. The high level shutdown float appeared to not be closed indicating that liquid hadn't reached that high.

As everyone stood by the LPR the discussion went something like, "It's winter and cold outside. Maybe the liquid migrated up to one of the condensers?" It hadn't. "Maybe some of the liquid feed valves on the new equipment are leaking." This wasn't it either.

The suggestion was made to verify the float switches on the LPR were working correctly. The head of the make-up float was removed and tipped back and forth. The liquid feed solenoid clicked ON and OFF with the float switch. That seemed to be working. Maybe the float ball in the float had failed. The entire make-up float was changed out, with no change in the result. An operator was on a ladder up next to the make-up float when the second float check was done. As everyone was standing around wondering what in the world was going on, the operator on the ladder pulled the head up off the float and dropped it back down. Then he noticed something, "Hey, how far down is the head supposed to go?" The answer was just a little bit further than it was going down, same thing was happening with the high level float.

When the float column was re-insulated, the insulators had installed the insulation around the float chamber just a little bit higher than previously installed. This additional insulation kept both floats from operating correctly. Now we all knew where the ammonia was. The LPR was very nearly completely full.

Just a little bit of extra insulation had made a big difference and could have resulted in a very expensive accident.

Here's another example of a little detail that caused confusion.

I was working with the Chief Engineer at a facility that was also about to start-up. The Chief was going through the system using the P&ID's to not only check things in the system (line sizing, valves, valve tags, etc.) but also to help understand what went where and how it worked.

In the machine room there was a float drainer assembly to remove any liquid that might condense in the main hot gas supply line feeding out the system. The Chief Engineer looked at that assembly and its piping, looked at the drawing and asked me, "I just cannot figure out how this works."

When big things happen they really draw our attention, but in most cases it's the little things we miss that can result in unexpected and sometimes undesirable results.

I explained how the float worked. The Chief thanked me and said he understood how this worked, but still couldn't match up what he was seeing with what was on the P&ID's. I looked at the drawing for a few seconds and said "You see those two little lines connecting to the drainer. They are switched. The one on top should go in the bottom and the one on the bottom should go to the top." The small detail on the drawing had been missed. Fortunately, the Chief Engineer picked up on the error, others may not have.

Lessons learned about little details also impact our personal lives. Here's a personal experience.

My youngest daughter and I had planned a long multi-day hike. We had planned for this hike for months and carefully selected all of the gear and equipment we thought we would need. We considered not only the function of each item, but also its weight. The trail began in another State, and we flew, and then got transportation to the trail head from some very helpful people. We started out on a pretty warm day and over the next several hours finally made the 20 miles to our first destination.

I was really hungry, but first we had to set up our camp. After selecting a nice flat spot, we each set up our tents. Then I got water to heat and pour into our freeze-dried meals to re-hydrate and cook.

Since the first part of the trip was on a plane, there are certain items you cannot bring with you. A fuel canister is one of those. Fortunately, we were able to purchase two small fuel canisters after we landed so we were all set.

I got the small stove screwed onto the fuel canister, the water in the small pot, and had our two freeze dried dinners close by. Now I was ready to light the stove. I always carry two small lighters, one as a backup. However, since we flew I couldn't take my small lighters on the plane, and I had planned to get those lighters when I bought the fuel. Unfortunately, I hadn't. For want of a small flame, or even a spark, dinner wasn't going to be cooked or eaten that night. Fortunately for us there was a small store about a mile up a road where I was able to buy four little lighters. Lack of just one detail – a small flame just about put a great hike off to a very hungry start.

Little details can result in misunderstanding, confusion, accident, or just an unpleasant condition. Paying attentions to those little details can make a big difference so you don't have to learn a hard or unpleasant lesson later.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Social Security: Claim Early and Invest Versus Delaying Receipt for Increased Benefits

The IIAR and ARF reserve investment funds are currently managed by Stifel Financial Services under the investment policy established by their respective board of directors. In this and subsequent issues of the Condenser, you'll find a "financial tech tips" article from the firm on this page. Members of IIAR may use the financial services of Stifel for personal and business investments and take advantage of the reduced rate structure offered with IIAR membership.

Financial Advisors are occasionally asked to provide an analysis of the potential results of claiming Social Security early and investing the proceeds versus delaying receipt for increased benefits, which can be claimed as late as age 70. The following are the reasons that delaying social security income can be a prudent strategy.

Once you reach a certain age, delaying benefits does pay off, and its value continues to rise for many.

Delayed Retirement Credits – An individual receives 76% more Social Security at age 70 than at age 62. Most people realize they can receive 100% of Social Security at their full retirement age (FRA), but they might not realize that their benefit goes up by 8% annually when they wait beyond their FRA to claim benefits, until they reach age 70. So, someone at an FRA of 66 will receive 132% of that amount when they turn 70. This is low-risk, inflation-adjusted, lifetime income stream backed by the "Full Faith and Credit Clause" of the U.S. government. Keep in mind, delayed retirement credits were built into Social Security during an era when life expectancy was lower and interest rates were higher. Plus, depending on your age, there may still be an opportunity to leverage spousal benefits through a creative claiming strategy.

Risk – Social Security is a low-risk proposition unaffected by market risk, interest rate risk, inflation risk, or longevity risk. Mortality risk, which is the risk of passing away before claiming benefits, is associated with Social Security. Mortality risk is not as prevalent for the breadwinner in a relationship, as that individual's Social Security benefit will be paid out over two lifetimes – theirs and their spouses. Unfortunately, mortality risk is what most people associate with Social Security when what they should be most concerned with is longevity risk. Social Security certainly addresses longevity risk as a lifetime, inflation-adjusted, and government-backed income source.

Comparable Investments – When the benefits associated with Social Security are compared to other similar low-risk investment opportunities, like the 10-year Treasury or 10-year Treasury Inflation Protected Securities (TIPS), Social Security is generally a much better deal. Comparing Social Security to equity-based investments, like large cap stocks, is not a fair comparison, since the risks associated with each are vastly different. It is possible that if you take your Social Security early and invest the proceeds in equities, you could raise the breakeven point if the market has positive returns. However, it is also possible that if market returns over the time frame are not positive, you could regret the decision.

Once you reach a certain age, delaying benefits does pay off, and its value continues to rise for many. Even when a reasonable rate of return is used for comparison purposes, the breakeven point comes before the individual's IRS life expectancy.

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Using the Right Type of Monitor for CO_2

The use of CO_2 is becoming common in the industrial refrigeration industry, especially with cascade refrigeration systems. But many people are not as familiar with CO_2 as they are with ammonia, some believing that the only respiratory issue with CO_2 is that it is an inert gas like nitrogen or argon.

While most people are aware that CO_2, like nitrogen and argon, represents an asphyxiation hazard, it might not be commonly known that CO_2 also influences our breathing and how our body responds to oxygen in the lungs.

Although CO_2 is a non-toxic gas, it acts as an asphyxiant and causes oxygen depletion at elevated concentrations. When CO_2 concentration rises in the lungs, the space for oxygen decreases, resulting in CO_2 intoxication. Because CO_2 intoxication is independent of oxygen deficiency, the oxygen content in the air is not an effective indication of a potential hazard.

Therefore, from a safety standpoint, it is important that facilities using CO_2 use the right type of monitor in situations where atmospheric monitoring is required or desired. CO_2 monitors, not oxygen monitors, should be used in such situations.

"I've seen cases where facilities were using an oxygen monitor, believing that was protecting them against a CO_2 hazard; but CO_2 may affect your breathing and metabolism well before the lack of oxygen becomes a problem," says Martin Timm, a corporate process safety manager at Praxair, Inc. "Even if the concentration of oxygen is otherwise adequate, an excessive concentration of CO_2 can depress your breathing function and cause problems leading to unconsciousness."

According to the Safety Advisory Council (SAC) of the European Industrial Gasses Association (EIGA), a common cause of serious accidents occurring at CO_2 facilities has been due to the failure to recognize the actual CO_2 concentration in the working environment.

As established by the Occupational Safety and Health Administration, oxygen monitors must be set to alarm at an oxygen level of 19.5 percent. Once the level drops below that, workers will experience diminished capacity. As CO_2 concentration rises, it may reach the IDLH (immediately dangerous to life or health) value of 40,000 parts per million. But at that point, the reading on the oxygen monitor

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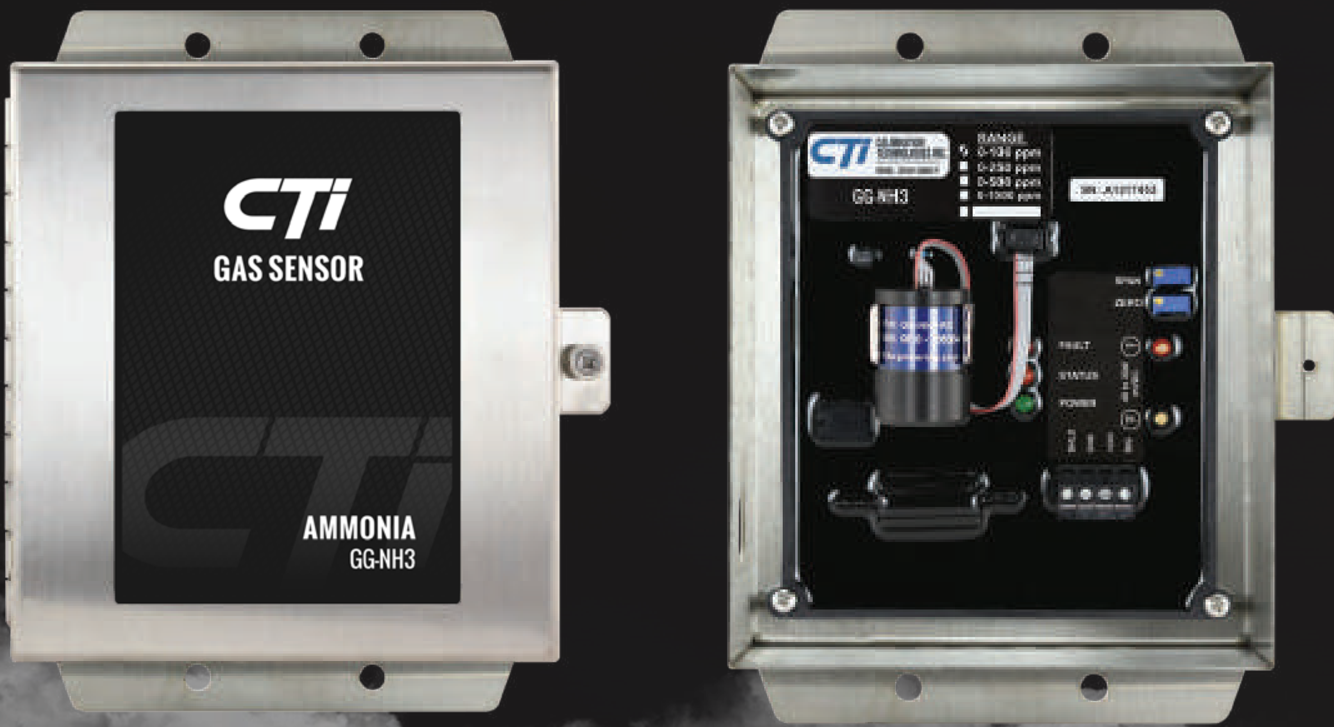

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may have only dropped to approximately 20 percent. Therefore, the oxygen monitor alarm would not sound. By the time the oxygen level drops to 19.5 percent, triggering the alarm, the CO_2 concentration has risen to 69,000 ppm, or seven percent. At that level, unconsciousness may occur in less than one minute and further exposure may result in death.

"You may be over the IDLH for CO_2 but the alarm on the oxygen monitor has not gone off," Timm says. "The oxygen monitor can give you a false sense of security. If you have determined through a hazard evaluation that you need protection against a possible accumulation of CO_2, make sure you're using a gas-specific CO_2 monitor. Don't rely on just an oxygen monitor."

Additional details and information on atmospheric monitoring for CO_2 can be found in documents published by the Compressed Gas Association (CGA) in the United States, and by the European Industrial Gases Association.

For example, CGA's publication G-6, "Carbon Dioxide", contains a section on safety. EIGA has published document 24/17 "Carbon Dioxide Physiological Hazards, Not Just an Asphyxiant." While neither document is targeted at the industrial refrigeration industry, each provides relevant safety information for our industry.

CO_2 has been in use in the food and beverage industry and in general industry for a very long time, and its characteristics are well known to the traditional users. Since CO_2 is now experiencing a resurgence in industrial refrigeration applications, it is important that our industry not only understand the obvious benefits that are driving its increasing use, but also be reminded of the requirements for its safe application. Those requirements include using a monitor specific to CO_2, when monitoring for CO_2 is required or desired.

"Even if the concentration of oxygen is otherwise adequate, an excessive concentration of CO_2 can depress your breathing function and cause problems leading to unconsciousness."

–Martin Timm, a corporate process safety manager at Praxair, Inc.

Appeals Court Denies Rehearing of Ruling Against EPA Regulation of HFCs

iiar government RELATIONS

BY LOWELL RANDEL, IIAR GOVERNMENT RELATIONS DIRECTOR

On January 26, 2017, the United States Court of Appeals for the District of Columbia Circuit denied petitions requesting a rehearing by the full court of a decision finding that the Environmental Protection Agency (EPA) had exceeded its authority by regulating the use of HFCs through the Significant New Alternatives Policy program (SNAP). The petitions, filed by two chemical manufacturers (Honeywell and Chemours) and the National Resources Defense Council (NRDC), sought to have the full court reconsider its previous ruling and reverse the decision that EPA cannot use SNAP to regulate HFCs. The court's denial creates additional uncertainty for the future of HFC regulation in the United States.

On January 26, 2017, the United States Court of Appeals for the District of Columbia Circuit denied petitions requesting a rehearing by the full court of a decision finding that the Environmental Protection Agency (EPA) had exceeded its authority by regulating the use of HFCs through the Significant New Alternatives Policy program (SNAP).

BACKGROUND

At issue is the 2015 EPA rule changing the designation of some HFCs, including R404A, R134a, R407C and R410A, from the approved SNAP list to the prohibited list. The policy changes impacted manufacturers that had replaced the ozone depleting refrigerant R-22 with a refrigerant such as R404A or R134a (when it was on the approved list) by prohibiting its future use in certain applications.

The original case was brought by two HFC international manufacturers (Mexichem and Arkema) that sued EPA challenging the validity of an EPA rule requiring manufacturers to replace HFCs with refrigerants that have a lower global warming potential. The companies argued that EPA exceeded its statutory authority under Section 612 of the Clean Air Act, which was initially designed to address ozone depleting substances. The court's three judge panel agreed, by a margin of 2-1, that the authority given to EPA under the Clean Air Act is limited to restricting ozone depletion and does not cover global warming potential. While the court was clear that Section 612 of the Clean Air Act does not authorize EPA to regulate HFCs, it did offer the agency some options for addressing the use of HFCs, including the use of alternative authorities such as the Toxic Substances Control Act (TSCA), National Ambient Air Quality Standards Program and the Hazardous Air Pollutants program.

While EPA defended the SNAP rule before the court panel, it did not choose to pursue a rehearing or appeal to the Supreme Court. Instead, Honeywell, Chemours and NRDC filed petitions for a rehearing by the full Court of Appeals. A majority of justices for the Court of Appeals voted to deny the petitions.

NEXT STEPS

In the wake of the court's refusal to rehear the case, Honeywell has indicated that it will pursue an appeal to the Supreme Court. While it not certain the Supreme Court will agree to hear the case, such an appeal signals how strongly some companies feel about reinstating the EPA rule. These companies argue that large investments have already been made in alternatives to HFCs and that not allowing EPA to regulate HFCs through SNAP creates uncertainty in the market. Chemours and NRDC are likely to join Honeywell in the Supreme Court effort.

Despite the court rulings, some states have indicated that they are planning to move forward with HFC restrictions at the state level. Eleven states joined the petitioners in requesting the Court of Appeals to reconsider the ruling. The chair of the California Air Resources Board (CARB) has stated that regulations have already been drafted that would implement the EPA SNAP rule at the state level. Members of the California State Legislature are also planning legislation that would restrict so-called "super pollutants" including HFCs. Should California and other states implement their own HFC restrictions, it would create a patchwork of rules that will make it more complicated for manufacturers and end users to understand and manage their refrigerant choices.

While the federal EPA policy to regulate HFCs through the SNAP program has been disallowed by the courts, global momentum continues to grow towards the phasedown of high global warming potential HFCs. The Kigali Agreement, approved by 189 countries in late 2016, brings HFCs within the parameters of the Montreal Protocol and calls for global reductions. Over twenty parties to the agreement have already ratified the agreement, which

Despite his concerns over the Paris Climate Agreement, and climate change policies in general, there are some indications that the Trump Administration may not oppose the Kigali Agreement and ultimately present it to the Senate for ratification.

was the number needed to trigger the agreement going into effect. As a result, the phasedown targets under the Kigali Agreement will go into effect on January 1, 2019.

The United States signed the agreement during the Obama Administration in 2016, but it has yet to be ratified by the U.S. Senate. President Trump has not articulated a formal position on the Kigali Agreement. Despite his concerns over the Paris Climate Agreement, and climate change policies in general, there are some indications that the Trump Administration may not oppose the Kigali Agreement and ultimately present it to the Senate for ratification. Administration officials have acknowledged that some U.S. companies have made investments based on the Kigali Agreement and that the Administration is evaluation the potential impact ratification may have on U.S. jobs.

While uncertainties remain about U.S. federal policies related to future HFC regulation, including a potential Supreme Court challenge regarding EPA's use of the SNAP program, the overall movement away from HFCs continues. This is evidenced by global policy such as the Kigali Agreement, state policies such as those being considered by California, and investment by industry in natural refrigerants and other HFC alternatives.

Energy Performance of Low Charge, Central Type, Dual Stage NH_3 Refrigeration Systems in Practice

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ABSTRACT

Development of low charge NH_3 refrigeration systems is taking place throughout the world for various applications, predominantly for refrigerated storage and packaged solutions to chill liquids and/or condition refrigerated spaces. These developments are initiated by a global phase-down of high global warming (GWP) refrigerants of the hydrofluorocarbon (HFC) type. This phase-down is a direct result of the "top-down" emissions reduction agreement resulting from the Conference of the Parties (COP 21) in Paris, December 12, 2015.

Ammonia refrigerant offers improved vapor compression cycle efficiencies in comparison with most other refrigerants. The energy performance improvements associated with the application of ammonia refrigerant in combination with other energy efficiency engineering techniques such as state-of-the-art superheat/quality (SH/X) expansion control, advanced low charge evaporator technology, extensive integration of variable frequency drives, two-stage compression, low oil carry-over compressors, low friction loss pipe lines, and genuine central plant concept have not been the subject of widespread investigations and reporting.

Where compliance costs are directly proportional with NH_3 inventory, favoring multiplexing as opposed to central plants is tempting for stakeholders. This, of course, risks sacrificing energy performance in return for reduction in NH_3 inventory. For signatories to the COP 21 agreement, this is neither in the national interest nor is it in the commercial interest of plant owners if compliance cost increases outweigh energy cost reductions.

This paper describes the energy performances of several refrigerated distribution centers with storage volumes of approximately 10,000 to 50,000 m^3 (353,000 to 1,766,000 ft^3). The performance evaluations are based on the electrical energy consumption as measured by the electrical energy providers over representative periods of time. All systems are serviced by central, state-of-the-art low charge, dual stage NH_3 refrigeration systems. In the case of one plant the contribution of the photovoltaic panels to the energy requirement of the facility as a whole is shown on a month-by-month basis.

An energy performance comparison is also made between two refrigerated distribution centers with a volume of approximately 10,000 m^3 (353,000 ft^3), but serviced by two different types of ammonia refrigeration systems. In one case the plant is a single-stage economized dual screw compressor based system with gravity flooded refrigerant feed. In the other case, the plant is a central, low charge NH_3 dual-stage system with speed controlled semi industrial reciprocating compressors. Other features of the two facilities include general warehouse designs that are more or less identical. The energy performance comparisons are again based on the electrical energy consumption as recorded by the electrical energy provider over one calendar year.

INTRODUCTION

In the wake of the pending global phase-down of HFCs due to their contribution to global warming, users and owners of refrigeration systems are faced with decisions that at times appear difficult. These decisions relate to whether or not users continue to employ HFC-based refrigeration systems, switch to low GWP synthetic refrigerants or consider future-proof natural refrigerants such as NH_3, CO_2, hydrocarbons, water, or air in their new and/or expanded systems. In this decision-making process, one very important factor is often either overlooked or underestimated. This factor is energy performance—particularly the energy performance of low charge NH_3 systems.

Discussing the energy performance of systems that proponents of refrigeration systems that use synthetic refrigerants market is not in their commercial interest so they rarely do. Their marketing focus is often attractive capital costs, refrigerant "safety," availability of service/maintenance resources, and simplicity. Synthetic refrigerant proponents often seek to marginalize the pending HFC phase-down by referring to several factors: the anticipated relatively long time frame of the HFC phase-down; the future availability of alternative synthetic low GWP refrigerants; the capital cost penalties associated with a switch to natural refrigerants; and the allegedly expensive, frequent, and specialized service/maintenance requirements associated with refrigerants such as ammonia or NH_3.

Promoters of natural refrigerant-based systems, however, tend to undersell the excellent energy performances of natural refrigerant-based refrigeration systems— particularly low charge NH_3 systems. This is understandable because low charge NH_3 refrigeration systems are not yet as common as liquid overfeed or gravity-flooded systems and documented annual energy performances for low charge NH_3 plants—particularly the modern versions—are relatively scarce.

The decision between HFCs and low GWP synthetics or natural refrigerants is often made difficult by the quality, the independency (or lack thereof) of, and the sources of the decision-making material presented to users. Claims of improvements in energy performances of 40–70% associated with low charge NH_3 refrigeration plants as compared with industry standard HFC-based systems are often dismissed as exaggerated, biased, and therefore irrelevant. The confusion on the part of end users when faced with conflicting technical information is understandable and decisions in favor of low-capital cost solutions is perhaps not surprising.

As this paper will show, the claims of 40–70% improvement in energy performance are not exaggerated. In fact low charge NH_3 systems can, if designed correctly, present an attractive business case in favor of straight replacement of existing outdated HFC-based systems with new, modern low charge NH_3 plants. Modern low charge NH_3 refrigeration plants can also provide significant energy savings compared with conventional liquid overfeed NH_3 systems with screw compressors.

THE REFRIGERATION PLANTS

The following sections summarize the refrigeration plants that are the main subjects of this paper.

Perth

This 43,000 m³ (1,519,000 ft³) refrigerated distribution facility is situated in Perth, Western Australia. The facility comprises a 16°C (61°F) room, a 4°C (39°F) cool room, a -25°C (-13°F) freezer, and a 4°C (39°F) annex. The refrigeration plant is a dual-stage low charge NH_3 system with four identical speed-controlled reciprocating compressors, evaporative condenser, internally surface-enhanced evaporators suitable for dry expansion refrigerant feed, and refrigerant injection controlled by superheat.

All interconnecting refrigerant pipe lines are carbon steel. A plan layout of the facility is shown in Figure 1.

Tamworth

This 10,000 m³ (353,000 ft³) refrigerated distribution facility is located in Tamworth, New South Wales. The facility comprises a 4°C (39°F) cool room, a -25°C (-13°F) freezer, and a 4°C (39°F) annex. The refrigeration plant is a dual-stage low charge NH_3 system with four speed-controlled semi-industrial reciprocating compressors, evaporative condenser, internally surface-enhanced evaporators suitable for dry expansion refrigerant feed, and refrigerant injection controlled by superheat. Figure 2 shows the floor plan.

Lismore

This 10,000 m³ (353,000 ft³) refrigerated distribution facility is located in Lismore, New South Wales. The facility comprises a 4°C (39°F) cool room, a -25°C (-13°F) freezer, and a 4°C (39°F) annex. The refrigeration plant is a single-stage NH_3 system with two fixed-speed industrial screw compressors with common economizer and evaporative condenser. The medium temperature evaporators are arranged for dry expansion refrigerant feed; the freezer is fitted with evaporators arranged for gravity- flooded feed and hot gas defrost. The plan layout is similar to that shown in Figure 2.

Melbourne

This 43,000 m³ (1,519,000 ft³) refrigerated distribution facility is situated in Melbourne, Victoria. The facility comprises a 4°C (39°F) cool room, a -25°C (-13°F) freezer, and a 4°C (39°F) annex. The refrigeration plant is a dual stage, low charge, central NH_3 system with four identical speed-controlled reciprocating compressors, oversized evaporative condenser, internally surface-enhanced evaporators with longer circuits and suitable for dry expansion refrigerant feed, and refrigerant injection controlled by a combination of superheat and quality signal. All interconnecting refrigerant pipe lines are 304 stainless steel. The system was from the outset fitted with a desiccant drier in the freezer. This decision was based on the good result obtained in Perth when a desiccant drier was retrofitted at that facility.

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Townsville

This 31,000 m³ (1,095,000 ft³) refrigerated distribution facility is situated in Townsville, Queensland. The facility comprises a -25°C (-13°F) freezer, a 4°C (39°F) cool room, a 16°C (61°F) flour room, and a 4°C (39°F) annex. The refrigeration plant is a dual-stage low charge NH_3 system with four identical speed-controlled reciprocating compressors, oversized evaporative condenser, internally surface- enhanced evaporators with longer circuits and suitable for dry expansion refrigerant feed, and refrigerant injection controlled by a combination of superheat and quality signal. All interconnecting refrigerant pipe lines are 304 stainless steel. The system is fitted with a desiccant drier in the freezer.

In each case except Townsville, these figures are for the entire facility and typically include other services such as information technology (IT), general light and power, services for refrigerated trucks, forklift charging, and office air conditioning. Detailed records of the energy consumption of the NH_3 systems in isolation only exist for the Townsville plant. In this facility the supervisory control and data acquisition (SCADA) system is fitted with hardware and software to facilitate the separate measurement of the NH_3 plant energy consumption. In part this is to evaluate the feasibility and economic viability of providing office air conditioning services via the central low charge NH_3 system as opposed to fitting individual, HFC-based, air-cooled split air conditioning systems.

Table 1. Recorded Energy Consumption

Plant	Total Annual Energy Consumption (kWh)	Record Period	Refrigerated Volume (m³/ft³)	Specific Energy Consumption (SEC) (kWh/m³*yr/ kWh/ft³*yr)
Perth	(700,072 + 219,440)/ 9*12 = 1,226,016	1.7.14 to 31.3.15	43,289/ 1,528,737	28.3/0.801
Tamworth	409,597	1.7.14 to 30.6.15	9,474/ 334,571	43.2/1.22
Lismore	1,135,027	1.7.14 to 30.6.15	10,748/ 379,562	105.6/2.99
Melbourne	1,098,390	1.1.16 to 30.6.16	42,619/ 1,505,076	25.8/0.731
Townsville	406,781/7*12 = 697,339	1.2.2016 to 31.8.2016	31,344/ 1,106,903	22.2/0.630

Recorded Energy Consumption Details

Table 1 shows the measured annual energy consumption details for the five facilities. The value specific energy consumption (SEC) is derived by dividing the annual energy consumption of the refrigerated facility measured in kWh per year (kWh/yr) by the total refrigerated volume measured in m³ (ft³). The unit for SEC is hence kWh/m³*yr (kWh/ft³*yr).

Some evidence in Table 1 shows that the energy consumption of auxiliary services such as office air conditioning, IT, general light and power, etc. is sufficiently significant to warrant separate recording. The Townsville facility is located in a subtropical area, has 26% less refrigerated volume than the Melbourne facility, yet features 14% lower SEC. Both facilities are fitted with desiccant driers. Based on the difference in refrigerated volume between Melbourne and Townsville, the SEC for Townsville should have been 27.7 kWh/m³*yr (0.78 kWh/ft³*yr) using the SEC for Melbourne as the base for extrapolation and possibly even a little higher due to the approximately 3°K (5.4°F) higher wet bulb temperature in Townsville. The difference between 22.2 and 27.7 kWh/m³*yr (~20%) may therefore be taken as being representative of the energy consumption of the auxiliary services.

On more recent installations that are not included in this paper, part of the regeneration heat for the desiccant drier is being recovered from the NH_3 plant via a desuperheater, which then also provides heat for the subfloor heating below the freezer via a water/ethylene glycol heat exchanger. Figure 3 shows an example of such an installation. This recent installation also employs a secondary refrigerant for the medium temperature segment (food processing area) and horizontal accumulators. The latter two features reduce the specific refrigerant charge to approximately 0.65 kg/kW (5 lbs/TR).

In the case of Perth, the 700 MWh represents the electrical energy supplied from the grid and the 219 MWh is the energy supplied from the photovoltaic (PV) panels. The sum of 919 MWh represents the energy consumption of the entire facility for the nine-month period shown. The total amount of electrical energy supplied from the grid to the Perth facility is 915.6 MWh for the period July 1, 2014, to June 30, 2015. The contribution of the PV panels is only known for this period. Therefore Table 1 only shows the nine-month period where supplies from the grid and the PV panels overlap. Figure 4 shows the monthly contribution from the PV panels. The annual electrical energy consumption of 1,226 MWh for the Perth facility is simply estimated by extrapolation as shown in Table 1. If an assumed 20% of the annual electrical energy consumption is allocated to services other than the NH_3 plant, the annual specific energy consumption (SEC) of the NH_3 system becomes 22.7 kWh/m³*yr (0.643 kWh/ft³*yr).

At the conclusion of the energy consumption recording period for Lismore, the attention of the plant owner was drawn to the fact that the set point for the condensing pressure control was higher than necessary. Following reduction of the condensing pressure set point to enable floating condensing pressure, the monthly average electricity account fell from approximately $22,000 to approximately $12,000 according to the plant owner. (These values are in Australian dollars; the conversion is approximately A$1.0 = US$0.7). The electrical energy consumption recording period after the condensing pressure set point adjustment was too short to establish the exact impact on SEC. For the Tamworth facility the average monthly electricity account ranges from A$6,000 to A$8,000. The condensing pressure set point adjustment at Lismore is estimated to have reduced SEC by 20% to 40% to around 65–85 kWh/m³*yr (1.84–2.41 kWh/ft³*yr). Figure 5 compares the electrical energy consumption for the Tamworth and Lismore facilities.

The Perth and Tamworth energy performance results are excellent for facilities of these sizes. Other facilities of similar volume and function consume around double based on the correlation shown in Figure 6, which originates from a study carried out by the California Energy Commission in 2008 covering 67 public and 96 private refrigerated warehouses. The graph shows specific energy consumption as a function of warehouse volume.

The significant difference in energy consumption between Tamworth and Lismore is most likely mainly attributable to the selection of the type of compressor, the plant configuration, and the fixed-speed compressor drives. Table 2 details modeled annual energy consumption values of various compressor configurations and two different load patterns (Lorentzen 1981). The advantage of reciprocating compressors compared with screw compressors in terms of energy performance is clear.

The various compressor configurations and load patterns are as follows.
Compressor combinations:

- 1: Single-stage screw compressor,
- 2: Single-stage screw compressor with economizer,
- 3: Single-stage screw and dual-stage reciprocating compressor,
- 4: Single-stage screw compressor with economizer and dual-stage reciprocating compressor,
- 5: Dual-stage screw compressor,
- 6: Dual-stage screw and dual-stage reciprocating compressor, and
- 7: Dual-stage reciprocating compressors.

Load patterns:

- I: Combination of plate freezers and freezer stores, load variation 10–100%; and
- II: Combination of blast freezers and freezer stores, load variation 40–100%.

The maximum refrigeration capacity at -40°C evaporating temperature is 500 kW in all cases.

The modeling results in Table 2 do not reflect the presence of medium-temperature refrigeration loads and the use of variable-frequency compressor drives. As such they do not fully explain the energy consumption differences between Tamworth and Lismore. However, the results in Table 2 do illustrate the importance of compressor part load efficiency with respect to the delivery of superior system energy performance. The comparison of typical compressor part load efficiencies in Table 3 further illustrates the importance of considering this element during system design (Grasso Comsel Compressor Software version v3.20.02). All values are coefficients of performance (COP) calculated as refrigeration capacity divided by compressor shaft power. The operating condition is -10°C saturated evaporating temperature, 35°C saturated condensing temperature, 0°C superheat, 0°C subcooling, refrigerant NH_3. The reciprocating compressor is a Grasso V600 with a refrigeration capacity at

Table 3. Comparison between part load efficiencies (COPs) for screw and reciprocating compressors

Load (%) ↓	Fixed speed		Variable speed	
	Reciprocating	Screw	Reciprocating	Screw
100	3.80	3.55	3.80	3.55
87	3.74	3.42	3.83	3.47
75	3.66	3.31	3.84	3.36
62	3.55	3.12	3.84	3.18
50	3.40	2.82	3.82	2.98
37	3.16	2.36	3.80	2.70
25	-	1.79	3.64	2.44

Table 4. Estimated design heat loads for Perth warehouse serviced by low charge NH_3 system

Estimated heat loads kW (TR)	LT	HT
Refrigerant temperature, oC (°F)	-31 (-23.8)	-3 (26.6)
Flour room, 16oC (60.8°F), LxWxH = 40.5x5.9x10.0 m (133x19.4x32.8 ft)	n.a.	11.1 (3.16)
Chiller, 4oC (39.2°F), LxWxH = 40.5x22.5x10.0 m (133x73.8x32.8 ft)	n.a.	51.1 (14.6)
Freezer, -25oC (-13°F), LxWxH = 55.5x40.5x10.0 m (182x133x32.8 ft)	173.8 (49.5)	n.a.
Annex, 4.0oC (39.2°F), LxWxH = 71.6x13.0x10.0 m (235x42.7x32.8 ft)	n.a.	166.2 (47.4)
Total ~43,000 m³ (1,518,500 ft³)	173.8 (49.5)	228.4 (65.1)

Table 5. Estimated design heat loads for Cocos Dr. warehouse serviced by HFC systems

Estimated heat loads kW (TR)	LT	HT
Refrigerant temperature, oC (°F)	-31 (-23.8)	-3 (26.6)
Freezer 1, -25oC (-13°F), LxWxH = 35.5x24.0x9.0 m (116x78.7x29.5 ft)	88.8 (25.3)	n.a.
Freezer 2, -25oC (-13°F), LxWxH = 30.0x29.5x9.0 m (98.4x96.8x29.5 ft)	94.8 (27.0)	n.a.
Chiller 1, 4oC (39.2°F), LxWxH = 35.5x7.5x9.0 m (116x24.6x29.5 ft)	n.a.	46.1 (13.1)
Chiller corridor, 4oC (39.2°F)	n.a.	6.0 (1.7)
Chiller 2, 4oC (39.2°F), LxWxH = 14.5x8.3x9.0 m (47.6x27.2x29.5 ft)	n.a.	17.7 (5.0)
Dock, 4°C (39.2°F), LxWxH = 20.0x19.0x4.5 m (65.6x62.3x14.8 ft)	n.a.	41.0 (11.7)
Annex, 4.0oC (39.2°F), LxWxH = 37.5x6.0x4.5 m (123x19.7x14.8 ft)	n.a.	82.3 (23.4)
Total ~22,000 m³ (776,923 ft³)	183.6 (52.3)	193.1 (55.0)

100% (1,500 rpm) of 315.7 kW, corresponding shaft power consumption 83.1 kW.

The screw compressor is a Grasso HR2655S without economizer with a refrigeration capacity at 100% (2,940 rpm) of 294.5 kW, corresponding shaft power 82.9 kW.

LOW CHARGE NH_3 VERSUS INDUSTRY STANDARD HFC

The owner of the Perth facility operates a second distribution facility in the same suburb around two km (1.2 mi) from the warehouse serviced by the low charge NH_3 plant.

The second facility is referred to as the Cocos Dr. warehouse. The Cocos Dr. warehouse is serviced by industry standard, individual air-cooled HFC-based, single- stage condensing units with electric defrost in the low-temperature areas. Tables 4 and 5 show the design refrigeration loads for the Perth and Cocos Dr. distribution centers. Clearly the sum of the design refrigeration loads for the two distribution centers are similar.

The financial records of the operator of the Cocos Dr. warehouse indicate monthly electrical energy supply costs of around A$42,000 on average. The electricity account for the Perth warehouse for the period April 1–30, 2015, was A$13,751.57, including 10% Goods and Services Tax (GST). This was for a total supply of 81,264 kWh. Based on Figure 4, this level of monthly electrical energy consumption is not unusual.

Given that this is the same electrical energy provider for both the Perth and the Cocos Dr. warehouses, it may be concluded that the energy performance improvement of the Perth warehouse serviced by a low charge NH_3 system could represent a reduction of approximately (1-13,752/42,000) *100, or 67% compared with Cocos Dr. This significant difference in energy consumption between HFC and NH_3 may appear extraordinary, but it is not when comparisons are made between other facilities operated by the same owner. A 1,385 m² (14,908 ft²) facility situated at Kunda Park in Southeast Queensland, Australia, and serviced by HFC-based air-cooled systems with electric defrost consumes around 1,265 MWh annually. An 1,130 m² (12,163 ft²) facility serviced by a dual-stage, liquid overfeed NH_3 system situated at Somersby north of Sydney in New South Wales consumes 546 MWh annually (Jensen 2013).

FACTORS AFFECTING LOW CHARGE NH_3 SYSTEM ENERGY PERFORMANCE

A low charge NH_3 refrigeration plant does not necessarily feature superior energy performance compared with other NH_3 based systems. As the comparison between Tamworth and Lismore shows, using NH_3 as the refrigerant is no guarantee of above-average energy performance either. Several factors individually contribute to the improvement of energy efficiency. Table 6 summarizes the author's order of significance for nine factors. The percentage improvements shown cannot be interpreted as cumulative. Each factor is to be considered as one individual change all other things being equal.

Item 1. Compressor type

A refrigerated distribution facility comprising 46,000 m³ (1,624,475 ft³) frozen storage plus a 7,000 m³ (247,203 ft³) annex (Jensen 2000) recorded a specific energy consumption of 35 kWh/m³*yr (0.991 kWh/ft³*yr). This facility was serviced by a dual-stage, liquid overfeed system comprising three identical fixed-speed drive screw compressors, one booster, one second-stage compressor, and one dual duty standby machine. The penthouse evaporators were fitted with variable frequency drive fans.

A 23,000 m³ (812,237 ft³) refrigerated storage facility in the same geographic location with a slightly different mix between low- and medium-temperature services recorded a specific energy consumption of 27 kWh/m³*yr (0.765 kWh/ft³*yr) (Jensen 2013).

The latter facility was serviced by a dual-stage, liquid overfeed system with four fixed-speed drive reciprocating compressors. The percentage shown in Table 6, item 1, refers to the comparison between these two practical systems, but a similar energy performance improvement estimate may be derived from Table 2.

Item 2. Evaporator fan speed control

A refrigerated distribution facility comprising 46,000 m³ (1,624,475 ft³) frozen storage plus a 7,000 m³ (247,203 ft³) annex (Jensen 2000) with variable-speed penthouse fans recorded a 35% lower specific energy consumption than a similar neighboring facility with the

Table 6. Factors impacting upon energy performance of low charge NH_3 systems

Item	Energy Conservation Factor	Percentage Impact (%)
1	Selection of compressor type	15–25
2	Evaporator fan speed control	15–25
3	Evaporator design	5–25
4	Compressor capacity control	10–20
5	Quality of match between compressor turn-down ratios and heat load variations	0–15
6	Condenser size, condenser fan speed control, and condenser efficiency	5–10
7	Liquid injection control into the evaporators	5–10
8	Elimination of liquid within suction lines	2–15
9	Use of low-friction-loss 304SS schedule 10 refrigerant pipe lines in lieu of carbon steel	1–2

same owner and fixed-speed fans fitted to the penthouse evaporators. Around 8–9% of the 35% energy performance difference was attributable to warehouse design. This forms the basis for the percentage in item 2, Table 6.

Item 3. Evaporator design

Many practical examples of dry expansion feed air coolers for NH_3 failing to meet performance expectations exist (Jensen 2006 and Jensen 2011). There are several reasons for this. The most important are summarized below:

- Incorrect evaporator circuiting causing inadequate turbulence and stratified flow;
- Nonuniform refrigerant distribution within the air cooler;
- Presence of water in the refrigerant causing a refrigerant bubble point rise toward the conclusion of the evaporation process, which in turn provides a false superheat control signal;
- Air cooler core tube material with inadequate thermal conductivity again causing lack of turbulence and stratified flow;
- Mismatch between the operating envelope provided by the air cooler manufacturer and the operating envelope required by the system;
- Oil fouling on the internal tube surfaces of the air coolers;
- Inadequate condensate removal during hot gas defrost due to inappropriate condensate drainage provisions;
- Inappropriate selection of expansion valve for the application; and
- Suboptimal control methodology applied to the refrigerant injection and the control of the hot gas defrost procedure.

New air cooler technologies are available that address the problem of inadequate exposure of the internal tube surfaces to the boiling refrigerant. These are based on internal tube surface enhancement that causes a capillary effect or the insertion of turbulators. New liquid distribution technologies have also been made available to enlarge the operating envelope (Nelson 2013; Jensen 2015a and Jensen 2015b). The main issue for the refrigeration plant designer to understand here is that reliance on air cooler suppliers to provide heat exchangers that deliver the specified thermal performances will not necessarily guarantee a successful outcome. The system designer must look at all heat exchanger designs critically with a view to addressing all of the previously summarized issues.

Item 4. Compressor capacity control

Table 6 refers to the retrofitting of variable frequency drives to an existing refrigerated warehouse in Sydney, Australia. This measure reduced annual energy consumption by >15% (New South Wales Office of Environment and Heritage 2012). The plant is a dual-stage liquid overfeed system with screw compressors servicing a mixture of low-temperature, medium-temperature, and blast-freezing rooms, with a total area around 30,000 m² (323,000 ft²).

Item 5. Compressor turn-down ratio and heat load variation

Extensive part load operation of compressors is a common problem in many industrial refrigeration systems. The percentage impact referenced in item 5, Table 6, is a function of the severity of the problem; Table 2 describes the magnitude of the potential efficiency loss.

Item 6. Condenser size, control, and efficiency

Evaporative condensers may be designed and selected such that the energy consumed by the condenser (the sum of fan and pump energy) is less than 1% of the design heat rejection, but ratios of 2–3% are no rarity in practice. Furthermore, oversizing the condenser such that it reduces the saturated condensing temperature by 1°K (1.8°F) improves the coefficient of performance of a typical second stage compressor by 2.6%. The percentage improvement in item 6, Table 6, is readily within reach with this simple measure.

Item 7. Liquid injection control into the evaporators

Quality-based control of the liquid injection into the evaporators is superior to conventional superheat-based control (Jensen 2015b). Practice has shown that entering temperature differences (ETD) between air and refrigerant of around 2.5°K (4.5°F) are possible without excessive control instability. In this context minimizing the possibility of liquid hold-up in the evaporator is important. The percentage range nominated in item 7, Table 6, is derived by estimating the impact on energy efficiency of raised plant suction pressure that reduced ETD gives rise to.

Item 8. Elimination of liquid in suction lines

As yet no experimental basis exists for the claimed 2–15% impact. This value range is a result of many practical observations of the energy performances of conventional liquid overfeed systems versus central type, low charge, dry expansion NH_3 plants of a design as described herein.

Item 9. Low friction piping

The claimed value range of 1–2% is based on actual line pressure drop measurements at the Melbourne plant. The measurements were based on the SCADA system and the pressure transmitters fitted at the evaporators (for superheat-based injection control) and the pressure transmitter fitted in the central engine room for provision of the compressor capacity control signal. The pressure drops measured were minimal and not particularly accurate due to the accuracy of the instrumentation. This is reflected in the value range in Table 6.

CONCLUSION

Ammonia refrigeration systems with reduced refrigerant inventory (low charge NH_3 systems) have been presented as potentially highly attractive alternatives to both industry standard HFC-based systems and conventional liquid overfeed and/ or gravity-flooded NH_3 systems. Appropriately designed low charge NH_3 systems demonstrate measured specific energy consumption values in kWh/m³*yr (kWh/ ft³*yr) that are up to 67% lower than industry standard HFC-based air-cooled, single-stage systems with electric defrost and up to 50% lower than gravity-flooded, single-stage screw compressor based systems employing NH_3 refrigerant. The energy performances of low charge NH_3 systems are sufficiently attractive to warrant straight replacement of existing industry standard HFC-based systems with new NH_3 systems provided plant owners can accept rates of return of 20% and prevailing unit electricity prices are ≥A$200/MWh. Added benefits of low charge NH_3 systems are the exceptionally low refrigerant inventories in the air coolers located within the refrigerated space. Complete loss of the operating charge from one of three air coolers within a refrigerated warehouse will under normal circumstances not give rise to an ammonia concentration within the warehouse of more than 200 ppm (complete mixing) and usually less. NH_3 concentrations that are 20–25 times greater and exposure times of 0.5–2 hours are required to pose significant risks to human health.

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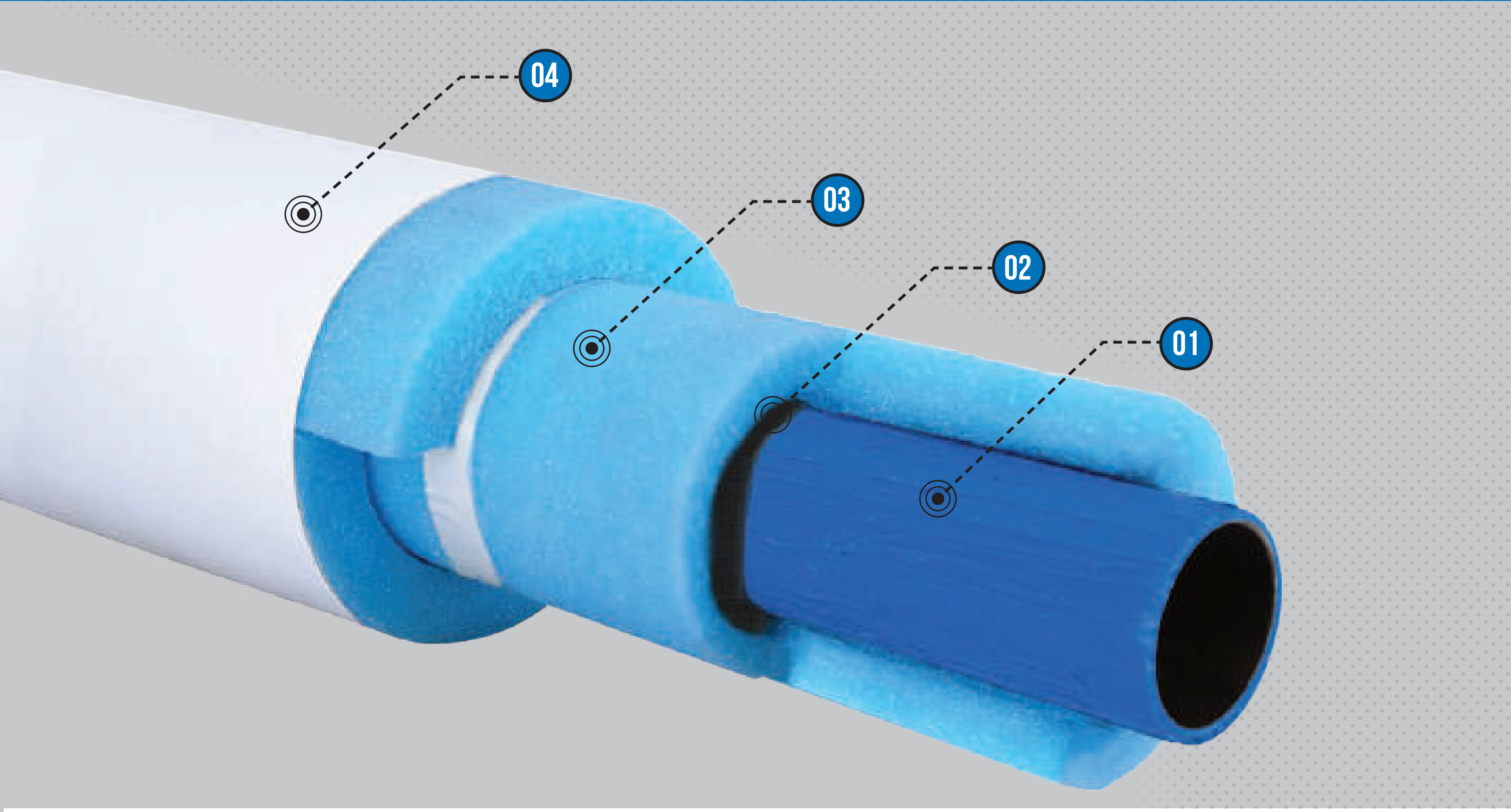

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