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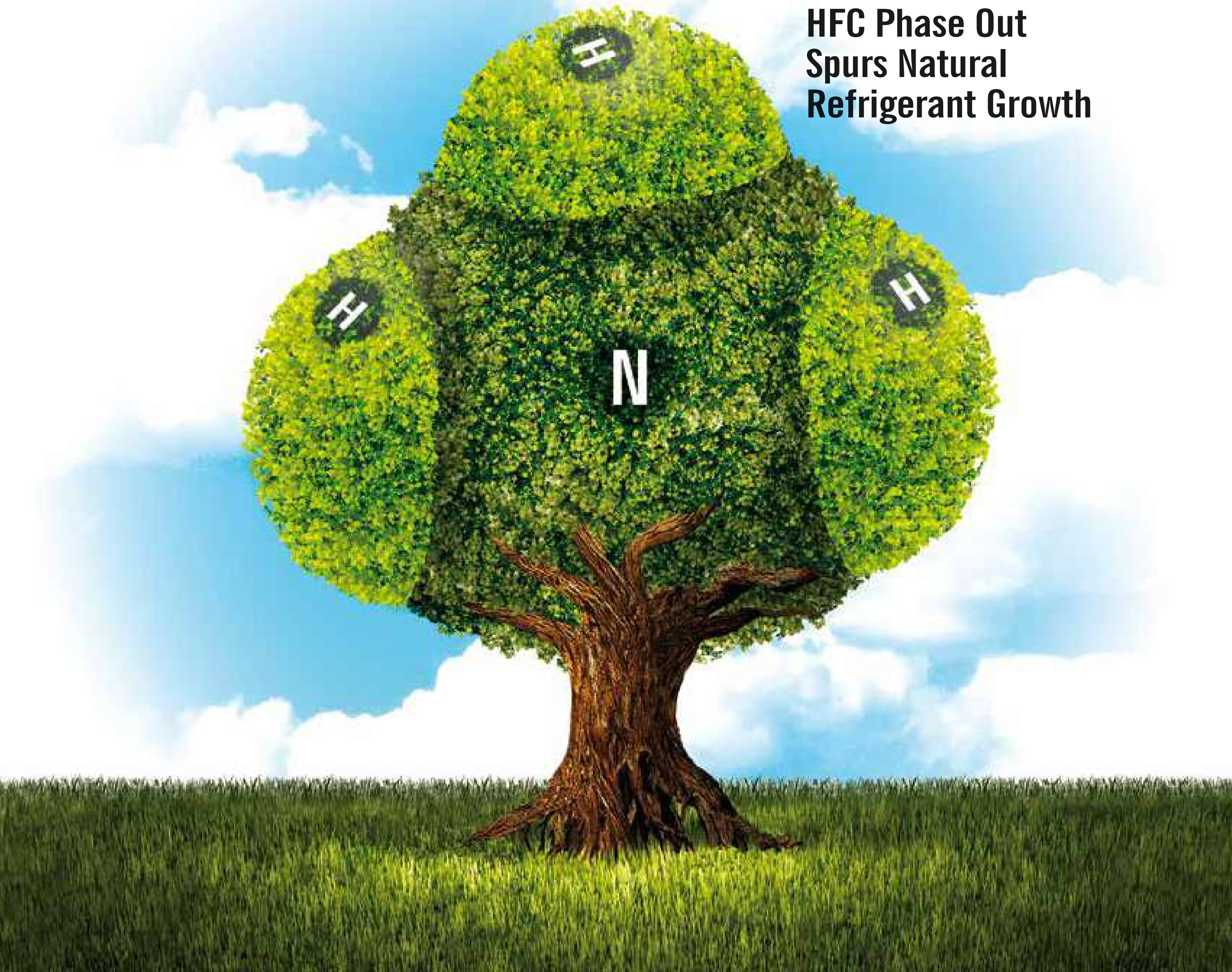
CONDENSER

The Green TRANSFORMATION

HFC Phase Out Spurs Natural Refrigerant Growth



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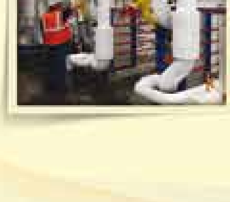

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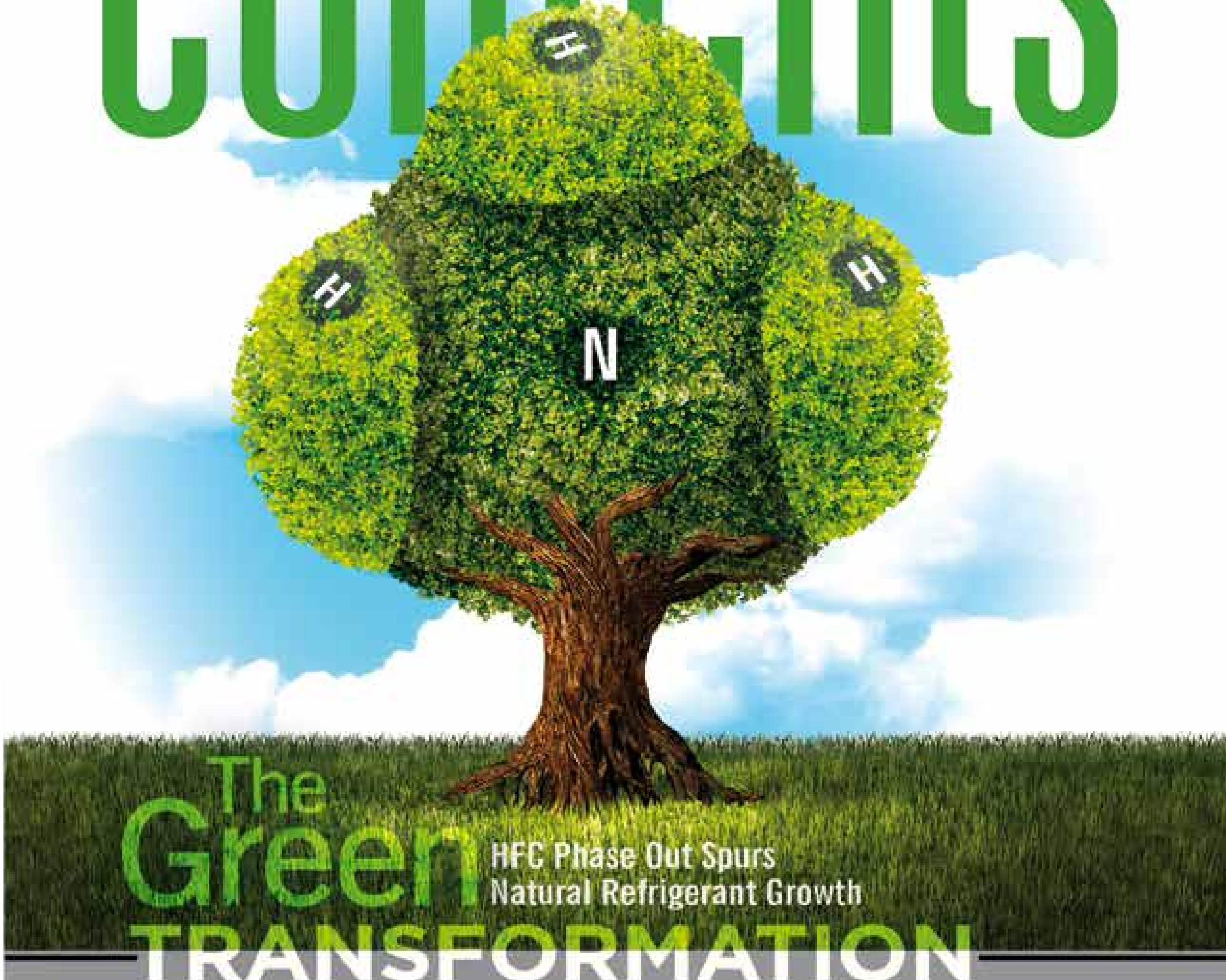

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chairman's MESSAGE

WALTER TEETER

The Annual Conference and Heavy Equipment Show was a great success this year, and now that the flurry of committee meetings, networking events and technical discussions has ended and we're all back at work, it's time to set some new goals and carry the momentum of our recent meeting into the rest of the year.

For the executive committee and your staff at headquarters, that means everyone is working hard to make sure our recent initiatives – from the new IIAR education program to the many new projects our committees have started – are continuing to develop and reach new milestones. As your new chairman, my first priority this year is to carry those initiatives forward and make sure the growth of the industry is well supported by our organization's leadership. I'd also like to pause here and add a big thank you to the staff for all of their efforts in creating a successful conference.

As Mark Stencel hands over the reins as IIAR Chairman, he's leaving big shoes for all of us to fill. Under his leadership, our committees have seen one of their most productive years yet. In the international arena, IIAR has established close ties with regions where ammonia refrigeration and the global cold chain is growing. We'll continue to foster communication with all our international partners while at the same time looking for new opportunities to grow as a presence on the global stage.

Key to that effort is our newly formed education program, the Academy of Natural Refrigerants, which – in addition to serving as a vital educational resource within our industry – is also laying the groundwork for powerful advocacy in the regulatory world.

As Mark mentioned in his last column, the expansion and codification of IIAR-2, our industry's Safe Design Standard for Closed-Circuit Ammonia Refrigeration Systems, has enabled its recognition by both EPA and OSHA as RAGAGEP (Recognized and Generally Accepted Good Engineering Practices) for our industrial refrigeration applications. Both agencies have welcomed IIAR's educational initiative and the development of our IIAR-2 Certificate Program, which enables consistent documented evidence of attainment of knowledge of the safe practices detailed in the Standard.

Meanwhile, through the efforts of the IIAR Government Relations Committee, as well as our industry colleagues with the IRC, GCCA and ASTI, we have supported and embarked on several educational initiatives for the field personnel of EPA and OSHA. This reflects our belief, and theirs, that knowledge of safe ammonia practices and ammonia system design benefits inspectors, emergency response providers, ammonia refrigeration practitioners and the communities we serve.

My priority this year will be to make sure that this program continues to make gains in delivering the best collective knowledge and resources our industry has to offer, both internally, to our members, and externally, to any regulators, support personnel or industries that touch industrial refrigeration.

I view these projects, and my tenure as your Chairman as a continuation of a new phase of IIAR leadership. As we begin this new membership year together, I hope you feel free to contribute with the new ideas and level of participation that has become the hallmark of this group.

Speaking of participation, no post-conference Chairman's column would be complete without giving recognition to the outpouring of support and record-breaking attendance of IIAR members.

This year was one of our best conferences yet. The packed technical paper sessions, workshops and technomercials were the usual highlights of our annual meeting, as well as the exhibit hall, which was crowded this year with a record-breaking number of exhibitors and sponsors, representing manufacturers, service providers and our industry's sister organizations.

While it's hard to turn our attention away from all the excitement of our most recent conference, it's time to start thinking about how to use that renewed enthusiasm in the coming year to strengthen IIAR's member presence and plan for our next event.

The 2018 IIAR Industrial Refrigeration Conference & Exhibition, will be held March 18 – 21 in Colorado Springs, Colorado.

If you have a Technical Paper or a workshop that you would like to present in Colorado, please contact Eric Smith at IIAR headquarters to submit your abstract as soon as possible. Technical Paper and session topics are the fabric of IIAR meetings, and will be selected quickly to allow presenters plenty of time to prepare their presentation.

I'm looking forward to accomplishing several goals as your Chairman this year. As members, your ongoing work and participation make all of our activities possible. Thank you for continuing to enrich our industry with your support.

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president's MESSAGE

BY DAVE RULE

Now that we've all returned from San Antonio, it's a new member year, and your staff is digging in to accomplish many of the new goals set out for 2017. First among them is planning the next successful conference. We're looking forward to returning to the Broadmoor in Colorado Springs, and I hope to see you all there. Now is the time to take advantage of IIAR's early membership renewal opportunities and get involved in the work of your committees.

IIAR's flagship education program will offer educational opportunities in four major curriculums with formal certificate training.

At headquarters, we're building several new services I'm excited to discuss here in my column this month. First, we'll implement our eagerly anticipated learning management system to support the newly created Academy of Natural Refrigerants. Other activities this year will include enhancing our website with Spanish-language features and adding a job board.

Meanwhile, we're moving ahead with the development of the Academy of Natural Refrigerants. We'll continue to carry forward the IIAR-2 classes and exams and we'll begin work on the Board of Directors-led initiative to create similar classes and exams for IIAR Standards 4, 5, and 8 as well as a PSM/ RMP introduction course.

As I mentioned at this year's business meeting, IIAR's advocacy and outreach efforts are growing like never before, and I'm pleased to report that recent meetings with OSHA, EPA and DHS have been a success, especially where our new education initiatives and broader effort to inform the regulatory community are concerned.

At the same time, our new regional program with ASTI and an emphasis on training for coordination with first responders, will broaden our educational efforts.

I'm going to focus on those efforts, under the Academy of Natural Refrigerants – in this month's column – because they are addressing a number of major needs of our end users and other sectors of our membership.

Looking forward, IIAR's flagship education program will offer educational opportunities in four major curriculums with formal certificate training.

First, educational material developed for the IIAR suite of standards will take our industry's knowledge, expertise and most valuable technical resource beyond the printed page and make it into a useable, practical reference for our industry and the rest of the global cold chain.

IIAR-2 is already available under this initiative, and conversion of standards 4, 5 and 8 into similar courses will begin in October of 2017. Other standards, such as 6 and 9 are also slated for development next year.

Next, education around the PSM and RMP general duty clause – in the form of an introductory course – is also planned to begin in October or November of 2017. These additional courses will create a template for PSM/ RMP auditors working in our industry.

Finally, the third and fourth future IIAR courses that are planned address design publications and basic engineering design for industrial and commercial refrigeration facilities

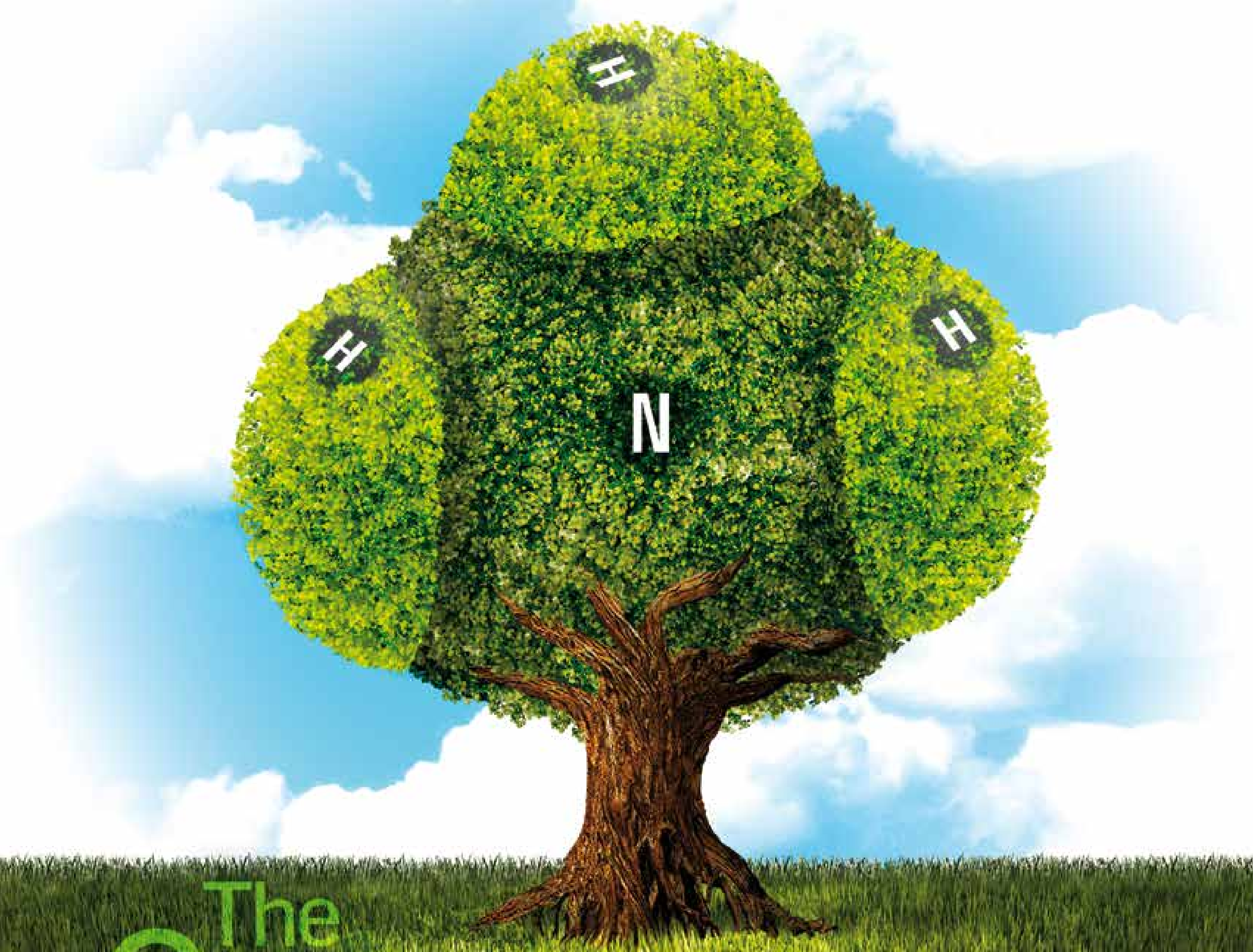
Our expansive educational program is being designed for the long term – to provide members with educational choices to meet their business and professional development requirements, and I hope you, as an IIAR member, will find value in it for years to come.

IIAR members may work on any one of these areas I just described, or pursue groups of curriculum to develop their industry knowledge and address the growing professional demands that are placed on them.

As this is happening, I hope you'll support the many committee programs and objectives that IIAR is always pursuing – from standards and code development to government relations outreach to safety compliance and educational programs.

There are so many exciting changes and programs going on in our industry that there is always a place for anyone to get involved and find their best way to contribute. Whatever that is, it begins with your participation in our organization as an IIAR member.

Now is the time to get engaged and become a member. If you haven't already, or it's time to renew your membership, I urge you to do that now and join all of us in making this group of professionals and our industry at large, the best it can be again in 2017.



The Green TRANSFORMATION

HFC Phase Out Spurs Natural Refrigerant Growth

Refrigeration manufacturers said they would make production plans and future product development decisions according to the expected worldwide HFC refrigerant phase down put forth by the Kigali Amendment. The amendment, last year's Montreal Protocol add-on, will specify phase-out deadlines for HFC's, adding those refrigerants with high global warming potential to the group of ozone depleting hydrochlorofluorocarbons that are already being outlawed under the international agreement.

Meanwhile, UN officials and manufacturers said they believed the amendment would encourage investment in clean, energy efficient technologies such as natural refrigerants and prompt countries with developing cold chains to skip traditionally used HFCs and HCFCs in favor of moving directly to low-global-warming replacements.

"This is about much more than the ozone layer and HFCs. It is a clear statement by all world leaders that the green transformation started in Paris is irreversible and unstoppable. It shows the best investments are those in clean, efficient technologies." said UN Environment chief Erik Solheim.

Mark Menzer, director of public affairs for manufacturer, Danfoss, said the Kigali Amendment will allow both manufacturers and users of equipment to make clear plans for what lies ahead. "Even though we don't have a full set of rules yet, we can look at the scheduled Kigali timeframe and pretty much figure out what refrigerants need to be phased out when and plan accordingly."

Lowell Randel, vice president, government affairs for the International Institute of Ammonia Refrigeration, said industry by and large has supported the Kigali agreement. He said that while some countries may have concerns about what the transition process will do to their economies, the agreement gives them additional time to meet the goals.

The Kigali Amendment establishes multiple legally binding schedules for participating countries to cap and phase down the use of HFCs in favor of alternatives which have lower global warming potential. The Kigali Amendment will enter into force on Jan. 1, 2019, if it is ratified by at least 20 parties to the Montreal Protocol or 90 days after ratification by the 20th party, whichever is later.

The Amendment contains several schedules: two schedules for two groups of developed countries and two schedules for two groups of developing countries.

"The developing countries have a much later freeze or cap followed by reductions," said Lambert Kuijpers, who served as a senior expert to the United Nations Environment Program's Technology and Economic Assessment Panel.

The phase-down for developed countries, including the United States and the European Union, starts in 2019, assuming the amendment has been ratified by then. Most developing countries, including China, several Asian and all South American and African countries will freeze at a certain level of HFC consumption in 2024 and begin reducing their use with a 10 percent reduction in 2029.

Other countries, including India, Iran, Iraq, Pakistan, Saudi Arabia and the Gulf Cooperation countries, will freeze their use in 2028 and make a 10 percent reduction in HFC consumption in 2032. More steps will follow.

The nearly 200 nations and parties to the Protocol, who met in Kigali, Rwanda, in October 2016 have been supportive of the action. In Europe, adoption is moving ahead, while in the U.S., political uncertainty may briefly stall action on the initiative, but is not expected to create too much of a delay.

In early February, the European Commission adopted a proposal for the EU to ratify the Kigali amendment. "Not only will this landmark

UN officials and manufacturers said they believed the amendment would encourage investment in clean, energy efficient technologies such as natural refrigerants and prompt countries with developing cold chains to skip traditionally used HFCs and HCFCs in favor of moving directly to low-global-warming replacements.

deal help us meet our climate objectives, but also it will provide new opportunities for European manufacturers of air conditioning and refrigerants to access the global market, creating additional jobs and attracting new investment," said Miguel Arias Cañete, Commissioner for Climate Action and Energy.

In the United States, uncertainty remains over how the Trump administration will respond and whether or not the U.S. will ratify the amendment.

IIAR's Randel said industry groups have sent letters to the administration and to members of Congress, asking them to move forward with the agreement. "The fact that industry has generally been supportive of Kigali may mean that this is a fight the Trump administration doesn't feel it needs to get into."

At a meeting in Las Vegas, Rajan Rajendran, vice president of System Innovation Center and sustainability for Emerson, said that although the United States' participation in the Kigali Amendment is uncertain with a Trump presidency, the path for Emerson and other global manufacturers is clear.

"As a global company we have to be able to meet the needs of our customers in Europe, Asia, Latin America and so on," Rajendran said. "And to the extent that all of them are going to sign on to the Kigali amendment and start acting upon some of these phase-outs, we are going to have to think about the products we offer to the rest of the world. So even if we don't necessarily go through some of [the Kigali amendments] step downs in the United States, it is still happening elsewhere."

Even if the U.S. were to fail to ratify the Kigali Amendment, Randel said he believes other countries will stay in. Randel said he believes that countries are planning to move forward with whatever their responsibilities would be under a ratified Kigali amendment. "When you look at European countries, most of them are where they need to be or getting close because of the EU policies. You have other countries that are not as far along as the EU but they will continue their efforts."

Kuijpers said the EU's 2014 F-gas regulation targets a 79 percent reduction by the year 2030, from the baseline year 2015.

He added that the Kigali Amendment does not present a more stringent phase-down schedule than the schedule the EU has already embraced. "Under the Montreal Protocol, there are 194 countries in total, of which 40 countries are developed countries. In the developed countries, a large amount have already worked on how to deal with curbing HFC consumption," Kuijpers said, adding that he believes it will be easy to have the 20 necessary parties ratify the Kigali Amendment. "People will ratify it because it will enable certain things to happen."

Menzer said the goal is to keep countries from going from HCFCs to HFCs and then to something else. "That is the path we went in this country. We're trying to get China and other developing countries to skip that HFC step entirely and go [directly] to low-global-warming replacements."

As one of the signatories to the Kigali amendment to the Montreal Protocol, India has committed to cutting down HFC use, and Honeywell has opened a new laboratory at the Honeywell India Technology Center in Gurgaon, Haryana, India. The company said the new laboratory will support local and regional partners in designing, incubating and testing new refrigerants and help them transition to low-global-warming-potential alternatives.

Menzer said the goal is to keep countries from going from HCFCs to HFCs and then to something else. "That is the path we went in this country. We're trying to get China and other developing countries to skip that HFC step entirely and go [directly] to low-global-warming replacements."

"Honeywell is committed to providing next-generation solutions that are available today as an option to support the Indian government on transitioning from HFCs to environmentally preferable materials," said Julien Soulet, managing director for Honeywell Fluorine Products in Europe, Middle East, Africa and India. "With the launch of this laboratory at HITC, we look forward to working hand-in-hand with our Indian partners to design near drop-in refrigeration solutions that help them meet their environmental commitments."

Kuijpers said that between 2017 and 2019, many parties are expected to ratify the Kigali Amendment. "How to achieve the phase-down is something that has not been decided in all detail and that cannot logically not be expected at this moment," he said, adding that he expects ammonia and carbon dioxide will help countries meet their HFC reduction goals.

The Kigali Amendment: How It Began, Where It's Going

The 2016 Kigali Amendment to the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer arose from the Montreal Protocol's success in phasing out ozone-depleting substances, including refrigerants.

While successful at phasing out hydrochlorofluorocarbons, which deplete Earth's ozone layer, the subsequent shift to hydrofluorocarbons created another problem: while HFCs are not ozone-depleting substances, they normally have a high or very high global-warming-potential. If emitted into the atmosphere, those HFCs contribute to global warming, said Lambert Kuijpers, who served as a senior expert to the United Nations Environment Program's Technology and Economic Assessment Panel.

To address that problem, at the closure of the Meeting of the Parties (MOP-28) in Kigali, Rwanda, many Montreal Protocol Parties adopted an amendment to bring HFCs under the Montreal Protocol and to phase them down following agreed-upon schedules.

To follow up on the Kigali agreement, countries will meet in Bangkok in July to discuss safety measures as well as codes and standards related to the flammability of natural refrigerants, said Mark Menzer, director of public affairs for Danfoss. "You have to get those safety measures into standards and then the designers and installers need to be familiar with those," Menzer said. "Global companies are making global products; you want to have some harmonization."

Kuijpers said the parties requested the Technology and Economic Assessment Panel (TEAP) report on safety standards, the process of their revisions, as well as the impact on the implementation of the Montreal Protocol, to take into account the requirements from the Kigali Amendment in the future. The task force is scheduled to meet in March in Amman, Jordan, to discuss a first draft of this report.

The Technical Options Committee Refrigeration under the Montreal Protocol, where most task force members come from, will also meet in Jordan to discuss first drafts for their 2018 Assessment Report, which will report on all relevant refrigeration, AC and heat pump sub-sectors and the refrigerant choices available for them.

The committee will take into consideration the Kigali Amendment's requirements to use lower GWP refrigerants to comply with future, Kigali-mandated control measures, Kuijpers said.

Where Rules Regulate Refrigeration, Uncertainty Surrounds Trump Administration

A new presidential administration always brings changes, but the election of President Trump has also brought a new level of uncertainty for the natural refrigeration industry.

"We're in a very new world with the Trump administration," said Lowell Randel, vice president, government and legal affairs for the International Institute of Ammonia Refrigeration. "We can get clues and signals but it is hard to know exactly what is going to happen at this early stage in the process."

Randel said the new administration has brought a "severe shift" in the regulatory climate. For the last few years the emphasis was on creating and strengthening regulations. "Now we're in a climate of reforming the regulatory process and minimizing the burden. There is a shift in mindset," he said.

Randel said he expects to see fewer regulations. President Trump signed an executive order that would require two existing regulations be eliminated for every new regulation, he explained. "He is also proposing spending limits for regulations for each agency. We know that it will be much more difficult for the Environmental Protection Agency or Occupational Safety and Health Administration to initiate and finalize a regulation under these policies."

OSHA was starting to revise Process Safety Management, but Randel believes it is unlikely that there will be much action to advance a new PSM rule under this administration, which could benefit the natural refrigerant industry. "We feel like there is not a need to add additional burdens to facilities under the PSM regulation and that the PSM program does not need to be amended at this time," Randel said. "From our position we would be pleased not to see additional restrictions on PSM-covered facilities."

The Risk Management Rule was finalized by the Obama administration but wasn't slated to take effect until

March 14, 2017. "For rules in that situation, the Trump administration has placed a delay on the effective date," Randel said, adding that there could be further delays of the effective date as the new policy decision makers in EPA and other agencies look at the late-term regulations finalized by the Obama administration.

Liz Whiteley, former executive director of the North American Sustainable Refrigeration Council, said reversing or vacating parts of regulations is a cumbersome and complicated process. "For the most part, refrigerant regulations have the support of industry, albeit there are some specific decisions that are more contentious," Whiteley said. She added that she doesn't think going after Significant New Alternatives Policy [SNAP] program delisting rules, the recent section 608 rule or the rules regarding federal procurement are really worth the fight for this administration.

Mark Menzer, director of public affairs for Danfoss, based in Baltimore, Maryland, said he expects to see some reorganization and budget changes, but expects the existing Significant New Alternatives Policy Program rules that have already been issued to remain in effect. "Recent rules have been pulled back to be re-evaluated, but none of the SNAP rules fall into that category," he said, adding that the EPA uses SNAP rules to enforce the HFC phase out. "Industry will talk to EPA about continuing that."

Menzer said SNAP has helped equipment manufacturers and end users make long-term plans, providing a degree of certainty.

Whiteley said natural refrigerants are subject to fewer EPA regulations. "For example, the section 608 rules, which now apply to HFCs, do not apply to CO_2 or propane. And natural refrigerants will never be subject to a phasedown or SNAP delisting. So, in some ways natural refrigerants are the 'anti-regulation' choice," she said.

BUSINESSES LIKELY TO MOVE FORWARD

Whiteley said regulations are perhaps the most meaningful driver of change especially in end-uses such as retail food refrigeration. "We haven't gone from CFCs, to HCFCs, to high-GWP HFCs to now mid-GWP HFCs just for kicks. We've made those transitions due to our obligations set forth in the

Montreal Protocol and the Clean Air Act," she said.

While end-users are influenced by regulations or the expectation of future regulations, they are also driven by a sense that moving to non-fluorinated refrigerants is the right thing to do. "How much of that decision is driven by the desire to reach the end solution and minimize regulatory burden and how much is driven by a desire to combat climate change, I don't know. It probably varies from business to business," she said, adding that both are very valid reasons for adopting natural refrigeration technologies.

Menzer said he thinks major food retail and cold storage operations will continue to phase out HFCs even if they don't feel like they're being enforced. "I think they show corporate responsibility and I think they will continue to do so," he said. "The pendulum swings both ways and I think it is pretty clear that the world is moving in this direction and things can change in four years. Companies should keep that in mind as well."

Randel said that if companies have already decided to move from HFCs to a natural refrigerant, he doesn't see the uncertainty of the next four years changing their long-term vision. "In the short term we might see a slowing of HFC restrictions and we may not see them advance quite as quickly as we would have had Clinton won or if Obama were still in office, but I don't necessarily see that changing the momentum and the dynamics from HFCs to an alternative, which in many cases would be a natural refrigerant."

Tristam Coffin, director of sustainability and facilities at Whole Foods Market, said that although Whole Foods is mindful of regulation, government mandates are not the driving force behind the company's decision to adopt natural refrigerants. Instead it is driven first by its values, and being stewards of the environment ranks high on its agenda.

"We of course keep a close eye on regulations and would prefer to be far enough out ahead of any given regulations so that we never feel like we are playing catch-up and because we strive to be innovators," Coffin said, He added that administrations come and go, and in order to be successful in business, companies have to be cognizant of the short term and conscious of the long game. "In other words, have a vision and make sure everything you do is in the name of executing on that vision, even if the vision evolves, as all do."

Administrations come and go, and in order to be successful in business, companies have to be cognizant of the short term and conscious of the long game. "In other words, have a vision and make sure everything you do is in the name of executing on that vision, even if the vision evolves, as all do."

Tristam Coffin, director of sustainability and facilities at Whole Foods Market

Because part of Whole Foods' vision is to be a conscious organization, the company plans to implement the best and most sustainable systems and programs, such as natural refrigerants, as they become available, assuming they make good business sense, Coffin said. "And natural refrigerants make good business sense," he said.

THE TRUMP ADMINISTRATION AND THE KIGALI AMENDMENT

Not only has the Trump administration created uncertainty about regulation and how business will approach natural refrigerants, it has also created uncertainty over the Paris Climate Agreement and Kigali amendment. "Trump has signaled he would like to pull the United States out of the Paris Climate Agreement. His secretary of State has stated a little bit of a different position saying he thinks it's better if we are at the table," Randel said.

Whiteley said ultimately it will be up to the State Department, which is now headed by Rex Tillerson, to bring the Kigali amendment to Congress for ratification. "In his confirmation hearing, Tillerson said the HFC amendment requires 'review and study.' Not exactly an enthusiastic endorsement. However, I believe there is enough industry support behind the HFC phasedown that the U.S. will ultimately ratify the Kigali Amendment to the Montreal Protocol," Whiteley said, adding that it may take longer than it should or longer than it would under a Democratic administration.

Menzer said the Montreal Protocol and the Kigali amendment make the SNAP program even more important. "If we ratify the Kigali amendment, we need a way of enforcing it. We think the SNAP program is a good way of doing it," he said.

CONTINUED NATURAL REFRIGERANT GROWTH IN CALIFORNIA

Despite federal uncertainty, those within the industry said they expect California to continue its path towards phase outs. "The California legislature has set very aggressive greenhouse gas emission reduction targets, and agencies like the California Air Resources Board are fully committed to enacting regulations that ensure California will meet those targets," Whiteley said.

The high level of uncertainty about the new presidential administration will likely reaffirm California's commitment to combating climate change and following through with its emissions reductions goals, Whiteley said. "As California stays the course and shows that we can reduce emissions and still maintain a thriving economy, I think it will set a really great example for the rest of the country. And perhaps that will help the United States maintain credibility on the global climate stage as well," she said.

Who's Ready?

BY KEM RUSSELL

The majority of ammonia refrigeration systems are well built, well maintained, and operated by people who know what they're doing. IIAR has several Standards established to help in design, construction, maintenance and inspection of ammonia refrigeration systems and all of these factors usually result in no more than incidental releases from systems. Although rare, a system can have a potentially large release, or an actually significant event.

Because larger releases are uncommon it puts a burden on us, each facility and company, to be prepared.

The machine room was quickly filling with ammonia vapor. Not having any personal protective equipment that might have (falsely) let them approach the release, they used the control system to shut down all compressors, and quickly left. The facility had no response capabilities, and realized they needed help fast.

In the event I'm about to describe, no one was injured, either in the facility or in the surrounding community, but it was a BIG wake-up call to not only the facility, but to many groups and individuals in the community.

The incident happened around 7 am on a cold morning. Light wind, totally overcast sky, and temperature in the low 20's. I was on my way to meet with the refrigeration manager at a large cold storage facility when I got an alert on my phone from the Office of Emergency Management. When I got to the cold storage facility, the refrigeration manager wasn't there to meet me, which was unusual. I called his cell phone, and he answered saying that he had gone to pick up his grandmother and would be back shortly. I didn't know at the time that his grandmother – along with several hundred other people in the small community – were in the process of being evacuated because of an ammonia release.

At the release site, the refrigeration operators had been in the control room, which was located in the machine room, when they heard a loud hissing noise. Looking into the machine room they saw next to one of the screw compressors a large white plume of ammonia shooting toward the ceiling. The machine room was quickly filling with ammonia vapor. Not having any personal protective equipment that might have (falsely) let them approach the release, they used the control system to shut down all compressors, and quickly left.

The facility had no response capabilities, and realized they needed help fast. 911 was called, and since it was early, many people had not yet left for work so the local Fire Department, made entirely of volunteers, quickly responded. (Something to think about, who will be responding to help you?). Since the facility that was in the middle of the release was right down the street from the Fire Department, the Fire Department didn't have to go anywhere. The Fire Chief realized he also needed additional help because none of his fireman were trained to respond to an ammonia release.

Appropriate calls were quickly made by the facility experiencing the release, as well as the Fire Chief. And as other emergency agencies arrived, Unified Command was quickly established and it was determined that an evacuation of the area surrounding the facility was necessary since it could take close to an hour before ammonia hazmat-capable responders arrived.

Now, here are some lessons learned in just the first few minutes of this event. Recall the outdoor conditions: cold temperatures, light wind, low cloud cover. The ammonia vapor leaving the machine room did not immediately rise and disperse in the atmosphere, but slowly began spreading out downwind of the release point. Ammonia doesn't always go up and away. Ambient conditions make a difference.

Remember too, ammonia vapor is lighter than air, and will move fairly rapidly. In this particular case the ammonia could be smelled just outside of the Fire Department within a short time. With the ammonia spreading, it was quickly determined that the small community business center, as well as the surrounding homes for more than a mile around the release should be evacuated. Another lesson here is, how do you quickly notify all of the surrounding businesses and homes of an ammonia release?

In this case the Office of Emergency Management and the county had in place a system to call all phones. Land lines in certain districts, as well as cell phones were called. Two challenges came to light. One, the computerized message could only be 90 characters long, so careful thought had to go into the messages, which left many in the public wondering exactly what was happening. Two, the cell phone coverage area is 360 degrees around cell towers, so many people were notified that were not within the incident area, which also caused some confusion.

People in the area were instructed to go to one of the local schools well outside of the release area. Now let's go back to the refrigeration manager I was going to meet. He realized his grandmother was in the affected area. He was concerned and tried to call his grandmother, but couldn't get a hold of her so he decide to go to her house.

Here is another lesson learned. Depending on the area of an emergency, and how large that emergency is, there may not, at least initially, be enough emergency personnel to respond. In this case there wasn't. So, even though hundreds of people were self-evacuating from the area and the area was supposed to be closed to entry, there were many roads into the area that could not be manned. People outside the area were very concerned about their family members inside the affected area. Several of those people drove around the unmanned road blocks. When the refrigeration manager reached his grandmother's house, she wasn't there. Where was she?

Unbeknownst to the refrigeration manager, one of his grandmother's neighbors had taken her to the school. Here another lesson was learned. One of the emergency messages sent out was that the school was in "lock-down". Now if you had one of your family members in a school that said it was in "lock-down", what comes to mind? One of the first thoughts might be "active shooter". Many people had that very thought and were very interested in getting their family member(s) out of there. (If you don't know, when a school is in "lock-down," no one gets in or out.) The emergency message might have caused much less concern if it had stated that the school is a "shelter-in-place" location. A few well-chosen words can make a big difference.

Even with some confusion as the incident unfolded, no one in the business area or surrounding homes was injured or physically affected by the release. The emotional aftermath, at least for a short period following the incident, was another story. The school did an outstanding job accommodating the surrounding community in this emergency even though it really wasn't a "lock-down," which the school often practiced. The school also knew and had practiced the redirecting of students coming into the area from other schools. Smart.

Let's look at the incident from the facility point of view. The refrigeration operators and many others that worked at the facility safely evacuated or sheltered-in-place. The facility had not really spent much effort in training employees about evacuation or shelter-in-place, which they are now correcting.

The facility also learned that the machine room ventilation system did not function properly, and neither did the machine ammonia detector. There was also no emergency shutdown located outside of the machine room, nor any ventilation system control. There were no drawings of the refrigeration system that could have helped in narrowing down the release point. The facility did learn they were prepared to make the required notifications by calling 911, NRC, State, and LEPC. In that regard the attendance of some of the company personnel at a past LEPC meeting where plastic cards with emergency contact information were handed out proved very beneficial.

Now let's look briefly at what was learned from the interaction of the facility with emergency responders. Due to the fact that the refrigeration operators (wisely) quickly left the machine room, they could not help much as the emergency responders began deciding what to do. The power company was called to shut off power, but the event was over before they could assemble their team at the facility. Many ammonia events are like that. They happen quickly, and everyone needs to respond in an appropriate and timely manner. In this case having everyone remain at a safe distance was a good decision.

About 1.5 hours or so into the release, it could be clearly seen that the release rate had greatly reduced, and the white vapor leaving the machine room was almost nonexistent. Since the refrigeration operators could not point to what was going on in the machine room, the hazmat team had suited up, Level-A, and with ammonia detector in hand were preparing to enter the machine room to close the king valve.

People can argue about whether to close the king valve or not. An understanding of the possible effects of this action should come from the facility personnel who should have sufficient knowledge of their system, as well as other information that can help the emergency responders make a reasonable plan. The best, not just good, not just better, but the best outcome occurs when facility and emergency responders work together.

In this case closing the king valve would have had no effect on the amount of ammonia release. In this incident the release was coming from a high pressure liquid line that was dedicated for liquid injection oil cooling of the screw compressors. This was a separate liquid supply line coming from the high pressure receiver. The release was stopped when a valve in the high pressure liquid injection supply line was closed just upstream of the valve assembly that had failed.

We can learn a lot from past incidents. This incident actually went pretty well. However, the one big lesson that needs further learning is that facilities and emergency responders must work together. They must communicate and practice often enough to be prepared for an emergency. They must develop a working relationship so that when help is needed all parties can cooperate and work together to have a good outcome for all.

The best, not just good, not just better, but the best outcome occurs when facility and emergency responders work together.

news

MARK STENCEL
ARF FOUNDATION CHAIRMAN,
AMMONIA REFRIGERATION FOUNDATION

Message from the Foundation Chairman

"If your actions inspire others to dream more, learn more, do more and become more, you are a leader"
–John Quincy Adams

The son of John Adams, our more widely renowned second President, John Quincy Adams, and our nation's sixth President, was an incredibly accomplished statesman and visionary. And he set a great example of devotion to a calling that many of IIAR's past Chairs have followed. It's an example of leadership that all can aspire to, and one that I hope to emulate as well.

Having lost a re-election campaign, and motivated by love of country, John Quincy Adams became the only American president to have followed his presidency with a term in Congress.

12,000 volume library, JQ Adams pre-Google knowledge source

That extraordinary service was distinguished by many activities, including, among other accomplishments, his outspoken advocacy against slavery. Most notably, he defended the escaped slaves of the slave ship Amistad before the U.S. Supreme Court.

In such demonstration of service, our former IIAR Chairs have displayed similar passion for their industry and their work. I have witnessed the ongoing devotion to our industry of many of our former Chairs through their committee work and committee leadership. Truly, the world of natural refrigeration can be a lifetime commitment offering a lifetime of learning and growth.

The progression of Chairs, in the design of IIAR's Executive Committee, now bestows responsibility for ARF Chairmanship on the Immediate Past Chair of the IIAR. That important role is a privilege and also a signal that the conclusion of one's chairmanship is not nearly the end of one's engagement with our industry.

Contributing to the ARF mission by helping build a strong foundation for our future and adding talent and knowledge to the industrial refrigeration community we serve is viewed as a welcome responsibility for all of us.

I take on that responsibility to serve as ARF Chair with great enthusiasm for building upon the tremendous efforts that have preceded my tenure. And I very much look forward to continuing to serve alongside of you.

Our Foundation has, in the last year, added a dynamic and dedicated new leader, Executive Director, Lois O'Connor. We have expanded our scholarship activities, as remarkably demonstrated in the character of the recent recipients attending our Conference in San Antonio. And we have supported active, important and ongoing research projects. Finally, we remain blessed with the engagement and contributions of our board and our trustees.

Most recently, we have collaborated with our partners at RETA and the Department of Defense to establish a streamlined pathway to serve our industry for our nation's veterans. Building a bridge between the service performed by our distinguished veterans and a civilian career in industrial refrigeration is one of the most rewarding challenges we face.

Tom Leighty, immediate past ARF Chair, through his continued leadership in our organization, has laid a path for ARF of ever more relevant contributions to our industry and a financial solidity that I am inspired to continue.

I thank you all for your leadership as exemplified by the growth of the natural refrigeration industry. I welcome and encourage your efforts, personal and financial, to support our Industry's Foundation.

Let's work together to ensure that the ARF continues to serve the needs of our industry's future.

ARF and RETA Announce Joint Scholarship Fund

The Ammonia Refrigeration Foundation (ARF) and Refrigerating Engineers and Technicians Association (RETA) recently announced that they would partner to create a scholarship fund to benefit military veterans, National Guard and reservists who wish to study in RETA certified refrigeration technicians training programs across the country.

In keeping with its mission to promote the development of industry talent through scholarships, academic alliances and outreach, the fund will help to expand the Foundation's scope and growth in new and exciting directions. "We want to encourage and support all aspects of industry talent, which is what led us to support our sister organization (RETA), which is the credentialing body for those working in the field as technicians," said Lois O'Connor, the Foundation's executive director.

"As a foundation, we can and will provide the conduit between our collective IIAR and RETA membership, along with multiple government agencies and local chambers of commerce to encourage our transitioning military, our National Guard and reservists to consider the refrigeration industry as a career," O'Connor said.

Jim Barron, RETA executive director, echoed his support for the partnership. "This is in keeping with RETA's mission statement of developing operators and professional engineers," he said. "We have veterans coming out of the service that need a job or a skill, or who want to continue on with the things they have already learned. This is right up their alley. For us to be able to do something of this nature where we can train these veterans and keep our industry moving forward is a positive thing."

Donations can be designated specifically to the new fund, which will be set up online at the Foundation's website, and by all the traditional ways of giving to the Foundation. All money raised will be used for scholarships in the natural refrigeration industry for training at trade and technical schools that are using the RETA certification curriculum and approved by the RETA scholarship committee.

"We want to reach out to our veterans because, first of all, it's the right thing to do," said O'Connor. "Nobody was really sure how to do it, and this seems like a valid method and time to take action. Our industry has numerous members who are veterans. To reach out to this sector gives us an immediate and logical progression toward developing industry talent."

Barron said that attracting young talent to the refrigeration industry is a tremendous challenge. "It's not just refrigeration, but all the trade industries that are hurting for young people coming into the field. We need to target those people who are coming out of the service or college and make opportunities available to them," he said.

O'Connor previously worked with the military and the Department of Defense in her role as senior director of advancement, programs and outreach for the Vietnam Veterans Memorial Fund and as director of advancement for the Air Force Association and the Air Force Memorial. In December, the Foundation joined with the Global Cold Chain Alliance to sign a statement of support for the DOD's "Employer Support for Guards and Reserves" program. "That means as an industry we are supporting the hiring of our guard and reserves," she said.

The partnership signals a new path for the Foundation and RETA, as both organizations work together to entice talented people toward a career in the ammonia refrigeration industry. Currently, RETA does not have a 501/c/3 Foundation, so this partnership provides the opportunity for both IIAR and RETA to solidify their existing strong working relationship, IIAR said.

"RETA may not have a foundation, but it has the educational materials and programs in place to obtain the certifications and credentials necessary to work in the ammonia refrigeration industry," O'Connor said. Added Barron, "This is just another way that shows how we can work together for the betterment of our industry. I think it's important for us to do that every chance we get so that we can make our industry the best it can be." The Foundation will act as trustee and holder of the fund, and it will work on behalf of RETA on fundraising. Meanwhile, an advisory committee created by RETA will identify and select scholarship recipients.

"This is part of our new mission to develop individual talent and to build a bridge between two organizations that might be distinct and different, but that also have similar goals and purpose," O'Connor said. "This is an exciting new venture. It is an opportunity as a foundation to provide access for developing talent and maximizing the skill sets and opportunities for our men and women in the military."

Although a date has not been determined for awarding the initial scholarships, the goal is for a September roll-out. Those interested in more information on the scholarship fund can visit the Foundation's website or contact O'Connor at Lois_Oconnor@nh3foundation.org.

"This is a great opportunity for many people," Barron said. "It's not just for those in the industry but for the people who want to enter the industry. I'd like to thank the Foundation and IIAR for coming to RETA with this high visibility opportunity."

Thank you to the Sponsors of the Second Annual William E. Kahlert Golf Tournament!

- Thanks to all sponsors and attendees of the recent annual golf tournament. The event was a great success with over $80k raised for the Foundation and all sponsorship opportunities sold out weeks in advance.
- Lois O'Connor, The Ammonia Refrigeration Foundation Executive Director represented the industry at the Pentagon in December and signed a letter of support for the ESGR program (Employer Support of Guard and Reserve), part of the Department of Defense and the US Chamber. The letter addressed hiring veterans into specific industry jobs.
- The Ammonia Refrigeration Foundation thanks everyone who participated in the matching gift program for November and December, especially Innovative Refrigeration for the matching gift and the Kahlert Foundation. Special thanks to Hank Bonar for his most generous gift of $10,000. The Foundation raised well over $49,000.

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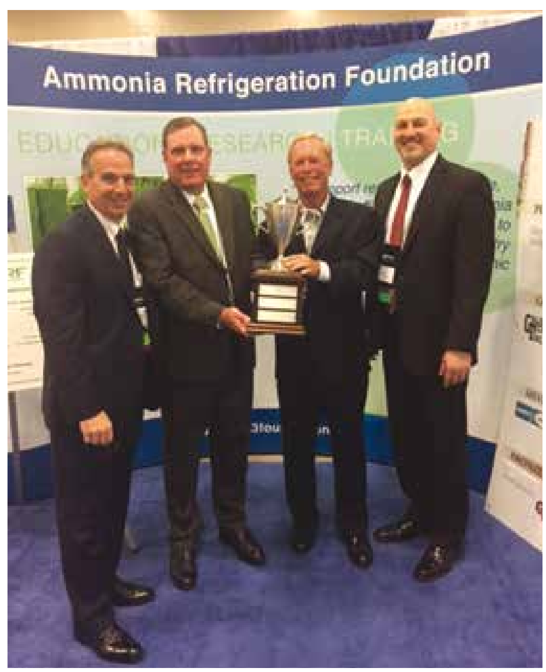
Ammonia Refrigeration Foundation Executive Director Lois O'Connor signs a letter of support for a U.S. Department of Defense veteran hiring program on behalf of the industrial refrigeration industry.



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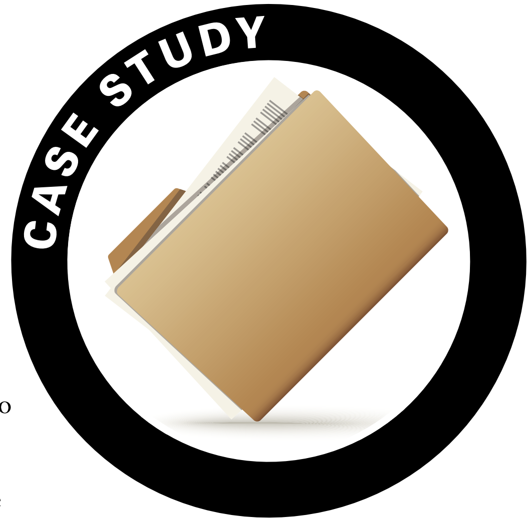

Stick to the Design and Keep Coils Clean for Maximum Efficiency

Understanding and sticking to the design characteristics of a cold room refrigeration system, along with keeping evaporator coils clean, is the key to maintaining a system's maximum efficiency level. Deviating from a system's specified operating design, or failing to check the cleanliness and condition of coils, will waste energy and reduce the desired results.

A case in point may be seen in a problem with a supermarket distribution system in Ohio that I was asked to check several years ago.

The produce room was designed to operate at 35°F, yet the eight evaporator units operating on a typical ammonia liquid recirculation fed system operating at 20°F suction could not maintain the desired room temperature.

The first thing I checked was the cleanliness and condition of the finned coils that were spaced 6 or 8 fins per inch. Using a flashlight, I could see they were so dirty and clogged with dirt and cardboard fibers, due to lack of proper cleaning and maintenance, that the flashlight beam could barely be seen through them.

A special crew was then dispatched to thoroughly clean each unit. The cleaning process consisted of pumping each unit out and enclosing it with Visqueen from the top of the unit to the floor, to protect all nearby boxed products from the over-spray and use of the power sprayer. Then each unit was power-sprayed with just enough pressure to clean the dirt off the entire depth of the coil without bending the fins, using mild soap without chemicals that would attack the galvanized surfaces, a good supply of warm water, carefully and thoroughly cleaning the coil of each unit and flushing its drain line. The coil was dried by running "fans only" for several hours.

But even after all this was done and the units started up, desired temperature could still not be attained and was about 5 to 8 degrees too high. So next I checked the inlet air and outlet air temperatures of two or three units with a two-point electronic thermometer. The temperature reduction was not even close to what it should have

IIAR Guideline to Address Low-Charge Ammonia Systems

IIAR said it is developing an informative guideline document designed to help facilities with low-charge ammonia refrigeration systems simplify compliance with the OSHA and EPA General Duty Clause requirements from the Occupational Safety and Health Administration and Environmental Protection Administration.

The proposed guideline, currently titled Compliance Guidelines for Low-Charge Systems, will be independent of IIAR's existing Ammonia Refrigeration Management Program, which is being updated.

"This is not intended to replace the existing ARM program. It would stand alone. The intention is that this will be applicable to those kind of systems that have a total charge less than a typical industrial ammonia refrigeration system," said Eric Smith, vice president and technical director for IIAR. It's been called "ARM light," Smith added.

The main ARM program was written for anything less than 10,000 pounds, which satisfies the EPA and OSHA General Duty Clause that applies to any amount of ammonia refrigerant less than 10,000 lbs. The ARM program was last published in 2005 and is being reviewed for consistency and accuracy and being updated where necessary. Low-charge, package systems weren't specifically addressed in the 2005 edition.

"Low-charge is a term that gets thrown around frequently, and it is a relative term," Smith said. "What many people are referring to these days as low-charge systems are minimally charged, package-type systems where most of the refrigeration equipment will fit on a single skid-mounted assembly."

Such package systems could be mounted on the roof or on the ground or in other locations, but the idea is that most of the components are factory assembled rather than field assembled, Smith said.

Smith said he believes that the development of this guideline will help to promote the use of ammonia in applications that have traditionally used HCFCs or HFCs, which are being phased out. An easier, yet safe way to be compliant will help to remove the barriers of resistance for owners of facilities with moderate refrigeration needs.

Jim Marrella, president at J. C. Marrella & Associates, said the use of low-charge, package systems is on the rise. "A lot of people are looking at that higher efficiency. That is probably the reason they're going there since the technology is there."

The guideline document, which Marrella is drafting, will most likely be utilized by commercial and small industrial occupancies. "The goals of the new program are to make sure everyone is in compliance and to head off any trouble when it comes to hazardous releases," he said.

The document will include a definition of low-charge ammonia refrigeration systems, the compliance elements that should be incorporated, implementation methodologies that could be utilized, documentation management, program management, written program and example forms, and information on how the program satisfies the General Duty Clause requirements.

"The General Duty Clause has no specific threshold quantity. It is based on release. You have to make sure if you're going to follow the general duty clause that all of the boxes are checked because it is a minimum requirement," Marrella said.

The document will also provide a recommendation on what might be the range of ammonia mass that would be used to qualify a system as low charge. The recommendation will consider that the charge amount would be below any program levels for compliance other than the General Duty Clause that presently exists within the U.S., Smith said. It will also consider the impact of having multiple low-charge ammonia refrigeration systems at a common commercial or industrial occupancy and if threshold criteria would change as a result.

It is believed that commercial and industrial facilities with low-charge ammonia refrigeration systems would most often utilize qualified service contractors for their operation, maintenance or both. The final document will provide guidance for the owners, installing contractors, service contractors and package manufacturers.

The document will provide guidance for the service contractors to advise about necessary package and system files to be maintained at the site, the contractor's facility or both, and address operating instructions, on-going maintenance schedules, emergency plan requirements, and protective equipment and service training for personnel.

It will clarify what information, programs and procedures service contractors should provide to the owner of the facility and help facility owners with instruction on their responsibilities of system ownership. The owner is responsible for understanding, at least on a basic level, the information provided, including operations and maintenance documents, files that need to be maintained on site, an on-going maintenance program and an emergency plan.

Most of the guidance should be drafted by the spring, when it is slated to be reviewed by IIAR's Compliance Guidelines Committee. It will not be an ANSI standard, so it won't go through an ANSI standards process review.

The overall goal is to provide a document that will satisfy the General Duty Clause for low-charge ammonia refrigeration systems and how they are easily assembled, and Marrella said his goal is to help members comply with regulations. "The mom-and-pop operations don't have the money budgeted for compliance issues like the big companies do. But they have to stay in compliance. I want to make it as friendly as possible for the mom-and-pop operation – to operate safe systems and comply with the general duty clause," he said.

been; i.e. for a 35°F room and 23°F coil temperature (allowing 3°F loss due to pressure loss from coil to compressor suction), one would expect a 27°F to 29°F discharge air temperature. Temperature readings of the discharge air were only about 40% of what they should have been.

Upon further discussion with the operator we found that he had throttled all the hand expansion valves of all the units to only one-half turn open, due to an unnecessary and unjustified fear of over-feeding the units with liquid and perhaps causing high liquid levels and possible compressor slugging. I explained how the units are circuited and designed to operate with a surplus amount of liquid ammonia (4:1 overfeed rate) that assures all inside surfaces of all the tubes are thoroughly wetted with boiling liquid ammonia to produce a maximum inside-the-tube film coefficient that results in the maximum heat transfer.

Then, using the two-point electronic thermometer, we adjusted all the manual hand expansion valves to the number of "turns open" that produced the most cooling, recorded those settings with instructions to keep them set "as is." The result was that the operating pump's amperage increased because we were now circulating close to the design mass flow rate for a 4:1 overfeed amount of liquid, the accumulator's "normal level" remained the same, and "miraculously" the room temperature fell 6°F to 8°F.

More recently, a flip side of that situation was brought to my attention by some contractors who knew of jobs where well-meaning but uninformed operators and production managers are operating liquid recirculation systems with both normal and stand-by pumps running together and then fully opening the hand expansion valves at all system evaporators.

The thinking there, that "more is better," doesn't agree with the heat transfer reduction in the evaporators that occurs due to the liquid ammonia "brining" effect.

Note that the maximum cooling occurs at a certain hand expansion valve setting determined by a trained technician, taking inlet and outlet temperature measurements. If the expansion valve is closed or "pinched off" from the optimum setting, the coil receives less cold liquid ammonia than it is designed for and this results in less heat transfer, because some inside tube surfaces are not fully "wetted" with cold boiling refrigerant, but rather with cold ammonia vapor. The resulting "inside the tube" heat transfer film coefficient at those areas is much lower.

If the hand expansion valve is opened several turns more than the optimum or, worse yet, fully opened, the pump pressure drop is reduced and the flow increases. This produces a "brining" flow much like chilled water flowing through an air conditioning coil, where, due to the excess liquid, refrigerant boiling does not occur. Here again, the "inside the tube" heat transfer film coefficient is less and the capacity is reduced.

The important message here is twofold:

Note that recirculating systems built by experienced, qualified contractors and manufacturers have two pumps, both sized only for the flow required to feed all the connected evaporators for the selected over-feed rate, usually 4:1 or 3:1. One is meant to operate continuously and the other is for stand-by duty, for example, if the motor of the operating pump fails.

Also, the liquid piping is sized for the design flow only, not for twice that amount.

Once the optimum hand expansion-valve setting is established and properly recorded by an experienced mechanic or service technician, leave it alone and do not run the stand-by pump. All it does is waste energy and reduce the desired results.

IIAR Issues 2014 Call for Technical Papers

The International Institute for Ammonia Refrigeration issued its annual "call for papers," in preparation for the the 2018 IIAR Natural Refrigeration Conference & Expo in Colorado Springs, March 18 – 21.

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:

- **energy efficiency case studies;**
- **energy management for utility demand response;**
- **mechanical integrity – specific practices;**
- **comparison of secondary systems with direct systems in various applications;**
- **operator training;**
- **troubleshooting case studies;**
- **low charge and DX design;**
- **packaged system design and application or options to replace "freon" systems;**
- **OSHA citations and response;**
- **equipment design for improved efficiencies;**
- **charge reduction case studies;**
- **Comparison of Transcritical CO2 to ammonia cascade systems in warm climates.**

For a technical paper to be considered by IIAR, a paper proposal must be submitted and should include a 150 to 200 word abstract as well as a 50 to 75 word description of the practical applications of the paper's proposed contents. IIAR's proposal submission deadline for the 2018 conference is May 1, 2017.

Technical paper abstracts will be chosen for development by June 15, and authors will be asked to commit to a development timeframe that will begin with the submission of a first draft on September 1, and will undergo all peer reviews and subsequent edits by November 30.

Contact information such as name, address, phone and fax number should be submitted with each author's proposal.

Once a paper is chosen, IIAR offers each primary author a complimentary conference registration. Every year, the IIAR award for presentation excellence is presented to the author of the English and Spanish technical papers that have received the highest ratings. The primary author of each award winning paper receives a complementary registration for the following year's IIAR conference.

Papers should be submitted to the IIAR Technical Director, Eric Smith, at eric.smith@iiar.org.

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EPA Publishes Final Rule on Risk Management Program

iiar government RELATIONS

BY LOWELL RANDEL, IIAR GOVERNMENT RELATIONS DIRECTOR

The Environmental Protection Agency (EPA) completed it multi-year effort to revise the Risk Management Program (RMP) regulation with the publication of a Final Rule on Friday, January 13, 2017. The rulemaking was initiated as a part of President Obama's Executive Order on Improving Chemical Facility Safety and Security, which came in response to the fertilizer plant explosion in West, Texas in 2013. IIAR played an active role engaging with EPA on its proposed revisions to RMP and led an industry coalition expressing concerns with several of EPA's proposals along the way.

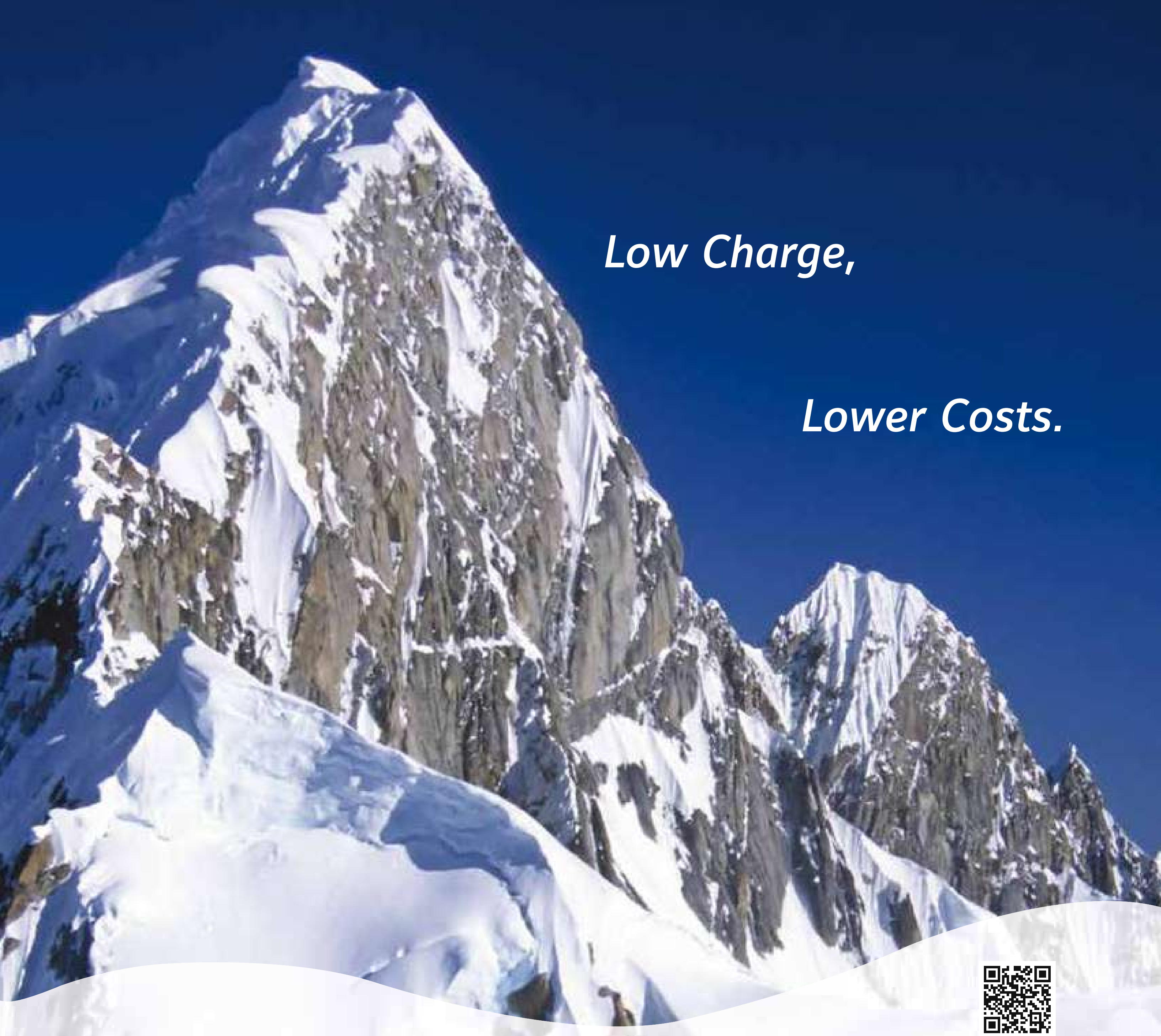
The Final Rule includes some improvements over the Proposed Rule, several of which IIAR suggested through various public comments, oral testimony and input through the small business advocacy rule process. While the Final Rule is improved, significant concerns remain with several provisions.

Below is a summary of the major provisions included in the Final Rule.

THIRD PARTY AUDITS

One of the proposed provisions that created the most concern from industry was the requirement for independent third party audits after a reportable accident. The changes to the Final Rule address some of the concerns raised by IIAR and its coalition partners. For example, the PE requirement has been eliminated and retirees will not qualify to lead third party audit teams. However, the fundamental nature of the new policy has not changed and IIAR continues to have concerns with the requirement to force independent third party audits and that third-party firms doing work outside auditing would be disqualified if they had conducted business with the company within two years of the audit in question.

PROPOSED RULE	FINAL RULE
Independent third party audit required within 12 months of a reportable accident, or when EPA determines non-compliance	Independent third party audit required within 12 months of a reportable accident, or when EPA determines there are conditions present that could lead to an accidental release
Requires an independent third party to conduct the audit	Requires an independent third party to lead the audit, but allows in-house and other affiliated persons to be a part of the audit team
Requires third party auditor to be a Professional Engineer (PE)	Removes the PE requirement
Thirds party auditors are barred from doing any other work with company, aside from audits, for period of 3 years before and 3 years after an audit	Reduces the time limit to 2 years before and 2 years after an audit
Barred retirees from conducting third party audits	Allows retirees to lead third party audits
Draft and final audits must be sent to EPA and retained for 5 years	Final audits must be retained for 5 years, but not sent to EPA
Auditor must certify the final audit report	Auditor must certify the final audit report
Owner/operator must prepare an audit findings response	Owner/operator must prepare an audit findings response



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INCIDENT INVESTIGATIONS AND ROOT CAUSE ANALYSIS

The incident investigations and root cause analysis provisions are largely unchanged. Most of the revisions deal with definitions, including important guidance on the term "near miss".

PROPOSED RULE	FINAL RULE
Requires root cause analysis report within 12 months of an incident or near miss	Requires root cause analysis report within 12 months of an incident or near miss
Proposed a new definition of "catastrophic release"	Adds that the report must include the consequences/impacts of the incident and emergency response actions taken
Defined "root cause" in a way that assumed all incidents are caused by management system failures	Does not revise definition of "catastrophic release" Removed language in the definition tying all incidents to management system failures
Does not define "near miss"	While not defining "near miss", EPA give guidance that a "near miss" is an event that: "could reasonably have resulted in a catastrophic release"

SAFER TECHNOLOGIES AND ALTERNATIVES ANALYSIS

The biggest change to the Safer Technologies and Alternatives Analysis provision in the Final Rule is the shift from evaluating the "feasibility" to the "practicability" of implementing identified inherently safer technologies. This is an improvement, as some identified technologies may be feasible to implement, but not be practical.

PROPOSED RULE	FINAL RULE
Facilities in 3 select industry codes (322 – paper manufacturing, 324 – petroleum and coal products manufacturing, and 325 – chemical manufacturing) are required to conduct a safer technology and alternatives analysis (STAA) as part of their PHA	Facilities in 3 select industry codes (322 – paper manufacturing, 324 – petroleum and coal products manufacturing, and 325 – chemical manufacturing) are required to conduct a safer technology and alternatives analysis (STAA) as part of their PHA
Analysis must evaluate the feasibility of any inherently safer technology (IST) identified	Analysis must evaluate the practicability of any inherently safer technology (IST) identified

LOCAL COORDINATION AND EMERGENCY RESPONSE

The Final Rule removes several burdens on regulated facilities and emphasizes the importance of coordination between LEPCs/local responders and facilities to work out the details of response exercises.

PROPOSED RULE	FINAL RULE
Required at least annual coordination with LEPCs and response organizations	Requires at least annual coordination with LEPCs and response organizations Final rule requires owners/operators to request an opportunity to meet, but does not require an actual meeting, if local authorities deem it is not required
Coordination must be documented	Coordination attempts must be documented
Mandated strict timelines for emergency response planning activities: • Annual notification exercise • Field exercise every 5 years • Tabletop exercise all years except those years of the field exercise	Allows for coordination with local responders to set schedule, but sets the following minimums: • Annual notification exercise • Tabletops at least every 3 years • Field exercises at least every 10 years
Review and update emergency response plan annually	Review and update the emergency response plan as appropriate based on changes at the facility or new information
Required facilities to evaluate local response capabilities	Removed evaluation requirement
Required a facility to become a "responding facility" when requested by LEPC or local responders	Removed provision

INFORMATION SHARING

The Information Sharing provisions are improved in the Final Rule by relying on coordination between facilities and LEPCs/local responders to determine information sharing needs. It also eliminates the requirement of public posting of chemical hazard information and making such information available upon request. The extension of the time period to 90 days for a public meeting after a reportable accident is also an improvement.

PROPOSED RULE	FINAL RULE
Required specific document sharing with LEPCs and responders upon request	Incorporates information sharing into the local co-ordination requirement. LEPCs and responders can request information through this process.
Required facility to provide chemical hazard information, emergency response program details, and LEPC contact information to the public through an easily accessible manner, such as a website. Information had to be updated annually.	Changes provision to require facilities to share information to the public upon request. Facilities will have 45 days to respond. Facility must alert public that this information is available upon request, and how to access the information.
Required public meetings within 30 days of a reportable accident.	Public meeting required within 90 days of reportable accident.

COMPLIANCE DATES

The Final Rule maintains the same compliance date schedule as the Proposed Rule. The effective date of the Final Rule is March 14, 2017. The table below shows the compliance dates for the various requirements.

FINAL RULE PROVISIONS AND CORRESPONDING COMPLIANCE DATES RULE PROVISION	COMPLIANCE DATE	INITIATED AFTER AN RMP REPORTABLE ACCIDENT?
Third-party audit	March 15, 2021 (4 years from effective date)	Yes
Root cause analysis	March 15, 2021 (4 years from effective date)	Yes (also required after near misses)
STAA	March 15, 2021 (4 years from effective date)	No
Emergency response coordination activities	March 14, 2018 (1 year from effective date)	No
Owner/operator determines that the facility is subject to the emergency response program requirements of § 68.95	Within three years of the determination	No
Emergency response exercises	March 14, 2018 (1 year from effective date)	No
Information sharing	March 14, 2018 (1 year from effective date)	Partially- public meeting within 90 days
Update RMP	March 14, 2022 (5 years from effective date)	No

POTENTIAL CHALLENGES TO THE FINAL RULE

While EPA did make some improvements to the Final Rule, significant concerns remain with several provisions. Because the rule was finalized late in the Obama Administration, there is a possibility for the Republican Congress to use the Congressional Review Act (CRA) to disapprove of the regulation. The CRA allows for the House and Senate to pass a resolution by a simple majority that would completely eliminate the Final Rule. IIAR recently joined a coalition letter urging Congress to use the CRA to stop the RMP Final Rule and efforts are underway to advance CRA legislation.

Congressman Markwayne Mullin (R-OK) has introduced House Joint Resolution 59, which would disapprove of the RMP Final Rule. Senator James Inhofe (R-OK) has introduced a similar resolution, Senate Joint Resolution 28, in the Senate. The resolution must be passed and signed into law within 60 legislative days of the Final Rule. Successful use of the CRA would also bar the EPA from proposing substantially similar changes to RMP in the future.

The CRA has only been used successfully once, to disapprove of an OSHA ergonomics rule at the beginning of the George W. Bush Administration. Because the Republicans control both chambers of Congress and the White House, the CRA becomes a viable option. However, Congress is looking at a large number of regulations finalized during the end of the Obama Administration as potential targets for the CRA, and it is unclear whether the RMP rule will make the final cut.

In addition to the CRA, an industry-led RMP Coalition, of which IIAR is a member, has submitted a Petition for Review to the EPA. The petition outlines industry's concerns with the Final Rule and requests EPA to delay implementation pending a further review of the regulation. On March 13th, EPA Administrator Scott Pruitt issued a 90 delay of the effective date and cited the Petition for Review in the order. The delay will give the new policy officials within the Trump Administration time to consider the concerns that have been raised regarding the Final Rule. It is also expected that industry will pursue legal action to challenge the Final Rule.

The CRA allows for the House and Senate to pass a resolution by a simple majority that would completely eliminate the Final Rule. IIAR recently joined a coalition letter urging Congress to use the CRA to stop the RMP Final Rule and efforts are underway to advance CRA legislation.

SUMMARY

The EPA's Final Rule to revise the Risk Management Program, while an improvement over the Proposed Rule, contains several troublesome provisions that will place additional burdens on IIAR members. Members are encouraged become more aware of the Final Rule's provisions and understand the impacts that it may have on their facilities. IIAR will continue to be actively involved with coalition partners to explore actions such as the CRA to mitigate the potential negative impacts on the industry and will keep members informed as the process moves forward.

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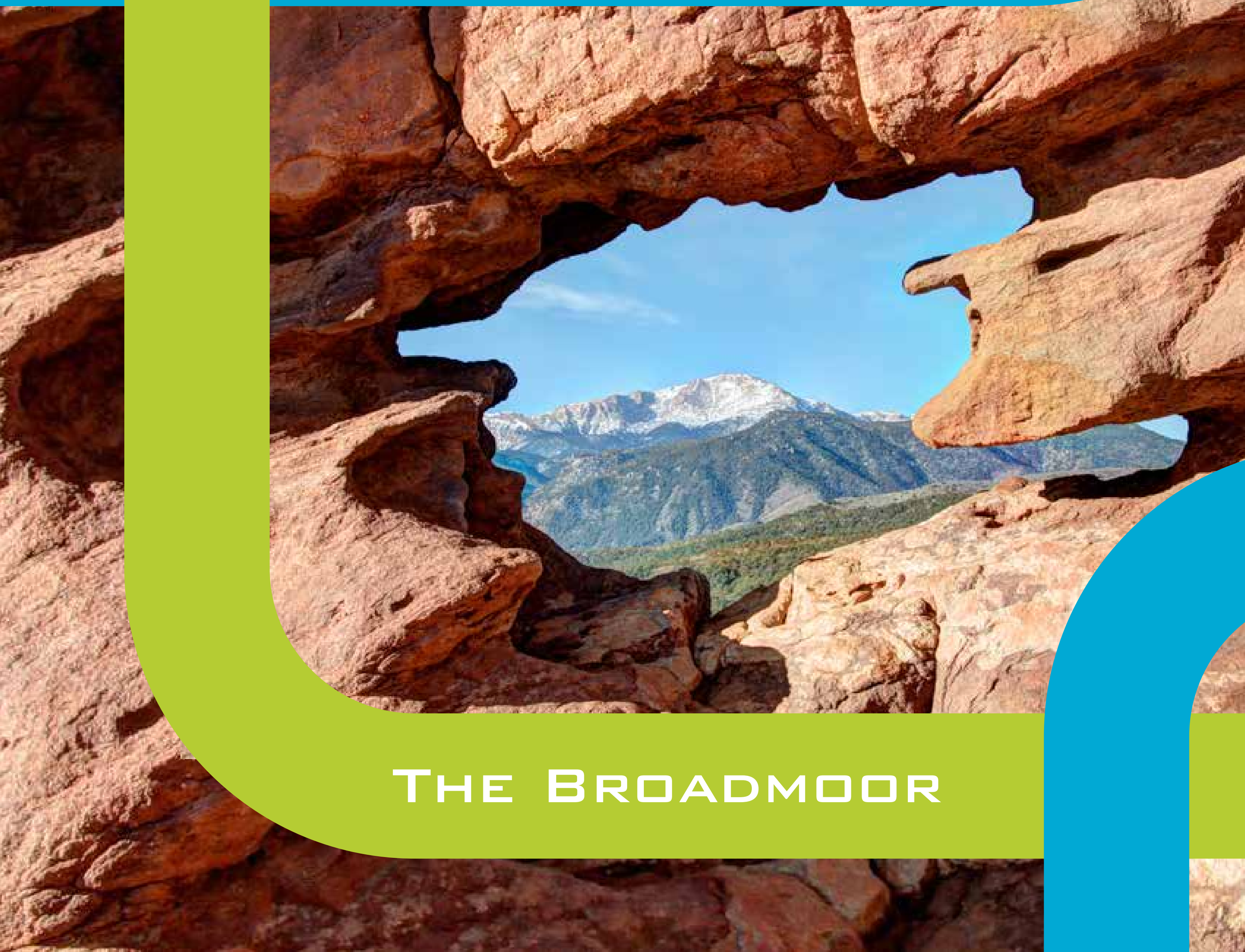

THE BROADMOOR

Compliance Doesn't Automatically Mean Safety

Your industrial ammonia refrigeration facility meets all the local, state and federal requirements regarding regulatory compliance, the Process Safety Management program or Risk Management program is up to date, the paperwork has been properly filed and you pass a government inspection.

Does this mean that your facility is safe?

Not necessarily, according to Peter Jordan, senior principal engineer at MBD Risk Management Services, Inc in Pennsylvania. "You can't rely solely on meeting regulatory compliance and think that the plant is safe," says Jordan, who serves as a consultant for facilities preparing for PSM audits. "Conversely, the plant can be safe and not meet all the regulatory requirements. That is the conundrum. Facility owners must realize that forgetting one of those aspects puts the facility at peril."

As an example, Jordan cites an inspection that the Occupational Safety and Health Administration did several years ago at a facility in Texas where the inspector called the facility's PSM program "one of the finest he'd ever seen." As he was leaving the facility, the plant experienced an ammonia release. "With that, the plant was suddenly hit with a number of citations," Jorden says. "So just because a PSM or RMP can withstand the scrutiny of a government audit does not by definition make the facility safe."

Finding the proper balance between ensuring a safe facility and one that meets regulatory requirements should be the goal of every industrial ammonia refrigeration facility. In order to successfully accomplish that objective, facilities must divide their time and resources properly so that each goal is reached.

"Many times a facility gears its PSM or RMP program to keep inspectors happy, which is important. But sometimes they forget that it's not all just about paperwork," Jordan says. "In order to keep the facility safe, you may need to upgrade equipment, spend more time in the field inspecting the equipment, gather and follow-up on input from operators and mechanics, and ensure that appropriate codes and standards are being followed. Don't fall into the trap of spending all your time on paperwork while neglecting to focus on what is important to operating and maintaining a safe plant."

Jordan says that when he conducts a compliance audit at a facility, he devotes equal time to reviewing paperwork, touring the facility, and interviewing the key employees. The typical recommendations from the audit include not only action items to improve PSM and RMP documentation, but also action items to upgrade facility equipment to comply with Recommended and Generally Accepted Good Engineering Practices. "It's not just about collecting records and documentation to meet regulations," he says. "A facility needs to pay attention to the quality of their program, their equipment and their personnel."

As an example, Jordan indicated that the goal of a training program should be to produce well-trained operators and mechanics. Having appropriate records which document that operators and mechanics have attended classroom training and passed written tests is important and might be sufficient to satisfy some auditors, but additional work is needed to be sure your personnel are truly qualified to safely operate and maintain the equipment.

"The best training programs I've seen are those facilities that provide equal emphasis on classroom training and on-the-job training," Jordan says.

The on-the-job training often involves pairing a young operator with an experienced "mentor" who can provide instruction on how to conduct rounds, operate and maintain equipment, and shut down the system in an emergency. These facilities have thorough records to document the on-the-job training, often in the form of checklists.

"I'm not sure a written test is always the best way to judge the competence of a refrigeration operator," Jordan says. "In many respects, I'd prefer that the operator demonstrates that he understood the training by actually carrying out each task under the watchful eye of an experienced operator. The trick is to document these demonstrations."

Another critical safety measure when looking at your PSM or RMP is the attention to detail given when filling out management of change documentation. "Don't just fill out a MOC form and check boxes," Jordan says. "Look deeper into the change and understand why the questions on the form are being asked. Let's say you made a change involving the installation of a new compressor in the engine room. Don't just check the box that says the ventilation is not affected. Installing a new compressor should force you to review the temperature control ventilation calculations. Going through these steps carefully will help make your plant safer."

Finally, don't forget to review the basic requirements of a PSM and RMP with facility owners and managers. By educating facility owners and managers, they will then be knowledgeable enough to ask the right questions regarding the PSM or RMP and how it relates to the facility, Jordan explains.

"That training is very helpful so that a facility manager understands the risks and the issues that are involved," he says. "Paying attention to these details makes the facility safer."

Eight Things to Know About Your 5-Year Mechanical Integrity Inspection

RECOMMENDED PRACTICES

Mechanical integrity inspections should be conducted on the entire refrigeration system every five years in order to determine that an ammonia refrigeration facility's equipment is safe and working to premium capacity.

And the effectiveness of that five-year inspection hinges on eight critical points:

Timing of the inspection

Most inspections will examine all equipment in the ammonia refrigeration system, including (but not limited to) compressors, condensers, evaporators, piping, insulation, supports, relief valves and headers, ammonia detection, heat exchangers, pressure vessels, maintenance records, emergency stop, ventilation, door signage, eyewash/showers and lighting. During the inspection process, safety shutdowns will be conducted multiple times. So it's important that a facility selects a quiet time to conduct the inspection.

"The inspector has to test high-level shutdowns, emergency stops, ammonia detection and compressor safety for high and low pressure shutdown and low oil failure shutdown," said Gene Dumas, project manager at SCS Tracer Environmental. "You don't want to have inspections during a peak time when you're in high-demand production. I have noticed lots of problems in this area because plants don't test these annually due to the necessary interruptions to production."

> **"The inspector has to test high-level shutdowns, emergency stops, ammonia detection and compressor safety for high and low pressure shutdown and low oil failure shutdown."**
>
> **Gene Dumas, project manager at SCS Tracer Environmental**

The inspector will need a person at his side who knows the system

Inspectors must have an employee who knows where everything is located. "Sometimes I'm trying to locate something and my contact person doesn't know where all the [system components] are," Dumas said. "I need someone who has knowledge of where everything is, so they can serve as a guide. That person should know every aspect of the plant. They don't need to be an expert, but they should know where everything is within the system."

Provide the inspector with an employee capable of operating the system

Inspectors are not allowed to test the equipment. "I can't close and open valves, trip floats or test compressor safety," Dumas said. "I can only witness it and make sure it is completed properly and documented."

Weather can play a factor in the quality of the inspection

Inspectors will require access to the roof of the facility and to sometimes difficult-to-reach pressure valves. In order to receive the most thorough inspection, facilities in cold weather climates should not schedule inspections when ice or snow may cover the inspection areas or render areas inaccessible or unsafe.

"It's hard to go onto a roof to inspect items when everything is covered in snow," Dumas said. "I can't safely climb ladders when there is ice on the roof. In that case, I can only tell you what I can see from the ground. So it's important to pick the right time of year."

Have U1-A forms for all pressure vessels readily available

U1A forms will answer any questions the inspector has regarding how the vessel was constructed, the materials that were used, the corrosion allowance, and the pressure ratings. "For example, if I can't read the pressure rating for a vessel, I can't determine if you have the proper safety relief valve. The forms will provide the answer," Dumas said.

Recommend hiring an independent third party to conduct inspections

The independent third party is a person who does not see the system on a daily basis nor has any financial interest in the company. An independent third party inspector will notice issues that may be overlooked by the staff who works on the system every day.

"I don't recommend a facility use their contractor or company employee to conduct the [5-year mechanical integrity] inspection because of a potential or perceived conflict of interest," Dumas said. "I would suggest an outside person that has no monetary incentive and basically doesn't have any skin in the game."

Prior to the inspection, the facility should communicate with the inspector on required personal protection equipment, where to enter the site and whom to contact

The inspector should be informed of what personal protection equipment is required to comply with the facility's safety program. The name and phone number for the person the inspector is to meet and where this meeting takes place is also important. "I find more often than not that at 5 a.m., most lobbies are locked and the receptionist is not available," Dumas said. Resolving these issues usually involves a pre-inspection meeting that can be conducted on the telephone or with a short email.

A list of action items will then be presented. The facility must address these recommendations, findings and suggestions in a timely manner, with the timeframe depending on the risk ranking given to the particular issue.

Timely response to recommendations is required

The inspection will take an average of three days, depending on the size of the facility and the amount of equipment. A list of action items will then be presented. The facility must address these recommendations, findings and suggestions in a timely manner, with the timeframe depending on the risk ranking given to the particular issue. The risk ranking is determined by the potential frequency and consequences associated with the action item. For example, an event that is "frequent" and "catastrophic" may receive a risk ranking of "1" or "high," which could require resolution within six months.

"But in any case you have to acknowledge the recommendation to be in compliance," Dumas said. "Depending on the severity and the state regulations, you might not have to follow it, but you must document" the action plan and identify items to be completed or omitted from the plan.

Operating Procedures for Ammonia Refrigeration Systems

Tony Lundell, Director of Standards and Safety with the International Institute of Ammonia Refrigeration, hosted a webinar in January titled "Operating Procedures for Ammonia Refrigeration Systems" as part of IIAR's program aimed at educating and advancing safety initiatives for its members.

Lundell's webinar was part of a series for members to share their knowledge about such topics as minimizing risk, hydraulic shock prevention, pressure vessel replacement, process hazard analysis, qualifying ammonia refrigeration contractors, benefits of deep cleaning evaporator coils, and noncondensables in refrigeration systems, just to name a few recent webinars.

The January webinar featured a PowerPoint presentation discussing the required operating procedures for the safe and sustainable use of ammonia as a natural refrigerant. Among the key categories within a standard operating procedures program that Lundell addressed were how the operating procedures element relates to other process safety management elements, the purpose and general requirements for operating procedures, the steps for each operating phase, operating limits, and safety and health considerations.

A facility's operating procedures describe the tasks to be performed, the data to be recorded, the operating conditions to be maintained, the samples to be collected, and the health and safety precautions to be taken, thus providing a benchmark for quality with operations, maintenance and standardization, while building protection and raising confidence. In his presentation, Lundell outlined the necessary requirements when developing and implementing written operating procedures.

One of the webinar's critical points centered on the regulatory requirement that facility owners must annually certify that their operating procedures are current and accurate.

"This provision can be confusing," Lundell said. "It does not mean that you have to update each operating procedure annually. To clarify this, if there have not been any changes, then you just have to certify that the operating procedures are current and accurate. If there had been changes, the affected operating procedures need to be updated in a timely manner as part of managing the change."

Rather than simply updating annually, Lundell pointed out that operating procedures must be reviewed periodically to reflect any changes in current operating practices in order to guard against them becoming outdated or inaccurate. A facility may choose to do the periodic reviews on a different frequency than annually. For example, he said, review 10 percent of them per month.

Lundell said that a facility's operating procedures must address three important steps: each operating phase, operating limits and safety and health considerations.

The steps for each operating phase are initial startup, normal operations, temporary operations and emergency shutdown, including conditions under which shutdown is required and details on the operators who are responsible for the shutdown. Emergency operations, normal shutdown, and start-up following a turnaround or emergency shutdown also fall into this category. Other steps to consider are lockout/tagout, pull-out/pump down, oil draining and other safe work practices.

As an example, a normal start-up step would include checking for flow through the chiller and making certain the ammonia liquid-stop hand valves are open.

Operating limits should include the consequences of deviation and the steps required to correct or avoid the deviation. Facilities should also consider the various controls, instrumentation and safety systems.

Of course, safety and health considerations should be a main focus in a facility's operating procedures. It should detail the properties of ammonia and the associated hazards, the precautions necessary to avoid exposure, the required personal protection equipment, and the engineering and administrative controls. Among the critical factors to be considered are control measures, protection from physical contact and airborne exposure, the chemical inventory levels and any unique hazards. The facility's safety systems, such as the interlocks, detection systems and suppression systems should be covered in this section, Lundell said.

Among the safety and health examples Lundell cited was taking precautions such as wearing rubber gloves, splash goggles, and a face shield when performing work where there is a potential for ammonia to be released, when draining oil or when charging ammonia into the system. He also said that respiratory protective equipment should be readily available when performing the work.

Finally, operating procedures must be readily accessible to employees, and the status for procedures must be ready and up to date.

Lundell pointed out that the development of the operating procedures is the responsibility of the facility owner. "It is permitted to have a contractor develop them and even use them, but ultimately, operating procedures are the owner's responsibility," he said.

In the final analysis, Lundell concluded, "Current and accurate operating procedures provide for the safe operation and maintenance of ammonia refrigeration systems."

The "Operating Procedures for Ammonia Refrigeration Systems" webinar as well as other IIAR education webinars may be accessed online through the IIAR website.


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CAUSES OF SURFACE CONDENSATION ON INSULATED PIPING

JIM YOUNG
DIRECTOR OF TECHNOLOGY
ITW INSULATION SYSTEMS

In addition to reducing heat gain from the ambient environment, one of the main purposes of insulation on pipe and mechanical equipment operating at below ambient temperatures is to prevent condensation on the outer surface of the insulation system. Preventing this surface condensation is simple in concept. Merely design the system to keep the surface temperature of the insulation system above the dewpoint temperature of the surrounding air. This simple relationship is made complicated because each of these two temperatures is dependent on the interrelationship of a myriad of factors. All of these factors must be fully and properly considered or selected to assure optimum control of insulation system surface condensation – commonly called condensation control.

The influence of each of the design and climatic factors influencing condensation control is discussed and recommendations are made on how to select or identify the appropriate value for each factor. Lastly, some common mistakes, tips, and tricks related to achieving condensation control are described.

Pipe, tanks, ducts, vessels, and other mechanical equipment operating at below ambient temperatures are insulated for various reasons with a key one being to prevent condensation of water vapor from the ambient atmosphere on the exterior surface of the insulation system. Condensation can lead to numerous problems including:

- Safety hazards as the water drips onto the floor below
- Damage to inventory as the water drips onto the merchandise below
- Poor aesthetics when dripping water stains ceiling tiles
- Damage to the insulation system materials
- Reduced insulating ability of the insulation (increased k-Factor)
- Shortened insulation system lifespan
- Corrosion of jacketing or pipe
- Growth of mold on the insulation system surface or on other building materials where condensed water drips

Because of these potential problems, prevention of condensation on the surface of cold mechanical insulation systems is of critical importance.

This document will discuss the causes of surface condensation, the factors influencing it, and how to best identify design conditions and select system components to prevent surface condensation on mechanical insulation systems.

Various tables or charts are presented below that show the insulation thickness necessary to prevent condensation under various conditions. These thicknesses were not generated by experimentation but, rather, are based on common modeling or thickness calculations using the ASTM C680 standard thickness calculation method. This is the normal method in which insulation thicknesses are designed in the mechanical insulation industry. All of the thickness charts or tables presented assume that the material properties and ambient conditions are correctly known. These thickness charts or tables presented also assume that the insulation system is working perfectly and is impervious to water and water vapor penetration. While the water resistance of various system components is important, especially in a cold pipe application, that is a subject for another time. There will be no discussion here related to which insulation or vapor retarder materials have better or worse resistance to water. These assumptions about material properties and system performance are often wrong but are useful and necessary for the purpose of this discussion.

This discussion will be limited solely to insulating to achieve condensation control. Other design criteria including meeting energy code requirements, achieving heat gain limits, maintaining temperature control, and freeze protection will not be addressed.

The theory of surface condensation will be presented first followed by the influence of climatic conditions and system components on surface condensation. Lastly, recommendations are made on how to best select climatic conditions and system components to prevent surface condensation.

THEORY OF SURFACE CONDENSATION

The cause of surface condensation is quite simple in concept. Water vapor in the air will condense on a surface that is below the dewpoint temperature of the surrounding air. This is a complicated topic when applied to mechanical insulation systems because there are so many factors which influence either the dewpoint or the surface temperature of the insulation system. Figure 1 illustrates this concept and lists the various factors influencing each component of the equation. The factors shown in red are discussed in detail in this document.

The system designer must understand this theory, select the appropriate climatic design conditions, the proper insulation system components, and then determine the required insulation thickness to achieve their desired performance.

INFLUENCE OF CLIMATIC CONDITIONS

Ambient Temperature

The first climatic condition to be examined for its influence on insulation surface condensation is ambient temperature. Table 1 shows how insulation thickness has to be adjusted to prevent surface condensation as the ambient temperature is changed. This is shown for a very cold pipe at -80°F as well as for a pipe at 20°F. The insulation material used for this table is polyisocyanurate (PIR) which is specified by ASTM C591, Grade 2, Type IV. The specific constant conditions used for this table were 90% r.h., 7 mph wind, aluminum jacket with an emittance (ε) of 0.1, and horizontal pipe. The pipe size, ambient temperature, and pipe temperature were varied as shown.

As Table 1 shows, a higher ambient temperature can lead to a slightly increased insulation thickness being needed to prevent surface condensation but this influence is small and only typically seen at higher pipe temperatures. For the system designer, this means that it is acceptable to determine the ambient design temperature only roughly. There is no need to expend significant effort pinning down this design variable. While the ambient temperature plays only a small role in condensation control, it is a key factor in energy conservation and other design criteria which are not being addressed in this document.

Figure 1 – Cause of surface condensation and the factors influencing it

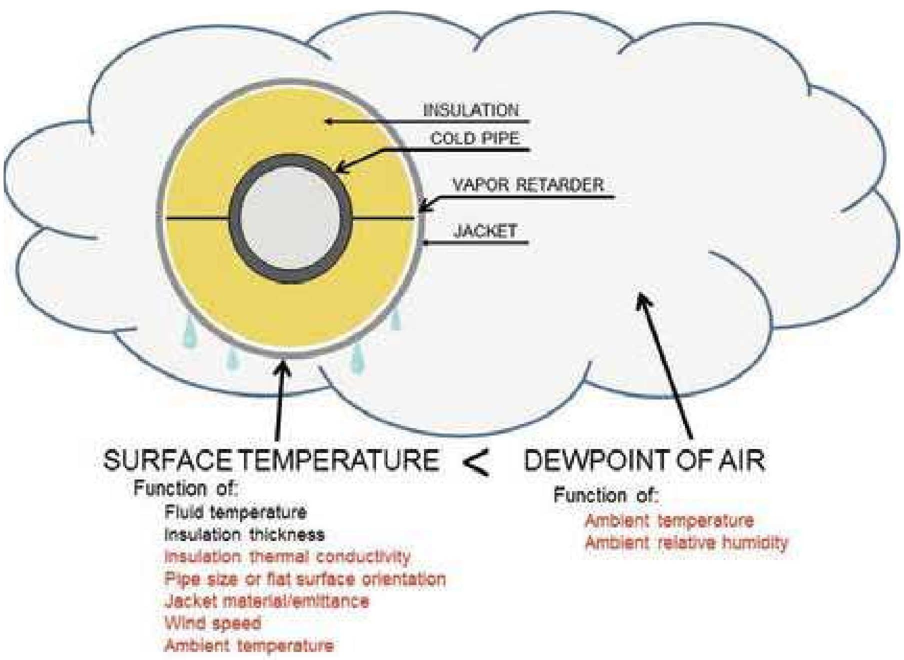


Table 1 – Influence of ambient temperature on the likelihood of surface condensation

Insulation Thickness (inches) for Condensation Control at Various Ambient Temperatures*

NPS	-80°F Pipe Temperature				+20°F Pipe Temperature			
(in)	70°F	80°F	90°F	100°F	70°F	80°F	90°F	100°F
1	4	4	4	4	1.5	2	2	2
1.25	4.5	4.5	4.5	4.5	1.5	2	2	2.5
1.5	4.5	4.5	4.5	4.5	2	2	2	2
2	5	5	5	5	2	2	2	2.5
2.5	5	5	5	5	1.5	2	2	2.5
3	5.5	5.5	5.5	5.5	2	2.5	2.5	2.5
4	6	6	6	6	2	2.5	2.5	3
6	6.5	6.5	6.5	6.5	2.5	3	3	3
8	7	7	7	7	2.5	3	3	3.5
10	7.5	7.5	7.5	7.5	2.5	3	3.5	3.5
12	7.5	7.5	7.5	7.5	3	3	3.5	3.5
16	8	8	8	8	3	3.5	4	4

No change in thickness (-80°F Pipe Temperature) — Small changes in thickness (+20°F Pipe Temperature)

*PIR insulation, 90% r.h., 7 mph, ε = 0.1, horizontal pipe

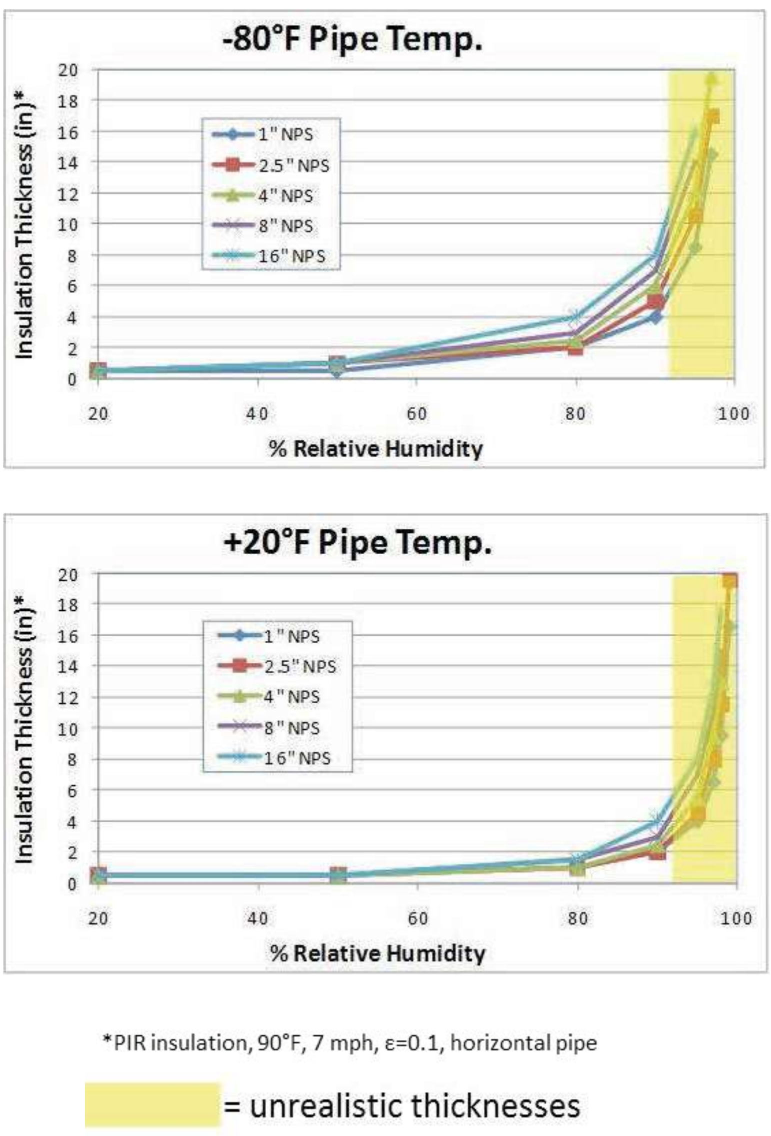
Ambient Relative Humidity

The influence of ambient relative humidity on surface condensation is shown in Figure 2 which graphically displays the insulation thickness necessary to prevent surface condensation as the ambient relative humidity is changed. This is shown for a very cold pipe at -80°F as well as for a pipe at 20°F. The insulation material used for these charts is again polyisocyanurate (PIR). The specific constant conditions used for these charts were 90°F ambient temperature, 7 mph wind, aluminum jacket with an emittance (ε) of 0.1, and horizontal pipe. The pipe size, ambient relative humidity, and pipe temperature were varied as shown.

As Figure 2 shows, the influence of relative humidity on surface condensation is very large especially as the r.h. gets above around 70-80%. As the relative humidity increases, the insulation thickness necessary to prevent surface condensation increases. This effect is present regardless of pipe size and pipe temperature and is particularly pronounced at r.h. above about 80%. It is important to note that the insulation thickness required to prevent surface condensation asymptotically approaches infinity as the r.h. approaches 100%. In other words, designing a system to prevent condensation at 100% relative humidity would require the use of an infinite thickness of insulation which is obviously impossible. As a result of this asymptotic behavior, above a relative humidity of around 90-95% it takes an unrealistic and impractical insulation thickness to prevent condensation. This leads to a practical design limit for relative humidity of around 90-95%.

In Figure 2 and many later graphs and tables showing insulation thickness, sections are highlighted in yellow to indicate "unrealistic thicknesses". These are insulation thicknesses which the owner/engineer/specifier would likely consider too large to be considered practical in the specified application. There would certainly be debate as to what thickness is considered "unrealistic" and these yellow highlights are not meant to indicate some specific point at which insulation thickness becomes unrealistic. Rather, these are shown to help illustrate the point that there are practical limits that play a role in the system design as well as the theoretical factors that are being discussed.

Figure 2 - Influence of ambient relative humidity on the likelihood of surface condensation



Since most cold pipe systems are designed using a fairly high relative humidity, the influence of this factor is of paramount importance. Consider the five insulation system scenarios shown in Table 2 for the usually important 80-95% r.h. range. For each scenario, the insulation thickness required to prevent surface condensation is shown as a function of high % relative humidity. As this table shows, the insulation thickness required increases very rapidly above about 80-85% r.h., especially at colder pipe temperatures. Impractical insulation thicknesses are reached at 85-95% r.h. depending on the pipe temperature.

As the pipe temperature in an application gets colder, the specifier of an insulation system will typically reduce the design relative humidity or introduce other design features such as higher jacket emittance in order to avoid the need for unrealistic insulation thicknesses.

Ambient Wind Speed

In a cold pipe situation, the surface temperature of the insulation system will be below that of the surrounding atmosphere. Wind will increase the rate of heat transfer and warm the insulation surface thus leading to a reduced likelihood of surface condensation. The influence of wind speed on surface condensation is fairly large but reaches diminishing returns above the 5-7 mph range. Table 3 shows the influence of wind speed on the insulation thickness required to prevent condensation for several scenarios. As this table shows, the required insulation thickness increases at lower wind speed and is especially high at zero wind speed.

When considering the influence of wind speed, remember that 0 mph is also a speed and in most indoor applications, the wind speed will indeed be zero. In outdoor applications, it is typical to assume the presence of some wind in the design of the insulation system. A commonly assumed wind speed in the industry when there

Table 2 – Insulation thickness to prevent surface condensation in five scenarios at high % r.h.

Scenario*	80% r.h.	85% r.h.	90% r.h.	95% r.h.
CHILLED WATER - 8" NPS pipe at 42°F, Phenolic Insulation	1	1	2	4
REFRIGERATION LINE - 2" NPS pipe at 20°F, PIR Insulation	1	1.5	2	4.5
AMMONIA REFRIGERATION SUCTION LINE - 10" NPS pipe at -40°F, XPS PIB Insulation	3	4.5	7	14
ETHYLENE PLANT COLD LINE - 16" NPS pipe at -100°F, PIR Insulation	4	6	9	17.5
LIQUID NATURAL GAS LINE – 32" NPS pipe at -265°F, PIR Insulation	7	10	15.5	>>20

*All scenarios share: 90°F air, outdoor location, 7 mph wind, aluminum jacket with ε = 0.1, horizontal pipe

Table 3 – Influence of wind speed on insulation thickness necessary to prevent surface condensation

Scenario*	0 mph	2 mph	5 mph	7 mph
CHILLED WATER - 8" NPS pipe at 42°F, Phenolic Insulation,	2.5	1.5	1.5	1
REFRIGERATION LINE - 2" NPS pipe at 20°F, PIR Insulation	3	2	1.5	1.5
AMMONIA REFRIGERATION SUCTION LINE - 10" NPS pipe at -40°F, XPS PIB Insulation	9.5	6.5	5	4.5
LIQUID NATURAL GAS LINE – 32" NPS pipe at -265°F, PIR Insulation	>> 20	14	11	10

*All scenarios share: 90°F air, [illegible] relative humidity, outdoor location, aluminum jacket with ε = 0.1, horizontal pipe

is not a specific reason to use a higher or lower value is 7 mph.

With the discussion of climatic design conditions complete, the next category of factors to examine is the system components and their influence on surface condensation.

INFLUENCE OF SYSTEM COMPONENTS

Jacket Type – Emittance (ε)

Emittance is an important factor in the radiative component of heat transfer and is defined in ASTM C168 as:

"The ratio of the radiant flux emitted by a specimen to that emitted by a blackbody at the same temperature and under the same conditions."

This is certainly not as simple to understand as wind speed or ambient temperature which are straightforward even to a layperson. Emittance ranges from 0 to 1 with lower values being representative of materials that have comparatively low ability to transfer heat through radiation such as aluminum or stainless steel metal jacketing and higher values being representative of the performance of plastic, paper, or other non-metallic surfaces which typically have a greater ability to transfer heat through radiation.

It is important to note that emittance is not the same as solar reflectance. In solar reflectance the color of the jacketing is important. A black colored plastic jacket would have a much lower solar reflectance than a white jacket and would therefore absorb more heat from the incident sunlight. In emittance, the color of the jacket has a minimal influence. A black plastic jacket might have an emittance of 0.92 while a white plastic jacket might have an emittance of 0.9 which is an insignificant difference.

Table 4 shows the influence of jacket emittance on the likelihood of surface condensation. Jacket materials with lower emittance like most metals yield a colder outer surface which makes surface condensation more likely and increases the required insulation thickness. Materials with higher emittance like paper, plastic, or mastic yield a warmer outer surface which makes surface condensation less likely. This has an obvious and significant effect on the insulation thickness needed to prevent the condensation from occurring.

The use of PVC jacketing is not typically recommended for outdoor use due to sensitivity to ultra violet light and is included in Table 4 just to illustrate the impact on insulation thickness from using jacketing with high emittance. The use of painted metal jacketing in outdoor applications is an often overlooked but excellent way to reduce the required insulation thickness by raising the jacket emittance.

Insulation Type – Thermal Conductivity

The insulating ability of the insulation material used has an obvious and significant impact on the likelihood of

Table 4 - Influence of jacket emittance on insulation thickness necessary to prevent surface condensation

Scenario*	Aluminum Jacket (ε = 0.1)	Stainless Jacket (ε = 0.3)	Painted Aluminum (ε = 0.8)	PVC[+] Jacket (ε = 0.9)
CHILLED WATER - 8" NPS pipe at 42°F, Phenolic Insulation	2	1.5	1	1
REFRIGERATION LINE - 2" NPS pipe at 20°F, PIR Insulation	2	2	1.5	1.5
AMMONIA REFRIGERATION SUCTION LINE - 10" NPS pipe at -40°F, XPS PIB Insulation	7	6	4	4
ETHYLENE PLANT COLD LINE - 16" NPS pipe at -100°F, PIR Insulation	9	7.5	5.5	5
LIQUID NATURAL GAS LINE – 32" NPS pipe at -265°F, PIR Insulation	15.5	12.5	9	8.5

*All scenarios share: 90°F air, 90% relative humidity, outdoor location, 7 mph wind, horizontal pipe

Table 5 – Thermal conductivity (k-Factor) of several insulation types at 75°F mean temperature

Insulation Material	K-Factor* (Btu-in/hr-ft2-°F)
Phenolic	0.15
PIR	0.19
XPS	0.259
Elastomeric Rubber	0.28
Cellular Glass	0.31

surface condensation and the insulation thickness necessary to prevent this condensation. There are many ways to characterize insulating ability with the most common in the N. American mechanical insulation industry being the thermal conductivity (k-Factor) at 75°F mean temperature. This simple characterization is useful when discussing insulation materials but should not be used in actual thickness or other heat transfer calculations. The often complicated relationship of thermal conductivity to mean temperature requires that any heat transfer calculations be done using this actual and full curve not a single point representation of this curve such as the 75°F value. When comparing k-Factor, note that a lower value is better. Table 5 shows the k-Factor of several mechanical insulation types at 75°F mean temperature taken from the respective ASTM material standards.

Of course, there are many properties besides k-Factor that should be considered when selecting an insulation material including cost, water resistance, flammability, availability, and more. Nonetheless, the insulation material used and its thermal conductivity have a direct and strong impact on the thickness required to prevent surface condensation and must be considered when selecting an insulation material and certainly when designing the thickness of the insulation.

Table 6 shows the strong influence of the insulation thermal conductivity on the insulation thickness needed to prevent surface condensation. As the thermal conductivity goes down (gets better), the required insulation thickness also decreases.

System Geometry - Pipe Size and Flat Surface Orientation

The last factor to be discussed is the geometry of the system. What this means is the NPS for pipe scenarios and the orientation of the surface for flat tank or duct scenarios. The cold flat surface can be vertically oriented, horizontal facing downward, or horizontal facing upward. The influence of the flat surface orientation is a phenomenon that is often overlooked leading to the mistake wherein all surfaces of a tank or duct are insulated with the same thickness. In reality, the convective component of heat transfer is different in each of these orientations and this leads to a need for different insulation thicknesses for each orientation. The difference in convective heat transfer is caused by the cold air sinking and hot air rising phenomena coupled with the possible interference of this movement by the tank or duct. As an example, on the top of a tank or duct, the cold air next to the surface of the insulation system should naturally sink but it is "trapped" by the presence of the duct and insulation system below it. This causes the cold air to stay longer at the insulation system surface which leads to a colder insulation system surface, and a greater tendency to get condensation on this surface. To account for this, the insulation thickness on that top surface must be increased.

Table 7 shows the influence of pipe size and flat surface orientation on the insulation thickness required to prevent

Table 6 - Influence of k-Factor on insulation thickness necessary to prevent surface condensation

Scenario*	Phenolic k=0.15	PIR k = 0.19	XPS k = 0.259	Rubber k = 0.28	Cell Glass k = 0.31
CHILLED WATER - 8" NPS pipe at 42°F	1	1.5	2	2	2
REFRIGERATION LINE - 2" NPS pipe at 20°F	1.5	1.5	2	2	2.5
AMMONIA REFRIGERATION SUCTION LINE - 10" NPS pipe at -40°F	3	3.5	4	5	5.5
ETHYLENE PLANT COLD LINE - 16" NPS pipe at -100°F	5	6	6.5	7.5	7.5
LIQUID NATURAL GAS LINE – 32" NPS pipe at -265°F	8.5	10	10.5	13	13.5

*All scenarios share: 90°F air, 85% relative humidity, outdoor location, aluminum jacket with ε = 0.1, 7 mph wind, horizontal pipe

Table 7 – Influence of system geometry on insulation thickness necessary to prevent surface condensation

Scenario*	1" NPS	8" NPS	32" NPS	Tank Bot.	Tank Side	Tank Top
CHILLED WATER at 42°F	1	1.5	2	1	1.5	2
REFRIGERATION at 20°F	1.5	2	2.5	1.5	2	3
AMMONIA RFG SUCTION at -40°F	2	3.5	4.5	3	4	5.5
ETHYLENE PLANT COLD at -100°F	3	5	6.5	4.5	5.5	8.5
LIQUID NATURAL GAS at -265°F	4.5	7.5	10	7.5	9.5	14

*All scenarios share: PIR Insulation, 90°F air, 85% relative humidity, outdoor location, aluminum jacket with ε = 0.1, 7 mph wind, horizontal pipe or specified flat surface

condensation. As can be seen, as the pipe size (NPS) increases, the insulation thickness required also increases and this is a moderate effect growing in significance at colder pipe temperatures. As can also be seen, the insulation thickness required on cold flat surfaces is greatest on the top of a tank/duct, lowest on the bottom, and intermediate on the sides of the tank/duct.

SUMMARY OF THE INFLUENCE OF THE VARIOUS FACTORS

The influence of all the factors is summarized in Table 8 which shows both the effect of each factor on insulation thickness and also a qualitative assessment of the magnitude or size of the effect of each factor.

Another way of summarizing the influences is to categorize the factors as either helpful – that is they reduce the likelihood of condensation or reduce the insulation thickness required to prevent condensation or harmful - that is they increase the likelihood of condensation or increase the insulation thickness required to prevent condensation. This is shown in Figure 3.

When examining the impact of a design condition, the SIZE of this effect must also be considered. For example, more care should be taken in considering relative humidity than in ambient temperature due to the former having a much larger effect.

SELECTING DESIGN CONDITIONS & SYSTEM COMPONENTS

Design Ambient Temperature

Recall from earlier in this document that the impact of the ambient temperature on the likelihood of condensation control or insulation thickness needed to prevent condensation is small. As a result, accurate selection of an ambient temperature is simply not very important. The most common and a perfectly acceptable approach is to select a reasonably harsh temperature for the situation.

Table 8 – Summary of the influence of all climatic and system component factors

Factor	Factor Change	Effect on Insulation Thickness	Size of Effect
Ambient Temp.	Increase	Increase	Small
% Relative Humidity	Increase	Increase	Large from 80-95% Huge at >95%
Wind Speed	Increase	Decrease	Large from 0 -5 mph
Jacket Emittance (ε)	Increase	Decrease	Large
Insulation k-Factor	Increase (worse)	Increase	Large
Pipe Size	Increase	Increase	Medium

Figure 3 – Assessment of factors as helpful or harmful.

Helpful Design Conditions:

Low ambient temp. — Low % r.h.

Painted metal jktg — High wind

Low k-Factor — Small pipe or tank bottom

Harmful Design Conditions:

High ambient temp. — High % r.h.

Bare metal jktg. — Low wind

High k-Factor — Large pipe or tank top

Table 9 – Examples of reasonable ambient temperatures for use in system design

Application	Ambient Temperature (°F)
Outdoors, desert climate	120+
Outdoors, hot climate	90-100
Outdoors, moderate climate	80-90
Indoors, Food/beverage plant, processing area	80-90
Indoors, commercial building, conditioned space	75
Indoors, commercial building, machine room	80-90
Indoors, commercial building, above suspended ceiling	75-85
Refrigerated warehouse	40-50

Table 9 shows some examples of reasonable ambient temperatures for use in the design of insulation systems for several different applications.

Of course, if energy efficiency is a separate design criteria, selection of ambient temperature is of critical importance.

Design Wind Speed

In indoor applications, it is usually best to select 0 mph (no wind) unless it is certain that a forced ventilation will always be present and providing a wind speed above zero.

In outdoor applications there are two approaches that can be used. A reference source for climatic information can be used such as the ASHRAE Handbook of Fundamentals, an online database such as weatherbase.com, or a computer program with weather data such as WYEC2 or TMY2. The problem with this approach is that it is not clear which type of wind speed value should be used. Should it be a yearly average, the highest speed recorded, some high percentile value like 99th, or something else? As an alternative the industry standard 7 mph value can be used unless the system is known to be in a high or low wind location. Examples of locations where a higher wind speed may be appropriate include on or near the ocean shore, under bridges, and in mountain passes. An example of a location where a lower wind speed may be appropriate is on a rooftop location where the pipe is blocked from the prevailing winds by some solid structure. While it is certainly less accurate to use a single 7 mph value as a rule of thumb for most locations, this approach does have the advantage of simplicity and is very widely practiced.

Insulation Type and Thermal Conductivity

There are many factors that should influence the selection of the insulation material type and one of the key factors is the insulating ability (thermal conductivity) of the material. Where it is reasonable and appropriate, select an insulation material type that has the better (lower) thermal conductivity. Once an insulation material type has been selected or where it has already been specified, obtain thermal conductivity data for that insulation material from the most recent version of the appropriate ASTM material standard. Be cautious of using thermal conductivity claims by individual manufacturers. There are many ways to obtain thermal conductivity test values that are better than those published in the ASTM standards and these "better" values may not be truly indicative of long-term material performance.

System Geometry - Pipe Size and Flat Surface Orientation

This is not really a factor that can be controlled during insulation system design. The pipe size and orientation of any flat surfaces have already been set by the needs of the facility. The response by the insulation system designer on this factor is merely to understand that the pipe size and flat surface orientation can have an influence on the likelihood of surface condensation and on the insulation thickness needed to prevent this condensation. The required insulation thickness for each pipe size and surface orientation must be determined independently.

Jacket Type – Emittance (ε)

In most applications in N. America, the jacket choices are straightforward. In outdoor locations aluminum jacketing (ε = 0.1) is used for UV resistance and strength. In indoor locations PVC jacketing (ε = 0.9) is used. However, there are exceptions to these general practices when a different jacket type is dictated by conditions specific to the application. In an indoor environment where a great deal of physical abuse is likely such as in a loading dock, aluminum jacketing (ε = 0.1) should be considered. It might even be prudent to use a greater thickness of aluminum jacketing to provide even more physical abuse resistance. In an indoor or outdoor environment where there will be either excessive exposure to corrosive chemicals or a need for an especially high resistance to fire, stainless steel jacketing (ε = 0.3) should be considered.

As mentioned briefly earlier in this document in the section on the influence of emittance on surface condensation, the use of painted metal and especially painted aluminum (ε = 0.8) can be quite helpful in reducing the likelihood of surface condensation or reducing the thickness of insulation necessary to prevent surface condensation. This benefit of painted metal jacketing arises solely as a result of its higher emittance than bare metal. Consider, for example, Table 10 which shows the insulation thickness required to prevent surface condensation on an ammonia refrigeration line with standard aluminum and painted aluminum jacketing. The use of painted aluminum jacketing in this scenario yields an almost 50% reduction in insulation thickness. The use of painted aluminum jacketing also provides an increased resistance to exterior jacket corrosion and is particularly useful on rooftop refrigeration lines operating at pipe temperatures in the -60 to +20°F range.

While the use of jacketing with a higher emittance (e.g. painted metal) has a strong influence on insulation thickness related to control of surface condensation, it should be noted that a higher emittance jacketing has a very minor influence on overall heat transfer. Therefore, the use of higher emittance jacketing will have minimal impact on energy efficiency.

Regardless of the type of metal jacketing used (aluminum, painted aluminum, stainless steel, or some other metal) it is critical that the metal jacketing have a 3 mil thick polysurlyn moisture barrier factory heat laminated to the interior surface to help prevent galvanic and pitting/crevice corrosion on the interior surface of the jacketing.1

Relative Humidity

Selection of the proper relative humidity for control of surface condensation in mechanical insulation system design is definitely more complicated than selection of the other factors and also has the largest influence on the necessary insulation thickness. The first step is to distinguish between indoor and outdoor locations.

Relative Humidity Indoors

In indoor locations surface condensation on mechanical insulation systems is usually a disaster leading at best to demands that the contractor fix the system and at worst to lawsuits. Surface condensation can drip on floors causing slip hazards. It can drip onto manufactured goods below damaging them. It can drip onto food either during processing or storage contaminating it. It can drip onto ceiling tiles causing unsightly water stains. It can lead to mold growth on the surface of the vapor retarder particularly when the outer surface of the vapor retarder is made of paper. It can lead to mold growth inside the insulation system especially when the insulation material offers little or no resistance to water absorption and water vapor permeability. It can lead to reduced insulating ability of the system which exacerbates the surface condensation problem even further.

Indoors, surface condensation must be avoided 100% of the time. This is possible with proper insulation system design provided the indoor air is de-

Table 10 – Influence of painted aluminum jacketing on insulation thickness for condensation control

Scenario*	Aluminum Jacket (ε = 0.1)	Painted Aluminum (ε = 0.8)
AMMONIA REFRIGERATION SUCTION LINE - 10" NPS pipe at -40°F, XPS PIB Insulation	7	4

*All scenarios share: 90°F air, 90% relative humidity, outdoor location, 7 mph wind, horizontal pipe humidified and controlled at a relative humidity well below 100%.

Relative humidity in indoor locations can vary widely. Consider these examples:

- Food/beverage processing areas can have high r.h. and be subject to washdowns
- Machine rooms of commercial buildings can have high r.h. and can even be ventilated with outside air
- Concealed areas of commercial buildings can have higher r.h.
- Plenum areas of commercial buildings can be higher in r.h.
- Office areas and other occupied spaces of commercial buildings are usually low in r.h.

Insulated pipe in indoor locations should be designed to prevent surface condensation at a very high r.h. compared to what is likely in that area. Designing for an ambient relative humidity of 85% or higher is completely reasonable since it is necessary to prevent surface condensation 100% of the time indoors. Designing for such a high ambient relative humidity usually has less impact on required insulation thickness indoors because of the high emittance of the jacketing (usually 0.9), the pipe size usually being smaller, and the pipe temperature usually not being that cold – especially on chilled water lines in commercial buildings.

Relative Humidity Outdoors

The key fact to remember in order to understand the philosophy of insulating to prevent surface condensation in outdoor locations is that it is impossible to prevent surface condensation 100% of the time. Sooner or later, the relative humidity outdoors will reach 100% which would require an obviously impossible infinite thickness of insulation to prevent surface condensation. Even if you design to a high relative humidity like 90-95% r.h. it will eventually reach a relative humidity above this limit. This high humidity might be reached during or immediately after a rainstorm. It might be reached on a cool morning when there is a heavy dew. It might be reached when there is fog on the ground. Any concern with the inevitability of surface condensation on outdoor cold pipe is tempered once it is realized that periodic surface condensation on outdoor pipe is perfectly acceptable. After all, the pipe surface gets wet from rain, dew, fog, and snow. It is not a significant problem if the frequency of surface wetness is increased slightly due to actual surface condensation.

The key for insulated pipe in outdoor locations is to design the system to prevent surface condensation a reasonably high percentage of the time but how should this be done? There are several approaches that can be considered.

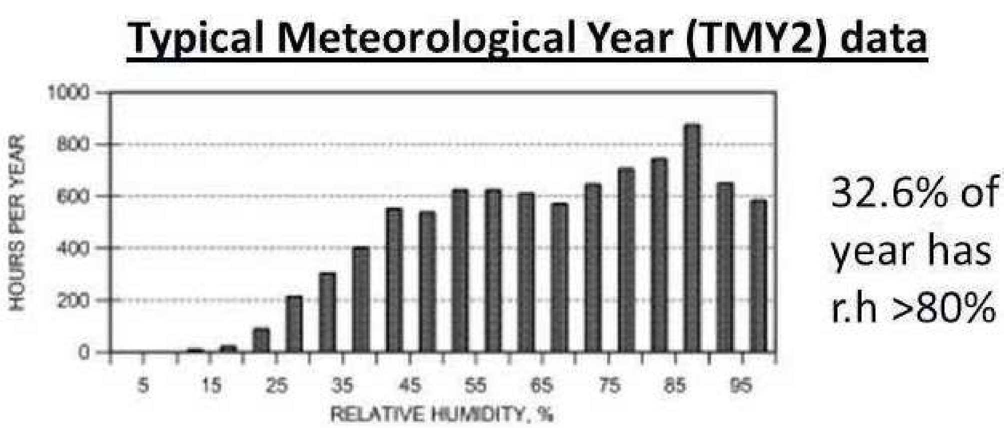
1. 2009 ASHRAE Handbook of Fundamentals, Chapter 14

This is the trickiest approach. The American Society of Heating, Refrigeration, and Air conditioning Engineers Handbook of Fundamentals, Chapter 14 contains climatic information on extreme conditions for numerous global locations. The tables in this chapter include the 0.4th percentile dewpoint and mean coincident dry bulb (MCDB) temperature. From this information and a psychrometric chart or program, the percent relative humidity can be determined. However, field experience has suggested to this author that the conditions arising from this approach are not harsh enough. As an example, consider the information in this chapter for Charlotte, NC. The 0.4th percentile dewpoint is 74°F with a MCDB = 80.8°F. This yields a relative humidity of 80%. However, consider Figure 4 which shows the frequency distribution of outdoor relative humidity based on the typical meteorological year data for Charlotte.2 As this figure shows, there is a very significant portion of the year (32.6%) when the relative humidity is above 80%. Too often, this approach seems to yield design conditions which are not harsh enough and which would allow surface condensation too frequently.

2. 2009 ASHRAE HANDBOOK OF FUNDAMENTALS, CHAPTER 23

This chapter recommends the use of 90% r.h. for all outdoor applications and indoor applications vented to outdoor conditions. This is coupled with the 0.4th percentile dew-point and with the use of a psychrometric chart, the dry-bulb temperature can be determined. Using the Charlotte,

Figure 4 – Frequency distribution of relative humidity in Charlotte, NC



NC example again, the 0.4th percentile dewpoint is 74°F. Coupling this with 90% relative humidity yields a dry-bulb temperature of 77°F so the design conditions recommended according this this approach would be 77°F and 90% relative humidity. This approach ignores the fact that the 0.4th percentile dewpoint has a mean coincident dry-bulb temperature already associated with it as was discussed in the first approach. The approach of always using 90% r.h. would probably yield acceptable results in commercial building chilled water applications where the pipe temperature is seldom lower than 40°F. For colder temperature applications and especially those at cryogenic temperatures like liquid oxygen (-297°F), liquid nitrogen (-320°F), liquid natural gas (LNG) (-265°F), and even very cold ammonia refrigeration lines at -40 to -60°F, the use of 90% r.h. yields a requirement for an insulation thickness to prevent surface condensation that is often considered impractical. As an example, consider the 15.5 inches of PIR insulation thickness required on a large diameter LNG pipe to prevent surface condensation at 90% r.h. from Table 2. This thickness is impractical and would never be used. Instead, the system designer would design to a lower relative humidity, accept the consequence of more frequent surface condensation, and design other aspects of the insulation system to prevent damage from the more frequent surface condensation.

3. RECOMMENDED APPROACH TO SELECTING OUTDOOR DESIGN RELATIVE HUMIDITY

Unless there are detailed specific reasons to use a higher or lower relative humidity, use a value in the range of 80-90%. Within this recommended range, base the specific value selected on knowledge of the climate at the job location and the pipe temperature. At warmer pipe temperature including chilled water in the 35-45°F range, it is reasonable to use 90% r.h. At colder pipe temperature, use the lower design relative humidity values in this range (80-85%) to determine the required insulation thickness and examine this thickness to see if it is impractical. If it is too thick, then take some step to reduce the required insulation thickness. This could be the use of a higher emittance jacket such as painted metal instead of bare metal or it could be to design to a lower relative humidity with commensurate changes to other aspects of the system design such as vapor retarder permeance and quality to prevent system damage from the more frequent surface condensation.

COMMON MISTAKES, TRICKS, AND TIPS

Common Mistakes in Mechanical System Design Related to Surface Condensation

- Owners, system designers, or others involved want to design the insulation system to prevent condensation at 100% relative humidity. This issue most commonly manifests itself as a request for the insulation thickness that will prevent condensation at 100% r.h. This cannot be done since it would require an infinite thickness of insulation to accomplish. The proper approach is to design to between 80-90% r.h. outdoors depending on various factors described above and to about 85% r.h. indoors.
- Owners, system designers, or others involved want to design the insulation system to prevent condensation 100% of the time in an outdoor or non-climate controlled indoor location. This cannot be done. Sooner or later the relative humidity will rise to above any design value and will occasionally reach 100% r.h. To accomplish this impossible design goal would require an infinite insulation thickness. The proper approach is to design the insulation system to allow surface condensation a small but non-zero fraction of the time and to design other aspects of the system so that this infrequent but inevitable surface condensation does not damage the insulation system.
- Designing an insulation system for climate controlled indoor conditions and then starting up the system before the building has been enclosed and completed. In effect, this is simply operating the system in an environment with a higher r.h. than the system was designed to handle. Surface condensation in this situation is common and has been the cause of some high profile system failures.
- Unrepaired damage to the insulation system during construction – often by other trades. This type of damage almost always causes breaches in what is supposed to be a continuous vapor retarder. If the system is started up without repair to the damaged insulation system, water vapor quickly enters the insulation system and condenses. This is the beginning of a classic vicious circle. The condensed water leads to poorer insulating ability of the insulation (higher/worse k-Factor) which leads to more condensation and ever worsening k-Factor. The water intrusion into the insulation system can also cause pipe and jacket corrosion, mold growth, ice formation, and loss of process control.
- Designing for 50% relative humidity in indoor locations. This level of r.h. may make sense in the occupied portion of an office building if the air conditioning/dehumidification system can guarantee this value is never exceeded. However, there are other parts of a commercial building which may have higher r.h. including machine rooms, kitchens, locker/shower rooms, and even concealed spaces like pipe chases. It is critical that the humidity is not assumed to be always less than 50% in these other portions of the building. In light industrial facilities such as food and beverage manufacturing, high humidity processing areas can readily exist despite the air conditioning of the building in general or portions of the building. The same pipe may need different thicknesses of insulation or other changes to the insulation system depending on which portion of a building it is in.
- Using an emittance of 0.4 for aluminum jacketing. This is a common error based on some older specifications and handbooks that list this value as the emittance of aluminum jacketing. Using this incorrectly high value will result in inadequate insulation thickness to prevent surface condensation at the specified conditions. An accurate

value to use for standard oxidized in service aluminum jacketing of all finishes (plain, stucco, and 3/16" corrugated) is 0.1. This emittance is also contained in the new ASTM standard on aluminum jacketing, C1729.

Common Useful Tricks in Mechanical System Design Related to Surface Condensation

- Use painted metal jacketing to significantly increase the emittance. Bare aluminum has an emittance of 0.1 while painted aluminum is 0.8. This is a very large increase since the scale of emittance only goes from 0 to 1. Making this change will raise the surface temperature significantly which will either reduce the insulation thickness required to prevent surface condensation or prevent surface condensation to a higher percent relative humidity. This trick is most helpful in outdoor applications where metal is the preferred type of jacketing. While not widely practiced in cryogenic applications, this is a trick that engineers and other system designers should consider when designing insulation systems to prevent surface condensation on pipes and other mechanical equipment operating at cryogenic temperatures. Painted aluminum jacketing has the added advantage of being more corrosion resistant than standard (bare) aluminum jacketing.

Tips Related to Preventing Surface Condensation on Mechanical Insulation Systems

- Contractors, facility owners, and insulation system designers should work with manufacturers who understand the complex design issues described in this paper
- Some insulation manufactures know as much or more about some aspects of insulation system design than do the persons charged with designing these systems. Contractors, facility owners, and insulation system designers should seek input from these knowledgeable manufacturers on selecting appropriate design conditions and on insulation system design but should also educate themselves on these issues so manufacturer's recommendations can be properly assessed.
- When comparing insulation materials, comparing insulation thickness tables, or preparing new insulation thickness tables, it is very important that the same conditions be used for all materials. Even a seemingly small change like one manufacturer using an aluminum emittance of 0.4 while another uses the correct value of 0.1 can have a significant impact on the recommended/calculated insulation thickness.
- While this paper has focused only on condensation control, remember that this is only one design criterion. There are many other possible design criteria including code compliance, process control, energy efficiency, personal protection, and fire protection.
- This document is merely an overview of the impact of various factors on the likelihood of surface condensation and is not intended to replace proper system design by an engineer experienced with mechanical insulation on cold surface. Insulation system design has many subtleties that are not addressed by the more simplistic review presented here.

CONCLUSIONS

Surface condensation on insulation systems for cold mechanical equipment (pipe, tanks, vessels, etc.) is a simple concept. Surface condensation will occur if the surface temperature of the insulation system is less than the dewpoint temperature of the surrounding air. This simple relationship is made complicated because each of these two temperatures is dependent on the interrelationship of a myriad of factors as shown in Figure 5.

All of these factors must be fully and properly considered or selected to assure optimum control of insulation system surface condensation – commonly called condensation control.

Of these factors, selection of the proper relative humidity to use for system design is the most important and also the most complicated to handle.

One last but very important point to emphasize is that in outdoor applications, surface condensation cannot be prevented 100% of the time.

REFERENCES:

1 J. Young, "Preventing Corrosion on the Interior Surface of Metal Jacketing", Insulation Outlook, November, 2011.

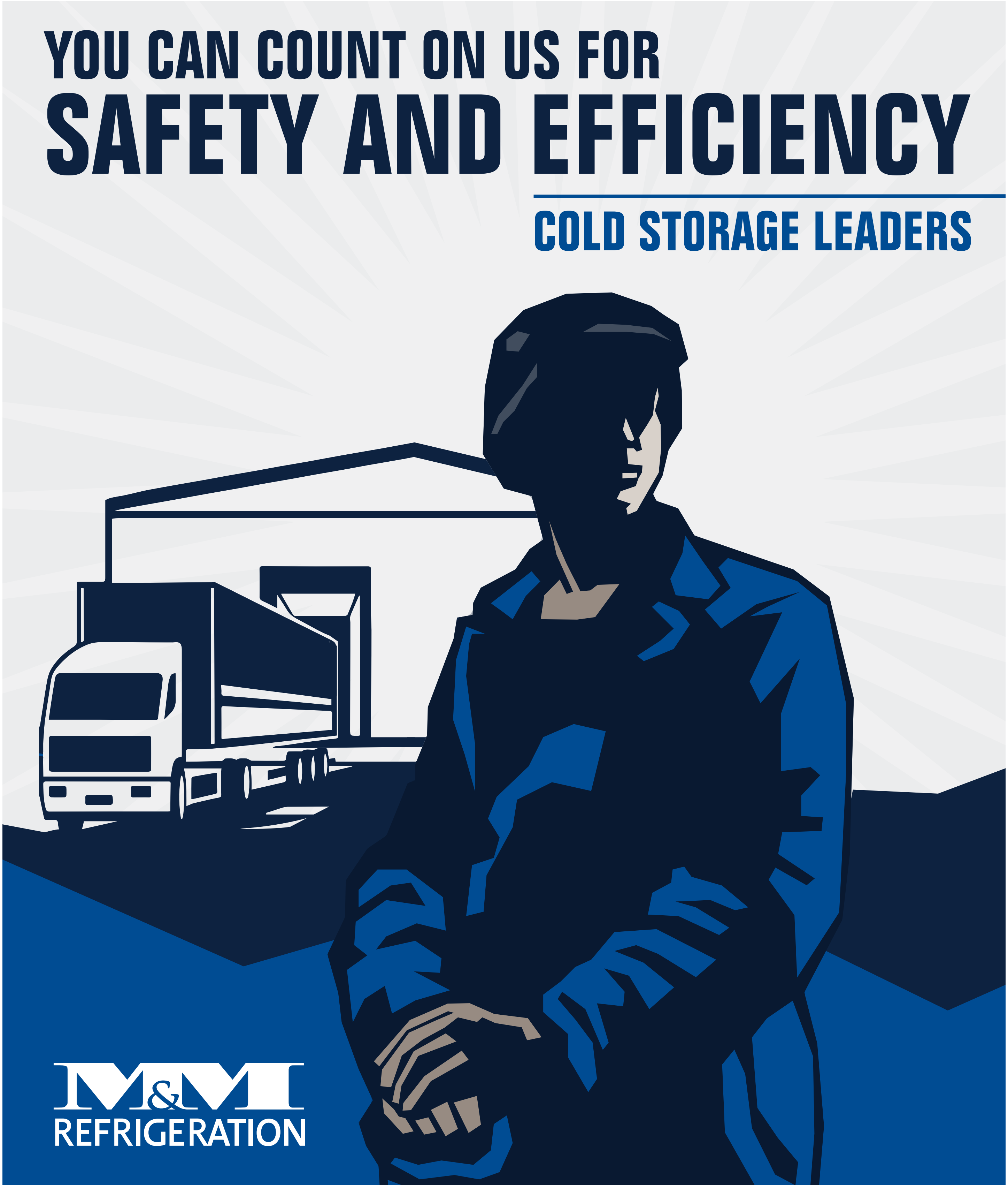
2 ASHRAE 2009 Handbook of Fundamentals, Chapter 23, p. 3

Figure 5 –Factors Influencing Surface Condensation

SURFACE TEMPERATURE < DEWPOINT OF AIR

Function of:
- Fluid temperature
- Insulation thickness
- Insulation thermal conductivity
- Pipe size or flat surface orientation
- Jacket material/emittance
- Wind speed
- Ambient temperature

Function of:
- Ambient temperature
- Ambient relative humidity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