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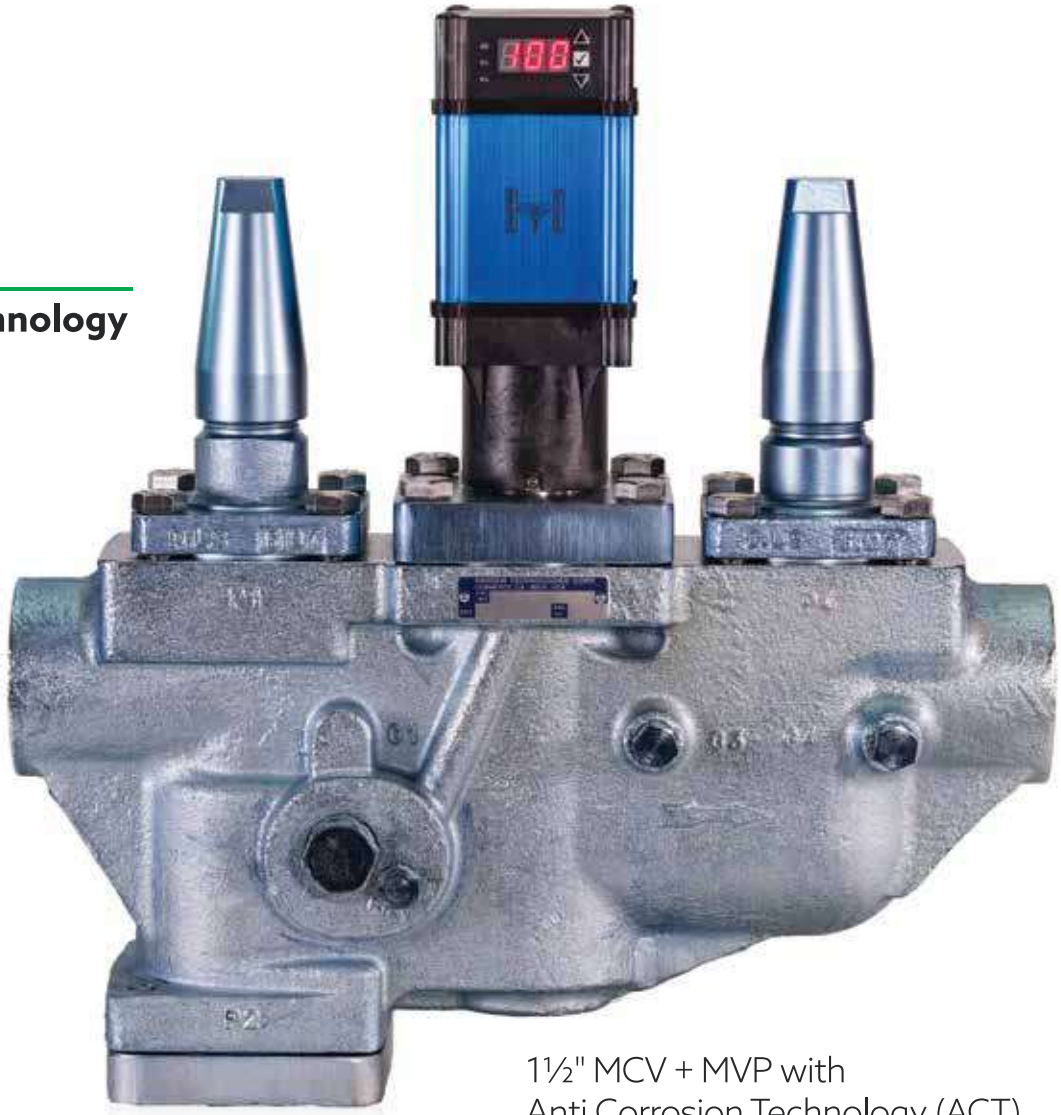

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president's MESSAGE

BY DAVE RULE

Having just returned from IIAR's exciting 2019 annual conference, I'm even more committed to the importance of our association and the many advantages of membership. The conference, held in Phoenix in March, was another record-setter in terms of attendance and the span of our technical program.

The 2019 conference included a duel industrial-commercial technical track – an IIAR first that will be continued at next year's conference in Orlando. Thanks to everyone who attended and made IIAR's meeting a great success.

This year's wonderfully successful and invigorating conference highlights the value of IIAR membership, but the ability to attend and participate in the annual conference is just one advantage of being an IIAR member. There are year-round benefits that will pay off for you and your colleagues in many ways.

IIAR membership helps keep you plugged into changes in industry standards development and is the best way to be sure that personnel can keep informed of technical changes in refrigeration, both regulatory changes and safety practices. Now is a critical time for any company using natural refrigerants to participate. It's important to renew your membership in IIAR, so you can keep up with the many new services IIAR offers and stay on top of the continual improvements in existing programs.

As you renew your own membership, this is a great opportunity to review your employees' membership status and to take advantage of our improved rates for multiple members. As you increase the number of members from one company, the cost of membership goes down.

That makes especially good sense for multi-facility companies –- it's particularly important to have at least one IIAR member in every facility. Your IIAR member representative will remain informed of all IIAR services and new products available to members. This is, without a doubt, the best way to ensure your employees are well informed, have access to our monthly webinar training and to ensure that your facility remains compliant with regulatory changes.

Among the many activities and member services we are pursuing on the industry's behalf are regulatory advocacy to update reporting requirements, IDLH regulations and the approved application of ARP's to address safety issues in our industry. We will continue the monthly webinar training programs that offer free access to members. The IIAR Staff also provides the monthly "Connect" for members to stay informed of industry news, periodic email correspondence to introduce new publications and services, and the quarterly Condenser for news and technical information. And, many of these publications and services are now offered in Spanish to serve our growing membership from around the world. IIAR membership is the best way to stay informed in our industry.

Finally, IIAR is expanding its Academy of Natural Refrigerants certificate program with new courses coming on line, such as IIAR-6, safety courses addressing process hazard analysis, mechanical integrity, how to develop an SOP program, PSM engineering calculations and a new basic ammonia refrigeration design course. As the ANR certificate curriculum continues to build over the next several months, IIAR members are provided with an economical method to train their employees, meet regulatory requirements for continuing education and build their professional credentials. ANR courses are now available online complete with testing to obtain PDH credits and ANR course certificates. This is the best way for members to demonstrate competence in IIAR Standards, engineering design and safety while benfiting from the membership preferred pricing.

The coming year will see many changes in standards and new products from IIAR. IIAR-7 will be coming out by end of May, IIAR-2 Addendum A will be published by June, closely followed by IIAR 6 – inspection, testing and maintenance. The CO_2 standard has just finished its first public review and should be published later this year. The scheduled five-year review of IIAR Standards 2, 4 and 8 are in process and should be published by the end of this year.

We've recently published the new ARM and ARM LC guidelines, the new piping handbook is scheduled for publication in June, updating the original manual. It will also offer a new chapter and software on economic analysis and pipe sizing based on the Ammonia Refrigeration Foundation's research. Additionally, the standards and Series I videos are now available in Spanish.

All of this means it is a great time to stay engaged and to take advantage of member discounts on all these new products and services. I encourage you to renew your membership now and consider adding employees to your IIAR membership roster and take full advantage of all your IIAR has to offer.

I'm looking forward to working with you in the coming year!

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chairman's MESSAGE

BRUCE NELSON

Secondary Systems Offer IIAR Opportunity For Expansion

As your IIAR chairman for this year, I would like to thank and congratulate everyone who made our 2019 annual meeting in Phoenix a great success, and especially to welcome all our new IIAR members. Your participation and spirit of volunteer leadership is essential to helping our industry meet the many challenges that lay ahead.

Our great mission together as IIAR members is to make the world a safer place through the safe and efficient use of natural refrigerants.

Embracing the many applications of natural refrigerants helps make the environment safer for ourselves and 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.

I believe we can and should be extending the reach of natural refrigerants to all sorts of refrigeration applications. That's a goal that our membership and our board is fully embracing, as evidenced by our focus on producing safety standards not only for ammonia but also for carbon dioxide and most recently, for the hydrocarbons.

It is a goal I am committed to pursuing during my term this year as your chairman.

One topic I intend to bring forward to the IIAR Board of Directors and membership this year is expanding the use of natural refrigerants in secondary refrigeration systems.

Secondary refrigeration systems – those which use a chiller to cool a secondary refrigerant which is circulated to and from the cooling load - are already widely used to cool occupied spaces in office buildings and food processing facilities, in supermarkets, in pharmaceutical and medical facilities, in data centers, and elsewhere. Traditionally these chillers have used synthetic refrigerants with their associated environmental risks.

The compact "plug-and-play" nature of chillers offers an interesting opportunity to manage and mitigate the toxicity (ammonia) and flammability (hydrocarbons) issues that must be addressed when applying natural refrigerants to occupied spaces. New compact heat exchanger technologies mean the required refrigerant charge for a given cooling duty can be made very small. Assembly and testing at the chiller manufacturers facility insures quality and reliability. The packaged nature of chillers also allows flexibility in regard to their location and ventilation requirements in a facility.

Embracing the many applications of natural refrigerants helps make the environment safer for ourselves and 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.

In addition, the secondary refrigerants themselves have evolved and improved in recent years giving designers many more choices which improve heat transfer and reduce pumping power. There are a number of new secondary refrigerants now on the market which greatly extend the practical temperature range of secondary refrigerant applications, even to blast freezing temperatures.

For example, CO_2 is being applied in secondary refrigeration systems as a volatile brine. This approach takes advantage of the CO_2's latent heat of vaporization, greatly reducing the amount of CO_2 circulated and pumping power required for a given cooling duty.

I feel strongly that there is an opportunity for IIAR to do what we do so well, which is to develop design guidelines and best practice information to take advantage of these new secondary refrigeration technologies and in doing do expand the use of natural refrigerants to other markets and industries. We can create technical expertise and competence by producing engineering handbooks and best practices documents that do not now exist, and we can develop and disseminate this information through our national conferences and the Academy of Natural Refrigerants.

I intend to bring this topic to the Board of Directors to start a discussion regarding how we can best contribute to the expanded use of natural refrigerants in secondary refrigeration systems. This exciting subject is one which I feel will have broad appeal and support with all our membership, national and international. Please watch for upcoming announcements regarding these activities, and be prepared to get involved!

Future-Proofing Refrigerants

Naturals Reach Wider Markets as Environmental Incentives Increase

Against a shifting regulatory landscape, with restrictions of hydrofluorocarbon synthetic refrigerants growing by fits and starts, use of natural refrigerants is increasing among a widening range of companies seeking to ensure that their investments will be viable in the future.

In industries ranging from biotechnology and pharmaceuticals to retail groceries, data centers and office buildings, companies are embracing more sustainable refrigerant options to reach their sustainability and climate goals and achieve regulatory compliance.

"Eliminating halogenated hydrocarbons is an integral part of our sustainability strategy to reduce our impacts on the environment. The program helps us future-proof our operations by staying ahead of relevant legislation, reduce risks to our business and in many cases improve energy efficiency," said Scott Hemphill, global environmental sustainability expert in the Diagnostics Division at The Roche Group.

Halogenated hydrocarbons are hydrocarbon chemicals containing elements called halogens, such as chlorine or fluorine. Used as synthetic refrigerants such as HFC, production and use of the chemicals is restricted by environmental authorities because of their stability and persistence in nature.

In addition to being a green alternative, the concept of future-proofing has taken on greater importance as businesses monitor varying state, federal and global requirements. Morgan Smith, manager of programs and operations at the North American Sustainable Refrigeration Council, said the industry is currently facing uncertainty regarding regulatory requirements at state, federal and global levels.

While the Environmental Protection Agency's Significant New Alternatives Program Rules 20 and 21, which were issued under the Obama administration, have been vacated by the Trump administration, some states have moved in with their own regulations.

"Those SNAP regulations were deemed invalid, and we've started to see the Environmental Protection Agency begin dismantling other HFC policies in the wake of those decisions," said Lowell Randel, IIAR director of government relations.

However, some states have their own plans to phase down high global-warming-potential refrigerants. "In the absence of federal regulations, a number of states have announced plans to enact their own HFC regulations," Smith said.

California has passed the California Cooling Act, which will put forward regulations restricting the use of HFCs and create incentives for companies to shift from high global-warming-potential refrigerants to low-GWP refrigerants.

Although California's legislation was slated to include an incentive program, that went unfunded in the proposed 2019 budget. "It was disappointing to see the program go unfunded because it has the potential not only to help offset the cost premiums of low-GWP alternatives in California, but it also has the power to stimulate volumes of adoption that will drive economies of scale across the United States," Smith said, noting that there is still a significant cost barrier.

Washington State is considering legislation that would restrict HFCs and would phase down their use, Randel said. Smith added that the effective dates vary for different refrigerant applications. Supermarkets would need to begin complying in 2020, while refrigerated food processing and compact residential facilities have until 2021. The deadline is 2022 for residential consumers and 2023 for cold-storage warehouses.

Randel said some companies might be challenged to meet those deadlines. "Some people have raised concerns that there may not be enough transition time built into the legislation to provide suf-

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ficient time for industry to make those adaptations," he explained.

In Connecticut, the legislature passed a bill concerning climate change planning and resiliency. "Their governor has signed that into law and has asked for the Connecticut Department of Energy and Environment Protection to develop regulations that would phase down HFCs," Randel said.

In New York, Gov. Andrew Cuomo has charged the Department of Environmental Conservation to develop a plan to address HFCs. Some refrigerants will begin being phased down in 2020, Randel said.

Also, "New Jersey's legislature is looking at legislation that would address HFC phasedowns, and Maryland has approved a greenhouse gas emission reduction and HFC's could be part of that policy as it moves forward," Randel added.

However, many would like to see the federal government take the lead on regulatory requirements. "It would be a real challenge to manage different HFC regulations across a number of states," Smith said.

Even with the uncertainty surrounding regulatory requirements, several businesses are moving forward with natural refrigerants.

THE PHARMACEUTICAL SPACE

The Roche Group is a leading biotechnology company and an early leader in natural refrigerants in the pharmaceutical and biotechnology space. "We strongly believe using natural refrigerants is the right thing to do and that as a big company we not only have a responsibility to improve patients' lives but also to the society in which we operate," Hemphill said.

The Roche Group's commitment to phasing out halogenated refrigerants is governed by the K6 Directive, one of 24 mandatory corporate directives that every part of the Group must follow. "The halogenated hydrocarbon elimination program has been prioritized throughout Roche by including it in a mandatory Group Directive that has the backing of senior managers," Hemphill said.

The K6 Directive was first introduced in 1994 to reduce and ultimately eliminate ozone-depleting substances in all operations, which was effectively achieved for the original business scope in 2015. The directive has been continuously updated and strengthened over the years to include other halogenated hydrocarbons that have a negative impact on climate, such as HFCs, with corresponding reduction targets set, Hemphill explained.

"Between 2002 and 2015, halogenated hydrocarbon inventories were reduced by nearly 90 percent. The current target to reduce inventories by a further 20 percent by 2020 has already been achieved," Hemphill said. "The K6 directive aims to phase-out halogenated hydrocarbons in equipment in all our facilities including air conditioning systems, cool rooms, refrigeration and freezer units, fire suppression systems, etc., and promotes only natural replacements —ammonia, carbon dioxide, non-halogenated hydrocarbons, water and air — to be used."

Hemphill explained that existing non-compliant equipment is being replaced continuously at all Roche facilities. "New acquisitions have been consequently applying the directive with corresponding later timelines," he said.

Hemphill said environmental sustainability objectives are easier to achieve with clear and mandatory requirements, strong management support and robust control mechanisms. "The K6 program is an excellent example of what can be achieved with the right pre-conditions," he said.

One challenge, Hemphill said, is that there are many types of smaller equipment, such as environmental chambers, centrifuges, split air conditioning systems and lyophilization units, that are not yet available on the market with natural coolants. "Roche still has significant numbers of such equipment in our inventories, and these will be challenging to replace. The biggest efforts in our program will be required to remove the remaining halogenated hydrocarbon inventories in small equipment," he said.

For those looking to switch to natural refrigerants, Hemphill advises that they obtain top management support, make requirements clear and mandatory and continuously control compliance within the organization. "Be prepared to invest more time in searching for halogenated hydrocarbon-free equipment, be willing to work with external partners on solutions that may not yet be available on the market and be prepared for possible higher equipment costs as HFC solutions are in many cases still cheaper than natural alternatives," he said.

THE GROCERY INDUSTRY

Several grocers are investing in natural refrigerants. An analysis by the private Environmental Investigation Agency identified Aldi U.S. as an industry leader, along with Whole Foods, Target, Sprouts and Ahold Delhaize USA.

Earlier this year EIA unveiled a new initiative identifying U.S. retailers committed to taking leadership action to reduce HFCs. As part of the initiative, Aldi U.S. announced its goal to add HFC-free refrigeration systems to 100 more stores in 2019.

"Aldi is deeply committed to reducing its refrigerant emissions and believes natural refrigerants are the best long-term solution for the planet," said Aaron Sumida, vice president at ALDI.

Aldi has adopted transcritical CO_2 refrigeration systems in many of its new and remodeled stores. "We're excited to continue to drive forward change with our commitment to hydrofluorocarbon reduction and adopting natural refrigeration systems," Sumida said.

Randel said CO_2 systems are finding a lot of traction in supermarkets. "Quite a few of the facilities that are transitioning to more climate-friendly refrigerants are looking to CO_2 or a cascade system," he said, adding that distribution centers are more likely to have ammonia or CO_2 or some type of cascade system. "We're seeing hydrocarbons coming in and being used in some of the self-contained equipment."

Avipsa Mahapatra, lead of climate campaign at EIA, said smart companies, such as Aldi U.S., are committed to rapidly scaling-up energy efficient HFC-free technologies, demonstrating that it makes business and climate sense to lead in adopting future-proof refrigeration systems not reliant on potent super-pollutants.

"We are committed to limiting our climate footprint, including taking steps to reduce HFCs used in cooling," said Brittni Furrow, vice president of sustainable retailing for Ahold Delhaize USA. "Our company's global target to lower the average GWP of refrigerants in stores to 2,230 by the year 2020 reflects this commitment."

Furrow said Ahold is continuing to look for opportunities to use climate-friendly cooling technologies such as those already employed in one Food Lion and three Hannaford stores in the U.S.

Frank Davis, director of facilities and engineering at Sprouts Farmers Market, said Sprouts is also committed to lowering HFC emissions from cooling by reducing leaks and piloting sustainable refrigeration technologies in stores.

"We continue to follow through on this commitment through our participation and certification of stores in EPAs GreenChill Partnership," he said.

Christina Starr, climate policy analyst at EIA, commended the companies which are taking action but said there is much more the U.S. supermarket sector should do. "These leading companies represent just 15 percent of U.S. supermarkets, so there's a big opportunity for more commitments such as phasing out the worst HFCs like R-404A, adopting climate-friendly refrigerants in new refrigeration systems, or joining the EPAs GreenChill Partnership and taking steps to limit leaks," she said.

If all U.S. supermarkets join the EPA's GreenChill Partnership and achieve similar reduced leak rates, it would mitigate an additional 15.5 million metric tons CO_2 annually, EIA said.

EIA has created a map of supermarket locations in the U.S. using climate-friendly cooling. The site, www.climate-friendlysupermarkets.org, highlights specific company actions in three key areas: adopting technologies, refrigerant management, and engaging in technical and policy dialogue.

"The fact that these major retailers are coming out and aligning themselves in this climate-friendly supermarket marketing is a signal that a lot of these companies are thinking about their environmental footprint and recognize that going with natural refrigerants like ammonia or CO_2 is the right choice for them," Randel said. "The more you see people taking these actions, that will build on the momentum for other companies to say we can do this and do it efficiently and it improves the bottom line."

INDUSTRIAL REFRIGERATION

Natural refrigerants have always been the mainstay for industrial refrigeration and Campbell Soup Co. has long had a commitment to natural refrigerants. Most of Campbell's loads are high-temperature applications and are serviced from either a 40 °F chilled water circuit or a 28 °F glycol circuit, said Chuck Taylor, president of CRT Design Inc., a Campbell's engineering contractor. Using ammonia to chill the water and glycol makes it possible to take advantage of the benefits of ammonia without having ammonia in the plant.

Each of these facilities also has a very small freezer. In the Campbell's plants in Denver, Pennsylvania, and Lakeland, Florida, Campbell's installed a CO_2 low-side compressor package to service the freezer and transferred the heat of rejection from the low stage CO_2 system to the 28 °F glycol loop. This enabled the use of natural refrigerants without having ammonia in the plant, Taylor said.

In another application, Campbell's needed to install a spiral freezer in the middle of its Downingtown, Pennsylvania, facility. Again, Campbells wanted to keep the ammonia in the machine room and use natural refrigerants. Campbell's installed a low side CO_2 system to service the spiral and transferred the heat of rejection to the 28 °F glycol loop. The spiral utilized 6 DX evaporator coils and a rack manufactured by Hill Phoenix, Taylor said.

In addition, Campbell Soup Co. needed to add a 25,000-square-foot freezer and cooler to its research and develop center at the company's corporate headquarters in Camden, New Jersey. Again, the company wanted to utilize natural refrigerants but because of New Jersey regulations did not want to use ammonia. Campbell's installed a transcritical rack in the machine room and direct expansion evaporators in the freezer and cooler.

In all three applications CRT Design engineered the systems. "Campbell's commitment to the environment and natural refrigerants, coupled with some very challenging applications, lead to innovative solutions utilizing CO_2 as the refrigerant," Taylor said. "Campbell Soup Co. is very happy with the results."

COMMERCIAL HVAC SYSTEMS

Star Refrigeration installed five air-cooled ammonia chiller packages for a data center in Denmark in 2018-2019. "Two chillers were supplied for office cooling 190kW(54TR) each at 14/7C water temperatures," said Alan Walkinshaw, special projects sales manager for Star Refrigeration. "Three chillers were supplied for electrical room cooling 610kW (173kW) each also at 14/7C fluid temperatures."

Walkinshaw said natural refrigerants are strongly favored in Denmark, and ammonia offered an efficient, future-proof solution for the project.

Azane, Inc. installed an Azanechiller (300 TR) at a Campbell's Soup facility in Napoleon, Ohio. "This was also providing chilled water for air-conditioning at their plant. ," said Caleb Nelson, vice president of business development for Azane Inc.

Nelson said Azane built three more Azanechillers (900 TR total) for a similar application for a large bakery in Portland, Oregon. "That application was primarily AC with a bit of industrial process," he said.

As part of the Portland project, a third-party engineering consulting group studied the air-cooled Azanechiller packages and determined that they exceeded the efficiency requirements for water-cooled chillers of the Oregon Energy Efficiency Specialty Code, Nelson said. "The additional benefit of air-cooled packages is that they reduce the total running costs significantly because they eliminate water usage and sewage costs as well as chemical water treatment and maintenance costs for cooling towers or evaporative condensers," he added.

Scantec Refrigeration Technologies installed the first ammonia-based air conditioning retrofit in a public administration building in Queensland, Australia, about eight years ago. The ammonia-based air conditioning system replaced two R22-based air conditioning systems. The secondary refrigerant was reticulated chilled water.

The system was expected to save $100,000 (Australian) annually due to energy savings. Stefan Jensen, managing director for Scantec, said the payback period was around six years, less than the original estimate of 8.5 years.

Jensen said the project was able to prove that, despite all the negativity from the HFC proponents within the local HVACR industry, the use of ammonia for air conditioning of buildings fitted with a chilled water reticulation type AC system is very viable and future-proof.

The same type of technology could be used in several other applications. "There is little, if any, technical difference between the reticulated chilled water system in a hotel and that of a multi-story administration building," Jensen said.

Despite the benefits of ammonia refrigeration, however, Jensen said the Queensland project wasn't the game changer he had hoped to see. "There is much inertia in the traditional way of doing HVACR with HFC refrigerants and changing that is a bit like changing the direction of the Titanic," he said.

IIAR Releases New Standards and Updates

The IIAR presently has eight American National Standard Institute (ANSI) approved standards at this time and three additional new standards that are presently in development making a total of 11 standards overall.

ANSI/IIAR approved standards are reviewed entirely from cover-to-cover, at a minimum, every five- years for periodic maintenance. In addition to the five-year periodic maintenance reviews, a standard may be modified as an addendum. Although addenda are few, IIAR 2-2014 Addendum A is an example of the most recent addendum.

"During our closing forum at the IIAR [2019] annual conference, this last session covered a review of all of our standards," said Eric Smith, IIAR vice president and technical director.

Smith, along with Tony Lundell, director of standards and safety for IIAR, and Bob Czarnecki, chair of the standards committee and a member of IIAR's board of directors, provided an in-depth look at the status of each IIAR standard.

IIAR 1: IIAR 1 covers definitions. "It is just easy for terminology reference," said Czarnecki. He added that IIAR 1 was updated in 2017 and that members of the standards committee are monitoring it for any questions that come up. "They're noted, and when it is updated in 2022, they will be addressed."

IIAR 2: IIAR is slated to release Addendum A as an update to ANSI/IIAR-2014. ANSI/IIAR 2-2014 was a significant rewrite of IIAR 2, making it a standard for safe design encompassing both standard and code language, Lundell said.

"It was the most comprehensive and well-written version of IIAR 2," Smith said. "It was very good, but after we started using it, we found it needed a few corrections and some provisions addressed for clarity. Also, since the document was so comprehensive, we began approaching code bodies to gain sole adoption or reference to the IIAR 2, 2014 version. This process pointed out the need for some additional language changes.

Smith said IIAR 2 was accepted by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) who began referring to IIAR 2 for ammonia systems. "The caveat to that was that in order for ASHRAE to feel comfortable with referring to IIAR 2 for ammonia systems, we needed to cover all ammonia systems, which included absorption systems."

While the 2014 release didn't cover absorption systems, the update does. "We have changed the scope to address absorption systems in IIAR 2. We have corrected some minor errors and filled some gaps that were discovered among ASHRAE, IIAR 2 and the codes review," Smith said.

The IIAR presently has eight American National Standard Institute (ANSI) approved standards at this time and three additional new standards that are presently in development making a total of 11 standards overall.

IIAR 2-2014's Addendum A has taken about three years to produce and will be released soon. "At this point, ANSI working through their approval of our procedures," Smith said. "We are awaiting the final ballots from the consensus body." All approvals should be received by the time the May Condenser issue is published.

Smith noted that IIAR 2-2014's Addendum A took longer to approve than was originally anticipated because the topic of vessel corrosion allowance was complicated, which he covers in depth on page 36.

After Addendum A is completed, the entire standard will then be opened up for a full cover-to-cover periodic maintenance review.

IIAR 3: This standard pertains to the performance criteria of ammonia refrigeration valves. It was last updated in 2017.

IIAR 4: A periodic maintenance review update to IIAR 4, a standard related to installation, is due next year. Czarnecki said there is a subcommittee working through the document and it is undergoing updates, but there isn't an expected release date.

IIAR 5: An update to IIAR 5, which addresses the startup of closed-circuit ammonia refrigeration systems, is presently under its five-year periodic maintenance review and is expected to be released later this year. Lundell said the update specifies the minimum requirements for startup and is being revised to concur with the updates to other standards. "IIAR 5 will flow with IIAR 6 and IIAR 7," he explained.

Czarnecki said the update has completed two public reviews, and the committee has received several comments on public review No. 2 and will be addressing the comments. Should there be any substantive changes as a result of the comments, the standard will go out for a third public review.

IIAR 6: IIAR 6, which is the newest standard, was approved by ANSI on April 16th, 2019.IIAR 6 is a standard for the minimum requirements for inspection, testing, and maintenance of closed-circuit ammonia refrigeration systems. "This standard is now being designed and formatted for publication," Czarnecki said, adding that IIAR has been working on this standard for years.

Lundell said there are some claims that people within IIAR worked on it for over 13 years. "When I got involved a couple of years ago, I could see they were trying to put their arms around the entire world," he said, adding that the standard was trying to address every variation of all equipment, and all the means to inspect, test and maintain it. These techniques and equipment continually evolve and are enormous in scope. Further, there are often many ways to accomplish the required tasks. The committee became more focused on the minimum inspections, testing, and maintenance requirements, including the

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minimum record keeping requirements for continued safe operations and was successful in completing the document.

IIAR 6 is the first comprehensive consensus standard for the inspection, testing, and maintenance of closed-circuit ammonia refrigeration systems, and it provides a path forward for the ammonia refrigeration industry.

"The main issue was determining exactly what the scope and purpose should be," Smith said, adding that other publications get into the details of how to do maintenance, inspections, and testing. "At first I think there was a struggle on how extensive the standard should be. We determined that what was really needed was to establish the minimum requirements for what is necessary to be done and how often it is to be done."

The release of IIAR 6 will supersede IIAR Bulletin No. 109. "A lot of facilities have adopted the Bulletin No. 109 checklists (i.e., 109's) as RAGAGEP," Lundell said. "Basically the 109s are replaced with Appendix B. A company that has been doing 109s for years can adopt IIAR 6, Appendix B "Ammonia Refrigeration System Safety Checklists" and continue on with them." Including the checklists in the standard development process has enabled them to be reviewed and enhanced where necessary.

IIAR has also been publishing Bulletin 110, first issued in 1993, predating OSHA and EPA regulations, and the current ANSI public review process. "When bulletins 109 and 110 were written, there wasn't a broad public review process in place. They were never ANSI approved standards, and were not maintained on a regular schedule," Smith said. "Furthermore, technology has advanced since then. And they weren't written in a way that clearly delineates between normative functions and informative functions."

While Bulletin 110 was a good document for the time in which it was written, it wasn't drafted with regulatory oversite in mind. Now, the information within Bulletin 110 has been incorporated into IIAR 6, Ammonia Safety Data Book, and several other of IIAR's standards Smith and Lundell said.

IIAR 7: IIAR 7 Developing Operating Procedures for Closed-Circuit Ammonia Refrigeration Systems, has recently been updated under periodic maintenance. It is intended for those who develop, define, and review operating procedures for ammonia systems, Lundell said. This standard focuses on developing operating procedures for ammonia refrigeration systems and not general operating procedures for all types of chemicals.

An update to the standard recently received ANSI approval. "It was basically putting it into the format we've adopted for all of our standards," Czarnecki.

IIAR 8: Czarnecki said he doesn't expect many changes to IIAR 8, Decommissioning of Closed-Circuit Ammonia Refrigeration Systems, which is presently open for periodic maintenance. It will be published next year.

IIAR 9: IIAR 9, a new standard for the minimum system safety requirements for existing ammonia refrigeration systems, recently finished its third public review and it is slated to be published this year. "It is going to require owners to review their existing systems and confirm they're meeting the minimum system safety requirements on these older operating systems," Lundell said. He added that IIAR 9 also describes the methodology to be used to conduct the safety evaluations.

CO_2 Standard: IIAR is working on a new CO_2 standard, and it has just completed its first public review. "The industry is pushing for low global-warming-potential alternatives, and CO_2 falls into that category," Lundell said. He said CO_2 can be used in industrial and commercial applications. This standard in development program will be more comprehensive and will include installation, startup, inspection, testing, and maintenance of carbon dioxide refrigeration systems.

Smith said the end-user community and CO_2 manufacturing community wanted a standard that would encompass design, installation, maintenance, and operation of CO_2 systems, for which there is a wide variety of equipment available. "They felt it would benefit the industry as a whole if a single standard addressed all of these issues," he said, adding that IIAR is not planning to supersede other design standards, such as ASHRAE 15, or seek code reference to the CO_2 standard. "This is an ancillary standard to raise the quality and level the expectations for CO_2 systems."

IIAR is working on a new CO_2 standard, and it has just completed its first public review. "The industry is pushing for low global-warming-potential alternatives, and CO_2 falls into that category."

–Tony Lundell, director of standards and safety for IIAR

Czarnecki said the CO_2 standard received 133 comments during its first public review and will probably go through a few more rounds of public review before it is published.

Hydrocarbon Standard: IIAR is just beginning work on a hydrocarbon standard. "The standards committee was directed by the board of directors to write the standard. The committee is in the process of getting started on it right now," Czarnecki said, adding that there isn't a timeline for completion.

Lundell added that this hydrocarbon standard is intended for natural hydrocarbon refrigerants with no ozone-depleting potential (ODP) and very low global-warming potential (GWP). The standard will include installation, start-up, inspection, testing, and maintenance of these systems. It is also intended as a companion standard to ASHRAE and will be scoped to exclude equipment that is listed by nationally recognized listing agencies.

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ARF AMMONIA REFRIGERATION FOUNDATION news

MIKE LYNCH
ARF CHAIR

Putting Funds to Use to Drive Innovative Solutions for the Industry, Foundation Members

At ARF, our mission, as a non-profit research and education foundation, is to promote, fund and provide scientific and educational projects that are related to the use of ammonia, natural refrigerants and industrial refrigeration. It's not only our mission, but it is our reality.

As members of our organization, the industry and the community, we believe that providing our end users with transparent data is the key to a successful research and education foundation. That's why we'd like to share with you – our valued members – our screening process for proposals, our current research projects and our successes that you have made possible.

THE VETTING PROCESS

ARF is extremely selective when determining which research proposals to fund. In fact, the process is quite complex because we are committed to only funding research projects that add value to our end users.

While in the past, the screening process was not as thorough, for the past 5-6 years, we have adopted a formal vetting process to achieve the results we feel are most beneficial for our members and the industry.

This vetting process includes a scoring sheet for each proposal received by the foundation. The scoring sheet evaluates the following:

- **Value:** Each proposal is placed into a category to determine who gains value. These categories include contractors, design engineers, equipment manufacturing and end users.
- **Innovation:** All proposals are evaluated for how the project will make a meaningful contribution to the industry. Innovation is scored based on whether or not the research project will help reduce costs, help with efficiency, assist with manufacturing, installation of equipment and safety and reduce manpower or material.

ARF is extremely selective when determining which research proposals to fund. In fact, the process is quite complex because we are committed to only funding research projects that add value to our end users.

- **Significance:** Our team wants to make sure that the research project addresses questions that are scientifically important and addresses our overall mission. In addition, we score based on whether or not the proposal's goals and end results will have a meaningful impact on our alliance membership and the industry.

THE RESEARCH PROCESS

Once a research project is evaluated based on the vetting process criteria, budget and academic impact, our team

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compiles a research agreement that outlines the statement of work, the period of performance, the expected outcome and benefit to the organization and a schedule of payments.

Because we want to provide our membership and the industry with quality work, we have instituted a thorough contract for each project and require progress reports before any funds are released. On average, due to the complicated subject matter, most research projects take two to three years to complete.

As a member of our organization, you have access to past research projects in our expansive library of data. However, we'd like to pinpoint a few active projects that we are currently funding to show you the type of innovation that is happening because of your donations and contributions to ARF.

At any given time, the foundation funds from two to three projects so that we can provide deliverables that benefit our members and the industry.

We also make it mandatory for each research team to compile a technical paper and present their findings at our annual conference. In addition, all technical papers are added to our extensive library that is accessible to our members for future use.

AN UPDATE ON ARF RESEARCH PROJECTS

As a member of our organization, you have access to past research projects in our expansive library of data. However, we'd like to pinpoint a few active projects that we are currently funding to show you the type of innovation that is happening because of your donations and contributions to ARF.

- **Development of a Mechanical Insulation Installation Guideline for Refrigeration Applications:** This project is intended to provide best practice details for inclusion in an installation guideline for insulation systems for refrigeration applications (pipes, tanks and equipment). This will include a thorough treatment of vapor retarder joints, insulation joints and insulation system terminations. As a minimum, this guideline will address the installation of insulation systems of all of the materials currently listed in the IIAR Piping Handbook.

- **CFD Simulation of an Ammonia Dispersion Within Refrigerated Spaces:** The goal of this research is to assess and if necessary, develop code language concerning ammonia detector placement in cold rooms based on numerical simulation of ammonia releases within them.

A few of our completed research project scopes include:

- **Optimum Pipe Sizing:** The objective of this research was to revisit the economic sizing methodology, originally proposed by Genereaux and subsequently transplanted into the industrial refrigeration industry by Richards, in order to update and expand the recommended pipe sizing tables included in the IIAR Piping Handbook. A primary aim of this project is to provide a computer-based analysis tool that will allow users to explore optimum pipe sizing based on input data that includes piping system capital cost information, system energy cost data, piping system life expectancy, and refrigeration system operating efficiency information.

- **Influence of P-Trap vs. 90 Degree Elbow Inlet on Two-Phase Pressure Drop in Vertical Suction Risers:** This study was carried out on the test rig developed for ASHRAE RP-1327 at the Danish Technological Institute (DT) in Aarhus, Denmark. The information produced by this study has furthered the understanding of two-phase pressure drop and flow in risers and should lead us to better designs with this critical part of ammonia piping systems.

THE BENEFITS OF SUPPORTING ARF RESEARCH

Our goal is to provide our members and the industry with deliverables that ultimately help you to operate more efficiently and save money. Contributions to your foundation make it possible for innovative researchers to analyze, evaluate and test strategies and techniques that directly impact the work you do on a daily basis.

As a non-profit organization, ARF relies heavily on contributions to make research not just a goal, but a reality. We believe in providing transparency so that you can directly benefit from the research that is performed. This research not only impacts the present, but also the future of this industry. We encourage you to consider donating to ARF so we can continue to uncover innovation that will last a lifetime.

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CHECK OUT WHAT'S ON THE HORIZON FOR THE **2019–2020 IIAR MEMBER YEAR …**

Newest Certificate Program for the Academy of Natural Refrigerants:

- Performing an Effective PHA
- IIAR 6
- Basic Ammonia Design

Due to be released – IIAR Standards and Publications:

- IIAR 9: Recognized and Generally Accepted Good Engineering Practices (RAGAGEP) for Closed-Circuit Ammonia Refrigeration Systems
- IIAR 2: Standards for Safe Design of Closed-Circuit Ammonia Refrigeration Systems
- The Piping Handbook
- IIAR 6: Standard for Inspection, Testing, and Maintenance of Closed-Circuit Ammonia Refrigeration Systems

IIAR Discounts – IIAR members receive discounts on industry publications, conference registration, and IIAR Academy of Natural Refrigerants certificate courses.

Well-attended Auxilary Session at IIAR Phoenix Conference Explored Energy Efficiencies

Energy efficiency was the focus of a well-attended and extensive auxiliary educational program at the International Institute of Ammonia Refrigeration annual conference, held in March in Phoenix.

Sponsored by CIMCO Refrigeration, the event brought together engineers to discuss a wide variety of topics related to the design, maintenance, operation and retrofitting of refrigeration systems to make them run more efficiently. Eric Smith, IIAR vice president and technical director, said these topics are critically important to IIAR membership, and the industry as a whole.

"The program was put together because energy efficiency is incredibly important to our end users," Smith said. "Not only from the aspect of saving money but also for environmental purposes."

Approximately 150 people attended the session. This is impressive because it was an auxiliary program to the regular conference sessions, held on the Sunday before the conference officially kicked off. Attendees spent their Sunday and had to pay a bit extra to participate in these sessions, which Smith said is a clear indicator of the topic's importance to the industry.

The overall message at the session was that as technologies improve, there are myriad ways energy can be conserved, Smith said. No single solution is a panacea, but by analyzing and understanding the many different elements of systems while prioritizing efficiency – even if gains are incremental – can make a tremendous difference.

The overall message at the session was that as technologies improve, there are myriad ways energy can be conserved, Smith said. No single solution is a panacea, but by analyzing and understanding the many different elements of systems while prioritizing efficiency – even if gains are incremental – can make a tremendous difference.

"There are many disparate aspects of control, design and maintenance that affect energy efficiency," Smith said. "The more they are discussed, the more people realize that small changes here and there can have large impacts one way or the other."

"We wanted to put this panel together to help bring awareness, education and understanding of the most important methods of design and control that impact energy efficiency," Smith said. "We tried to pick subject matter for the Sunday program that people would like to get a more in-depth understanding of, beyond the typical 45- or 50- minute presentations that occur through the rest of the conference. This is a four-hour program; that permits us to dive a bit deeper on the various topics."

Panel members included Doug Scott, president of VaCom Technologies; Josh Bachman, director of customer engagement at Cascade Energy; and Joseph Pillis director of engineering at Johnson Controls.

Scott's presentation offered an overview of energy management in industrial ammonia refrigeration systems. He discussed the importance of return-on-investment when modeling energy efficiencies in a system, current trends in electric utilities including renewables, how to best manage energy programs, and how operators should be continuously improving their systems.

Bachman discussed reducing system lift, optimizing part load, how to estimate energy savings, and how to use this information in building a meaningful energy program designed to increase efficiency using real-world examples.

Pillis took a deep dive into the energy benefits of using screw compressors. Attendees learned the basics of how these systems work in the context of increasing efficiencies as well as more technical aspects including the impacts of volume ratios, part-load operations, economizers and side loads. They also learned about how the types of oil used affects operations.

These presentations were followed up by a discussion session in which attendees were invited to ask questions of the panelists to better understand the materials presented, Smith said. Interested attendees were directed to additional informational resources.

Smith said he believes that high-level, high-quality educational programs such as this session and others like it, coupled with an environment in which discussion and conversation are encouraged, will be of tremendous benefit to the industry. He said he hoped attendees will apply the lessons they learned at the Phoenix session.

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IIAR Announces Awards for Presentation Excellence

Each year, some of the best minds and top talent in the industrial and commercial refrigeration industry gather from around the world at the IIAR Natural Refrigeration Conference & Expo. These experts present technical papers at the IIAR Technical Program in conjunction with this event, and each year the best, most informative presenters are honored with awards of excellence. Below are 2019's recipients.

Chris Herzog

Pete Lepschat

IIAR AWARD FOR PRESENTATION EXCELLENCE

Chris Herzog, Industrial Refrigeration Equipment Partners

Pete Lepschat, Henningsen Cold Storage Company

For their Technical Paper presentation: "Operating Cost Comparison Between Transcritical CO_2 and Ammonia Recirculation Systems in a Cold Storage Warehouse"

In their presentation, Herzog and Lepschat examined operating costs of two similar cold storage facilities: one with a modern and efficient recirculated-NH_3 system, the other with a transcritical CO_2 system. Their analysis included utility costs and other operating costs such as insurance, maintenance, personnel, compliance, water, chemical, and drainage were reviewed.

Gildardo Yañez Angli

IIAR INTERNATIONAL AWARD FOR PRESENTATION EXCELLENCE

Gildardo Yañez Angli, Bohn De Mexico

For his technical paper presentation: "Regulation of synthetic refrigerants for Latin America"

Yanez Angli's presentation analyzed why and how the air conditioning and refrigeration sector should adapt to global changes and revisit the safe use of natural refrigerants and new refrigerants that can replace the synthetic refrigerants. Natural refrigerants have the lowest potential for global contamination. This means that we should harmonize efficiency in the energy consumption and security steps. There is also a new generation of refrigerants that includes flammable refrigerants, toxic refrigerants, and refrigerants of the highest pressure of operation.

These experts present technical papers at the IIAR Technical Program in conjunction with this event, and each year the best, most informative presenters are honored with awards of excellence. Below are 2019's recipients.

IIAR AWARD FOR PRESENTATION EXCELLENCE (IN CONJUNCTION WITH NASRC)

Tristam Coffin, Whole Foods Market

Keilly Witman, KW Refrigerant Management Strategy

Tom Wolgamot, DC Engineering

For their Commercial Technical Paper Presentation: "Case Study: The First Commercial Propane/Carbon Dioxide Cascade Refrigeration System in North America"

In 2016, Whole Foods Market opened the first, and to date the only U.S. installation of a supermarket that uses a propane/CO_2 cascade rack system.

This session outlined the regulatory approval processes, the journey from system concept to final product installation, and the operations and maintenance performance to date. In addition, they included details on the multiple safety features built into the system, leak rate history, energy use, refrigerant cost, and service technician experience.

These and many more technical papers on a variety of topics are available for IIAR members to view digitally through the IIAR eLibrary in the members only section of the IIAR website. Information on how to submit a technical paper for next year's conference can also be found on IIAR's website or by calling the office at 703-312-4200.

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International Committee Focuses on Standards Adoption

The International Committee of the IIAR is working across Latin America to educate leaders in several countries in the region, helping them adopt IIAR standards to better promote safety, sustainability and international commerce.

Yesenia Rector, director of the IIAR, said all of the IIAR's standards have now been translated into Spanish, and these documents were made available for purchase for the first time at the association's annual conference in March. This is a tremendous step forward, she said, as it provides the entire region with greater access to IIAR's expertise and will energize its industry.

Specifically, Rector highlighted important updates from four different countries:

Costa Rica: Rector said that Costa Rica recently adopted three IIAR standards – IIAR 2, IIAR 4 and IIAR 8 – and promoted them as voluntary best practices. In addition, she said, the nation's regulatory bodies are now initiating the process of making these standards mandatory. Regulators are also working to implement IIAR 5, which covers system installation, as a voluntary standard, with the ultimate goal of eventually making it mandatory as well.

Each standard is up for review and revision every five years, so the staggering of the approvals ensures revisions can be made on different time frames, Rector said.

Argentina: IIAR is now working to plan a conference scheduled for Aug. 8 and 9 in Buenos Aires, Rector said.

"The idea of the seminar is to invite and include the local regularity agencies, particularly the national institutions that write the norms," Rector said. "We want them to attend so they can get to know IIAR. They're very open to this and willing to do the work of developing their safety standards [based on IIAR's standards]."

This is an important first step, Rector said. In order to work together, these regulatory bodies need to understand the IIAR organization, what it does and how its resources can be best utilized in the country and region.

The seminar's topics will include maintenance of ammonia systems, energy efficiency measures, safety and security, according to Rector.

"I think we're in the process of establishing a good relationship – a good sound basis for what's coming in the pipeline," Rector said. "The idea is for them to follow Costa Rica's example and adopt these norms, but this is, of course, a process."

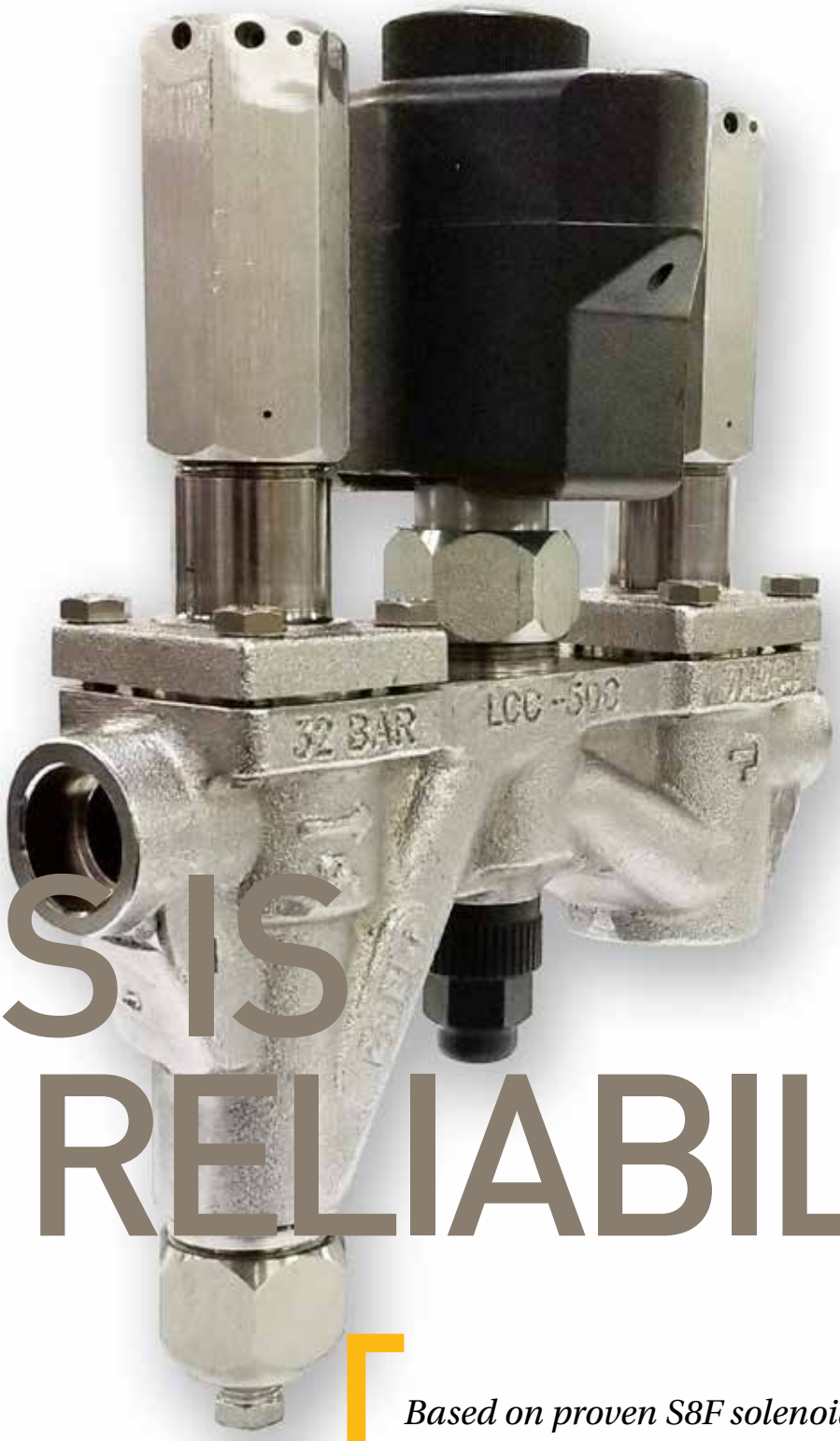
Mexico: Similar to the event in Argentina, another conference is scheduled for August in Guadalajara. The purpose is to invite and involve the county's regulatory authorities so they can gain a familiarity with IIAR and its resources.

The meeting in Mexico is a little more complex than that set for Argentina, Rector said. Because Mexico covers such a large area and has so many different states and provinces, its legislation and regulations can be a little more fragmented; however, the message will be the same.

"The idea is to bring the message of IIAR – what is the mission of the organization and how are we structured – and encourage the local authorities to get more acquainted and more knowledgeable with and about us," Rector said. "I think the opportunity lies in getting the word out to these local government agencies."

Chile: The University of Santiago is now offering a degree in refrigeration engineering, with a curriculum developed largely from IIAR materials, along with input from local industry experts and governmental regulatory agencies. "It's a joint effort using IIAR publications and Academy of Natural Refrigerants certificate materials," Rector said, "but they're also using their experience, their expertise and their knowledge of the local market."

The first students are in classes now, Rector said.



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IIAR, NASRC, Partnership Delivers New Technical Track

At this year's IIAR Natural Refrigeration Conference and Expo, held in Phoenix, the IIAR announced its partnership with the North American Sustainable Refrigeration Council. Through this partnership, educational programming at the conference was expanded to include a Commercial and Food Retail education Track.

At this year's IIAR Natural Refrigeration Conference and Expo, held in Phoenix, the IIAR announced its partnership with the North American Sustainable Refrigeration Council. Through this partnership, educational programming at the conference was expanded to include a Commercial and Food Retail education Track.

Launched in 2015, NASRC is a nonprofit organization dedicated to advancing and promoting the use of natural refrigerants in commercial applications. The organization brings stakeholders from the industry together to help clear the hurdles preventing natural refrigerants from being widely embraced in the commercial sector.

"As the refrigeration industry continues to grow, we here at IIAR have seen cross-over in the use of natural refrigerants within the industrial and commercial sectors," Eileen McKeown, IIAR vice president of marketing and sales said. "With new technology, it is now possible to use natural refrigerants in ways that were previously deemed impractical. By expanding our annual conference to include a commercial technical track, we have created new opportunities to broaden our scope."

Many conference attendees in Phoenix came from the retail food sectors of the refrigeration market, which created new networking opportunities for conference attendees and highlighted the technical opportunities to learn and advance their understanding of natural refrigerants throughout the refrigeration industry, McKeown said.

"Our partnership with NASRC helped us kick-start this program," she said. "IIAR continues its work to promote the safe and efficient use of natural refrigerants wherever they are being applied."

Three technical papers were presented in the newly formed commercial track:

Natural Refrigerant System Selection Comparisons in Commercial Systems

Presented by Dustin Lilya, specialty services production manager at DC Engineering, this session provided insights from an engineering consultant's perspective regarding how natural refrigerants compare to each other in terms of market penetration, cost, energy efficiency and performance in the commercial sector.

The First Commercial Propane/Carbon Dioxide Cascade Refrigeration System in North America

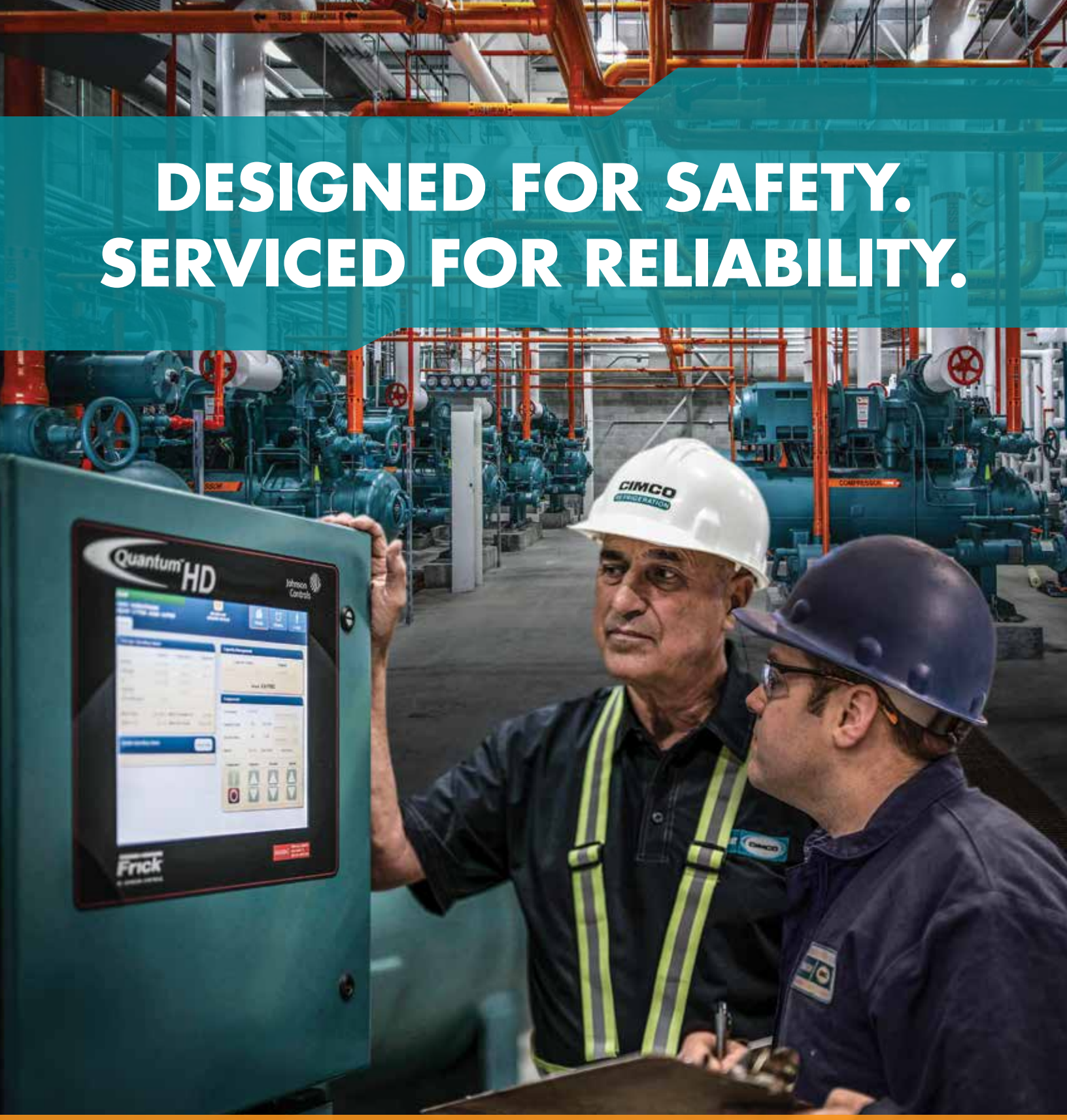
Presented by Tristam Coffin, director of sustainability and facilities for Whole Foods, Keilly Witman, owner of Kw Refrigerant Management Strategy, and Tom Wolgamot, principal at DC Engineering, this case study examined the first and only installation of a supermarket using a propane/CO_2 cascade rack system. The session outlined the regulatory approval process and the journey from concept to final product.

Fire Hazards and Mitigation Measures of ASHRAE Class A3 Refrigerants in Commercial Refrigeration Applications

Presented by Scott Davis, president of Gexcon U.S., this session explored the options available for assessing fire risks associated with propane as a refrigerant and evaluated methods to reduce these risks, specifically when charge sizes are larger than currently mandated limits.

These sessions brought a new, important focus and prioritization to the educational materials presented at the conference. "IIAR's emphasis on technical research and unique, data-driven content are well-positioned to support the needs of the commercial sector," Danielle Wright, director of NASRC said.

"We received very positive feedback from supermarket stakeholders that see the benefit in this type of educational program. There is much we can learn from the industrial sector's in-depth experience with natural refrigerants. We are honored to have partnered with IIAR on the launch of this commercial track and look forward to supporting its growth in future years," Wright added.



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Safety Committee Working on Hazardous Energy Lockout Standard for Manual Valves

The IIAR's safety committee is continuing its efforts to draft a guideline for the application of the Occupational Safety and Health Administration Standard 29 CFR 1919.147, more commonly called "the control of hazardous energy (lockout/tagout)," or LOTO for short.

The project includes a second survey to IIAR members that pays particular attention to actual refrigeration-industry practices on LOTO for manual valves, according to Kem Russell, vice president, engineering, at Doubl-Kold in Yakima, Washington, who is leading the guideline project.

OSHA's LOTO standard states that it "covers the servicing and maintenance of machines and equipment in which the unexpected energization or startup of the machines or equipment, or release of stored energy, could harm employees. This standard establishes minimum performance requirements for the control of such hazardous energy."

IIAR has stated the application of this standard usually applies to the isolation and electrical lockout/tagout of a compressor, condenser fan, evaporator, valve or other components. When referring to manually operated hand valves, however, the lines blur. Manual valves cannot open unexpectedly, but could they release stored energy? Should these valves be covered by this standard, and if so, what would be the best practices in doing so?

There are many opinions and viewpoints regarding when manual hand valves should get locked out and/or tagged which IIAR examined in depth in the February issue of the Condenser.

Another challenge is that this standard is not drafted specifically for the refrigeration industry, and as such, its application is open for interpretation.

In the February Condenser, IIAR stated that there is no clear guidance from the industry about how this standard should be applied, and IIAR's intention is to provide this information. However, in order to provide that guidance, IIAR

needed to better understand of what was being practiced in the field.

In December 2018, IIAR released a survey to its members asking for detailed information on how the LOTO standard was applied in their facilities. Two of the major findings were:

- Most companies, regardless of size, do have a LOTO program and feel that the program should apply to all components of their refrigeration systems, including manual hand valves.
- Over 80 percent of respondents indicated that they believe their LOTO program is applied to every manual hand valve in their system, even during routine tasks

This second finding was interesting, and as IIAR stated at the time, might suggest that the respondents were not refrigeration technicians who work on or operate these systems. Field observations indicate that LOTO procedures are not being used as often as respondents seemed to indicate.

It was clear to Russell, who is serving as the chairman of the sub-committee to draft guidance on LOTO, that more information was needed. The group is sending out a second survey, this time to a wider audience, to better understand how LOTO is practiced in the field.

"We've generated another survey… there's just a lot of confusion [surrounding this issue.]," Russell said. "We're hoping we can get enough responses from the survey to get some direction." Additionally, he said, IIAR has developed a proposal to have an expert in the matter to draft the guideline once the survey results are in.

The questions asked on the survey seek to probe more deeply into the issue and get a feel for what technicians and operators are actually doing in the field with manual hand valves. "We're asking if they have a lockout/tagout program, and we're asking in particular operations if they would lock out particular valves." For example, if they're changing a pressure gauge, whether they would have locked out the valve below the gauge.

Russell said the problem is a discrepancy between what's reported and what is actually happening in the field. The previous survey indicated everyone seems to be locking out everything possible, but on-site observations indicate that is not the case.

"It might be possible that someone does it, but it would be really rare," Russell said. "There might be occurrences where you could lock out a valve, but where you probably wouldn't. We're trying to zero-in on what people are actually doing… we're trying to clarify it."

At the time of this writing, the survey is close to being finalized. Russell said he expects to be able to solicit responses through June and have the results in by the end of that month. Then the results will be analyzed and given to the authority selected to draft the guidance. This process is still in flux, but Russell said he hopes the result will be a series of best practices that will increase safety across the industry.

Continuing to allow the LOTO standard for manual values in the refrigeration industry to exist in a grey area is not wise, Russell said. It's important for IIAR to take leadership in this clarification process.

"A lot of the instances where people get hurt or a release occurs have to do with a valve being opened. What can we do to reduce that potentiality of occurring," Russell asked. "We don't want to be so restrictive that you can't do your work, but our goal is to get to a point where we have better safety procedures in place dealing with manual valves."

Charitable Giving

Charitable giving can play an important role in many estate plans. Philanthropy cannot only give you great personal satisfaction, it can also give you a current income tax deduction, let you avoid capital gains tax, and reduce the amount of taxes your estate may owe when you die.

There are many ways to give to charity. You can make gifts during your lifetime or at your death. You can make gifts outright or use a trust. You can name a charity as a beneficiary in your will, or designate a charity as a beneficiary of your retirement plan or life insurance policy. Or, if your gift is substantial, you can establish a private foundation, community foundation, or donor-advised fund.

MAKING OUTRIGHT GIFTS

An outright gift is one that benefits the charity immediately and exclusively. With an outright gift you get an immediate income and gift tax deduction.

Make sure the charity is a qualified charity according to the IRS. Get a written receipt or keep a bank record for any cash donations, and get a written receipt for any property other than money.

WILL OR TRUST BEQUESTS AND BENEFICIARY DESIGNATIONS

These gifts are made by including a provision in your will or trust document, or by using a beneficiary designation form. The charity receives the gift at your death, at which time your estate can take the income and estate tax deductions.

CHARITABLE TRUSTS

Another way for you to make charitable gifts is to create a charitable trust. You can name the charity as the sole beneficiary, or you can name a non-charitable beneficiary as well, splitting the beneficial interest (this is referred to as making a partial charitable gift). The most common types of trusts used to make partial gifts to charity are the charitable lead trust and the charitable remainder trust.

There are expenses and fees associated with the creation of a trust.

CHARITABLE LEAD TRUST

A charitable lead trust pays income to a charity for a certain period of years, and then the trust principal passes back to you, your family members, or other heirs. The trust is known as a charitable lead trust because the charity gets the first, or lead, interest.

A charitable lead trust can be an excellent estate planning vehicle if you own assets that you expect will substantially appreciate in value. If created properly, a charitable lead trust allows you to keep an asset in the family and still enjoy some tax benefits.

HOW A CHARITABLE LEAD TRUST WORKS

John, who often donates to charity, creates and funds a $2 million charitable lead trust. The trust provides for fixed annual payments of $100,000 (or 5% of the initial $2 million value) to ABC Charity for 20 years. At the end of the 20-year period, the entire trust principal will go outright to John's children. Using IRS tables and assuming a 2.0% Section 7520 rate, the charity's lead interest is valued at $1,635,140, and the remainder interest is valued at $364,860. Assuming the trust assets appreciate in value, John's children will receive any amount in excess of the remainder interest ($364,860) unreduced by estate taxes.

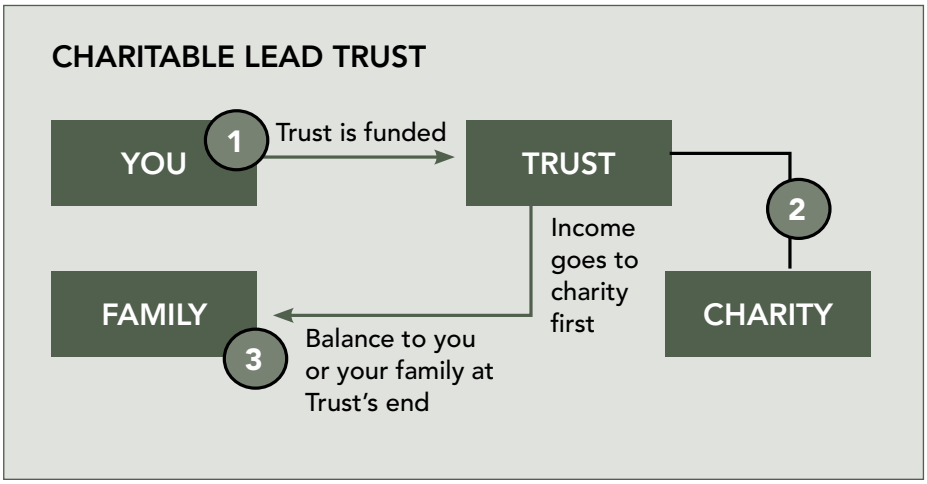
CHARITABLE REMAINDER TRUST

A charitable remainder trust is the mirror image of the charitable lead trust. Trust income is payable to you, your family members, or other heirs for a period of years, then the principal goes to your favorite charity.

A charitable remainder trust can be beneficial because it provides you with a stream of current income — a desirable feature if there won't be enough income from other sources.

HOW A CHARITABLE REMAINDER TRUST WORKS

Jane, an 80-year-old widow, creates and funds a charitable remainder trust with real estate currently valued at $1 million, and with a cost basis of $250,000. The trust provides that fixed quarterly payments be paid to her for 20 years. At the end of that period, the entire trust principal will go outright to her husband's alma mater. Using IRS tables and assuming a 2.0% Section 7520 rate, Jane receives $50,000 each year, avoids capital gains tax on $750,000, and receives an immediate income tax charitable deduction of $176,298, which can be carried forward for five years. Further, Jane has



removed $1 million, plus any future appreciation, from her gross estate.

PRIVATE FAMILY FOUNDATION

A private family foundation is a separate legal entity that can endure for many generations after your death. You create the foundation, then transfer assets to the foundation, which in turn makes grants to public charities. You and your descendants have complete control over which charities receive grants. But, unless you can contribute enough capital to generate funds for grants, the costs and complexities of a private foundation may not be worth it.

A general guideline is that you should be able to donate enough assets to generate at least $25,000 a year for grants.

COMMUNITY FOUNDATION

If you want your dollars to be spent on improving the quality of life in a particular community, consider giving to a community foundation. Similar to a private foundation, a community foundation accepts donations from many sources, and is overseen by individuals familiar with the community's particular needs, and professionals skilled at running a charitable organization.

DONOR-ADVISED FUND

Similar in some respects to a private foundation, a donor-advised fund offers an easier way for you to make a significant gift to charity over a long period of time. A donor-advised fund actually refers to an account that is held within a charitable organization. The charitable organization is a separate legal entity, but your account is not — it is merely a component of the charitable organization that holds the account. Once you transfer assets to the account, the charitable organization becomes the legal owner of the assets and has ultimate control over them. You can only advise — not direct — the charitable organization on how your contributions will be distributed to other charities.

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. Members of IIAR may use the services of Stifel for personal and business investments and take advantage of the reduced rate structure offered with IIAR membership. For additional wealth planning assistance, contact your Stifel representative: Jeff Howard or Jim Lenaghan at (251) 340-5044.

Stifel does not provide legal or tax advice. You should consult with your legal and tax advisors regarding your particular situation.

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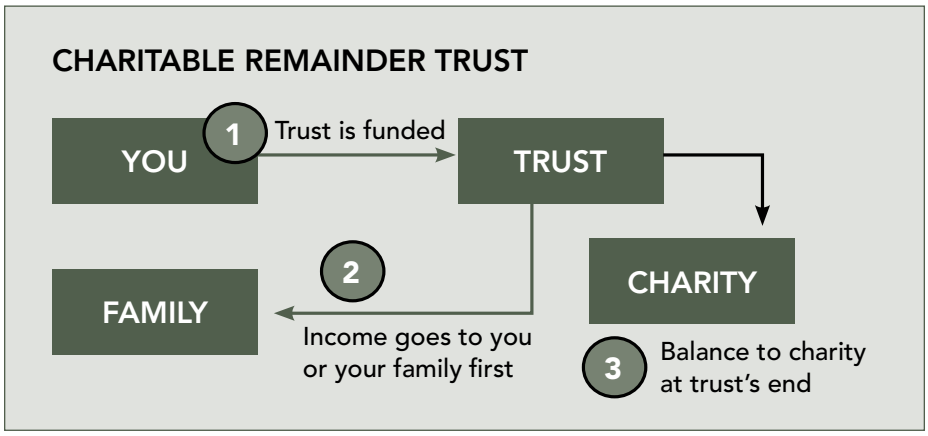

Who's Prepared?

I have been in the industrial refrigeration industry for, well, a long time. Over the decades I have seen many changes in technology and regulations. However, one thing that in more recent years really stands out is who is prepared to take over a position?

The industrial refrigeration field has been a fairly secure occupation for operators, engineers, supervisors and managers. Anyone interested in working in this field can often find a position relatively quickly, and with continued effort and learning have a good life time occupation. This is still true, but where are the new people?

Over the last few years, I have noticed a lack of personnel to fill both operational and maintenance positions, and even more so in compliance positions. You may have noticed this same thing. Here are just a few examples I have seen:

- A longtime Chief engineer at a seafood processing facility had mentioned to me on several occasions that he was thinking about retiring. He had two primary responsibilities. One, the operation and maintenance of the refrigeration system, and two, compliance with PSM Standard and RM Program. He made an effort to find someone to start working in the refrigeration department, but had limited success. People were hired, but after a few months they moved on. Eventually, a knowledgeable and qualified person working at a similar facility was hired and took over the refrigeration department. The person was a good fit for operation and maintenance of the refrigeration system, however for the compliance programs about all he could do was spell "PSM". The new Chief had a steep learning curve to understand requirements and how much effort was needed for PSM Standard and RM Program. A big void was left when the original Chief left, and the company was in a less than desirable position in meeting their compliance requirements.

- The HR/Compliance Manager at a fairly large refrigerated storage facility had many responsibilities. One of those was responsibility for the PSM Standard and RM Program. He had been doing this for about four years. One of the other facility managers had on numerous occasions sat in on meetings for audits, hazard analysis, SOP reviews, etc. This other manager called me recently asking about their Emergency Action Plan (EAP), and I told him the information I had was several years out of date, but the HR person would have the most current EAP. The manager said the HR person had recently left the company, and he was now tasked with overseeing the PSM Standard and RM Program. Although familiar with portions of the programs he had no in-depth knowledge and in many cases didn't understand what was required. I met with him to try and bring him up to speed with the programs, only to find that what we both thought had been done by the previous HR person in record keeping was sadly lacking. There was a lot of learning and work to be done.

- A very knowledgeable and hard-working refrigeration technician was employed by a refrigeration contractor. One of the technician's prime customers was a large cold storage company, which had multiple large facilities within about a 100 miles radius. The technician enjoyed what he did and worked closely with the customer for many years, and was the cold storage companies' only (notice I said "only") refrigeration person. After years of hard work, long days, and overtime during harvest, the technician finally decided to retire. The company wanted him to continue to work with them, but the technician said, "Thanks, but no thanks." There was no one prepared to fill the big void left by the technician.

- A cold storage facility had four (4) separate systems at one site all over the threshold quantity (10,000 lbs.) of ammonia, and employed a lady responsible for meeting the requirements of the PSM Standard and RM Program. This same person also had the prime responsibility of the company's food safety program, as well as several other important programs. After several years of trying to keep her head above water, she decided to stop drowning and move on. Over several years she had worked fairly regularly with the head refrigeration operator on the PSM and RM Program, but these OSHA and EPA programs really took a back seat to her other responsibilities, especially food safety. Prior to her leaving the company she met with the refrigeration operator and briefly passed on information (saved in several notebooks) and the location of electronic files for these programs. The Head of Refrigeration felt like he had been thrown into the deep end of a pool, and he had no idea how to swim.

- Another refrigerated facility with several independent systems needed additional help for operation of the refrigeration systems. They didn't have anyone within the company that wanted to, or even could, fill the position. They ended up hiring a person who was very dedicated and attentive to record keeping to monitor, and to a limited extent, operate the refrigeration systems. One of this persons tasks was logging of key system operational parameters, such as suction and discharge pressure, oil pressure, amps, temperatures, etc. After several weeks one of the reciprocating compressors in one of the systems had a major failure, requiring a complete re-build. After the event an investigation was done to determine, if possible, why the compressors had failed. The answer was found in the logged data. The new refrigeration person had dutifully and accurately recorded key parameters, one of which was oil pressure for the failed compressor. The record showed oil pressure readings of 35

psig, then 34 psig, then 33 psig, and so on over many days of time. A steady decline in oil pressure until failure. The person was doing what they were told in recording the information, but didn't have a clue to what it meant.

The above are just some examples. I am sure many of you have experienced or seen similar things happen. As in the above examples, there was either limited preparation or none at all for who would be responsible for operation and maintenance of a system, and/or working on the requirements of the PSM Standard and RM Program. What can be done?

There is wise council in the saying "Don't put all your eggs in one basket." Start training others to take over another's responsibilities sooner instead of later. For operation and maintenance of a system find good people to start learning industrial refrigeration specific to a facilities system(s). Have those people work with an experienced refrigeration operator who knows a company's specific refrigeration needs, how equipment should be operated, and be able to identify and correct improper operations long before something bad happens.

Similarly, for the meeting the requirements of the PSM Standard and RM Program at least two (2) persons should be very familiar with all aspects of these programs. Where documents are (both paper and electronic), what the documents are, what should be done, and on what time frame, etc. Another often missed aspect of these programs is how the information to fulfill the programs is organized.

I see in both the industrial refrigeration operation and maintenance field, and in the effort to meet the requirements of the PSM Standard and the RM Program the need to take this "who's prepared" issue much more serious. There are many job opportunities available. There are resources that can help people learn new skills and further advance their knowledge base. IIAR and RETA both stress education as one of their prime areas of focus (see under the Education tab on iiar.org, or on reta.com). Valuable knowledge can be accessed through these organizational websites, as well as by attending annual conferences and/or area meetings. Being prepared means doing something earlier, not just as you're walking out or in the door.

BY ERIC SMITH, P.E., LEED AP, IIAR VICE PRESIDENT AND TECHNICAL DIRECTOR

Corrosion Allowance

The latest version of IIAR 2, Standard for Safe Design of Closed-Circuit Ammonia Refrigeration Systems will soon be published as "IIAR 2-2014, with Addendum A". Among other important changes to the standard, there will no longer be a requirement for an additional 1/16" corrosion allowance (CA) on ammonia refrigeration vessels. The design of pressure vessels results in a calculation for the minimum thickness (Tmin) at various places on a vessel (e.g., shell, seams, heads, and nozzles). The ASME Boiler and Pressure Vessel Code permits the use of steel plate materials that are manufactured with an "under-tolerance" that is the smaller of 0.01 in. (0.3mm) or 6% of the nominal material thickness. In the past, this aspect of the design code has rarely been used. But with more modern and precise steel plate manufacturing, resulting in the capability to make steel plates thinner, the possibility exists that even a new vessel could be made with plate material that is less thick than the calculated Tmin, yet still be "legal". When such plates are used, corrosion can cause a vessel to no longer meet its minimum thickness requirements and can result in the need for repair, replacement, or de-rating of the vessel. It should be noted that IIAR is unaware of any catastrophic failures due to the use of "under-tolerance" plate materials, and the concerns regarding their use are because of regulatory inspections and ultimately economics.

The inclusion of corrosion allowance in the 2008 version of IIAR 2 was an effort to address the inspection of vessels that are in-service and prevent the erroneous assumption that vessels built with steel plates having an under-tolerance are consequently not compliant with the ASME B&PV code, even in the case of mild corrosion. However, it was brought to the attention of the IIAR Standards Committee (SC) that vessel manufacturers were not usually providing the additional corrosion allowance. They were providing a material corrosion allowance only when specifically requested, as is reflected in the ASME B&PV Code. This initiated a debate among interested parties about whether or not the additional corrosion allowance was necessary. The SC proffered a solution in a standards interpretation. However, when this position was included in the first public review of IIAR 2-2014, Addendum A, it was met with objections. After more debate, a corrosion allowance task force was formed to study the issue and provided background and proposals for the SC's consideration. In each of the first three public review documents published for IIAR 2-2014, Addendum A, there was opposition to the proposals. In brief, the proposals ranged from mandating the CA in all applications, only in some circumstances, to not mandating the CA in the standard. It became apparent to the committee that there would not be a solution that satisfied everyone…many people want an additional corrosion allowance to be included in the standard, but many other

people do not believe there is a compelling reason to require it.

The SC concluded that mandating CA does not necessarily contribute to safety, even though including a CA could potentially increase the chances of a vessel being used for a longer period of time. In any case, protecting against corrosion, where applicable, remains within the scope. The language included in IIAR 2-2014, Addendum A, reflects these positions. This language was voted on using a double elimination ballot process that included the entire balanced voting membership of the IIAR SC. Several proposals were presented to the committee, ranging from mandating the corrosion allowance in all cases to eliminating it altogether. A first round of balloting narrowed the proposed measures to the two most popular positions. A second round of balloting settled the final language to be included. The final measure was approved by the SC with over a 2/3 majority vote, per IIAR and ANSI procedures.

The prevailing logic for the approved language was based on the Scope of IIAR-2 being defined to specify minimum requirements for safe design of closed-circuit ammonia refrigeration systems. The absence of a corrosion allowance does not represent a safety concern if the vessel is well maintained. Vessels with corrosion are not a typical source of ammonia releases, and thereby, requiring a corrosion allowance will not necessarily increase safety. Thousands of ASME pressure vessels in our industry have no corrosion allowance and have served for decades without incident or measurable wall loss.

The problem lies with inspection. Until recently, recognized and generally accepted good engineering practices (RAGAGEP) had not been defined for the ammonia industry for inspecting vessels that have corrosion on the surface. This has led to inspectors condemning vessels with minor corrosion, simply because no RAGAGEP existed to verify that the vessel is safe. The imminent publication of IIAR-6 is the appropriate document to address RAGAGEP for inspecting vessels and to give the end user criteria by which to assess whether the vessel needs repair or replacement. Requiring new vessels to be thicker by requiring a corrosion allowance will not relieve end-users from inspection requirements.

Proper maintenance of vessels prevents corrosion from materially affecting the wall thickness. Recent advancements in surface treatment technology allow for better protection of carbon steel from corrosion. Manufacturing vessels with thicker material may not provide the best method to deal with corrosion and doing so can add complications in supporting additional vessel weight, the need to taper pipe when welding standard wall pipe to heavier vessel nozzles (increased thickness to accommodate corrosion allowance), and the increased cost for ammonia vessels as compared to other refrigerant vessels.

The SC recognizes that the cost increase for adding a 1/16" corrosion allowance may not be significant in many cases. However, the majority of the SC does not consider the material cost differential to be a substantive reason to mandate a corrosion allowance. It is the general consensus of the SC that an economically prudent purchaser will not only request the corrosion allowance, but also purchase vessels that are rated for a higher design pressure (which is also not mandated). This message is conveyed to the industry through the informative language in IIAR 2-2014, Addendum A suggesting specifiers and purchasers consider adding corrosion allowance to increase life expectancy of a vessel.

Green New Deal and Climate Policy RELATIONS

iiar government

BY LOWELL RANDEL, IIAR GOVERNMENT RELATIONS DIRECTOR

Climate policy is taking center stage with Democrats in Congress who gained control of the House of Representatives after the 2018 elections and the over 20 candidates vying for the Democratic presidential nomination in 2020. The debate, and rhetoric, is heating up and looks to continue as we head into the presidential election next year.

One of the most high-profile proposals is the so-call "Green New Deal" (GND), which has generated a lot of attention and controversy. So, just what is the GND, and what are the prospects for it and other climate proposals? The GND is an ambitious set of goals meant to address climate change and transform the nation's economy. It has taken the form of a non-binding joint resolution introduced in Congress by Rep. Alexandria Ocasio-Cortez (D-NY) and Sen. Ed Markey (D-MA).

According to the sponsors, the GND would aspire to:

- Move America to 100% clean and renewable energy
- Create millions of family supporting-wage, union jobs
- Ensure a just transition for all communities and workers to ensure economic security for people and communities that have historically relied on fossil fuel industries
- Ensure justice and equity for frontline communities by prioritizing investment, training, climate and community resiliency, economic and environmental benefits in these communities.
- Build on FDR's second bill of rights by guaranteeing:
  - A job with a family-sustaining wage, family and medical leave, vacations, and retirement security
  - High-quality education, including higher education and trade schools
  - Clean air and water and access to nature
  - Healthy food
  - High-quality health care
  - Safe, affordable, adequate housing
  - Economic environment free of monopolies
  - Economic security for all who are unable or unwilling to work

Few details have emerged regarding what specific policies or programs would be implemented to achieve the GND's goals. Republicans have criticized the GND as being extremely expensive and promoting a radical shift in the economy. Because there is a lack of information about how the GND would be implemented, estimating the total cost is very difficult. Some of the more frequently cited estimates range between $50 trillion and $100 trillion, but there are many policy variables that would impact the overall cost.

The GND resolution has garnered the support of 91 Democrats in the House of Representatives and 12 Democrats (including one independent) in the Senate. Among those supporting the GND are most of the candidates for the Democratic presidential nomination. One major exception, to date, is Joe Biden, who has not taken a formal position on the GND and has indicated his desire to find a "middle ground" on climate policy.

Because the GND was introduced as a joint resolution, Congressional approval would be more symbolic than programmatic. Passing such a resolution would not establish any new programs or regulations. However, passage would signal that there is strong enough support in Congress to enact specific legislation to support programs that will advance the GND agenda. Of course, anything passed by Congress would be subject to a potential veto by President Trump.

Since the introduction of the GND resolution, both parties have been trying to get the political upper hand. Democrats are hoping to use the GND to highlight need to take action on climate change, while Republicans are pointing to the cost and government overreach possible with the proposal.

Senate Majority Leader Mitch McConnell (R-KY) pushed for a vote on the GND resolution in the Senate to force Democrats to take a hard position on the proposal. The procedural vote was defeated by a margin of 57-0. Three Democrats and one independent joined all of the Republicans in voting against the resolution. The remaining Democrats voted "present" to avoid being on the record supporting the resolution without having to formally oppose it.

It appears that no further Congressional action on the GND is likely in the short term, but GND advocates are keeping climate change at the center of policy debates. In addition, several Democratic presidential candidates have released their own proposals that provide outline details for how they would address climate change. While reducing hydrofluorocarbons (HFCs) is not specifically mentioned in the GND, such reductions are spelled out by name in recent proposals released by former Washington Governor Jay Inslee and former Representative Beto O'Rourke.

Given the current division of power in Congress, and with President Trump in the White House, it is unlikely that the GND or any other major climate policy changes will make it into law in the near future. However, climate change will remain a high profile issue and play an important role in shaping the 2020 elections and beyond.

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Johnson Controls

Avoiding Brittle Fracture When Repressurizing Carbon Steel CO_2 Vessels That Have Lost Pressure

Martin Timm, Corporate Process Safety Manager

and

Jason Haley, CO_2 Process

ABSTRACT

A vessel containing liquid CO_2 may form dry ice and be at a temperature below -100°F (-73.3°C) if a leak or control malfunction causes its pressure to drop to atmospheric pressure. If the upset condition is corrected and the vessel is repressurized too quickly with warm high-pressure CO_2, there is a possibility of brittle fracture if the vessel material of construction is carbon steel. The industrial gas industry has developed safe and acceptable methods of repressurizing carbon steel CO_2 vessels that have lost pressure. These are described in the Compressed Gas Association guideline CGA-6.7. This paper describes the metallurgical and thermodynamic issues, and the methods used for repressurization in the industrial gas industry.

INTRODUCTION

Carbon dioxide (CO_2) as a refrigerant is increasing in popularity. It has many admirable characteristics, including low toxicity, non-flammability, high vapor density requiring less compressor volumetric capacity, ability to be used as a secondary coolant, ability to be integrated into an ammonia-CO_2 cascade system, etc. Less desirable characteristics include:

- High operating pressure
- Liquid CO_2 cannot exist at pressures below 60.4 PSIG (4.2 barg) (saturation temperature -69.9°F (-56.6°C)
- The equilibrium temperature of dry ice at atmospheric pressure is very low at -109.3°F (-78.5°C)

A temperature of -109°F (-78.5°C) is well below the minimum allowable temperature for most carbon steels that are used in pipes and vessels in industrial refrigeration.

At this low temperature, carbon steel becomes brittle, and significant derating of allowable pressure is required. While at this temperature, the material is subject to brittle fracture resulting in loss of containment, especially if stressed by impact, or by shrinkage of inflexible piping arrangements.

The industrial gas industry handles large quantities of carbon dioxide in production facilities, distribution chains, and in tanks located at customer facilities. The

trade associations serving the industrial gas industry have developed harmonized guidelines for safe repressurization of CO_2 tanks that have lost pressure[1-3]. Following these guidelines allows for safe and effective restoration of the carbon dioxide vessel to normal operating conditions.

Auto-refrigeration: Ammonia vs. CO_2

Liquid refrigerant in a partially full pressure vessel or heat-exchanger is usually considered to be saturated. Even if the liquid enters the vessel in a subcooled condition, with time the liquid equilibrates with the vapor space and reaches saturation conditions, at least at the liquid surface.

When the pressure is reduced in such a vessel, some of the liquid flashes to vapor, auto-refrigerating the remain-

ing liquid. As the pressure drops, the pool temperature follows the saturation curve for that refrigerant. If the refrigerant is ammonia at a pressure of 300 PSIG (20.7 barg), the starting temperature is 126.5°F (52.5°C), with a lower temperature of -28°F (-33.3°C) as the refrigerant reaches atmospheric pressure. This process is depicted as moving from point A to B in Figure 1. If the refrigerant is CO_2 at a pressure 300 PSIG (20.7 barg), the starting temperature is 1.7°F (-16.8°C). As the pressure of the CO_2 drops, some of it evaporates, leaving cooler liquid behind, but only until the pressure reaches 60.4 PSIG (4.2 barg) at -69.9°F (-56.6°C). This process is depicted as moving from point C to D in Figure 1. At point D, the "triple point" temperature, vapor, liquid, and solid CO_2 can coexist. But if the pressure is dropped even lower, all the liquid converts to a mixture of dry ice (solidified CO_2) and vapor at a temperature below -69.9°F (-56.6°C). As the pressure of the dry ice/vapor mixture is dropped from the triple point down to atmospheric pressure, temperature of the solid dry ice and the vapor in contact with it reaches -109.3°F (-78.5°C), depicted as moving from point D to E in Figure 1.

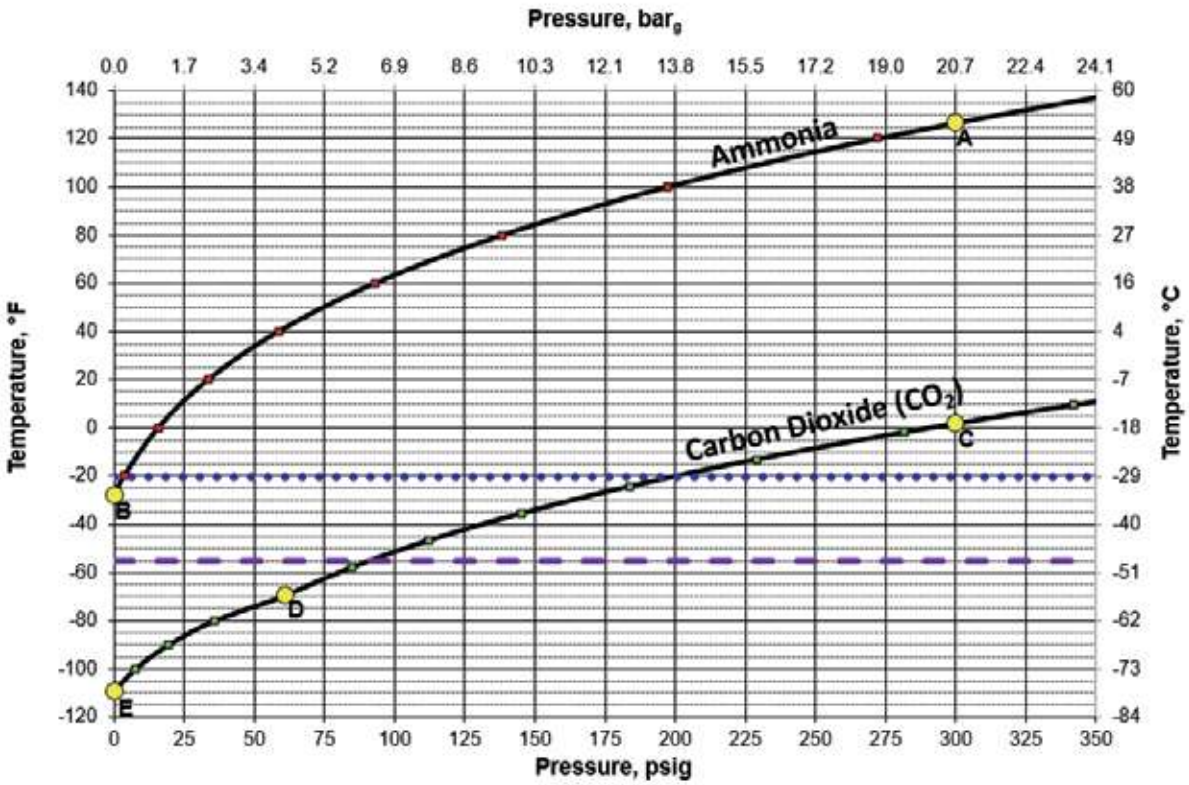
Minimum Design Metal Temperature (MDMT)

The horizontal dotted and dashed lines in Figure 1 represent the temperature range of -20°F to -55°F (-28.9°C to -48.3°C). Carbon steel pressure vessels normally show a minimum design metal temperature (MDMT) on the ASME nameplate somewhere in this range and are often dual stamped. The lowest MDMT shown is often no lower than -55°F (-28.9°C) or so.

The problem regarding repressurization of CO_2 vessels that have lost pressure is that when the repressurization process is started, the vessel and its contents may be at a temperature below the lowest listed MDMT, and care must be exercised to avoid adding heat and raising pressure in the vapor space faster than the heat can be transferred to the cold dry ice at the bottom of the vessel. If the pressure rise occurs slowly and/or in controlled steps, the dry ice has time to absorb heat and reliquefy, equilibrating with the vapor space, and the metal walls can absorb heat and rise to a temperature where they are no longer in a brittle condition.

If the pressure rise occurs too quickly, the stratified tank may have a uniform pressure throughout, but warmer vapor at the top and much colder dry ice and/or liquid at the bottom, in contact with the carbon steel lower shell. Thus, the vessel may be in a vulnerable condition if repressurized too quickly. "Too quickly" is a relative term. It is meant to convey the idea that the rate of change is such that contents of the vessel are able to equilibrate by heat transfer from warmest areas into the coldest areas. "Safe" rates of change are addressed in the referenced documents mentioned earlier[1-3], but the preferred time scale for repressurization to the normal operating state is on the order of hours rather than minutes.

Figure 1. Saturation Temperature vs. Pressure Ammonia and CO_2.



CARBON STEEL BRITTLE FRACTURE

Treatment of Embrittlement in the IIAR CO_2 Handbook

The possibility of low temperature embrittlement is mentioned in Chapter 1 of the IIAR CO_2 Handbook[4] and also in section 16 of the sample Safety Data Sheet in Chapter 4. Chapter 7 in the handbook, the evaporator chapter, elaborates that "carbon steel is known to become brittle at temperatures below about -20°F (-28.9°C) and prone to fracture when subjected to impact loading even though the strength of the metal increases as the temperature is reduced." Chapter 15 in the handbook, the pressure and leak testing chapter, states that "A repaired or modified section of an existing system must be above the ductile-brittle transition temperature before pressure or leak testing is carried out. Sections of pipe under insulation with residual liquid CO_2 may be colder."

Chapter 7 in the CO_2 Handbook states that stainless steel "is not susceptible to embrittlement even at extremely low (cryogenic) temperatures," and provides similar guidance for copper.

So, clearly, IIAR's CO_2 Handbook has multiple statements alerting the reader to the possibility of embrittlement of carbon steel when exposed to temperatures approaching the triple point temperature and temperature of dry ice at atmospheric pressure. While the alerts are valuable and appropriate, however, they do not provide specific guidance on how to deal with a pressure vessel that has lost pressure and is in a low temperature condition.

Incident Reports

Failure of a CO_2 pressure vessel is a relatively rare event, and failure due to repressurization from a cold condition is even more rare, possibly due to the rarity of a total loss of pressure and the industrial gas industry having guidelines in place on how to safely repressurize. The authors were unable to find any published reports regarding failure of a CO_2 pressure vessel during repressurization. The following references are included because they provide good background information on CO_2 vessel design.

In one of the earliest reports found, Copeland and Wishart[5] from Sandia Laboratory discussed issues around coarse-grained carbon steels and speculated on metallurgical aspects related to the reported failure in 1974 of a storage vessel at a CO_2 production facility. They stated that original press reports suggested the initial failure was of an ammonia vessel, but they concluded the vessel that failed first probably contained CO_2. Copeland and Wishart reported that Sandia evaluated the several CO_2 tanks they had in service at the time and, based on considerations of potential brittle fracture, elected to replace a vessel made from coarse-grained A515 steel with a new tank manufactured from A516 steel. None of the vessels discussed appear to have been used in a closed-cycle CO_2 refrigeration system.

Zhang and Schork[6] describe four incidents in which CO_2 vessels catastrophically failed, including two in which brittle fracture played a role, but those scenarios involved overfilling or overheating of trapped contents rather than intentional repressurization from a cold, low-pressure state. None of the four incidents involved vessels used in closed-cycle refrigeration systems. One of the four vessel failures is described in detail by Clayton and Griffin7.

Evaluation Methods

Engineering literature in various industries address concerns about brittle fracture of carbon steel vessels and piping systems. The following references are representative of publications that examine the analytical methods that can be applied to designing and operating vessels within a safe range. Such considerations are the foundation for the CO_2 vessel repressurization methods commonly used in the industrial gas industry.

Riley[8] provides a general discussion of stresses in ammonia refrigeration piping and of the requirement for flexibility analysis and/or the derating of certain materials in piping systems operating below -20°F (-28.9°C).

Kumar[9] provides a detailed discussion of brittle fracture metallurgy and selection of materials for hydrocarbon applications when low-temperature excursions are infrequent but possible. He includes references to applicable ASME and API guidance documents.

King[10] states that the following three conditions are necessary for brittle fracture to occur:

1. A susceptible steel (susceptibility increases as temperature decreases);
2. A stress riser, such as a crack or a notch (as often is found in weld defects);
3. A sufficient applied stress above a minimum stress level (~7000 psi [48MPa] for carbon steels).

He represents this graphically with the diagram reproduced in Figure 2. King goes on to recommend an analysis approach and provide examples. His approach is consistent with the methods embodied in the discussion and recommendations in CGA Guideline G-6.7 and by AIGA and EIGA in their harmonized documents.

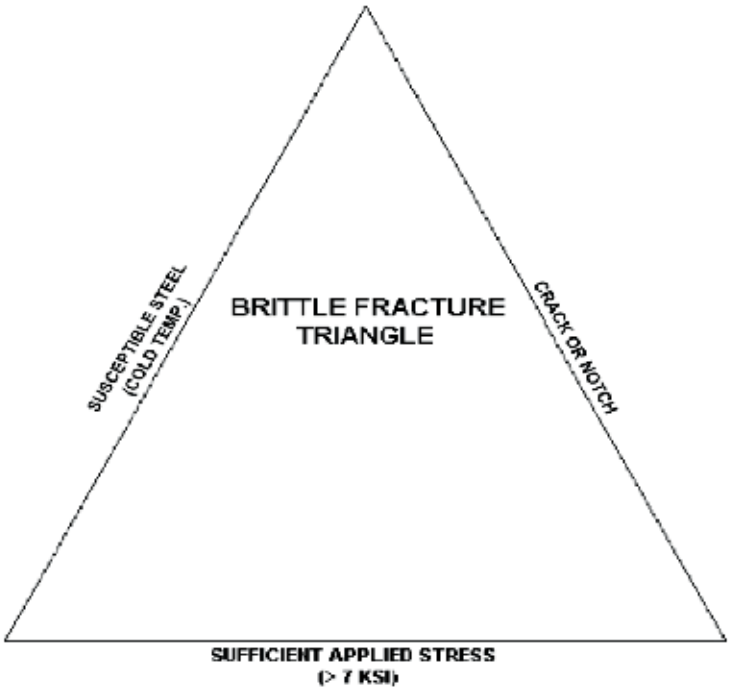
Pragar[11] provides a detailed review of the history of impact testing exemption curves, and makes a strong argument that the curves in the ASME BPVC Section VIII are too conservative for steels made with modern manufacturing methods.

Banac et al[12] discuss brittle fractures in ammonia-related industries. They discuss API methods for vessel evaluation regarding brittle fracture potential and describe some incidents that have occurred in the ammonia production industry. Like King, Banac et al discuss the three conditions necessary for brittle fracture, but they also state that high residual stresses can be present due to welding or heat treatment, even before the application of internal pressure.

CO_2 TEMPERATURE AND PRESSURE VS. TYPICAL CARBON STEEL VESSEL RATING

A useful technique when discussing repressurization methods is to superimpose allowable temperature vs pressure for a given vessel on a graph like that shown in Figure 1. Figure 3 shows such a graph for a "sample" CO_2 storage vessel constructed from normalized A516 carbon steel, a common material of construction for carbon dioxide storage vessels, and capable of holding 30 tons of CO_2. The boundary for the brittle zone was calculated as recommended in ASME BPV Code[13], including section UCS 66. Note that this graph is specific to the material, and wall thickness assumed for this example is representative of the trends that are observed. Similar

Figure 2. Brittle Fracture Triangle (King[10])



graphs can be constructed for vessels manufactured with different materials, wall thicknesses, heat treatments, etc., and many combinations will result in making the vessel either more or less susceptible to brittle fracture.

For this sample vessel, a dramatic reduction in allowable pressure is seen at temperatures below about -50°F (-45.5°C). Below -50°F (-45.5°C), the carbon steel is in a brittle condition. It is desirable to avoid operating in the cross-hatched area (below the solid black line) due to the possibly of brittle fracture of the material.

Now consider what happens if the contents of such a vessel are depressurized. Figure 4 illustrates the reduction in temperature as the vessel pressure drops. In this case, for this A516 vessel, the saturation temperature of the CO_2 at a given pressure never drops below the vessel's minimum allowable temperature for that pressure. There is little or no danger of brittle fracture as the vessel is depressurizing.

Figure 3. Comparison of CO_2 T-P Curve and SA516 Typical Pressure Rating.

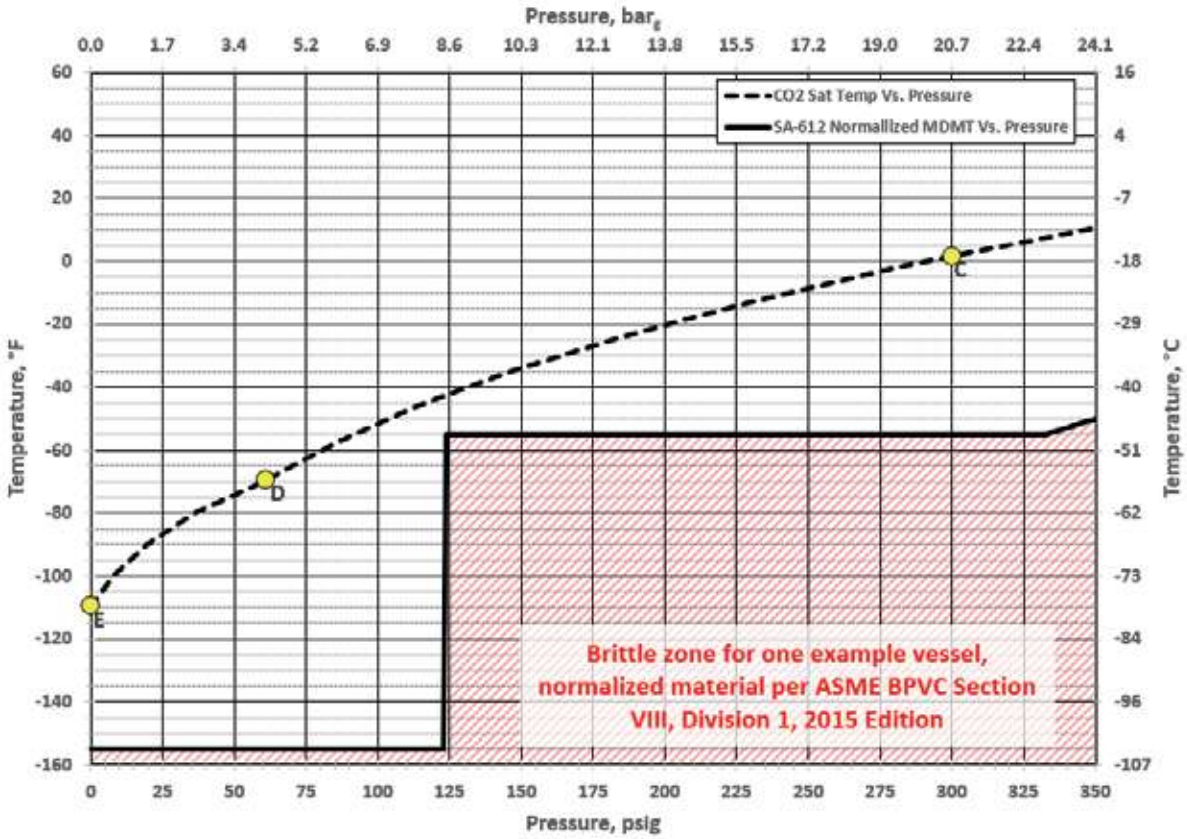
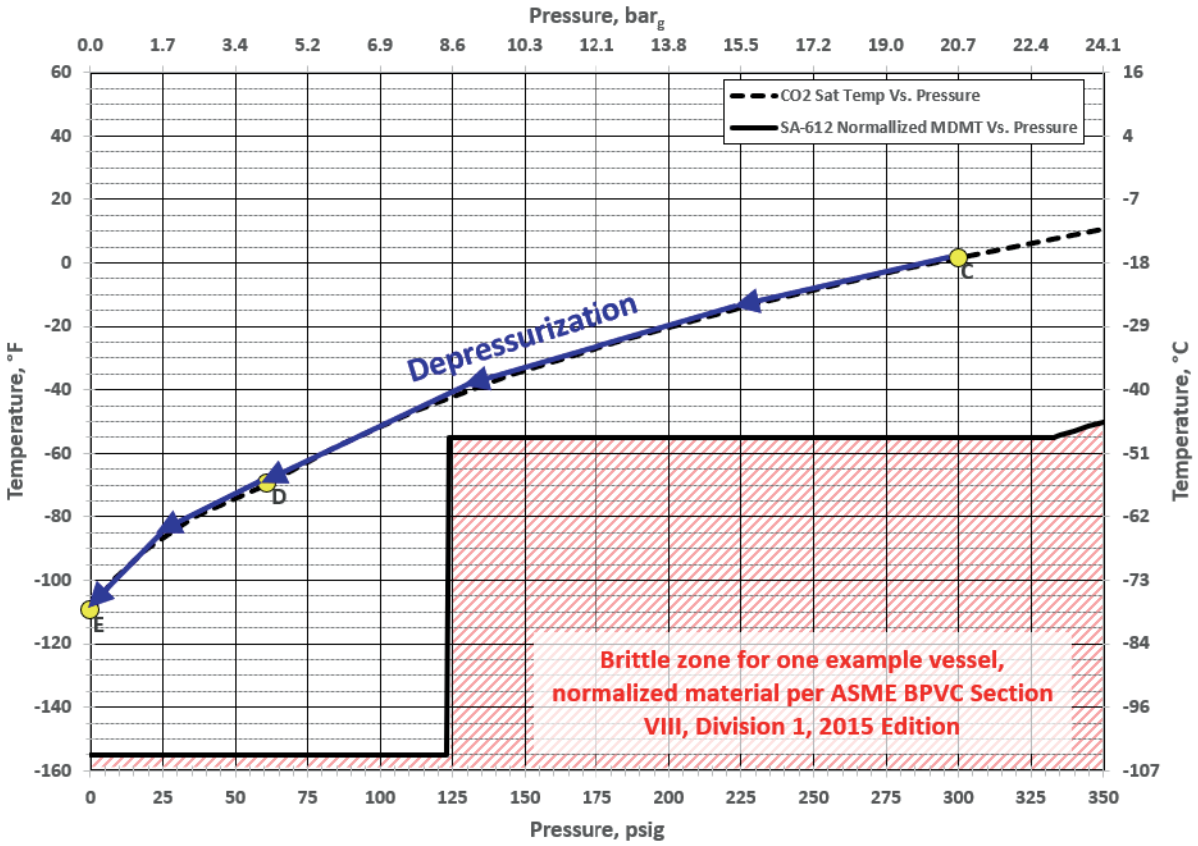


Figure 4. Depressurization Process.



Let's now consider a couple of pathways that could occur during the repressurization process. Figure 5 shows a rapid repressurization process. It assumes that a source of relatively warm carbon dioxide gas is added to the head space at a rapid rate, causing the pressure to rise quickly, creating a non-equilibrium condition within the vessel.

Given enough time, the warm gas would equilibrate with the cold dry ice and/or cold CO_2 liquid in the vessel, but initially, near-equilibrium conditions only exist near the surface of where the gas is contacting the liquid pool or residual dry ice. If the repressurization has raised the pressure in the head space to 150 psig (10.3 barg), but there is residual dry ice in the bottom of the vessel, instrument lines, etc., that dry ice may still be at -109°F (-78.3°C), as illustrated by point "F" in Figure 5. From this figure, it can be seen that point F is in the "brittle region," so those portions of the vessel at that combination of pressure and temperature may be vulnerable to brittle fracture.

Raising pressure at a "rapid rate" may be possible in a large industrial refrigeration system where multiple evaporators are operating in parallel and high pressure defrost gas is available from a central machinery room. If this gas is introduced in an uncontrolled fashion to a small "iced" vessel in the system, it might be possible to increase the pressure in the vessel very quickly. On the other hand, in small or simple systems that don't utilize multiple evaporators, it may be difficult to generate enough high-pressure gas to effect repressurization at even the desired slower rate, much less a fast rate. In general, the desired time scale of repressurization to avoid the brittle fracture range is on the order of hours, not minutes.

Next, let's consider an alternate repressurization process, as shown in Figure 6. In this process, warm gas is added to the head space of the vessel to raise its pressure to 100 PSIG (6.9 barg) (point G), and then the pressure is held there for enough time to reach near-equilibrium between the head space and any liquid or dry ice in the bottom of the vessel, eventually reaching point H. Further addition of warm gas or heat to a vessel containing only liquid and vapor would then be expected to follow the saturation curve upwards towards point C.

The recommended methods in CGA 6.7 and harmonized industrial gas industry documents are similar to the one shown in Figure 6. The recommended methods include variations on how heat is added back into the vessel in the form of vapor or liquid. Further details are provided below.

WAYS A CO_2 VESSEL CAN ICE IN A CLOSED CYCLE REFRIGERATION SYSTEM

Carbon dioxide has the unique physical property of forming a solid phase in equilibrium with a vapor phase, with an absence of liquid phase below a certain pressure. This condition occurs when the pressure of liquid carbon dioxide is allowed, either intentionally or accidently, to be reduced below its triple point

Figure 5. Rapid Repressurization.

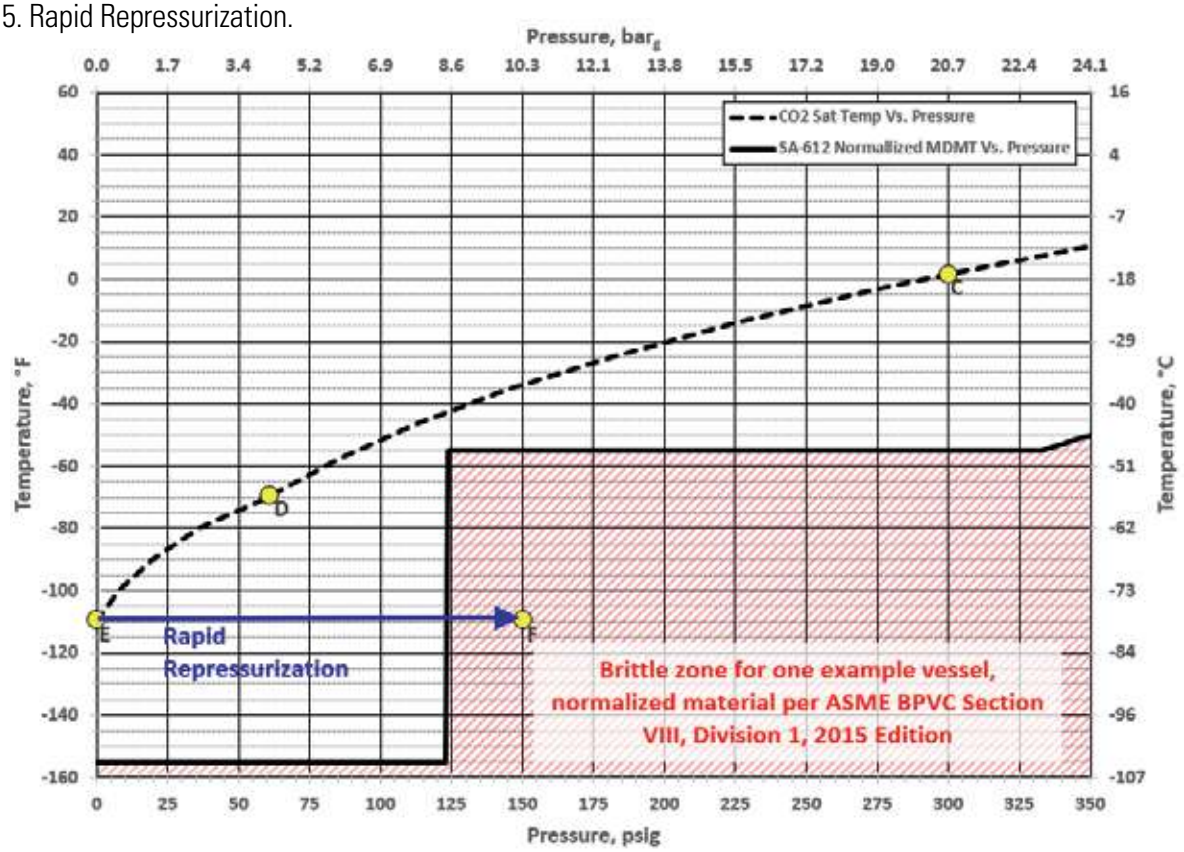
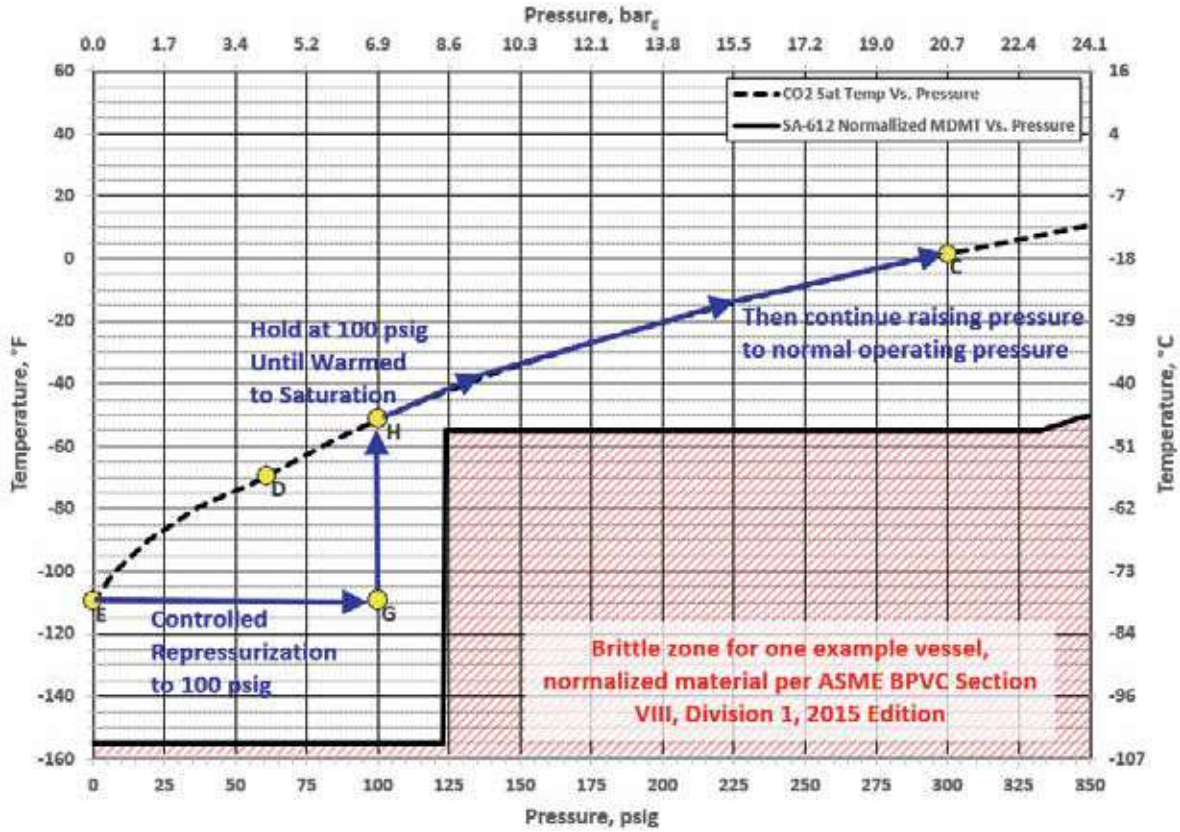


Figure 6. Controlled Repressurization with Hold Point.



pressure of 60.4 psig (4.2 barg). When this occurs, the liquid contents within a tank or vessel are converted to a mixture of solid carbon dioxide and vapor. When this happens in an undesired condition it is commonly referred to as "icing" the tank or vessel.

Leaks

One cause of liquid content losing pressure and subsequent "icing" of a tank is loss of pressure due to a leak to the atmosphere. Gasket failures due to improper selection and/or installation, cracks in piping or vessels, pressure relief valves "sticking open," and/or leaks at threaded connection are common causes of icing. Valves accidently left open during maintenance, or opened incorrectly during operation, also can cause a loss of pressure leading to formation of dry ice.

Control Failures

Within a CO_2 refrigeration system, the pressure of a CO_2 refrigerated evaporator may be managed by a control loop incorporating a downstream CO_2 compressor. Failure of this control loop could result in lower than desired operating pressure. If this event were to continue, low pressure cut-out devices should de-energize compression equipment prior to it reaching an unsafe operating pressure. However, if these systems were to fail and evaporator pressure was allowed to drop below 60.4 psig (4.2 barg), the result would be formation of dry ice in the evaporator.

Charging Liquid CO_2 Directly into an Evacuated System

During initial charging of a CO_2 refrigeration circuit, pressure should be raised to above the pressure corresponding to the MDMT of the vessel using gaseous CO_2. If liquid CO_2 is "sprayed" into piping or vessels that are at a pressure below the triple point pressure of 60.4 psig (4.2 barg), the liquid will flash into dry ice "snow" and vapor. As the dry ice snow deposits within the vessel, surfaces may be cooled down below the MDMT and stresses may be created due to differential thermal contraction of the metal.

REPRESSURIZATION OPTIONS IN G-6.7

The industrial gas industry, as outlined in CGA G-6.7 "Safe Handling of Liquid Carbon Dioxide Containers That Have Lost Pressure" has recommended four methods as safe practices to repressurize a container in an upset condition. These methods are based on decades of experience using carbon steel vessels in liquid carbon dioxide storage applications. The following descriptions are only summaries. Reader are highly encouraged to obtain CGA G-6.7 if in the USA, or the harmonized versions in regions outside the USA.

Method 1 – Unassisted Natural Repressurization

In this method, the container is isolated and pressure within is allowed to rise to no more than 100 psig (6.9 barg) until all signs of dry ice are gone. During this time, ambient heat slowly warms the contained CO_2 causing the dry ice to melt and resulting liquid to warm to normal operating temperatures.

This method has the disadvantage of being extremely slow depending on the inventory of solidified CO_2, ambient temperature, and quality of the insulation on the container. This method does, however, offer the benefit of being a self-regulating process.

Method 2 – Hot Gas Warming at No Pressure

This method begins by removing the container from service and any venting and remaining pressure in the container. Pressure should be removed through a process of first draining any residual liquid carbon dioxide from the tank through a liquid connection. After all liquid carbon dioxide is removed from the container it should be depressurized completely through a vapor connection. With the tank now under no pressure, large quantities of warm, dry air or gas may be introduced to the container through an open manway or connection and vented to atmosphere. The heat within this gas will cause the dry ice to sublime to vapor carbon dioxide, which will then be carried away along with the purge gas.

The major advantage of this method is that there is no risk of container rupture, as all warming is conducted with no pressure on the container. As far as disadvantages, the hot gas warming method can cause large volumes of carbon dioxide to be released as the dry ice is sublimed. If not vented correctly this can create an asphyxiation hazard. Also, prior to returning the container to service, it must be cleaned and purged to remove moisture and contaminants that were introduced via åthe purge gas. Finally, this method may necessitate entry through a manway, which would require confined space entry restrictions and procedures.

Method 3 – Carbon Dioxide Gas Pressurization up to 100 psig (6.9 barg)

This method is commonly the first step of a two-part process, in which this approach is subsequently followed by Method 4, outlined below.

This method attempts to repressurize the container to 100 psig (6.9 barg) using an external source of vapor carbon dioxide and therefore partially liquefy the dry ice held within the depressurized container. The external source of carbon dioxide, bulk liquid cargo trailers or other, is connected to the depressurized container and allowed to send vapor carbon dioxide. This vapor will condense against the dry ice, simultaneously causing the dry ice to melt. The resulting liquid level in the tank will rise to cover the dry ice at which time the incoming vapor will rapidly pressurize the tank.

Method 3 offers a more rapid way to repressurize the container to 100 psig (6.9 barg) while maintaining the container below its minimum stress level for brittle fracture.

All of this is accomplished without the loss of carbon dioxide from the system.

This method does require further action, as on its own it does not provide enough warming to the tank to ensure all dry ice held within the container has been melted. Further warming and recirculation of the liquid per Method 4 is recommended.

One disadvantage of this method is that if a system is already at the proper charge level when the icing event happens, it will be overcharged with CO_2 once the thaw is completed unless the source of carbon dioxide gas is from within another part of the system. CO_2 evaporators already equipped with hot gas defrost are ideally suited for this method, but if constructed from carbon steel the pressure should be limited to 100 psig (6.9 barg) until all dry

ice has been liquified and temperatures raised back above the MDMT.

Method 4 – Recirculation of Warmed Liquid

This method should be preceded by Method 3 unless the container is already at or above 100 psig (6.9 barg). In this method liquid carbon dioxide is pumped from the tank, sent through an external heater, and then returned to the tank, causing any remaining dry ice to melt and promoting a more uniform temperature throughout the tank contents. This circulation operation can be stopped after the container pressure has reached a pressure exceeding the pressure coincident with the MDMT of the container. If the pressure condition remains stable, indicating its contents are at or near equilibrium, the container may be returned to service.

Method 4 offers a relatively rapid method for returning a container to normal service while minimizing the risk that the vapor pressure in the container will exceed the equilibrium pressure of the circulating liquid. During this procedure, no carbon dioxide is released from the system. This method does require sourcing, setting up, and energizing additional equipment with minimal connection requirements. The additional equipment may or may not be readily available at the typical industrial refrigeration facility.

Comments on the Four Methods

The four methods summarized were originally recommended for liquid carbon- dioxide storage applications and based on experiences in that industry segment. However, the advantages and disadvantages of each are still relevant when evaluating for use in a closed-cycle CO_2 refrigeration application. The closed-cycle CO_2 refrigeration application also brings with it some additional or different criteria.

One important criterion is the acceptable time until the equipment is brought back online. If part of a multi-unit refrigeration system in which running without a single unit is acceptable, Method 1 may provide a simplistic and self-regulating option, without the need of external equipment, gas sources, or outside resources.

Another aspect that must be considered is the complexity of the equipment that has depressurized. In a closed-cycle refrigeration system, the equipment that has iced may not just be a simple vessel. It may consist of heat exchangers, receivers, etc., all needing to be safely returned to pressure. With this type of equipment comes additional challenges such as restrictive geometries posed by tubes and baffles in heat exchangers, or additional working fluids within the system, as is the case with ammonia/CO_2 cascade systems.

Method 3, controlled repressurization with warm gas, is probably the most widely applicable for the industrial refrigeration industry due to a familiarity and comfort level with hot gas defrost of evaporator coils. The concepts and practicalities are similar.

Each refrigeration end user should evaluate their system to determine what system limitations exist, which criteria are most important to them, and which repressurization methods best fit their system. These should then be appropriately documented in standard operating procedures and operating manuals.

Consideration of which repressurization method to be used should not be limited to end users. Planning for the possible need for repressurization of a system that has lost pressure should start back in the system design phase. The inclusion of appropriate nozzles and connections to facilitate a recommended repressurization method should be considered.

CONCLUSIONS AND RECOMMENDATIONS

The risk of "icing up" a pressure vessel or heat exchanger in CO_2 refrigeration service is credible but of low probability. Many owners of CO_2 refrigeration systems and their contractors will never experience this phenomenon. Still, owners and their contractors should know what to do if it happens.

Repressurization can be done safely with methods similar to industrial gas industry methods detailed in CGA G-6.7 and internationally harmonized regional versions.

The authors of this paper recommend that industrial users review their refrigeration system to determine if carbon steel vessels and heat exchangers are being used for carbon dioxide, and whether there are credible scenarios for a loss of pressure that would cause the CO_2 temperature to drop below the minimum design metal temperature (MDMT). If a credible threat of pressure loss exists, the following steps, if not already taken, should be considered:

1. Include these scenarios in process hazard analysis documentation (HAZOP, what-ifs, etc.).
2. Include appropriate cautions and warnings in operating procedures and maintenance procedures
3. Obtain CGA G-6.7 or one of the harmonized versions for your region and studying the safety information and guidelines provided.
4. Assemble a task force to examine how methods best suited to storage tanks in the industrial gas industry might be modified for the needs of the industrial refrigeration industry and applied in an industrial refrigeration facility.
5. Train personnel on proper steps to take if repressurization of an "iced" system must be performed.

In addition, the authors of this paper suggest that IIAR consider including recommendations for design details that might facilitate vessel and heat exchanger thawing/warming in future editions of the CO_2 Handbook and related IIAR documents.

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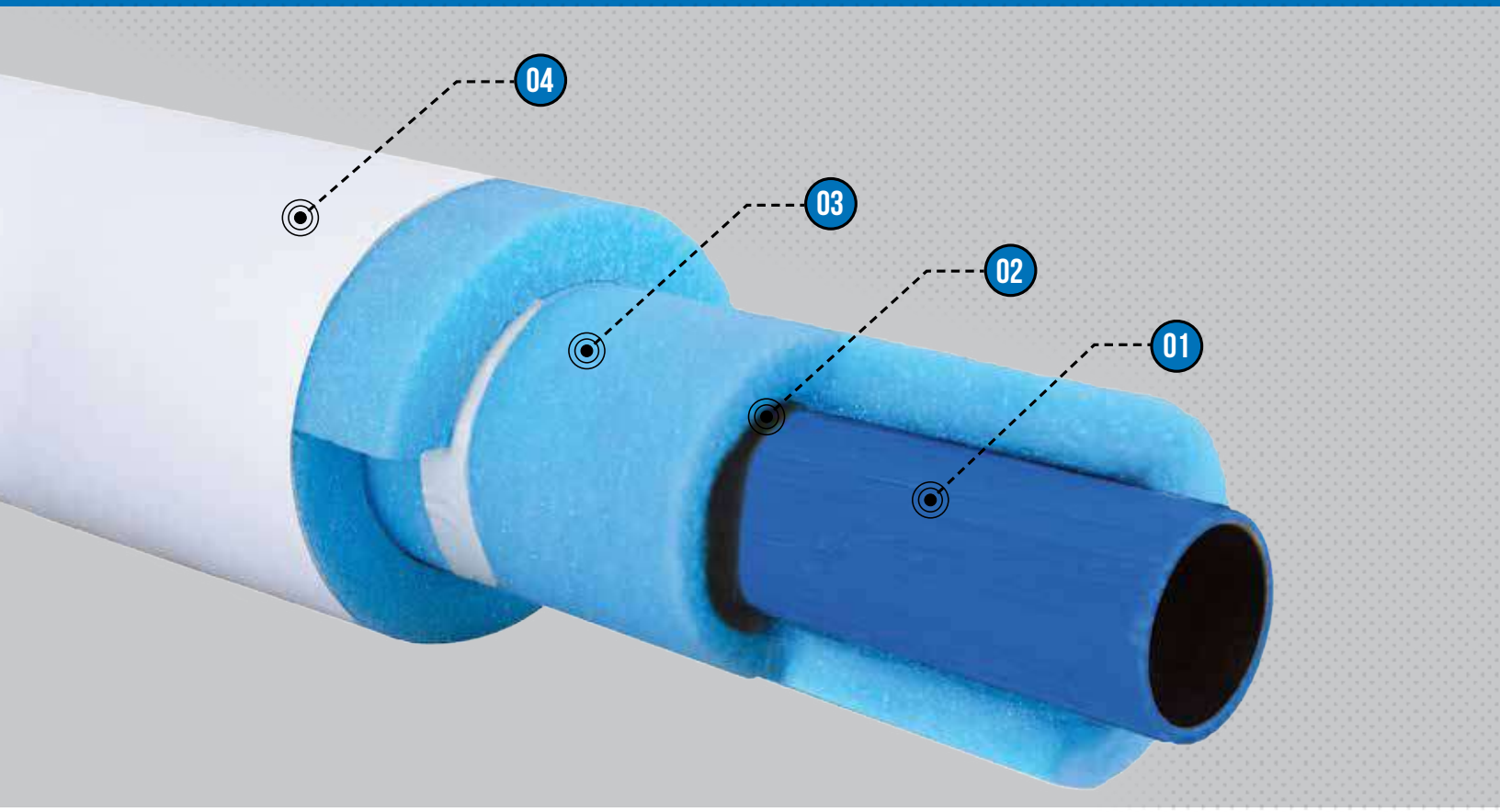

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