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CONDENSER

IIAR-2 GOES TO WORK

Code Bodies and Regulators Recognize Standard

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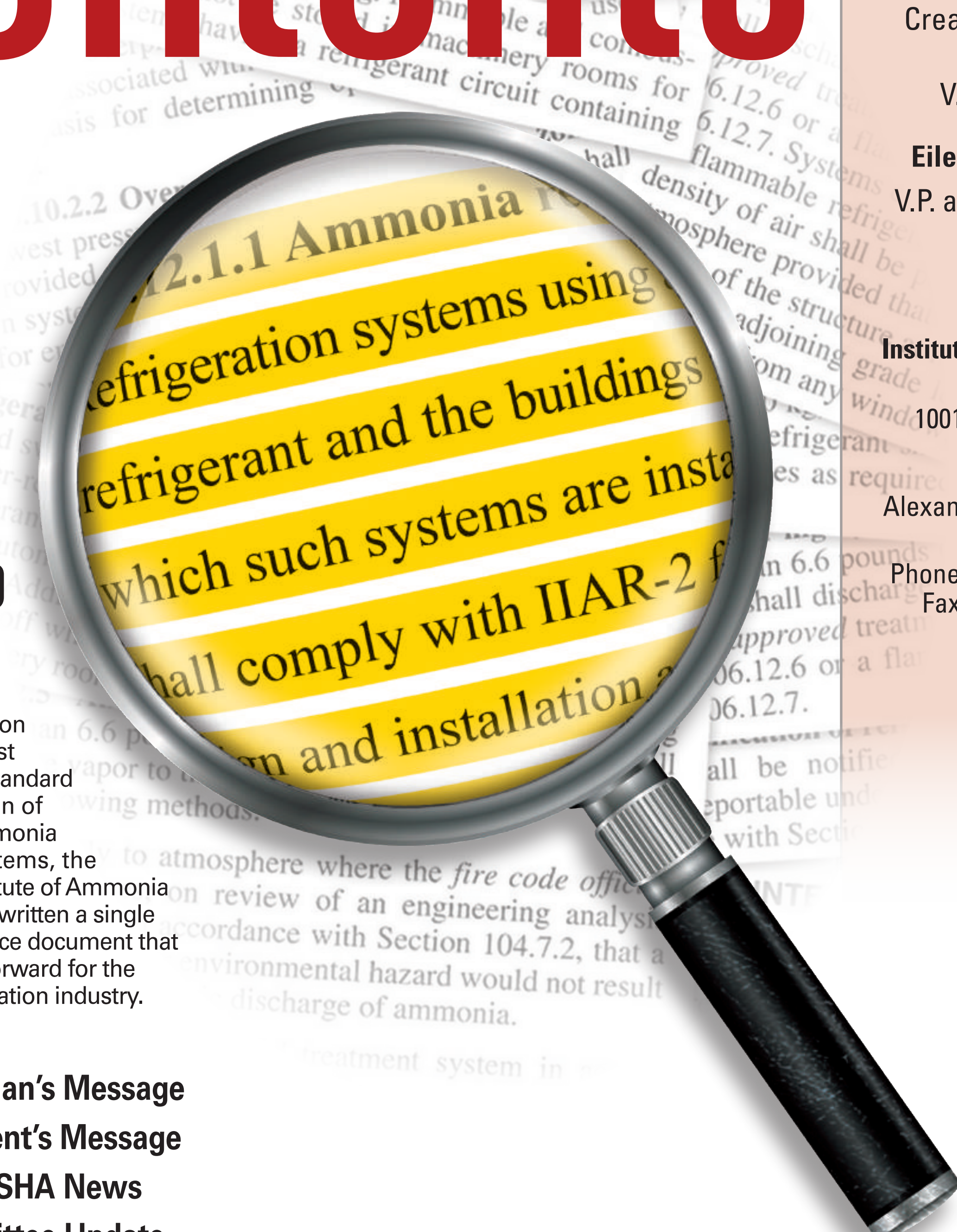


Parker

chairman's MESSAGE

THOMAS LEIGHTY

We are officially three months away from the 2016 IIAR conference, and while most people are busy getting ready for the holidays, the IIAR team is also hard at work adding the final touches to our annual conference programming.

While most people are busy getting ready for the holidays, the IIAR team is also hard at work adding the final touches to our annual conference programming.

I am happy and excited to report to you that we are looking forward to delivering another outstanding and record-breaking event next year. IIAR will be hosting the 2016 Industrial Refrigeration Conference & Exhibition in Orlando, FL on March 20-23, 2016.

I believe this year's conference will reflect our drive to incorporate your insights and suggestions into our conference program.

This year, I'm especially pleased to announce that we'll be releasing a new member benefit, the IIAR app which is totally new, written specifically for us. In today's world of fast-paced communications, mobile technology has become more important than ever. With the release of this app, IIAR is making the vital technical resources and member services we depend on as an industry even more accessible. Watch in the next several weeks for the release. I personally cannot wait!

Meanwhile, we'll be debuting another installation of the popular Sunday educational program in 2016, the IIAR-2 Education Program. This event will give attendees an overview of how recent updates to the IIAR-2 standard will impact plant and equipment design as well as regulatory compliance expectations, and we expect it to be one of our most valuable and useful programs yet.

Here in this column, I'd like to draw your attention to the one member benefit that fuels every major task we accomplish on behalf of this industry, and that is the hard work and dedication of our volunteer committee members.

As you may know, IIAR-2, the industry's first comprehensive safety standard, has been released. To accomplish this task, the Standards Committee members and IIAR staff spent countless hours completing the exhausting work of carrying the standard through an arduous ANSI review process.

Their work highlights the initiative and focus that every IIAR committee displays when our volunteer committee members go to work to create something special from which we all benefit.

We highlight the IIAR-2 here but it is not the only work done in the committees. There are many other achievements, too numerous to list. Each committee is focused on different initiatives; collectively they are making the ammonia refrigeration world safer and our effort stronger by ensuring all of us have access to the best resources available.

As IIAR members, your involvement and input within this industry is the sole force that moves us all forward.

Our committees move our ideas and initiatives from abstract goals into reality. And at the same time, our Board officers and voting members bring so much vitality and substance to our organization as they direct the goals of the IIAR committees.

If you are an IIAR member and have not yet had a chance to get involved in the work of your industry, I urge you to take a look at how your expertise might help an IIAR committee further its work goals.

I'm looking forward to welcoming you in Orlando in 2016 to learn, share and build our knowledge base together. While the official conference dates extend from March 20th to the 23rd, our committees will meet over the previous weekend and all members are welcome to attend committee meetings on the Sunday morning preceding the conference.

I would like to extend a special welcome in advance to new members and first-time conference attendees. New attendees are one of the key markers of the success of our conference programming and we want to do all we can to get you involved and provide to you a great conference experience.

As we close out 2015 and look forward to a new cycle of growth for our organization, I'd like to extend a special thank you – to our sponsors for their support, and to you, our members, for the incredible engagement and dedication that you bring to this organization.

Please accept my very best wishes for a safe and happy holiday season and a prosperous 2016 in your business activities and family life. I look forward to seeing you in sunny Orlando in March.

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president's MESSAGE

BY DAVE RULE

As you've likely noticed, this issue of the Condenser is all about the re-release of IIAR-2, the first comprehensive code standard for the safe, reliable and efficient design of ammonia refrigeration systems.

We're dedicating so much space to IIAR-2 because it is perhaps one of the most important, long reaching projects our association has completed in recent years. As your association president, I'm using my column this month to outline why IIAR-2 is so important to our industry and to you, our members.

The standards development process is complex and often spans years, and the development of IIAR-2 has been no exception. To recognize the work behind this monumental effort is to recognize the dedication and support of the many standards committee members and IIAR staff who have taken the writing and review process to completion – not to mention the hundreds of IIAR members and industry professionals who have lent their support by providing literally hundreds of comments during multiple rounds of public reviews.

I'm proud to announce that IIAR was able to address every one of those comments, an effort that took over three years of work by dedicated individuals who are passionate about our industry and its future.

The result is a standard that truly reflects the ideal ANSI process, balanced by the participation of members from every sector of our business. From engineers, to end-users, to academics, to regulators, IIAR-2 mirrors the broad input of our industry.

And this groundbreaking standard also highlights one of the most important goals of our association, and gets to the heart of the very reason we exist – to inform the codes and practices that dictate how our industry will operate.

The process is never an easy one. To create a standard of the breadth and substance of IIAR-2, an organization must be prepared to truly address all concerns posed by those participating in the standard's creation.

For us, that has meant working through the many valuable viewpoints of every participant, regardless of whether or not the opinions expressed fall in line with those of the majority, or even the authors of the standard.

I'm proud to say that in this capacity, IIAR has made the best use of the ANSI consensus process, producing a final product that reflects the true consensus and broad input of our industry.

And this standard's impact in the real world will be just as broad. As we adapt to the new technology that is even now opening doors to new markets – where natural refrigerants have the potential to create real environmental gains – the issues addressed by the re-release of IIAR-2 are more vital and timely than ever.

From the beginning, we took a practical approach to IIAR-2, remaking it into our industry's first comprehensive safety standard by developing it specifically for adoption by code making bodies.

As a result, it is already being recognized and adopted by various code bodies around the country. And at the same time, the weight IIAR-2 garners as a code-informing standard has earned it recognition in the regulatory environment, where OSHA, EPA and the Department of Homeland Security are already making references to the operational and safety practices it outlines.

This is a watershed moment for our organization and our industry because IIAR-2 is setting a precedent for the larger goal this organization has – to develop a suite of standards in addition to IIAR-2 that establish generally accepted engineering practices.

Establishing these practices through the ANSI standards process, as recognized by code and regulatory bodies, ensures that our industry will follow the best practices available – that those practices are recognized to improve safety for operating personnel, and most importantly, are technically correct.

In the rapidly changing environment in which we are now operating, our standards activities are more important than ever. The Environmental Protection Agency has recently released preliminary rules that will shape new regulations for all synthetic refrigerants.

That means that the reporting and regulatory requirements that have long boosted operating costs for natural refrigerants will likely soon apply to synthetics as well. And that opens an opportunity for a broader range of end users to start considering natural refrigerants.

Given this important development, IIAR isn't missing a beat. Now that IIAR-2 is complete, we're starting the entire development process again for a CO_2 standard, RAGAGEP For Existing Facilities and other significant programs, as we continue to expand our suite of standards to address the new needs of our industry.

Whether you are a member of an IIAR committee, a participant in the standard review process, or a nonmember working in our industry, your support is essential. Please join me in congratulating all those who made IIAR-2 a reality, and if you haven't already, I urge you to find a way to get involved in the work of our committees. These efforts could not be completed without the dedication of members like you.

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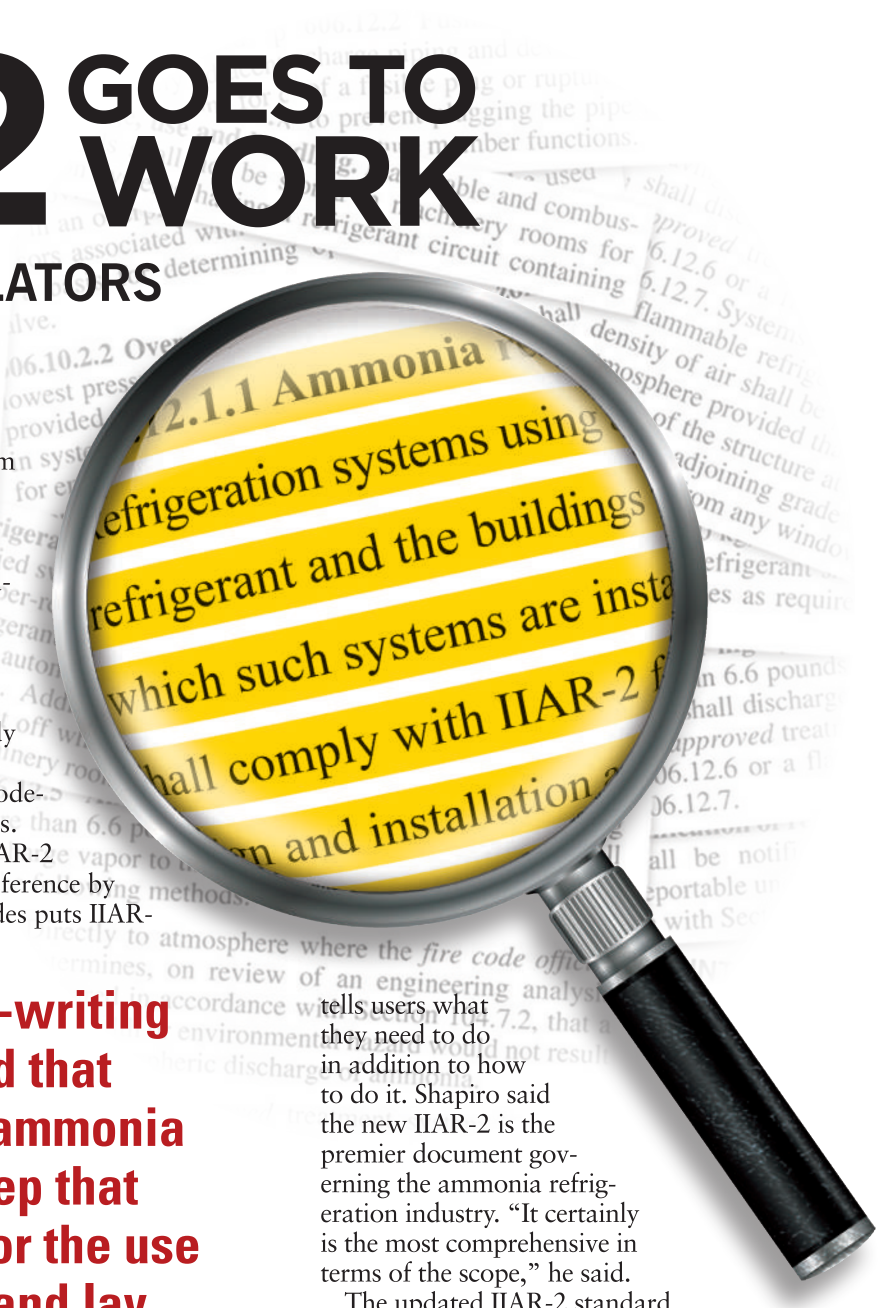
IIAR-2 GOES TO WORK

CODE BODIES AND REGULATORS RECOGNIZE STANDARD



With the completion of IIAR-2, the most comprehensive standard for the safe design of closed-circuit ammonia refrigeration systems, the International Institute of Ammonia Refrigeration has written a single authoritative source document that provides a path forward for the ammonia refrigeration industry.

For the first time, model code-writing bodies have a single standard that comprehensively addresses ammonia refrigeration, an important step that will open new possibilities for the use of ammonia as a refrigerant, and lay the foundation for the growth of the industry in years to come.

For the first time, model code-writing bodies have a single standard that comprehensively addresses ammonia refrigeration, an important step that will open new possibilities for the use of ammonia as a refrigerant, and lay the foundation for the growth of the industry in years to come.

In addition to providing a single information source for code-writing bodies, the all-new IIAR-2 standard gives regulators, such as the Occupational Safety and Health Administration, and the Environmental Protection Agency, a more comprehensive guideline to the generally accepted good engineering practices (RAGAGEP) of the industry for new system designs. This is expected to enhance the industry's relationship with regulators.

The new IIAR-2 standard is already being widely adopted by code-writing bodies.

"Getting IIAR-2 adopted by reference by the model codes puts IIAR-2 in the position of being a legally enforceable document," said Jeff Shapiro, IIAR's code consultant. "With IIAR-2 serving as a comprehensive regulatory document for ammonia refrigeration, IIAR's technical experts are in a better position to manage our industry's regulatory affairs, versus relying on others who are not focused on ammonia."

The revised standard addresses the industry's advances in technology, incorporates new design approaches and tells users what they need to do in addition to how to do it. Shapiro said the new IIAR-2 is the premier document governing the ammonia refrigeration industry. "It certainly is the most comprehensive in terms of the scope," he said.

The updated IIAR-2 standard covers all aspects of ammonia refrigeration safety, such as the application of systems, where ammonia equipment can be housed, and how safety standards should be applied to different applications, said Bob Czarnecki, chairman of IIAR's Standards Committee.

Eric Smith, IIAR vice president and technical director, said the new IIAR-2 integrates topics that were found in other standards but had not previously been included in the IIAR-2 standard. "Essentially a gap analysis was done that compared the International Mechanical Code, Uniform Mechanical Code, the International Fire Code, the International Mechanical Code and ASHRAE 15 with the prior edition of IIAR-2. We addressed or

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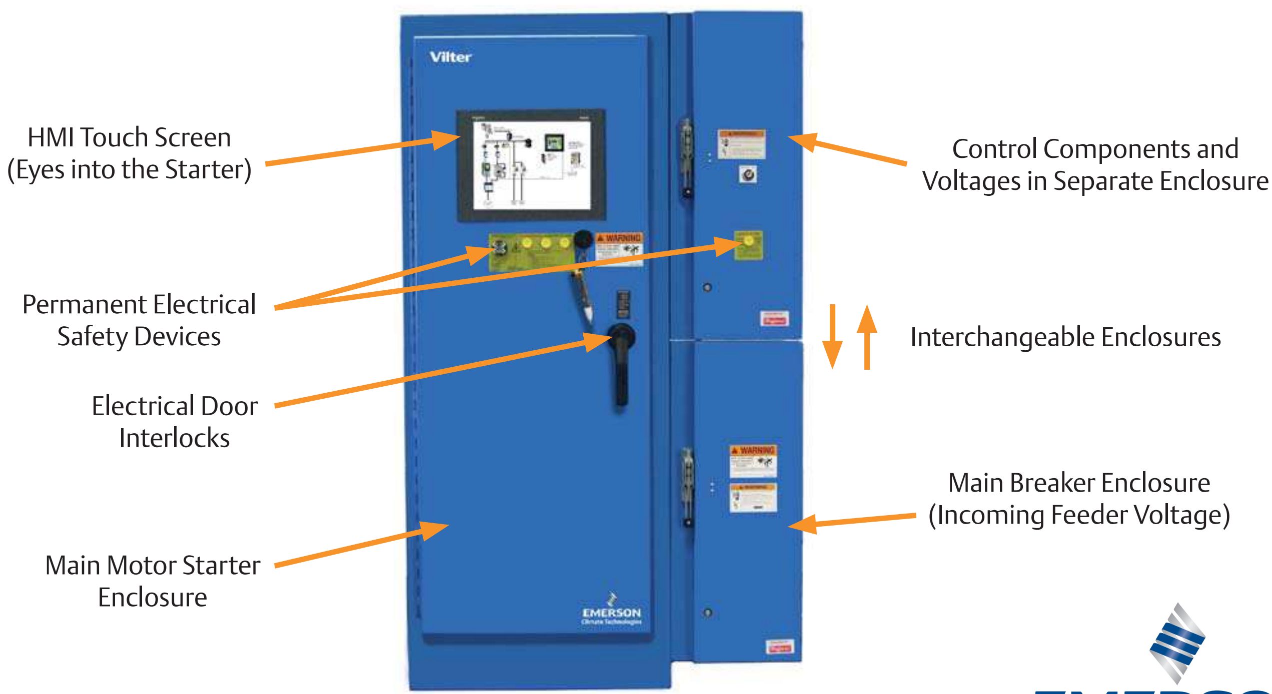

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attempted to address those things that were in other codes and standards but weren't in IIAR-2," Smith said.

Dave Rule, president of IIAR, said, "We wanted to make sure the rewrite of the standard addressed some of the important issues that were going on in refrigeration today and to make sure we had a comprehensive safety standard for our industry."

As Czarnecki put it, "The whole purpose was to create a comprehensive, safe-design document for ammonia refrigeration. In addition to featuring new information, IIAR-2 was reorganized to make it a much more workable document. "It was divided into chapters to make it an easier document to work with and much simpler to access information," Rule said.

"To enhance the usability of the document, Appendix A clarifies things in layman's terms," Lundell said, adding that agreeing to provide an informative appendix was a major breakthrough. "That was a landslide that allowed the people on the code language side to say 'we're going to get it written in the code language' and the people on the explanation side who wanted the informative language to get that too, so it was easily digestible."

Smith said Appendix A also helps users understand why certain provisions were included and how to apply them.

WORK WITH THE CODE BODIES

IIAR-2 includes about a dozen changes that were made to coordinate with associated model codes, Czarnecki said.

"We wanted to make sure the rewrite of the standards addressed some of the important issues that were going on in the refrigeration industry and to make sure we had a comprehensive safety standard for our industry."

– Dave Rule, president of IIAR

Dave Schaefer, chief engineer for Bassett Mechanical and chair of the subcommittee for IIAR-2, said that now individual chapters separately address specific pieces of equipment. "Before, multiple types of equipment would appear in one chapter. It made much more sense to separate it into system components," he said.

One of the most significant changes was the inclusion of an informative appendix – Appendix A, said Tony Lundell, director of safety and standards for IIAR. The main document had to be written with enforceable language in order to be adopted by the code bodies, but Appendix A allowed IIAR to include additional, informative explanatory material on the normative—mandatory— requirements found in the main body of the document.

"In an enforceable standard or code, you can't write descriptive information into an enforceable text," Shapiro said. "They are good changes that allow us to mold our document more into what we would like to see it become."

Shapiro said, "IIAR-2 was written previously as a design standard. The objective of IIAR for the rewrite was to expand the scope of IIAR-2 to become a comprehensive document that combines features of a code with features of a standard. Codes typically tell you what to do, and standards typically tell you how to do it. The new IIAR-2 does both."

In developing the standard, IIAR staff also worked directly with OSHA, meeting with the agency several times. "OSHA had certain issues they wanted to get clarity on, so the standard addressed practices that could help to prevent certain situations from occurring," Lundell said.

OSHA was particularly interested in portions of the standard that address packaged systems as well as ammonia refrigeration equipment in areas other than machinery rooms. "OSHA was thankful that we are getting the information into a standard we can use," Lundell said, adding that while OSHA did not comment on the standard formally, the agency did provide some feedback throughout its development. The agency was particularly in favor of consolidated requirements, he added.

"IIAR-2 has the capability of standing on its own without relying on a code, but it has been written in a way that allows it to work hand-in-hand with the building, mechanical and fire codes that are used by jurisdictions throughout the U.S.," Shapiro said.

Rule said the standards writing process at IIAR follows the American National Standards Institute consensus method, which includes input from manufacturers, engineers, end users and educators. "It ultimately ensures that IIAR-2, as well as IIAR's other standards, are recognized by the regulatory agencies—OSHA, DHS, EPA and the code bodies around the country."

The consensus body for IIAR-2, which included 28 members, was a balanced interest group, but Shapiro said it is important to remember that consensus doesn't equate to unanimity. "There are often dissenting opinions in a consensus decision, but isn't a disadvantage. On the contrary, it demonstrates the broad perspective and input involved in the decision making process, and that was certainly the case with IIAR-2" he explained.

NEW DESIGNS AND EQUIPMENT

As technology has changed, so has the placement and use of the refrigeration equipment and components the industry relies on. For that reason, one of the first goals of IIAR-2 was to create a standard that reflected current practices in ammonia refrigeration.

For the first time in the industry, the IIAR-2 standard broadly addresses ammonia equipment outside of machine rooms in industrial settings.

"Typically everything but evaporators had to be in a machine room, but a lot of processes require equipment to be out on the floor," Czarnecki said. "One of the things that was never allowed on the floor was an ammonia pump. Now there are pumps that don't leak and have safeguards, which we've termed low-probability pumps."

The standard also addresses low-charge, small package systems. "There is a whole chapter on packaged equipment, which is a new topic for this standard," Czarnecki said, adding that IIAR-2 is the first standard that specifically addresses packaged ammonia equipment. "Packaged equipment has been around forever but now it has gone main stream, so we dedicated a chapter to it."

Lundell said, "For years, businesses have been installing equipment outside of machinery rooms, but standards did not address this situation. The new IIAR-2 includes a full chapter on equipment outside of machinery rooms." Now, the practice is specifically allowed if precautions are taken.

IIAR-2 also eliminates the need for direct outside egress for machine rooms, which allows companies to place a machinery room in the center of a building if necessary and not require them to have a direct outside wall. Smith said, "Now they can safely house refrigeration equipment next to production equipment."

The standard also discusses requirements for outdoor installations. "It is a practice that people have been following for a long time, but standards never clarified the questions of if outdoor installations are acceptable and under what conditions," Smith said.

The updated IIAR-2 includes a chapter on ammonia detection and alarms, standardizing their system response functions, and revisits the question of "shunt-tripping," or the de-energizing of electrical equipment in the presence of large concentrations of ammonia. "IIAR-2 addresses this in Appendix M. No one wanted to make it a mandatory requirement, but the informative appendix provides guidance on shunt tripping and operational containment and explains what you can do," Czarnecki said.

FURTHER CLARIFICATION

IIAR-2 also added some definitions for certain terms, such as combustible material, trained operators, public access and public assembly. IIAR-2 includes further clarification on pipe terminations, seismic bracing, text to be included on signage, labels and pipe marking, and the minimum size for relief connections, Smith said.

"It is important to understand what the body of the standard is discussing," Smith said. "It is also important that when there are questions of code compliance, you have a definition that will, as clearly as possible, provide an explanation of what you are talking about, so there is less room for interpretation."

An important direct change related to safety is the minimum pressure for low-side vessels, Smith said, adding that it has been raised to 250 PSIG from 150 PSIG.

Requirements for alarms have also changed. Lundell said "In the machinery rooms, the biggest change is with the detection level that triggers ventilation. If you're below 25 parts per million, you do not need to alarm. Maintenance can often release minor amounts of ammonia e.g. you may be changing coalescent filters on a twin screw compressor, and there is no need to alarm in these cases. Once a 150 ppm is detected, it shall activate your emergency ventilation system. It used to be it would not activate until 1,000 ppm was detected."

Schaefer added that ventilation requirements are divided into different segments: temperature control ventilation, fresh air ventilation and emergency ventilation. Ventilation for occupant fresh air was added as a new segment.

As part of the updated standard, there is now a requirement to consider functional testing in the design of the system. "What that means is the system designer needs to think about and incorporate provisions into the system so it can be functionally tested," Smith said.

Smith also said that IIAR-2 mandates the consideration of worst-case scenarios of over-pressurization for vessels and heat exchangers. "For example, there are scenarios when equipment is cleaned that could produce an over-pressure situation. We've added a lot of ways to determine these scenarios," Smith said.

THE REVIEW PROCESS

Including pre-public review discussions, pubic review comment breakout sessions and conference call team meetings for the development of comment responses and document drafting, this IIAR-2 revision required hundreds of meetings to get it finalized, approved and published. The Standards Committee addressed hundreds of public review comments, creating a change to the draft or an explanation for each concern submitted.

Even though the most recent version of IIAR-2 has just been released, IIAR and its members are already working on improvements, which have been ongoing since IIAR-2 was originally introduced to the industry in 1974. The original standard was ANSI-approved in 1978 and has been going through a rewrite every five years or so. "It is all done to address existing designs, to improve the systems and meet our mandate to operate safely as an industry," Rule said.

Schaefer said those involved with the current rewrite have kept a running list of items to explore. "One of the things that will be addressed in the future is one or several provisions for high pressure cut-off testing on compressors," he said.

The current document lays the groundwork for the future, Czarnecki said. "We brought into play and started to mention things like automatic controls that were never mentioned before. We didn't say a lot about it, but we got the ball rolling."

Rule said the committee will start an earnest rewrite process in about two years. "If there is anything critical that needs to be addressed sooner, there are processes we can follow to address those and present an addendum to the standard."

Shapiro said, "Codes and standards are never perfect. That is the reason we have a process by which we continually update them. Technology changes. People's understanding of how to use technology changes."

For now, IIAR's Rule said the organization would be focused on informing members and the industry at large on the technical details and widespread implications of the newly released standard.

IIAR announced that it is planning a special education program on Sunday, March 20, ahead of the IIAR 2016 Annual Conference and Exhibition. The program will provide an overview of the new, final IIAR-2 standard, including new areas of interest and changes to the standard that will have a major impact on the industry today, Rule said. He added that IIAR members may register online and learn more about the upcoming educational session via the IIAR website.

"IIAR-2 represents the culmination of some of the most important and vital work our organization has had the opportunity to complete in recent years," Rule said. "This standard truly lays the foundation for the future of our industry. IIAR's upcoming educational session will be the first step for many in our industry as we begin the process of putting it to work in our day-to-day operations."

EPA, International Community Moves Forward with HFC/HCFC Phase Out

The U.S. Environmental Protection Agency is continuing its phase-out of certain hydrofluorocarbons and hydrochlorofluorocarbons in favor of safer, more climate-friendly alternatives, which is expected to create new opportunities for the natural refrigerants industry. So far, the EPA has focused on commercial applications, although a rule on industrial applications may emerge eventually.

"As you're removing synthetic refrigerants from being acceptable alternatives, you're going to see people asking where they go next," said Lowell Randel, vice president of government and legal affairs for IIAR. "Natural refrigerants, like ammonia and carbon dioxide, are alternatives companies will consider."

In July, EPA published its final rule under the Significant New Alternatives Policy prohibiting certain hydrofluorocarbons — HFCs, and it is no longer acceptable to use those particular HFCs in specific applications after specified dates. EPA said HFC-containing blends affected by the rulemaking are used in aerosols, foam-blowing, motor-vehicle air conditioning, retail food refrigeration and vending machines.

"To date, that [phaseout] has really been focused on the refrigeration space for commercial applications rather than industrial applications," Randel said, adding that he expects a rule that will apply to the industrial sector eventually. "They haven't tipped their hand on when we might see a rulemaking. It is not imminent but indications are that is the direction we're going."

The overall trend is going to continue to move away from the HFCs. "It is a matter of when and not if," Randel said. "Ammonia and CO_2 will be good viable options for the transition and we've already seen that to be the case in Europe."

A number of countries are pushing to include the prohibition of certain HFCs in the Montreal Protocol, an international treaty designed to phase out the production of certain substances in order to improve Earth's ozone layer. "There have been a few countries that have been hesitant to include that because of the impact it would have on their economy," Randel said.

Parties involved in the Montreal Protocol met in November in Dubai. "Meetings like that one are hopefully going to give us more clarity on where things are headed," Randel said, adding that with meetings at the international level it takes a long time to come to a resolution, which is typically followed by a lengthy transition period. "They're negotiating right now what the phasedown might look like."

During the meeting, attendees agreed to a pathway for including HFCs in the Montreal Protocol. "The goal is to complete work on adding HFCs by the end of 2016, although that timeline can obviously slip," Randell said.

The Montreal Protocol already requires reductions of certain hydrochlorofluorocarbons — HCFCs. "The main one we're concerned about is R-22," Randel said.

The EPA's published schedule calls for an end to R-22 production by 2020. "EPA published the phase-out schedule about a year ago and there hasn't been much development on the HCFC front, other than that people are trying to figure out the transition," Randel said. Under the R-22 phase out, the chemical can't be produced in or imported into the U.S. The result has been a dramatic increase in the price of the refrigerant with a significant economic impact on the industry.

OSHA Urges Employers to Verify Authenticity of Inspectors

The Occupational Health and Safety Administration recently warned employers of a situation in which an imposter posed as an OSHA inspector and requested unaccompanied access to a workplace. The agency asked company officials to utilize due diligence anytime they interact with someone claiming to be an OSHA official.

The warning came after an incident in September when a man visited three construction sites in the Houston area claiming to be an OSHA safety inspector, said R. Casey Perkins, area director in Austin for the U.S. Department of Labor's Occupational Safety and Health Administration.

After arriving at a site, the man presented a simple business card and said he had the right to walk the job site unaccompanied by anybody. Perkins said both of those actions are red flags.

OSHA inspectors do have the right to enter a workplace and inspect without delay, but the employer and an employee representative are welcome and are encouraged to accompany the inspector on a walkthrough, Perkins said.

OSHA representatives also carry credentials that include a badge, photo, name and title along with a Department of Labor embossed seal on it. Inspectors should also have a business card that lists contacts for the OHSA area office. If a situation seems out of line, the employer should check with the agency's area office.

IIAR-2 Committee Recognized for Four-Year Publication Effort

Updating the IIAR-2 standard was a massive four-year effort, during which IIAR's volunteer committee – working to achieve consensus – took a "divide and conquer" approach to handle the approximately 1,500 comments and more than 1,000 off-the-record suggestions, said standards committee vice chairman Don Faust.

"Arriving at a consensus within the entire industry was our biggest challenge, especially with a scope as broad as IIAR-2. The difference between a standard and a code is that a standard must achieve that consensus, so we had to address formal and informal comments," said Faust, vice president of Gartner Refrigeration in Minneapolis. "I saw pretty quickly due to the sheer mass of comments that we had to break up into groups, with each group tackling a section of the standard and addressing the comments related to that standard."

Committee members at times held daily conference calls lasting up to four hours, and the new standard went through six public reviews before IIAR published the final document. Before the first public review draft was submitted, many other drafts were created as discussions generated changes. "We began naming the drafts after animals just to distinguish one from the other," IIAR Vice President and Technical Director Eric Smith said. "The last one before public review began was called osprey."

Although committee members had a hand in each section of the updated standard, members also focused on specific areas. Faust helped develop standards for ammonia detection and safety systems for engine rooms.

Dave Schaefer, chief engineer at Bassett Mechanical in Wisconsin, and the IIAR 2 subcommittee chairman was involved with most parts of the standard but made a large contribution to the development of package systems and pumps. Standards Committee chairman Bob Czarnecki, who recently retired from Campbell's Soup Company, established the subcommittees, weighed in on technical issues and distributed information. Other members divided into groups to work on various chapters.

"This committee rewrote the standard to make it more comprehensive and to improve the level of safety design for new facilities."

Dave Rule, IIAR president

"This committee rewrote the standard to make it more comprehensive and to improve the level of safety design for new facilities," said Dave Rule, IIAR president. "They were all volunteers, and they all offered their time and their commitment to the industry to produce a document that will improve the safety and efficiency of the ammonia refrigeration industry."

As the Standards Committee chair, Czarnecki managed the process and kept the project on track. "The amount of comments were way more that we would normally receive on a public review because the document had changed so much, so it took a lot of time to work up responses," he said. "We learned a lot about how to streamline the process for the future."

In addition to quarterly meetings in Washington, D.C., committee members spent countless hours on conference calls and working individually to resolve issues. "A lot of people put more time into this than you would normally expect from a volunteer," Czarnecki said.

The committee faced a deadline for publication of the updated standard if it hoped that it be referenced in codes for the for the next code cycle. "A standard holds less weight on its own, but its incorporation in codes provides significant status," Faust said. "We were under tremendous time pressure to get this done."

Faust utilized his experience writing standards to field public comments and draft responses. "We developed a concept for the latest standards for ammonia detection and safety systems in engine rooms," he said. "A lot of what I did was overseeing the process. There were many, many hands involved in every section."

As a subcommittee chairman, Schaefer's role was to make certain that responses were formulated to the proposed solutions that came from debates and public comments.

Members of the SC Committee, IIAR-2 SubCommittee and IIAR Staff were recently awarded special plaques by IIAR for their efforts in developing this new standard, said IIAR's Rule.

"Everyone played an equal part in the process depending on which chapters they worked on," Rule said. "They are very passionate, dedicated people."

IIAR-2: Addressing the Machinery Room

The recent release of IIAR-2 provides an updated standard that clarifies previously cloudy codes and regulations and provides new information that enables facilities to meet the highest safety standards. Specifically where safe machinery room operation is concerned, the standard is critically important to the future of the ammonia refrigeration industry.

There are five key elements that increase safety in a machinery room:

- construction;
- ventilation;
- the emergency detection system;
- the emergency shutdown system; and
- the relief systems.

IIAR-2 spells out the specific areas that facilities must address to operate safely, and, in the event of an ammonia leak, how the leak is mitigated.

The road to safety begins with the machinery room's construction. IIAR defines a machinery room as an enclosed space that is designed specifically to safely house refrigerating equipment. That equipment includes compressors, refrigerant pumps or other refrigerant liquid transfer equipment that raises the pressure of the refrigerant.

The updated standard also requires that the machinery room be separated from the remainder of the building by tight-fitting construction of non-combustible materials with a one-hour fire-resistance rating. The fire rating also applies to doors and windows.

Doors that are used for emergency egress must be identified and equipped with panic hardware.

Piping that penetrates the walls or the ceilings of the machinery room must fit tightly and include fire-preventative material.

Machinery rooms must also be designed so that manually operated valves that are not accessible from floor level can be reached via portable or fixed platforms, ladders, or with a chain-operated system.

"These items were part of the previous standard but some of the provisions weren't clear. IIAR-2 - 2014 has removed those ambiguities and provided clarification," says Jack Piho, president of Piho Engineering, a company that assists facilities in understanding and addressing safety codes and regulations.

Ventilation can be the most confusing aspect of designing a machinery room because there have been so many different standards in place, said Piho. “The Fire Marshall or the Fire Chief has the final say, so facilities need to maintain a good working relationship with them.”

Machinery room exhaust to the outdoors must be at least 20 feet from a property line or from openings in the building, measured horizontally, vertically or a combination of both. Emergency exhaust fan motors located in the air stream or inside the machinery room should be totally enclosed but need not be explosion proof. Emergency mechanical ventilation systems should include a minimum of 30 air changes per hour based on the gross machinery room volume.

IIAR-2 has also provided clarification regarding the activation of visual indicators and the audible alarm regarding detection of ammonia concentrations. Detection reaching 25 parts per million (ppm) should activate the indicators and the alarm. Both can be automatically reset if the ammonia concentration drops below 25 ppm. Ammonia concentrations reaching 150 ppm require that the emergency ventilation system starts and continues to operate until it is manually reset by a switch located in the machinery room.

IIAR-2 requires emergency shutdown when detection of ammonia concentrations exceed the lower of the detection’s highest limit or 40,000 ppm. With that, machinery-room refrigerant compressors and pumps and normally closed automatic refrigerant valves must be de-energized. “What’s new is that you now only shut down the rotating refrigerant equipment in the machinery room,” Piho says. “In the old days you would shut down the entire room.”

The new standard requires this shutdown to be automated. Formerly this was not specified.

Finally, the updated standard provides clarification about relief systems. It states “pressure relief devices shall have sufficient mass flow carrying capacity to limit the pressure rise in protected equipment to prevent its catastrophic failure.” Simply, this means . . . protect all equipment.

One provision requires that the risk device capacity factor should be increased to 1.25 when combustible material is stored within 20 feet of a pressure vessel. “The reason is that you could be somewhere else in the facility or even outside where oil drums or other unprotected items are right next to a pressure vessel. In those cases you need to change the calculation method,” Piho says.

The new standard clarifies what a combustible material is and that the concern is about the storage of such materials.

Finally, atmospheric discharge vapor pressure relief devices should send vapor directly outdoors, although exceptions are permitted, and may be required by local jurisdictions.

So how does an existing facility address these new codes and regulations, which in some cases could require costly renovation and design?

Facilities will need to evaluate the costs of updating against the risks of not doing so.

Facilities that have not yet been constructed should hire a designer who is familiar with all the current codes and regulations. “The bottom line is that a new facility won’t get a certificate of occupancy that allows it to operate if it doesn’t meet these standards,” Piho says.

Existing facilities that meet the codes on which they were built will typically be grandfathered unless there have been modifications. So why do it? “Owners will – in keeping with internal policy or possibly recommendations of outside resources – choose to update their refrigeration system to meet IIAR-2 and be current, and it’s the right thing to do,” said Piho.

Hands-On Facilities Improve Ammonia Refrigeration Training

The ideal training for ammonia systems should include classroom training coupled with a hands-on component in which operators and technicians can combine book learning with practical application, according to some industry training specialists.

"Ammonia refrigeration operators tend to have learning styles that hinge on them being able to put their hands on the system to make it make sense," said Dallas Babcock, an ammonia program instructor at Garden City Community College and a past committee member for the IIAR joint operator training guideline committee.

Vern Sanderson, Safety Services Group Leader with Wagner-Meinert based in Fort Wayne, Indiana, and a member of RETA (Refrigerating Engineers and Technicians Association) Board of Directors said, "If you're not getting your hands dirty with training, you probably need to do more training."

Currently, a number of training programs, both domestic and abroad exist for ammonia, and they vary based on the skills individuals are trying to acquire. Companies also hold training in-house and can utilize training from equipment providers and contractors.

Doug Reindl, a professor at the University of Wisconsin and a member of the IIAR board, said there are several locations around the country that have operating ammonia refrigeration systems to support operator training, including two separate programs in Garden City, Kansas— Garden City Community College and Garden City's Ammonia Program, the Tex Hildebrand Training Center by Wagner-Meinert in Fort Wayne, the Industrial Refrigeration Technical College in Lyndhurst, Virginia, and Lanier Technical College, in Georgia.

"Facilities with operating ammonia refrigeration systems for training have grown up in various locations. Some of the programs were driven at a local or regional level by end users wanting opportunities for their operators to receive structured training in their area," Reindl said, adding that industry partners are another resource for more specialized product-specific training.

"Many of the equipment manufacturers, valve manufactures, compressor manufacturers and larger component manufacturers offer training on their specific products. In addition, the contractors that build and install ammonia refrigeration systems conduct quite a bit of training on the specific systems they build for their clients."

Sanderson said training is becoming even more important as equipment and systems become more complex. "As an industry, we probably have less experienced operators today working on more advanced equipment, than we had 20 years ago" he said.

Bruce Nelson, president of Colmac Coil and a member of IIAR's board of directors recently visited an ammonia operator training facility that opened in 2014 in Bogota, Colombia — Centro de Capacitacion Refrisistemas Industriales (CCRSI). The location is operated by IIAR member Juan Carlos Hencker and can be used by end-

users with facilities in Latin America.

"It is the first training center in Latin America with pumped, flooded and DX ammonia, single- and two-stage systems, a CO_2/ammonia cascade system and a Freon system," Hencker said.

Nelson said, "The Columbia location offers industrial refrigeration users in Latin America a place to send their operators for training on the safe operation of industrial ammonia systems, which hasn't been possible before."

Bogota provides an ideal location to serve the Latin American market because of its central location between North and South America, Hencker said. He expects 200 students per year to train at the location.

Because the ammonia refrigeration industry is so varied, Babcock said it is important for programs to have a range of equipment. "We have four different systems in our lab and the four systems are as different as we could make them," he said.

Sanderson said the differences between equipment become more apparent when more detailed maintenance is done. "As you get into more advanced work, the differences in equipment and manufacturers are more profound" he said.

In the spring, the Garden City Ammonia Program plans to launch a technician course that will involve charging a 13-compressor engine room. Jeremy Williams, a voting member of IIAR's education committee and directing manager of the Garden City Ammonia Program, also known as GCAP, said that to his knowledge, the program is the first of its kind.

"Trainees will be charging a system from a delivery truck. They'll do pressure tests and bring over an ammonia charge and try to get that mechanical refrigeration system going in four days. It is kind of like commissioning a new plant," Williams said.

In addition to the new engine room, GCAP has several other pieces of equipment for trainees to use. "During training, we're trying to show one way of doing everything that can be done in the industry. They might not be able to relate to an entire system from their plant, but there are things in each system they can relate to," Williams said. "Once they have the opportunity to see the mechanical concepts, they can take it and have it for a lifetime."

In addition to giving students the opportunity for hands-on instruction, Sanderson said he believes facility specific training programs should incorporate block flow diagrams into the instruction. "A block flow diagram gives you the opportunity to see how the system operates as a unit. Every facility is required to have one but very rarely are they ever used," he said. "After acquiring a baseline knowledge of components and their operations, operators can then expand their knowledge to the system level by incorporating the use of block flow diagrams. Ultimately this allows for a transition to the use of process and instrumentation diagrams as well as standard operating procedures in training.

The kind of training and the frequency of training that operators need varies. Facilities that utilize certain amounts of ammonia fall under Occupational Safety and Health Administration Process Safety Management and the Environmental Protection Agency's Risk Management Plant programs, which have training requirements.

"One aspect of these regulations is that operations staff receive training on the specific operating procedures applicable for their own systems," Reindl said, adding that there are additional training requirements that apply to maintenance, emergency response, and other aspects of systems depending on the work the facility does and the staff involved.

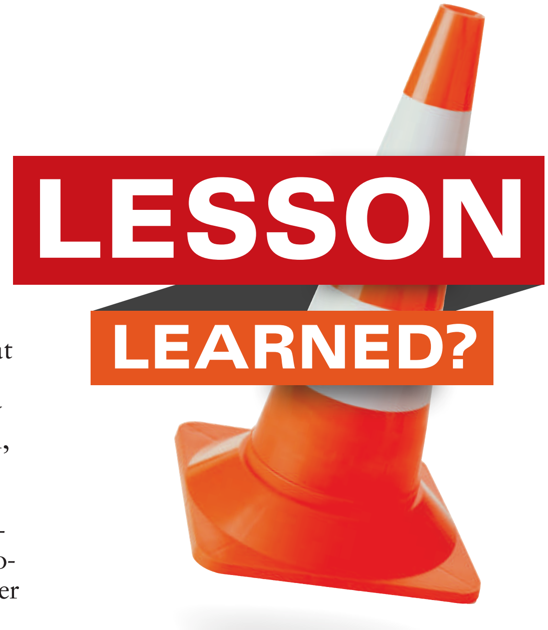
Wagner-Meinert offers 24 refrigeration and emergency response-related courses out of its training center in Fort Wayne, through an agreement with Polk State Corporate College in Bartow, Florida, and outreach locations throughout the country. However, the majority of classes the company does are onsite at their customers' locations. Sanderson said the two types of training—on-site and off-site—complement each other. "They need to have exposure to what they've got and what they're likely to encounter in the future," he said. "A well balanced training lab, one consisting of old and new equipment, is vital to the training process. Understanding their system and having training specific to their system is also vital."

Babcock said learning within a training facility can be more effective than on-site training because it removes distractions and training can be consolidated into a shorter timeframe. "The [average] plant isn't going to stop production for training," he said.

Training facilities typically offer a variety of programs, based on the level of education technicians need, Babcock explained. Garden City Community College, for example, offers five different one-week seminars, which start with basic theories of operations. Garden City Community College's programs pack a semester of learning into one week, and the condensed timeframe is particularly useful for those who are entering into the ammonia refrigeration industry as a second career, Babcock said.

Williams said it is important for people to have the right expectations of any third-party training program. "Training isn't the end of the story. It is a part of the process. Companies need to have a vigorous training program within their facility that is specific to the plant," he said. "Education starts somewhere and then you apply it to daily experience and then it becomes knowledge."

Re-Learning the Most Important Lessons



Most facility operators believe that they and their employees know what needs to be done in an ammonia release situation. But knowing what needs to be done is very different than knowing you will be able to do what needs to be done when the stress of an event makes reaction time and clear thinking crucial. The need for learning and re-learning of those lessons is a critical discipline. As the following three scenarios illustrate, even the most experienced professionals are not naturally immune to the uncertainty that comes in the first phase of a release.

Scenario 1: He was driving down the highway and suddenly noticed a strong smell. He asked himself, "What is that smell?" As the answer (ammonia) dawned on him, his very next thought was, "The only facility around here is mine! We have an ammonia leak! I know I'm supposed to do something, what was it?"

Scenario 2: The refrigeration operator got an alarm indicating a higher-than-normal ammonia level in the machine room. He hurried to the room and yanked the door open. An extremely strong smell of ammonia hit him and he saw a white cloud, filling most of the machine room. Slamming the door shut, he thought, "Oh man! What do I do now? Who do I call?"

Scenario 3: It was a Saturday evening, so there were few people at the plant. One of the few working noticed sirens in the distance. "I wonder what's going on?" he thought as the sirens got closer. He went back to his work, but just a few minutes later a fire truck pulled into the plant yard. The fire officer jumped out of the truck, asking, "What's going on?" The man responded, "Nothing that I know of." But, the fire officer replied, "We got a call about an ammonia smell from one of your neighbors." It didn't take long to find the source of the release – a safety relief valve that was continuing to blow. "What do I do now?" the man thought.

There's a common thread running through all of the above events – company personnel did not know (or forgot) what to do on the spot when an ammonia release occurred.

Knowing what to do in an ammonia release is important, but even more important is the knowledge that you and your personnel will act in a real event. That confidence is the key to staying in compliance with federal, state and local requirements, and hopefully to keeping everyone safe.

Some might think at first that not remembering what to do when an ammonia release happens is not too bad. After all, it's an indication of just how well designed, built, and operated most ammonia systems are, that so few experience an ammonia release. Releases are usually small, have little if any effect on company personnel, and rarely affect the surrounding community or environment. Yes, sometimes our industry has larger incident, but those are rare.

Many companies have well-developed and written emergency procedures in place, their employees are routinely trained and local emergency responders know the companies' capabilities. When an ammonia release does happen, it is an emergency, but properly trained people know what they're supposed to do. Generally, ammonia-release incidents go fairly smoothly from discovery through termination of the event.

However, I have seen that there are a surprising number of companies that are not adequately informed about what actions they should take in the event of an ammonia release, and their employees aren't prepared to deal with an emergency.

Some of the lessons we can learn from recent releases are:

Lesson 1: A well-maintained contact list is essential.

In all of the releases mentioned above, not knowing who to contact extended the time for appropriate action to occur. In one case the primary company contact could not be reached, and it took valuable time to figure out whom else to notify. In the meantime the ammonia release continued and the ammonia spread off the company's property.

There should always be a readily accessible, up-to-date list of who to contact in an emergency. And it's best to have more than one contact on that list. This list can shorten the time between discovery and taking the appropriate actions.

Besides having current contacts within a company, you also should know who to contact in a timely manner at the federal, state and local levels. It may be helpful to have a contractor's contact information on that list.

Facilities and local emergency crews should be well-prepared for the actions they need to take.

One of the releases mentioned above was large, and even though the facility had an emergency response plan, there was only one person at the facility at the time of the release that was able to respond. When the local responders arrived, they were volunteers with very limited knowledge about ammonia.

Lesson 2: Determine what level of action your company will take in an event. Ideally, a company should have an Emergency Action Plan and an Emergency Response Plan.

Some of the main aspects of an Emergency Action Plan are:

- notification within the facility on discovery of a release, as well as proper and timely notification to federal, state, and local agencies;
- notification to businesses, schools, residences and others near your facility;
- evacuation of and accounting for all persons from affected areas;
- defensive actions that may reduce the impact and/or spread of the release;
- coordination with local emergency responders.

An Emergency Response Plan should include everything in the Action Plan, plus:

- having sufficient personnel on-site or readily available who are trained to deal with an emergency and have sufficient and appropriate personal protective equipment to respond to the release;
- and having personnel trained on the "Incident Command System."

An Emergency Response Plan requires more planning, training, and equipment, but may be the better approach for your company, especially when local responders are not adequately prepared to deal with an ammonia release.

Lesson 3: Be sure that emergency drills are done regularly.

Even in the most prepared facilities, this is an area that often needs much more attention than it gets. It can be challenging to find the right time to do emergency drills, but these drills can be lifesaving.

Fortunately in all the above mentioned releases no one was injured. Drills should be frequent enough that all personnel understand and know what they are supposed to do to remain safe. Learn and practice the actions that may be needed in an emergency. If you practice, you will develop experience and understanding that can help in an emergency even if the emergency is different than a scenario you were trained to deal with. Make emergency drills a priority.

Lesson 4: Know what incident reports must be completed and submitted.

For all of the releases I mentioned above, not knowing which reports to submit where was a common situation. The companies either forgot or didn't know that reports on releases are required to be submitted. In the United States there should be a follow-up incident report sent to state and local (typically the LEPC) agencies. These follow-up reports may be required within 15 to 30 days after the incident; check with your state to verify the timing.

For any release you should do an incident investigation. This investigation should include at least the following: determine what "really" happened; who and what was impacted by the release; develop appropriate recommendations of actions to take that could change or improve the system, training, procedures, etc. to reduce or eliminate the possibility of a repeat incident.

The results of the investigation should be reviewed with all appropriate personnel to help them learn and be better prepared.

Do you know what to do when an ammonia release happens? Do the other people at your facility know what they are supposed to do? These are lessons we need to learn, and keep re-learning to be prepared to respond well if and when a release happens on our watch.

For additional information and training tools concerning an ammonia release, please refer to the IIAR Series II, "First Thirty Minutes" videos and other safety publications available at www.iiar.org.

Planning for Piping

Advances in technology have produced ammonia refrigeration piping systems capable of withstanding dramatic climate changes, leading many in the industry to locate as much of their facilities' equipment as possible on the roof, which is a safer alternative in the event of an accident than the traditional location inside the building.

While locating ammonia piping systems on the roof is a positive step, owners of ammonia refrigeration facilities should be diligent about where they place the piping and how it is supported. Failure to take into account the load-bearing capabilities of the support system, the compressive strength of the insulation and the access to the valve stations could lead to serious issues, including potential safety hazards and roof damage.

It's important to know that not one support system for piping fits all rooftops.

"It's like the plumbing system in your house," says Jared Kirkpatrick of MIRO Industries, Inc. which manufactures products for supporting rooftop piping systems. "The pipes must be at different heights for routing purposes. Support systems should also vary in size and capability depending on the load being carried."

Piping systems should be installed with unrestricted access to the valve stations, which are often six to eight feet above the roof. Although some facilities have used temporary access such as ladders, a bucket or a stack of blocks to reach the valves, Kirkpatrick said it is safer to build a permanent platform that allows the worker to walk to the valves.

How workers will interact with the piping is another important consideration. Will they have to climb over or slip under pipes to perform maintenance checks? Is there is a clear path of access and egress? Workers who climb over pipes risk damaging the insulation. If they are forced to jump onto the roof after climbing over a section of piping, their weight will stress the roof membrane and the insulation beneath the roof. Bridges, crossovers and access platforms protect employees, piping, equipment and the roof insulation.

"At a food production facility, somebody is on the roof almost every day performing maintenance or checking valves. Climbing over pipes that are carrying toxic gas is a safety hazard because your weight could rupture the pipes," Kirkpatrick says. "Every time a 200-pound man jumps from two feet there is 400 pounds of impact on the roof. He's weakening the roof membrane and the insulation."

The environment and the system's load-bearing capabilities should be considered when selecting a support system. Field-fabricated bases are often too small to transfer the load without damaging the insulation. Field-fabricated supports are usually built by the pipe installers, who leave them in place when the job is completed. These supports are stable, but their footprint is often not large enough to distribute the load at the five pounds-per-square inch (PSI) or below load recommended by the National Roof and Contractor's Association.

"As a result, the insulation is being crushed and the roof membrane is being punctured, creating leaks and potential safety hazards if the support ever fails," Kirkpatrick says.

Many support platforms are built with a wood base, which is not advisable for long-term use. Harsh weather conditions can cause the wood to crack and disintegrate within one to two years. A base constructed of polycarbonate and galvanized steel is a better, longer term, option because it is suited for temperatures ranging from minus 80 degrees to plus 240 degrees. Rubber supports are another option. They are designed to carry specific loads for footprints from 36 to 45 square inches.

Insulation used on most commercial roof assemblies is either EPS (expanded polystyrene) or PolyIso (polyisocyanurate). PolyIso has a greater load-bearing capability, also called compressive strength, while EPS is less costly. But the performance levels are similar.

It is important not to exceed the compressive strength of the insulation by loading a device that is too heavy. Compressing the insulation creates dimples equal in size to the support base in the insulation. When it rains, water collects in the dimples and leaves puddles of water on the roof. "So you have this weight sitting in a puddle of water," Kirkpatrick says. "Over time the compression continues to press down and you end up stretching the roof membrane."

This problem can be prevented by using a larger footprint that disperses the load over a wider area. "By expanding the area you lower the PSI," Kirkpatrick says.

It's also important to note that piping stands must be directly attached to the building's structure to meet seismic bracing requirements, said IIAR Vice President and Technical Director, Eric Smith.

"In these cases, it's vital that the roof penetration be appropriately sealed and that the stands be insulated if necessary to prevent the formation of ice or water on the lower portions of the stands. Failure to do this could cause corrosion of the stands or failure of the roof and insulation.

In the final analysis, a properly supported and located rooftop ammonia refrigeration piping system will protect your investment in the roof, while enhancing the safety of your employees and the surrounding community.

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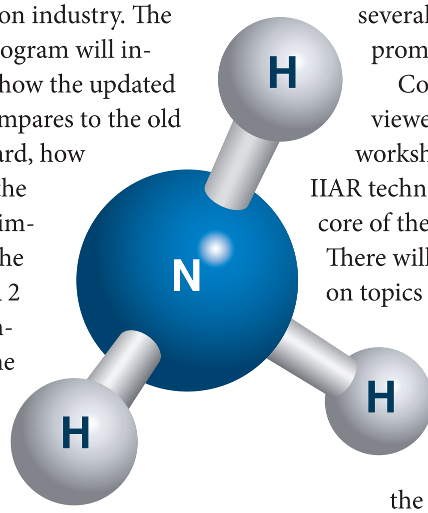
THE FUTURE OF NATURAL REFRIGERATION BEGINS HERE ONLINE REGISTRATION IS AVAILABLE NOW!

The future of natural refrigeration begins at the 2016 IIAR Industrial Refrigeration Conference & Exhibition.

Showcasing the latest equipment, products, services and technologies available in industrial and commercial refrigeration, this tradeshow provides attendees the opportunity to meet with hundreds of industry professionals, reconnect with clients and network with industrial refrigeration experts and key decision makers from around the world.

The 2016 IIAR Industrial Refrigeration Conference & Exhibition will be held in Orlando, FL at the Caribe Royale All-Suite Hotel and Convention Center. The Caribe Royale is located just minutes from some of Orlando's famous theme parks and attractions. All meetings will take place at this expansive state-of-the-art event facility.

The conference kicks off with the IIAR 2 Education Program on Sunday, March 20th from 1:00 pm – 5:00 pm (additional fees apply). The new and improved ANSI/IIAR 2 – *Standard for the Safe Design of Closed-Circuit Ammonia Refrigeration Systems* is the definitive design safety standard of the ammonia refrigeration industry. The IIAR 2 Education Program will include discussion on how the updated version of IIAR 2 compares to the old version of the standard, how it will be applied in the field, and the major impact it will have on the industry today. IIAR 2 has undergone extensive revision since the 2008 (with Addendum B) edition was published on December 3, 2012. A major focus of changes made to this edition has been incorporating topics traditionally addressed in other codes and standards, new packaged system technology and other existing industry issues so that IIAR 2 can eventually serve as a single, comprehensive standard covering safe design of closed-circuit ammonia refrigeration systems.



Monday begins with the IIAR Business Meeting followed by keynote speaker, **Dr. Joe MacInnis**. Dr. MacInnis is a physician-scientist, author and deep-sea explorer. He has led more than thirty expeditions into the Atlantic, Pacific and Arctic Oceans and written several books about undersea exploration. His work has earned him a number of distinctions, including his country's highest honor, the Order of Canada. He is a leader in safety and exploration.

Conference highlights include the 2.5-day acclaimed technical program, the expansive exhibit hall, and several networking and promotional events.

Consisting of peer-reviewed technical papers, workshops and panels, the IIAR technical program is the core of the annual IIAR show. There will be presentations on topics ranging from the construction of CO2 commercial supermarket refrigeration systems in Europe to expanding the case for air-cooled condensers in industrial applications.

IIAR publishes the technical proceedings at each year's conference and distributes them digitally to all conference attendees.

Growing every year and with more than 100 exhibitors in attendance, the exhibition hall will host product displays from leading industrial and commercial refrigeration manufacturers and service providers from around the world. The exhibition also features Technomercial presentations. Reserved exclusively for exhibitors, a Technomercial presentation is a targeted 30 minute product or service demonstration which highlights a company's new or existing technologies.

Orlando, Florida • March 20–23 • www.iiar.org

Exclusive to the IIAR conference this year will be the annual Monday night networking event to be held at CityWalk® Orlando. This event, which replaces the traditional Monday night banquet, will be a huge bash that fills three different clubs in Universal CityWalk® at Universal Orlando® Resort. Take a trip to New Orleans at Pat O'Brien's® where it's Mardi Gras 365 days a year, explore the home of the king of reggae at Bob Marley–A Tribute to Freedom℠, and take the stage at CityWalk's Rising Star karaoke nightclub. It's an entire evening of excitement which frees you up to connect with your peers, discuss business in an informal setting and make new contacts.

The future of natural refrigeration starts here. To learn more about the IIAR conference, go to www.iiar.org.

Online registration in now available, simply log on to www.iiar.org/events to register. Take advantage of our early bird rates now through February 5, 2016.

AT A GLANCE

What: IIAR Industrial Refrigeration Conference & Exhibition

Where: Caribe Royale All-Suite Hotel and Convention Center

When: March 20-23, 2016

IIAR 2 EDUCATION PROGRAM

March 20th, 2016
1:00 pm – 5:00 pm
Program Fee: $375.00

IIAR TECHNICAL PROGRAM INCLUDES:

- Simultaneous Interpretation in Spanish for all English presentations
- Simultaneous Interpretation in English for all International presentations
- Emerging CO2 Technologies
- Extensive International Program
- PSM and RMP presentations
- Regulatory Updates
- And much more…

EPA Proposes Rule to Strengthen Refrigerant Management Requirements

iiar government RELATIONS

BY LOWELL RANDEL, IIAR GOVERNMENT RELATIONS DIRECTOR

On November 9, 2015, the Environmental Protection Agency (EPA) published a Notice of Proposed Rulemaking entitled "Protection of Stratospheric Ozone: Update to the Refrigerant Management Requirements under Section 608 of the Clean Air Act."

Through this proposed rule, EPA is seeking to update existing requirements as well as extending them to non-ozone-depleting substitute refrigerants, such as hydrofluorocarbons (HFCs).

Section 608 of the Clean Air Act requires EPA to regulate the use and disposal of ozone-depleting substances (ODS) in such a way to reduce the use and emissions of such substances and maximize the recapturing and recycling of such substances. Section 608 also prohibits any person from knowingly venting, releasing, or disposing into the environment any ozone-depleting or substitute refrigerant in the course of maintaining, servicing, repairing, or disposing of air-conditioning or refrigeration appliances or industrial process refrigeration (IPR).

The proposed rule is another step towards implementing the Obama Administration's Climate Action Plan which is designed to cut carbon pollution and reduce the use and emissions of substances that deplete the ozone and contribute to global warming.

EPA has stated that it has three goals for this rulemaking. The first is to protect the stratospheric ozone layer by reducing emissions of ozone-depleting substances. The second is to protect the climate system by reducing emissions of other refrigerant gases with high global warming potential (GWP). EPA's third goal with this proposed rule is to improve the clarity and effectiveness of the regulations.

Current EPA regulations require that persons servicing or disposing of air-conditioning and refrigeration equipment observe certain service practices that reduce emissions of ozone-depleting refrigerant. Through this proposed rule, EPA is seeking to update existing requirements as well as extending them to non-ozone-depleting substitute refrigerants, such as hydrofluorocarbons (HFCs).

The proposed updates include strengthening leak repair requirements, establishing recordkeeping requirements for the disposal of appliances containing five to 50 pounds of refrigerant, changes to the technician certification program and changes for improved readability, compliance and restructuring of the requirements.

This proposed rule would also more fully implement the prohibition under section 608 of the Clean Air Act against knowingly venting, releasing or disposing of ozone-depleting and substitute refrigerants. It would accomplish this by updating the existing requirements under section 608 that currently apply to ozone-depleting (ODS) refrigerants and then extending them to non-ozone-depleting substitute refrigerants, such as HFCs.

The existing regulations require that persons servicing or disposing of air conditioning and refrigeration equipment observe certain service practices that reduce emissions of ozone-depleting refrigerant. Specifically, these provisions include:

- requiring that technicians be certified to work on appliances;
- restricting the sale of refrigerant to certified technicians;
- specifying the proper evacuation levels before opening up an appliance and requiring the use of certified refrigerant recovery and/or recycling equipment;
- requiring the maintenance and repair of appliances that meet certain size and leak-rate thresholds;
- requiring that ozone-depleting refrigerants be removed from appliances prior to disposal;
- requiring that air conditioning and refrigeration equipment be provided with a servicing aperture or process stub to facilitate refrigerant recovery;
- requiring that refrigerant reclaimers be certified in order to reclaim and sell used refrigerant;
- establishing standards for technician certification programs, recovery equipment and quality of reclaimed refrigerant.

This rule proposes to update the existing requirements that currently apply to ozone-depleting refrigerants and extend those requirements to non-ozone-depleting substitute refrigerants, including but not limited to hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

EPA is also proposing changes to the National Recycling and Emission Reduction Program. Some of these

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EPA Proposes Rule to Strengthen Refrigerant Management Requirements

changes are intended to strengthen the existing program, in particular by requiring a number of industry best practices. Others are intended to extend the regulations to HFCs and other substitutes for ODS. The major regulatory changes proposed are:

- extending the requirements of the Refrigerant Management Program to cover substitute refrigerants, such as hydrofluorocarbons (HFCs). *(Note that some substitutes, including ammonia, have already been exempted from the section 608 venting prohibition as provided for under section 608 in previous EPA rules; such substitutes would also be exempted from the requirements under this proposed rule.)*;
- requiring technicians to keep a record of refrigerant recovered during system disposal from systems with a charge size from 5 to 50 lbs. This would apply to both ODS and non-ODS refrigerants.
- lowering the leak-rate threshold above which owner/operators of refrigeration and air-conditioning equipment normally containing 50 pounds or more of refrigerant must repair leaks, as follows:
- lower from 35 percent to 20 percent for industrial process refrigeration (IPR) and commercial refrigeration equipment;
- lower from 15 percent to 10 percent for comfort cooling equipment.
- requiring regular leak inspections or continuous monitoring devices for refrigeration/air conditioning systems as follows:
- annual inspections for systems normally containing 50 pounds or more of refrigerant;
- quarterly inspections for commercial refrigeration and IPR systems normally containing 500 pounds or more of refrigerant;
- prohibiting operation of systems normally containing 50 pounds or more of refrigerant that have leaked 75 percent or more of their full charge for two consecutive years;
- allowing the purchase of cans containing two pounds or less of non-ODS refrigerant for motor vehicle air conditioner servicing without technician certification so long as the small cans have a self-sealing valve to reduce refrigerant releases;
- requiring that certifying organizations publish lists or create online databases of technicians that they certify;
- updating the technician certification test bank with more questions on handling substitutes, including flammable substitute refrigerants, and on the impacts of climate change.

While ammonia would not be subject to the updated requirements in the proposed rule, it is important for members to be aware of the proposed changes.

It is important to note that certain refrigerants, including ammonia, are currently exempted from the requirements of Section 608. EPA has stated that it will continue to exempt through regulation certain substitutes from the venting prohibition, and the other safe handling provisions, based on a determination that their release does not pose a threat to the environment.

This is the case in the current regulations, for instance, with all approved uses of hydrocarbon refrigerants, ammonia, and carbon dioxide. EPA is not proposing in this rulemaking to extend any of the requirements under section 608, including the technician certification program and the sales restriction, to refrigerants that are exempt from the statutory venting prohibition (CO_2, hydrocarbons in certain SNAP-approved applications, ammonia, etc.). The current list of exempted refrigerants is:

- carbon dioxide in any application;
- nitrogen in any application;
- water in any application;
- ammonia in commercial or industrial process refrigeration or in absorption units;
- chlorine in industrial process refrigeration (processing of chlorine and chlorine compounds);
- hydrocarbons in industrial process refrigeration (processing of hydrocarbons);
- ethane (R–170) in very low temperature refrigeration equipment and equipment for non-mechanical heat transfer;
- propane (R–290) in retail food refrigerators and freezers (stand-alone units only), household refrigerators, freezers, and combination refrigerators and freezers, self-contained room air conditioners for residential and light commercial air-conditioning, heat pumps and vending machines;
- isobutane (R–600a) in retail food refrigerators and freezers (stand-alone units only) and vending machines;
- R–441A in retail food refrigerators and freezers (stand-alone units only), self-contained room air conditioners for residential and light commercial air-conditioning, heat pumps, and vending machines.

While ammonia would not be subject to the updated requirements in the proposed rule, it is important for members to be aware of the proposed changes.

The full text of the proposal and additional information about the Section 608 program can be found at: http://www2.epa.gov/snap/608-proposal. Public comments on the proposed rule must be received on or before January 8, 2016. To submit comments, you can use the Federal eRulemaking Portal at http://www.regulations.gov and file them under Docket ID No. EPA–HQ–OAR–2015–0453.

A Preview of Upcoming Model Codes

iiar code advocacy UPDATE

BY JEFFREY M. SHAPIRO, P.E., FSFPE

IIAR's overall objective with respect to model codes continues to be facilitating coordination between model codes, ASHRAE 15 and IIAR 2 with the intent of positively influencing model codes with respect to treatment of ammonia refrigeration.

Codes march on… Difficult as it may seem to believe, the 2018 editions of some model codes are already well on their way to completion. The 2018 International Mechanical Code is already completed, pending final ratification of recommended changes by members of the International Code Council. Recommended changes to the 2018 editions of the International Fire Code, NFPA 1 Fire Code and Uniform Mechanical Codes will have begun processing prior to publication of this article.

IIAR's overall objective with respect to model codes continues to be facilitating coordination between model codes, ASHRAE 15 and IIAR 2 with the intent of positively influencing model codes with respect to treatment of ammonia refrigeration. We have had much success in that regard, which I've documented in previous articles.

The rewrite of IIAR 2, along with IIAR's new suite of standards that are focused exclusively ammonia refrigeration, has firmly established IIAR as the leading international standards development organization (SDO) representing the interest of the ammonia refrigeration industry. As a result, our focus on coordinating model codes with IIAR's standards, and gaining formal adoption of these standards, has intensified. Getting IIAR's standards recognized and adopted by model codes is an essential step towards having IIAR's industry experts assume the primary role in establishing regulations that govern ammonia refrigeration.

With this in mind, a summary of our more significant accomplishments with the 2018 IMC and other model codes is presented below.

2018 IMC (pending final membership ratification):

Changed the definition of "Machinery Room" and associated provisions to clarify that spaces must only meet machinery room construction requirements when the machinery room is required by code. Accordingly, spaces that contain limited machinery that does not trigger a machinery room requirement, are clearly not required to be constructed as machinery rooms simply because some ammonia machinery happens to be present.

Changed machinery room door requirements to make it clear that only doors serving as a means of egress are required to swing outwards from the machinery room. Previous code text suggested that all doors leading out of a machinery room were required to swing out from the machinery room, even if they led to a control room, electrical room or other space that was not part of the intended egress path.

IIAR 3, IIAR 4 and IIAR 5 were adopted as official, enforceable reference standards.

Added an allowance for "low-probability pumps" to be located outside of a machinery room in refrigerated industrial process and storage areas. This coordinates with provisions that were added to the 2014 edition of IIAR 2.

Deleted an outdated provision that related to providing a minimum of 100 square feet of floor space per occupant in refrigerated industrial process and storage areas.

Added two new exceptions to the requirement to provide ammonia refrigerant leak detection in refrigerated industrial process and storage areas. The exceptions allow omission of leak detection where: 1) A space is unoccupied and contains only continuous piping that does not include valves, valve assemblies, equipment, or equipment connections, or 2) Approved alternatives are provided for rooms or areas that are always occupied, and for rooms or areas that have high humidity or other harsh environmental conditions that are incompatible with detection devices.

Eliminated vague restrictions on permissible locations of refrigerant piping in buildings.

NFPA 1 Fire Code (pending further public comment and membership ratification):

IIAR 6 and IIAR 8 were recommended for adoption as official, enforceable reference standards.

Coordinated the requirements for refrigerant detection alarm and ventilation initiation with the new provisions in IIAR 2-2014, which are 25 ppm and 150 ppm, respectively.

UMC and IFC (processes begin January 2016)

IIAR proposals to gain adoption of IIAR standards and coordinate requirements with IIAR 2-2014 will be processed.

National Electric Code (NEC): In addition to model fire, building and

continued on page 32

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mechanical code advocacy, IIAR has also been advocating a change to the NEC that would eliminate a long-standing requirement to provide ventilation in refrigerated industrial process and storage areas where such areas are not designated as Class I, Division 2 hazardous (classified) locations. It is well understood and agreed by all that this requirement should apply to ammonia machinery rooms, but the NEC text, literally interpreted, extends this requirement to also include process and storage areas of refrigerated industrial facilities. Of course, providing emergency ventilation systems or Class I, Division 2 electrical equipment

Development of model codes and standards is an ongoing activity that involves many dedicated IIAR member volunteers serving on the IIAR Code Committee and IIAR Standards Committee.

in these areas has never been industry practice, but the NEC text has presented a potential "gotcha" that is best eliminated. After two meetings with the committee that governs this portion of the NEC, IIAR has gained the committee's support of a change that fixes this issue. The final vote on this change will be in June 2016 at NFPA's annual conference.

Development of model codes and standards is an ongoing activity that involves many dedicated IIAR member volunteers serving on the IIAR Code Committee and IIAR Standards Committee. Individuals who serve on these committees as representatives of the membership help to identify and respond to issues of concern to the industry and play a key role in directing future changes, such as those described above, many or all of which can be expected to appear in upcoming editions of model codes.

Pressure Vessel Replacement Considerations

When it's time to replace a pressure vessel on a closed-circuit ammonia refrigeration system, considerations such as facility design, installation, operation, and maintenance can help operators determine what to purchase.

To help owners and designers, including a site's in-house refrigeration operators and technicians, in their decision-making process, Tony Lundell, Director of Standards and Safety at IIAR, hosted a webinar on the subject, covering several questions that they should ask themselves when evaluating their specific needs.

The most critical issue for a safe design is for operators to ensure that the pressure, temperature and capacity of their replacement vessel meets or exceeds what the vessel will need to handle in both the short term and long term.

Tony Lundell, director of safety and standards at IIAR

"Overall, these pressure vessel replacement considerations will help in your review to achieve a safe design while getting the most integrity for the least cost," Lundell said, adding that the considerations can also improve communications with manufacturers and help in defining the equipment-specification requirements that are needed now as well as in the future.

Lundell said the most critical issue for a safe design is for owners to ensure that the pressure, temperature and capacity of their replacement vessel meets or exceeds what the vessel will need to handle in both the short term and long term.

"Keep in mind, if you're going to reuse the vessel, plan now to have it ready for the long-range pressure and low-temperature requirements for the future system since it is going to be considered for another system in a few years down the road," Lundell said.

"Another consideration is the size, type and quantity of nozzle connections on the replacement pressure vessel for overpressure relief protection. You want to make sure you have

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enough nozzle capacity for pressure relief discharge flow to protect the vessel that you are going to operate the system at in the future on the long-range plan and, of course, on the short-range plan."

Having the replacement vessel sized and installed now for both present and future loads is better than paying for another vessel and its associated installation costs later, Lundell explained. "Avoid putting a vessel in now and then five years later, due to production load changes, be forced to replace the vessel in order to meet new and different safe design requirements. This would be an added expense that can be avoided with proper long-range planning," Lundell said.

During the webinar, Lundell covered 12 specific pressure vessel replacement considerations. They are:

How long will this replacement pressure vessel need to operate once installed?

What is the minimum design pressure and the lowest operating temperature of the system that the replacement pressure vessel will be operating under once installed?

Will this new pressure vessel be considered for future use on a different system that has a higher minimum design pressure and/or a lower operating temperature?

Will this new pressure vessel be carbon steel and/or subject to an environment that could result in external corrosion?

Should you install a horizontal or vertical replacement pressure vessel?

Should the heads of the pressure vessel be hot-formed or stress-relieved after cold-forming?

What size, type and how many vessel nozzle connections should be installed for over-pressure relief protection?

Should a new pressure vessel be dual-stamped when purchased?

What information will be provided on the pressure vessel nameplate?

Should Non-Destructive Testing inspection ports be installed now, when it is being insulated, so they are available for the first NDT testing?

Does the pressure vessel need to be insulated?

When the pressure vessel is shipped, do you need to assure it is internally and externally protected?

Lundell offered insight into each of the considerations during the webinar, which members can access via the IIAR member website in the member's only section.

"I'd hate to have you put a vessel in and then five years later, production changes or the site changes and the vessel will not meet the requirements, and you have to replace it with a different vessel."

Tony Lundell, director of safety and standards at IIAR

Eliminating Vapor Drive

Energy represents the second greatest cost in industrial ammonia refrigeration, and a compromised vapor barrier is a significant contributor to energy losses.

Facilities often fight a losing battle against vapor drive and air infiltration and sealing the building envelope can produce significant savings. It comes as no surprise that efficiency is directly related to a facility's ability to control vapor drive and air infiltration.

When the vapor barrier is compromised, warm, moist air flows over the tops of walls, seeps in from loading docks and creeps between the freezer, cooler and battery rooms. The resulting vapor drive and air infiltration can mean an increase in energy costs of nearly 20 percent.

A 500,000 square-foot distribution center with an average monthly electric bill of $100,000 would save nearly $250,000 per year by sealing the building envelope.

A 500,000 square-foot distribution center with an average monthly electric bill of $100,000 could save nearly $250,000 per year by sealing the building envelope. Not only does the facility run more efficiently, but there are also savings in labor costs that are incurred when employees are hired to remove ice and condensation.

"The biggest benefit from a properly sealed building envelope is on the bottom line," says Eric Finnerty, president of Vapor Armour, Inc. "I can't stress enough the potential cost reduction in your operation. Imagine that you're trying to cool a 100,000 square-foot freezer section and warm air is leaking in from the outside. It's like running your air conditioner at home with the windows open."

Additional costs are incurred with the energy needed for defrosting.

The build-up of ice and condensation is a universal issue with cold storage facilities. Moisture leads to the corrosion of pipes, which, if left unchecked, can cause a hazardous situation. It also creates a breeding ground for microbes that in the food industry results in risk of contamination and product recalls.

Despite the obvious benefits of maintaining a vapor-tight facility, the ammonia refrigeration industry has been slow to embrace new technology that can retrofit existing facilities to create tighter building envelopes and vapor barriers. For many years, certain levels of vapor drive and air infiltration were considered unavoidable, and the loss in energy efficiency was seen simply as the cost of doing business.

But that attitude is changing, and not solely because of technological advances. The Food Safety Modernization Act (FSMA) that took effect in September requires that facilities eliminate condensation and ice from coming into contact with food products.

"This is a huge issue that is about to affect the industry. Now you have a government agency getting ready to come in and inspect your facility for ice and condensation," Finnerty says. "Not only is there the energy efficiency benefit from sealing the building envelope, but there is now the contamination issue. Sealing the building envelope and eliminating vapor drive is more important than ever."

The return on investment for retrofitting an existing facility is typically five years, according to Finnerty. So how should facilities address the issue of vapor drive and air infiltration?

Finnerty says the first step is to conduct a forensic evaluation of a facility. The steady increase of energy consumption needed to maintain temperature is a sign of vapor drive, which is the movement of humid air from one location to another. But the source of the issue is often hidden. Once the source is identified, a plan can be set in motion to seal the building and eliminate the ice.

"A vapor barrier system in a controlled environment is the most important part of the building when it comes to reducing energy usage," Finnerty says. "With advances in technology, we have materials available that eliminate vapor drive from happening."

And advanced cold storage door technology is now able to combine the insulating and sealing qualities of hard-core doors with the fast action of high-speed doors.

Thick, flexible foam core panels are better able to withstand impact and have a sufficient R-value to make defrosting unnecessary.

On the mechanical side, faster opening rolling doors with more effective perimeter seals have been developed.

With any system, a facility should research the investment and long-term costs as well as conduct a thorough energy analysis.

Facilities that have ice or a contamination problem should search out the new technologies that specifically address building envelopes and vapor barrier issues. "I've seen this problem in facility after facility for 25 years. The energy savings with a properly sealed envelope is staggering. Now the federal government is becoming involved, which ups the ante."

REFRIGERANT CHARGE REDUCTION: STRATEGIES AND RESULTS IN BUILDING ULTRA LOW CHARGED AMMONIA SYSTEMS

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ABSTRACT

This paper presents an overview of the reasons for charge reduction in air conditioning and refrigeration systems and discusses strategies for charge reduction: in compressors (oil), vessels, pipes, and heat exchangers. The focus is on heat exchangers, microchannel in particular. In addition to a trivial reduction of internal volume as a strategy for charge reduction, the effect of mass flux on void fraction and needed manipulation of circuiting is presented. A framework and example of comparison between refrigerants based on their potential for low condenser charge is provided.

1. INTRODUCTION

This paper presents the issues related to refrigerant charge reduction in following parts:

1. Reasons for charge reduction in general
2. Strategies, specifically in heat exchanger, microchannel in particular
3. Evaluation of potential for charge reduction in various refrigerants
4. Examples of extremely low charged ammonia chillers

2. REASONS FOR CHARGE REDUCTION:

Reduction of refrigerant charge is attractive for any refrigerant for several reasons:

- Low charge may expand the possibilities for some very good refrigerants (based on high cycle efficiency, high heat transfer/pressure drop performance, etc.) in areas and locations where either these fluids are totally restricted or only allowed in limited quantities due to flammability or toxicity issues. This is particularly true for fluids like ammonia and hydrocarbons which in some applications and locations are already accepted below certain levels (typically 150 kg for NH_3 and 150 or 50 g for HCs).
- System efficiency could be increased in cycling when refrigerant migration in off periods is significant.
- Direct environmental effects (limited importance for ammonia or hydrocarbons) are reduced: ozone depleting issues if any, global warming issues, etc… especially in the case of catastrophic leaks.
- Reduction of the first costs for refrigerant and lubricant expenses (not very important for ammonia or hydrocarbons since they are very inexpensive).

POSSIBLE DRAWBACKS OF LOW CHARGE:

Reducing charge beyond some point could result in problems in operation such as:

- If receiver is inadequate, then small leaks will result in insufficient charge thus reducing performance.
- If charge reduction is achieved by reducing the hydraulic diameter of pipes too severely, then pressure drops and flashing may affect efficiency and perhaps capacity.
- Reduced reliability of pumps (if present) due to possible vapor entrainment and cavitation.

STRATEGIES FOR CHARGE REDUCTION IN THE SYSTEMS AND HEAT EXCHANGERS

1. The first and almost trivial options for charge reduction is to **add a loop with another fluid** in the refrigeration system and in that way reduce the primary refrigerant charge. These options could be either cascades or secondary refrigerant loops which actually turn a refrigeration system into a chiller with either single or two phase secondary refrigerants. These options were, and are, very popular for their simplicity. Refrigerant in the primary (or only) system is in each component: compressor, vessel(s), liquid, two phase and suction lines, and finally, heat exchangers.
2. Reduction of **liquid quantities in vessels** can be achieved by reducing their volume and liquid levels and sometimes orientation.
3. Reducing refrigerant charge **in compressor** by a) reducing the internal volume b) reducing the quantity of lubricant and c) reducing refrigerant solubility (if reasonable). Needless to say, reduction of the volume on the high side yields greater results than on the suction due to density difference. A part of lubricant charge in the compressor is a function of refrigerant charge in the system to allow for oil retention in the system.
4. Reduction of the **refrigerant charge in pipes** is typically achieved by reducing internal volume (diameter and possibly even length). Reduction of diameter results in increased pressure drops. Pressure drops in liquid lines do not affect the system performance but can cause non-desirable flashing which affects the operation of flow controllers. Pressure drops in suction lines affect system efficiency and therefore may not be advisable.
5. The most attractive and important strategy is to **reduce the charge in heat exchangers** and that will be our main focus. Reduction of refrigerant charge in heat exchangers is always related to a reduction in internal volume. One must be careful to balance the adverse effects regarding either increased pressure drop or reduced heat transferred.

STRATEGIES FOR CHARGE REDUCTION IN HEAT EXCHANGERS

Almost every refrigerant inventory reduction strategy is related to reduction of internal volume. We should not forget that the internal volume of heat exchangers is typically determined in the desing phase based on the heat transfer area needed for the main purpose: heat transfer, pipe size and circuiting based on the target pressure drop. It is a great advantage that reduction of the volume is proportional to the channel (pipe) diameter squared while the heat transfer area is a linear function of the diameter. Typically consequence of the diameter reductoion is pressure increase that can me mitigated by increasing number of parallel circuits. Nevertheless, reduction of the internal volume is just one, relatively trivial, path to reaching the objective.

In the cases of spray evaporators, significant charge reductions were achieved compared to shell and tube even for the same volume.

To provide sufficient capacity with in-tube flow heat exchangers, it is necessary to provide a refrigerant flow that is inversely related to the latent heat of vaporization (h_{fg}). Therefore, refrigerants with larger values latent heats will have lower mass flow rates for the same capacity and all else being equal, consequence is lower pressure drop compared to those that require higher flow rate. These lower pressure drops may then allow for smaller diameter tubes to be utilized. We should not forget that ammonia has very high latent heat of vaporization compared to other refrigerats but also very light vapor that increases in tube velocity for the same mass flux.

Heat transfer effects of the charge reduction strategies are related to refrigerant side heat transfer. Higher heat transfer coefficients mean that smaller surfaces are required for a given duty. The effect of refrigerant heat transfer coefficient is greater for heat exchangers where the refrigerant side is a relatively large component of the total heat transfer resistance. As an example, charge is easier to be minimized in heat exchangers like water cooled condensers or chiller evaporators where water, rather than air, is heated or cooled. This is because a greater heat transfer area is required for a given capacity in the case of a heat exchanger with air due to its lower overall heat transfer coefficient.

In addition, those refrigerants that allow flow regimes that are better for heat transfer (annular or intermittent in evaporation or mist in condensation) or geometries that stimulate such flow regimes (i.e. microfins) will provide better opportunities for change reduction. Whether these opportunities will be realized is a function the adequacy of the design.

As already said, every reduction of internal diameter, with everything else being the same will increase pressure drop. The option to reduce the pressure drop in the same diameter tube with the same fluid is to reduce the length of the tube or decrease flow through the tube. This drives heat exchanger design towards parallel flows of small diameter tubes with the shortest possible circuits. That indicates a parallel heat exchanger design with single pass as an asymptote.

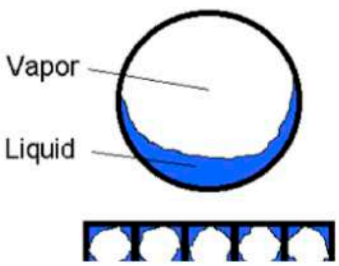
Nevertheless, the reality is more complex than this straight forward direction. The main goal should be to optimize system COP for a given mass flow by working on the balance between heat transfer and pressure drop. A fine discussion of this subject was given by Cavallini, 2011.

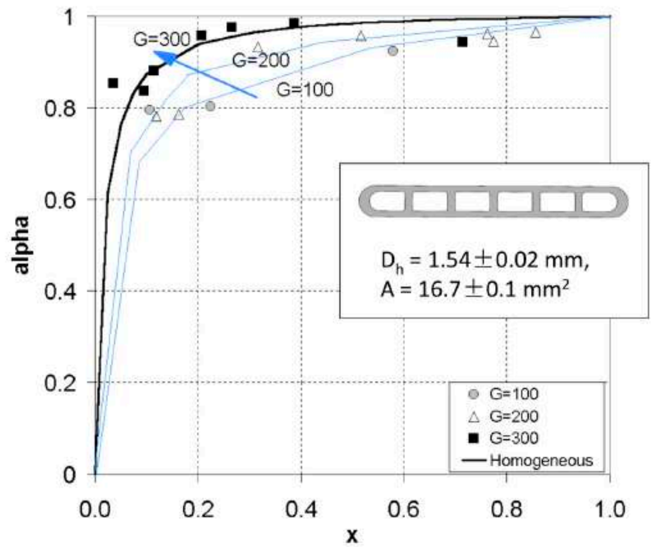
When calculating the refrigerant charge in a heat exchanger, engineers typically use void fraction, □ (□=Vapor volume/(Vapor+Liquid Volumes)) as a main variable. Figure 1 presents the relationship between R134a and void fraction in a microchannel tube (Nino et. al. 2002).

Void fraction is a misnomer. There are no voids in any heat exchanger. Better name would be "vapor volume fraction". Even more, we are interested not in vapor but instead on liquid because liquid carries the mass of refrigerant which we are trying to reduce:

Fig. 1 Void fraction: relationship, concept, and some values (mass flux 100 kg/m2s = 2.3 oz/in2s)

$$=\frac{1}{1+\frac{1\quad x}{x}\;\frac{v}{l}}$$





So, the mass of liquid M_l can be calculated as:

$$M_l = \int_0^L (1-\alpha)\rho_l A dz$$

and the total mass is calculated as:

$$M_l + M_v = \sum (1-\alpha_i)\rho_l A\Delta z_i + \sum (\alpha_i)\rho_v A\Delta x z_i$$

It is very important to have in mind that the void fraction is a function of mass flux (this fact even some void fraction correlations neglect). This relationship is a very important tool when designing to reduce refrigerant charge. The trend is the same as discussed above: reduction in diameter increases mass flux and increases void fraction, consequently reducing charge. This trend was shown in the graph shown in Figure 1.

There is a practical difficulty when following the strategy described above. When a higher capacity of a heat exchanger is desired, the number of parallel passes increases; consequently the headers where channel flows will merge are becoming larger. Flow regimes in headers are less well described and much less predictable, and typically void fractions are lower in header than in tubes.

Probably the best known low charge heat exchangers based on reduction of internal volume are of the microchannel type. They offer extremely low charge (less than 10 g/kW even for air on the other side), unless the headers are designed incorrectly. Hrnjak and Litch (2001) reported charges of 18 g/kW for a 15 kW air cooled microchannel ammonia chiller with a condenser charge of 6 g/kW. Traeger and Hrnjak (2005) reported an R290 system with 8-10 g of charge in a 1kW serpentine microchannel evaporator. There are some microchannel heat exchanger designs with water as the fluid on the other side (see Palm, 2009).

Other effective low charge heat exchangers are the plate type. They are better known in chiller applications and are typically made of stainless steel which is either brazed with copper or nickel or else are gasketed. Similar variations are becoming more common in plate and shell designs. Plate heat exchangers with air on the other side are predominantly used in automotive a/c systems as evaporators. Typical refrigerant charges in larger heat exchangers (Pearson, 2003) are 1kg/kW, 0.5kg/kW, and 0.25kg/kW for shell and tube, plate, and gravity fed plate heat exchangers, respectively.

Z. Ayub, (1996) reports on low charges (54 g/kW) in large spray evaporators for ammonia (4MW).

MASS FLUX EFFECTS ON CHARGE REDUCTION IN HEAT EXCHANGERS

Even though void fraction has been studied extensively [see Zivi, (1964), Butterworth, (1975), Newell, (1999), Adams et al., (2003) & (2006), etc.] mass flux effects were not always considered. Typically, for a given fluid and local quality, increase of the mass or heat flux affect flow regimes in a way that increases void fraction thus reducing charge.

Nino, Hrnjak, and Newell, (2002) showed the effect of mass flux on the void fraction for R134a in microchannel tubes (Figure 1), while Adams, Hrnjak, and Newell, (2003) shed some light on void fraction for ammonia (shown in Figure 2 and 3), carbon dioxide, and R245fa in microchannels. Figures 2 and 3 present void fraction as a function of quality for three mass fluxes, along with correlation predictions from the homogenous and Nino et al., (2002) models. It is obvious, despite some scattering of experimental data that higher mass fluxes result in higher void fractions (reduced refrigerant charges). Photos in Figures 4, 5, and 6 [from Niño, Hrnjak, & Newell, (2002)] provide visual evidence of the same trend, in transparent microchannels, for R134a, R410A, and air-water (whose fluid flow resembles ammonia). The same conclusion holds for tubes of larger diameter even not presented here.

It is clear from experimental data and the photographs that increase in mass flux reduces the charge (increase void fraction).

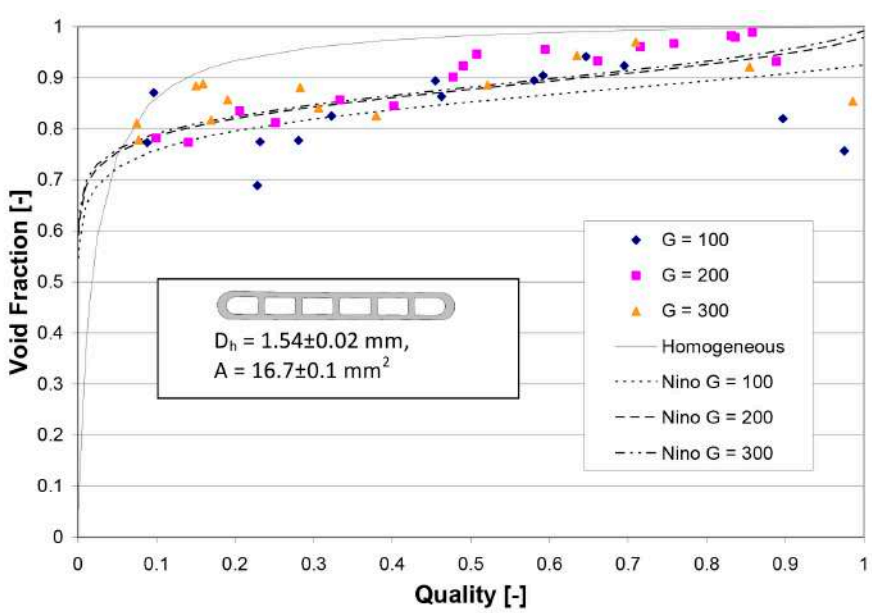
ANALYSIS OF CHARGE IN SOME REFRIGERANTS INDICATES AMMONIA HAS EXCELLENT POTENTIAL FOR REDUCTION

As discussed previously, it is clear that low charge is beneficial for every refrigerant in every application.

Comparisons of refrigerants based on their efficiency are common. The basis for efficiency comparison is cycle analysis (typically Rankine or Evans-Perkins) using thermophysical properties. Cycle analysis involves significant simplification that could be even misleading in some cases. It does not include realities of the heat exchanger (heat transfer, pressure drops, power for air or water movers, etc.). That approach is based on thermodynamics and is accepted as a first approximation in the comparative analysis.

It would be interesting to know whether refrigerants can be compared based on their potential for charge reduction. We will try to present here the concept to compare refrigerants based on their potential for charge reduction in heat exchangers and illustrate it with an example. The concept is in principle based on assumption that refrigerant which is less sensitive to reduction of internal volume and has less (high void fraction) and lighter (lower density) liquid has greater potential for charge reduction. The sensitivity to reduction of internal volume is defined by reduction of COP due to pressure drop. Pressure drop is a function mostly of mass flow rate determined by (available) portion of latent heat, specific volume of vapor, and viscosity of liquid.

Fig. 2 Void fraction of ammonia in a 6-port microchannel, Adams, Hrnjak and Newell, 2003 (mass flux 100 kg/m2s = 2.3 oz/in2s)



APPROACH

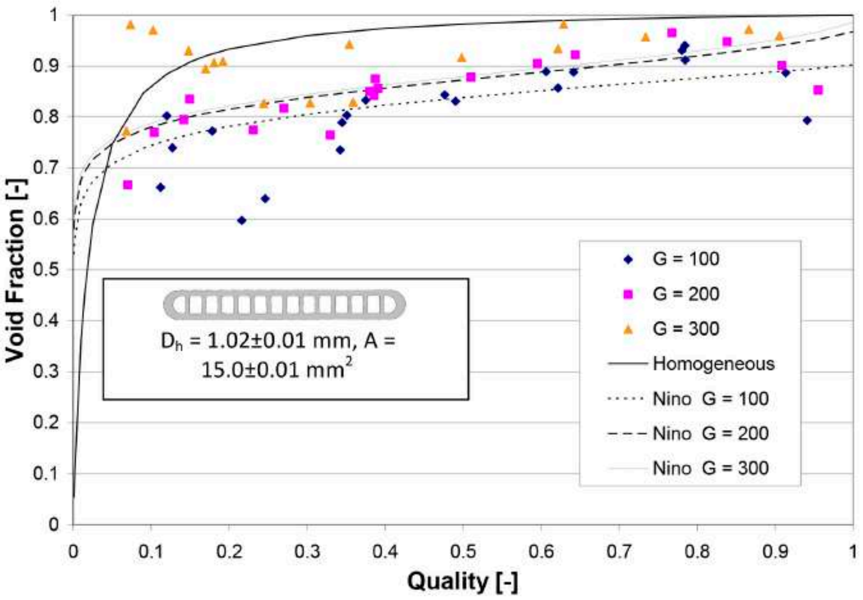
As said above, the most logical starting point for reducing charge in heat exchangers begins with the reduction of internal volume. A result of reducing the pipe diameter is increased pressure drop. The fair comparison of refrigerants should be based not on equal pressure drop itself but on the effect pressure drop has on efficiency (COP) while maintaining the same capacity.

The heat transfer on both sides (not only on refrigerant that is mostly affected when varying design options for charge reduction) is important and affects the result. That is the reason why maintaining identical air side is important. To maintain identical outside (air-side) conditions for each refrigerant, the heat exchanger type selected is the microchannel serpentine (two circuits) shown in the Figure 7 and with dimensions given in Table 1. Selection of microchannel type is due to its relevance today and for its anticipated acceptance by more manufacturers. In addition, high heat transfer coefficients and fin enhancement place this type of heat exchanger between conventional round tube plate fin types and water cooled or cooling types, providing a more universal basis for conclusion. A serpentine design was selected to avoid uncertainties in predicting the charge in headers for various refrigerants. The serpentine design does not reduce the generality of the conclusions or even limit the increase in mass flux. Figure 7: Baseline serpentine condenser design

For the example presented here, the internal diameter of the channel was the only variable in the model used to adjust refrigerant pressure drop. In the experiments it was easier to vary the number of active channels and the model was adjusted to facilitate validation.

To estimate the condenser charge required for different refrigerants, the internal volumes (diameters) of identical baseline heat exchangers are shrunk to create a pressure drop which causes an equal (here selected 1%) reduction in COP. Certainly, 1% is arbitrary value, but it is equal for each refrigerant. One could question if equal penalty is fair, Wujek, (2012). More about this subject may be found in Hrnjak (2009) and Padilla and Hrnjak (2012).

Fig. 3 Void fraction of ammonia in a 14-port microchannel, Adams, Hrnjak and Newell, 2003 (mass flux 100 kg/m2s = 2.3 oz/in2s)



The adopted model takes into account the effect of the ratio between the refrigerant and air side heat transfer areas when iterating to find the solution.

A fair comparison of minimum refrigerant charges requires maintaining the system capacity while modeling heat exchangers with the same face area, exterior tube dimensions, identical fins, and same operating conditions on the air side (velocity, temperature, humidity). Additionally, the effect of the condenser on the rest of the refrigerant side of the system should be the same. Here it is defined as a 1% difference between COPs of the system with a real condenser and one without pressure drop on the refrigerant side. The condenser channel diameter is modified to generate the same degradation of COP due to refrigerant side pressure drop compared to an ideal condenser (without pressure drop) while maintaining the same evaporator capacity. A similar option would be to vary the number of active channels while maintaining

Fig. 4 Visualization of effect of mass flux and quality on void fraction supports measured values (R134a, 1mm, 9-port), Nino, Hrnjak, Newell, 2003 (mass flux 100 kg/m2s = 2.3 oz/in2s)

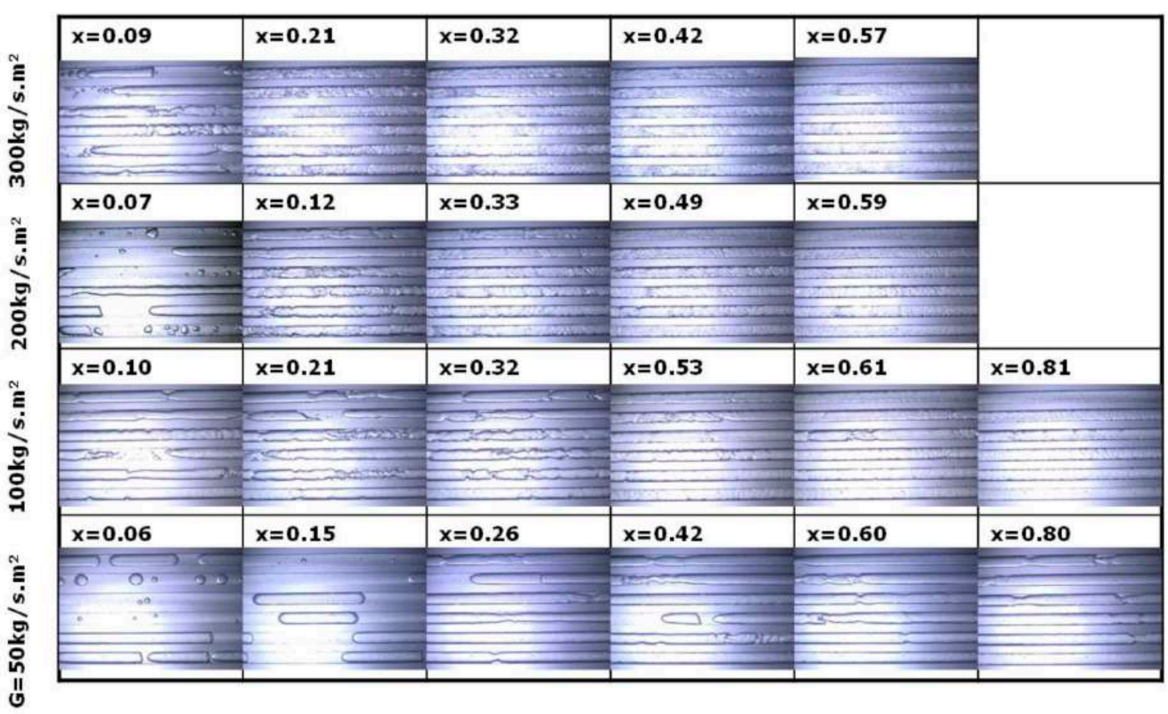


Fig. 5 Visualization of effect of mass flux and quality on void fraction (R410A, 1mm, 9-port),Nino, Hrnjak, Newell, 2003 (mass flux 100 kg/m2s = 2.3 oz/in2s)

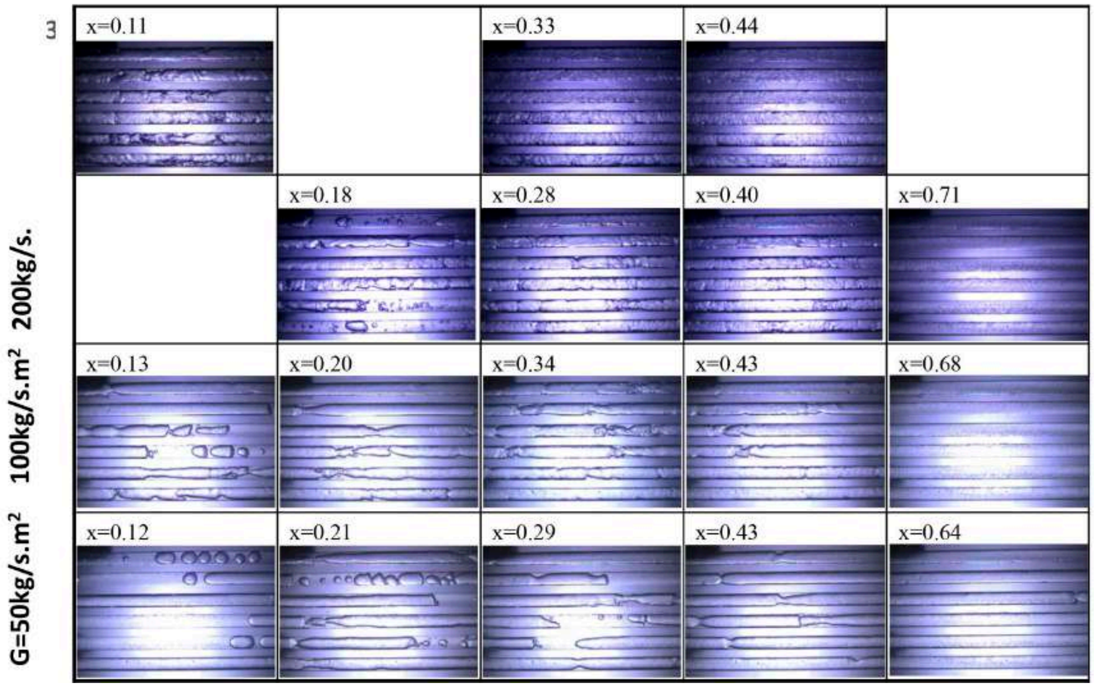


Fig. 6 Visualization of effect of mass flux on void fraction (air–water, 1mm, 9-port), Nino, Hrnjak,Newell, 2003 (mass flux 100 kg/m2s = 2.3 oz/in2s)

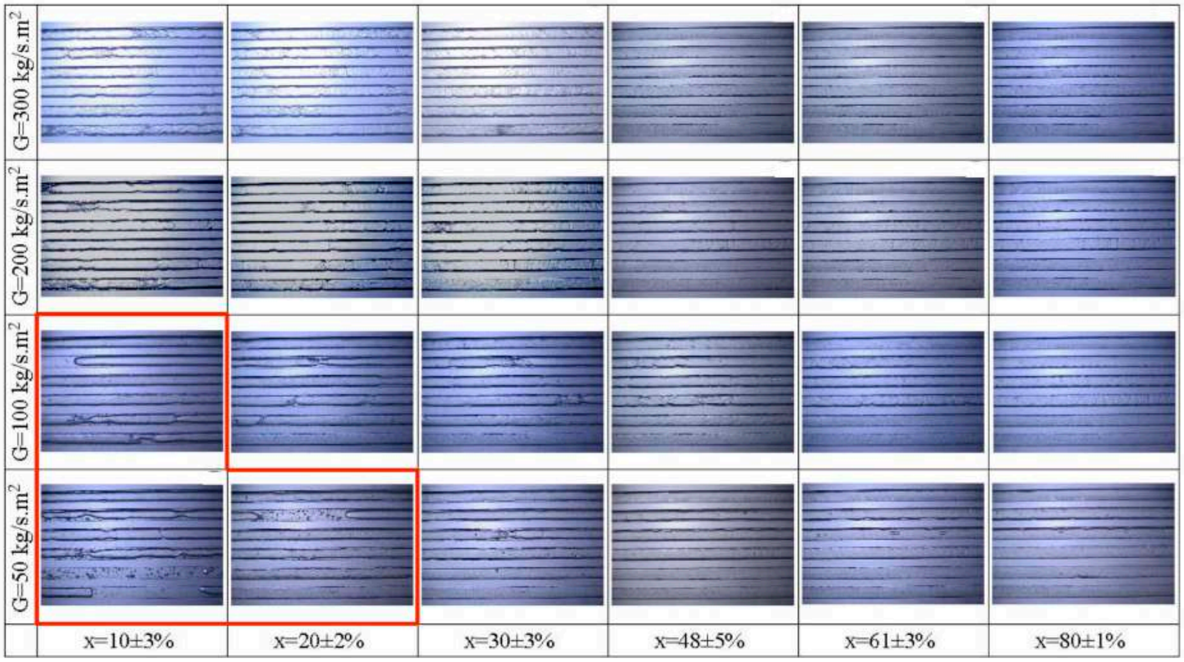


Fig. 7 Baseline serpentine condenser design

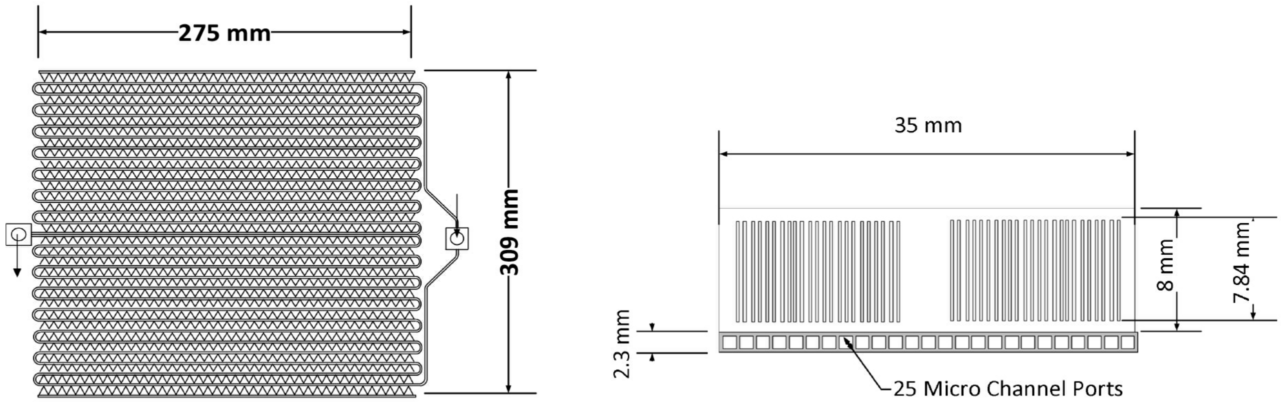


Table 1 Characteristics of the condenser

Fins		Tubes		Overall	
Fin height [mm]	8	Number of tubes (circuits)	2	Width [mm]	275
Fin depth [mm]	35	Tube thickness [mm]	2.3	Height [mm]	200
Fin thickness [mm]	0.15	Tube depth [mm]	35	Depth [mm]	30
Fins per inch [in^{-1}]	15	Number of ports [-]	25	Circuits [-]	2
Fin pitch [mm]	1.41	Hydraulic diameter [mm]	Varies	Runs per circuit [-]	10
Louver height [mm]	7.84	Absolute roughness [mm]	0.001	Air HT area [m^2]	1.612
Louver pitch [mm]	1.72				
Louver angle [°]	27				

the channel diameter and the outer dimensions of the flat tube. This approach has been tested experimentally in Hoehne and Hrnjak, (2004).

Fig. 8 compares the "ideal" baseline cycle, in solid line, to the "real" cycle, with pressure drop, shown with the dashed line. The pressure drop in the "real" condenser is set to cause a 1% reduction in COP compared to "ideal" cycle. Isenthalpic expansion and isentropic compression are assumed in the ideal cycle for all fluids. The Zivi void fraction model was used because it is refrigerant independent but consequently the effect of mass flux was not reflected. These assumptions do not affect the generality of conclusions. Cycle operating conditions in this example are: $T_{evaporation}$=0°C, T_{airin}=20°C, superheat 5 K. Based on the evaporator and condenser models, the necessary charge to achieve 1 kW cooling capacity for various refrigerants is evident from the Fig. 9. Additionally, the "real" hydraulic diameter of the condenser to minimize charge with only 1% degradation in COP can be found. Ammonia requires the lowest charge but not the smallest tube size. Isobutane requires a much larger tube diameter.

R717 and R744 show the best potential for low charge systems but for different reasons. R717 is known to have a very high pressure drop for a given mass flux because of very low vapor density (see second to last column in Table 2) which causes higher velocity for a given mass flow rate in comparison to other fluids. However, due to its very high latent heat (h_{fg} = 1167 kJ/kg), the mass flow needed for the same capacity is significantly lower for R717 than for any other fluid. The sensitivity of ammonia to pressure drop is neither exceptionally low nor high in comparison to the other fluids shown in Table 2 (column 5, ΔP). Since vapor density is very low for ammonia, the total mass is the lowest for a given void fraction. Light vapor is helpful in building a low charge system.

Carbon dioxide (R744) has different characteristics than ammonia. R744 has a low sensitivity to pressure drop, which means that high pressure drop will not result in high temperature drop. The sensitivity to pressure drop is given in Table 2, Column 5. The potential for building a low charge R744 system comes

Fig. 8 Illustration of the process–Pressure drop that causes 1% change in COP

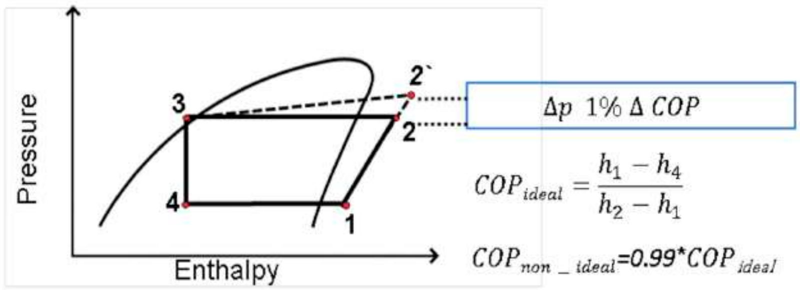
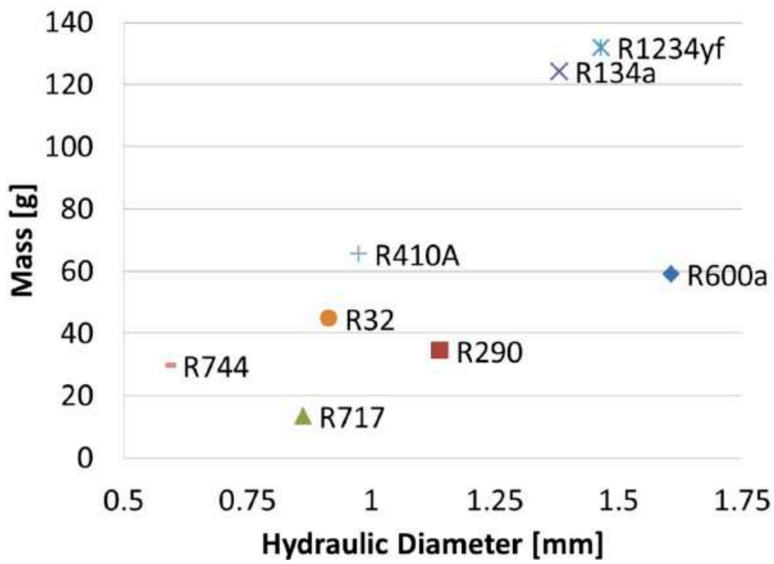


Fig. 9 Refrigerant charge and hydraulic diameter of serpentine condenser for 1kW refrigeration system causing 1% difference from ideal COP due to condenser pressure drop



from having low pressure drop (due to dense vapor) and very low sensitivity to pressure drop. The small channel sizes, dense vapor, and low sensitivity to pressure drop indicated that microchannel heat exchangers are ideal for R744. Because R744 has a dense vapor, it will have more refrigerant mass at a given void fraction and internal volume.

The largest hydraulic diameter is required for R600a (Isobutane) mostly because of the lighter vapor (second to ammonia). The combination of both light vapor and liquid keeps the charge reasonably low even with the largest diameter.

The two refrigerants that require the highest charge are R1234yf and R134a even though their individual thermophysical properties are balanced. High density of liquid combined with high sensitivity to pressure drop requires significantly greater charge than other fluids presented here.

5. SOME EXAMPLES OF EXTREMELY LOW CHARGED AMMONIA SYSTEMS

Recent advances in manufacturing technologies of microchannel tubes and heat exchangers resulted in expansion of some important mass production markets and consequently opened opportunity for further reduction of costs. That situation generates the possibilities for application of microchannel heat exchangers in areas with traditionally lower production volumes, ammonia being one of them.

Litch and Hrnjak [9] presented data for an ammonia chiller with an air cooled microchannel condenser. This resulted in the lowest specific charge air-cooled chiller for ammonia reported in the literature so far.

Two aluminum condensers were evaluated: one with a single serpentine tube and the other with a parallel tube arrangement between headers having 24 tubes in the first pass and 14 in the second. Each tube has 19 triangular ports of equal dimensions with a hydraulic diameter less than 1 mm. The fins are multi-louvered. The serpentine condenser has a single tube that passes 16 times through multi-louvered fins. There are five enhanced square ports in the tube. Additional details of these condensers may be found in Litch & Hrnjak [9].

Overall heat transfer performance and charge measurements were taken for each condenser and the system as a whole. The microchannel heat exchanger with parallel flow performed better in every respect. Overall, condenser performance was quantified in terms of U values for different air flow rates, superheating and subcooling conditions and is presented in Figure 10.

Refrigerant inventory measurements of the condenser were taken at different operating conditions. Refrigerant inventory measurements are compared to model results using different void fraction model predictions. All void fraction correlations perform similarly in helping to predict total charge. The use of Newell's correlation (Newell et al. [10]) for serpentine condenser yields the smallest average error of 9.3%, with a maximum of 15.7%. With the Butterworth [5] and Zivi [14] correlations, the average and maximum errors are 10.1/22.8% and 12.3/24.9%, respectively. The slight over prediction results in a simulated subcooled region that is larger than the actual region, inflating predicted charge. Data by Adams, Hrnjak and Newell [1] fit well in the prediction. These results are presented in Figure 11.

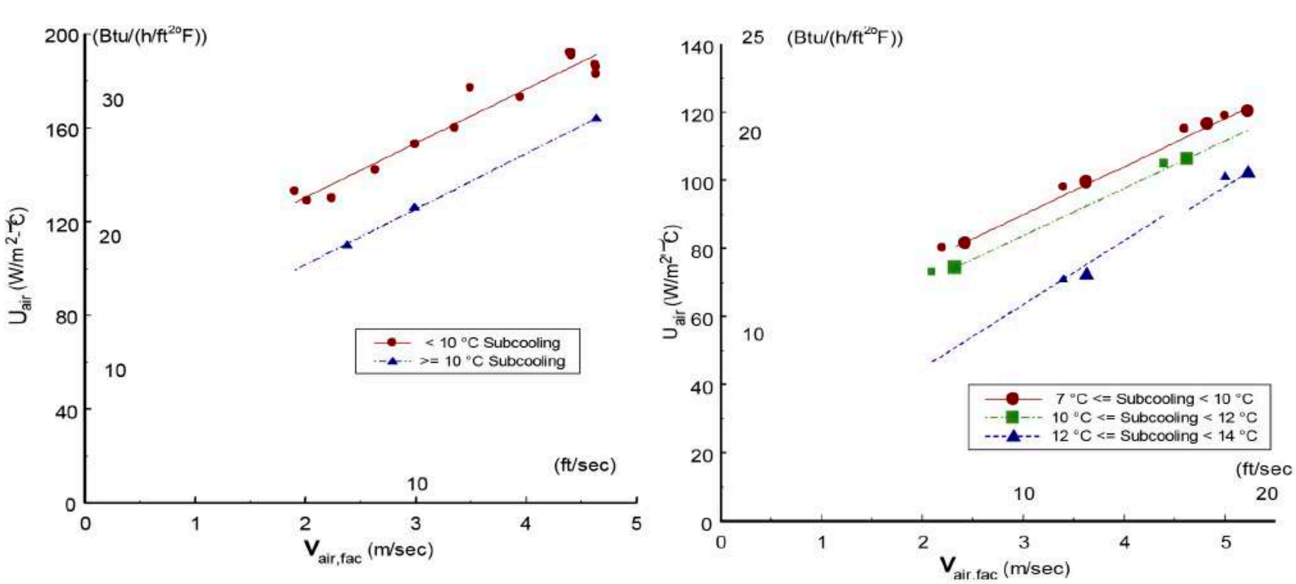
Table 2 Refrigerant charges in evaluated condenser serving 1 kW evaporator based on pressure drop that causes 1% COP reduction compared to idealized (ΔP=0 cycle)

Fluid	Ref. Mass	Hydr. Diam.	Mass Flow	ΔP [1 % COP reduction]	COP Ideal	Cond. Temp.	Rejected Heat	Liquid Density	Sat. Vapor Density	Latent Heat
	[g]	[mm]	[g/s]	[kPa]	[-]	[C]	[kW]	[kg/m³]	[kg/m³]	[kJ/kg]
R717	13.4	0.86	0.86	7.45	10.0	24.6	1.043	604	7.72	1169.0
R744	29.8	0.59	5.94	35.79	7.0	24.3	1.103	725	234.70	125.9
R290	34.4	1.14	3.15	6.58	9.6	25.2	1.048	492	20.72	335.7
R32	44.9	0.92	3.63	11.46	9.4	24.8	1.054	963	47.12	271.7
R600a	59.1	1.61	3.31	3.17	9.8	25.5	1.067	550	9.285	329.4
R410A	65.6	0.98	5.32	11.65	9.4	25.1	1.067	1063	66.15	187.8
R134a	124.2	1.38	5.96	5.52	9.5	25.6	1.094	1206	32.88	177.7
R1234yf	132	1.46	7.52	5.41	9.3	25.6	1.077	1091	38.42	145.6

Obviously, predictions for a serpentine condenser are much more accurate than for microchannel when using the same correlation and experimental data. That clearly indicated a significant inaccuracy in the charge prediction in headers (see Figure 12.). Another insight from Figure 7. (serpentine) is that liquid subcooling is a large contributor to total charge. The relative predicted charge contributions from the refrigerant phase zones for the data point with the highest liquid subcooling tested are 0.5% in superheated zone, 29.2% in the two-phase region, and 70.3% in subcooling region. From the data point with the lowest liquid subcooling, the contributions are 0.5%, 60.1%, and 39.4% in subcooling. Even though the subcooling region is only 26% of the total tube length, it comprises 70% of the total charge. Thus it is advantageous to reduce subcooling not only for increased heat transfer, but to reduce refrigerant charge.

From the experimental data taken, the microchannel parallel flow con-

Fig. 10 Overall heat transfer coefficients for two microchanel condensers for ammonia



denser appears to outperform the macrochannel serpentine condenser. The overall heat transfer coefficient for a given face velocity is 60-80% higher than for the serpentine condenser; and the charge is an average of 53% less. The microchannel condenser has a smaller volume for approximately the same face area. Also, it has less charge and better heat transfer than the serpentine and typical condensers.

6. NEW DEVELOPMENTS IN COMPRESSORS AND MICROCHANNEL HEAT EXCHANGERS AS CONDENSERS IN SMALL SYSTEMS

Probably the most important recent development is the new Mycom hermetic compressor that is used for both refrigeration and heat pumping. The wrap is specifically designed for use with ammonia. Nominal capacity in cooling (at -5oC/50oC) is 45 kW while in heat pumping is 47 kW. Motor is IPM type with aluminum windings. There are two models: for low and high temperature. The weight of the hermetic version is about 100 kg. This compressor is equipped with an oil pump. The ammonia charge of the unit is 6 kg (see Table 3 and Figures 13 and 14).

Development of microchannel condensers for ammonia has moved from the Air Conditioning and Refrigeration Center at the University of Illinois to Creative Thermal Solutions (CTS), a high tech company that specializes in research and development of novel refrigeration and air conditioning approaches. Figure 15 presents a photo of a condensing unit with microchannel heat exchanger used in an experimental facility for evaluation of ammonia evaporators, while Figure 16 shows a unit from Figure 9, CTS instrumented for implementation of MC condensers. The MC condensers used improved performance with 87% face area of original round tube condenser, with only 19% of core volume and just 7% or original weight and 27% or original refrigerant volume – charge. Just few weeks ago M. Tomooka of Mycom presented these results in the paper at IIAR meeting in Orlando, FL "Application of Microchannel heat exchangers to compact ammonia systems"

Another very good example is presented by Cecchinato and others [23] who described the main features of the newly designed prototype, including:

- refrigerating capacity of 120 kW
- open inverter-driven screw compressor with nominal volumetric flow rate equal to 118 m3/h
- evaporation and condensation temperatures of 2°C and 50°C respectively
- temperature of the secondary refrigerant (water) at the evaporator outlet was set at 7°C and at the evaporator inlet at 12°C
- plate heat exchanger evaporator with 52 plates having high chevron angle with overall dimensions equal to 618x191 mm

The chiller use low internal volume heat exchangers and the direct expansion evaporator providing the charge of 10.0 kg of ammonia. Experimental results showed COP of 5.0 to 2.7 at ambient temperatures from 10 to 40°C. The authors estimated potential for a charge reduction of 20% if microchannel condenser would be used.

FEW ADDITIONAL COMMENTS

At this point of heat exchanger development, the lowest charges have been achieved by using a microchannel approach and will be presented later in more detail. Nevertheless, microchannel technology is not the only way to reduce charge. Very good results have been achieved by using plate evaporators or condensers with water, or other fluids, on the other side (brazed, gasketed, cassette, welded shell and plate, etc…). The automotive industry has developed plate evaporators for air cooling, but the application is still limited to mobile air conditioning (aero, automobiles, off-road vehicles etc…). Spray evaporators are also

Fig. 11 Predictions and measured values for the charge in two condensers

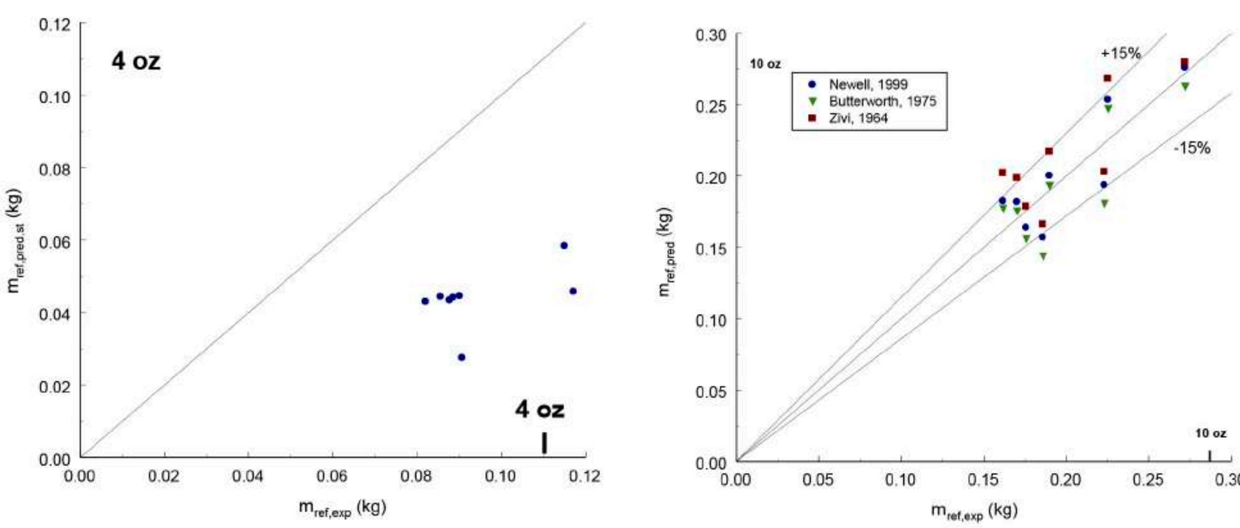


Fig. 12 Charge distribution in two microchannel condensers

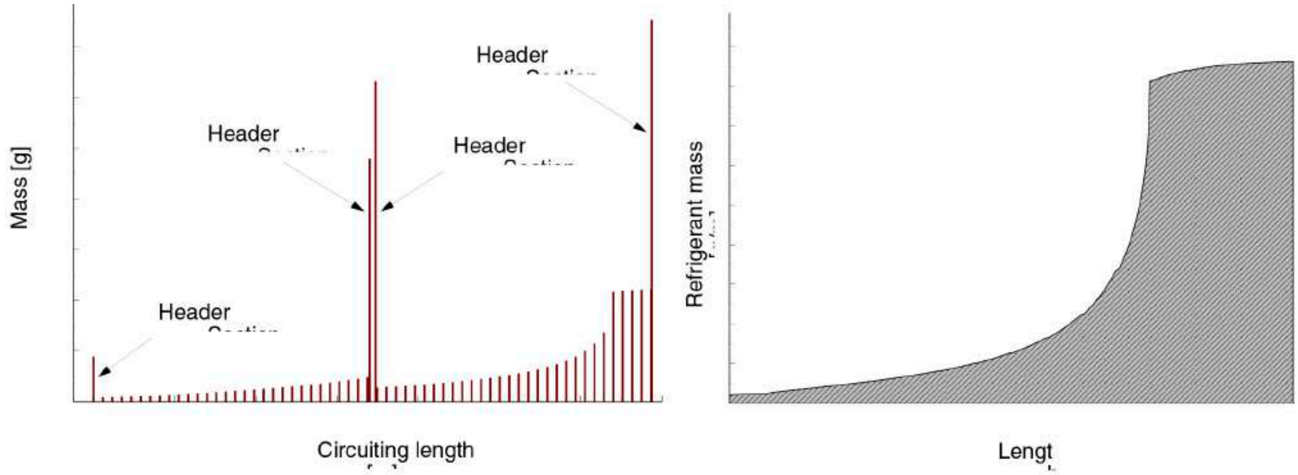


Fig. 13 New compressor: cross section and photo

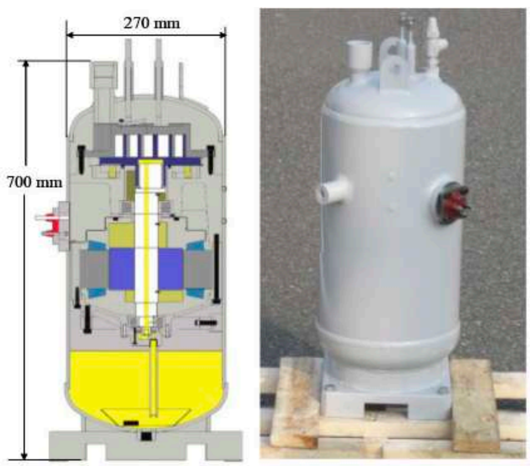


Fig. 14 New chillers with hermetic ammonia scroll and conventional condensers

known for their low charge. It should not be forgotten that in microchannel heat exchangers significant liquid quantity is retained in the headers.

Typical values for refrigerant inventory in larger heat exchangers as given by Pearson [13] are shown in Table 4.

Ayub reports about low charges in spray evaporators and recent improvements, shown in Table 5.

Pearson reports that "optimal charge" chiller had 100g/kW charge. The optimal value had an unspecified additional charge for leakage and operation.

Litch and Hrnjak presented data for some small ammonia systems with published charges in Table 6.

B. Palm in the summary of a decade of charge reduction at KTH presented a small ammonia system (a laboratory setup simulating a domestic water to water heat pump) as a part of Sherhpa project. Their largest challenge was to get the oil back to the compressor in the direct expansion system so they used miscible oil and a heat exchanger with narrow channels. The same special aluminum heat exchangers were used as condenser and evaporator. Plate heat exchangers were also tested and performed well as condensers but not as evaporators due to problems with oil return. The system with an open compressor had 9kW capacity with 100g of charge (an amazing 11 g/kW, half of the charge of ILKA MAFA 100.2-11K45).

SUMMARY AND CONCLUSIONS

This paper presented reasons for charge reduction and strategies for the actions:

1. Introduction of another (secondary) fluid
2. In the compressor:
   - Reducing the internal volume
   - Reducing quantity in lubricant
   - Reducing solubility to reduce refrigerant absorption.

Table 3 Characteristic of the first chiller unit with hermetic scroll compressor

New Mycom unit with hermetic scroll compressor		
Shell	High pressure chamber	
	Design pressure	2.7 MPa
Motor	PM type Al windings	15 kW
Operating Conditions	Design temperature	120 oC
	Condensing temperature	30 to 55 oC
	Evaporating temperature	35 to +10 oC
	Rotational speed	1800～3600 rpm
Lubrication	Oil pump	
	Oil cooling	Liquid injection
	Oil type	PAG
Weight		100 kg
Refrigerant charge		6 kg
Capacity at -5/50 °C	Cooling	45 kW
	Heating	47 kW

3. In vessels by reducing volume and liquid levels.
4. In pipes by reducing internal volume (diameter and possibly even length).
5. In heat exchangers by reducing tube diameter, length and most importantly balance mass flux and design

Because it is the most attractive, the last strategy is elaborated in detail. Obviously, to reduce the charge internal volume needs to be reduced, but the most important is to take in consideration effects of heat transfer balance and mass flux on void fraction.

Special attention is given to explore and design a methodology for fair way of comparing refrigerants based on their potential to be used in low charge condensers.

This paper also presented a case for a small, low charge, air cooled ammonia chiller using microchannel condensers and hermetic compressor with miscible oil. Microchannel air cooled condensers along with DX plate or similar evaporators provided basis for low charge.

In addition, the external volume of the chiller could be reduced because

Fig. 15 Condensing unit with MC condenser as used at CTS during NH_3 evaporator studies

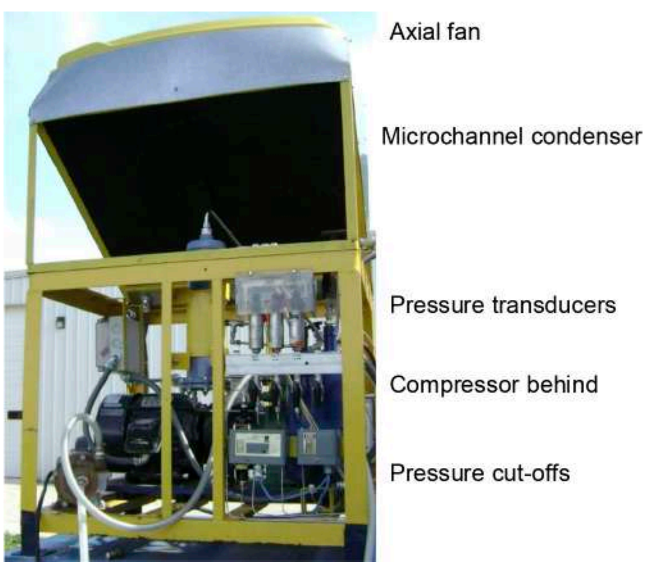


Fig. 16 NH_3 chiller with prototype hermetic compressor, CTS instrumented

the external volume of a microchannel design is small. Besides being compact, microchannel heat exchangers are also made lightweight, from aluminum. Thanks for the technology developed in the automobile industry these exchangers are relatively inexpensive.

Expanding the use of aluminum beyond MC condenser it is possible to reduce the weight and the cost even further, making the chillers cost competitive to conventional systems.

Hermetic compressor with miscible oil provides a low leak and a low maintenance environment and in every respect similarity to conventional chillers.

Since ammonia is one of few refrigerants that have vapor lighter than air

Table 4 Refrigerant inventory for larger heat exchangers

Heat exchanger type	Specific charge [g/kW]	Specific charge [oz/Ton]
Shell and tube	1000	130
Plate	500	65
Gravity fed plate	250	30

Table 5 Specific charge values for some ammonia spray evaporators

Ref.	Capacity [kW]	Specific charge [g/kW]	Specific charge [oz/Ton]
1	1408	113	14.5
2	2816	72	9.2
3	4189	54	6.9

Table 6 Specific refrigerant charges for some commercially available ammonia chillers

Chiller System	Capacity, Evaporator [kW] / [Ton]	System specific charge [g/kW]/ [oz/Ton]
Air cooled:		
Hrnjak & Litch (MC condenser)	13 / 3.8	18 / 2.3
Cecchinato & others	120 / 34.8	84 / 10.7
Refcomp VKA16-14	16 / 4.6	125 / 16
York YSLC F4F00UW	220 / 63.8	129 / 16.5
N.R. Koeling LK 25	25 / 7.2	159 / 20.3
Water cooled:		
Palm, KTH – Sherpa project	9 / 2.6	11 / 1.4
ILKA MAFA 100.2-11K45	108 / 31.3	23 / 2.9
ABB (York) BXA	108 / 31.3	157 – 43 / 20 – 5.5
Gram (York) LC	38 – 228 / 11–66	228 – 37 / 29 – 4.7
Sabroe (York) PAC	57 – 1074 / 16.5–311	172 – 36 / 22 – 4.6

location of the chiller should be on the roof. Assuming unobstructed release, even in the worst case scenario of catastrophic leak refrigerant vapor cannot increase its concentration in specific zones beyond LFL (lower flammability level) or toxic concentrations values. That represents great improvement in safety and puts ammonia below the radar of regulations.

All said above leads to an excellent opportunity for the ammonia as a refrigerant in urban areas: very low charged, hermetic chiller placed on the roof with unobstructed vapor release.

Nomenclature

A = Area [m²]

α = void fraction [-]

L = tolat lentgh [m]

m= mass [g]

ρ = density [kg/m³]

x = quality [-]

z = length

Subscripts

l = liquid

v = vapor

i = counter

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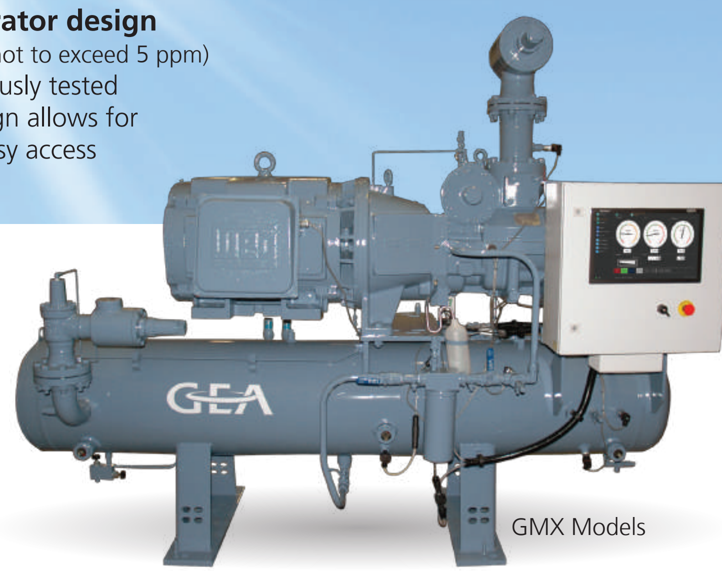

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