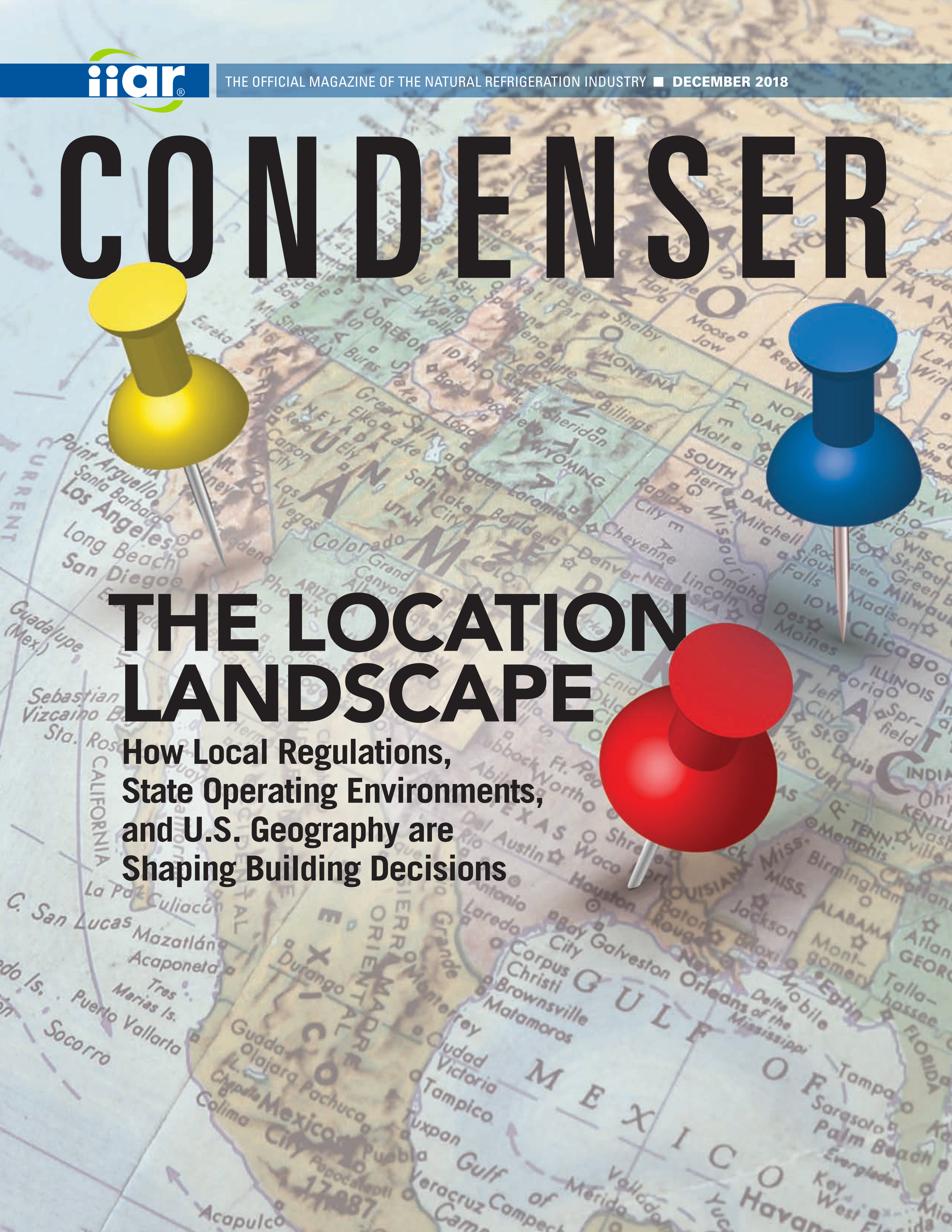
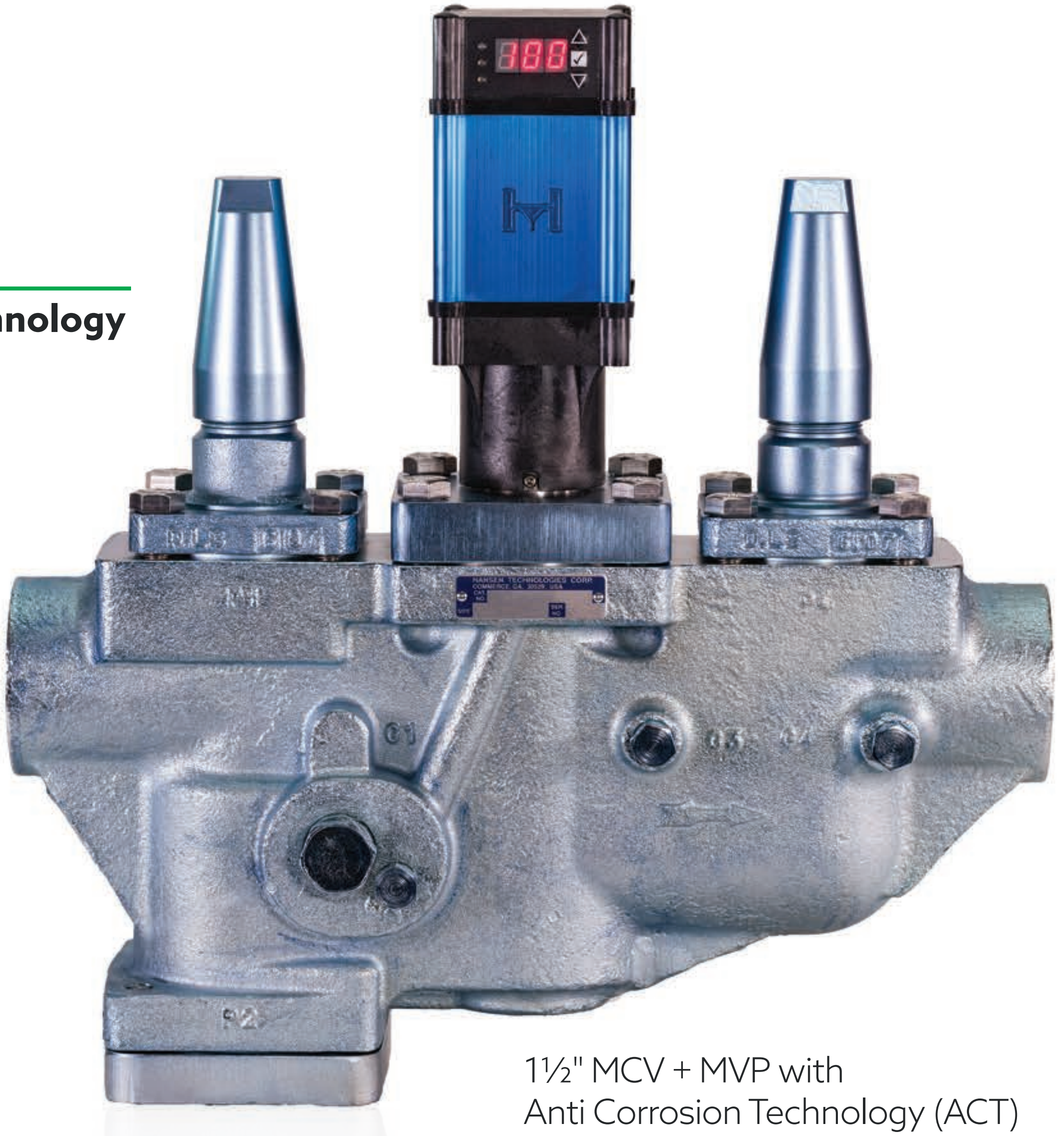
THE OFFICIAL MAGAZINE OF THE NATURAL REFRIGERATION INDUSTRY ■ DECEMBER 2018

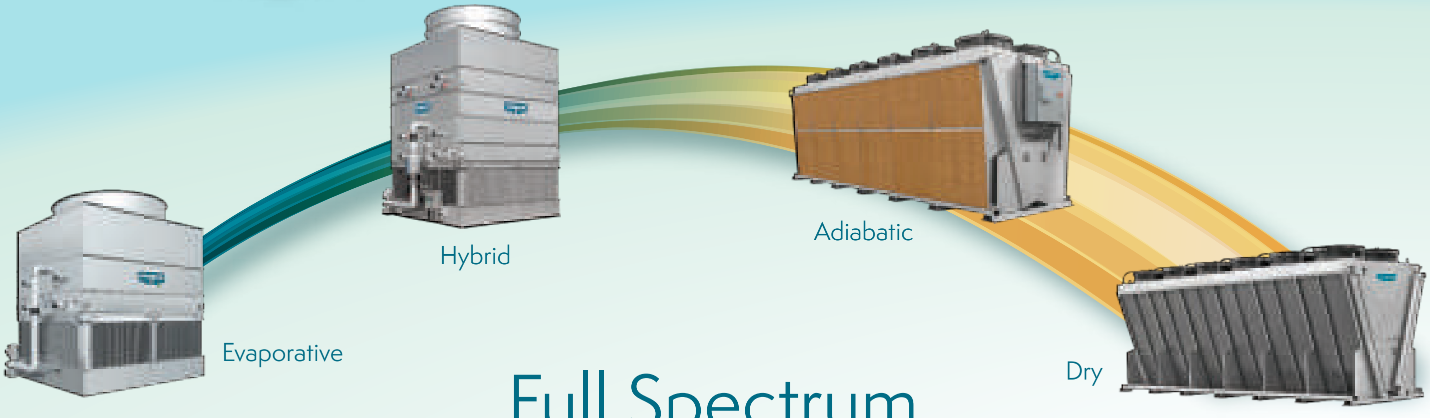
CONDENSER



THE LOCATION LANDSCAPE

How Local Regulations, State Operating Environments, and U.S. Geography are Shaping Building Decisions





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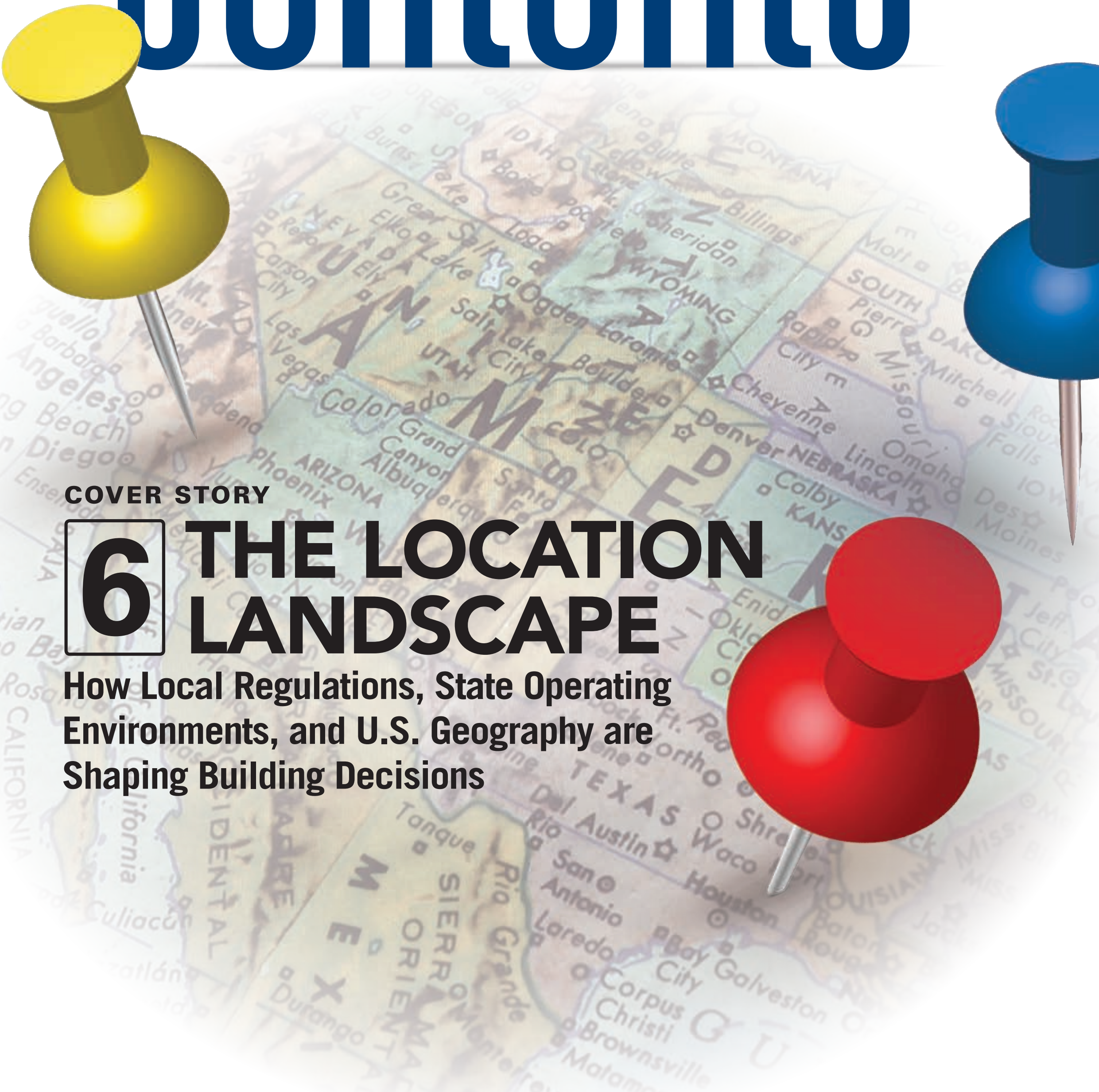
contents



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president's MESSAGE

BY DAVE RULE

This issue of the Condenser is all about operations. As you can see from our cover, one of the most important factors in that equation is geographical location. The regional and local operating environments define the business and regulatory landscape across the country. And that definition, in turn, determines how we uphold our high standards for safety and efficiency. The role that the regulatory framework plays in our industry, and even more importantly, how we respond to and inform it, is a central focus for IIAR.

The IIAR Suite of Standards is the primary way we ensure safety and compliance both within the regulatory world and within our own facilities and operations. And because the Suite of Standards was written intentionally in code language, it has become a significant asset to our membership due to its adoption into building and fire code and the reference and recognition given to it by regulatory agencies.

That has been one of IIAR's most important accomplishments, and thanks is due to our standards committee which has led the effort to develop and write these standards, as well as to the many IIAR member volunteers who have assisted in their formation. We also recognize the work of Jeff Shapiro and Lowell Randel, our code and government experts who have guided standards adoption into the code and regulatory community.

We're currently working on two more standards that will provide significant benefit to our members, proper guidance for regulators, and improved safety in our end user facilities.

The first is IIAR-6, "Standard for Inspection, Testing, and Maintenance of Closed-Circuit Ammonia Refrigeration Systems." Focused on inspection and testing, the final sections of the document are currently out for a fourth public review.

The complete document for IIAR-9, "Standard for Minimum System Safety Requirements for Existing Closed-Circuit Ammonia Refrigeration Systems," is currently out for a second public review.

Our standards committee and industry volunteers have vigilantly worked together, in accordance with ANSI procedures, to submit constructive comments and improve these important standards. And all of these important public review comments are being resolved to ensure the highest level of industry consensus.

Now it is vitally important to move these documents forward to address the needs of our industry and improve the safety, operations and practices in our facilities to make sure we keep pace with our rapidly changing technological and regulatory environment.

Unfortunately, our industry has suffered the loss of life in three ammonia release accidents in recent years. These events have highlighted, more than any message from me or advocacy effort ever could – the fundamental duty of IIAR members to uphold our industry's high standards of safety by actively participating in the formation and adoption of our standards.

In all three events, the necessary practices presented in IIAR-6 and IIAR-9 could have prevented these accidents and ensured the safety of operating and maintenance personnel.

Now is the time to move IIAR-6 and IIAR-9 forward to complete the consensus process and finalize the IIAR Board and ANSI certification process. Whatever role you have, whether you are directly involved in helping form these standards, or simply lead the implementation of IIAR's Suite of Standards in your own facility, I urge you to take action.

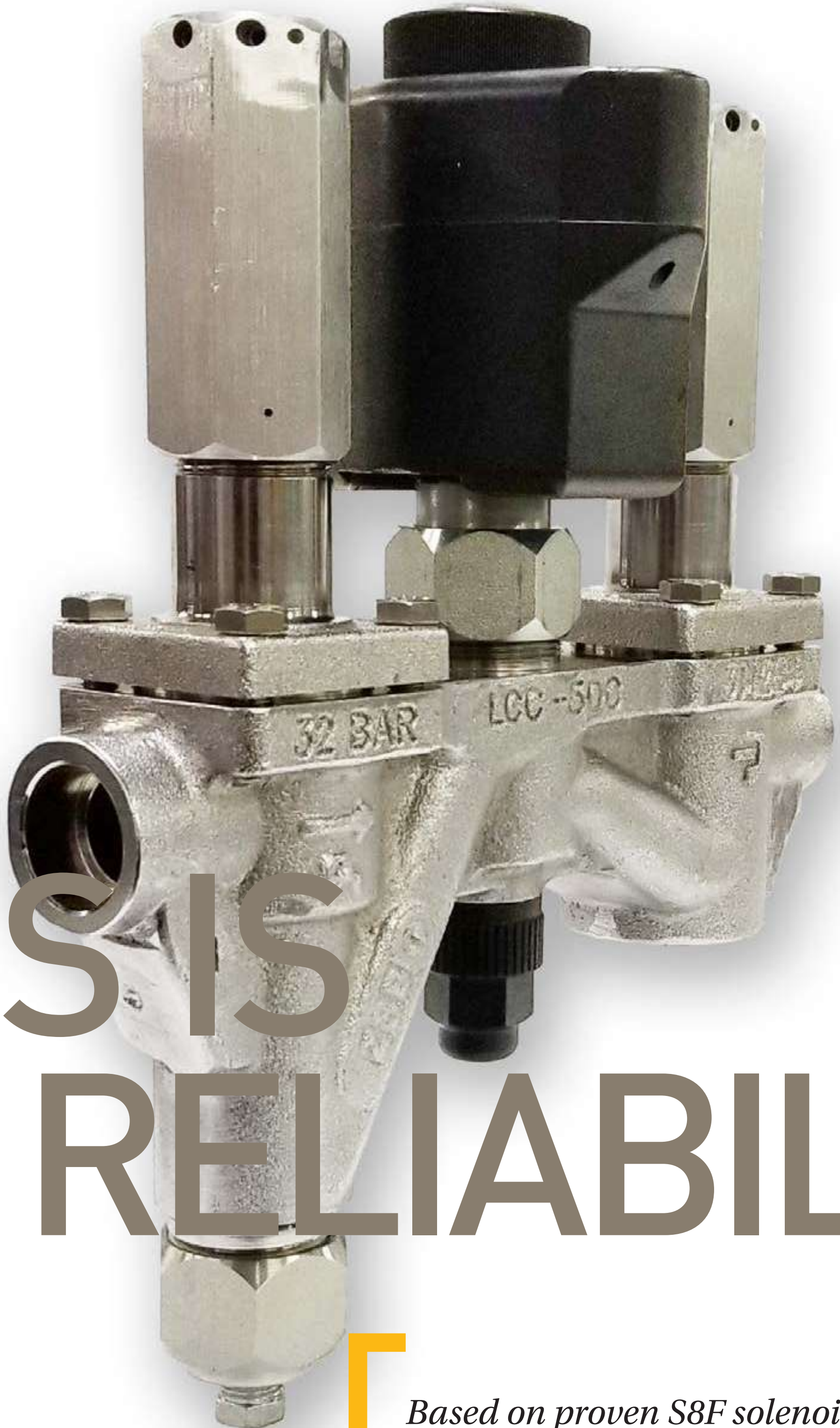
The industry recognizes the need to address inspection, testing and maintenance in our facilities and to develop appropriate RAGAGEP (Regularly Accepted Good Engineering Practices) to ensure the safety of our personnel and regulatory compliance.

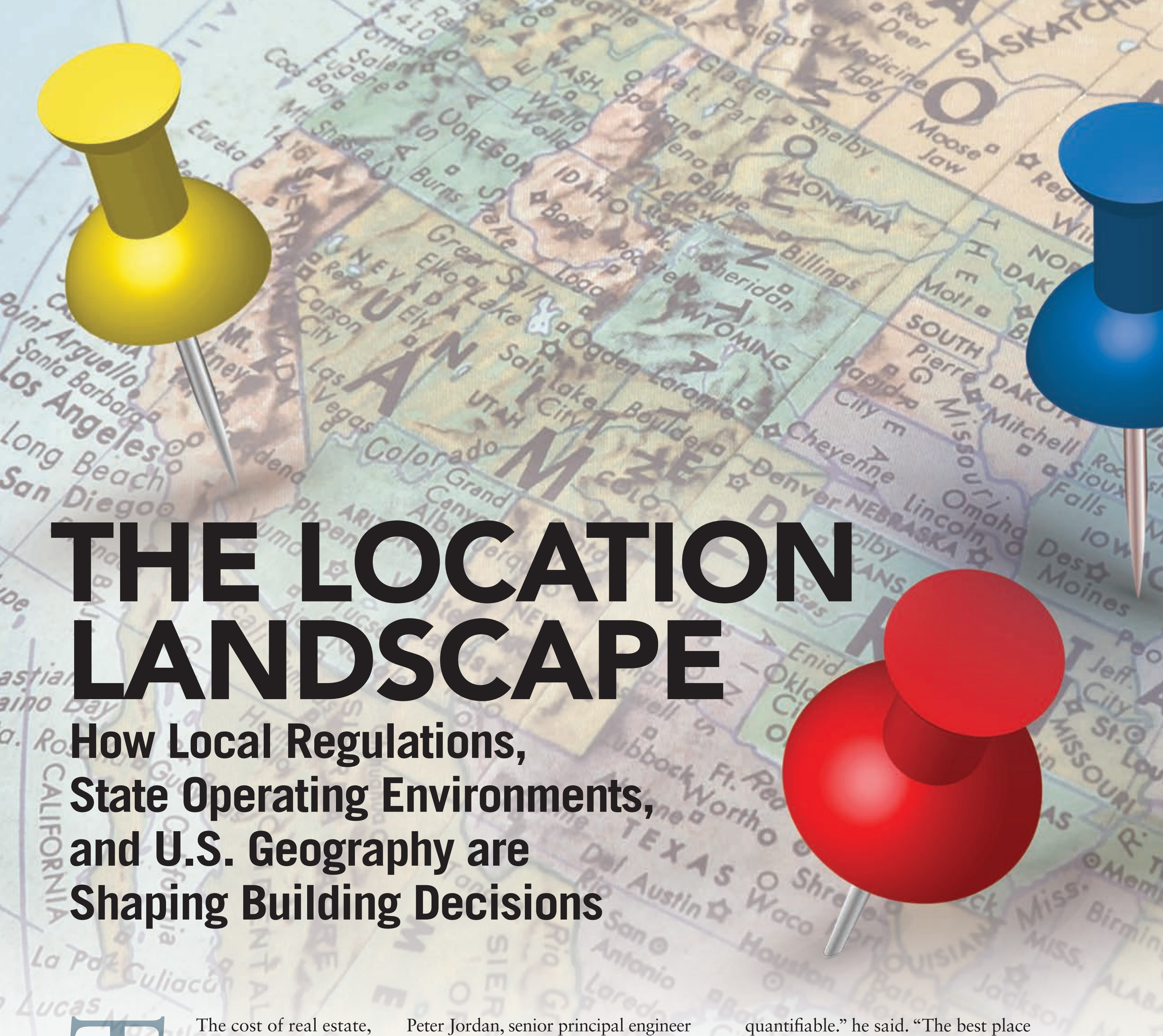
The operating facilities and safety operators are asking for these standards and I am happy to report that the IIAR standards committee and its many IIAR member volunteers are now ready to deliver.

This is a significant step forward for our industry in our mission to improve regulatory guidance and the general safety in all our facilities.

I'm looking forward to our organization's focus on standards development and education programs at our annual conference in Phoenix. Our expanded program will present a dual track of both commercial and industrial refrigeration tech papers, workshops and panels. And as always, you, as an IIAR member, represent the experience and institutional knowledge that keep our facilities, operators and the public safe. Your participation and membership are vitally important.

See you all in Phoenix!





THE LOCATION LANDSCAPE

How Local Regulations, State Operating Environments, and U.S. Geography are Shaping Building Decisions

The cost of real estate, an available workforce and proximity to transportation dictate where businesses build industrial refrigeration facilities, and those factors are more important than ever in recent years. As rising demand spurs cold chain growth, clear winner (and loser) locations are emerging from the patchwork of regional U.S. regulatory and business environments. Increasingly, those environments are taking center stage in decisions to build a facility or what refrigerant to use.

Some states, such as California and New Jersey, can take a hit on the issue of the cost of envionmental compliance, said Peter Jordan, senior principal engineer at MBD Risk Management Services Inc., which is based in Langhorne, Pennsylvania. “Facilities and large corporate companies know which states are more difficult from an environmental compliance standpoint than others and they absolutely take that into account,” he said.

Chuck Taylor, president of CRT Design which is based in Jacksonville, Florida, said it is very difficult to install an ammonia system in New Jersey. And, “no matter what you do in California, it is tough,” he added.

However, Eric Smith, vice president and technical director for IIAR, said there is no single formula businesses can use. “The best place is often not so easily quantifiable.” he said. “The best place depends largely on what you’re doing.”

REGULATORY RESTRICTIONS

Federal regulatory requirements include the Occupational Safety and Health Administration’s Process Safety Management standard and the Environmental Protection Agency’s Risk Management Program, but some states, including California and New Jersey, administer requirements at the state level. “They comply with the federal program, but they have other more restrictive covenants as part of their state mandate,” said Michael Lynch, vice president of engineering for U.S. Cold Storage, which operates 38 facilities across 13 states.

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Those within the industry know New Jersey is particularly onerous when it comes to refrigeration facilities.

New Jersey has regulations in place to protect the environment that are particularly stringent. “New Jersey developed the Toxic Catastrophe Prevention Act as a precursor to PSM/RMP,” Smith said, adding that enforcement can be quite strict. “Given those two factors, we know that some companies have moved out of New Jersey and others have chosen to just build smaller facilities with Freon-based systems or they just rely on neighboring states.”

Lynch said many companies avoid New Jersey by locating facilities in Delaware or Pennsylvania or they avoid using ammonia within the Garden State. “That is a problem because they tend to use a chlorofluorocarbon or hydrochlorofluorocarbons or some type of refrigerant, which is probably on someone’s watch list,” Lynch said.

“New Jersey isn’t against ammonia. But there are additional burdens,” Jordan said.

As a result, Taylor said that the location could dictate the type of refrigeration it might use.

Jordan noted that there are more ammonia and ammonia refrigeration companies in Pennsylvania’s Lehigh County than in the entire state of New Jersey. Lehigh County has a population of 350,000 whereas New Jersey has a population of 8.9 million, he noted.

Lynch said United States Cold Storage has located warehouses just inside the Pennsylvania border, which allows the company to service the Northeast without having to operate in the confines of New Jersey. “We’re not the only company that has done that. Unfortunately it puts the state of New Jersey at a disadvantage,” he said.

Several years ago, Ocean Spray closed its facility in Bordentown, N.J., which it had operated for more than 70 years, and relocated to Upper Macungie, Pa. When announcing the decision to move, Ocean Spray cited lower utility and transportation costs.

Industry experts said there are also disadvantages to locating in California. Bing Cheng, senior manager of utilities, environmental and sustainability programs for Campbell Soup Company, said it is difficult to maintain a profitable business model in the Golden State due to local regulations, such as AB-32 — the California Global Warming Solutions Act of 2006 — and utility costs.

In California, the cost of electric power is higher than in the other locations. “It costs seven to eight cents per kilowatt hour in the Midwest but 12 to 13 cents in California,” Lynch said. “That is the cost of doing business in the state.”

California’s environmental policies can be restrictive, Lynch said. “There are a lot of permitting fees and air-quality fees,” he explained. “You’re complying with the federal program, but then there are additional state layers of regulations that must be considered.”

Lynch added that permitting a site in California could cost $1 million to $2 million per location. In other states, such as Texas, it is much cheaper, with permitting running about $100,000 to

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$200,000. “They are more supportive of industry in Texas compared to what we’ve experienced in other parts of the country,” Lynch said.

U.S. Cold Storage has several operations in Texas and said the state is pro-business. “The regulatory laws there are fairly benign and the costs are low,” he said. “Our power costs in Texas are some of the lowest in the country.”

Cheng said Texas has additional attractive elements, including having no state income tax, good incentives, less intrusive local regulations, low labor wages and a central location.

However, Cheng said that while a state’s regulatory environment comes into play, the few greenfield sites that Campbell’s has initiated over the past decade haven’t been selected based on favorable industrial refrigeration regulations.

“I would say this would be lower on the criteria checklist,” Cheng said. Campbell’s has its world headquarters and one bakery site in New Jersey. “We are actually looking at CO_2 as an alternative for the bakery, which utilizes some R22-based refrigerant equipment. In partnership with Taylor’s CRT Design, we recently commissioned a new CO_2 refrigeration package for our world headquarters pilot plant centralized storage cooler and freezer.”

Taylor said the ammonia market in California is strong and always will be, mainly because the state has large fresh produce output.

Smith agreed. “With California, its climate is such that a large percentage of our country’s fruits and vegetables come from this area of the country. Many facilities are located not more than a mile or two from the place where the food is grown, and there is no other choice to this,” he said.

Campbell’s has two tomato plants in California that do not use any refrigeration. The company’s other California site, which is in Bakersfield, is well over the 10,000-pound ammonia threshold, which makes the facility subject to Federal PSM/RMP rules, due to the size and refrigeration load the facility requires.

California is leading the states initiative is to phase out HFCs and encouraging natural refrigerants,” Taylor said. “The whole movement towards low-charge ammonia systems is going to open up ammonia to be used in many other locations around the country. Ammonia is also being considered in many new applications that were historically commercial Freon systems and are now being approached with natural refrigerants.”

Cheng said several states follow California’s emission standards: Connecticut, Delaware, Michigan, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Vermont, Washington and the District of Columbia.

STATE-SPECIFIC NUANCES

Some states have state-specific design requirements. “These design elements may be onerous, but they’re done for a reason,” Smith said.

For example, California also has a progressive energy code, and warehouses have to be built to a high level of efficiency, which requires efficient, evaporative

condensers and refrigeration controls, Lynch said. There is also a high seismic classification, which adds expense.

Due to the risk of earthquakes, California requires pipes and vessels to be engineered to seismically withstand a quake. “You have to basically constrain the pipe to the building, and it just makes the design much more complex,” Taylor said.

Also in California, based on old codes, many localities require engine room exhaust scrubbing, Smith said. “It is not a state requirement but based on old state codes that have not been updated. Some municipalities require them because they’re familiar with them and they have not considered the new safety standards and technology available today.”

Smith said that in Illinois, the state boiler inspection division had a misunderstanding of the nature of ammonia refrigeration vessels and at one point asked companies to inspect the interior of the vessels for corrosion. “We have convinced them that it is not a phenomenon that occurs. They’ve reconsidered their enforcement policy, but haven’t taken an official position,” Smith said.

In very northern climates, it is common to block off sections of a condenser in the wintertime when it is so cold outside that the capacity for the condenser isn’t required. “A historical problem is that operators had a tendency to isolate a section and then forget to open it back up when the warm weather came along, creating a hydrostatic pressure problem,” Smith said.

Therefore some states instigated a code requirement to have relief valves installed on evaporative condensers.

Some fire departments are more stringent than others. “A lot depends on the official in charge and their beliefs,” Smith said, adding that the fire department in Phoenix, Arizona, is a proponent of using diffusion tanks to capture releases from relief systems. “That is because of one official who was convinced of their necessity based on old codes and his understanding. Our position is that they are a good idea if a refrigeration system is located in a highly dense population zone like a downtown or next to a nursing home or a hospital, but otherwise, this design may often create other operational and safety issues.”

Even the frequency of OSHA or EPA inspections can vary by state. “In some of the more rigorously enforced states, like California and Ohio, you may see them every three years. In New Jersey, even the smallest plants know they’ll most likely have an inspection by the New Jersey Department of Environmental Protection every year that lasts two to five days. That is the on-site time. It doesn’t include the preparation time,” Jordan said.

THE ROLE OF LOGISTICS

When selecting a location, Lynch said that location, particularly proximity to Interstate highways, is critical. “You don’t want trucks required to travel far off the highway and through side streets,” he said.

Smith said companies don’t want to be transporting raw materials very far from where the food products are grown. “Then you spend a lot of money trucking things around, and it is beginning to spoil at the same time,” he said. “Once food is processed and the initial heat is taken out, the processor can immediately begin to transport its products to distribution centers and cold storage facilities.”

Jordan agreed that the location of raw materials makes a difference. “If you’re packaging raw tomatoes, you want a facility where those are close,” he said, adding that at the opposite end of the spectrum is where customers are located. “A big soup market is in the Northeast United States. It would make sense to have your production facilities close to a ready market.”

Specific products have nuances that can also be influenced by geography. “You can’t really ship bulk ice cream through the Rockies because of the air in the ice cream. That is why many ice cream facilities have a high-altitude plant,” Jordan said.

Cheng said that supply chain management costs have been a key driver in Campbell’s recent distribution center initiatives. He added that the company has opened new product distribution centers in Findley, Ohio, and Fort Worth, Texas.

“We are also building a new distribution center in Fayetteville, North Carolina,” Cheng said, noting that Campbell’s strategy over the past decade has been to expand or upgrade existing manufacturing sites. “These centers are strategically located near our major manufacturing sites.”

Another factor is the availability of utilities, such as water, sewer and power. “You typically have all of those utilities readily available, but when you’re in unincorporated areas, water may not be nearby or in the quantities you need,” Lynch said.

THE IMPORTANCE OF A WORKFORCE

All facilities need labor, and Lynch said it is a top priority to be in areas with a competent workforce.

The cost of labor is a high priority for companies, Jordan said. “End users have to look at the availability of labor and subdivide that into an educated workforce versus key technical support.” He explained that in some operations technical support may be more important while others may seek out more unskilled labor.

Large facilities in New Jersey, such as a warehouse, require licensed operators on staff, which run about $100,000 a year, Lynch said. “You need one for each shift, but they can’t be away from the engine room for any period of time, so you’d have to have two,” he said, adding that with multiple shifts, costs could exceed $500,000 annually.

Jordan testified before the New Jersey Senate Environmental and Energy Committee in an attempt to convince lawmakers that they were stacking the deck against companies wanting to move into or stay in New Jersey. Additional refrigeration engineer costs and regulatory costs in New Jersey mean a medium-size plant pays between $25,000 to $100,000 more in initial upfront costs compared to what it would pay in other states. Annual maintenance costs run between $40,000 and $100,000 higher in New Jersey as well, Jordan said.

“As for licensing requirements like those that exist in New Jersey, to my knowledge there are no other states which have refrigeration licensing requirements,” Jordan said. “But there are licensing requirements in some individual cities in the U.S. For example within the boundaries of New York City, the person supervising the operation of an ammonia refrigeration system needs to obtain a Certificate of Qualification for ‘Refrigeration Operating Engineer’.”

Smith said technology has changed, but the requirements for certified operators have not. “We’ve tried to get things changed in New Jersey, but it is very difficult,” Smith said.

New Jersey has a more restrictive labor environment than some states in other regions of the country. “If you were a company that didn’t have a union, you’d be pressured into an organized-labor environment, which may or may not be something a company wants to do,” Lynch said.

According to the U.S. Labor Department’s Bureau of Labor Statistics, unions represent 16.9 percent of the workforce in California, versus just 5.8 percent in Texas. New Jersey’s rate of workforce union representation is 17.1 percent, while Pennsylvania is 13.0 percent.

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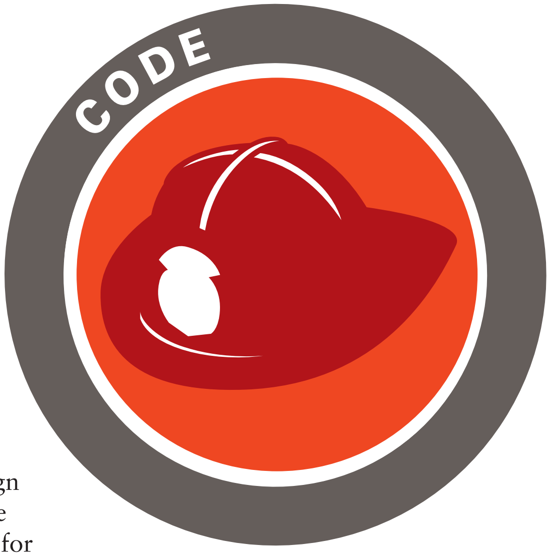
The 2018 and 2021 Codes: Where We Are & Where We Are Headed (Part 2)

JEFFREY M. SHAPIRO, P.E., FSFPE



Part 1 of this article presented IIAR's many successes in changing the 2018 editions of model mechanical, building, fire and electrical codes in working with FM Global to update their recommendations for facilities with ammonia refrigeration.

Part 2 provides a preview of IIAR's proposed changes to ASHRAE 15 and the 2021 model codes.

Some changes in code text in this article are shown in "legislative format" to indicate deleted text (strike-out format) and new text (underline format) for clarity.

> **Part 1 of this article presented IIAR's many successes in changing the 2018 editions of model mechanical, building, fire and electrical codes in working with FM Global to update their recommendations for facilities with ammonia refrigeration.**

2021 IMC

1101.1 Scope. This chapter shall govern the design, installation, construction and repair of refrigeration systems that vaporize and liquefy a fluid during the refrigerating cycle. ~~Refrigerant piping design and installation, including pressure vessels and pressure relief devices, shall conform to this code.~~ Permanently installed refrigerant storage systems and other components shall be considered as part of the refrigeration system to which they are attached.

1101.1.1 Refrigerants other than ammonia. Refrigerant piping design and installation, including pressure vessels and pressure relief devices, for systems containing a refrigerant other than ammonia shall comply with this chapter and ASHRAE 15.

1101.1.2 Ammonia refrigerant. Refrigeration systems using ammonia as the refrigerant shall comply with IIAR 2, IIAR 3, IIAR 4 and IIAR 5, and shall not be required to comply with this chapter.

~~**1101.6 General.** Refrigeration systems shall comply with the requirements of this code and, except as modified by this code, ASHRAE 15. Ammonia-refrigerating systems shall comply with this code and, except as modified by this code, ASHRAE 15, IIAR 2, IIAR 3, IIAR 4 and IIAR 5.~~

Discussion: *Similar to the 2018 UMC and the tentative acceptance of IIAR's 2021 NFPA 1 proposal (see below), the 2021 edition of the IMC will delete regulations for ammonia refrigeration in the in favor of referencing IIAR standards. The changes above show the core revision, which defers to IIAR standards 2, 3, 4 and 5. Additional changes, which are not shown here, are also proposed to remove all other references to ammonia refrigeration in Chapter 11.*

2021 IFC

605.1.2 Ammonia refrigeration (standards). Refrigeration systems using ammonia refrigerant and the buildings in which such systems are installed shall comply with IIAR-2 for system design and installation, IIAR 6 for maintenance and inspection, and IIAR-7 for operating procedures. Decommissioning of ammonia refrigeration systems shall comply with IIAR 8, and engineering practices for existing ammonia refrigeration systems shall be in accordance with IIAR 9.

Discussion: *References adopting IIAR 6 and IIAR 9 were approved for inclusion in the 2021 edition of the IFC, provided that the standards are completed by a December 2020 deadline, which IIAR expects to meet.*

605.10 Emergency Pressure Control System. Permanently installed refrigeration systems in machinery rooms containing more than 6.6 pounds (3 kg) of flammable, toxic or highly toxic refrigerant or ammonia shall be provided with an emergency pressure control system in accordance with Sections 605.10.1 and 605.10.2.

Discussion: *The original concept of emergency pressure control systems (EPCS) was to serve as a substitute for cross-over valves in manual emergency control boxes. Emergency control boxes were previously required only by the Uniform Fire Code (a model code that preceded the International Fire Code), with an expectation that am-*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monia could be transferred to another pressure zone or released to a water tank, treatment system or atmosphere to reduce system pressure in the event of a building fire that exposed the system to high temperatures.

Because the original focus of the EPCS concept was large, stationary equipment that would be found in a machinery room, IIAR considered it appropriate to submit this proposal to revise the requirements in a way that makes it clear that EPCS are not required for portable equipment or equipment located outdoors.

The change has been approved for inclusion in the 2021 edition of the IFC.

605.12.4 Ammonia Refrigerant (discharge). Systems containing more than 6.6 pounds (3 kg) of ammonia refrigerant shall discharge vapor to the atmosphere in accordance with one of the following methods:

1. Directly to atmosphere where the fire code official determines, on review of an ~~engineering~~ analysis prepared in accordance with Section 104.7.2, that a ~~fire,~~ health ~~or environmental~~ hazard would not result from atmospheric discharge of ammonia.
2. Through an approved treatment system in accordance with Section 605.12.5.
3. Through a flaring system in accordance with Section 605.12.6.
4. Through an approved ammonia diffusion system in accordance with Section 605.12.7.
5. By other approved means.

Exception: Ammonia/water absorption systems containing less than 22 pounds (10 kg) of ammonia and for which the ammonia circuit is located entirely outdoors.

Discussion: *The subject of refrigerant discharge from pressure relief valves (PRV) has been continuously evolving over the past 20+ years. From a default of having to discharge releases into large water diffusion tanks, previously required by some fire codes, to today's more performance oriented approach that permits atmospheric discharge in some cases, the industry has gained significant flexibility in venting options.*

The proposed changes to Item 1 above continue this evolution by reducing some unnecessary barriers to atmospheric PRV discharge outlets. Inclusion of the word "engineering" has unnecessarily suggested that the referenced analysis must be performed by a licensed engineer, precluding the use of other qualified individuals.

Also, "fire" and "environmental" have been eliminated as criteria to be evaluated in the analysis. Looking first at flammability, ammonia's lower flammability limit is in the range of 160,000 ppm (16% in air), and it becomes too rich to burn in the range of 250,000 *ppm or more (25% in air).*

Extinguishers on the vehicle are more readily accessible to the operator, which improves the speed of deployment, and this allowance also offers a way to avoid maintenance requirements associated with fixed fire extinguishers in refrigerated storage areas.

The difficulty of achieving ammonia ignition in an outdoor environment is recognized by UN/DOT, which does not classify ammonia as flammable for shipping purposes. Likewise, achieving a stable mix between the upper and lower flammable limit concentrations in open air as a result of vent-release scenarios isn't reasonably possible.

With respect to environmental analysis, ammonia is a natural refrigerant consisting of nitrogen and hydrogen, which are readily dissipated into the atmosphere upon release from a PRV outlet. While the release may be noxious, there is no basis for predicting that ammonia vapor released from a vent pipe into open air will harm the environment.

The change has been approved for inclusion in the 2021 edition of the IFC.

906.1 Portable Fire Extinguishers:

906.1 Where required. Portable fire extinguishers shall be installed in all of the following locations *(only Item 1 is shown because that is the only item affected by IIAR's proposal)*:

1. In new and existing Group A, B, E, F, H, I, M, R-1, R-2, R-4 and S occupancies.

Exceptions: *(only Exception 3 is shown because that is the only item affected by IIAR's proposal):*

3. In storage areas of Group S Occupancies where forklift, powered industrial truck or powered cart operators are the primary occupants, fixed extinguishers, as specified in NFPA 10, shall not be required where in accordance with all of the following:

3.1. Use of vehicle mounted extinguishers shall be approved by the fire code official.

3.2. Each vehicle shall be equipped with a 10-pound, 40A:80B:C extinguisher affixed to the vehicle using a mounting bracket approved by the extinguisher manufacturer or the fire code official for vehicular use.

3.3. Not less than two spare extinguishers of equal or greater rating shall be available onsite to replace a discharged extinguisher.

3.4. Vehicle operators shall be trained in the proper operation, use and inspection of extinguishers.

3.5. Inspections of vehicle mounted extinguishers shall be performed daily.

Discussion: *In large storage warehouses, such as cold storage facilities, where the occupants are primarily riding on powered industrial trucks, it makes more sense to provide suitable extinguishers on vehicles, as opposed to distributing them in fixed locations throughout a warehouse. Extinguishers on the vehicle are more readily accessible to the operator, which improves the speed of deployment, and this allowance also offers a way to avoid maintenance requirements associated with fixed fire extinguishers in refrigerated storage areas.*

The change has been approved for inclusion in the 2021 edition of the IFC.

2021 NFPA 1

Chapter 53 Mechanical Refrigeration:

53.1* General.

53.1.1 Applicability.

53.1.1.1* Refrigeration unit and system installations having a refrigerant circuit containing more than 220 lb (100 kg) of Group A1 or 30 lb (13.6 kg) of any other group refrigerant shall be in accordance with Chapter 53 and the mechanical code.

53.1.1.2 Temporary and portable installations shall be exempt from the requirements of this chapter when approved.

51.1.1.3 Ammonia Refrigeration Ammonia refrigeration systems shall be exempt from the requirements of this chapter, other than Sections 53.1.2 and 53.1.3.

53.1.2 Permits and Plans.

53.1.2.1 Permits, where required, shall comply with Section 1.12.

53.1.2.2 Plans and specifications for devices and systems required by this chapter shall be submitted to the AHJ for review and approval prior to installation.

53.1.3 Reference Codes and Standards.

53.1.3.1 Refrigeration systems using a refrigerant other than ammonia shall be in accordance with ASHRAE 15 and the mechanical code.

53.1.3.2 Refrigeration systems using ammonia as ~~a the~~ refrigerant shall ~~also~~ comply with ~~ANSI/~~ IIAR 2, ~~*Standard for Equipment, Design and Installation of Closed-Circuit Ammonia Mechanical Refrigerating Systems*~~ ~~IIAR 6, IIAR 7, IIAR 8 and IIAR 9~~.

Discussion: *Similar to the 2018 UMC and the tentative acceptance of IIAR's 2021 IMC proposal, NFPA 1 is poised* *to delete regulations for ammonia refrigeration in the 2021 edition in favor of referencing IIAR standards. The changes above show the core revision, which states that only the applicable requirements in Chapter 53 will be for permits and to follow IIAR's standards 6, 7, 8 and 9 (pending final completion of IIAR 6 and 9). Additional changes, which are not shown here, are also proposed to remove all other references to ammonia refrigeration in Chapter 53.*

IIAR's longstanding commitment to consolidating industry regulations, with an emphasis on eliminating conflict and overlap, produced significant results in the 2018 code editions and will show further success when the 2021 model codes are published. In addition, having ASHRAE 15 defer to IIAR standards for regulation of ammonia represents a landmark achievement for the ammonia refrigeration industry.

The NFPA 1 Technical Committee recommended this change for approval at their meeting in May 2018, but final acceptance will be subject to additional review pending completion of the public comment period.

2019 ASHRAE 15 (ADDENDUM A TO ASHRAE 15 2016 EDITION)

2. SCOPE

2.1 This standard establishes safeguards for life, limb, health, and property and prescribes safety requirements.

2.2 This standard applies to:

a. the design, construction, test, installation, operation, and inspection of mechanical and absorption refrigeration systems, including heat-pump systems used in stationary applications;

b. modifications, including replacement of parts or components if they are not identical in function and capacity; and

c. substitutions of refrigerants having a different designation.

2.3 This standard shall not apply to refrigeration systems using ammonia (R-717) as the refrigerant.

Informative Note: See ANSI/IIAR Standard 2 for systems using ammonia (R-717).

Discussion: *For decades, IIAR 2 has served as a companion to ASHRAE 15 for regulation of ammonia refrigeration systems, providing supplemental requirements that are applicable only when ammonia is used as the refrigerant. That approach changed upon publication of the 2014 edition of IIAR 2, which was written to serve as a comprehensive, independent document that can be applied without reliance on supplemental provisions in ASHRAE 15, fire codes or mechanical codes.*

Given that IIAR 2 no longer relies on ASHRAE 15, IIAR submitted a proposed Addendum A to the 2016 edition of ASHRAE 15 to remove ammonia systems from the scope of that standard and delete all ammonia-specific requirements from the standard.

The key part of this addendum, shown above, is the addition of a new Section 2.3, which exempts ammonia systems. In addition, an informational note has been added, which points to IIAR 2 for ammonia systems. This pointer was not allowed to be included directly in the code text because ASHRAE policy does not permit mandatory references to non-ASHRAE standards.

Following two public reviews, Addendum A was approved by the ASHRAE 15 technical committee and has been issued as an official addendum to the 2016 edition of ASHRAE 15. The changes will be directly integrated into the text of the 2019 edition.

In summary, IIAR's longstanding commitment to consolidating industry regulations, with an emphasis on eliminating conflict and overlap, produced significant results in the 2018 code editions and will show further success when the 2021 model codes are published. In addition, having ASHRAE 15 defer to IIAR standards for regulation of ammonia represents a landmark achievement for the ammonia refrigeration industry. The last major challenge in IIAR's initiative to make IIAR standards the "one stop shop" for ammonia refrigeration regulations will be the International Fire Code. That hurdle is on our agenda for the 2024 IFC code development cycle.

IIAR's accomplishments in the model codes and standards arenas are directly attributable to the hard work and dedication of the many volunteers who have contributed to IIAR's Standards Committee and the now-retired Code Committee. These efforts are always looking for new talent, and if you were interested enough in codes and standards to read this article and haven't yet participated, you're a good candidate for getting involved. Time to contact IIAR and let them know you're ready to jump in!

Understanding Compliance

BILL LAPE

I was talking recently to a professional acquaintance who told me that he is encountering more and more facility managers that ask him, “What is the minimum that we have to do to comply with 29 CFR 1910.119 and 40 CFR Part 68?”

He said others often go so far as to make a statement, “If we reduce our charge of ammonia in our refrigeration system, we won’t have to do any of the processes and paperwork spelled out in 29 CFR 1910.119 and 40 CFR Part 68.” When asked the nature of their question/comments, these people often go on to say, “We simply can’t afford the resources to deal with all of that paperwork.” Unfortunately, these people are looking at the costs of compliance when they should be looking at why the regulations were created in the first place.

On June 1st, 1974, an explosion rocked the Nypro plant when a coupling holding a temporary pipe in place ruptured, releasing an estimated 30 tons of flammable cyclohexane vapor. Cyclohexane was a precursor chemical used in the production of Caprolactum, an ingredient in Nylon 6. Twenty eight people were killed, and 36 were injured on site.

As far back as the dawn of the industrial age, there have been accidents that had a tremendous cost both in terms of the financial well being of the company, but more importantly in terms of injury or the loss of human life. In 1921, a silo at the BASF plant in Oppau, Germany that contained Ammonium Sulfate and Ammonium Nitrate fertilizer exploded when small dynamite charges were used to loosen the mixture in the silo, as it had a propensity to bind and clog. Between five and six hundred people were killed and around 2,000 more were injured. From the book entitled, “German Industry and Global Enterprise: BASF: The History of a Company” by Werner Abelshauser, Wolfgang von Hippel, Jeffrey Allan Johnson, and Raymond G. Stokes, simple damage costs are estimated to be 570 million Marks for the plant itself and 100 to 120 million Marks for the damage in the surrounding towns. In addition, the book indicates that 3.4 million Marks were paid as compensation to the families of the accident’s victims.

On June 1st, 1974, an explosion rocked the Nypro plant when a coupling holding a temporary pipe in place ruptured, releasing an estimated 30 tons of flammable cyclohexane vapor. Cyclohexane was a precursor chemical used in the production of Caprolactum, an ingredient in Nylon 6. Twenty eight people were killed, and 36 were injured on site. The casualties likely would have been higher, but the plant was operating with a skeleton crew during the weekend. Offsite, around fifty injuries were reported and somewhere on the order of 2,000 buildings were damaged. The resulting fires that raged at the plant burned for a week and a half despite the efforts of 250 fire fighters. The plant was rebuilt at a rough cost of £24 million. This does not include any costs incurred from the roughly 6,000 public liability insurance claims filed after the accident.

A few years later, on July 10, 1976, six tons of dioxins were released due to an overpressure in a reactor that occurred when the batch reaction process was shut down mid-cycle to comply with an Italian law that required shutdown of manufacturing operations over the weekend. As the facility shut down operations, the steam that was being used to heat the reactor rose in temperature due to lower loads on the steam system.

This overheated portions of the reactor and when the agitator was shut off, caused highly localized heating that resulted in a runaway decomposition reaction that increased pressure in the reactor until the vessel’s safety relief valve lifted. The release of chemicals poisoned a seven square mile area around the plant, and while there were no human fatalities, 3,300 animals were found dead over the next several days, and 80,000 animals were slaughtered to keep them from entering the food chain.

One hundred and ninety-three people were treated for skin lesions as a result of exposure to the high levels of dioxins. In the 40+ years since the accident, the region has experienced elevated levels of long term health effects, including cardiovascular and respiratory diseases. Costs estimates for the cleanup and compensation are estimated to be 20 billion lire. In 1986, two former employees of the company were sentenced


BRRR-ING IT.

to prison after exhausting their appeals for a conviction on charges of being responsible for the disaster and failing to provide adequate safety measures to prevent it.

Fast forward to 1984. On the night of December 2nd, roughly 30 metric tons of Methyl Isocyanate were released from a storage tank at a Union Carbide chemical plant in Bhopal, India, after a runaway reaction, believed to be due to the introduction of water into the tank, caused the pressure to rise uncontrollably in the tank, lifting the vessel's safety relief valves. Over 500,000 people suffered injuries in the shanty towns surrounding the plant and thousands were killed. Mitigation systems, such as a refrigeration system for the tank, a vent gas scrubber, and a vent gas flare stack that could have prevented or minimized the tragedy were offline at the time of the accident due to improper maintenance.

As a result of the accident, Union Carbide paid $470 million to the Indian government to pay for medical issues that are related to the exposure that may develop in the survivors. The company also paid $17 million to construct a hospital in Bhopal. Seven former employees of the Indian subsidiary were convicted of causing death by negligence and sentenced to two years in prison and fines of 100,000 rupees each. Warren Anderson, the CEO of Union Carbide at the time of the accident was charged with manslaughter in 1991, but the U.S. refused to extradite him. A class action suit against him was dismissed in 2012 after having been filed in 1999 under the U.S. Alien Tort Claims Act.

Now let's jump a little closer to home. On October 23, 1989, an explosion rocked the Phillips 66 chemical plant in Pasadena, TX, throwing debris 6 miles and killing 23 people. An additional 314 people were injured. During routine maintenance to clear a choke on the drop leg on a reactor used in the manufacture of High Density Polyethylene (HDPE), air lines that control the valve operation were incorrectly attached, causing the valve to open when it should have remained closed. This caused approximately 39 tons of flammable vapors to be released, which exploded upon reaching an ignition source. The resulting blast caused $715.5 million in damage with an additional estimate of $700 million in business interruption. Subsequent to the explosion, Phillips 66 agreed to pay $4 million in fines as part of a settlement with the Occupational Safety and Health Administration. This accident was the straw that broke the camel's back in the U.S. and led to the promulgation of OSHA's Process Safety Management standard (29 CFR 1910.119) and EPA's Chemical Accident Prevention Provisions (40 CFR Part 68).

Now many in our industry might say, "Those are chemical plants. We don't have accidents like that with ammonia refrigeration." Perhaps not on that scale, but here's some food for thought. On December 11, 1983, a large ammonia leak occurred at the Borden Ice Cream plant in Houston, TX. Firefighters responded to the scene. As they were suiting up to enter to try to contain the ammonia leak, it deflagrated, blowing out the sides of the building and showering the street with glass, bricks, ice cream, and wooden ice cream sticks.

Thankfully, no one was killed or severely injured. If the blast had occurred but a few minutes later, or the firefighters had attempted to enter but a few minutes earlier, the consequences would have been disastrous. However, the plant was never rebuilt. This was the first time that firefighters had experienced what happens when ammonia burns. It was followed by another incident shortly thereafter. On September 7, 1984, a large ammonia leak at Dixie Cold Storage in Shreveport, LA, resulted in a deflagration that killed one firefighter and severely injured another.

On August 23, 2010, thirty two people were hospitalized when 152 people were exposed to anhydrous ammonia after 32,000 lbs were released from the Millard Refrigeration Services facility in Theodore, AL. The release was due to a hydraulic shock event that ruptured a 12 inch suction header on the roof and a distributor on an evaporator inside the building. The company paid a $10,750 fine to OSHA after a protracted legal battle and the company was sold in 2014. While this event did not cause any fatalities, two more recent events did.

On March 23, 2016, a maintenance worker at Stavis Seafoods in Boston lost his life when a pipe nipple at the bottom of a Controlled Pressure Receiver cracked releasing liquid ammonia and overcoming the employee. As if one fatality is not bad enough, on October 17, 2017, three people, including one contract employee, died when an ammonia release occurred at the Fernie Memorial Arena in Fernie, British Columbia.

These are but a few examples of the accidents that have occurred in the ammonia refrigeration industry. The regulations that encompass process safety in the United States apply to facilities with over 10,000 pounds of ammonia in a process (or interrelated processes). If your facility has less than that, the General Duty Clauses found in the OSH Act and in the Clean Air Act, give OSHA and the EPA the power to enforce many of these regulations under the requirement of keeping employees and the public free from harm.

However, simple compliance and fine avoidance is not the reason that we should be implementing a robust Process Safety Management program. If we don't take steps to ensure that our system is designed, built, operated, and maintained safely, then the consequences could be severe, ranging from financial and business losses, through criminal or civil penalties, all the way to potential employee injury and loss of life.

This goes beyond the paperwork. It includes committing the necessary resources to keep your systems safe and includes not only money for maintenance and capital improvements, but also training for your maintenance mechanics and refrigeration operators. These resources are vital to keep your business operating without interruption. But more importantly, as managers in industry, whether you are a facility supervisor, or whether you are a Chief Operating or Executive Officer, it is your responsibility to ensure that your employees, your contract employees and visitors, and the public are safe. Isn't that what each of us mean when we say "Safety First?"

Bill Lape is Project Director for SCS Engineers. The opinions expressed within are solely his and do not necessarily reflect the opinions, policy or position of SCS Engineers or its affiliates. Bill is a Certified Industrial Refrigeration Operator and a member of the National Board of Directors of the Refrigerating Engineers and Technicians Association.

ARF news

AMMONIA REFRIGERATION FOUNDATION

DAVE L. RULE
PRESIDENT, IIAR

Dear Colleagues,

The end of the year offers a time of reflection and an opportunity to give back to the programs, organizations and people that have supported us throughout the year. I am excited to tell you about all your foundation has accomplished in 2018 . . . and issue a challenge to you to get involved by giving to the programs which create opportunities to sustain the future of our industry.

The Ammonia Refrigeration Foundation is a 501(c)(3) education and research organization, which means all donations are fully tax deductible. Whether you choose a large corporate gift, participate in our individual giving program, set up a planned gift, or participate in this year's annual William E. Kahlert Memorial Golf Tournament in Phoenix, it's never been easier to give back to your industry. The return on that investment has never been more important.

We have witnessed a significant increase in the number of students participating in our scholarship programs in 2018, with several of them accepting new jobs with IIAR member companies. The Foundation also continues its partnership with RETA to fund education for veterans and assist in their transition into the many job opportunities offered in this industry. Attracting new engineering and technician talent is a vital pursuit for the future of our industry and requires sustained activity and financial support.

In addition, three of our Foundation research projects – which will provide significant benefits to our members moving forward — are nearing completion as 2018 draws to a close.

An insulation study will soon yield best practices and procedures for the installation of insulation in our systems, a data correlation study will be used to update the IIAR Piping Handbook and ensure more accurate piping selections in our system designs, and an ammonia CFD analysis will produce scientific analytics that will support recommendations to place ammonia detectors in a refrigerated space.

This research, a growing scholarship program and the many other programs the Foundation supports are making your industry a better, safer and more rewarding place for all of us to work.

I hope you are as excited as I am to see our Foundation giving back so much to the industry we have all devoted our professional careers to serve. Please join me in contributing your time and financial support to sustain these important Foundation programs. (www.NH3Foundation.org)

As an industry pioneering natural refrigerants at a time of immense technological and environmental change, your support will help us define what the future looks like for years to come.

Sincerely,

David L Rule

David L. Rule
President, IIAR

–FOURTH ANNUAL–

WILLIAM E. KAHLERT MEMORIAL GOLF TOURNAMENT

March 2, 2019

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For more information, email us at golf@nh3foundation.org

In conjunction with the 2019 Natural Refrigeration Conference and EXPO
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Year-End Tax Planning Strategies

FINANCIAL TECH TIP

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

If you are not engaging in year-end tax planning, you could be leaving money on the table. Consider the following strategies to identify potential opportunities to lower your 2018 (or 2019) tax bill. Be sure to consult with your a qualified tax professional before implementation.

TAX GAIN/LOSS HARVESTING

Toward the end of the year, review your taxable investment accounts with your financial advisor to determine whether year-to-date sales and purchases result in a capital gain or capital loss. If faced with a gain, consider harvesting unrealized losses. Alternatively, if faced with a loss, consider harvesting unrealized gains. The ability to offset capital gains can be a valuable tool if implemented as part of a holistic tax planning strategy that considers all available tax information, including additional sources of taxable income (or losses) and capital loss carryforward available from the previous tax year.

The standard deduction amount was nearly doubled by the tax reform bill signed into law by President Trump on December 22, 2017. As a result, many taxpayers who itemized their deductions in 2017 will no longer itemize their deductions in 2018.

REQUIRED MINIMUM DISTRIBUTIONS (RMDS)

Although RMDs must generally begin by April 1 of the year following the year in which the account owner reaches age 70 ½, the first distribution calendar year is the year in which the account owner reaches age 70 ½. Thus, if you reach age 70 ½ in 2018, you can delay the first required distribution until 2019. However, if you do this, you will have to take a double distribution in 2019 (i.e., the amount required for 2018 plus the amount required for 2019). Failure to take an RMD can result in a penalty of 50% of the RMD amount not withdrawn.

If faced with RMDs, consider a qualified charitable distribution (QCD). A QCD is a direct transfer of funds from your IRA to a qualified charity. Generally, RMDs are considered taxable income. However, your RMD is excluded from income to the extent the QCD strategy is utilized. For example, if your RMD for the year is $10,000 and you make a $7,000 QCD, only $3,000 of your RMD will be taxed.

POSTPONEMENT OF INCOME AND ACCELERATION OF DEDUCTIONS

Some taxpayers may benefit from postponing income. This strategy may allow those taxpayers to claim deductions, credits, and other tax breaks for 2018 that otherwise may have been phased out if adjusted gross income (AGI) were allowed to exceed certain thresholds. These benefits include child tax credits, higher education tax credits, and deductions for student loan interest. Those taxpayers who anticipate being in a lower tax bracket in 2019 may also benefit from postponing income.

Conversely, some taxpayers may benefit from accelerating income into the current tax year. This strategy could be particularly useful for taxpayers whose 2018 marginal tax rate will be lower than their 2019 marginal tax rate. Additionally, by reducing income for the upcoming tax year, taxpayers may be able to take advantage of additional deductions and/or credits.

Below are some examples of how you may be able to shift income/expenses between tax years:

Talk to your employer about deferring your 2018 bonus until early 2019.

Consider using a credit card to pay deductible expenses before the end of the year. Doing so will increase your 2018 deductions even if you do not pay your credit card bill until after the end of the year.

Apply a bunching strategy to medical expenses. These expenses are only deductible to the extent they exceed 7.5% of your 2018 AGI.

Consider making charitable gifts. Rather than gifting cash, donate appreciated stock that you have held for more than one year. Take it to the next level by using an advanced charitable giving strategy such as a donor-advised fund, charitable remainder trust, or QCD.

CAUTION:

The standard deduction amount was nearly doubled by the tax reform bill signed into law by President Trump on December 22, 2017. As a result, many taxpayers who itemized their deductions in 2017 will no longer itemize their deductions in 2018. Be careful not to waste your time postponing or accelerating

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itemized deductions if you will be taking the standard deduction on your next return. For help determining whether you should anticipate itemizing your deductions, speak with your Stifel Financial Advisor and a qualified tax professional.

Additional information is also available in a recent Stifel article entitled, “To Itemize, or Not to Itemize? That Is the Question.”

Implement Roth Conversion Strategies

There are a number of benefits for those who convert traditional IRA funds into Roth IRA funds, including:

Tax-free growth.

Roth IRAs are funded with after-tax dollars. Generally, when distributions are taken from a Roth IRA, there is no tax due on the original contributions or any subsequent growth.

No RMDs.

Unlike traditional IRAs, Roth IRAs are not subject to RMDs.

Reduced traditional IRA RMDs.

Converting funds from a traditional IRA to a Roth IRA reduces the traditional IRA balance, which, in turn, reduces the size of RMDs the traditional IRA owner will eventually be forced to take.

CAUTION:

The amount of the conversion will be considered taxable income just like any other distribution from a traditional IRA. Under previous tax law, taxpayers were allowed to undo or “recharacterize” Roth conversions. Under the current tax law, however, recharacterization is no longer permitted. Any conversion of funds from a traditional IRA to a Roth IRA is final. For this reason, you may consider delaying Roth conversions until the end of the tax year when total taxable income is more easily projected.

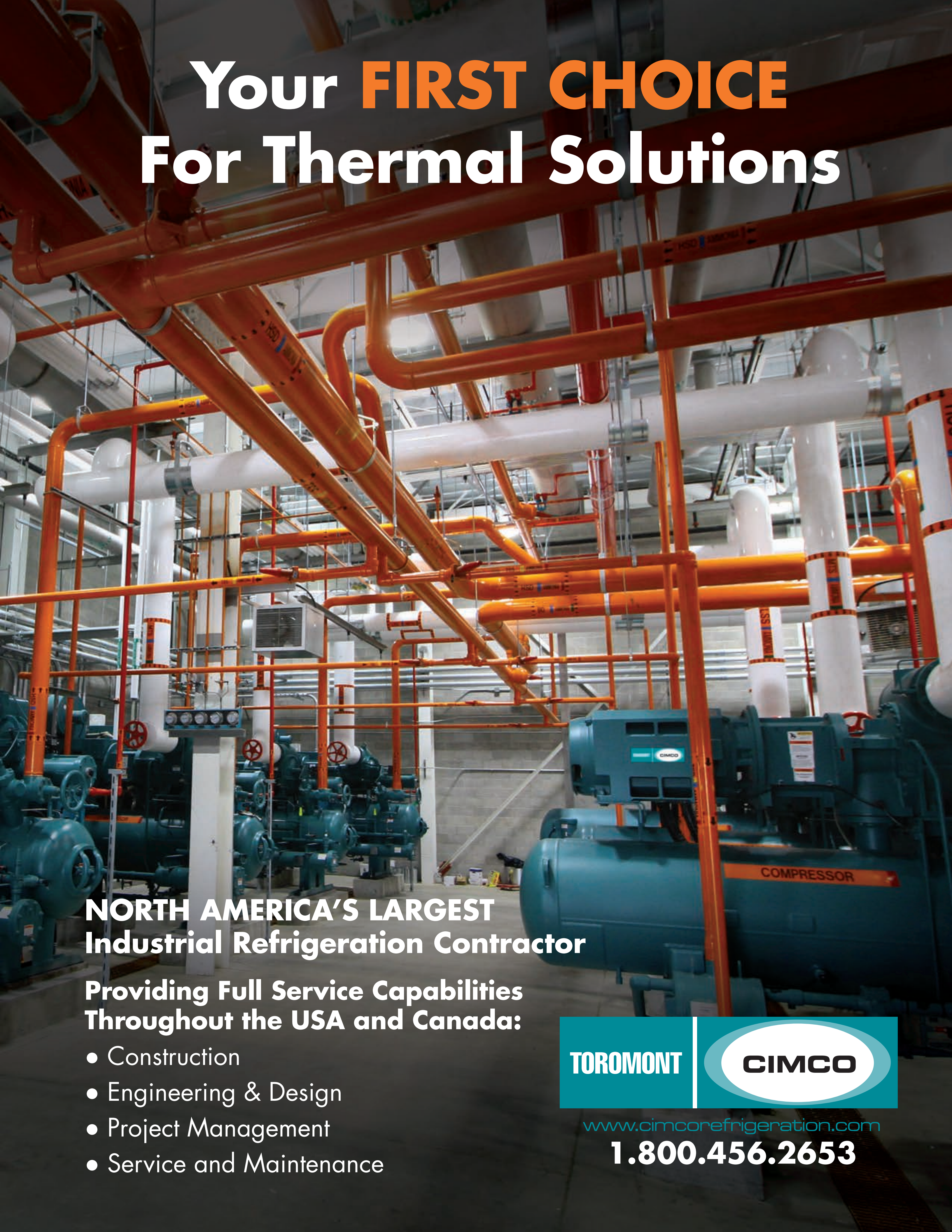
Utilize Annual Exclusion Gifts

In 2018, every individual has the ability to make $15,000 gifts to an unlimited number of recipients without any estate or gift tax consequences. You cannot carry over unused annual exclusion gifts from one year to the next. In addition to the estate and gift tax benefits, annual exclusion gifts may save families income taxes when income-producing property is given to family members who are in lower income tax brackets and are not subject to the kiddie tax.

These are just some of the year-end steps that can be taken to reduce your income tax burden. Please contact your financial advisor if you have additional questions about one of the strategies discussed above.

The IIAR and ARF reserve investment funds are currently managed by Stifel Financial Services under the investment policy established by their respective board of directors. Members of IIAR may use the services of Stifel for personal and business investments and take advantage of the reduced rate structure offered with IIAR membership. For additional wealth planning assistance, contact your Stifel representative: Jeff Howard or Jim Lenaghan at (251) 340-5044.

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


COMPRESSOR

Awareness

BY KEM RUSSELL

Are you "aware" in all, or at least most of the aspects of your life? Awareness implies that you have knowledge of something by maintaining a level of alertness in observing or in interpreting what you see, hear, feel, etc. Some people are very aware, but most of us limit our awareness to what we concentrate on. We focus so much on a specific "thing" that we don't realize there is a forest of "things" out there, with many potential outcomes that can impact us for good or bad.

Many years ago a very good friend of mine, Patrick Johnson, responded to an ammonia leak at a facility in Shreveport, Louisiana, where he served as a Fireman. During this incident, more than once, Patrick had the feeling that something just wasn't right. They had followed proper procedures in responding by briefly referring to the information sources they had about ammonia, which at that time didn't alert them to some critical information. They did not know that under certain conditions and at high concentrations, ammonia vapor could ignite.

The first entry into the facility, and the room where the ammonia leak was located, was made by two of the facility personnel along with two fire fighters. All of them had on SCBA's, but the facility personnel did not have on totally encapsulating suits. Due to the high PPM of ammonia in the room, the facility maintenance men soon began feeling a burning sensation under their clothes and couldn't stay in the room. Patrick's partner Percy noticed that the facility men were gone, and they decided to also leave. Once outside, they saw the facility men being washed down to stop the burning sensation of the ammonia on their skin. After further discussion with the maintenance men, it was decided to try one more time. After seeing what had happened to the maintenance men, and recalling the condition in the room where the leak was located, Patrick had an uneasy feeling about the situation. Percy felt it was worth trying again, so together they decided to make a second entry.

Unfortunately, not long after entering the room the second time, a spark was created when the forklift being used changed directions, and the ammonia in the room ignited. Both Patrick and Percy were wearing butyl rubber totally encapsulated suits, which mostly melted. Patrick was severely burned and has had to live with the results of those burns all his life. Patrick became a strong advocate for the use of ammonia, and the safe and proper response to ammonia incidents. Over the many years I've known Patrick, he often wondered how would things have turned out had he just followed his "gut feeling?"

At the IIAR Annual meeting in 2016, the keynote speaker was Dr. Joe MacInnis. He gave an informative, fascinating, and extremely interesting talk. In the book Dr. MacInnis wrote titled "Deep Leadership Essential Insights From High-Risk Environments," in the chapter "Fierce Ingenuity," he makes a statement that relates to our awareness. He says, "To prepare for the hard moments, you master all the details. There are hundreds, maybe thousands of them and they contain the truth about your state of readiness. Ignore them and you expose yourself to hasty and superficial decisions."

Awareness can be, and many times is, critical to our proper response to the world around us. Being aware is not a one-time thing, where you are aware and always will be aware. To be aware we must consciously think about the details – such things as: what am I doing, where am I, what is around me, who else is around me, what are the potential results from my actions, what do I hear, see, feel, etc. In our field of industrial refrigeration (as well as other aspects of life) work on improving your awareness and thus improve your state of readiness to make the best decisions. Taking the appropriate actions at the time they are needed is always worthwhile.

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Supreme Court Declines to Hear HFC Case, EPA Proposes Removing HFC Leak Requirements

iiar government RELATIONS

BY LOWELL RANDEL, IIAR GOVERNMENT RELATIONS DIRECTOR

On October 9th, the Supreme Court of the United States declined to consider the case of whether the Environmental Protection Agency (EPA) has the authority to regulate hydrofluorocarbons (HFCs) under the Significant New Alternatives Policy (SNAP) program. The case originated from a lawsuit brought by two HFC international manufacturers (Mexichem and Arkema) that sued EPA challenging the validity of an EPA rule requiring manufacturers to replace HFCs with refrigerants that have a lower global warming potential. The District Court found that the SNAP program only authorizes the regulation of ozone depleting substances and not substances with high global warming potential. The D.C. Circuit Court of Appeals upheld that ruling in an opinion written by Brett Kavanaugh, who has since been confirmed as a Justice on the Supreme Court.

In response to the lower court actions, chemical companies Honeywell and Chemours, manufacturers of refrigerant alternatives to HFCs, along with the Natural Resources Defense Council (NRDC) petitioned the Supreme Court to reverse the lower court's ruling and enable the SNAP program to restrict HFC use. Sixteen states and the District of Columbia have filed an amicus brief in support of the petitions filed by Honeywell, Chemours and NRDC. The Supreme Court denied a writ of certiorari to consider the case. Kavanaugh did not participate in the decision.

With the question of SNAP authority to regulate HFCs having been decided by the courts, EPA is reconsidering its overall approach to HFCs. On September 18th, EPA issued a proposed rule entitled: "Protection of Stratospheric Ozone: Revisions to the Refrigerant Management Program's Extension to Substitutes." The proposed rule reflects EPA's reinterpretation of how systems containing substitute refrigerants such as hydrofluorocarbons (HFCs) can be regulated.

In November 2016, nearing the end of the Obama Administration, EPA finalized a rule that extended the requirements of the Refrigerant Management Program to cover substitute refrigerants, such as HFCs. The 2016 policy contained requirements including: (1). Lowering the leak rate thresholds that trigger the duty to repair refrigeration and air-conditioning equipment containing 50 or more pounds of refrigerant (2). Requiring quarterly/annual leak inspections or continuous monitoring devices for refrigeration and air-conditioning equipment that have exceeded the threshold leak rate and (3). Reporting to EPA when systems leak 125 percent or more of their full charge in a calendar year.

The 2018 proposed rule presents a change in the agency's thinking about its authority to regulate HFCs. The current Administration, in the wake of the court case ruling that EPA cannot regulate HFCs through the SNAP program, is interpreting that it also lacks the authority to regulate HFCs under the Refrigerant Management Program. As a result, EPA is proposing to rescind the leak repair and maintenance requirements for HFCs, while leaving the provisions in place for ozone depleting refrigerants.

If finalized as proposed, systems with 50 or more pounds of substitute refrigerants would not be subject to the following requirements:

- Conduct leak rate calculations when refrigerant is added to an appliance.
- Repair an appliance that leaks above a threshold leak rate.
- Conduct verification tests on repairs.
- Conduct periodic leak inspections on appliances that exceed the threshold leak rate.
- Report to EPA on chronically leaking appliances.
- Retrofit or retire appliances that are not repaired.
- Maintain related records.

In addition, EPA is also considering the rescission of other provisions that were extended to HFCs including:

- Anyone purchasing refrigerant for use in an appliance or handling refrigerants (e.g., air-conditioning and refrigeration service contractors and technicians) must be a Section 608-certified technician.
- Anyone removing refrigerant from a refrigeration or air-conditioning appliance must evacuate refrigerant to certain level using certified refrigerant recovery equipment before servicing or disposing of the appliance.
- The final disposer (e.g., scrap recycler, landfill) of small appliances, like refrigerators and window air conditioners, must ensure and document that refrigerant is recovered before final disposal
- All used refrigerant must be reclaimed to industry purity standards before it can be sold to another appliance owner.

EPA held a public meeting on October 16th to hear from interested parties on the proposed rule. The public comment period ended on November 15th and EPA is now evaluating the comments received. A final rule is expected in 2019.

While the U.S. federal policy, via court cases and EPA proposed rules, is currently moving away from HFC regulation, the overall trend towards phasing down HFCs continues. The Kigali Agreement, which incorporates HFC phase downs into the Montreal Protocol is poised to go into effect on January 1, 2019. The ratification of Kigali by 20 countries is needed for the agreement to enter into force. At the end of October 2018, 58 countries had successfully ratified the agreement setting the stage for implementation at the beginning of 2019.

Energy and Function Analysis of Hot Gas Defrost in Ammonia Refrigeration Systems

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ABSTRACT

Ammonia has over decades proven its value as an effective refrigerant, but choosing the right—and correctly sized—defrost and control methods is important to ensure high efficiency.

Traditionally one of two methods for controlling drainage of the evaporator during hot gas defrost is used: pressure control, which keeps the pressure in the evaporator constant during defrost, or liquid drain control, which uses a float valve to drain condensed liquid from the evaporator. Each method's energy consumption is quite different, as the pressure-control method bypasses a certain amount of hot gas during the defrost period.

This paper is based on results from a research project focusing on energy savings potential during hot gas defrost in ammonia refrigeration systems (ELFORSK project 347-030).

In the ELFORSK project, an ammonia pumped circulation system was built at the Danish Technological Institute, enabling detailed measurements of the defrost system. Two methods of hot gas defrost were tested and analyzed (pressure control and liquid drain method), as were three evaporator designs (bottom feed, top feed, and side/bottom feed). A simulation model was also developed and validated using the measurements.

This paper will focus on the design requirements of the two most common defrost methods for ammonia systems (pressure control and liquid drain method) and describe the design requirements for both systems to obtain the highest efficiency. The efficiency of the two defrost systems will be analyzed and compared.

INTRODUCTION

Over time, air coolers in refrigeration systems, operating below the freezing point, will be covered with ice/rime. To ensure that the system is operating efficiently, the evaporator must be defrosted. The goal of a defrost is to remove the ice/rime from the heat exchanger surface. An effective defrost is a key feature of the system to preserve the plant's overall efficiency and product quality. In an ideal defrost, all added heat will be used to melt the ice on the evaporator surface, with a minimum of heating of the evaporator coil and the cold room.

Several elements should be considered when evaluating the effectiveness of a defrost, including:

- Removal of all ice/rime from the air cooler surface with minimum energy consumption, including
  - Minimum heat transfer into the refrigerated space,
  - Minimum transfer of moisture from the surface of the air cooler into the refrigerated space, and
  - Minimum flash gas and noncondensed hot gas bypass through the evaporator (gas will flow directly to the compressor for recompression);
- Electrical energy used for the defrost process;
- Defrost cycle duration; and
- Reliability and safety of defrost process.

Numerous defrost methods are known in the industry. Figure 1 shows the most common. The different systems have their pro and cons when in terms of effectiveness and cost.

Electrical defrost is the most common defrost method with an "external" heat source. From an application point of view, electrical defrost is an easy and attractive solution, but from an operational cost point of view it is very expensive—especially for low-temperature systems.

In hot gas defrost systems the heat comes from within the refrigeration system as "free energy." However, selecting the right method to control the hot gas supply to the evaporator is important to ensure that energy losses are minimized. Losses typically come from flash gas and noncondensed hot gas passing through the evaporator.

Figure 1. Defrost Methods

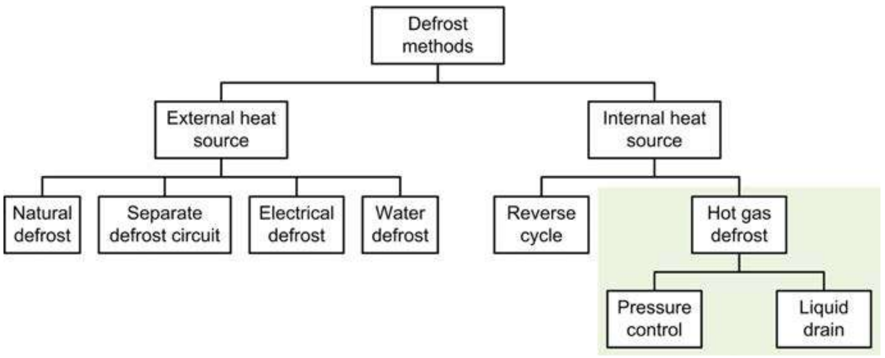


Figure 2 illustrates two methods for controlling the hot gas supply to the evaporator that are traditionally used:

- Pressure control method: the pressure in the evaporator is controlled during defrost with a back-pressure control valve in the defrost drain line. The pressure control method is the most commonly used method in the industry, mainly due to the simple design, but the energy losses are a challenge.
- Liquid drain method: condensed liquid is drained from the evaporator using a float valve in the defrost drain line. The liquid drain method ensures that only liquid refrigerant is drained from the evaporator during defrost, thereby minimizing noncondensed hot gas flow.

Noncondensed hot gas bypass happens when the evaporator cannot condense all supplied hot gas while keeping the pressure at the set point of the pressure control valve. The result is that the pressure control valve will open (to keep pressure at the setpoint) and let the hot gas bypass to the compressor. This does not happen to the same degree with the liquid drain method. A small bleed is necessary in the float valve though to ensure that any flash gas generated in front of the valve can be released to the valve discharge, but this bleed will bypass only a small fraction of the gas that would be bypassed using the pressure control method.

Vestergaard et al. (2016) measured the energy consumption of a system in operation comparing the two defrost control methods. The results showed considerable energy savings using the liquid drain method (Figure 3).

To generalize these results and investigate the influence of the type of evaporator, a series of measurements on different evaporators was made at the Danish Technological Institute in the ELFORSK (347-030) project. In parallel with the measurements, a simulation model was developed and validated using the measurements.

The simulation model was thereafter used to investigate the influence of varying the operating conditions, but also to quantify some of the parameters, which can be difficult to measure on a real system—for example, the mass of refrigerant in the evaporator during defrost and the size of convection losses from the evaporator to the surroundings (i.e., how much the defrost process heats up the cold room).

The findings and experiences gained in this project were collected in a series of design recommendations for hot gas defrost systems, both related to practical issues (such as piping arrangements) but also to recommendations for sizing valves and line components.

TEST SYSTEM

The laboratory test system at the Danish Technological Institute consists of a pumped recirculated liquid ammonia system and a climate chamber.

The amount of ice added to the evaporator surface during normal operation is controlled, and during defrost, the

Figure 2. Pressure Control and Liquid Drain.

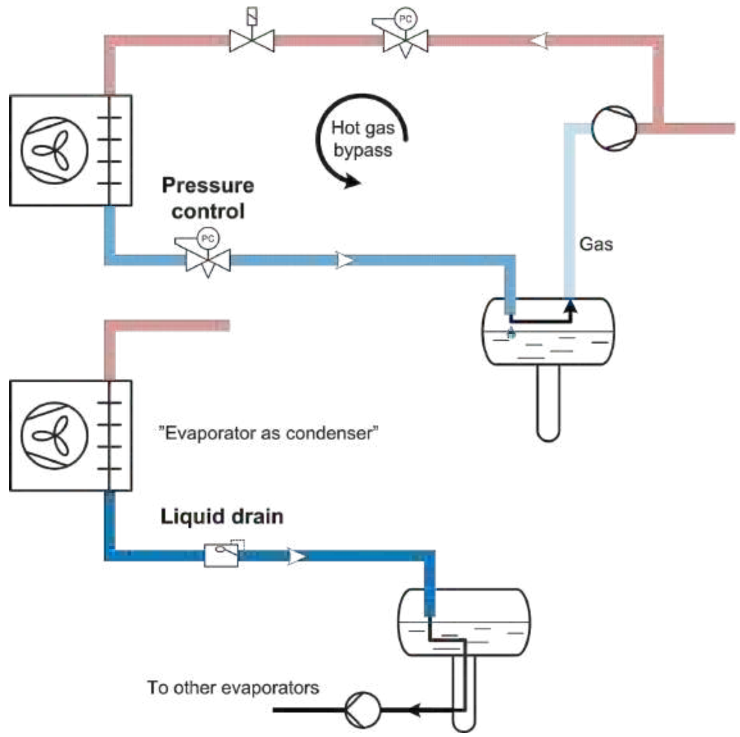
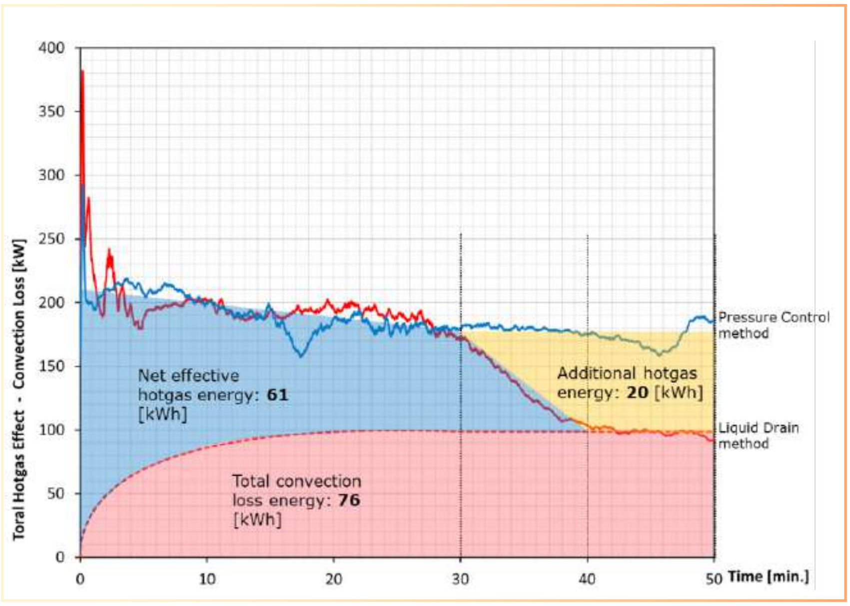


Figure 3. Example of Energy Distribution in Pressure Control Method vs. Liquid Drain Method (Bring Cold Store Facility in Kolding, Denmark)

Source: Vestergaard et al. (2016).



amount of ice removed is also measured to make sure that the ice on the evaporator before defrost is controlled.

The condensing hot gas supply is regulated to a pressure of about 15°C (59°F) (inlet of hot gas defrost valve (4) or (5,6)) from a condensing temperature of 31°C (87.8°F) (see Figure 4 for position of valves).

When the defrost starts, the hot gas flow is controlled by either a soft gas solenoid or a slow opening solenoid:

- Soft-gas solenoid: first the soft-opening valve (6) is opened for 10 minutes and thereafter the main defrost valve (5). The soft-opening valve has a capacity of about 10% of the fully opened defrost valve. Measurements in the following Test Results section are all taken with the soft gas solenoid.

- Slow-opening solenoid: the motor valve (4) opens slowly (from closed to fully open in 160 s). Measurements taken with the slow-opening solenoid are shown later in the Discussion section.

The temperature in the pump separator is approximately -22°C (-7.6°F) and is kept constant through all experiments.

When using the pressure control method (valve (7)) the defrost pressure is set to 7.3°C (45.1°F). Table 1 summarizes the operating conditions.

When designing hot gas systems, considering the design of the actual evaporator type is important. Bottom-feed evaporators without distribution orifices are very common in Europe, whereas top feed and side feed are the most common types in the United States. Top-feed evaporators normally have distribution orifices at the inlet, which means that hot gas is injected through the orifices creating additional pressure drop. Side-/bottom-feed evaporators have distribution orifices in the liquid inlet/condensate drain outlet, which means that liquid drain during defrost must pass through the orifices creating additional flash gas before the drain valve.

All three types of evaporators were tested using both the pressure control and liquid drain methods to control the hot gas supply during defrost (Figure 5).

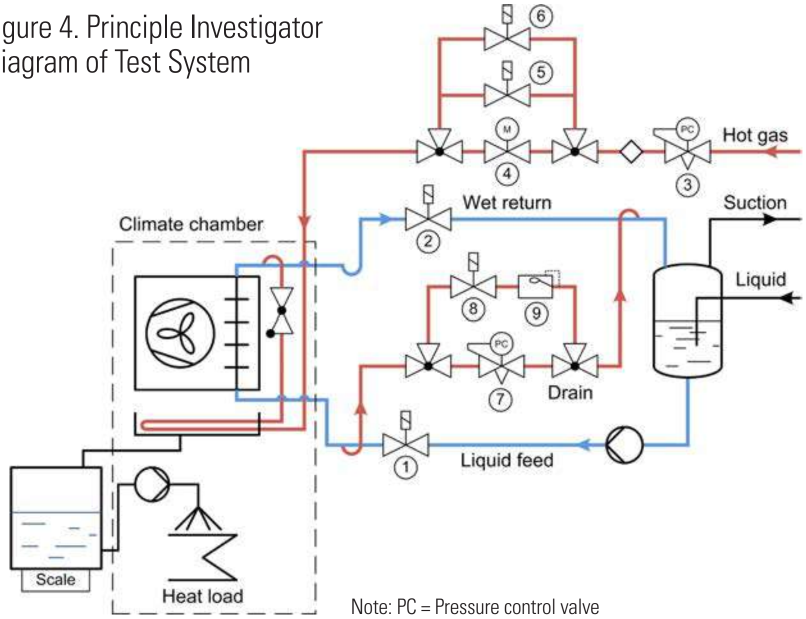
TEST RESULTS

Table 2 shows the results of the visual evaluation of the defrost process for the

Table 1. Operating Conditions

	Saturation temperature		Saturation pressure	
	°C	°F	bar	psi
Condensing temperature	31.0	87.8	12.0	174.5
Regulated hot gas	15.0	59.0	7.3	105.8
Defrost pressure	7.3	45.1	5.6	81.2
Pump separator	-22	-7.6	1.7	25.3

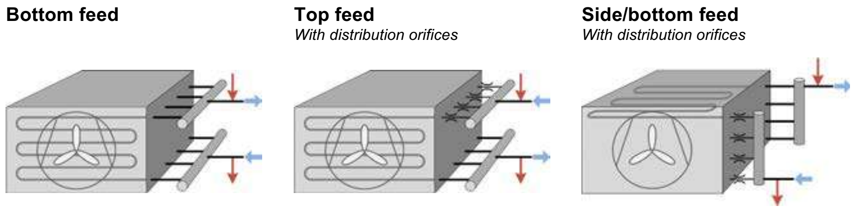
Figure 4. Principle Investigator Diagram of Test System



Note: PC = Pressure control valve

Figure 5. Tested Evaporator Types

Note: → Indicates refrigerant flow in cooling mode. → Indicates flow when defrosting.



different evaporator types (Appendix A provides details about the evaporators).

Figure 6 supports the conclusion of the evaluation. Figure 6 shows the evaporators in the following conditions:

- The system ran for approximately 60 hours and 50 kg (110 lb) of ice formed on the surface of the evaporator.
- BF1 and SF1 are from the start of the defrost (50 kg (110 lb) of ice).
- BF2 and SF2 are from after 12 minutes of defrost. SF2 shows the uneven defrosting with minor refreezing of ice on the bottom.
- BF3 and SF3 are from after 23 minutes of defrost (defrost completed).

Figure 7 shows the measured mass flow of hot gas for the different evaporator configurations and drain control methods.

For the liquid drain method, the shape of the mass flow curves differs slightly depending on the evaporator configuration, but the defrost duration does not seem to be affected by the evaporator configuration.

The peak mass flow for side-feed evaporator is higher than for the rest of the measurements. The operating conditions (pressures) were approximately the same for the different tests, so currently we believe that the higher mass flow for the side-feed evaporator is due to uncondensed gas mass flow passing through the evaporator in the top pipes, which have the largest orifice size. This gas flow continues while ice remains on the evaporator, and the gas must pass through the bleed when the drain float is installed. Whether more gas passes uncondensed through a side-feed evaporator still needs to be confirmed.

The effect of the distribution orifices on the evaporator outlet is evident when looking at the mass flow for pressure control and side-feed evaporator. The evaporator outlet pressure is kept constant by the pressure control valve, and as the pressure drop through the evaporator increases because of the orifices, the hot gas pressure at the inlet to the evaporator increases. At the same time, the pressure after the back-pressure regulator (valve (3) in Figure 4) is kept constant, so when the pressure at the evaporator inlet increases, the available pressure difference across the main hot gas solenoid valve (5) decreases, which means that the mass flow will also decrease (see also measured pressures in Figures 9 and 10).

The defrost time for the different evaporator configurations can be seen by looking at the mass of drained water during the defrost (Figure 8).

Looking at the drained water mass in Figure 8, concluding that the defrost time changes significantly by changing the evaporator configuration is difficult—especially given that the amount of ice on the evaporator was not exactly the same before a defrost was started. If anything, the side-feed configuration seems to defrost a bit faster, but this relates to the conclusion of the visual inspection (Table 2) where the defrost for the side-feed evaporator resulted in uneven defrost with minor refreezing. The top-feed evaporator also appears to defrost slightly more slowly than the others, but only by a few minutes.

Figures 9 and 10 show the measured hot gas pressure at the inlet and the outlet of the evaporator for the different configurations and control methods.

Table 2. Overview of Defrost Measurement Results in the ELFORSK Project

Evaporator type	Defrost method	Overall evaluation of defrost
Bottom feed	Pressure control	Fast uniform defrosting
	Liquid drain	Fast uniform defrosting
Top feed	Pressure control	Not tested
	Liquid drain	Fast uniform defrosting
Side/bottom feed	Pressure control	Uneven defrosting with minor refreezing*
	Liquid drain	Uneven defrosting with minor refreezing*

* Pieces of ice formed by the freezing of dripping water

Figure 6. Selected Pictures from the ELFORSK Defrost Measurements

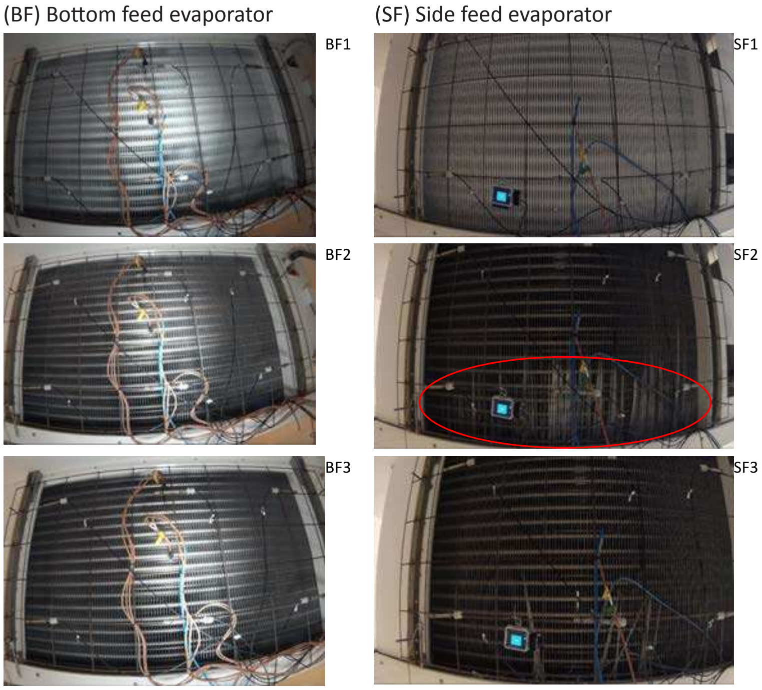


Figure 6. Selected Pictures from the ELFORSK Defrost Measurements

What should be noted when looking at the pressure curves is that

- The pressure increases more slowly for the liquid drain method during the filling period where the first step of the hot gas solenoid is opened. This is because the float valve opens as soon as liquid is present in the drain line. For the pressure control method, the pressure in the evaporator needs to build up to the set pressure for the control valve before it opens.
- For the pressure control method, the ice starts melting before the main step in the twostep solenoid opens.
- For the pressure control method and side-feed evaporator, the pressure drop through the distribution orifices is significantly higher than for the liquid drain method
- The pressure at the end of the defrost is higher for the liquid drain method than for the pressure control method, simply because the pressure in the evaporator rises to the regulated hot gas pressure as the flow decreases.

SIMULATION MODEL

Figure 11 illustrates the hot gas defrost system being modeled. The hot gas line directs hot gas from the compressor discharge to the hot gas valve and the soft-opening or slow-opening solenoid. Components located downstream from these valves such as pipes, stop valves, solenoids, etc., are collected into one inlet resistance.

After the evaporator, the drain line consists of an outlet resistance (collecting pipes, bends, stop valves, etc.) and either a pressure-controlled valve intended to keep the pressure in the evaporator constant or a liquid drain valve that opens only when liquid is present. As indicated in Figure 11, the liquid drain valve is equipped with a bleed to remove any gas in the drain line. The drain line leads to the low-pressure separator shown in Figure 4.

Skovrup et al. (2017) presents the details of the model, but the following explains the basic principles.

The valves in the hot gas and in the drain line are modeled using the valve equations from EN 60534 2011 (EN 60534-2-1 is identical to IEC 60534-2-1 and ANSI/ASI-75.01.01). The control valves (3) and (7) are moreover modeled as proportional regulators, with a smoothened opening curve (to help the numerical solver).

The evaporator is modeled as one lumped refrigerant volume with thermal mass in the refrigerant, the evaporator wall, and the ice on the evaporator (Figure 12).

The evaporator arrangement (top, bottom, side feed) has not been included in the model, but any pressure drops in the evaporator inlet or outlet (from orifices) are included in the inlet or outlet resistances.

For the pressure control method, the drain valve (9) is modeled in such a way that first the condensed liquid (if any) passes through the valve, and then the flow is “topped up” with saturated gas (or superheated gas if no liquid is present in the evaporator).

For the liquid drain method, if the valve is large enough to handle the amount of liquid condensed in the evaporator, then the valve lets exactly this amount pass plus an amount of gas decided by the bleed in the drain valve. If the amount of generated liquid is larger than the maximum allowable mass flow through the fully opened drain valve, then only the maximum liquid mass flow passes plus the gas mass flow through the bleed (this situation will result in an increase of mass in the evaporator).

The simulation model has four states, which are used to shift logically among dif-

Figure 7. Measured Mass Flow for Different Evaporator Configurations and Drain Control Methods

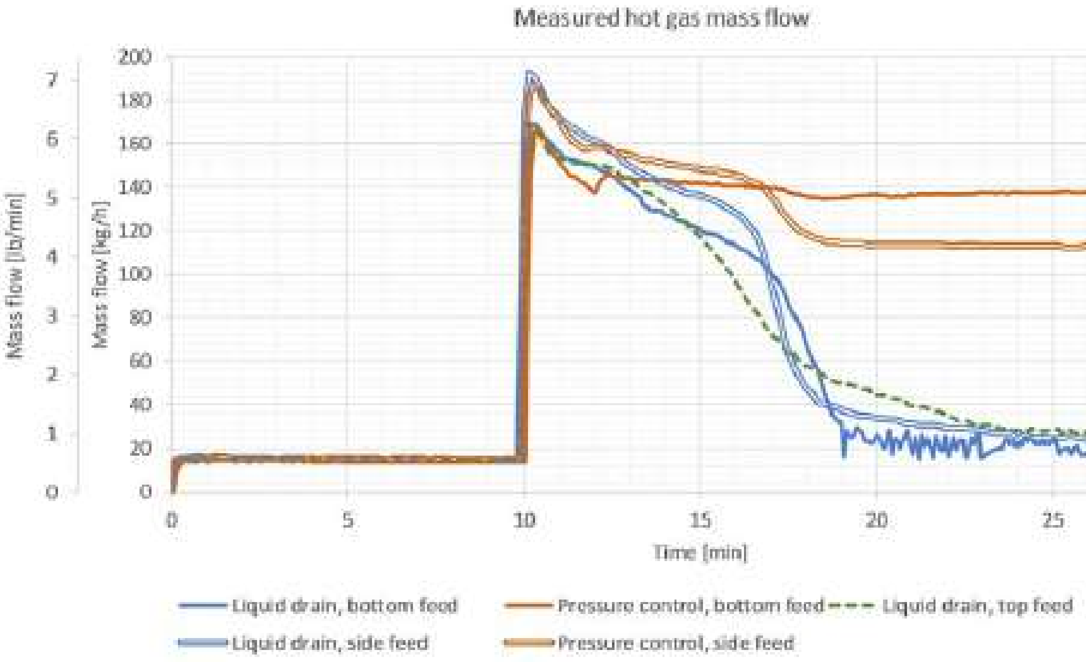


Figure 8. Measured Mass of Drained Water for Different Evaporator Configurations and Drain Control Methods

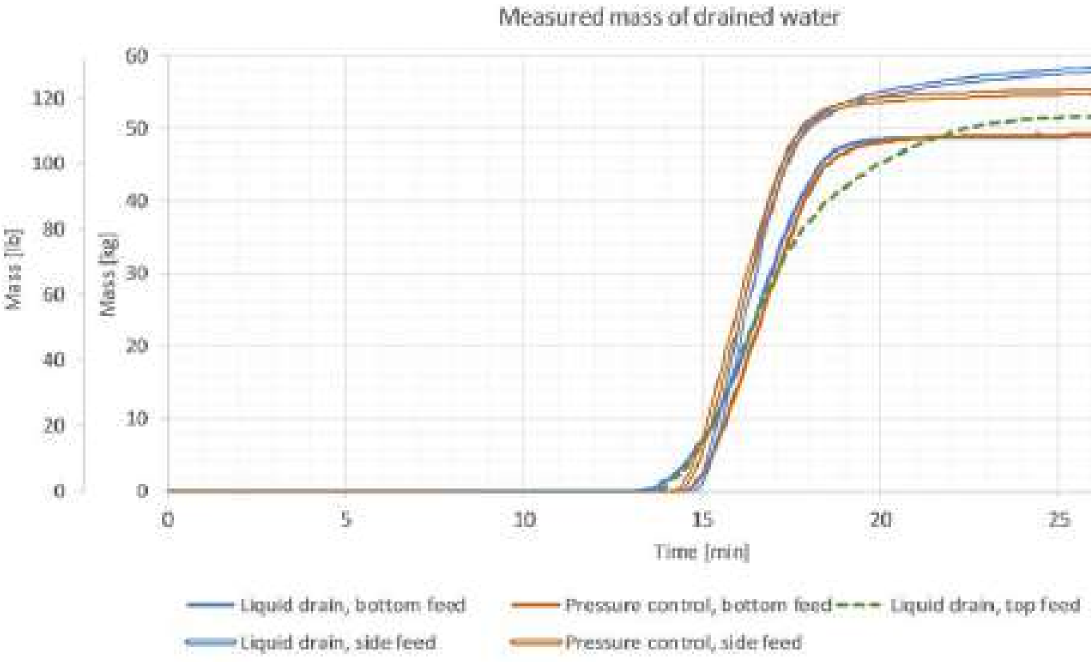


Figure 9. Measured Hot Gas Pressure into the Evaporator

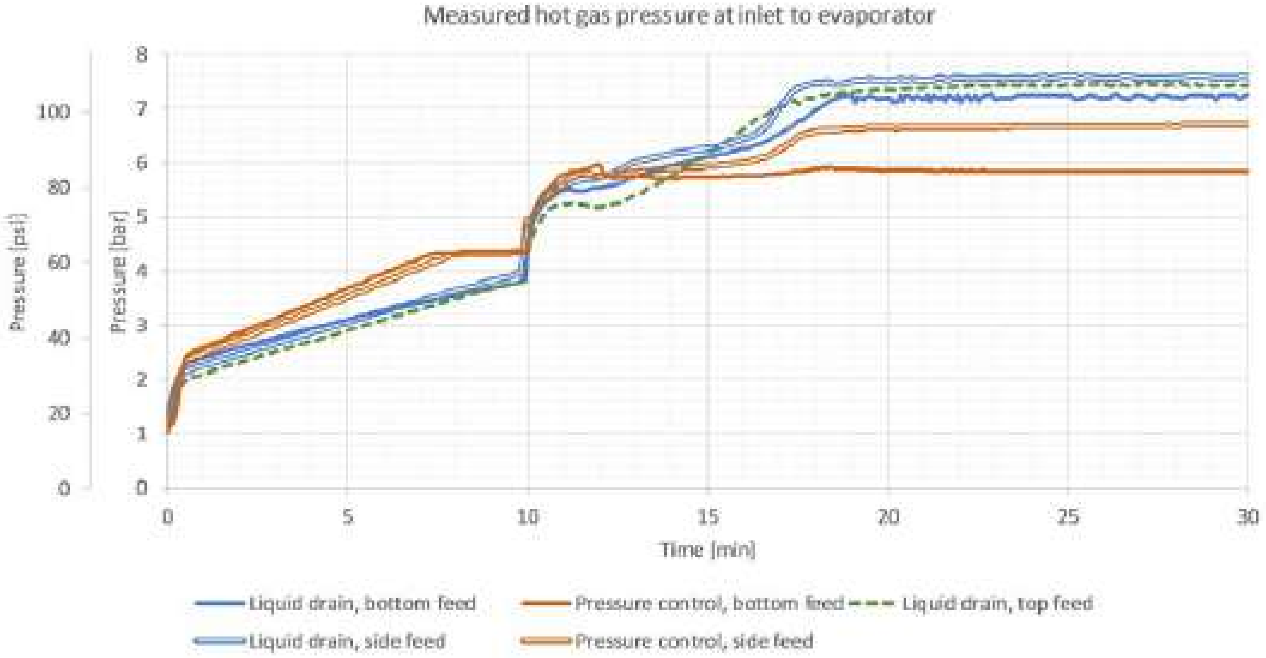


Figure 10. Measured Hot Gas Pressure at the Evaporator Outlet (Drain Line)

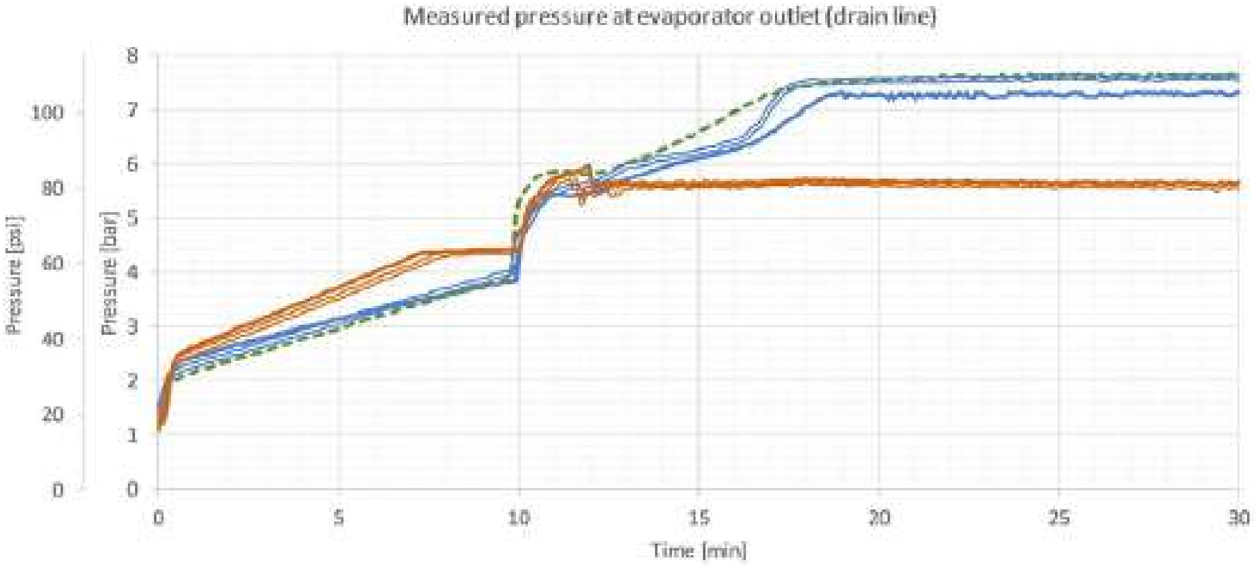


Figure 11. Diagram of the Modeled System

Note: PC = Pressure control valve

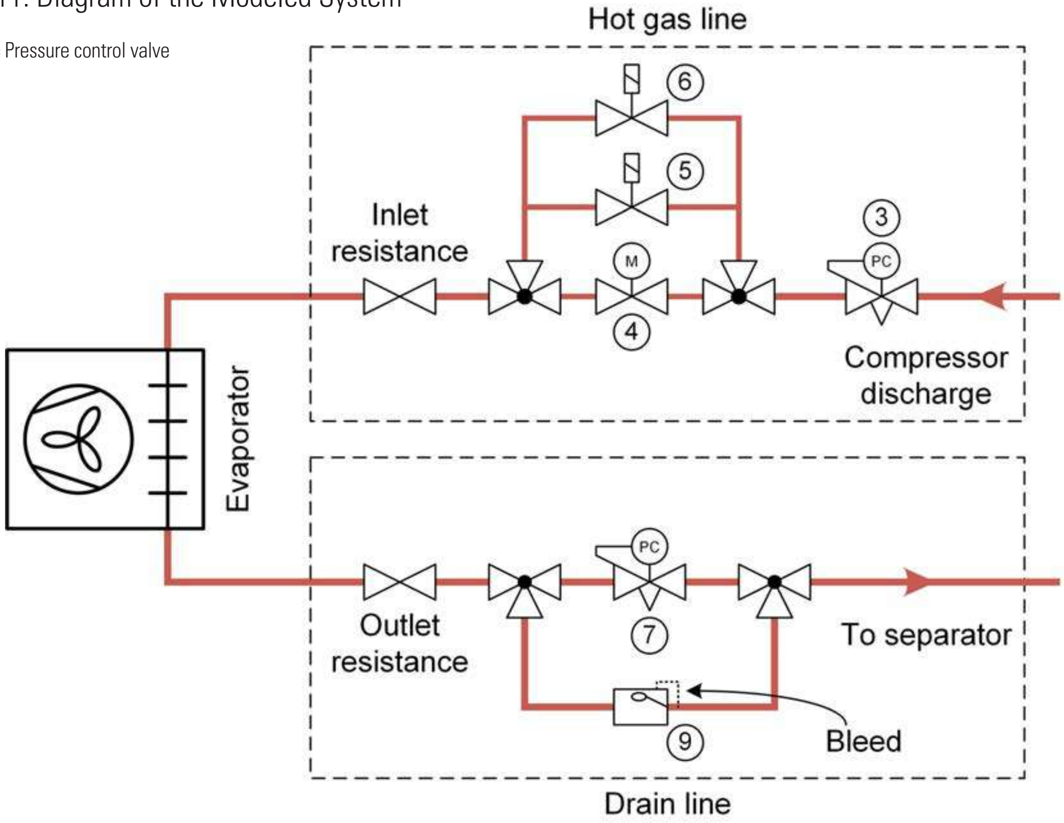
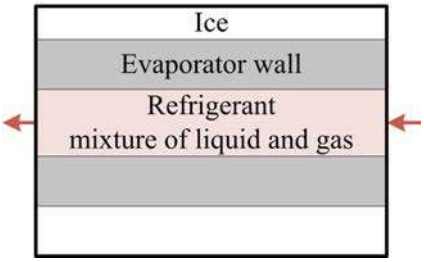


Figure 12. Lumped Evaporator Model



ferent sets of equations (defining the states enables the differential equation solver to handle discontinuities in the equations):

1. Filling of evaporator, either by soft-gas solenoid or slow-opening motor valve.
2. Heating of ice, where ice is heated from its initial temperature to 0°C (32°F). State 2 runs simultaneously with state 1. The model can change to state 3 either before or after state 1 ends.
3. Melting of ice continues until mass of ice on evaporator reaches 0 kg (can run simultaneously with state 1).
4. Heating of room, where all ice has been removed and heat is just added to the room. Continues until defrost ends.

Model Validation

The following model validation is done using the measurements from the bottom feed evaporator.

Figures 13 and 14 show the measured and simulated pressures in the evaporator for the pressure control and liquid drain methods and the mass flow into the evaporator. In each figure, the four states (1: filling, 2: heating of ice, 3: melting, and 4: heating of room) are indicated on the secondary yaxis on the right-hand side. Note that state 1 and state 2 run at the same time, and that the model shifts to state 3 for pressure control before the soft filling finishes at 600 s.

The qualitative shape of the simulated pressure curves follows the measurements satisfactorily. The pressure illustrates the difference between liquid drain and pressure control. At approximately 900 s, liquid generation in the evaporator starts to drop. The liquid drain method reacts by reducing the mass flow (it only allows liquid through the valve), and the pressure rises to the evaporator inlet pressure dictated by the hot gas line. The pressure control method, however, keeps the pressure almost constant, which means that the pressure control valve needs to allow an increasing amount of gas to flow out of the evaporator.

Note that in the simulations, the liquid drain method starts melting the ice later than the pressure control method but ends earlier, i.e., the defrost period is slightly shorter. This is also supported by the measurements, where the pressure for the pressure control method has a plateau of constant pressure from about 480 s to 600 s where the first step in the twostep solenoid ends, indicating that melting starts before the first step is finished.

Comparing the simulated and measured mass flow in Figure 14, the simulations appear to agree well with the measurements from the end of the filling time (where the main solenoid valve opens) to the defrost end. Agreement between measurements and simulations during filling is, however, not satisfactory. This

Figure 13. Measured and Simulated Evaporator Pressure

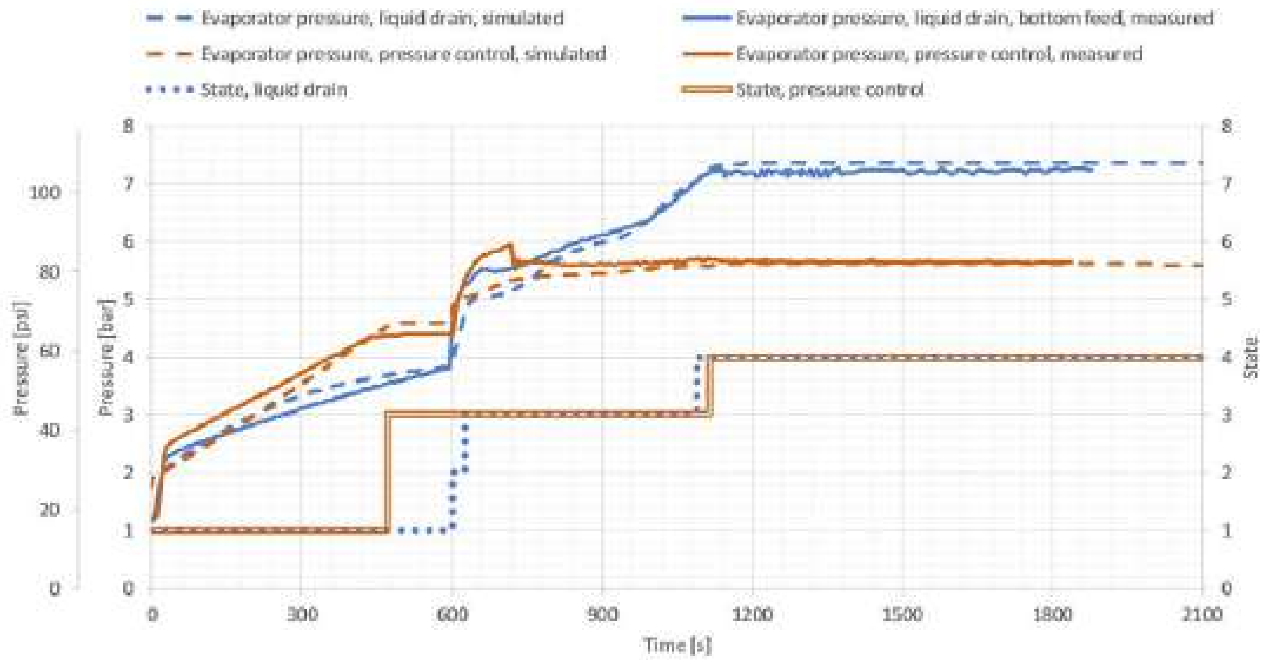


Figure 14. Measured and Simulated Mass Flows

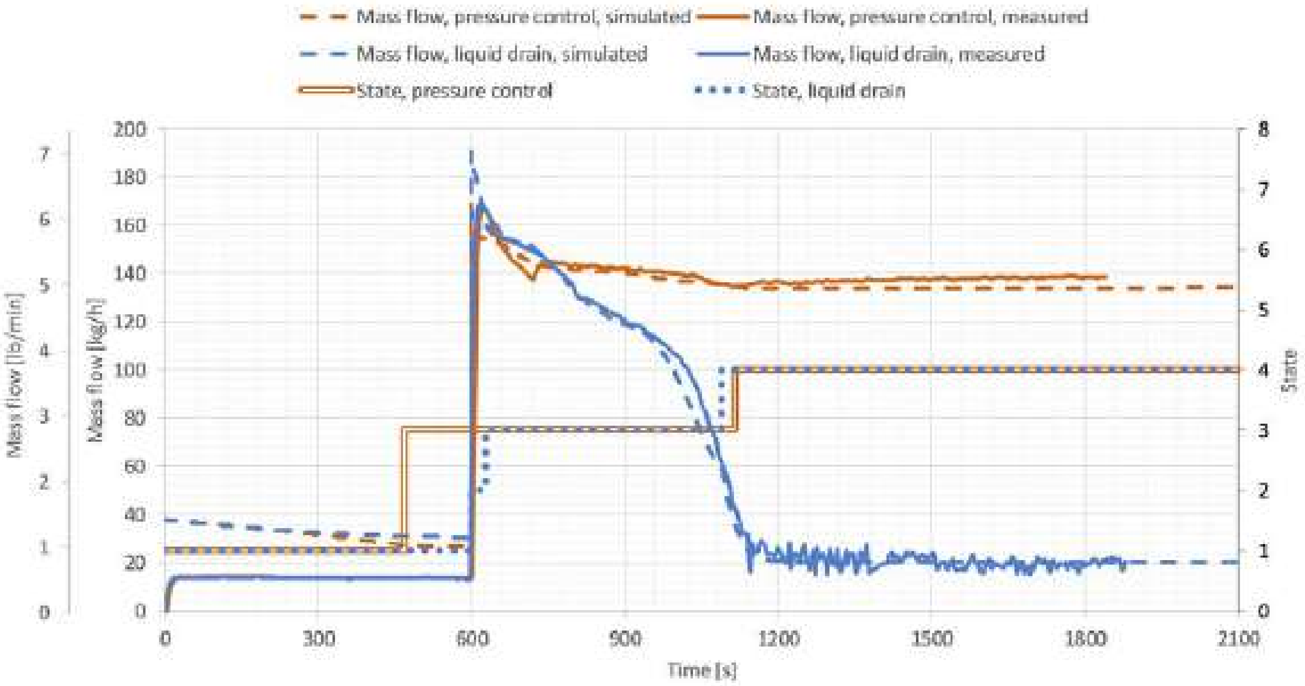


Figure 15. Slow-Opening Solenoid, Liquid Drain, Simulations and Measurements

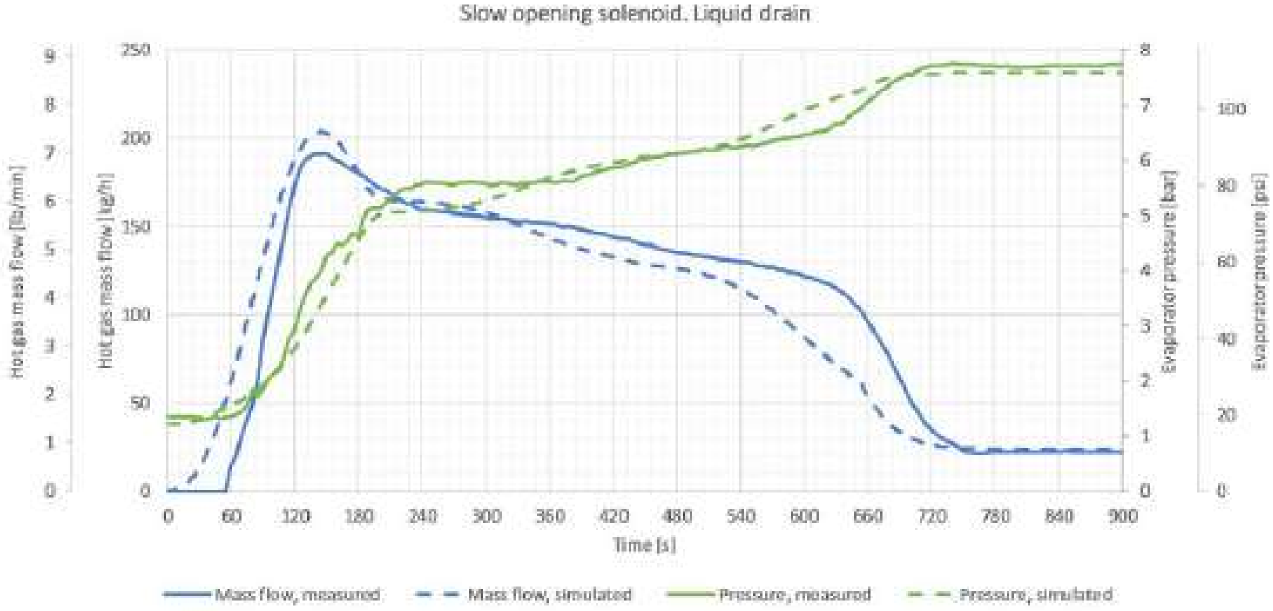


Figure 16. Distribution of Energy Consumption for Liquid Drain and Pressure Control Methods at Two Defrost Durations

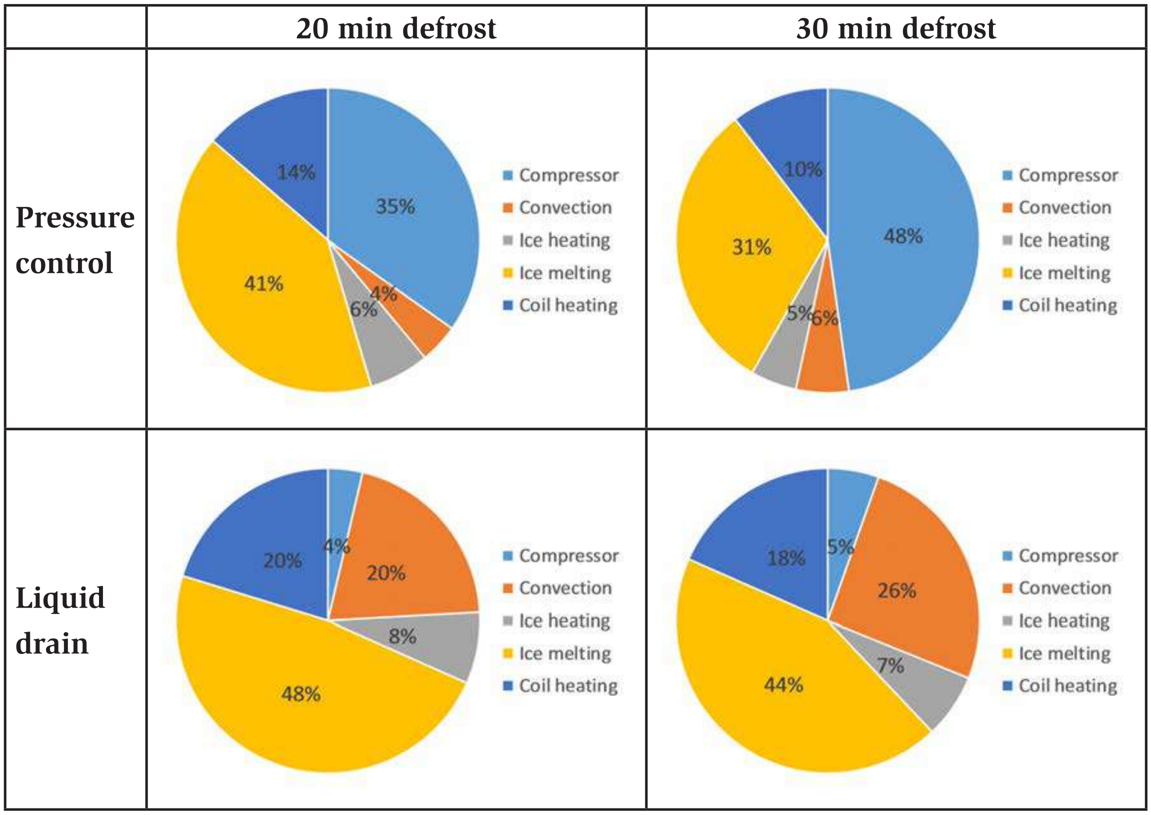
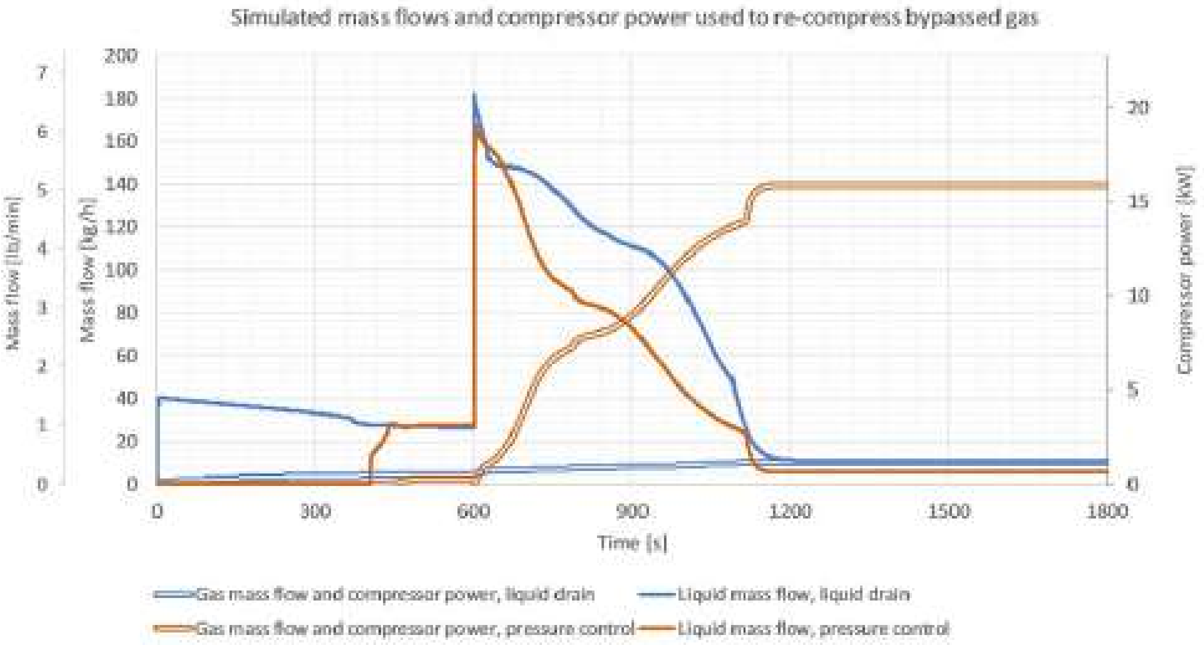


Table 3. Energy Consumption and Energy Savings for Pressure Control and Liquid Drain Systems

Total energy consumption	**20 min defrost**	**30 min defrost**	**Increase**
Pressure control	9.5 kWh	12.5 kWh	32 %
Liquid drain	8.1 kWh	8.9 kWh	10 %
Savings using liquid drain	**15 %**	**29 %**	

Figure 17. Simulated Gas and Liquid Mass Flows and Power Used to Recompress Bypassed Gas for Liquid Drain and Pressure Control Methods



is probably due to the fact that the drain pan is not part of the simulation.

For the liquid drain method, measurements using the slow-opening solenoid valve were also taken. Figure 15 shows the measurement and simulation results.

The results show that the simulation model can also reproduce—qualitatively—the pressures and mass flows in the evaporator if the two-step soft-opening solenoid is replaced by a slow-opening motor valve. The measurements show 0 mass flow the first 60 seconds of the defrost period. We have not been able to satisfactorily explain why this happens, but it might be because the motor valve does not open at low control signals.

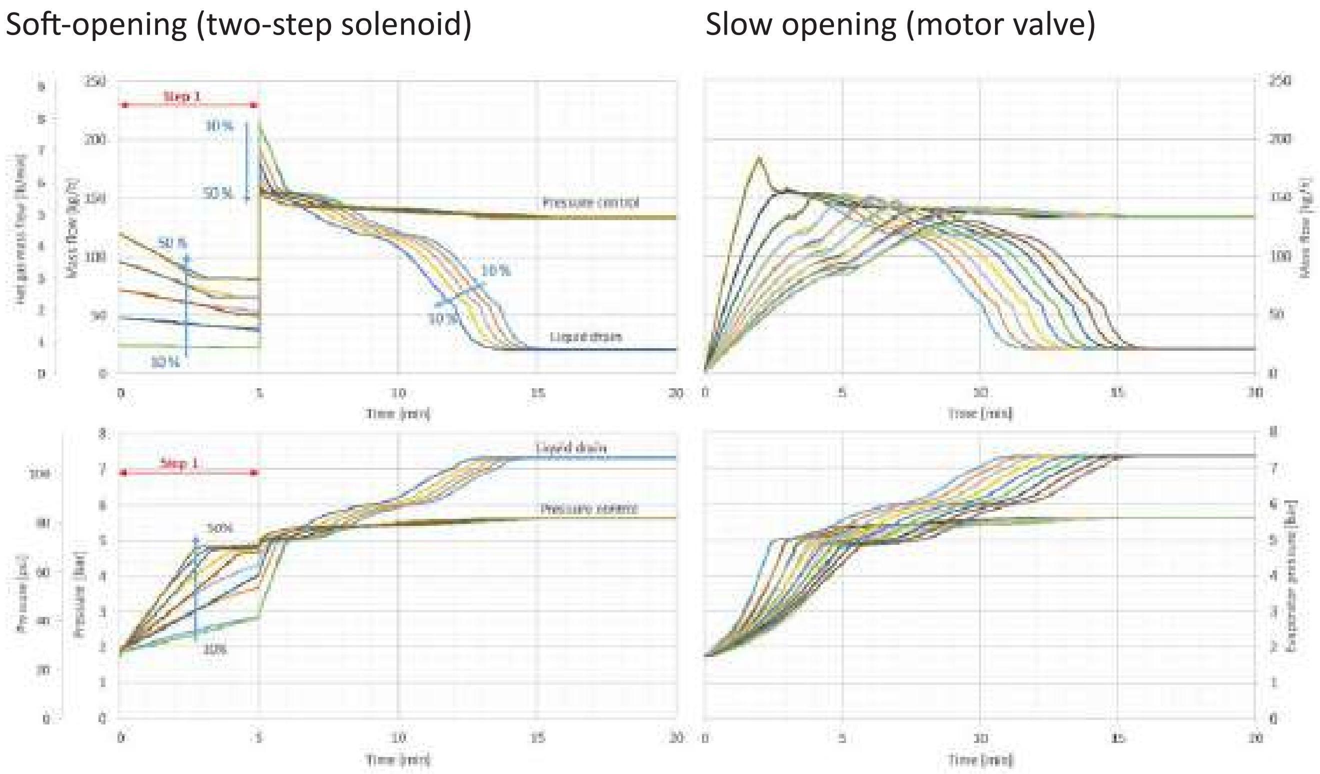
DISCUSSION

The validated simulation model has been used to investigate and quantify in detail energy consumption, soft versus slow opening hot gas valve, importance of pressure drops and defrost temperature, and the refrigerant charge.

Energy Consumption

For both pressure-controlled and liquid drain, a mass flow of uncondensed gas passes through the evaporator. For liquid drain, the mass flow occurs through the bleed in the liquid drain valve, and for the pressure-controlled case it simply flows through the valve together with the liquid. This gas flows to the separator and then into the compressor and is essentially equal to a hot gas bypass or loss.

Figure 18. Comparing Mass Flow and Pressure for Soft-Opening and Slow-Opening Solenoid


Soft-opening (two-step solenoid)

Slow opening (motor valve)

The pie diagrams in Figure 16 show the distribution of the energy consumption during defrost for simulations of two different defrost durations. The energy consumption is split into

- Compressor, i.e., hot gas flowing uncondensed through the evaporator and back to the compressor. To calculate the compressor power consumption, an isentropic efficiency of 0.7 has been assumed.
- Convection, the energy loss to the cold room by convection during the defrost. The convection loss will be negative in the beginning of the defrost (the ice is colder than the cold room) and will grow proportionally with the temperature of the ice/evaporator. Energy to remove the heat after the defrost is not included.
- Ice heating, the amount of energy necessary to heat the ice from initial temperature (-22°C/ -7.6°F) to the melting point. The initial temperature is chosen according to measured test conditions.
- Ice melting, melting of the mass of ice on the evaporator. In all simulations, 50 kg (110 lb) of ice on the evaporator has been assumed.
- Coil heating, the necessary energy to heat the coil during defrost. The necessary energy depends on the mass and specific heat of the evaporator material. Energy to cool the coil after the defrost is not included.

Ice heating and ice melting are constant no matter what defrost control method is used.

For the liquid drain method, the temperature of the refrigerant will end up being slightly higher than for the pressure control method, assuming that saturated conditions exist in the evaporator during the defrost (this will normally be the case as convection loss will keep refrigerant condensing even when no ice remains on the evaporator). This is because the liquid drain method allows the pressure to rise up to the hot gas supply pressure, whereas the pressure control method will keep the pressure at a defined level (see also Figure 13). This means that the coil heating and convection losses will be slightly higher for liquid drain than for pressure control, but as Figure 16 shows, the amount of gas bypass for the pressure control method dominates the losses and takes up a significant part of

Figure 19. Defrost Time as Function for Regulated Hot Gas Temperature

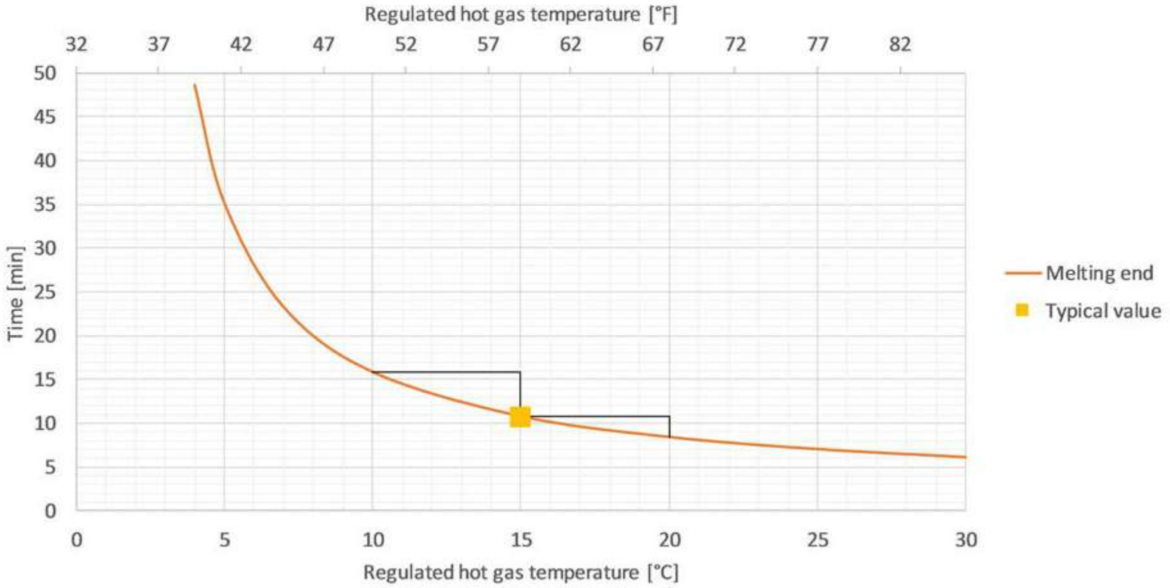
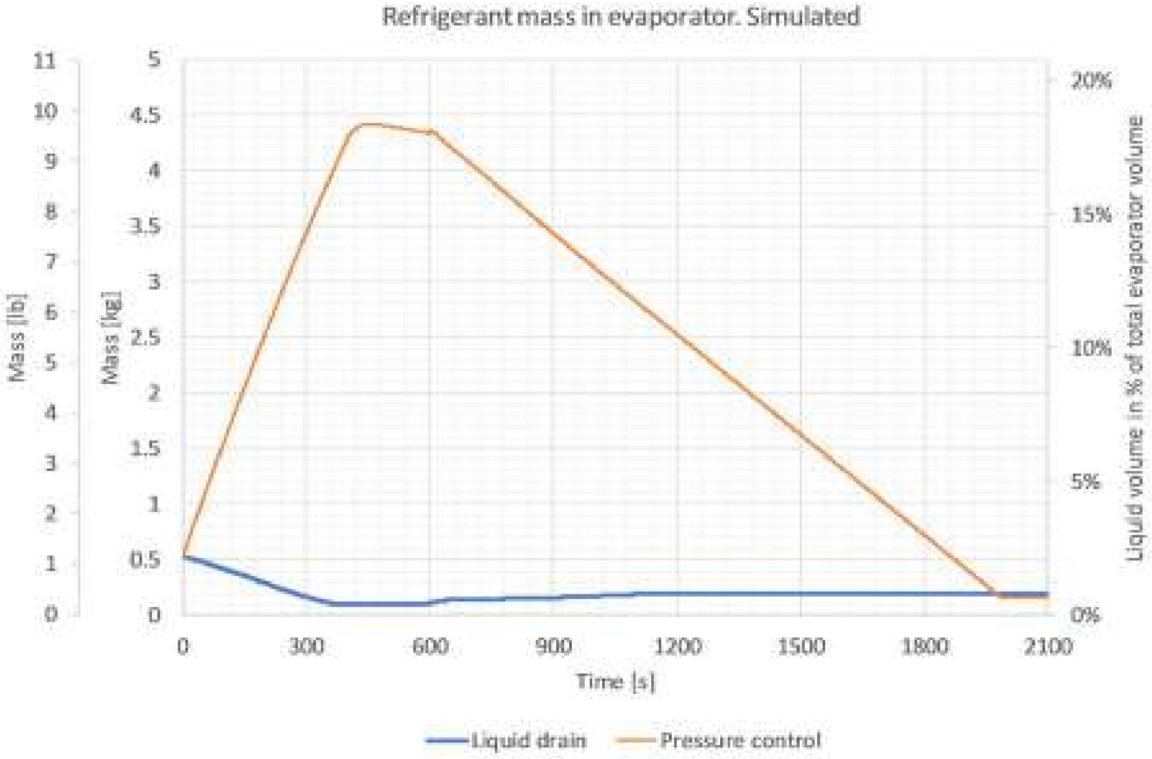


Figure 20. Simulated Refrigerant Mass in Evaporator during Defrost Using Liquid Drain or Pressure Control Method



the difference in energy consumption between the two methods—especially if the defrost duration is longer than the minimum necessary to melt the ice.

Table 3 summarizes the calculated energy savings for the two control methods.

The amount of gas bypass in the pressure control method also has another interesting consequence. At the end of the defrost process, the gas mass flow can exceed the amount of gas generated in the evaporator during normal operation—i.e., the load from the evaporator on the compressor(s) is larger during defrost than during normal cooling operation.

In the simulation results shown in Figure 17, the total defrost refrigerant flow is separated into gas mass flow and liquid mass flow. The gas mass flow is then converted to compressor power (using an isentropic efficiency for the compressor of 0.7), which for a given gas mass flow can be read on the right-hand y-axis. The gas mass flow for the liquid drain method is significantly smaller than for the pressure control method, resulting in much less compressor power used for recompressing the gas.

The capacity of the evaporator used in the calculations is approximately 20 kW (5.7 TR) at 22°C (-7.6°F), so 16 kW used to recompress bypassed gas during defrost is certainly larger than the power need to deliver 20 kW (5.7 TR) cooling at -22°C (-7.6°F).

Soft- or Slow-Opening Solenoid

The simulation model has been used to investigate the pressure and mass flows during initial opening of the hot gas supply. The reason for this is that high mass flow peaks were observed both in measurements and in simulations when the second (large) step of the two-step solenoid was opened.

Note: The valves in the simulation have been sized according to the principle described in the section "Dimensioning of Hot Gas Defrost Systems" later in this paper.

When the first step in the two-step solenoid is opened, hot refrigerant flows into the evaporator and starts to condense. This liquid refrigerant is—in the case of pressure control—not drained from the evaporator, simply because the pressure has not increased above the set point of the controller yet. So, when the second step is opened, a chance exists that the observed peak in refrigerant flow can accelerate the condensed liquid in the evaporator causing safety problems downstream from the evaporator.

Typically, sizing the low step of the two-step solenoid to 10% of the size of the main step is recommended (this was also done on the test system). To investigate the consequence of the sizing, simulations were carried out varying the size of the first step from 10% to 50% of the main step and comparing to a slow-opening motor valve, where the opening time was varied from 2 to 10 min (Figure 18).

The simulations show that 10% of the main step does not increase the pressure in the evaporator enough during the first step to avoid the peak in mass flow. A better size would probably be 20–30%. Looking at the motor valve, the peak in mass flow disappears when the opening time is longer than 3 min. Also the pressure rises continuously without large gradients for the motor valve when opening time is longer than 3 min. So controlling hot gas supply with a slow-opening motor valve seems to be an attractive method from a safety point of view and suggests that starting the defrost may be possible without draining the evaporator prior to injecting the hot gas. This method may be relevant to consider when keeping the defrost time short is important.

Defrost Temperature

The saturated temperature of the hot gas has an influence on the defrost time: the hotter the gas, the shorter the defrost time and vice versa. Figure 19 shows the simulated defrost time as a function of the regulated hot gas temperature.

The plot is simulated using the liquid drain method with a soft-opening valve (two-step solenoid) where the first step is opened in 2 min.

Figure 19 shows that if, for example, you increase the regulated hot gas temperature by 5 K (9°F) from 15°C (59°F), then the defrost time is lowered by about 2 min. If you decrease the regulated hot gas temperature 5 K from 15°C, then the defrost time is increased by 5 min.

Refrigerant Charge

As noted earlier, the pressure control method does not start to drain liquid from the evaporator until the pressure reaches the set point of the valve. This means that the amount of refrigerant in the evaporator during defrost is higher for the pressure control method than it is for the defrost drain method.

Figure 20 shows the total amount of refrigerant in the evaporator during a defrost using the two control methods.

Both simulations start with the same initial amount of refrigerant. Clearly, the refrigerant mass in the evaporator is significantly higher for the pressure control method, where the amount of liquid refrigerant fills almost 20 % of the evaporator before the control valve opens. This indicates that the liquid drain method should be considered when designing systems for low charge.

Dimensioning of Hot Gas Defrost Systems

Several elements must be considered when designing hot gas defrost systems, but besides safety, energy efficiency and defrost speed are the two most important elements. If speed is the most important design criterion, the defrost components should be selected accordingly, but the penalty of high speed is reduced energy efficiency, depending on the control method.

Selecting the components for a defrost system—whether optimizing for speed, energy efficiency, or both—essentially means calculating the required capacity of the components. Calculating the capacity needs detailed information about the operating conditions the components will work under, and these are sometimes very hard to get. Estimating operating conditions includes calculating pressure drop and density of refrigerant before and after the components (including two-phase flow), but also estimating the required mass flow of hot gas to get a satisfactory defrost.

The following sections provide an overview of how to estimate the necessary capacity of components in a hot gas defrost system. Also included in the overview are practical items to consider and take care of when the system is designed.

Dimensioning Capacity

Determining the hot gas capacity in the defrost lines is a question of defining the necessary hot gas mass flow in the selected line. Normally, some rules of thumb are used, which relate to the dimensioning (design) cooling capacity of the evaporator (or evaporators) the selected hot gas line connects to

$$\dot{m}_{hot\ gas} = Defrost\ capacity\ factor \cdot \frac{Dimensioning\ cooling\ capacity}{Defrost\ enthalpy\ difference} \qquad \text{(Eq. 1)}$$

The dimensioning cooling capacity is the cooling capacity of the evaporator(s) being defrosted. This value indirectly indicates the size of the evaporator.

The defrost enthalpy difference equals the energy content of the hot gas, which is equal to the enthalpy difference between points C and D in Figure 21.

The defrost capacity factor is a value selected based on experience, and it is important for sizing hot gas lines, hot gas solenoids, drain valves, and drain lines in a proper defrost system, but it is not intended for calculating exact defrost mass flow in the system. A defrost capacity factor of 2 is common practice and shows good correlation with the tests. Normally the value is selected between 1 and 3 depending on actual operating conditions. If the defrost temperature is increased to reduce the defrost time, as shown in Figure 19, then the mass flow needs to be increased too, i.e., a higher defrost capacity factor is required to ensure sufficient flow.

Dimensioning Quality

The dimensioning quality is used to determine the position of point D at the inlet to the defrost drain line (see Figure 21).

The term “quality” is a measure of the mass flow of gas compared with the total mass flow of refrigerant. The dimensioning quality differs significantly based on the drain control method you select.

For the liquid drain control method, the dimensioning quality should always be 0.0; i.e., the refrigerant in point D is saturated liquid (Figure 21). The function—or purpose—of a float valve in the defrost drain line is to avoid (as far as possible) gas passing through the float valve and only letting liquid pass through.

For the pressure control method, the defrost process will be quite different. Initially, all hot gas supplied to the evaporator will condense, and the valve will only see liquid at the inlet. Later in the process, some gas will not condense in the evaporator, and the valve will see a mixture of liquid and gas. This process is illustrated from D* to D in Figure 21.

Selecting the right dimensioning quality for pressure-controlled drain valves is very important for selecting the right valve size. If a dimensioning quality of 0.0 is selected (saturated liquid), then the resulting valve will be relatively small, which could mean that defrost will be prolonged at the end of the defrost cycle as gas cannot pass through the valve efficiently. It will also mean that pressure in the evaporator can rise to the hot gas supply pressure, which is not always wanted.

If a dimensioning quality of 1.0 is selected (saturated gas), then the resulting valve will be relatively large, meaning that a lot of gas will be bypassed (which equals larger energy consumption) and the valve can become unstable when pure liquid enters the valve in the beginning of the defrost cycle.

Using a relatively low dimensioning quality equal to 0.05 ensures that the valve is stable when liquid enters it and that the amount of bypassed gas is minimized.

Sizing a Hot Gas Defrost System

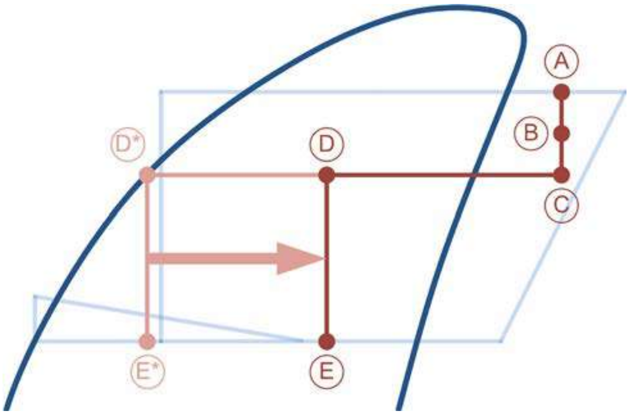
The defrost system is a very dynamic system, but applying appropriate design parameters simplifies the selection and calculation process significantly. The pressure drop in the hot gas line is often assumed to be less important, but calculating it as precisely as possible is strongly recommended, especially for systems with floating condensing pressure, where low condensing pressure may appear.

Sizing a Hot Gas Defrost System

In the following example, the following preconditions are set:

- Defrost capacity factor = 2,
- Defrost design temperature $= P_d + 10°C$ (50°F),
- Hot gas velocity ≈ 25 m/s (82 ft/s), and
- Pressure drop of Δp ≈ 1 bar [≈ 5K] – (14,5 psi [≈ 9°F]) in the complete hot gas line would normally lead to an acceptable choice of pipe size and valve capacity.

Figure 21. Defrost Principle in log(p)-h Diagram



(A) Main hot gas supply

(B) Reduced pressure hot gas supply

(C) Defrost pressure

(D) Dimensioning drain condition, depending on drain method

(E) Drain outlet into seperator

Table 4. Example of Capacity Change of Defrost Drain Valve Designed for Inlet Condition x = 0.05 (95% Liquid+5% Gas)

Quality x [-]	Capacity index [%]	Comments / fluid state
0.00	264%	100% liquid
0.05	**100%**	**Recommended design value**
0.20	53%	
0.40	38%	
1.00	24%	100% gas

If the maximum supply pressure is significantly higher than needed, consider an outlet pressure regulator in the hot gas supply line (regulated hot gas) to reduce the pressure before the evaporator is good practice. Supply pressure that is too high may lead to increased pressure in the evaporator (for the liquid drain method it will lead to increased pressure) and significantly increased gas bypass mass flow in pressure-controlled defrost systems. Especially for large evaporators, regulated hot gas is recommended for safety reasons.

Evaporator Types

When designing hot gas systems, considering the design of the actual evaporator type is important:

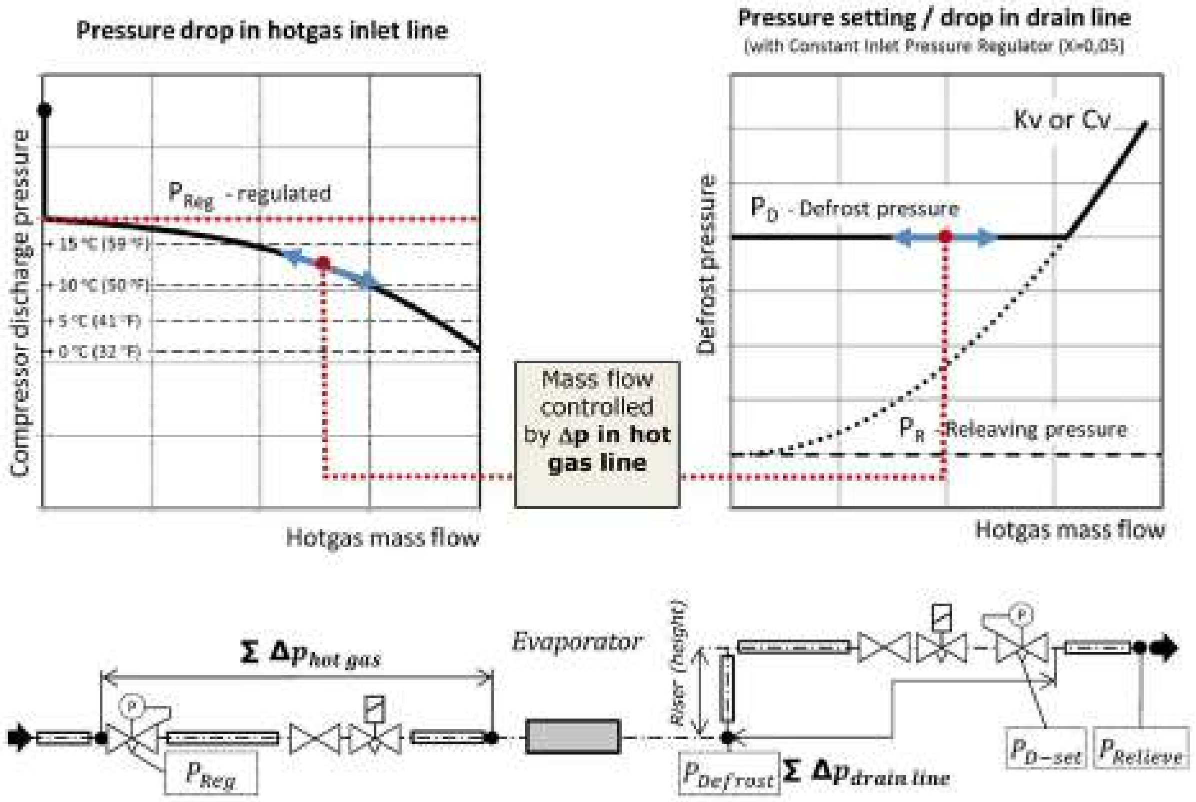
- Top-feed evaporators normally have distribution orifices at the inlet, which means that hot gas is injected through the orifices during defrost, creating an additional pressure drop in the hot gas supply to the evaporator.
- Side-/bottom-feed evaporators have distribution orifices in the liquid inlet/condensate drain outlet. The presence of these orifices needs to be considered when sizing the drain control device (the orifices will create flash gas before the drain control device).

For the pressure control method, the hot gas is injected into the evaporator, and the pressure is gradually built up. When the pressure reaches the set pressure of the regulator, the regulator will maintain the pressure in the evaporator by draining the condensate from the evaporator. After a few minutes, the hot gas mass flow into the evaporator is assumed to be equal to the combined liquid and gas mass flow out of the evaporator. The mass flow into the evaporator is then only a function of the pressure difference over the complete inlet line as shown in Figures 22 and 23, and the capacity of the pressure control valve needs to be selected so that the valve can maintain the pressure at the preset value (typically +10°C (50°F)).

Initially, the total mass flow out of the evaporator is liquid, but later in the defrost process a significant amount of gas will also pass through the pressure regulator. The capacity of the pressure control valve varies significantly depending on the quality of the fluid. Using a dimensioning quality of x = 0.05 leads to a valve size that ensures sufficient capacity for removing typical acceptable gas bypass (Table 4).

When sizing the pressure control system for the hot gas inlet, including all components and pipes is important. For evaporators, adding an additional pressure drop for any distribution orifices

Figure 22. Pressure Control Defrost Method



may be necessary.

According to the performed tests, the gas bypass for the pressure control method depends on the hot gas flow, but because predicting the exact pressure drop in the complete hot gas line precisely can be difficult, a manual adjusting valve may be considered a good feature (not shown).

Sizing Liquid Drain Systems

When sizing the valves at the inlet of the hot gas system controlled with the liquid drain method, the same dimensioning rules apply as described for pressure-controlled systems (compare Figure 22 and Figure 23). The mass flow in liquid drain systems is controlled by the amount of liquid condensate generated in the evaporator. When the condensate flow starts to decrease, the hot gas mass flow follows, lowering the pressure drop in the hot gas line. For liquid drain systems, considering the maximum supply pressure is important, which must be compatible with the design of the evaporator. An outlet pressure regulator is normally required to ensure that the inlet pressure is kept within acceptable limits. From a control point of view, the liquid drain method is very simple and "self-adjusting" according to the defrost drain demand.

An additional benefit with "self-adjusting" of the mass flow in the liquid drain method is the reduced pressure drop in the inlet line. For identical hot gas system designs, the liquid drain method can defrost at a lower discharge pressure compared with pressure-control systems.

Defrost Drain Line

Despite the simplicity of the liquid drain method, a couple of issues have to be considered carefully. Roof-mounted valve stations are very common, meaning that the liquid drained from evaporators is "lifted" to the liquid drain valve on the roof, which could be situated 5 m (16.4 ft) or more above the evaporator. It is therefore extremely important that the liquid drain valve has a bleed to remove any flash gas created due to pressure drop and liquid lift.

For side-/bottom-feed evaporators, the liquid drain must pass the distribution orifices, which creates additional pressure drop/flash gas, and this gas flow needs to be considered when dimensioning the gas bleed in the liquid drain valve.

A bleed with a flow coefficient of approximately 5–7% of the Kv-value (Cvvalue) of the float valve is normally sufficient for well-designed systems. The gas bypass is a loss, but the mass flow of gas is typically only around 10% of what the mass flow of liquid through a bleed of the same size would be.

Special attention needs to be paid to the liquid drain from the evaporator when it is lifted in a riser. For the liquid drain method, the velocity out of the evaporator decreases during the defrost process and the liquid is not "blown out" in the same way as it is for pressure control. Therefore the outlet of the evaporator must be designed so that liquid does not accumulate in the lower pipe. Therefore a "P-trap" near the inlet of the riser is strongly recommended (Figure 24).

CONCLUSIONS

Hot gas defrost is the most common method for defrosting evaporators in industrial refrigeration. Several elements are important to consider, when evaluating the effectiveness of a defrost:

- Reliable and safe defrost process;
- Removal of all ice/rime from the air cooler surface with minimum energy:
  - Minimum heat transfer into the refrigerated space,
  - Minimum transfer of moisture from the surface of the air cooler into the refrigerated space, and
  - Minimum flash gas and noncondensed hot gas bypassing through the evaporator (gas will flow directly to the compressor for recompression);
- Electrical energy to conduct the defrost process; and
- Defrost cycle time.

Different types or configurations of air coolers are used in the industry depending on accepted practice in different parts of the world. Performance testing and analysis shows that awareness of the actual design is necessary when sizing the defrost system, but also that defrost time (if system is properly sized) is largely unaffected.

The pressure control method is a commonly used method to control the defrost process, but the measurements show clearly that this method allows large amounts of noncondensed hot gas to bypass through the evaporator, increase the compressor load, and reduce the defrost efficiency.

The measurements show that the liquid drain method has a higher efficiency than the pressure control method because only liquid condensate is drained in this method, but measurements also show that the performance can be affected if the system is not configured properly.

The use of a “defrost capacity factor” has been found to be an easy and suitable tool to use when sizing inlet and outlet pipes. This factor allows easy selection of defrost controls, pipes, etc., based on evaporating capacity.

The simulation tool, calibrated with test results, has shown to be useful when analyzing the effect of sizing key elements when changing the boundary condition:

- The size of the first step of a two-step solenoid in a hot gas line must be bigger than 10%; 20–30% is a better fit.
- A slow-opening solenoid valve (motor valve) in hot gas lines is the perfect solution to ensure safe smooth pressure build-up.
- The efficiency of the pressure control method is significantly more sensitive to correct termination of the defrost cycle time than the liquid drain method.
- The hot gas temperature (saturated temperature) is the most important factor for the defrost cycle time. For example, if you increase the regulated hot gas temperature by 5 K (9°F) from 15°C (59°F), then the defrost time is lowered by about 2 min. If, however, you decrease the regulated hot gas temperature 5 K from 15°C, then the defrost time increases by 5 min.
- The load from an evaporator on the compressor(s) is larger during defrost than during normal cooling operation when using the pressure control method.

When sizing a pressure control system, considering that the hot gas mass flow is controlled by the actual set pressure of the control valve and the pressure drop in the inlet line is important; the whole hot gas inlet system, regarding pressure drop, needs to be considered.

In a liquid drain system, the hot gas mass flow is controlled by the actual condensate flow, and design considerations are less sensitive because of the self-adjusting control of the valve.

In this project, many tests were carried out and analyzed, but a lot of work still remains in understanding the details of the hot gas defrost process—especially regarding automatic detection of when to start and when to stop the defrost.

APPENDIX A

Technical data on the tested evaporators:

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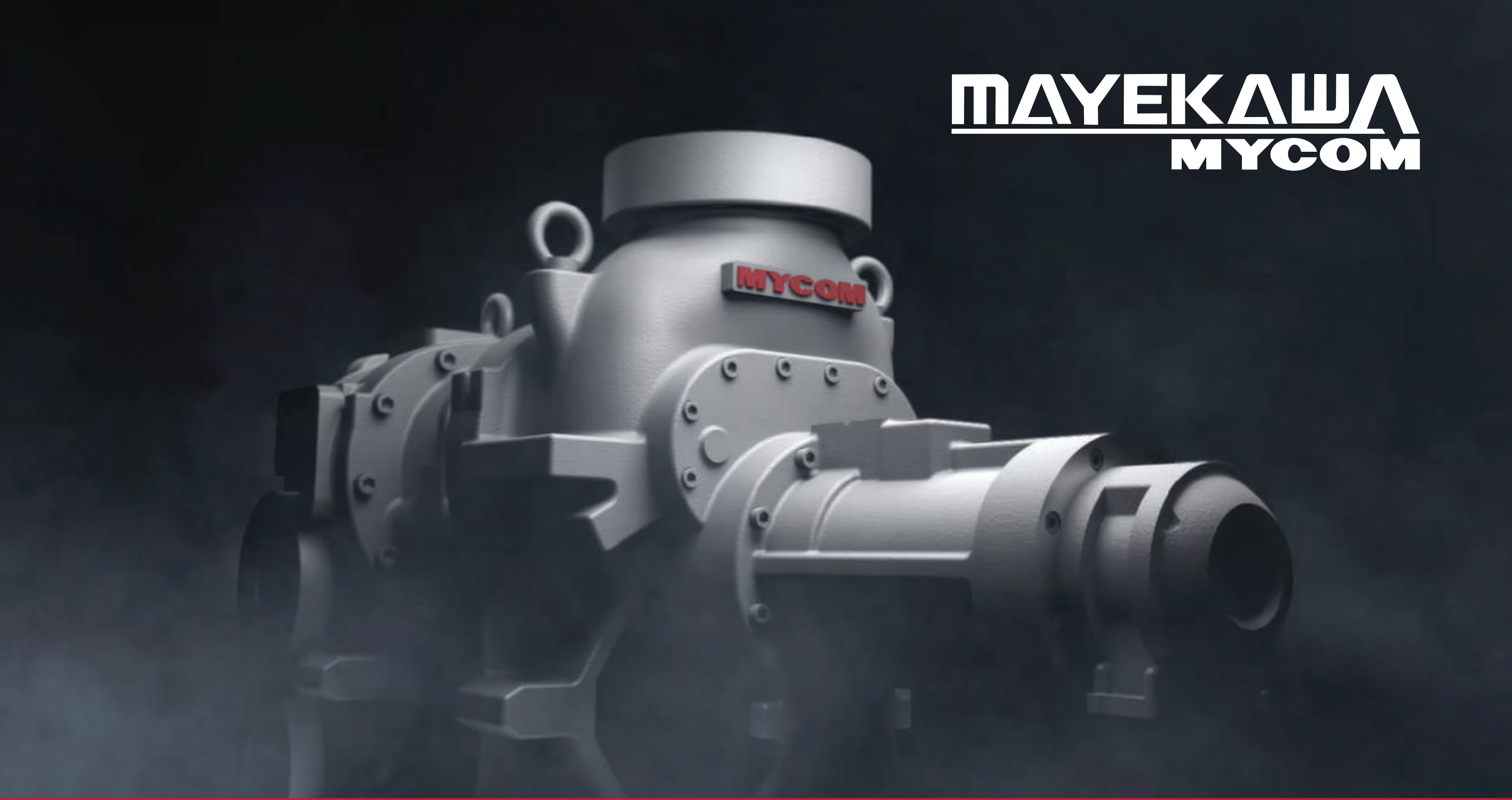

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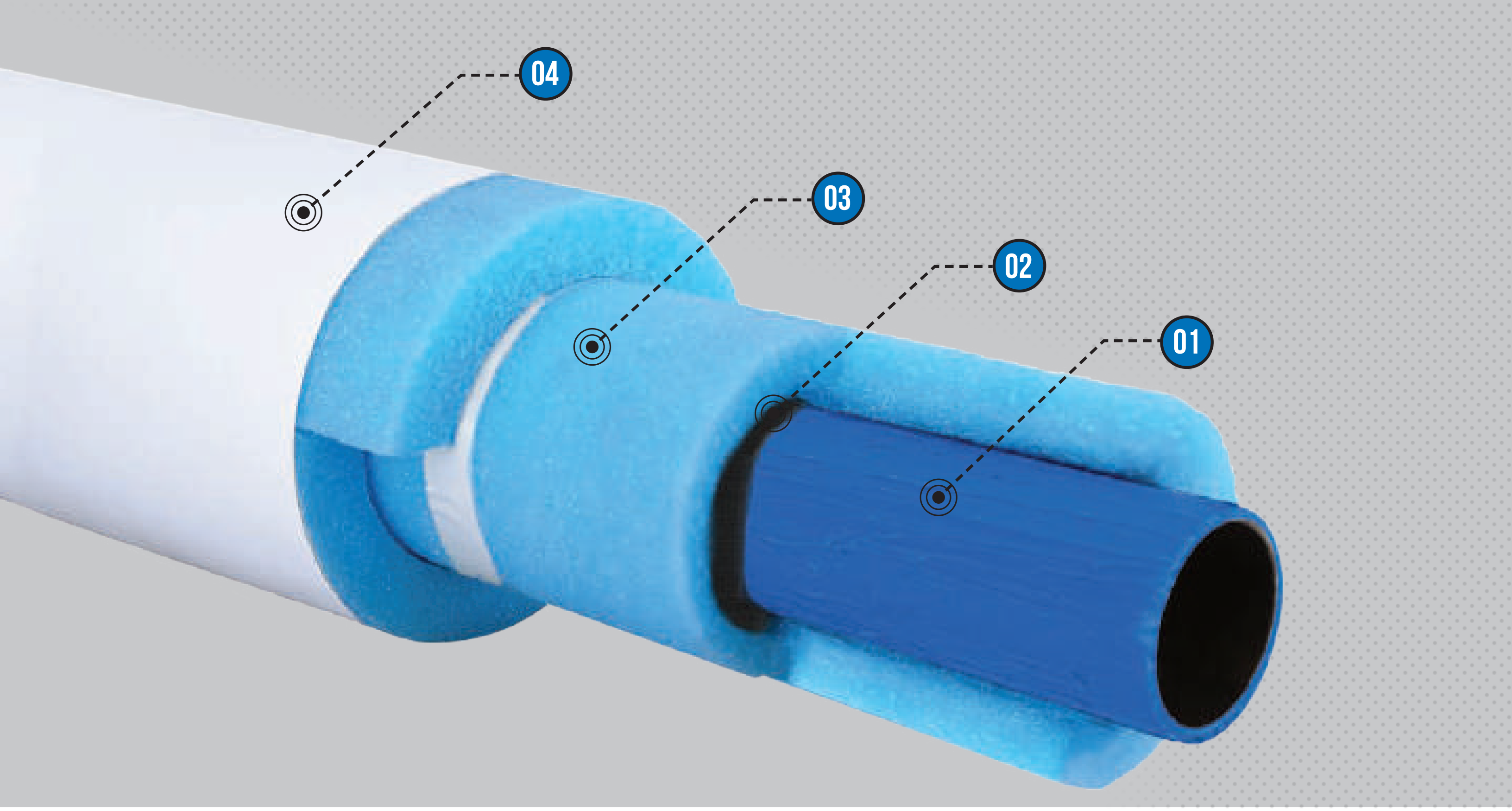

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