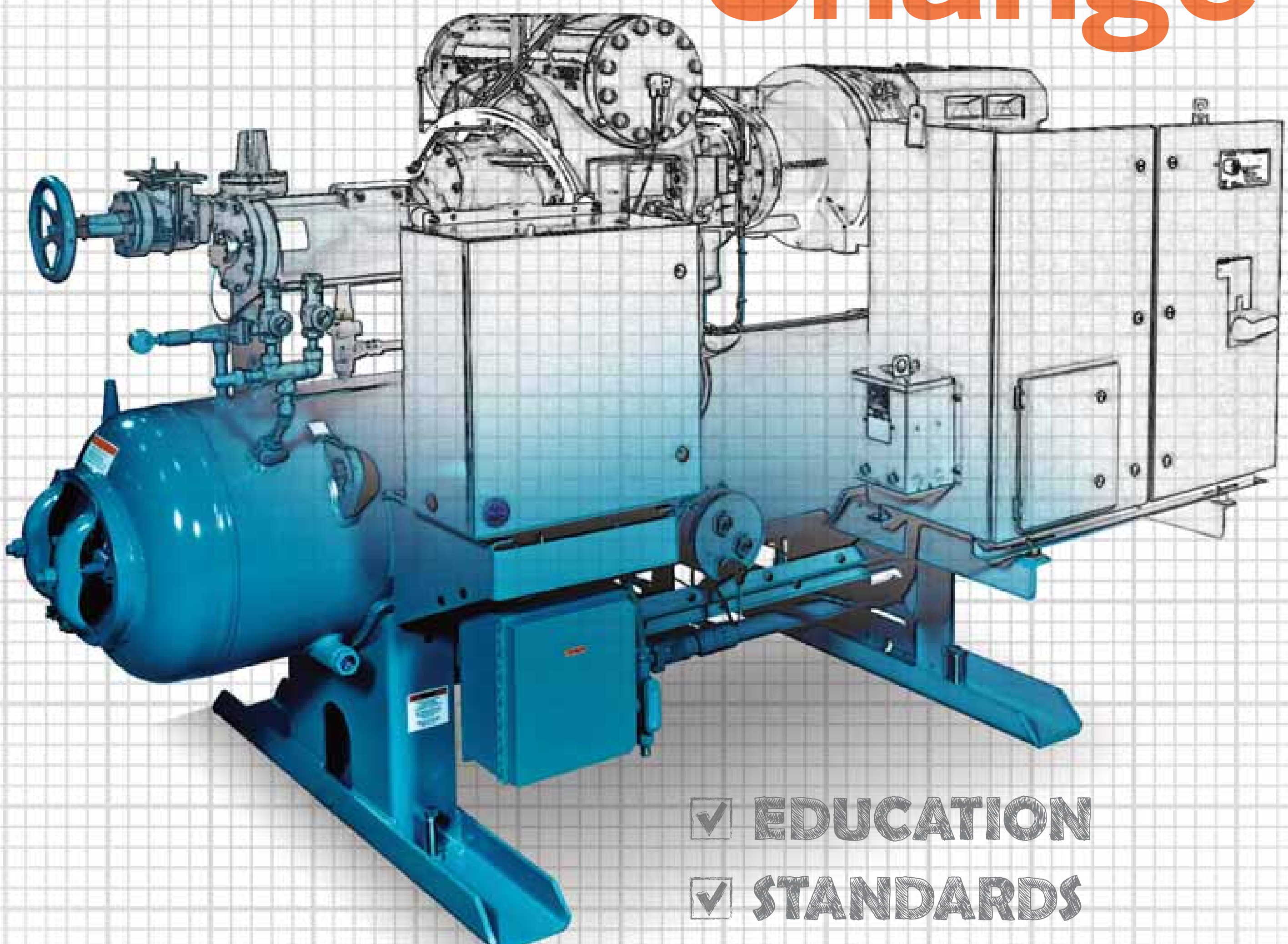
iiar
THE OFFICIAL MAGAZINE OF THE AMMONIA REFRIGERATION INDUSTRY ■ DECEMBER 2014

CONDENSER

THE MECHANICS OF Change



☑ EDUCATION
☑ STANDARDS
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DECEMBER 2014

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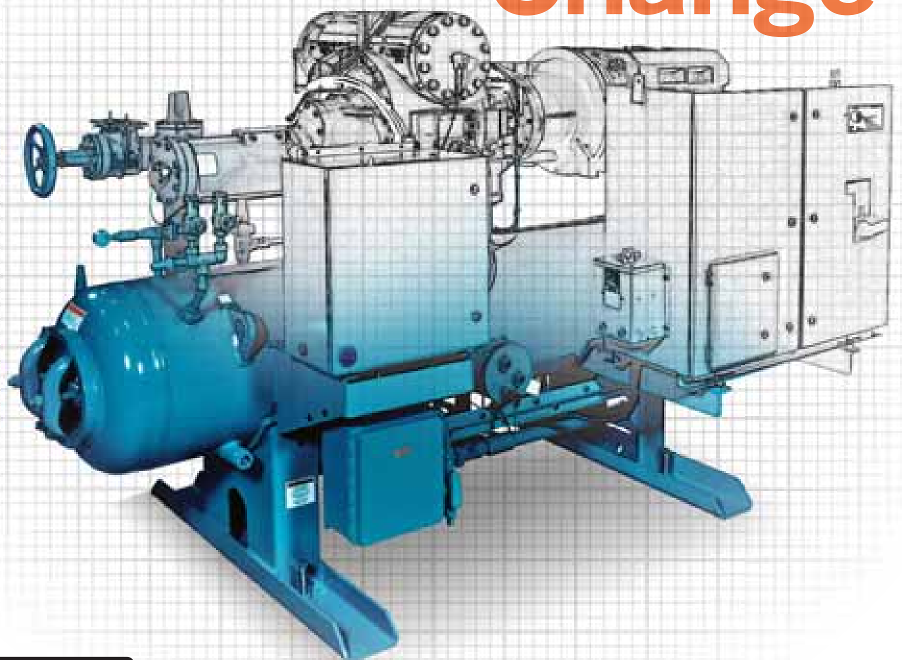
THE MECHANICS OF Change



Much has been made of the so-called manufacturing skills gap in the United States as manufacturers across a wide swath of industries report that the pool of prospective workers with the skill sets and certifications required to perform highly specialized job functions is narrowing, even as U.S. manufacturing continues its steady climb.

And for ammonia refrigeration, an industry poised to expand dramatically in the next decade – thanks to new technology and environmental mandates that are shifting the focus to natural refrigerants — a widening skills gap could be the one factor with real potential to hinder growth.

chairman's MESSAGE

MARCOS BRAZ

The New Year is almost here, and for many of us, that means we're wrapping up projects and getting ready for 2015. At IIAR headquarters, your staff team is hard at work adding the final touches to the annual conference programming and conducting general planning activities for the year ahead.

In fact, one of the most important functions of the IIAR Board of Directors is to set the strategic direction of the association every year. This year, board members met at IIAR headquarters in Alexandria, Virginia, to talk about ongoing initiatives and set new goals.

Our international presence was one important theme at our recent meeting, and one of the key outcomes of that meeting last October was that we received the go-ahead from committee chairs and board of directors to move forward with intensifying our efforts to promote a new international chapters program.

Our international strategy encompasses government relations, membership interaction and international publications.

And now, we will be working to help our member representatives from all around the world to get involved in publications translation, to help us promote global membership growth, and to help our international chapters take the lead in developing their own national standards.

Our board meeting also inaugurated our new conference committee, and at the same time, we took the first general steps towards developing CO_2 standards.

Meanwhile, our ANSI standard IIAR-2 has entered its third public review and the engagement of IIAR staff, our members, and the IIAR standards committee itself reaffirms that we are at the cutting edge of providing practical, safe and reliable information to this industry.

This is an accomplishment that reflects all the hard work and time of so many of our members and volunteers. Other standards are in review so I encourage you to get involved and help us to make all of our standards the best documents in the industry.

Speaking of standards and other important reference materials, if you work in this field, you owe it to yourself to have the latest technical information. That means making sure you have the complete IIAR library on your desk.

All of the publications represented in the IIAR library are designed to help our members get all the information they need for design and operation excellence. Indeed, not only these materials, but the work of our committees and our conference in March are all resources we have developed with the goal of solving the real world problems our members face every day.

In addition to the library, we also have a great wealth of information on our website representing years of experience and technical expertise. Take a minute to log on to our members-only section and get familiar with the resources you have as an IIAR member.

We're constantly working to give you the tools you need to advance the new technologies and create constant improvements in the safety and efficiency of day-to-day operations that are the hallmarks of our industry.

One more topic I'd like to cover in this month's Chairman's message is our upcoming annual conference. I am happy and excited to report to you that we are looking forward to delivering another outstanding and record-breaking event in 2015.

This March, in the beautiful city of San Diego, California, we will be bringing you all the latest information on the newest technologies and trends that are shaping our industry. If you want to stay updated and knowledgeable about the latest advancements in industrial refrigeration, the IIAR annual conference truly is a must-attend event.

Over the past twelve months we have done a lot of listening to our members and 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 will introduce a special global focus with simultaneous translation for technical papers for at least one major additional language in many of our sessions.

With this in mind, I look forward to welcoming you to San Diego to learn, share and build the knowledge base of our industry together. Our conference dates extend from March 22nd to the 25th and our committees meet on the Sunday morning preceding the conference.

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 give you a great conference experience.

I would like to extend a special welcome in advance to new members and first-time conference attendees.

As always, we are very thankful for the support of our sponsors and for our members' continuing high levels of engagement – it is this commitment that will make this another record breaking year for IIAR. ■

president's MESSAGE

BY DAVE RULE

One of IIAR's most important responsibilities is advocating on behalf of our members on state and federal policy. I'm happy to report that in 2014 we stepped up our efforts even more in this realm and we've been working closely with government regulatory agencies to provide them with our expertise in a number of different ways.

In addition, our efforts to develop standards are having a direct impact on our industry. By continuing to shape codes and provide guidelines that will improve the efficiency and safety of ammonia refrigeration systems, we're moving towards an exciting future in the next several years.

As you know, this year a presidential directive was issued to OSHA, the EPA and the Department of Homeland Security to review their regulatory programs in the aftermath of the West, Texas explosion. The whole chemical industry has been tasked with reviewing safety regulations and to consider where they may need to modify and write new regulatory directives. In response, first OSHA then the EPA and finally, the Department of Homeland Security each issued Requests for Information, or RFI's, formally seeking input from our industry on a number of proposed changes.

To respond to these RFI's, IIAR formed a task force to provide input on behalf of our industry to all three agencies. We also reached out to various associations around the industry – such as RETA, the Refrigerating Engineers and Technicians Association, and others involved in cold storage and food processing – to review these requests from our regulatory agencies and sign on to formulate a united response. And throughout this process, we met personally with representatives from OSHA to discuss our recommendations and the industry overall.

Creating this dialogue has been an effective process that will continue to impact our future interactions with these agencies in a very positive way.

Along with our growing profile and influence in the regulatory realm, 2014 was a big year for standards development. Through the ANSI process, we've been working to rewrite and expand existing IIAR standards to finalize a suite of eight standards for our industry.

The most time-consuming part of this effort has been the development of the revised IIAR-2 standard, the overall safety standard for design of closed loop refrigeration systems, and probably the largest and most important standard of them all.

After we completed our second public review of IIAR-2, OSHA offered to look at a draft and provide comments. IIAR representatives were invited to OSHA headquarters with the standards committee to meet with the enforcement team and to have a discussion about their suggestions.

Once again, this process marks a growing collaboration between IIAR and OSHA and is promoting a valuable exchange of ideas and development of solutions. Once again, this process marks a growing collaboration between IIAR and OSHA and is promoting a valuable exchange of ideas and development of solutions. As a follow-up to that meeting, IIAR invited members to meet with OSHA on December, 1, 2014, to discuss their thoughts on RAGAGEP and how it should be defined for both current and new construction facilities, yet another example of how OSHA values our member's views on these key topics.

At the state level, we have recently been very active in New Jersey, which has its own toxic substance regulations that cover ammonia refrigeration.

IIAR, IARW and RETA are working with the New Jersey Department of Labor and the Department of Environmental Protection on a pilot program to develop a standardized education curriculum for industrial ammonia refrigeration technicians at the community college level.

You can read more about this effort in the cover story of this issue of the Condenser.

Not only would this ease some of the regulatory burdens we face surrounding training, but it will also represent a huge move forward in our efforts to develop the technician skills pipeline for our industry. Because the curriculum can be used as a template for other training programs at community colleges around the country, we can use our industry training resources to help young people learn the real skills that will lead directly to employment within our industry.

These efforts and more show how important our members are in shaping our industry and if you are an IIAR member, I would like to thank you and tell you how grateful we are for your time, expertise and support.

For non-members reading this column, I encourage you to get involved by becoming an IIAR member. Once a member, you too can support our advocacy programs by joining committees and commenting on standards or help in the development of technical manuals and building codes.

Your voice is needed. Join us and together we will continue to take the lead in the regulatory activities and standards development that ultimately define the safety and efficiency of our technology, both now and in the coming years. ■

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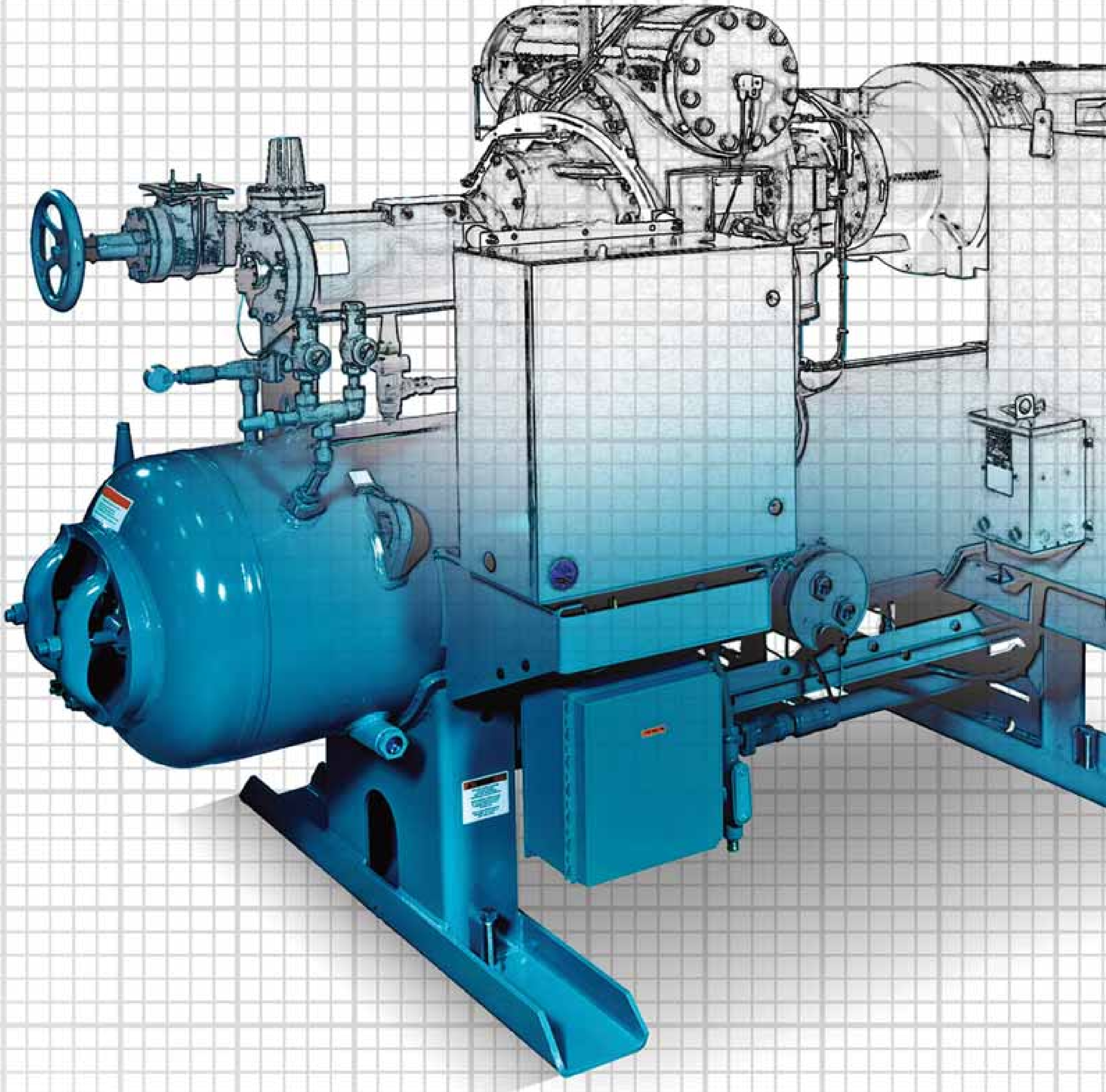
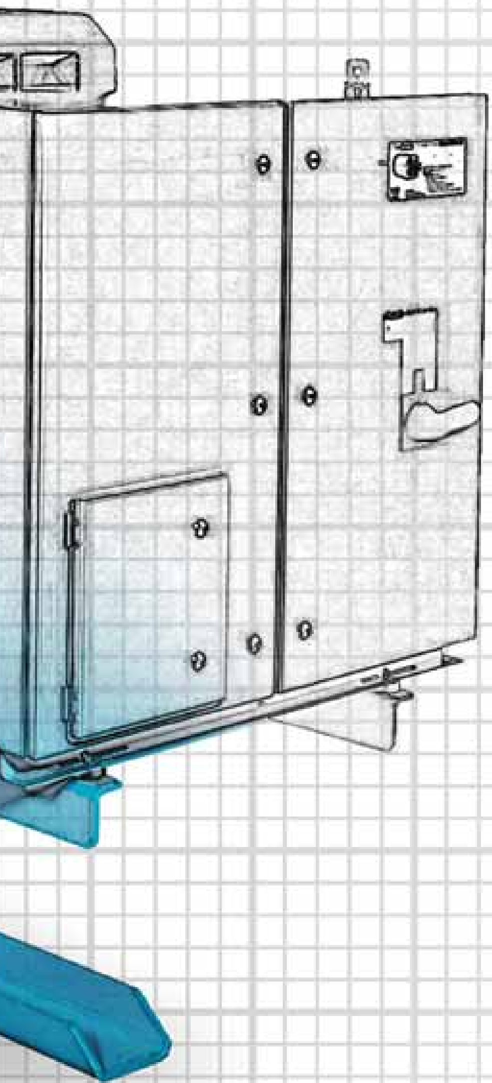


Change:

Developing Industry-Specific Education to Narrow Industrial Refrigeration's Skills Gap



BY ANDREA FISCHER

Much has been made of the so-called manufacturing skills gap in the United States as manufacturers across a wide swath of industries report that the pool of prospective workers with the skill sets and certifications required to perform highly specialized job functions is narrowing, even as U.S. manufacturing continues its steady climb.

And for ammonia refrigeration, an industry poised to expand dramatically in the next decade – thanks to new technology and environmental mandates that are shifting the focus to natural refrigerants – a widening skills gap could be the one factor with real potential to hinder growth.

In a report recently released by the Manufacturing Institute, and research firm Accenture, titled the 2014 Manufacturing Skills and Training Study, more than 75 percent of manufacturers reported a moderate to severe shortage of skilled resources, and over 80 percent reported a shortage in highly skilled manufacturing resources.

While those numbers may seem amorphous, they represent an all too real problem that will only grow for the industrial refrigeration sector, said Jim Barron, Executive Director of the Refrigerating Engineers and Technicians Association.

"People right now in our industry can't find anybody to fill technical roles essential to operation. We're facing a real skills shortage," said Barron. "We love what we do, and we'll keep doing it as long as we can, but we need to plan for the future. Now is the time to use the talent we have in our industry to train the next generation."

Eric Girven, Project Manager for SCS Engineers agreed with Barron, adding that while some end user companies are acutely aware of the problem, the industry as a whole has yet to meaningfully address it. "It may be a common theme throughout our industry – that the upper management of facilities may not understand the coming impact of a general skills shortage as much as they should. There simply aren't enough skilled technicians," he said.

"It may not be recognized now, but if we don't do something soon, there will come a day when we look around and wonder where all the skilled technicians are. The awareness that we have a growing skills shortage is certainly there, but I don't know if it's on the front burner as much as it should be."

Getting the issue on the front burner, much less beginning to address it may be much more complicated than it may seem for an industry focused on keeping facilities running. As baby boomers begin to exit the workforce, taking their years of experience with them, businesses will have to put primary resources towards keeping the talent they do have, rather than developing new talent.

Meanwhile, even though manufacturing as an industry has become more efficient through automation, which has resulted in a smaller workforce overall, a greater percentage of remaining US manufacturing roles require skilled workers who need many months, and, in some cases, years of experience and training to perform their jobs efficiently and effectively, according to the Accenture report.

That's a trend that can clearly be seen in the ammonia refrigeration industry, where automation has led to greater efficiency, but has, at the same time thrown the need for skilled technicians into sharp relief, said Dave Rule, president of the International Institute of Ammonia Refrigeration.

"There's a real need for qualified, trained operators who are highly skilled, but also understand industrial refrigeration at a level that goes beyond the basics," he said.

While the industry does have many resources in place to train and educate technicians, through shorter-term programs like the ones provided at the Garden City Ammonia Program and Lanier Technical College, or even through longer-term efforts like private training programs run by companies within the industry, there is not yet a generally accessible educational track capable of funneling new talent, from the vocational school level for example, directly into the industry.

That's something IIAR and RETA are working to change with a new effort to combine the resources of the two organizations to develop a standardized core refrigeration curriculum that can be offered by any community college across the nation.

Rule and Barron said IIAR and RETA are now looking for ways to develop that program.

"RETA and IIAR are working together to create one standard industrial refrigeration curriculum that can be integrated into educational programs at the community college level to make sure anyone who may be interested in coming into our industry can get the tools they need to excel in existing refrigeration programs and successfully attain the certifications and experience that will make them the kind of skilled operators we need," he said.

"With this effort, we're really laying the groundwork for a more holistic knowledge of refrigeration that will prepare students to move directly into more advanced operator programs."

The exact structure that such a core curriculum might take, and how it might be integrated into existing community college vocational programs across the country is still being worked out. But, said Rule, the fundamental progression would take the form of a one- to two-year degree track followed by a formalized apprenticeship program.

Such a large effort would, of course, depend on the buy-in and support of the industry in general, but Rule and Barron agreed that once a structure is put into place, end users and manufacturers alike would see it as a valuable resource.

"If we can put a structure in place to start turning out ready-to-hire operators, knowledgeable about refrigeration systems and theory, and prepared to attain industry certifications, that would be a very big step in starting to close the skills gap in our industry," said Rule.

"This effort is going to take all of us working together in our industry, and even beyond it," said Barron. "It's time to pull together and find a way to start using the community colleges to deliver a solid foundation for ammonia refrigeration education and hopefully create a stepping stone into industrial refrigeration for individuals who may not have considered it" as a path to a viable career.

Building pool of potential highly skilled technicians at the community college level will be valuable to any business in the industry, said Girven, especially given that the current educational burden at that level rests almost entirely with the end user.

"One of the biggest concerns for companies within our industry is that they may spend a large sum of money training internal candidates, only to see them leave the company and take an expensive training investment with them," he said. "With this effort, IIAR and RETA are hoping to partner with accredited schools to develop that fundamental training and help end users find qualified people right out of the gate. That removes some of the responsibility for providing an educational base from the individual employer and passes it to the industry."

Additionally, providing a way for a potential technician to enter the industry via a formalized career track could attract students who may not realize that ammonia refrigeration can be a rewarding, and well compensated long-term career.

"This is really about creating a formalized track to RETA's CIRO certification. It's a way we can say to the next generation entering the workforce 'here's a track for you' and at the same time show them what the end result would be," said Girven.

While the main goal of a standardized educational program would be to help the industry deal with its general skills shortage, the development of the curriculum will first focus on meeting a specific regulatory need in the state of New Jersey, said IIAR's Rule.

That need stems from a unique regulatory environment in the state which, in addition to having a much lower ammonia threshold quantity than anywhere else in the U.S., requires that all ammonia facilities must have at least one "gold seal" certified operator on site at all times in order to operate.

The "gold seal" certification requirement is specific to New Jersey, defined by the state, rather than the industry, and has created an environment where finding, hiring and supporting gold seal-certified professionals is prohibitively expensive, said Rule.

Meanwhile, as HFC's, including R-22, are phased out, the future of refrigeration in the state is uncertain.

To address that uncertainty, and to promote the use of natural refrigerants, IIAR worked with New Jersey legislators to find a more attractive solution to the certification requirement problem.

The result, said Rule, is that New Jersey will allow industry to develop its own certificate program – in the form of a standardized educational track – and will accept that program as a replacement for gold seal certification.

"It is our hope that this initiative would help to relieve the immediate regulatory burden that is keeping our industry out of the state," said Rule. "But perhaps more importantly, developing a standardized education program that can be offered at any community college across the country would be a valuable investment for our industry."

"In putting together such a program, we're solving an immediate regulatory problem in New Jersey, but we're also starting to address something that is bigger than just a local regulatory issue," said Rule. "The need for qualified, trained ammonia refrigeration technicians is consistent across the country. This is an investment in the long term health of our industry." ■

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IIAR Leads Coalition in Response to RMP Request for Information

iiar government RELATIONS

BY LOWELL RANDEL, IIAR GOVERNMENT RELATIONS DIRECTOR

On July 24, 2014, the Environmental Protection Agency published a Request for Information (RFI) regarding the agency's Risk Management Program (RMP) regulations. The RFI was generated as a part of the Obama Administration's efforts to implement Executive Order 13650 - Improving Chemical Facility Safety and Security.

The Executive Order came in response to the 2013 accident in West, Texas where a fertilizer plant exploded causing numerous fatalities. The order directs OSHA, the Department of Homeland Security, Environmental Protection Agency and other agencies to examine their regulations and propose ways to improve chemical safety and security.

Through the RFI, EPA requested comments on possible revisions to the RMP regulations. The RMP RFI is divided into two sections, one of which is very similar to the OSHA RFI on Process Safety Management issued in December of 2013. The second section addresses policies not included in the RFI for PSM.

In response to the RFI, IIAR created a task force to examine EPA's proposals and draft formal comments. IIAR also worked to build a coalition around these comments. Coalition members co-signing the comments to EPA include: American Frozen Food Institute, American Meat Institute, Global Cold Chain Alliance, International Association of Refrigerated Warehouses, Refrigerating Engineers and Technicians Association and the U.S. Poultry and Egg Association. IIAR will continue working with EPA and its coalition partners as the rule-making process moves forward.

Below is a summary of the comments submitted by the coalition:

UPDATING THE LIST OF REGULATED SUBSTANCES

EPA requested input on potentially changing the threshold quantities for regulated chemicals. IIAR commented that lowering the ammonia threshold quantity (10,000 lbs.) under the Risk Management program would require smaller independent companies to needlessly increase their operating costs and could inflict financial harm. The Clean Air Act Amendments of 1990, Section 112(r)(1) (General Duty Clause) already requires safe operations of facilities/processes with less than threshold quantities of RMP chemicals through prevention of accidental releases and minimization of consequences of releases that do occur.

ADDITIONAL RISK MANAGEMENT PROGRAM ELEMENTS

Revising the management-system elements raises a number of questions and concerns. Because RMP is supposed to be performance-based, the coalition opposes requiring specifying management-system metrics required by those subject to the regulation. Requiring facilities to use and share metrics is more prescriptive than a performance-based regulation should mandate.

In addition, RMP regulations already include management practices in almost all elements. Facilities should be free to choose those management system elements which are applicable to the complexity of their operations and to their industry; they should not be constrained to use management-system elements which were developed under circumstances which may not apply to their operations.

IMPOSING ADDITIONAL SAFETY REQUIREMENTS ON CONTRACTOR OWNERS AND OPERATORS

Additional requirements are not necessary for contractor owners and operators in the ammonia refrigeration industry. Existing federal regulations (EPA and OSHA) are very clear that the "contract owner or operator" is required to ensure training and understanding, following of safety rules, etc. Modification or additional requirements are not needed or required at this time.

CLARIFYING PHA AND HAZARD REVIEW REQUIREMENTS

Specifying the types of failure scenarios and damage mechanisms for PHAs and hazard reviews could be problematic. The implication of such a policy is that EPA would be essentially stating that they know more about the processes and potential failure mechanisms than the experts within each industry. In addition, this would seem to indicate that the scenarios and damage mechanics for all industries are identical. Identification of failure scenarios and damage mechanism is best left to those who have the most experience in each unique process which is being analyzed. Additionally, providing a list of prescriptive failure scenarios and damage mechanics might actually result in less thorough PHAs and hazard reviews.

DEFINE AND REQUIRE EVALUATION OF UPDATES TO APPLICABLE RECOGNIZED AND GENERALLY ACCEPTED GOOD ENGINEERING PRACTICES

Adding a definition for RAGAGEP could be useful to help owners better understand requirements under the standard. A definition for RAGAGEP may also be helpful in reducing the instances of EPA inspectors citing standards that are not as applicable to a given type of facility. Better defining RAGAGEP can reduce the misapplication of standards by inspectors and facilitate better understanding and application by facility owners. However, a definition of RAGAGEP should not take away the ability of a facility to identify which RAGAGEP they are applying to their operations.

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EXTEND MECHANICAL INTEGRITY REQUIREMENTS TO COVER ANY SAFETY-CRITICAL EQUIPMENT

Conceptually, the proposal to expand the coverage of the Mechanical Integrity element to all safety-critical equipment seems reasonable. For the ammonia refrigeration industry, covered facilities already must identify components, controls and PM frequency for them in accordance with OEM recommendations. However, for such a change to be effective, a workable definition of "safety-critical" must be developed and the determination of what is safety-critical can be subject to broad interpretation.

REQUIRE OWNERS AND OPERATORS TO MANAGE ORGANIZATIONAL CHANGES

There is some merit in expanding the Management of Change requirements to include organization changes, as long as there is clear guidance on what organizational changes qualify. If organizational changes are included, "replacements in kind" should be exempted from the management of change requirements. In the spirit of performance based standards, facility owners should be given a sufficient level of flexibility to design their own programs to meet the requirement.

REQUIRE THIRD-PARTY COMPLIANCE AUDITS

Compliance audits are useful tools for evaluating a facility's safety. However, there is concern about the intended definition of "third-party". Third-party audits should not be limited to hiring outside personnel to perform the audit. Outside consultants can be very useful, but facilities should have the flexibility to utilize internal safety experts from other facilities or corporate headquarters to perform audits.

SAFER TECHNOLOGY AND ALTERNATIVES ANALYSIS

The coalition expressed strong concerns with mandating inherently safer technology reviews. The regulatory burden of requiring costly IST reviews tends to stifle innovation. For those companies who are already looking to improve safety by implementing IST options, a formal IST review would add costs to a process by forcing them to document the activities they are already performing. Small operations might not have the manpower or expertise to do this and lack the resources to hire it out cost effectively.

Local communities should not be involved in IST analysis. While local communities have good intentions, they have virtually no expertise in safety and risk management as it applies to a specific industry, and often little knowledge of why processes and systems are necessary for economic and material well-being of the community and the country.

EMERGENCY DRILLS TO TEST A SOURCE'S EMERGENCY RESPONSE PROGRAM OR PLAN

Requirements for tabletop drills and/or functional emergency response exercises on alternating years will likely

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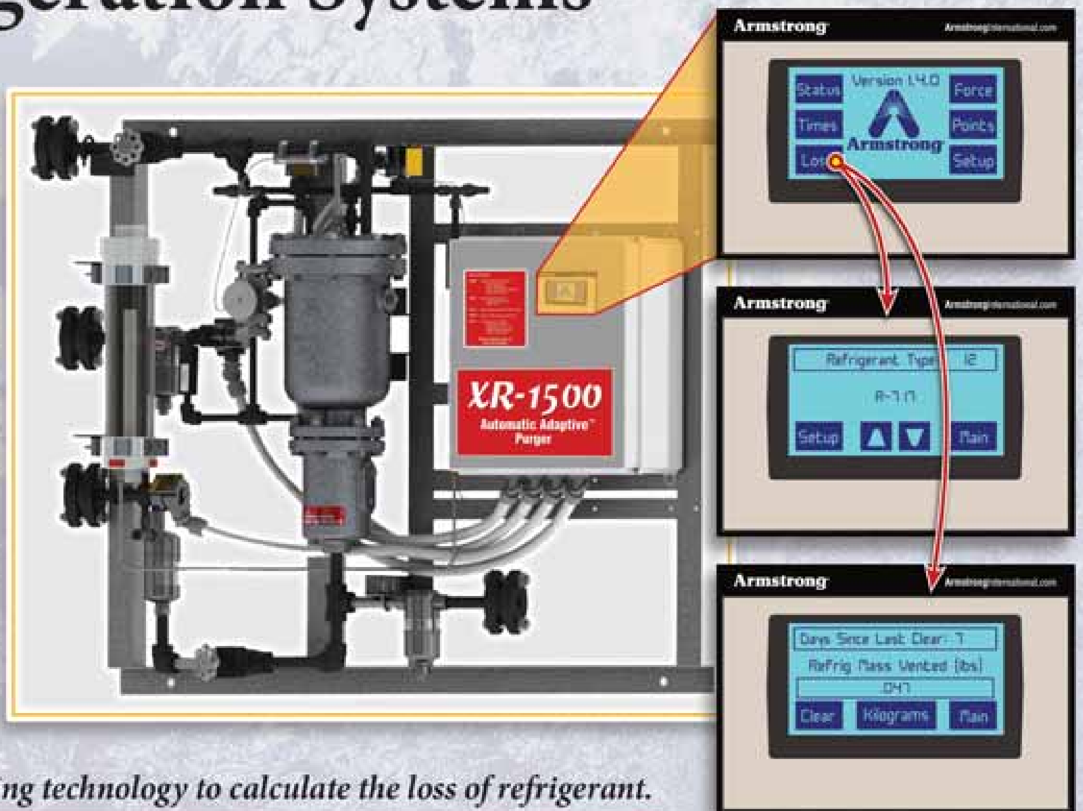

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enhance a chemical user's awareness and preparedness for emergencies. Recommendation or suggestion of inclusion of local emergency responders would be reasonable to enhance effectiveness of coordination requirements already in effect in the Risk Management Program Rules. Requirements for inclusion of offsite emergency responders, however is not recommended as these resources are not controlled by covered facilities. Staffing and funding limitations may inhibit some responders' exercise and/or coordination abilities. Covered facilities must not be penalized if offsite responders are not able to participate.

Facilities should be free to determine the exact technique used provided that the major causes and all contributing factors are identified as part of the incident investigating technique.

AUTOMATED DETECTION AND MONITORING FOR RELEASES OF REGULATED SUBSTANCES

RMP should remain performance based, and adding specific requirements for detection and monitoring would be counter to this performance basis. RAGAGEP should be used to determine if/when detection and monitoring devices should be used. EPA should allow facilities to install these devices based on industry standard and guidelines, not regulatory restrictions made by personnel who may have little to no understanding of the nuances of each industrial sector.

ADDITIONAL STATIONARY SOURCE LOCATION REQUIREMENTS

Providing specific requirements is against the performance based nature of the RMP regulation. Introducing siting restrictions such as distance from the covered process to occupancies could become a problem in situations where a facility might want to upgrade to a new and safer engine room but the best location is not compliant with siting restrictions. If adopted, this policy may ultimately encourage facilities to keep running older (potentially less safe) facilities rather than construct newer, modern (and potentially safer) facilities.

COMPLIANCE WITH EMERGENCY RESPONSE PROGRAM REQUIREMENTS IN COORDINATION WITH LOCAL RESPONDERS

Coordination with local emergency planning and response authorities is an important aspect of safety. As a result, such coordination is already specifically required in the RMP Rules. Enforcement of this issue is linked through Hazard Communication, Emergency Action and HAZWOPER Standards. The coordination with local agencies (e.g. LEPC, Fire Department, Police, etc.) is required by the EPA's Chemical Accident Prevention Provisions (40 CFR Part 68.95(c)). An argument can be made that the issue of coordination is already well covered and that adding requirements would be redundant.

Incident Investigation and Accident History Requirements

Incident investigation requirements as currently written are sufficient for determining the cause of accidents. OSHA PSM regulations already provides compliance guidance on the intent of incident investigation and the applicability of incidents that require investigations to include near misses. Facilities should be free to determine the exact technique used provided that the major causes and all contributing factors are identified as part of the incident investigating technique.

WORST CASE RELEASE SCENARIO QUANTITY REQUIREMENTS FOR PROCESSES INVOLVING NUMEROUS SMALL VESSELS STORED TOGETHER

In an ammonia refrigeration system, it is virtually impossible to release the entire ammonia inventory in any single event. Therefore to require the entire system inventory for the process to be used for the worst-case scenario would create an unrealistic picture of risk at the facility. Nearly all incidents, including very serious incidents, at ammonia refrigeration systems involve releases from a single vessel. The changes suggested could increase confusion due to their ambiguous nature of the requirements and thus lead to a lack of uniformity in worst-case scenarios and would not present a true representative of risk in our industry.

PUBLIC DISCLOSURE OF INFORMATION TO PROMOTE REGULATORY COMPLIANCE AND IMPROVE COMMUNITY UNDERSTANDING OF CHEMICAL RISKS

The information contained in the RMP which is submitted to EPA is readily available on-line and there are already requirements for the distribution of Tier II reports to appropriate local authorities. Allowing more information to be disclosed (audits, PHA, etc.) would have the effect of compromising public safety and security by allowing sensitive information be too readily available. Due to the confidential nature of this information, steps should be taken to avoid disclosure, not increase availability.

THE "SAFETY CASE" REGULATORY MODEL

The coalition is strongly opposed to shifting to the "Safety Case" regulatory model. Facilities have invested a lot of time and resources and in many cases are justifiably proud of their PSM and RM Programs. To suddenly move away from these programs in favor of a method not commonly practiced in the United States seems highly inappropriate. ■

Avoiding Complacency

KEM RUSSELL

Operational safety still comes down to the ability of experienced personnel to properly operate and maintain systems in a manner that will not result in injury.

In most cases, experience is something we build upon. It allows us to take advantage of the things we've learned, and hopefully, remember those lessons when they matter most. But sometimes, no matter how important the lesson, it can get overlooked.

In visits to several ammonia refrigeration facilities and ongoing talks with managers and operators of these systems, there's one recurring lesson that sticks out, precisely because it's the one lesson that is seemingly never learned. Here are a few examples:

In our first scenario, an experienced refrigeration operator was called to the process area because of a complaint of an ammonia smell. He quickly found the source, which was one of the hoses on a low temperature plate freezer.

The leak was a slow drip of liquid from a failed portion of a plate hose. He isolated the liquid and hot gas inlet to the plate freezer, and with a new hose began the replacement. As he was working the pressure slowly began to rise in the plate freezer and, being by himself, he was faced with a problem: how to stop (or greatly slow) the leak, while reaching for the replacement hose, which just happened to be at the limit of his fully extended arm. The process people in the area watched, from a safe distance, wondering . . . what is going to happen to this guy?

Similarly, in another facility, repair work was to be done on a suction pressure control assembly. The work would require isolation of the ammonia line and control assembly. Two refrigeration maintenance men were assigned the task.

Having some experience as well as having observed other experienced operators perform maintenance; they were reluctant to wear full face ammonia masks, as required by their SOP (Standard Operating Procedure). Nevertheless, they complied, even though they knew from past experience that putting on an ammonia mask may not be necessary.

As they proceeded with the work, isolating the assembly, and checking the control valve pressure gauge, everything seemed to be in order to proceed with removal of the valve flange bolts. As the flanges parted, ammonia pressure trapped on the outlet side of the control valve (apparently due to a stuck piston in the control valve) was released into the faces of the operator parting the flanges and the other man standing close by to assist.

Finally, at yet another facility, one commonly performed task was to drain oil from an oil pot located in the machine room. The facility had an SOP for this task that clearly stated the steps to be followed in the procedure. The refrigeration maintenance person doing this particular task had become very experienced and quite comfortable with the procedure and had started to skip two of the required steps in the SOP.

How long this slightly altered procedure had been occurring is unknown, but it just so happened that a regulator came to the facility to specifically review the Process Safety Management program, and observe some of the field applications of the program. The regulator, having briefly reviewed the oil draining SOP, was in the machine room with the facility manager when he noticed two things associated with the oil pot.

One; the oil drain hose was still connected to the oil drain outlet valve, and two; there was no plug in the oil drain valve (since the hose was connected). Both removal of the hose and re-installing the steel plug were procedural steps identified in the SOP.

So what are we learning here in all three cases? I'm sure that you've either heard of or have been directly involved in ammonia accidents or near misses that involved *experienced* people doing things they should not have been doing. As an industry and as individuals we rely on experience. However, this reliance is a double-edged sword. We need experience to properly carry out the required tasks, but with experience a person often becomes complacent in following proper procedures.

From the above three incidents, we can see that one lesson that can have a real, positive, effect on the outcome is the use of a "buddy system," especially when the task involves opening the system.

In the first example, the somewhat routine work of changing a plate freezer hose very nearly became a critical situation. There was no other appropriately trained person present to assistant. This other person could have both helped with the work, and have been another set of eyes to see the things the experienced operator may have missed or not realized.

In the second example, the two men had learned from watching other experienced personnel do work on the ammonia system, and those personnel they learned from did not follow proper protective procedures. No incidents had occurred over months (and sometimes years) of ammonia maintenance.

This complacency based on experience could have led to a serious harmful effect on these two maintenance men had they not, albeit reluctantly, put on full-face ammonia masks. From this particular event these two operators suddenly realized how important it is to wear the proper personal protective equipment (PPE). They continued to relate this experience to other maintenance personnel for months afterward.

In the third example, we again see complacency in experience leading to the skipping of important steps in a procedure. In this case, no release had occurred, but there was certainly the potential of a significant release.

Again, due to the experience of performing this procedure with no adverse impact, the maintenance person became lax in completing each required step. In addition, the visiting regulator asked "Has this refrigeration maintenance person been trained to do the oil draining procedure? Prove it." There was an SOP that was clearly not being followed. Unfortunately, there was no specific documentation showing the maintenance person had been trained to do this procedure and that he had acknowledged that training.

Anhydrous ammonia is an extremely important chemical in maintaining our life style. Besides being a natural refrigerant, it has great properties that make it efficient to use in many refrigeration applications. Its pungent smell is also very helpful. It can be detected at very low levels, long before it may be harmful.

In addition the guidelines developed by IIAR have helped improve the design, construction, and maintenance of ammonia refrigeration systems so that these systems are not only reliable, but safe.

These are important and necessary resources, but operational safety still comes down to the ability of experienced personnel to properly operate and maintain systems in a manner that will not result in injury to themselves, other employees, the public or the environment.

Do not become complacent due to your experience with ammonia. Treat it with the constant vigilance and respect that it requires, and constantly question the merits of making a decision based on your own "experience." ■

Guntner Brazil Implements ARM for Climatic Test Chamber

The Ammonia Refrigeration Management Program, built by the International Institute of Ammonia Refrigeration to help small facilities develop a sound safety plan focused on prevention, now has a global reach.

The IIAR's ARM program provides a tool that any small facility can utilize. The program directs companies and facilities toward proper safety procedures that fit their needs and guides them through the process of building a basic safety program that is suited to their unique operations.

Last month, ARM was implemented at Guntner Brazil's ammonia test facility in South America, site of the only climatic test chamber of this size in the country.

"This is a significant step forward because it expands the area in which the program is being used and gives it a little more credence," said Gordon Struder, vice president, product engineering, **North and Latin America**. "IIAR has been around a long time and is well established in the United States, and this allows them to expand into the international arena and widen its net globally. This is just a natural progression."

ARM was created to help facilities that use less than 10,000 pounds of ammonia navigate safety risks and avoid the potential consequences of an operation-related incident. Although smaller facilities don't face the same federal safety requirements of larger facilities, they are also susceptible to hazards that could result in serious consequences. In addition, they are held to a minimum safety standard set by OSHA and the EPA that places responsibility on employers to keep workers and neighbors safe from hazardous chemicals, regardless of the size of the facility.

The IIAR's ARM program provides a tool that any small facility can utilize to meet these challenges. The program directs companies and facilities toward proper safety procedures that fit their needs and guides them through the process of building a basic safety program that is suited to their unique operations.

It addresses such topics as the management system, documentation, contractors, mechanical integrity and emergency response. It also simplifies the record keeping and program maintenance elements of the more complex PSM and RMP requirements.

Guntner Brazil's climatic test chamber provides performance testing of full scale heat transfer equipment. "It is a state-of-the-art testing facility," Struder said. "Customers can see how the equipment works. It gives them a much better perspective on what they're buying."

The facility was built in accordance with ASHRAE 64, and it is expected to serve as the forerunner for other small ammonia facilities considering implementation of the ARM program.

"We felt sure this would be an excellent program for them," Struder said. "I think it's working quite well. We want this to take root and make sure they are 100 percent up to speed on the program, so that this will translate over to other facilities, and we can make sure that they are all following the same safety guidelines." ■

Managing Infiltration

The buildup of frost and ice in a freezer at an industrial refrigeration facility is a sure-fire way to drain dollars from the bottom line. When the psychrometric properties of freezer air mass and infiltration air are not properly managed, energy costs can increase substantially.

"I've seen so much ice build-up [in some cases] that it was questionable if the building structure was still safe," said Bob Port, Director, Technical Services, Supply Chain Engineering for ConAgra Foods. Freezers should be clean and safe to work in, ice caves are freezers that look more like a winter wonder land and this is what happens when we forget that the laws of psychrometrics apply below freezing. "It's never a good thing when it's raining or snowing *inside* a building."

The development of such an extreme environment can occur when unmanaged moisture infiltrates freezers and is transformed into ice and snow, while the cold air that flows out of freezers, cools improperly conditioned docks, corridors or other building spaces, said Port, who is also a former IIAR Board Chairman.

To avoid the "ice cave effect," Port suggests taking a multi-pronged approach, by starting with the source and applying mitigations at each step all the way to the freezer evaporator coils.

For a typical cold storage facility with a refrigerated dock, the truck and dock seals are the starting points.

Next, dock cooling units and the use of re-circulated horizontal air curtains should be examined.

Finally make sure that the freezer air mass has some capacity to absorb a reasonable amount of infiltration moisture and carry it all the way back to the evaporator coils.

Dock seals and pit leveler seals don't cost much to operate, and they reduce overall refrigeration load on both the freezer and refrigerated dock.

Treating infiltration air, both cooling and dehumidifying, on the refrigerated dock is the next, most cost effective, step. Generally, it costs between 1 to 1.5 hp per ton vs 3 to 4 hp per ton.

One way to get maximum cost effective dehumidification is to apply reheat to dock evaporator units.

"We often forget about the exfiltration air that comes out of freezers. Equal amounts of air enter and exit at freezer doorways," said Port. "When this happens, exfiltration air cools the dock and units designed to cool the dock shut off, temperature is satisfied, infiltration air is no longer treated and the dock is now cooled at 3 to 4 hp per ton. In one extreme case I have even seen a dock floor heaved due to freezer exfiltration. With the advent of automated freezers and storage retrieval systems, dock doors can remain open for hours at a time."

Installing horizontal recirculated air curtain vestibules at doorways between docks and the freezer can help mitigate this problem, by reduc-

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ing air exchange up to 80 percent in some cases while stabilizing infiltration and exfiltration psychrometric properties, said Port.

"These curtains capture air flowing from both sources and average out both temperature and humidity. It's not that you like warmer air getting into the freezer, but it has less humidity and more energy in it, so any moisture entering the freezer will make it to the evaporator coils and be taken out," he added.

Once the maximum mitigation has been applied to the infiltration issue, Port said facilities must look at how they operate inside the freezer. Specifically, they must understand the impact of operating freezer coils with not enough of a differential between air temperature in the freezer and the operating coil temperature.

"You don't want to raise suction pressure to where you get less than a 10°F temperature difference. Otherwise, you'll start to see frost accumulation, even if you're doing everything right on the dock," said Port. "Operating costs will also start to rise as a result of this accumulation. It impacts overall refrigeration load by 1114 BTU's per lb as water turns from vapor to ice to form an ice cave in a freezer."

"Ice formation starts above the doorway and over time begins growing inside the freezer. It creeps like a glacier," he added. "All the time you're operating your freezer that ice cap is growing, and then, when the freezer doesn't have traffic, your coils are working to cool things down and that ice sublimates. Then the water vapor refreezes farther into the freezer once freezer traffic starts back up. By the time the freezer is really starting to look like a first rate ice cave, you have paid to re-freeze pounds and pounds of ice and frost multiple times."

In some instances, taking a radical approach for freezer air mass conditions – by reheating coils on freezer evaporator units – may work.

Port said that approach worked well in one situation with a 0°F freezer located next to an unconditioned corridor, with high relative humidity conditions.

"Some people thought it was the dumbest thing they'd ever heard of," he said. "I knew infiltration was going to be a problem and the only mitigation would be maintaining a dry freezer air mass." That freezer has been clean since day one of the re-heat oil modifications. ■

IIAR Issues Call for Technical Papers, Announces New Production Schedule

The International Institute for Ammonia Refrigeration issued a "call for papers," in preparation for its 2016 IIAR Industrial Refrigeration Conference & Exhibition and beyond.

IIAR implemented a new timetable for the development of technical papers, which will now begin about 18 months prior to each annual conference. The change is meant to provide authors more time to develop and produce technical papers, as well as provide ample time for peer reviews, editorial, and presentation efforts.

Technical papers for the 2015 conference have been selected, but selection and development for conference years 2016 and forward is now taking place.

IIAR is currently requesting proposals for technical papers, including Spanish-language technical papers. Abstracts that address any topic related to ammonia refrigeration are invited. However, papers that address specific topics will receive preferential consideration.

Specific topics of interest to IIAR include:

- DX and/or Low Charge Ammonia Case Studies
- Oil Management in CO_2 Systems
- Hot Gas Defrost Costs
- Parameters Affecting Total Cost of Defrosting
- Economic Analysis of Desiccant Dehumidifiers in the Anteroom
- Energy Consumption of Various Arrangements of Evaporator Control Valve Groups
- Pipe and Vessel Inspection Criteria
- Establishing Communication with Fire Service
- Requirements of Emergency Action vs. Emergency Response
- Developing Confidence in Team Training for Emergency Events
- Verifying Adequacy of Training.
- Management: What to Look for During a Plant Walk-Through
- Codes and Regulations from a Global Perspective (NH3 and other refrigerants).
- Best Practices Managing OSHA and NEP Inspections
- US Government Regulatory Strategy and Relationships
- Regulatory Considerations for Small Charge Systems
- Future Refrigerant Choices
- Alternate Ventilation Design
- Ammonia Equipment Outside the Machinery Room
- Machinery Room Design
- System Contaminant Removal (purging, non-condensables, and water)
- Refrigerated Air Make-up Units (standards, safety and risk analysis)
- Comparison of Relief Valves, Rupture Discs, and a combination thereof
- Changes in IIAR-2
- Mitigation Methods for Ammonia Releases
- Trans critical CO_2 clarifying ASHRAE 15 9.2.6 language
- Review of Compliance Inspectors Check List Items

Technical papers should explore technical or regulatory topics that are substantiated by original research and development with documented references. Case studies should describe actual situations where actions, testing, or data accumulation are used to prove or demonstrate the outcome of applied methods, and could be reasonably applied to other similar situations. Promotion of products or companies or any other form of commercialism is prohibited.

The IIAR recognizes that new technologies are often offered by only one or a few companies. In these cases, it might be obvious that a method or technology is unique to a company. However, authors must strive to describe the method or technology based on a neutral analysis.

The technical papers are a central part of the Institute's annual meetings, representing a vital exchange of information within the field and serving as a forum for technical experts, engineers and operations managers as they address important issues within the industry.

Please submit abstracts along with author name and contact information online via the IIAR website annual conference page, or via email, to Eric Smith, IIAR Vice President and Technical Director, email: eric.smith@iiar.org.

The Ammonia Refrigeration Foundation, the research arm of the ammonia refrigeration industry, reported that it raised $400,000 in donations in 2014, bringing its endowment to more than $2 million.

"This is significant because it puts us at 60 percent of reaching our goal of $3.5 million by 2017. But there is still a long way to go," ARF executive director Tim Facius said. "We encourage continued support so that we can deliver the needed research and educational initiatives back to the industry."

ARF's mission is to fund research and educational projects that benefit the ammonia refrigeration industry. It searches for solutions to broad industry needs that drive safe and efficient design and the operation of industrial refrigeration systems, Facius said.

Currently, a research project is being conducted on two-phase flow in vertical suction risers. The study is being carried out on a test rig developed for ASHRAE RP-1327 at the Danish Technological Institute in Aarhus, Denmark.

Information produced will provide a greater understanding of two-phase pressure drop and flow in risers, and should lead to better designs with this critical part of ammonia piping systems. Another study on optimum refrigeration pipe sizing has recently begun, ARF said.

In the past year, ARF has also continued looking for ways to grow its scholarship program. Scholarships have previously been awarded at the University of Wisconsin, Erie Technical College and Louisiana Technical College. Awardees have been invited to the IIAR's annual conference as a way of exposing them to the industry.

The goal of the scholarship program is to encourage young engineers to pursue careers in industrial refrigeration. Scholarship awardees complete an independent study on an industrial refrigeration-related project at the University of Wisconsin's Industrial Refrigeration Consortium.

"We want to continue to expand these activities, which have the potential to bring more bright young talent to our industry," Facius said. "ARF has historically directed most of its funding activities toward research projects. But we have been gaining traction on the education side, with an increased number of scholarships awarded each year."

In 2015, ARF is looking to further develop the research and scholarship funding activities as projects identified by the IIAR Research and Education Committees are identified. It will also be working to grow the endowment by reaching out to industry stakeholders.

"We're continuing to get the word out on the good work that ARF is funding in terms of research and education," Facius said. "We've got aggressive plans to grow in both arenas. We want to make the scholarship program a larger piece of our overall work, and we have a long list of research projects that we want to complete."

While Facius expressed gratitude to all those who have contributed to ARF, he emphasized that there remains much work still to be done.

"I want to thank the many donors who have contributed so far, and to encourage continued annual giving by all, as well as encourage those who haven't yet contributed to consider a donation to this worthy cause," he said. ■

IIAR, Industry Partners Respond to Regulatory Information Requests

Last year's fertilizer plant explosion in West, Texas, drew the attention of regulatory agencies to nearly every corner of the chemical industry.

Following that incident, President Obama issued an Executive Order directing each agency to audit and make changes to the programs that govern the chemical industry. These requests could eventually result in new regulations for ammonia refrigeration facilities where they concern security and safety.

For the ammonia refrigeration industry, the increased regulatory scrutiny resulted in three "requests for information" from the Environmental Protection Agency, the Occupational Safety and Health Administration, and the Department of Homeland Security, respectively.

The responses to those RFI's from the International Institute of Ammonia Refrigeration and its industry partners could significantly impact the scope of regulatory changes in the near future.

"This gave us the opportunity to present information on how the industry is operating under our current standards and regulations," said Dave Rule, IIAR president. "It allowed us to remind the various agencies that we already have some very detailed standards that we are following. Our hope is they will keep regulations in line with the standards that we have developed."

As part of the response, IIAR formed a coalition with the American Frozen Food Institute, the American Meat Institute, the Global Chain Alliance, the Refrigerating Engineers and Technician Association and the U.S. Egg and Poultry Association to present a unified voice for the industry. "IIAR took a leadership role in putting together this coalition," Rule said. "It demonstrated a broad spectrum response on behalf of our industry."

Meanwhile, the RFIs the group convened to answer were extensive. EPA's request ran more than 100 pages and included more than 300 questions. Among the proposals were more detailed requirements documenting how a facility with over 10,000 pounds of ammonia meets the standards established within the Process Safety Management (PSM) and the Risk Management Program (RMP); changing the guidelines employed with RAGAGEP; improved coordination with emergency responders and the local community; lowering the threshold quantities for regulated chemicals; and building a stronger CFATS program.

OSHA proposed revising the PSM standard to require additional management-system elements, while EPA took a similar route regarding the RMP standard. Both questions raised concerns from the coalition that because the programs are performance-based, requiring facilities to use and share metrics is more prescriptive than a performance-based regulation should mandate. In addition, both standards already include management practices in almost all elements.

"The fact that PSM and RMP are performance-based standards is critical because it recognizes that there are unique characteristics to each regulated facility and it allows these facilities to assess their hazards and risks, and develop a plan tailored to their specific needs," said Lowell Randel, vice president of government and legal affairs with the Global Chain Alliance.

OSHA also proposed regulation that would require employers to evaluate updates to applicable RAGAGEP to help prevent or mitigate accidents. The coalition responded that IIAR standards represent the most applicable RAGAGEP for the ammonia refrigeration industry, that the standards should be the primary source material for OSHA inspectors in ammonia refrigeration facilities, and that it is important that facilities maintain the flexibility to define RAGAGEP for their own sites.

Among EPA's proposals was lowering the threshold quantities for regulated chemicals. The coalition responded that such a move with the ammonia threshold quantity (currently at 10,000 pounds) would require smaller independent companies to needlessly increase their operating costs and could create financial stress.

EPA also proposed mandating inherently safer technology, or IST, reviews and to include local communities in the process. It was felt by the coalition that the regulatory burden of requiring costly IST reviews could stifle innovation by forcing companies to document activities that they are already performing. Small operations might not have the manpower or expertise to do this. Furthermore, local communities have virtually no expertise in safety and risk management related to the ammonia refrigeration industry.

"It's not that we're against regulation. We think it's important to make sure our industry operates safely," Rule said. "But there is always a balance. We need to make certain that the regulations aren't overly onerous to the point where it creates an expense that's not necessary to achieve industry safety standards."

In August, the DHS issued an advance notice of rule-making for CFATS that could result in major changes in the regulatory approach and risk-based standards in the ammonia refrigeration industry. The request was fairly open-ended, asking the industry for input on how the program can operate more efficiently. The coalition pointed out that industrial refrigeration facilities using ammonia are not traditional chemical facilities, and a facility using closed-circuit systems with anhydrous ammonia should be exempt from the requirement of filing a Top-Screen with DHS unless another threshold quantity COI is present. The coalition responded that security measures in PSM and RMP already address the pertinent safety issues.

In summary, the coalition's response to OSHA and EPA focused on the desire for member facilities to maintain the flexibility to develop systems that fit their unique needs, and that the agencies continue to view IIAR standards as the leading source of RAGAGEP for PSM and RMP so that government inspectors don't misapply other standards to industry members. In regards to DHS, the coalition felt it was critical to reduce paperwork that did not provide a security benefit.

"Many of the issues raised in the RFIs are already covered in the standards that IIAR has developed," Rule said. "Our hope is they will review the points we made in our responses and see that our industry is already doing a good job of following existing regulations, and that it has developed a very detailed, comprehensive list of standards that provides the proper methods of designing and operating an ammonia refrigeration system safely." ■

Eurammon Forum Highlights the Status of Natural Refrigerants

CHRIS COMBS, IIAR INTERNATIONAL PROGRAMS DIRECTOR

The Natural Refrigerants Forum organized by Eurammon on Wednesday, October 15 at the Chillventa fair in Nuremburg, Germany provided an intriguing survey of the factors, both positive and negative, influencing the use of ammonia and other natural refrigerants around the world. Besides IIAR president Dave Rule's presentation on the status of the industry in the US, the remaining speakers focused on a vast and strategic region located at the crossroads of Europe, Africa and Asia; from Turkey and Egypt at the eastern end of the Mediterranean Sea to the sprawling Republic of Kazakhstan in Central Asia.

Speakers focused on a vast and strategic region located at the crossroads of Europe, Africa and Asia; from Turkey and Egypt at the eastern end of the Mediterranean Sea to the Republic of Kazakhstan in Central Asia.

KAZAKHSTAN:
Yuri Dubodelov of Sakada Engineering covered the situation of natural refrigerants in the former Soviet Republic of Kazakhstan –the world's largest landlocked country spanning from Eastern Europe to Eastern Asia– bordering China, Russia, the Caspian Sea and other former Soviet Central Asian Republics to the south.

During its days as a Soviet Republic, much of Kazakhstan's food industry consisted of large state owned processors using ammonia refrigeration systems. When the Soviet Union broke up, the privatization of state owned food and refrigeration companies and market conditions for the newly privatized companies almost led to the total collapse of the ammonia refrigeration industry. During the reconstruction stage that followed, many ammonia systems were replaced by easier to use Freon systems. This trend away from ammonia was encouraged by the lack of qualified refrigeration specialists in Kazakhstan. Although young Kazakhs can obtain these skills in Russian universities, requirements to work in Russia prevent these skills from reaching Kazakhstan. Ammonia has also faced local regulatory challenges, especially in urban areas. A general lack of awareness about ammonia and natural refrigerants among potential users, low salaries for ammonia operators while the average age of trained professional ammonia operators (trained in Soviet times) reaches 60 further complicates the situation for natural refrigerants.

However, there are several factors favoring the use of ammonia and other natural refrigerants in Kazakstan. These include plans by the Ministry of Environment and Water Resources to advocate for natural refrigerants, Kazakhstan's ratification of the Kyoto and Montreal Protocols and food industry consolidation. Furthermore, the government is implementing a National Allocation Plan for greenhouse gas emissions which includes a quota and emissions trading system for food and other industries.

TURKEY:
Turkey, another big country encompassing parts of both Europe and Asia, is the 17th largest economy in the world and the 18th in population. Hüseyin Yüksel of ISKID, Turkey's Air Conditioning & Refrigeration Manufacturers' Association, discussed current developments in natural refrigerants based technologies there.

Turkey successfully phased out CFCs in the 90s and its HCFC phase out program is well on its way today. Ammonia has been widely used in the food, beverage and cold storage industries at levels comparable to the European Union and the United States for decades. Turkey follows EU regulations that are advantageous to natural refrigerants.

CO_2 refrigeration in Turkey is beginning to take off. The government's "Meat and Milk Board" is planning five large cold storages around the country using multiple CO_2-Ammonia cascade units at each. Given Turkey's warmer climate and the higher resulting pressures, CO_2 cascade systems are preferred. Currently there is one CO_2 trans critical and two CO_2 cascade systems in supermarkets. Investment costs is still a limiting factor for CO_2 refrigeration systems. There is a need for more education on CO_2 in Turkish universities.

Yüksel also reported progress on the use of hydrocarbons (R600 and R290) in display cabinets, bottle coolers, domestic refrigerators and some split type air conditioners. Turkish manufactur-

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MIDDLE EAST:
Hans Raaymakers, General Manager of Adearest in Dubai, presented an engrossing survey of the factors driving industrial ammonia refrigeration throughout the Middle East. He argues that industrial refrigeration industries are stimulated by a number of factors including population, political stability, money, fertile land and sweet water, local food production and the availability, reliability and cost of energy.

For many of these factors, there are important disparities between the different countries in the region. For example, while the Middle East has roughly half the world's oil reserves, Raaymakers cites significant variations in energy costs from country to county. For example, energy costs in Jordan are 70% of European levels while in Iran they are only 15 percent of European levels.

Fertile land and fresh water are also unevenly distributed throughout the region; for example, while these are concentrated in Egypt's Nile delta and the Fertile Crescent of Iraq, countries like Saudi Arabia and the United Arab Emirates have very limited amounts of water and fertile land. Egypt, with its fertile Nile valley and delta and the region´s highest population, at around 80,000, is a big ammonia refrigeration market with investment picking up under the current government.

On the other hand, Saudi Arabia and the UAE have abundant food production that is highly dependent on imports – given the lack of fertile land – and on desalination for meeting fresh water needs; both rely on ammonia for large plants and Freons for smaller plants. Iraq, which mainly uses Freons in its limited domestic food production industry, with its fertile land and oil wealth has a huge potential that is hindered by the extreme political instability we see there today.

During the 1980s, commercial plants in the region were using CFCs and HCFCs. In the 1990s, the market was dominated by HCFCs and the introduction of ammonia by European companies in the meat and dairy sectors. Since 2000, ammonia use has been strengthened by the presence of local ammonia contractors.

The challenges for ammonia in the Middle East include the low evaporating temperatures with the high ambient conditions, water scarcity, technical skills, wide differences in legislation, lack of cross border coordination and the political climate. In addition, there has been no specific legislation favoring low ODP and GWP refrigerants, nor visible enforcement of environmental protocols. Consequently, HCFCs and HFCs are widely used today. Local standards are lacking so the application of standards depends on the initiative of suppliers; when applied in this manner they tend to be European standards.

According to Raaymakers, much of the movement towards natural refrigerants is dependent on the actions and example set by multinationals following European standards and green solutions in their operations in the Middle East. However, not all the local players follow their example. He noted that the lack of environmental consciousness within the region is a big challenge that must be overcome through education.

For more details on the subjects described above, you may find the presentations from the Natural Refrigerants Forum at Chillventa 2014 on Eurammon's website at: http://www.eurammon.com/chillventa-2014-lecture-event. ■

RECOMMENDED PRACTICES

Measuring Pipe Wall Thickness

The issue of when, and how, to measure wall thickness on a pipe has become a hot topic in recent months. Clearly, it’s important to maintain the mechanical integrity of refrigeration systems in order to avoid ammonia leaks. But there is debate in the industry over when pipes that display no visible damage should be examined.

“The question is, if you are doing an inspection to look for corrosion under insulation, are you introducing new hazards that didn’t exist before the inspection?” said Marty Timm, Process Safety Manager at Praxair, Inc. “We may be taking a perfectly good section of piping and insulation and introducing a hole through the vapor area that surrounds the insulation, thus creating a pathway for moisture to enter the insulation. And if we don’t do a good job of patching the hole, the moisture can migrate to the pipe and cause corrosion in a spot where it never would have happened.”

Accelerated corrosion has been reported at sites where insulation was removed for non-destructive examination.

Accelerated corrosion has been reported at sites where insulation was removed for non-destructive examination, or NDE, and the ensuing repair to the insulation or vapor barrier was inadequate. In other cases, adhesive-backed labels attached to non-insulated pipes to mark measurements of wall thickness have led to problems. Residual heat has caused the label to bubble, trapping moisture and leading to corrosion.

In one recent case cited by Timm, an end-user hired a contractor to perform a non-destructive examination, or NDE, of wall thickness. After removing a “plug” from the jacket and insulation, the technician experienced resistance from ice when cutting the compromised insulation. When he pressed harder, the drill pierced the pipe, resulting in an ammonia release.

No one was hurt and the leak was quickly contained, but there are some important things to learn from this incident, said Timm.

“When the technician met resistance he should have backed off, moved away from the insulation and looked through the hole to see what was going on,” he said. “He shouldn’t have assumed it was ice. He should have looked into the hole to confirm it.”

The incident also was a lesson in evaluating and managing risk. All NDE methods should be carefully analyzed to determine if new risks could be introduced, said Timm. Those new risks should then be managed before an issue arises.

“If you’re working with a drill you need to ask yourself what happens if I cut into the pipe?” Timm said. “By asking ‘what-if’ questions you can look for new hazards that might suggest safeguards to avoid them. It might suggest different protective clothing, rubber gloves, a respirator, or other safeguards to protect the employee from exposure to the refrigerant.”

The ultrasonic method for measuring wall thickness is one of many non-invasive techniques. A probe generates sound waves that measure the reflection from the metal bounce off the side wall and back again, with the delay creating a reading corresponding to the wall thickness. But the probe must come in contact with the metal surface of the pipe, thus requiring cutting away the insulation. “It’s non-destructive as far as the piping is concerned, but not with the insulation,” Timm said.

IIAR guidelines recommend a careful examination of pipes every five years. It’s important that facilities continue to follow RAGAGEP, but be aware that there may be opportunities to be more selective in the future, said Timm.

There isn’t a consensus yet, but there’s an evolving thought that we’re doing too much cutting into the insulation and that we should fine-tune our methodology, he said. There’s an emerging viewpoint that says, Let’s be selective. Look for visible deterioration, a missing insulation jacket, a missing vapor barrier, frost or condensation on the pipe.

Timm said that visual inspection works well with non-insulated pipes, but it can be ineffective with insulated pipes. The insulation can hide damage, making a pipe that has been compromised appear fine. Still, Timm believes spot-checking visually undamaged pipes can offer a solution.

Instead of cutting into the insulation of every pipe every five years, inspect only a fraction of the pipes that don’t show visible damage. If you find a problem, then go on and inspect more, he said.

A plant could be doing everything right. They’ve got good insulation, a vapor barrier, they’ve put on an external jacket so you’re not poking holes in it. Everything is going great. No moisture is getting into the pipe, Timm said. And then you arbitrarily determine that you have to cut a hole and check for wall thickness every five years, so you go in, cut a bunch of holes and then run the risk that they’re not patched properly.

“Maybe we should be a bit more strategic in which pipes we select to inspect,” he added. ■

Water Contamination in an Ammonia Refrigeration System Leads to Higher Costs

TONY LUNDELL, CIRO, PMP, IIAR DIRECTOR OF STANDARDS AND SAFETY

In many closed-circuit ammonia refrigeration systems, water contamination can occur over a period of time and the effects of that contamination can easily go unnoticed. One thing water contamination can do is cause an aqueous ammonia solution to be formed, which then replaces anhydrous ammonia refrigerant. This problem can become continuous if it isn't resolved, and will increase over time if the source is not identified.

Water contamination can result in many problems for an ammonia refrigeration system. The pressure-temperature relationship can become impaired, the compressor oil may start to form organic acids, and sludge may develop from a complex chemical reaction. Other changes might include pressure drops that increase through piping and pump and evaporator performance that are adversely affected.

Sometimes, the system must be operated at a lower suction pressure in order to maintain the desired room temperatures or to handle the same processing system loads. And as the suction pressure is lowered, this increases the BHP/ton causing less compressor capacity while at the same time causing an increase in power consumption, a two-fold penalty.

So how do we identify the cause of water contamination? First we must look at how and why it is occurring. Water can gain entrance to a system in many ways. Systems which operate with the suction pressure in a vacuum are the most common source. Leaks from valve stem packings, screwed and flanged piping joints, threaded and welded pipe connections, leaking safety relief valves, pump seals, booster compressor seals, deteriorated piping, and deteriorated evaporator coils become sources of infiltration with the system operating in a vacuum.

Other sources result from inadequate evacuation procedures on startup or following the opening of the system after a maintenance service or repair. The original source may be from moisture in new vessels which were not properly drained or dried after the completion of the ASME hydrostatic test. In another scenario, for example during construction, water can enter a system as vapor through open piping or weld joints that were only tacked in place and later condensed to liquid. Condensation could have occurred in the system if air was used as the medium for the final pressure testing.

A lack of adequate purging or no purging at all can keep any non-condensables that have made it into the system from being removed, resulting in the introduction of a contaminant.

While draining oil from vessels or bleeding equipment down with a hose into a container of water prior to service or a repair in which the pressure may still be in a vacuum range could result in unwanted infiltration. An inadequate oil draining procedure in itself could be the root cause of infiltration.

A ruptured tube or tubes in a shell-and-tube heat exchanger, such as a chiller or oil cooler, can also be a contamination source.

Performing adequate evacuation procedures on startup or following the opening of the system after a maintenance service or repair is crucial for contamination prevention.

There will be a continuous increase in water content of the ammonia in the system if steps are not taken to control the amount of infiltration. The effects of the water contamination in a system may take years to detect before the problem is truly recognized. During the non-detected time and until the water is removed and stopped, room temperatures may have been compromised from progressively deteriorated evaporator performances, suction pressures may have been lowered, more compressors may have been operating, and additional electrical energy very likely had to be consumed to meet the same requirements.

Meanwhile, the estimated amount of the water content of an ammonia system can be measured. Obtaining a sample from the system to test the water content must be done by a qualified person or persons familiar with the system using the appropriately developed and approved procedure to do so. The connection point on the system from which to take the sample should be determined to be the point where the highest water content buildup exists. The buildup of water is due to the large difference in vapor pressure between the water and the ammonia. In two-stage systems, the point will be located in vessels and evaporators serving the low side of the system. In recirculating systems, the point will be at the vessel which supplies liquid to the evaporators. In a pump system, the point will be at the pump receiver. In a gas pressure system, the point will be at the controlled pressure receiver. In flooded systems, the point will be at the evaporator and surge drum.

Once a 100 ml sample is obtained and evaporated using a graduated sampling container, the residual remaining will be a mixture of water, oil, non-volatile impurities, and approximately 30 percent ammonia (in the water residue). Once the ml residue amount is determined, the percent water present and the cost of additional operations can be estimated using specific developed charts.

Finally, a regenerator, distiller, dehydrator can be connected to remove the water in the system.

In summary, preventing water contamination in an ammonia system prevents higher energy operating costs and unnecessary maintenance service costs. ■

Editor's Note

The process of selecting air cooling evaporators to operate in a CO_2 refrigeration system is very similar to selecting evaporators for ammonia. Evaporator manufacturers typically require the same input data for both refrigerants and likewise display performance and selection data in the same way.

In this technical paper, author Bruce Nelson outlines the ways that CO_2 evaporators and ammonia evaporators differ.

While they are similar in that both have tubes, fins, and fans, CO_2 evaporators are very different in a number of respects which are important for refrigeration designers and operating engineers to understand.

In the following paper, the author addresses subjects including general use, material compatibility, pressure, heat transfer, the effects of oil in evaporators, the optimum overfeed rate for pumped CO_2, direct expansion with CO_2 and defrost.

CO_2 EVAPORATOR DESIGN

Bruce I. Nelson, P.E., President, Colmac Coil Manufacturing, Inc.

INTRODUCTION

The process of selecting air cooling evaporators to operate in a CO_2 refrigeration system is very similar to selecting evaporators for ammonia. Evaporator manufacturers typically require the same input data for both refrigerants and likewise display performance and selection data in the same way.

Typically, the following inputs are required for properly selecting either CO_2 or ammonia evaporators:

a. Elevation
b. Return air ('Air on') temperature
c. Return air relative humidity
d. Evaporating temperature
e. Type of feed
f. Overfeed rate (if pumped feed)
g. Liquid pressure and temperature at the expansion valve (if DX)
h. Required cooling duty
i. Type of defrost
j. Supply voltage
k. Materials of construction
l. Required MAWP (Maximum Allowable Working Pressure)

Other inputs may include:

m. Maximum allowable air velocity
n. Minimum air flow rate
o. Maximum allowable fan speed
p. Maximum allowable sound pressure (usually in dB(A))
q. Minimum air throw distance
r. Minimum number of fans
s. Dimensional constraints (maximum height or length limitations)

Output data typically includes:

t. Actual cooling duty
u. Air flow rate and air velocity
v. Leaving air temperature
w. Leaving air relative humidity
x. Sound pressure level
y. Air throw distance
z. Dimensional characteristics
    i. Cabinet H x W x L
    ii. Weights
    iii. Internal volume
aa. Electrical characteristics
    i. Number of fans/motors
    ii. Fan speed
    iii. Fan motor brake power
    iv. Full load amperage and/or power consumption

To the uninitiated, the above may imply that CO_2 evaporators and ammonia evaporators are interchangeable and essentially the same animal. While they are similar in that both have tubes, fins, and fans, CO_2 evaporators are very different in a number of respects which are important for refrigeration designers and operating engineers to understand. Highlighting and quantifying these differences is the subject of this handbook chapter.

GENERAL

Most commonly used feed methods for CO_2 are:

- Pumped liquid
- Direct expansion

While gravity flooded feed is very effective with ammonia, it is not commonly used with CO_2 due to:

The higher density of CO_2 liquid compared to ammonia. This higher density results in elevated evaporating temperatures in the evaporator due to liquid head in the surge drum and drop leg.

The higher pressure rating required for the surge drum.

Poor performance due to necessarily low pressure drop (equal to the available head of liquid in the surge drum drop leg). This reduces allowable mass flux and results in low boiling heat transfer coefficients.

Stainless steel is an ideal tube material for use in carbon dioxide evaporators because of its high yield and tensile strength.

Most ammonia evaporators are defrosted by air, water, or hot gas. Electric defrost is not commonly used due to the flammability characteristics of ammonia. This is because electric defrost elements typically have high surface temperatures and are necessarily placed in close proximity to coil tubes.

CO_2, on the other hand, is commonly defrosted by air, water, and electric resistance heating. However, hot gas defrosting is uncommon because of the high gas pressures required. Electric defrost is very effective and is widely used with CO_2 due to its simplicity and low first cost.

As explained above there are many similarities in evaporator rating methods and construction, however, the very different thermodynamic and chemical characteristics of CO_2 compared to ammonia require special attention with regard to:

- **Material Compatibility.** Unlike ammonia, CO_2 can be used safely with copper and copper-bearing alloys. Actually, dry CO_2 is quite inert and can be used with all commonly used base metals; copper, carbon steel, stainless steel, and aluminum. Care must be taken to select materials with sufficient strength to withstand the higher MAWP required for CO_2. This normally rules out the use of aluminum with CO_2.
- **Pressure.** CO_2 pressures are much higher than ammonia.
- **Heat Transfer.** Thermodynamic and transport properties are very different for CO_2 compared to ammonia and result in very different evaporator circuiting arrangements to achieve equivalent cooling capacity.

MATERIAL COMPATIBILITY

For many years, ammonia evaporators were made of carbon steel tubes and fins hot dip galvanized after fabrication. While this type of construction is corrosion resistant and has sufficient strength to perform well in most ammonia refrigeration systems, carbon steel is not an ideal material to use with carbon dioxide for two reasons:

1. **Tubeside Corrosion.** If there is any residual water present in the piping or vessels of a carbon dioxide system on startup, it can combine with the carbon dioxide to form carbonic acid. Carbon steel is susceptible to corrosion when exposed to even mildly acidic solutions.
2. **Embrittlement at Low Temperatures.** Carbon steel is known to become brittle at temperatures below about -20 deg F. Even though the strength of the metal increases as the temperature is reduced, even low carbon steel will become embrittled and prone to fracture when subjected to impact loading. One of the advantages of CO_2 is the improved cycle efficiency (reduced power consumption) at very low (blast freezing) temperatures. Low temperature operation with carbon steel evaporators is problematic for this reason and not recommended.

Aluminum is an excellent metal to use in evaporators for several reasons (Nelson 2012) and so is in wide use in industrial ammonia refrigeration systems. While the yield and tensile strength of this metal are sufficient to easily handle ammonia pressures, they are generally not high enough to achieve the higher design pressures needed for carbon dioxide. Aluminum is therefore not recommended for use with carbon dioxide.

Copper, unlike carbon steel, does not suffer embrittlement at low temperatures. It resists corrosion when exposed to mild acids and so can stand exposure to low concentrations of carbonic acid. Because of the possibility of exposure of the brazed joints to carbonic acid, it is highly recommended that copper tube evaporators be brazed using a non-phosphorous bearing alloy filler metal. The yield and tensile strengths of copper are high enough to reach required design pressures for freezer temperatures, but in rooms above about 0 deg F the required design pressures become higher than can be practically achieved with copper tubes. Therefore, copper tube construction is considered appropriate for carbon dioxide evaporators installed in rooms 0 deg F and colder.

Stainless steel is an ideal tube material for use in carbon dioxide evaporators because of its high yield and tensile strength and corrosion resistance. Also, like aluminum and copper, stainless steel is not susceptible to embrittlement even at extremely low (cryogenic) temperatures.

Conclusions:
Material Compatibility

- Both copper and stainless steel tubing and pipe are recommended for use in CO_2 evaporators provided the diameters and wall thicknesses meet the required design pressures.

- When using copper, a non-phosphorous bearing brazing alloy is recommended. This is needed to limit the risk of leaks caused by acidic conditions resulting from the presence of carbonic acid.

When using copper, a non-phosphorous bearing brazing alloy is recommended. This is needed to limit the risk of leaks caused by acidic conditions resulting from the presence of carbonic acid.

- Carbon steel is not recommended for use in CO_2 evaporators due to a) susceptibility to corrosion in the presence of carbonic acid, and b) embrittlement at low temperatures (lower than -20 deg F).
- Aluminum is not recommended for use in CO_2 evaporators due to its lower yield and tensile strength characteristics.

PRESSURE

Table 1 below compares the saturation pressures for CO_2 and ammonia and illustrates the significantly higher pressures (and consequently higher strength requirements) for CO_2.

ASHRAE Standard 15 "Safety Standard for Refrigeration Systems", sets the minimum design pressure for evaporators in Section 9.2.1. This section of the standard also refers to the ASME Boiler and Pressure Vessel Code, Section VIII, as the appropriate method of determining the design (or 'working') pressure given evaporator dimensions and materials of construction.

Section 9.2.1 sets up design pressure criteria for various types of refrigeration systems and states that "…Design pressure for mechanical refrigeration systems shall not be less than 15 psig and, except as noted in Sections… 9.2.6, shall not be less than the saturation pressure corresponding to the following temperatures: a.) Lowsides of all systems: 80 deg F (26.7 deg C)." From Table 1, for CO_2 the design pressure corresponding to 80 deg F is 969.6 psia (66.8 bar), or 955 psig.

Section 9.2.2 states "The design pressure for either the highside or lowside need not exceed the critical pressure of the refrigerant unless such pressure are anticipated during operating, standby, or shipping conditions." Critical pressure for CO_2 is 1070 psia (73.8 bar), or 1055 psig.

Section 9.2.6 (9.2.1 above) describes specific exceptions when carbon dioxide is the refrigerant, as follows:

"When a refrigerating system utilizes carbon dioxide (R744) as a heat transfer fluid, the minimum design pressure for system components shall comply with the following.

9.2.6.1 In a circuit without a compressor, the design pressure shall be at least 20% higher than the saturation pressure corresponding to the warmest location in the circuit.

9.2.6.2 In a cascade refrigerating system, the highside design pressure shall be at least 20% higher than the maximum pressure developed by a pressure-imposing element, and the lowside pressure shall be at least 20% higher than the saturation pressure corresponding to the warmest location in the circuit."

The intent (as understood by the author) of the phrase "warmest location in the circuit" is to mean the room temperature in which the evaporator(s) will operate. For example, a CO_2 evaporator in a cascade refrigerating system is being designed to operate in a 0 deg F room. From Table 1 the saturation pressure corresponding to 0 deg F is 305.7 psia. Minimum required design pressure according to Section 9.2.6.2 would then be 305.7 x 1.2 = 366.8 psia = 352 psig.

Table 2 shows the calculated minimum required design pressure for CO_2 evaporators according to Section 9.2.6.

Knowing the required minimum design pressure from the above now allows us to determine tubing diam-

Table 1 Saturation Pressure vs Temperature CO_2 vs Ammonia

Temperature		Ammonia Pressure		CO2 Pressure	
deg F	deg C	psia	bar	psia	bar
-60	-51.1	6	0.4	95	6.5
-40	-40.0	10	0.7	146	10.0
-20	-28.9	18	1.3	215	14.8
0	-17.8	30	2.1	306	21.1
20	-6.7	48	3.3	422	29.1
40	4.4	73	5.1	568	39.1
60	15.6	108	7.4	748	51.6
80	26.7	153	10.6	970	66.8

Table 2

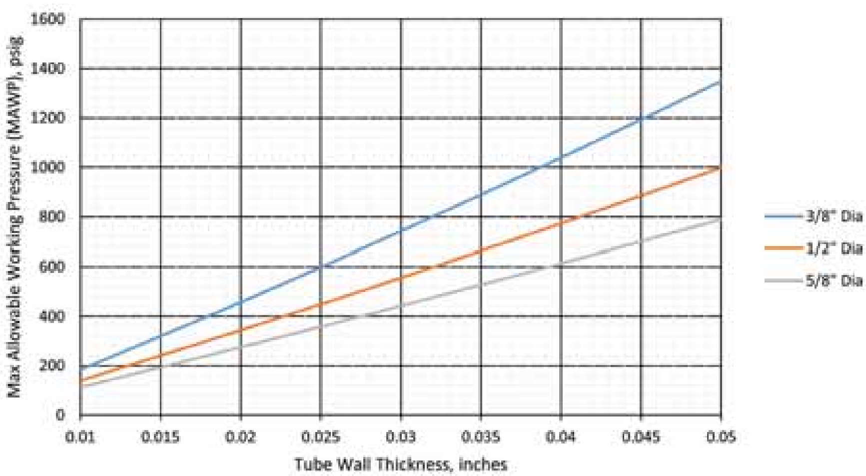
Minimum Design Pressure vs Temperature CO_2 Evaporators

Temperature		Minimum Design Pressure		
deg F	deg C	psia	psig	bar
-60	-51.1	113	99	7.8
-40	-40.0	175	160	12.1
-20	-28.9	258	243	17.8
0	-17.8	367	352	25.3
20	-6.7	506	492	34.9
40	4.4	681	666	47.0
60	15.6	897	883	61.9
80	26.7	1070*	1055*	73.8*

Fig. 1

MAWP vs Tube Wall Thickness Light Annealed Cu (SB-75)

ASME Boiler and Pressure Vessel Code, Sec VIII



eter and wall thickness according to the calculation method shown in the ASME Boiler and Pressure Vessel Code, Section VIII. Material properties used in the calculations are taken from ASME Section II.

Since copper and stainless steel are recommended for use in carbon dioxide evaporators (see above), Figures 1 and 2 below have been constructed to show the calculated Maximum Allowable Working Pressure (MAWP) for commonly used tube diameters over a range of wall thicknesses.

Using data from Table 2 with Figures 1 and 2 allows the required tubing wall thickness to be calculated for different tubing diameters and materials given the room temperature.

Table 3 shows the tube wall thickness needed to meet the requirements of ASHRAE Standard 15 in a CO_2 evaporator operating at various room temperatures.

Note that the minimum tube wall thicknesses shown in Table 3 are theoretical calculated values. In normal manufacturing practice, copper tubing with wall thickness less than about 0.016" is difficult to produce and to handle. With stainless steel tubing the practical minimum wall thickness is around 0.020".

Bear in mind that Table 3 applies only to evaporator tubes, not to headers or piping connections. The evaporator manufacturer must also properly design coil headers and piping connections according to ASME Section VIII to have MAWP equal to or greater than the tubing MAWP.

While lower temperatures may allow the use of light wall tubing and relatively low design pressures during normal operation, the system designer must remember that the design pressure must be selected to accommodate all potential temperature/pressure conditions including (but not limited to):

a. Startup conditions

b. Peak load operation

c. Abnormal loads (process temperature excursions)

d. Standby conditions that occur frequently

    ii. Power outages limited in time duration but which may happen with some frequency

    ii. Shutdown during cleanup

Conclusions: Pressure

- CO_2 evaporators will operate at significantly higher pressures than ammonia for a given temperature.
- In the United States, ASHRAE Standard 15 establishes design pressure requirements for CO_2 systems.
- ASHRAE Standard 15 requires the design pressure for CO_2 evaporators to be "…at least 20% higher than the saturation pressure corresponding to the warmest location in the circuit." The "warmest location in the circuit" is interpreted as the warmest anticipated room temperature in which the evaporator(s) will operate.
- Minimum recommended tube wall thicknesses are shown in Table 3, however, the evaporator manufacturer must insure that all pressure bearing components in the coil, including headers and pipe connections, are designed correctly.

Fig. 2 MAWP vs Tube Wall Thickness 304 SS (SA-249)

ASME Boiler and Pressure Vessel Code, Sec VIII

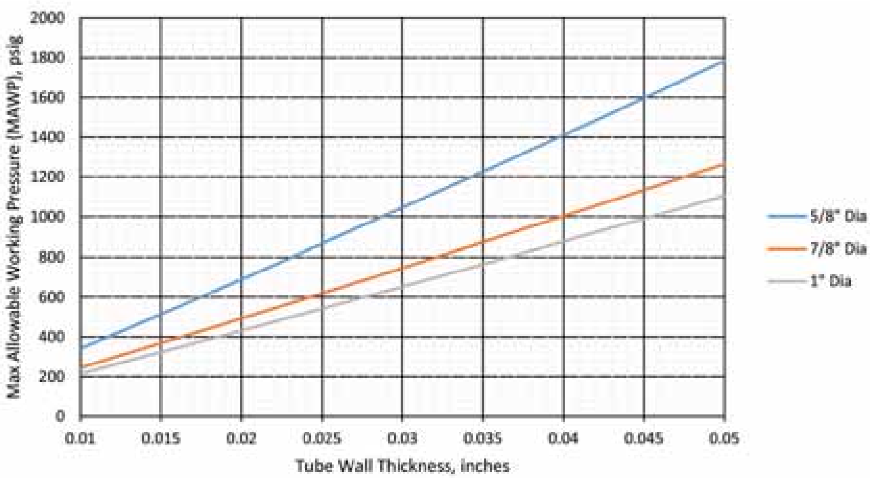


Table 3 Minimum Tube Wall Thickness vs Room Temperature (ASHRAE Std 15) CO_2 Evaporators

		Minimum Tube Wall Thickness, in					
Room Temperature		SB-75 Cu Tube Diameter			SA-249 304 SS Tube Diameter		
deg F	deg C	3/8"	1/2"	5/8"	5/8"	7/8"	1"
-60	-51.1	0.010	0.010	0.010	0.010	0.010	0.010
-40	-40.0	0.010	0.011	0.013	0.010	0.010	0.010
-20	-28.9	0.012	0.015	0.018	0.010	0.010	0.012
0	-17.8	0.016	0.020	0.025	0.011	0.015	0.017
20	-6.7	0.022	0.028	0.034	0.015	0.021	0.024
40	4.4	0.027	0.035	0.043	0.020	0.027	0.032
60	15.6	0.036	0.046	NR	0.026	0.036	0.041
80	26.7	NR	NR	NR	0.031*	0.042*	0.048*

- The temperature used to establish design pressure must be carefully selected to account for conditions which include (but are not necessarily limited to) those shown below:
  a. Startup conditions
  b. Peak load operation
  c. Abnormal loads (process temperature excursions)
  d. Standby conditions that occur frequently
     i. Power outages limited in time duration but which may happen with some frequency
     ii. Shutdown during cleanup

HEAT TRANSFER

The driving potential for heat transfer in an air cooling evaporator is the mean temperature difference between the air and the boiling refrigerant. Frictional pressure drop on the tubeside of the evaporator reduces the mean temperature difference and therefore the cooling capacity of the evaporator. This coupling of fluid flow (frictional pressure drop) and heat transfer is unique to evaporators. As refrigerant mass flux increases; a) the heat transfer coefficient increases which increases cooling capacity, but b) pressure drop also increases which reduces cooling capacity. Evaporator manufacturers optimize this balance of heat transfer with pressure drop by adjusting the number of feeds and passes for a given coil geometry and operating conditions.

Boiling heat transfer in tubes has been studied for several decades with continual improvement to correlations and accuracy of the predictions. The convective boiling heat transfer coefficient is a strong function of refrigerant mass flux (also called mass velocity), viscosity, and the ratio of liquid to vapor densities. It is a weaker function of thermal conductivity and specific heat. The combination of these properties actually favor ammonia, which produces significantly higher (200% to 300%) boiling heat transfer coefficients when compared to CO_2 at the same mass flux.

The good news with CO_2 is the much steeper slope of the vapor pressure curve compared to ammonia, shown in Figure 3 below. This relatively steep slope (dP/dT) means that CO_2 evaporator circuiting can be designed for higher mass flux without the pressure drop penalty seen with ammonia. The higher design mass flux with CO_2 offsets the lower boiling heat transfer coefficient compared to ammonia and results in evaporator performance which is very nearly equivalent.

The slope of the vapor pressure curve in Figure 3 has been tabulated in Table 4 and illustrates the difference between pressure drops seen in ammonia versus CO_2 evaporators. Typically evaporator manufacturers will design evaporator circuiting to limit tubeside pressure drop to a value corresponding to approximately 1.8 deg F (1.0 deg K) change in evaporating temperature. Using the slope of the vapor pressure curve (dP/dT) shown in Table 4, at -20 deg F saturated suction temperature, a 1.8 deg F change in evaporating temperature corresponds to a pressure drop of 1.8 x 0.489 = 0.88 psi for ammonia, and

Fig. 3 Saturation Pressure Temperature Ammonia and Carbon Dioxide

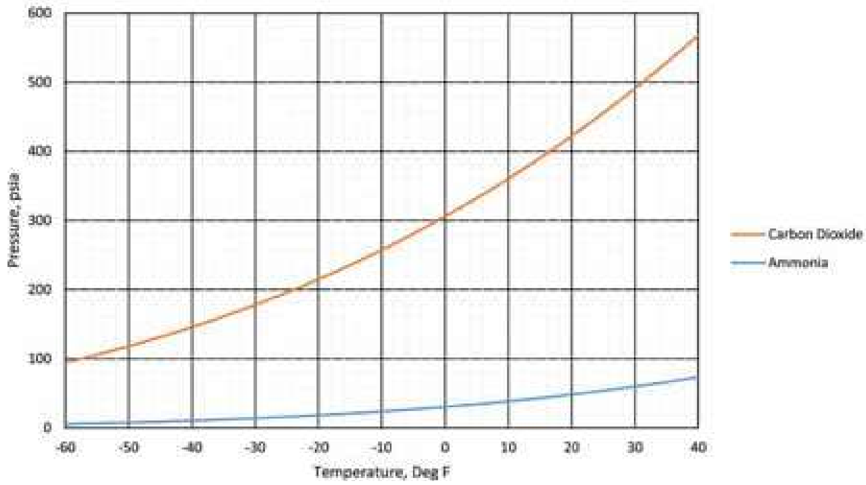


Table 4 dP/dT vs Saturation Temperature

dP/dT vs Saturation Temperature					
		Ammonia		CO2	
Temperature		dP/dT		dP/dT	
deg F	deg C	psi/deg F	kPa/deg C	psi/deg F	kPa/deg C
-60	-51.1	0.184	2.3	2.157	26.8
-40	-40.0	0.309	3.8	2.980	37.0
-20	-28.9	0.489	6.1	3.973	49.3
0	-17.8	0.735	9.1	5.143	63.8
20	-6.7	1.059	13.1	6.510	80.8
40	4.4	1.470	18.2	8.100	100.5

1.8 x 3.973 = 7.15 psi for CO_2. As explained earlier, this higher allowable pressure drop with CO_2 means that evaporator circuiting can be arranged for fewer feeds and more passes (longer circuit length) compared to ammonia. Again, when designed properly by the manufacturer, similar sized evaporators will produce cooling capacity with CO_2 which is equivalent to ammonia.

Conclusions: Heat Transfer

- CO_2 evaporators should be designed for higher mass flux and pressure drops than ammonia evaporators due to the much larger dP/dT characteristic of CO_2. This appears as longer circuit lengths for CO_2 compared to ammonia.
- If circuited properly, an evaporator operated with CO_2 will have equivalent cooling capacity to an evaporator of the same dimensions operated with ammonia. i.e. CO_2 does not penalize performance in evaporators compared to ammonia.

EFFECTS OF OIL IN EVAPORATORS

Industrial CO_2 refrigeration systems typically use immiscible oil for compressor lubrication. Unless effectively removed from the CO_2 discharge gas in the oil separator, some amount of oil is likely to reach evaporators and coat internal tube surfaces. The effect of this oil coating can be quantified in the form of a fouling factor, which is added to the overall resistance to heat transfer of the evaporator surface. Figure 4 below shows the calculated fouling factor for increasing oil film thickness in evaporator tubes.

Figure 5 translates this fouling factor into an expected reduction in cooling capacity for a CO_2 evaporator operated with increasing oil film thickness.

For example, a CO_2 evaporator design to operate oil-free will have its cooling capacity reduced by a factor of 0.87 (a 13% reduction) when the internal tube surfaces are coated with an oil film 0.002" thick.

Conclusions: Effect of Oil on Heat Transfer

- If immiscible compressor oil is allowed to coat internal tube surfaces in CO_2 evaporators, cooling capacity will be reduced.
- Installation of a high efficiency oil separator to minimize the amount of oil reaching evaporators is recommended.

OPTIMUM OVERFEED RATE FOR PUMPED CO_2

Reducing the overfeed rate in pumped refrigerant systems is desirable because pumping power will be reduced by the cube of the ratio of the reduction in flowrate. As the liquid overfeed rate is reduced, however, the risk of operating evaporators with the refrigerant in separated flow patterns (stratified/wavy) increases. Cooling capacity of the evaporator falls off dramatically when this occurs. With CO_2 in an evaporator having 5/8" tubes, a minimum mass flux of 200 kg/m2-s is required to avoid stratified/wavy flow.

The thermodynamic properties of CO_2 differ significantly from ammonia:

- Latent heat of vaporization is much lower resulting in higher mass flow rates for a given cooling capacity.
- The ratio of liquid to vapor density is much lower which results in lower void fractions (less tube volume occupied by vapor).
- Higher mass flux for reasons explained above (see Heat Transfer section).

Fig. 4 Inside Fouling Factor vs Oil Film Thickness

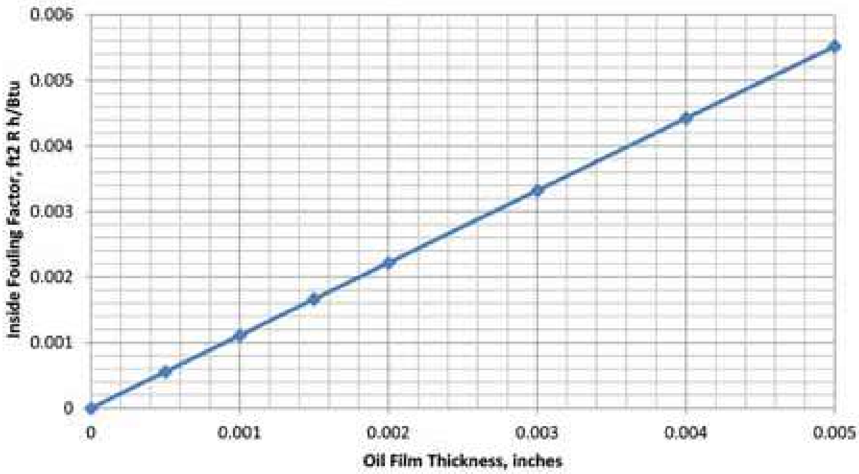
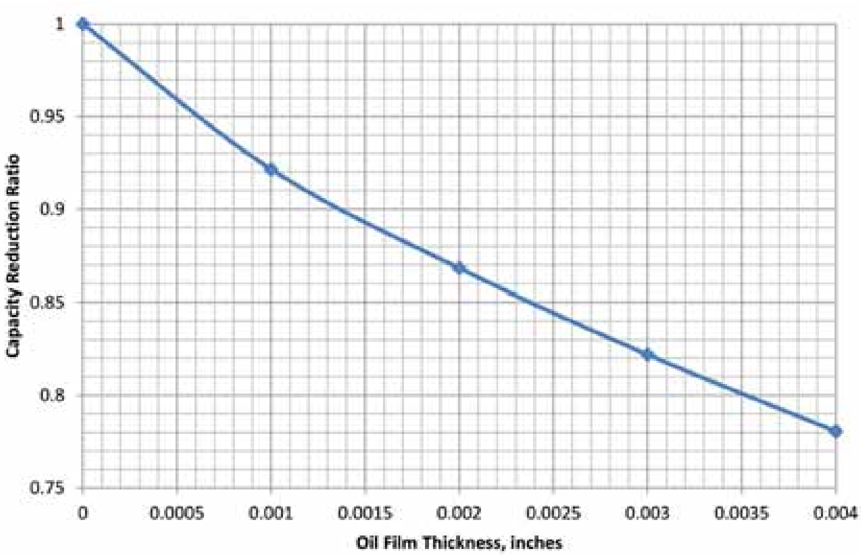


Fig. 5 Capacity Reduction vs Oil Film Thickness CO_2 Evaporator, -20 deg F SST, -10 deg F Air On



These characteristics allow pumped CO_2 evaporators to be designed for lower overfeed rates compared to ammonia. Recommended overfeed rates for pumped CO_2 evaporators are 1.5:1 for coolers and 2:1 for freezers.

In comparison, to avoid separated flow in pumped ammonia evaporators, recommended overfeed rates are 3:1 for coolers and 4:1 for freezers.

Conclusions: Optimum Overfeed Rate

- Pumped CO_2 systems can be successfully operated with lower overfeed rates compared to ammonia.
- Recommended overfeed rates for pumped CO_2 evaporators are 1.5:1 for coolers and 2:1 for freezers.

DIRECT EXPANSION WITH CO_2

CO_2 evaporators can be operated with direct expansion feed. Care must be taken by the evaporator manufacturer to circuit the coil in such a way that the refrigerant mass flux is kept above 200 kg/m2-s in order to avoid stratified/wavy flow. This becomes challenging with larger diameter tubes (greater than 5/8"). At very low temperatures, enhanced tubes (microfin copper) are recommended as a way to mitigate separated flow patterns and improve performance.

DEFROST

CO_2 evaporators are commonly defrosted using the following methods:

- Air
- Water
- Electric Resistance

Control valve groups for these methods of defrost are very simple and low cost.

Hot gas defrost with CO_2 evaporators is not commonly used. In a cascade system, the intermediate CO_2 temperature/pressure is normally too low to allow the CO_2 from that circuit to be used for defrost. This then requires a separate high pressure (capable of 50 bar) compressor with sufficient capacity to be installed expressly for purposes of providing hot gas for defrost. Other means of generating hot CO_2 gas for defrost include use of a heat-driven boiler vessel, typically heated by discharge gas from the high side of the cascade system. The complexity and added expense of hot gas defrost with CO_2 has limited its application.

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