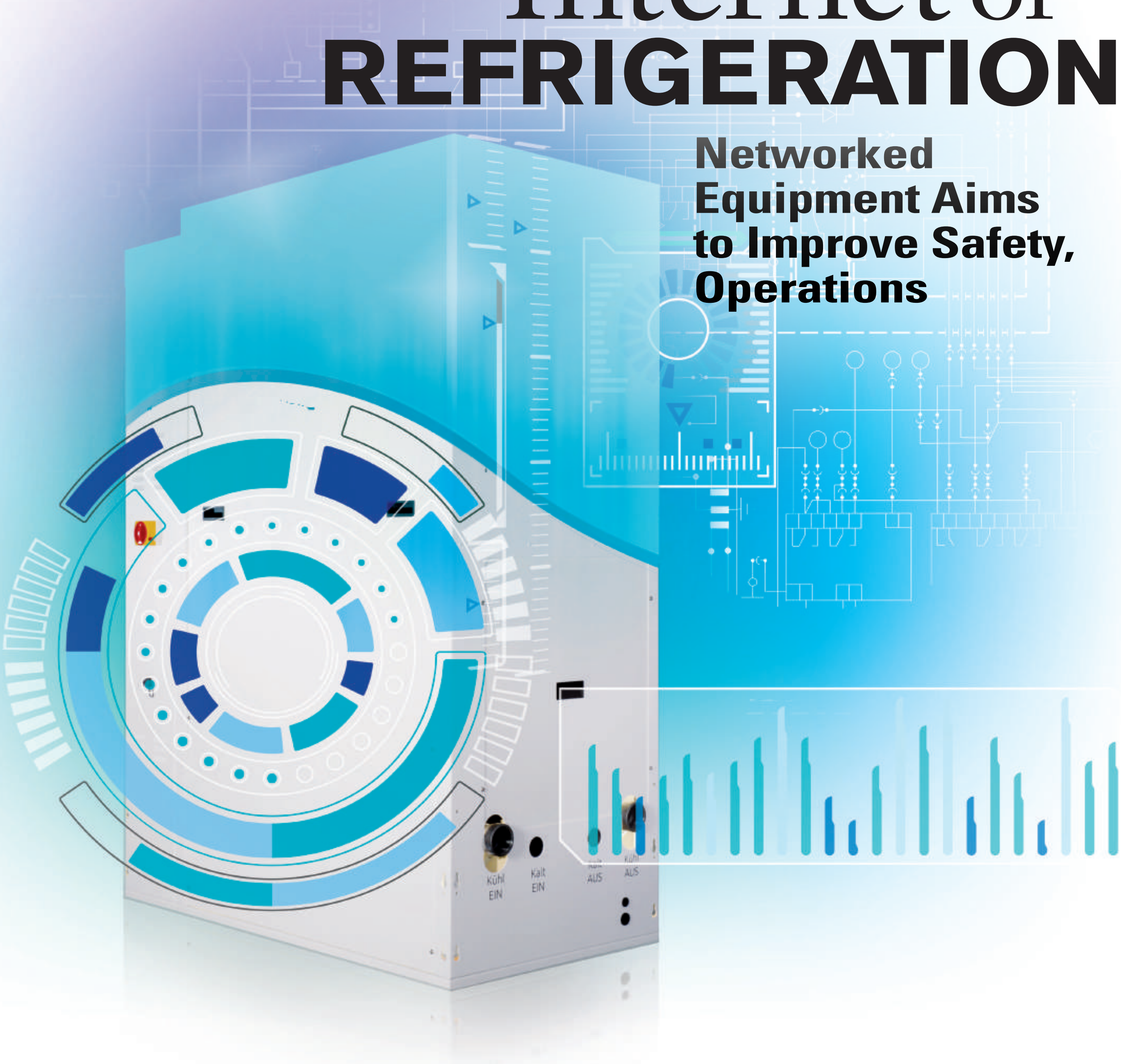
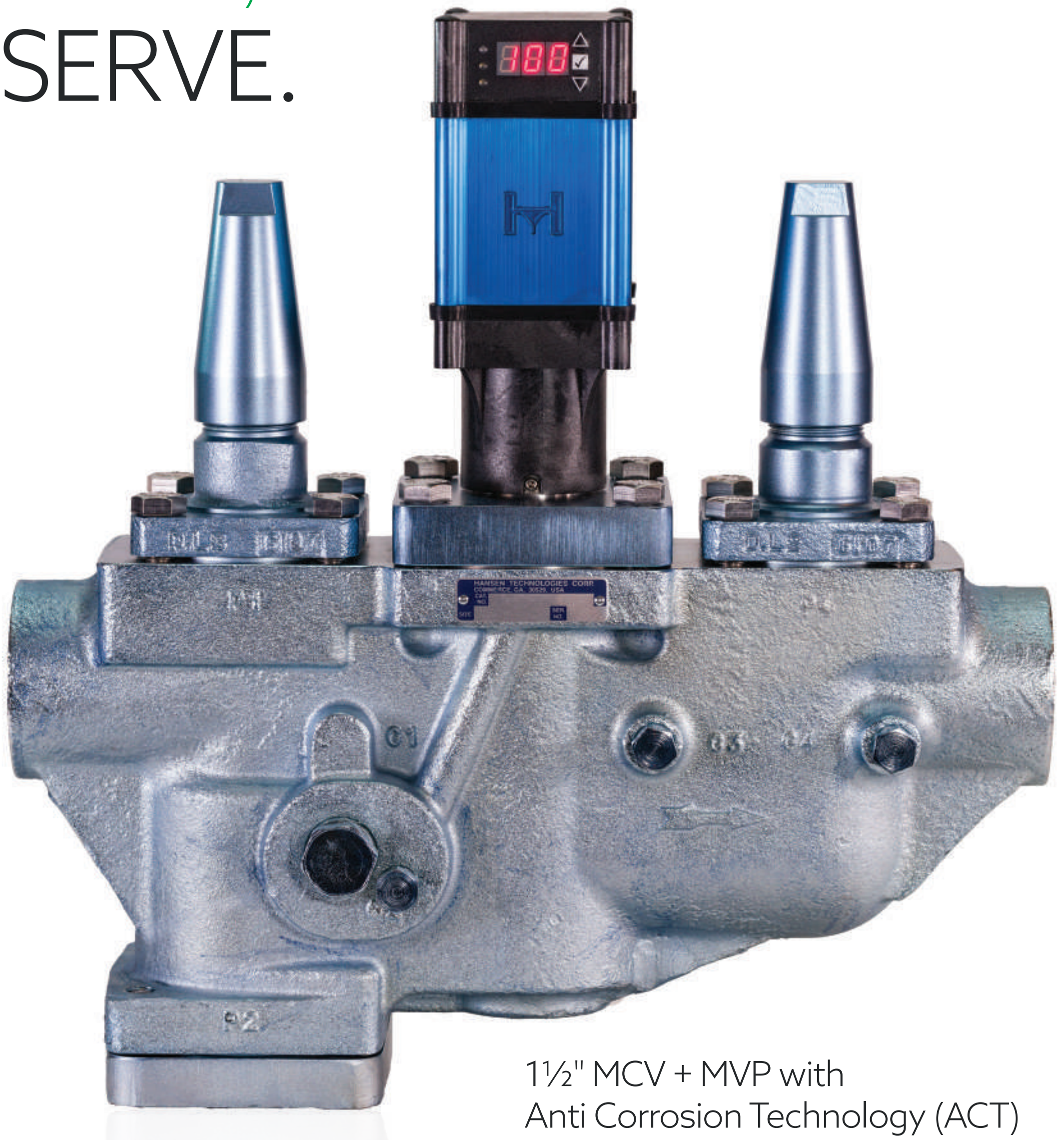
THE OFFICIAL MAGAZINE OF THE AMMONIA REFRIGERATION INDUSTRY ■ JUNE 2017

CONDENSER

The Internet of REFRIGERATION

Networked Equipment Aims to Improve Safety, Operations





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chairman's MESSAGE

BY WALTER TEETER

We're kicking off a new year and setting new agendas, and even though I'm well into my term as your IIAR Chairman, I'd like to take this opportunity to welcome everyone – new and renewing members alike.

We've just wrapped up our annual agenda-setting session and meeting of the Board of Directors, and I'm happy to report that IIAR is embarking on several ambitious goals this year as your staff is busier than ever completing products and projects that move us closer to our strategic vision.

This year's Industrial Refrigeration Conference was our first major step in that direction, and I'm very pleased to report that the event again saw record-breaking numbers of attendees and exhibitors, and added important alliances through developing relationships with the regulatory community.

IIAR's 2017 show was one of our best conferences yet, and that is always due to the hard work and contributions of IIAR's membership. It's appropriate to take a minute – as we begin our membership renewal effort - and extend special thanks and appreciation to all who contributed their time and financial support to this year's event.

If you didn't already realize that we're in the midst of IIAR membership renewal season, the success of our most recent conference – which surpassed expectations – is a great reminder of how essential IIAR membership is to the leadership of our industry.

Resolving some of the most complex scenarios we are facing will depend on the ability of IIAR's membership to come together and continue to develop the resources and communicate the potential of new technologies at our industry's central event.

This year, we looked at many of the challenges facing our business environment, talked about the regulatory landscape, and examined the technology and best practices we'll need to meet growing demand from so many new – and traditional – sectors.

Resolving some of the most complex scenarios we are facing will depend on the ability of IIAR's membership to come together and continue to develop the resources and communicate the potential of new technologies at our industry's central event.

I'd like to take this opportunity to call not only for your renewed membership, but also for your increased participation and leadership in IIAR's committees and development of conference technical papers. Whether you get involved as a committee member or tech paper author, or in any other way, your involvement is what moves us forward.

Our publications are second to none, addressing new trends and introducing new technologies, and you, as an IIAR member have the opportunity to contribute to them directly.

You also have an opportunity, as a member, to expand your interaction with your peers, and influence the policies, codes and standards that shape the way we do business. Our committees span all of these areas and beyond, and they all depend on your help and support in some form.

To that end, we'll be focused once more on the work of our committees this year, especially in the regulatory arena, where we've continued to build relationships on behalf of our industry, carrying the torch on initiatives with the Department of Homeland Security, EPA, OSHA and many other government organizations.

And we're continuing to grow as a resource for the educational and training materials that make our industry safe and enable the use of new natural refrigeration technologies. I encourage you to turn to Dave Rule's President's Message in this issue to read about the exciting developments around our new education program – starting with the success of the IIAR-2 training course.

The Academy of Natural Refrigerants is one of our most exciting new initiatives.

However you decide to get involved this year, I'm hoping you'll see this IIAR membership renewal season a little differently, as a chance to dive in to the work of your organization. We're growing like never before, and I'm looking forward to working with you all in the year ahead.

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president's MESSAGE

BY DAVE RULE

It's the beginning of the summer and that means it's time for one of IIAR's most important activities – leading membership renewals. And while this may seem like a routine activity we all work hard to complete every year, I'd like to take the opportunity in my column this month to point out that, as an IIAR member, this is one of the most important contributions you can make to the success of our industry.

The call for renewals is much more than an invitation to continue your membership. It's an invitation to support the growth and expansion of new initiatives, programs and goals, and to support the expansion of our industry in general.

We're focused on membership and committee work that will address the trends that are already shaping our future as a technical community. And your staff and dedicated Board of Directors are looking ahead to take stock of where we are now, and where we're headed. New technologies like low charge systems, greater adoption of CO_2, and other developments are taking natural refrigerants in new directions, and IIAR is keeping pace.

One of the most promising new programs you've heard me talk about is our Academy of Natural Refrigerants. The IIAR-2 initial class was a great success, the second round of new classes are now available online for members to complete their course work remotely, and we're looking forward to expanding this functionality in the year ahead.

This remote training platform is an important new way IIAR is providing members essential access to IIAR member benefits – and I'm looking forward to expanding this functionality in the year ahead.

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

We'll release course work in September for the IIAR 4, 5 and 8 Standards, and an introduction course for Process Safety Management and Risk Management will begin in November. The PSM and RMP module will be the first of several PSM/RMP course modules that will be offered by both IIAR and the University of Wisconsin to provide a comprehensive certificate for PSM/RMP professionals working in our industry.

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

We're also expanding our education program with the continued development of new materials for our monthly series of education webinars for IIAR members. I hope you'll take advantage of this great member resource – to expand your knowledge base, and just get new perspective on day-to-day operational issues in the year ahead.

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

I'd also like to touch on our upcoming Natural Refrigerants Conference & Expo, which is slated for the Broadmoor Hotel in Colorado Springs, CO next March. We are expanding our technical program this year to include more Tech Paper sessions, Workshops and Panels designed to address the expanded opportunities for natural refrigerants in both the industrial and commercial market sectors.

And we've recently confirmed the venue for our popular Monday night event, which will be held at the U.S. Olympic Training Center. The evening will include a tour of the facility with several Olympic demonstrations including gymnastics, wrestling and target shooting. This will be a rare opportunity to see how Olympic athletes train and, as always, a great chance for conference attendees to network with members of all sectors of our industry.

This is an exciting time to be a member of IIAR, and these member benefits, programs and projects are opportunities to make our industry more dynamic and effective than ever before.

Our success as an IIAR member community is directly related to your membership renewal, and, of course, the dedication and hard work of the many volunteer members serving on the various technical committees, executive committee and the board of directors.

As a member, you are IIAR's most valuable resource. I'm looking forward to working with the IIAR community this year to achieve all of our goals, and I invite everyone to renew your membership, and get involved in helping us fulfill the important mission of our organization.

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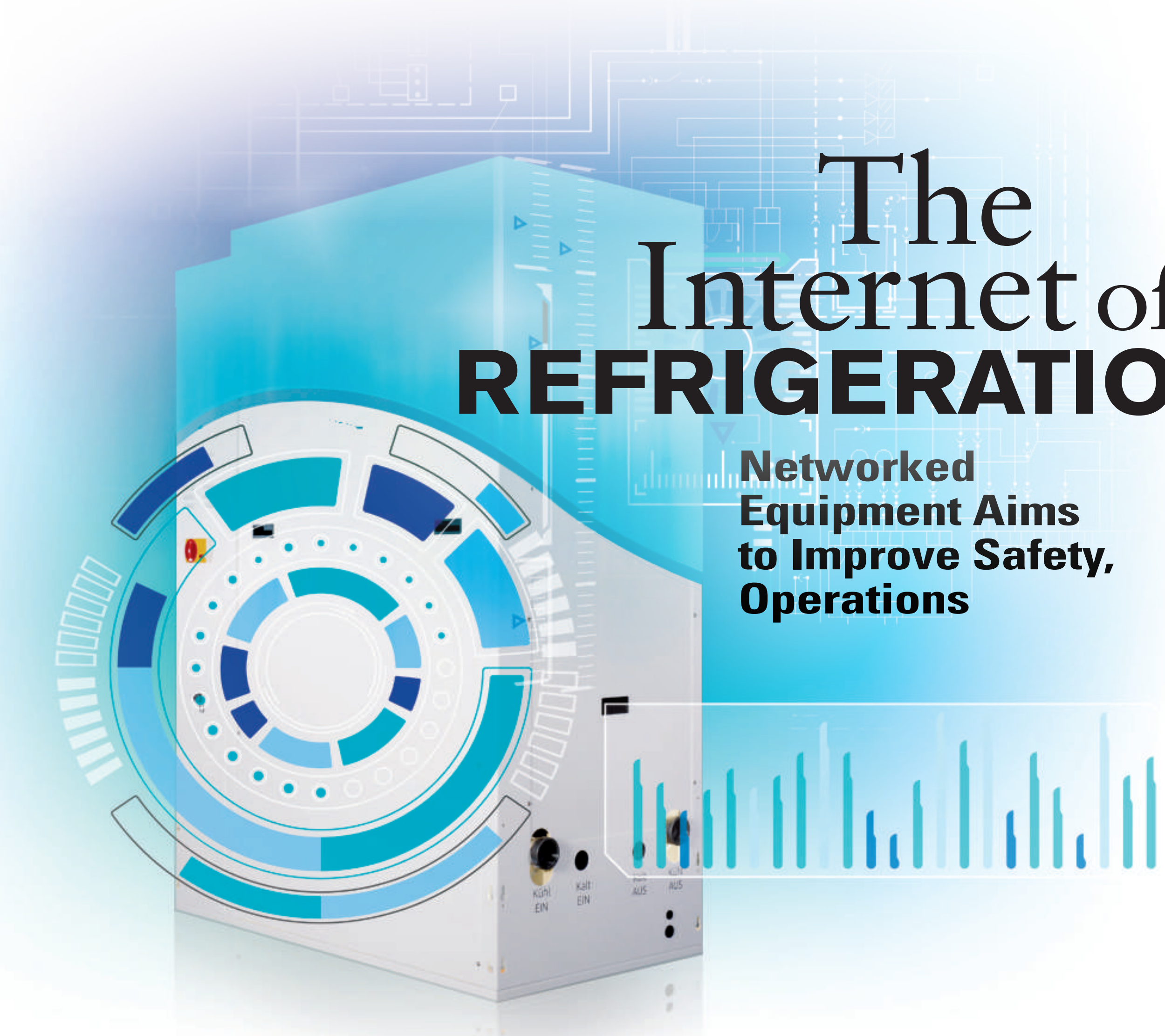

The Internet of REFRIGERATION

Networked Equipment Aims to Improve Safety, Operations

The Internet of Things — an increasingly massive network of electronically connected systems, devices and people that enables cross-platform data sharing — is creating a large, connected ecosystem across many industries, including refrigeration.

"There is continuing growth in remote monitoring with all types of refrigeration equipment, driven largely by the need to safeguard consumers and food, manage energy use, and provide a consistent, effective maintenance program," said Dean Landeche, vice president of marketing for Emerson Commercial & Residential Solutions, a technology and engineering services provider based in St. Louis.

Retail groceries have long recognized the importance of connected refrigeration systems, and have high adoption rates of connected devices, Landeche said. Previously, the primary focus was operating alerts and alarms to indicate problems. "Now, with more points of connection, more sophisticated data from embedded sensor and controllers and advanced analytics capabilities in the 'big data' world, the focus has changed to creating more insights that drive specific decisions and actions," he explained.

Landeche said he is seeing much more interest and use of information to prompt action in advance, based on opportunities and trends identified in data patterns rather than reacting to failure modes and alerts. "Applied at the system, site and enterprise levels, those types of insight-driven actions have huge implications for cost-saving, labor productivity, maintenance improvement, food safety and more," he said.

Tristam Coffin, director of sustainability and facilities for retail grocer Whole Foods, said there is value in having information housed in one location. "You can't manage what you don't measure. You want to be able to measure systems and compare them so you can manage loads properly and have access to troubleshoot, make changes or make adjustments so the system is operating appropriately," he said.

Coffin said Whole Foods is constantly looking for new solutions, and has remote control over the refrigeration systems and other major HVAC systems. However, Coffin said he hasn't found a single solution. "The main obstacle we're running into is one, equipment and two, whether that equipment is open protocol so we can integrate other software systems to take an enterprise approach. We're in the discovery process right now," he said.

Coffin said systems haven't evolved much in the last 10 years, but he is starting to see a shift. "We're seeing a little bit of fusion of technology with the Internet of Things and software-as-a-service technology becoming available. That is exciting," he said, adding that the challenge is making them all communicate with each other. "We have a lot of things but we don't have them all dialed in and connected with each other."

Through remote monitoring, equipment owners and their service providers can often detect problems as they emerge rather than after-the-fact in an emergency breakdown. "Major food safety risk and food loss is often avoided, and system operation can be maintained through proactive efforts," Landeche said. "We're also seeing more adoption of remote monitoring for refrigerant leak detection, where advanced data can often identify small leaks up to 30 days prior to discovery by leak detectors."

Colmac Coil's heat exchangers include sensors that talk to a central computer system in a facility. "We're reporting things like temperatures, pressures, different operating conditions of the machinery that indicate to the central computer system timeliness of maintenance, proper operation or failure modes," said Bruce Nelson, president of Colmac Coil. "Not only does it allow companies to do more preventative maintenance, but also anticipate failures and make adjustments before things fail. It also offers opportunities for increased efficiency of operation."

Landeche said he is also seeing simplification of the actual insights tools, meaning that users can often use software more easily than before rather than relying on expert third-parties for complex and costly project-style work. "Today's smarter systems are making it easier, faster and highly reliable to implement equipment monitoring and performance processes," Landeche said.

With more embedded electronics, self-diagnosing systems, automated data processing and easy access to wireless networks, many start-up challenges and operational difficulties have been minimized, Landeche said.

For many organizations considering remote monitoring, network security remains a concern, as a few well-publicized security breaches have been linked to access through IoT systems. "These concerns generally can be resolved through proven, managed security processes, effective firewall systems, separate operating networks, or even full outsourcing of IoT system functions to keep equipment and operational functions totally separated from customer records and financial data," Landeche said.

A wider array of embedded sensors provides more points of data to internal controllers. In turn, those controllers have more onboard functionality for automated operations, more storage capacity for data, and onboard communications capabilities that can often exchange information in a direct-to-cloud environment.

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– Dean Landeche, vice president of marketing for Emerson Commercial & Residential Solutions

For example, Emerson's CoreSense technology unlocks advanced diagnostics, protection and communication in Copeland compressors. With in-depth system information, technicians can make faster, more accurate decisions resulting in improved compressor performance and reliability. Based on user interest and contractor support, CoreSense availability has been extended as a basic component on many of Copeland's Scroll compressors.

Rob Seitz, owner of Kolbi Pipe Marker Co., said he is seeing an increase in the number of companies requesting QR codes. With QR codes, each piece of equipment would have its own code and anyone with a smart device can scan the code and view standard operating procedures for that equipment, preventative maintenance schedules, prior maintenance work and other pertinent information on their smart phone or portable device.

Kolbi can print the codes on five different substrates. "We're getting a lot of questions and opportunities about QR codes. Contractors and the individual owners are coming to us asking if we can do this. Because of our digital printing equipment and capabilities, we're able to say we can," he said.

"The information is accessible. It is powerful and everybody can have it," Seitz said, adding that the technology allows for the accumulation of information and makes it instantly accessible right at a piece of equipment as well as online.

Coffin of Whole Foods said he believes that as technology evolves and the industry moves into natural refrigerants there will be even more opportunity for visibility from a safety perspective. "I think it is important that technology continues to evolve and provide visibility for energy management and load-side management of the systems that are being employed in any given facility," he said.

People expect to have visibility into whatever they may be managing at their fingertips and Coffin expects customer demand will only increase. "It started with email on your phone, now you can be 3,000 miles away from a facility but dial in and see exactly how it is operating," he said.

Packaged Components Promise Flexibility, Lower Install Costs

Package systems are providing turn-key solutions for those within the refrigeration industry, and some manufacturers are turning to packaged components within those systems, which can cut down on the number of parts in use and make maintenance easier.

> **"Years ago, everything was basically custom, but today you're seeing lots of people packaging equipment and some of that has packaged components. Look at a valve. It used to be you had to buy six to eight components for a valve group. The manufacturers have gotten that down to a convenient assembly."**
>
> **—Bob Czarnecki, chairman of the IIAR standards committee and a retired refrigeration program manager at Campbell Soup Co.**

"Years ago, everything was basically custom, but today you're seeing lots of people packaging equipment and some of that has packaged components," said Bob Czarnecki, chairman of the IIAR standards committee and a retired refrigeration program manager at Campbell Soup Co. "Look at a valve. It used to be you had to buy six to eight components for a valve group. The manufacturers have gotten that down to a convenient assembly."

For example, some coils include valves and controllers. "You're seeing other people do that as well," Czarnecki said. "People are doing this mainly because the customers like it."

Bruce Nelson, president of Colmac Coil, said Colmac is always looking for ways to add value to the customer. "As a heat-exchanger manufacturer, we are increasingly offering our customers control valves and controls that are incorporated into the heat exchangers themselves," he said, adding that the company is also looking for ways to make systems more intelligent.

Danish equipment manufacturer Danfoss has taken a modular approach across its entire platform, including its valves, which creates a more compact and effective way of installing the valve station. "It is a natural fit for a package system, which has much more space constraints," said Terry Chapp, North American business development manager for Danfoss.

"The end user is looking for something that is more complete that isn't this custom thing they have to take care of. They're looking for more flexibility and lower install costs and equipment that takes up less space.

—Bob Czarnecki, chairman of the IIAR standards committee and a retired refrigeration program manager at Campbell Soup Co.

Colmac Coil's Advanced Direct Expansion evaporator technology now uses more specific control valves that are more sophisticated than the traditional hand expansion valve. "There is a digital controller that monitors the evaporator performance and controls the expansion valve appropriately and reports what it is doing to the facility control system," Nelson said.

When Emerson Commercial & Residential Solutions, St. Louis, Mo., creates a package with the screw compressor, they also provide the motor to go with it. "We put this together and sell this compression package to a design-build contractor or an OEM and they would add that to part of their larger architecture," said Andre Patenaude, director of CO_2 business development for Emerson Climate Technologies.

Generally, Emerson will approach an OEM or a design-build contractor and explain that the company has electronic controllers that can be packaged up or married to the electronic expansion valve controls or the CO_2 control.

SIMPLIFIED MAINTENANCE

Maintenance is part of any refrigeration system. "Any piece of rotating equipment like a compressor or a fan or a pump has a normal maintenance schedule," Nelson said. "All rotating equipment has a defined lifetime and even parts that don't move like coils and condensers, have other maintenance issues that have to be addressed."

However, the modular approach makes repairs easier, Chapp said. "Historically when you had different components, you have to isolate them and pump down the refrigerant," Chapp said. "With the valve station, there is much smaller internal volume and there is not as much liquid or gas to pump down and it is very easy to isolate which part has to be worked on."

Once it is pumped down, Chapp said, changing the module is as easy as removing four bolts, pulling out the module and replacing it.

Patenaude said package systems use semi-hermetic compressors. Because they are not fully hermetic, they can be serviced and repaired. "More and more techs today don't spend as much time repairing. They tend to want to replace a component," he said.

Being able to easily swap out components could be beneficial given the aging workforce within the industrial refrigeration industry. "The ability to spend the time learning and mentoring in today's environment is substantially reduced. You have to make it easier on the technician and the modular design makes it easy," Chapp said. "If a guy can pull four bolts and replace it, it is easier to find someone properly trained to complete the work."

Depending on the system, the initial cost of packaged components could be higher, but Chapp said insulation costs could decrease because there is no need to create vapor barriers for every little piece. "You're putting one piece on," he said.

Pump manufacturer Grundfos of Downers Grove, Ill., uses a variety of package components within its systems, including electrical panels, heat exchangers, control cabinets and variable frequency drives, said Doug Bolinger, national sales manager, industrial refrigeration for Grundfos.

THE FUTURE OF PACKAGE SYSTEMS

Bolinger said package systems have several benefits, including being a one-stop shop and coming with a complete package warranty. It also allows one manufacturer to handle order intake and complete an entire system, as well as provide technical support and service support going forward.

Regulations related to the handling of ammonia in a facility are typically triggered by the amount of ammonia in a facility. "Package systems reduce regulatory burdens by reducing the ammonia charge in each of the systems. There is also some interest in package systems as a way to reduce installation time," Nelson said.

"The end user is looking for something that is more complete that isn't this custom thing they have to take care of. They're looking for more flexibility and lower install costs and equipment that takes up less space," Czarnecki said.


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Cleaner Coils Boost Cooling Capacity

When a large food distribution facility was faced with major issues resulting from evaporator and condenser coils coated with dust, dirt, and production debris, it turned to EcoClear in Georgia and its deep-cleaning system. The facility was looking to improve air flow, increase dehumidification, improve energy savings and reduce maintenance cost through a deep cleaning of the coils.

The process involves self-contained pressure-washing rigs that are designed to deliver a high volume of water hot enough for sanitation. (While being treated, units are taken off-line for a limited amount of time.) The technique employed is more important than the amount of pressure in order to avoid flattening the coil fins, causing a further reduction in the coil heat-transfer performance, and unknowingly pushing dirt deeper into the coil due to a lack of water volume.

Coils with a layer of dust the thickness of a dime lose up to 21 percent in efficiency, because the coat of dust insulates the surfaces, thus reducing the cooling capacity. As reported by Tony Lundell, IIAR assistant technical director, in Condenser in June 2014, dirty evaporator coils "increase discharge head pressures, reduce compressor capacities, increase delivered supply air temperatures and overall increase energy usage."

Simply put, properly cleaned evaporator coils will prevent food contamination, improve air flow and reduce operating costs.

"We had an area that needed more air flow," the food distribution facility's refrigeration manager said. "The evaporator coils had frosted up. Initially, we had a mechanic clean them and we thought it was thoroughly done, but we couldn't see deep enough into the coils."

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Three employees worked on two five-foot-long evaporator coils, removing the fans from on top of the coils, removing the side panels, and then using biodegradable soaps and high-volume pressure washers to penetrate deep into the coils.

"With a clean coil, the temperature drop across the coil is typically 10 to 15 degrees. This company had a three-degree drop, which meant 50 percent less air flow. That costs around $5,000 per unit in energy efficiency annually," said Brian Hindt, EcoClear owner.

That translates for a company that has 20 units to as much as $100,000 in energy savings.

The company's deep-cleaning system improved heat transfer and air flow, allowing the facility to reduce running time and maintain temperature. "It takes longer for the cleaning, about one full day, but it's the right way to do it," the facility's refrigeration manager said. "They put some pressure on the coils and they got them clean. Just looking at the coil I can see more humidity being picked up out of the air, more condensation falling off the coils into the drain pans, and the coils definitely aren't freezing. I can also tell that the air flow has increased."

EcoClear uses a proprietary software to estimate the cost savings produced by their complete cleaning and coatings. The cost of this process is typically covered in four to six months.

"If you have a totally clean system you will reduce the running time on your compressor, and therefore reduce the frequency of oil changes. You're also not blowing foreign matter, which stops production and results in wasted product," Hindt said.

Following the deep cleaning, a proprietary disinfectant was applied that kills listeria, salmonella, E. coli to a log reduction of six.

The company said its disinfectant is a registered EPA and NSF product. The unique blend provides many advantages to current market chemicals, including the ability to be applied in unconditioned space, is food-safe with no wipedown required, and does not have any VOCs.

A specialized GreenScreen coating is then applied to the unit, which is one-half to one micron thick. The GreenScreen protective coating is a photocatalyst of nanocrystals that acts as a "wetting agent" to help water run off in sheets, instead of typical beading that leaves spots.

The coating forms a thin water film, which easily runs off, taking dirt, oils and contaminants with it. With less spotting, easier dirt release and oil removal, reduction in cleaning costs and faster evaporation, the coating provides superior heat transfer by inducing film flow and evaporation. Essentially, the coating prevents the surface from growing bacteria and does not allow anything to stick to it. Therefore, the coils will remain cleaner longer, which makes for easier future cleanings. The coating lasts, on average, one to two years.

The deep cleaning resulted in an eight-degree temperature drop across the coil and increased air flow from 7,500 to 13,900 cubic feet per minute in one coil, and from 8,100 to 14,000 cfm in the second coil. In addition, the post-coil dry-bulb split went from five to 9.8 degrees in the first coil, for a 70 percent improvement, and from 4.8 to 10.7 degrees in the second coil, for a 100 percent improvement.

"After the cleaning, we're using less horsepower and fewer kilowatt hours to run the coil," the refrigeration manager said. "The unit runs 40 percent less than before. This has made a big difference. We are able to maintain temperature much more easily."

IIAR Members Honored with Awards from Accelerate America

Accelerate America magazine honored five IIAR member companies for their work in advancing natural refrigerant adoption in North America as part of its second annual awards program. The awards were presented in June during the ATMOsphere America conference in San Diego

The magazine, which is produced by shecco America, presented best-in-sector awards to: Whole Foods Market in the food retail, category; United States Cold Storage in the industrial category; and Nestlé in the foodservice category. Hillphoenix received the Innovation of the Year award for its AdvansorFlex transcritical carbon dioxide modular refrigeration system designed for small-format stores.

"Congratulations are in order for all of these companies," said IIAR President Dave Rule. "Their leadership in this industry — developing and engineering new methods of using natural refrigerants to replace HFCs — and their support of IIAR and Atmosphere America is having a real, positive environmental impact."

Whole Foods has been a leader in natural refrigerants, including CO_2 and ammonia. The food retailer has transcritical CO_2 systems at several locations and is testing ammonia-CO_2. The company says its Whole Foods Market store in Santa Clara, California, has the most environmentally-advanced grocery retail refrigeration system in the U.S.

US Cold Storage provides temperature-controlled warehousing and transportation at 39 facilities across the country. In 2015, US Cold Storage installed its first ammonia-carbon dioxide refrigeration system and one of the first in the industrial refrigeration industry.

Hillphoenix, a provider of environmentally sustainable refrigeration systems, has created the AdvansorFlex CO_2 refrigeration system as part of its evolving Advansor CO_2 platform. The latest offering is designed to bring HFC-free refrigeration to small and medium-sized retailers.

The Person of the Year award was presented to Paul Anderson, senior director of engineering for Target, which has installed propane stand-alone display cases in more than 580 stores. "Paul Anderson has been a leader at Target, first in making CO_2 cascade systems a prototype for new stores, and then by installing propane cases on a national scale."

Anderson has been with Target since 2007. He also held positions with Eaton Corp., Taylor Industries and John Deer.

IIAR Remembers George Yoksas

George Yoksas was a long-time federal safety regulator, but he hated when red tape got in the way of solving issues.

"He wanted to find solutions. He would say, 'How can we make this work and have a meaningful impact?' " said Doug Reindl, a professor in the University of Wisconsin departments of Engineering Professional Development and Mechanical Engineering, and a founding director of the Industrial Refrigeration Consortium. "He was willing to think differently than someone who might look at a standard or regulation and say 'It says this.' He thought about what made sense."

Yoksas, who died at age 66 on June 5 in Darien, Ill., spent more than 40 years with the U.S. Occupational Safety and Health Administration, working in the safety and health field. He started with OSHA in 1975 as a safety specialist compliance officer and went on to serve as the area director in the Milwaukee office and as a Process Safety Management specialist for Region V. His duties included overseeing implementation of the PSM standard throughout the six states that make up OSHA Region V.

He was one of OSHA's leading experts on PSM and was closely involved in its application in ammonia refrigerated facilities. He was instrumental in working with IIAR to transplant knowledge of ammonia refrigeration technologies into the agency through a web-delivered training program designed specifically for OSHA compliance personnel.

"He worked his way up from a boots-on-the-ground position to various management roles," said Reindl, who taught a process safety management course with Yoksas at Wisconsin for 20 years. "He was familiar with OSHA standards and regulations, and he knew how to apply them. He was very involved when PSM was rolled out in 1992.

"I knew immediately I was blessed when I had the opportunity to work with George. His passion and commitment to improving workplace safety was endless and inspiring. He was a master of both the subject matter he taught and in the delivery of his message."

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>
> **– Doug Reindl, professor in the University of Wisconsin departments of Engineering Professional Development and Mechanical Engineering, and a founding director of the Industrial Refrigeration Consortium**

Dave Rule, president of IIAR, remembers Yoksas as a compliance officer who was zealous about improving safety. "He was always very involved in making comments and suggestions on how we could improve our standards," he said. "But he was always very reasonable. Some inspectors can be quick to make a citation of a little substance, but George didn't approach it that way. He approached things logically, always for the best interest of the industry in trying to make things safe."

Yoksas worked closely with IIAR in the search to improve safety standards. "He was very appreciative of the work that the IIAR was doing and he always wanted to be involved to help us in developing our standards," Rule said. "He was very supportive of what we were doing. Besides being an all-around good guy, it was really nice to work with somebody who had the best interests of our industry at his core."

Yoksas took the time to learn about the ammonia refrigeration industry, Reindl said.

"He wasn't afraid to get involved in a specialized industry and learn more about the technology so that he could help end users be in compliance and also educate people in his own agency as to how they should look at that industry," he said. "He learned a lot about ammonia refrigeration and was able to help people in OSHA understand that technology.

Yoksas played a major role in OSHA's creation of the Office of Chemical Process Safety Enforcement initiatives. "He recognized that ammonia is a specialized knowledge, and he was a key resource in helping field people understand how the technology works and how the standards should apply to that technology," Reindl said.

He was also a gifted instructor and presenter, Reindl said. "He was very engaging, people really liked his style. He had a little humor in there, all these things you wouldn't think of from a so-called 'stodgy regulator.' He was very dynamic, and his depth of knowledge was wide and deep," he said.

Yoksas, a respected advisor and a mentor to many in the industry, regularly taught PSM-related courses at the OSHA Training Institute, and at the time of his passing he was a staff member with OSHA's Office of Chemical Process Safety.

Tributes posted to his online obituary detailed his many contributions to safety and how he impacted those in the industry.

"He believed in safety, he enforced safety and he taught safety to all who would listen. He did all of this with a smile and with dignity," one tribute read.

"He will continue to save lives and make workplaces safer through all the compliance officers he has taught and assisted with PSM cases," read another.

Yoksas leaves his wife, Diana; two sons, Clay and Adam Yoksas; a sister, Dena (Jack) Kempf; and many nieces and nephews.

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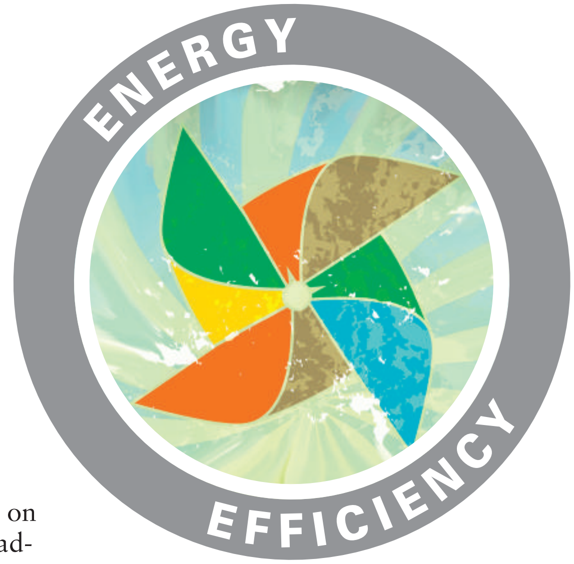
Sealless Pumps Reap Energy Savings



Seal-less magnetic pumps, or mag-drive pumps, have become the preferred option for a variety of conditions in the ammonia refrigeration industry, mainly because they take the heat generated by the pump's electric motor out of the cooling process.

Sealless magnetic-drive pumps (MDP) are equipped with totally enclosed fan-cooled (TEFC) motors, offering versatility for a variety of conditions in ammonia and carbon-dioxide refrigeration processes. Because the MDP avoids adding motor heat to the system's cooling load, the result can be significant energy savings. The other type of sealless pump is a canned-motor pump (CMP), which is totally enclosed liquid-cooled (TELC).

"The electrical motor on our mag-drive pump is fan-cooled by ambient air temperature, so we've removed the internal motor heat from a cooling process," says Joe Warrender, general manager of Warrender, Ltd, which has specialized in manufacturing sealless magnetic pumps for more than 30 years. "That is the primary source of heat, and adds to the overall heat load. Canned motor pumps must cool the electric motor windings with process liquid," he said.

"Another source of heat is the resistance to the magnetic field through static metallic barriers, with MDP rear casing or CMP isolation shell," Warrender said. "As opposed to CMP's electromagnetic field, the MDP has a permanent magnetic field in the drive coupling. Magnetic hysteresis losses from either type of field is reduced exponentially by lowering the rotational speeds."

A MDP rear casing with twice the wall thickness of a CMP, operating at 1,800 rpm, has comparable magnetic energy losses or resistance as the canned motor shell with the same metallurgy, operating at 3,600 rpm. Therefore, both canned-motor pumps and magnetic pumps generate eddy currents.

However, the heat load of TELC canned-motor pump windings is based on motor stator heat, independent of pump speed. For example, the CMP "reverse flow" by-pass line is necessary to manage liquid vaporization through the flow circuit. The CMP internal motor heat induction is more than five times that of the corresponding MDP magnetic drive coupling.

Continuous-duty recirculation pumps (vs. intermittent transfer) represent a more significant impact on energy consumption. Motor full-load-amp ratings are one indication. However, the heat rise through a pump's internal flow and cooling circuit is the primary determining factor.

There are four heat induction sources common to both MDP and CMP systems: pump hydraulic efficiency and internal recirculation, which varies with operating point and pump efficiency; eddy current losses, factored by speed, grade of alloy and thickness; motor efficiency; and internal bushing friction, factored by speed.

Heat induction sources unique to CMP include motor stator winding heat and motor armature/rotor slippage.

Magnetic-drive pumps utilize standardized motors that are accessible without decommissioning and evacuating the pump of ammonia. Thus, the MDP pump and motor offer the ability for field repair. Lower operating speeds provide stable NPSH (Net Positive Suction Head), without flow restrictive inducers, with lower wear coefficients, and extended pump life cycles. "When operating a CMP at 3,600 rpm, NPSHa (Net Positive Suction Head Available) can be marginal [between the system suction head pressure and the pump's Net Positive Suction Head Required]," Warrender said. "Operating with marginal NPSHa can affect pump life and potentially lead to vaporization and cavitation within the pump."

Operating at higher speeds may compromise the liquid film on the wearing surfaces. Compressed gases such as NH3 and CO_2 have low viscosity and specific heat values, and can vaporize through the pump lubrication and cooling circuit, increasing wear on the shaft sleeves, journal and thrust-bearing surfaces. Additionally, bearing-wear coefficients drop exponentially with speed.

CMP internal motor windings continue heating the liquid even after the pump stops. That means it may be necessary to operate continuously to avoid vapor-locking the pump, thus consuming excess energy. "We've developed a sealless transfer pump that will overcome the pressure in the high-pressure receiver and transfer directly from a control pressure receiver or lower pressure vessel," Warrender said.

Ammonia transfer pumps have long caused issues for conventional pumps due to the risks of extremely low NPSH, potential entrained vapor and frequent on/off cycling. Pump life is severely diminished with low NPSH, while on/off cycling can lead to flashing and vapor locking.

Steep pump performance curves, with higher rise to shut-off, accommodates varying head conditions for improved reliability. The rise to shut-off is the determined operating point before flow ceases and the pump is damaged – in other words, how much head pressure is generated before the pump reaches a shut-off condition.

"NH3 vapor pressure and corresponding head conditions can vary with ambient temperature," Warrender said. "Our mag-drive transfer pumps can generate very high head pressure that compensates for variations in discharge heads due to temperature fluctuation. We have two-stage and three-stage pumps. The three-stage pump can deliver liquid from the sidewalk to the sky deck of the John Hancock Tower in Chicago, which is 1,100 feet up."

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R-22: Five Things to Know

With production of HCFC refrigerants ending in less than three years, food and beverage manufacturers who currently rely on R-22 are faced with some difficult choices. Although facilities can continue to use recycled, reclaimed or stockpiled R-22 past Jan. 1, 2020, there will come a time when the shift to lower global-warming-potential synthetic refrigerants or natural refrigerants, such as ammonia, is unavoidable.

"Nobody really knows how fast the supply of R-22 will run out once production is stopped," said Jim Adler, P.E. department manager of Refrigeration Engineering at Hixson Architecture & Engineering. "It could be five or 10 years, but you will run out of inventory eventually. This is a risk that facility owners must consider."

Adler listed five things operators should know when making the transition from R-22 to a natural refrigerant. Adler recently presented a Food Plant of the Future webinar titled, "Beyond R-22: Refrigeration Solutions for Tomorrow."

1. Understand the numerous codes and regulations associated with natural refrigerants.

Although ammonia is an outstanding solution for meat and poultry plants, dairies and packaged food manufacturers, partly because the system can be flexible and run at a different temperatures, operators should be prepared for greater regulatory oversight, including increased paperwork and documentation. They will be required to adhere to local building, mechanical and fire codes, and IIAR's suite of standards (IIAR-2, 4, 5, 6, & 7). Federal guidelines will also require Process Safety Management and Risk Management programs for plants operating with 10,000 pounds or more of ammonia, and an Ammonia Refrigeration Managment program when operating below that figure.

2. Audit existing equipment.

Operators must understand what changes will be needed to the system and the equipment. Start with an equipment/system audit to document what type of systems and what materials of construction are presently used. Most HCFC systems are copper-based and are incompatible with ammonia, which requires carbon steel, stainless steel or aluminum. "You can't just merge the two systems together," Adler said.

Some field-erected R-22 systems may be able to be converted to ammonia but seals, gaskets, control valves, and relief valves may need to be changed. In addition, it will be necessary to check the pressure ratings of the components to verify that they are suitable for an ammonia system.

"The audit should be done by a professional, not your maintenance person," Adler said. "That person needs to understand the implication of switching to a natural refrigerant so they know where to look to collect the data."

3. Consider the cost.

Ammonia will be more expensive, at least at the outset. "You're looking at welded steel pipe, which is more expensive, as well as more robust system components than some of the commercial-grade systems you can get with R-22," Adler said. "Going natural isn't the lowest first-cost option."

4. Pay attention to training.

Employees must be fully trained on how to operate the system, on maintenance and on how to respond to a leak before the system is operational. Unlike R-22, ammonia is self-alarming and there is usually a zero-tolerance attitude regarding an ammonia leak. Operators must have an emergency response plan in place and a working relationship with local first responders.

Adler said several things can be done to reduce the risks and the regulatory burden required for ammonia systems. "You can design a low-charge system that utilizes a secondary refrigerant like glycol or use a low-charge package system currently offered by several manufacturers. Work with your design professional to make the best choice."

5. Think long term.

Ammonia typically operates at a lower kilowatt per ton, so it's an energy saver. And it probably won't be delisted by the EPA. "Ammonia is zero ODP and zero GWP and has been around and successfully used for over 100 years: It's not going to be phased out," Adler said.

He emphasized that operators won't be making the switch alone. There are many highly trained professionals in the ammonia refrigeration industry who are available to help make the transition from R-22. "The IIAR is there for support, along with a competent group of professional engineers, contractors, and safety pros who can help you get there," Adler added.

"In the end, it's a matter of determining what meets your goals and what is best for your company," Adler said. "Find out your leakage rates, how much R-22 you're currently buying and how much you're using. If you're buying 25 to 30 percent each year, you have a problem. If you're buying five to ten percent, you have a pretty tight system and maybe you can reclaim and reuse R-22 or have some stockpiled. Ultimately, though, that R-22 is going to be used up. We just don't know how long it will take."

ARF to Create Industry Insulation Standards and Quality Control Guidelines

While insulation is a critical element within refrigeration systems, there currently is no industry standard for installation or quality control of the installation, a gap that the Ammonia Refrigeration Foundation plans to address with a new research project.

"Cold insulation systems are very finicky about how they are installed. Just like a cold beer on a hot humid day on your deck, water wants to condense from the air onto cold surfaces," said Jim Young, technical director for ITW Insulation Systems. "Water is the enemy of insulation as it can cause corrosion, reduce the insulating ability, and even damage the insulation system. The key to a cold-pipe insulation system is designing it to keep water out. That is a tough thing to do, but it can be done with proper insulation system design and installation."

Because insulation is so critical, the Ammonia Refrigeration Foundation research project seeks to create insulation guidelines for industrial refrigeration systems and a quality-assurance procedure for installation, which will help improve safety, economics, insulation system longevity, and process control. The project will focus on cold pipe, tank, and equipment insulation.

Dave Rule, president of the International Institute of Ammonia Refrigeration, said the insulation project was determined to be of importance to all IIAR members and there was interest in identifying the types of insulation systems that have worked best.

> **"Cold insulation systems are very finicky about how they are installed. Just like a cold beer on a hot humid day on your deck, water wants to condense from the air onto cold surfaces."**
>
> **– Jim Young, technical director for ITW Insulation Systems**

"The public will benefit from having insulation systems that provide safer, longer-lasting, and more energy-efficient system installations," Teale said. "If the installation guidelines and quality assurance procedures are implemented at some future date, it will provide authorities having jurisdiction, inspectors and compliance officials criteria for inspections and approval of insulation systems."

– Eric Teale, director refrigeration engineering/food and beverage sales, Corval Group, Inc.

He said members are interested in which insulation is the most effective, particularly in protecting pipes from corrosion. They also want to know the most effective installation practices.

"That has always been an ongoing concern. It is an important concern in running a plant, maintaining the system and making appropriate decisions when modifying a system," Rule said. "When building a new system, it will help engineers make good, safe decisions on how to build their systems and install them for maximum service life."

Eric Teale, director refrigeration engineering/food and beverage sales for Corval Group Inc., said installation guidelines will allow all parties involved with installing insulation systems to speak a common language and have the same expectations for the finished product.

Currently, insulation manufacturers offer proprietary guidelines, but those don't provide the objectivity that an industry association can offer, Young said. "We realized that even if we as manufacturers have good installation guidelines, the industry lacks a good way of monitoring or controlling the installation of the insulation system," he said.

What's more, best practices vary from contractor to contractor, Teale explained. Most insulation is done by insulation contractors, and Young said the guidelines will provide information to help companies monitor installation and be sure it is done following industry standards.

Teale said that although manufacturers have created guidelines for how their specific products are to be used, they are not comprehensive on how to install the entirety of an insulation system. He added that the project is needed because end users, specifiers, inspectors and insulation contractors are left to rely on guidelines and procedures produced by insulation system material manufacturers. "These guidelines and procedures are often not specific to refrigeration systems and in certain instances are outdated or apply only for hot piping systems where the heat flux is in the opposite direction as compared to refrigeration systems," he said.

The guidelines and procedures currently available are also incomplete in how they address such things as insulation joints, vapor retarder/barrier joints and insulation systems, Teale said. "It is at these joints and terminations that the insulation system is most susceptible to failures due to expansion and contraction forces and mechanical damage," he said. "One of the end results is that the insulation thickness is increased by specifiers to decrease the heat flux into the insulation system giving false hope that this will prevent joints from failing and allowing moisture infiltration into the insulation system."

Teale said insulation systems installed in accordance with the industry guidelines arising from this research will increase their longevity and performance. He said there will also be economic benefits due to facility owners, specifiers, material manufacturers and contractors not having to produce their own installation guidelines and quality-assurance procedures.

"The public will benefit from having insulation systems that provide safer, longer-lasting, and more energy-efficient system installations," Teale said. "If the installation guidelines and quality assurance procedures are implemented at some future date, it will provide authorities having jurisdiction, inspectors and compliance officials criteria for inspections and approval of insulation systems."

IIAR and the Ammonia Refrigeration Foundation have been looking at the project for several years, and it was funded in late 2016. Young solicited project monitoring subcommittee members during the spring IIAR meeting and said he expects to begin holding meetings this summer. Young said the project will take two to three years to complete, and it will focus on compiling data and interviewing industry experts. "This is a bit of an unusual project in that it won't include any experimentation," Young said.

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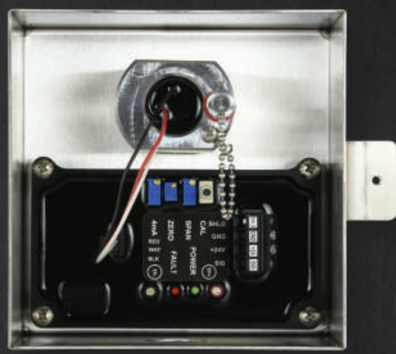

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RETA, IIAR Develop CO_2 Training Materials

As hydrofluorocarbons and hydrochlorofluorocarbons are being phased out, there is a growing emphasis on natural refrigerants. To help improve safety and educate those within the industry, IIAR and the Refrigerating Engineers and Technicians Association are working to create safety standards and develop educational materials

Dave Rule, president of IIAR, said ammonia and carbon dioxide are the most common natural refrigerants being used, and he is seeing more ammonia and CO_2 being used together in cascade systems. "Because of that and because new technology has brought different types of equipment designs, both ammonia and CO_2 are able to be used in places they wouldn't have been before," he explained.

As a result, Rule said he is seeing an increased need for safety standards and technical training related to CO_2. IIAR is addressing safety and is in the process of developing new standards. "We want to make sure the engineering and safety designs are correct, adequate and introduced to the industry in a timely manner. We also need to ensure the technicians and the engineers have the appropriate safety standards," Rule said.

IIAR offers a CO_2 handbook and is in the process of updating it to make it more current, Rule said. "All of this surrounds the emphasis on natural refrigerants being used more prevalently," he said.

The Refrigerating Engineers and Technicians Association is developing new training materials jointly with members of the North American Sustainable Refrigeration Council on both commercial and industrial applications of CO_2 as a refrigerant.

"As CO_2 becomes more accepted in both the commercial and industrial markets, the need for trained and skilled technicians and operators will increase. This need can be somewhat filled by on-the-job training, but additional methods will be needed to fully address the job opportunities," said Jim Price, education manager for RETA. "Those with training and certifications will be best prepared to take advantage of the opportunities."

Price said it will take about one year to produce the training materials, and RETA is halfway through the process. He anticipates multiple paths of study, including self-study, traditional brick-and-mortar classroom learning, seminars and online learning. He said multiple certification opportunities will be available.

Although the common principles of refrigeration apply to CO_2, there are some important differences that need to be understood.

"The paths may include general CO_2 studies, commercial systems, industrial system and combined studies," Price said, adding that the details of the study paths and certifications will be presented once the study material is closer to completion.

Although the common principles of refrigeration apply to CO_2, there are some important differences that need to be understood. "Pressures are different, much higher than we are used to seeing in typical ammonia refrigeration systems. New terms that are not familiar to us have to be learned and understood such as triple point, critical point, and transcritical," Price said.

In addition, simple tasks, such as system charging, system pump downs to opening the system, may have to be relearned.

"In many ways RETA and IIAR are working together to address the more common use of CO_2," Rule said.


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Trump Administration Advances Regulatory Reform

iiar government RELATIONS

BY LOWELL RANDEL, IIAR GOVERNMENT RELATIONS DIRECTOR

President Trump made regulatory reform a priority during the campaign and pledged to provide industry relief from overly burdensome regulations.Since President Trump took office, he has initiated a number of actions to advance regulatory reform that will impact the industrial refrigeration industry.

INITIAL "FREEZE" ON REGULATIONS

On January 20th, White House Chief of Staff Reince Priebus issued a memo directing agencies to freeze activity on late term Obama regulations.The Memorandum asked departments and agencies to:

- Send no regulations to the Federal Register until a department or agency head appointed or designated by the President after noon on January 20, 2017, reviews and approves the regulation.
- For regulations that have been sent to the Federal Register, but not yet published, immediately withdraw them (subject to the exceptions described above and consistent with Federal Register procedures).
- For regulations that have been published in the Federal Register but have not taken effect, temporarily postpone their effective date for 60 days for the purpose of reviewing questions of fact, law, and policy (and possible further review).
- Regulations subject to statutory or judicial deadlines are excluded.

EXECUTIVE ORDER 13771

On January 30, 2017, President Donald Trump signed an Executive Order entitled "Reducing Regulation and Controlling Regulatory Costs." The action addresses a promise he made on the campaign trail to curtail the impact of federal regulations. The Executive Order institutes a policy that for every one new regulation issued, at least two prior regulations must be identified for elimination.The new policy applies to "major" regulations that have at least a $100 million annual impact.

The order also calls for the reduction in costs of regulations and places a cap of zero dollars on new regulations for the remainder of fiscal year 2017. Any new incremental costs associated with new regulations in 2017 must be offset with the elimination of existing regulatory costs. Beginning in fiscal year 2018, each agency will be given a set budget for regulatory expenses. Agencies will be required to identify budget offsets for any regulation that is estimated to have increased costs in that fiscal year.

Beginning in fiscal year 2018, each agency will be given a set budget for regulatory expenses. Agencies will be required to identify budget offsets for any regulation that is estimated to have increased costs in that fiscal year.

EXECUTIVE ORDER 13777

President Trump followed his first Executive Order on regulatory reform with a second order that provides additional details on the process by which agencies should review regulations.Executive Order 13777 directs each agency to name a Regulatory Reform Officer and a Regulatory Reform Task Force. The task forces will identify outdated, unnecessary and ineffective regulations. Initial reports are due 90 days from the issuance of the order.The order includes an accountability mechanism, so agencies will be measured on their success in following the new policies.

REGULATORY REFORM AND RMP FINAL RULE

The Environmental Protection Agency (EPA) completed it multi-year effort to revise the Risk Management Program (RMP) regulation with the publication of a Final Rule on Friday, January 13, 2017, just one week before President Trump took office.The original effective date of the Final Rule was March 14, 2017.However, the Trump Administration put a "freeze" on all regulations finalized at the end of the Obama Administration.This included a delay of the RMP rule until March 21, 2017. In late February, a petition was filed by industry with EPA requesting a further delay in the effective date of the regulation.Administrator Scott Pruitt moved quickly to extend the effective date by an additional 90 days, to June 19, 2017. Pruitt also published a Proposed Rule that would make the effective date February 19, 2019.

IIAR helped lead a coalition of industry groups in submitting comments supporting the delay until February 2019.The extended delay will give the new policy officials within the Trump Administration time to consider the

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concerns that have been raised regarding the Final Rule and evaluate potential improvements to the regulation.The comment period for the Proposed Rule closed on May 19, 2017.EPA will now review the comments received and move forward with drafting a Final Rule regarding the revised effective date.

IMPACTS ON OSHA AND DOL REGULATIONS

OSHA began the process of considering changes to the Process Safety Management (PSM) regulation during the Obama Administration, similar to EPA's efforts to change RMP.OSHA's rulemaking process generally takes longer that EPA, and the agency was not able to get to the Proposed Rule stage before the change in administrations.As a result, it is very unlikely that OSHA will advance its rulemaking efforts on PSM for the foreseeable future.

In addition to halting rulemaking efforts on PSM, the Trump Administration has also taken action to stop or delay other OSHA regulations finalized late in the Obama Administration.On May 17, 2017, OSHA announced that it intends to extend the initial date by which certain employers are required to electronically submit their injury and illness logs.The Recordkeeping Rule currently requires certain employers to submit the information from their completed 2016 Form 300A to OSHA electronically by July 1, 2017. The extent of the delay is not known at this time, but the move signals that the new Administration shares some of the concerns raised by industry about the public posting of injury and illness logs.

On May 23, 2017, the Department of Labor (DOL) sent a new proposed rulemaking to the White House Office of Management and Budget that would rescind the Obama administration's persuader rule. The persuader rule altered the advice exemption under the Labor Management Reporting and Disclosure Act, effectively interfering with both employers' access to legal advice on labor matters and attorney-client privilege.The new policy would effectively discourage employers from engaging with attorneys and other experts during the course of a union campaign.The rule was permanently enjoined by a U.S. District Court in November 2016.The Trump Labor Department has decided not to appeal the ruling and is moving forward with rescinding the regulation.

The Trump Administration has moved to officially withdraw a letter of interpretation issued by the Obama Administration In 2013 that granted union representatives permission to accompany OSHA inspectors on walk around inspections at non-union workplaces.The LOI was in response to a request from organized labor to change the original policy that stated employee representatives "shall be" employees of the employer unless third parties could provide specific expertise such as language interpretation or technical expertise.The LOI expanded this to include union representatives as identified by employees. The Trump Administration's withdrawal came as part of a settlement arising from an industry challenge to the LOI.

The new policy direction should prove helpful in mitigating the impact of late term Obama regulations and slow the development of new regulatory burdens that may impact the industrial refrigeration industry. IIAR will continue to actively engage with new policy officials and like-minded industry partners as regulatory reform efforts move forward.

Congress has also been active in addressing regulations finalized late in the Obama Administration.The Congressional Review Act (CRA) give Congress the authority to disapprove of regulations within 60 legislative days of becoming final.Until 2017, the CRA was only used successfully once, to stop an OSHA ergonomics rule at the beginning of the George W. Bush Administration.Congress has passed, and President Trump has signed, 14 CRA resolutions in 2017.

Once such effort addressed an OSHA regulation known as the Volks Rule. The regulationthat would extend to five years the explicit six-month statute of limitations on recordkeeping violations in the Occupational Safety and Health (OSH) Act.The new policy was counter to the underlying statutory authority and went against multiple appeals court rulings on OSHA's statute of limitations on recordkeeping violations.Congress successfully utilized the Congressional Review Act to disapprove of the regulation and President Trump signed the resolution into law.

SUMMARY

President Trump's actions to reform the regulatory process and walk back certain Obama regulations signal a significant shift in the regulatory climate. The new policy direction should prove helpful in mitigating the impact of late term Obama regulations and slow the development of new regulatory burdens that may impact the industrial refrigeration industry.IIAR will continue to actively engage with new policy officials and like-minded industry partners as regulatory reform efforts move forward.


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If you would like to join an IIAR committee please email us at info@iiar.org and reference the committee of your choice.

Great things are accomplished through the dedication of our members with regard to IIAR committee work. IIAR is committed to our mission to provide advocacy, education and standards for the benefit of the global community in the safe and sustainable design, installation and operation of ammonia and other natural refrigerant systems.

WHAT'S ON THE HORIZON …

In the 2017 – 2018 member year IIAR will continue its work with the introduction of IIAR Standards 6 and 9 leading the way. Take a look at What's on the Horizon for IIAR:

- **The online Learning Management System –** Allows access to IIAR's Academy of Natural Refrigeration education programs, IIAR videos, webinars, and IIAR major publications.
- **Updates to the Ammonia Refrigeration Manual –** With a new Ammonia Refrigeration Manual for low charge systems
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VOICE ADDS IMPACT TO OUR INDUSTRY.

PARALLEL OPERATION OF SCREW COMPRESSOR PACKS

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ABSTRACT

Ammonia screw compressor packs utilizing parallel operation of two or three smaller industrial NH3 screw compressors offer the optimum way to fulfill maximum part load efficiency, increased redundancy, and other highly desirable features in the industrial refrigeration industry. Optimized parallel operation can secure continuous operation and can in most applications be configured to improve overall operating economy. New compressors have been developed to meet requirements for flexibility in operation and have intelligent controls. The intelligent control system must focus on all external demands and strive to offer always the lowest possible absorbed power, including future scenarios with connection to smart grid. This paper builds on and includes most of the results of an earlier investigation to show how to implement a series of compressor packs following basically the results of these findings.

Introduction

Ammonia compressor packs are typically equipped with one or more compressors. Figure 1 shows an example of a two-compressor pack. The compressors can be equipped with variable speed drive (VSD). A study about parallel operation of screw compressors for industrial ammonia refrigeration describes the optimum way of configuring packs with multiple compressors (Pijnenburg and Ritmann 2015). The findings from this study define the overall design criteria for highest possible part-load efficiency over a wide range of capacity. The first part of this article analyzes that same study, including the different methods of capacity regulation, the method for evaluating total efficiency, and the comparison between different numbers of parallel operating compressors.

Maintaining high efficiency is one of the most important criteria for industrial refrigeration customers. Operational safety and reliability are other important criteria that emphasize the need for a certain amount of redundancy. Often the customers' products or output from processes are far more expensive than the additional cost of securing proper back-up of their cooling system. Packs with multiple compressors offer high redundancy, in terms of having more smaller compressors and drive systems, thereby ensuring that the unit can continue to deliver cooling capacity, even during planned service or unforeseen repair in case of failures. Naturally, maximum up-time and minimum unintended stops have high priority in the industrial refrigeration system. This paper describes some of these requested redundancy features.

A dedicated control system is needed to fully utilize the advantage of parallel operation, both regarding efficiency and redundancy. The control system shall ensure maximum efficiency and operational reliability, when operating inside and even outside the compressor application limits, in the whole capacity range. The control system must focus on all external demands, yet strive to offer the lowest possible absorbed power, including the future ability to respond to smart grids or variations of the electricity pricing during night and day.

Figure 1. Example of a screw compressor package with two compressors.

Common Methods and Requirements for Capacity Control Systems

Different methods exist to control the capacity of a compressor system. The quality of the capacity control systems can be measured with different parameters:

- The ability to adapt the capacity to the cooling demand accurately, i.e., how well a certain suction pressure set point can be followed;
- The influence on the efficiency of the compressor and the drive line, i.e., how much the coefficient of performance (COP) of the system is affected;
- The requirements of and load on the power supply;
- The possibility to cover a large capacity range between minimum and maximum load;
- The cost of the capacity control system;
- Operational reliability; and
- Noise and vibration levels.

- The cost of the capacity control system;
- Operational reliability; and
- Noise and vibration levels.

BITZER (2014) provides a thorough description of different methods of controlling the capacity of a compressor system. Here only those methods used in the analysis later in this article are briefly described:

- On/off cycling,
- Speed variation (variable speed drive), and
- Slide valve regulation.

The first two methods are not incorporated in the compressor itself, but concern how to operate it. The last method requires a specific construction inside the compressor. The first method offers stepwise control, whereas the other two methods enable continuous variation of capacity. Each method is described briefly in the following sections, but Blumhardt (2006) details a comparative study on speed and capacity slide control for screw compressors

On/off cycling

On/off cycling is the simplest way to vary capacity. In simple systems, it can lead to large variation in operating condition and high cycling rates. It can make sense on systems with small load variation or large system buffer capacity. The ability to regulate capacity precisely with this method improves with the amount of parallel mounted compressors.

Speed regulation

The flow through the compressor varies with the rotational speed of the rotors. The speed-regulated screw compressor requires a specific drive line with a VSD. In most cases the speed regulation does not require changes to the compressor itself, but it affects the way the compressor operates.

Slide valve regulation

A slide valve parallel to the rotor shaft can be moved to create an internal bypass. Just before the gas is compressed in the rotor cavities, it can bypass internally to the suction side. The slide valve system makes a fairly simple and robust system for both stepwise and step-less variation of capacity. The slide valve regulation will also affect the volume ratio (VI) of the compressor. The influence on VI depends on the design of the compressor and the operating conditions. Some compressor designs are capable of independent regulation of capacity and VI.

The variation of capacity can influence both the volumetric and isentropic efficiency of the compressor. How much efficiencies are affected differs for each method and also depends on the operating conditions and the construction of the compressor. Volumetric efficiency relates to actual swept volume. In this article the term part load index (λ) is used to indicate the ratio between actual volume flow (at a certain load) and the nominal swept volume at maximum capacity (full load). Variation of capacity will also influence the efficiency of the drive line (motor and or VSD).

Description of Efficiency of Capacity Control Methods

The efficiency of the compressor, the motor, and the VSD can each be expressed as a function of some form of capacity (not necessarily the system cooling capacity). These efficiency data, also called performance data, are typically expressed in the form of graphs, tables, or polynomial functions. The total efficiency of the system can be obtained by coupling the performance data of different components in series and/or in parallel. The relation between cooling capacity and system efficiency cannot be obtained directly from the supplied performance data, but requires some calculation. The relation will also depend on the operation condition of the system (evaporating and condensing temperatures).

Figure 2 shows typical dependencies of the compressor part load index (λ) and isentropic efficiency (ηc) for a typical chiller condition (T_0/T_c = +5/+35 °C / +41/95 °F). The left figure shows the efficiencies as a function of capacity slide valve position (CR), and the right figure shows them depending on compressor shaft speed. The software to calculate compressor performance (BITZER 2016) contains data based on extensive measurements with different compressor models over the whole range of operating conditions, shaft speeds, and capacity slide positions.

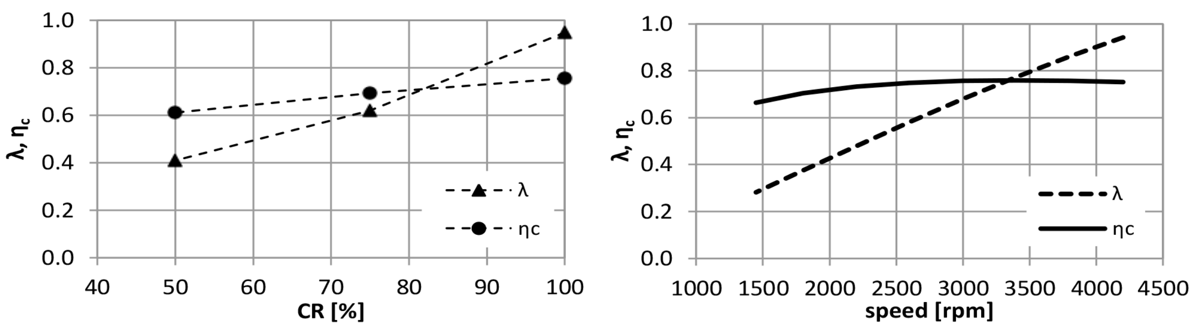

Figure 2. Example of compressor performance data curves.

Figure 3 shows a typical dependency of motor (η_m) and drive efficiency (η_d), depending on the ratio of shaft torque to nominal motor torque (T/T_n), for three different shaft speeds (1,200; 2,400; and 3,600 rpm). Motor and drive data are calculated with software from a major global supplier of motors and variable speed drives.

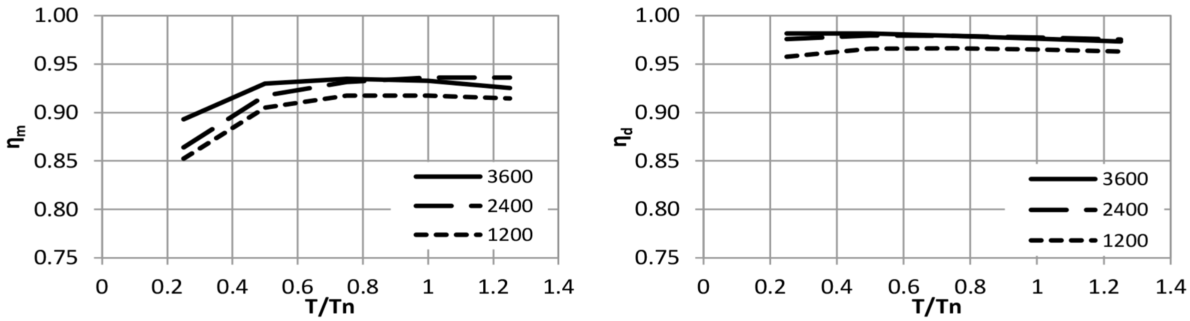

Figure 3. Example of motor and drive performance data curves.

The graphs show that cooling capacity is not mentioned directly. It must be derived from the performance data and the actual operating conditions of the system.

The capacity regulation systems can have other positive or negative effects on system performance, other than on energetic efficiency. Some of these effects include

- Potential for increased capacity with operation at speeds above synchronous with VSD.
- Built-in soft-start function in the VSD resulting in low motor and power supply load at start-up.
- Positive displacement compressors that require practically constant torque over the complete speed range. Therefore voltage vs. frequency ratio of the VSD must be constant. A VSD can normally not supply voltages above the supply voltage, which means that the motor will be supplied with "under-voltage" during operation above synchronous speed. This means it cannot supply the full torque, limiting the possible operating conditions of the compressor in this speed range.
- Operation with economizer that can be utilized for a large capacity range with speed regulation for most compressor designs. The economizer port is normally closed very early in the unloading process on compressors with slide valve regulation in combination with a fixed economizer port.
- Parallel compounding, which will require smaller compressors to deliver the same maximum capacity.
- Compressor, motor, and drive efficiency that will increase to some degree with size.
- Parallel compounding that automatically gives redundancy.
- Complexity of systems that increases with the number of compressors and combination of different regulation systems.

Method of Part Load Efficiency Evaluation

The part load efficiency of a compressor system can be evaluated based on the performance data of the components and the equations described in this section. The definitions and units for each symbol used in this section are listed in the nomenclature at the end of this paper. Equation (1) defines the cooling capacity that a screw compressor can deliver:

$$\dot{Q}_0 = \dot{m} \cdot q_0 = \lambda \cdot V_S \cdot \rho \cdot q_o \tag{1}$$

Equation (2) defines the shaft power of a screw compressor:

$$P_c = \frac{P_{is}}{\eta_c} = \frac{\dot{m} \cdot p_{is}}{\eta_c} = \frac{\lambda \cdot V_S \cdot \rho \cdot p_{is}}{\eta_c} \tag{2}$$

Equation (3) defines the electrical power consumption of the screw compressor package:

$$P_{el} = \frac{P_c}{\eta_d \cdot \eta_m} = \frac{\lambda \cdot V_S \cdot \rho \cdot p_{is}}{\eta_d \cdot \eta_m \cdot \eta_c} \tag{3}$$

Equation (4) defines the COP of the screw compressor package:

$$\mathrm{COP} = \frac{\dot{Q}_0}{P_{el}} = (\lambda \cdot V_S \cdot \rho \cdot q_o) \Big/ \left(\frac{\lambda \cdot V_S \cdot \rho \cdot p_{is}}{\eta_d \cdot \eta_m \cdot \eta_c}\right) = \frac{q_o}{p_{is}} \cdot \eta_d \cdot \eta_m \cdot \eta_c = \frac{q_o}{p_{is}} \cdot \eta \tag{4}$$

Plotting the COP as a function of the cooling capacity ($\dot{Q}_0$) is the traditional way to evaluate the part load performance. The previous equations show that for a certain operating condition and for a certain size of compressor system, a linear relation exists between the cooling capacity and the part load index (λ) and between the COP and the energetic efficiency (η). By showing the energetic efficiency as a function of the part load index we have a way to show the part load performance on a dimensionless scale from 0 to 1, which makes it easy to compare for different operating conditions and different sizes of systems.

The total part load index and energetic efficiency for a compressor package with multiple compressors can be found from the weighted sum of the individual efficiencies according to Equation (5) and Equation (6).

$$\lambda = \frac{\sum_{i=1,n} \lambda_i \cdot V_{s,i}}{\sum_{i=1,n} V_{s,i}} \quad (5)$$

$$\eta = \frac{\sum_{i=1,n} \lambda_i \cdot V_{s,i}}{\sum_{i=1,n} \frac{\lambda_i \cdot V_{s,i}}{\eta_{d,i} \cdot \eta_{m,i} \cdot \eta_{c,i}}} \quad (6)$$

The performance data curves (Figure 2) show that part load index (λ) and energetic efficiency (η_c) for a compressor can be controlled by two parameters: speed and capacity slide position. Operating conditions are assumed to be constant in this paper, but they can also depend on capacity, i.e., evaporating temperature will rise as evaporator load decreases.

The energetic efficiency of the motor (η_m) and the VSD (η_d) depend on speed and torque (as seen in Figure 3). The torque and, in case of VSD, the speed will vary with capacity. The compressor shaft power relates to the torque and speed according to Equation (7).

$$P_c = \frac{\lambda \cdot V_s \cdot \rho \cdot p_{is}}{\eta_c} = T \cdot \omega \quad (7)$$

The shaft speed is either constant or controlled actively, thus the shaft torque depends only on compressor part load index, energetic efficiency, and speed. A motor is typically selected with approximately 10% torque reserve at maximum (or nominal) load, giving the torque at maximum system load as 90% of the nominal motor torque ($T/T_n = 0.9$). The factor 0.9 is not constant and differs based on the available motor sizes and application type. Equation (8) defines the part load torque of the motor relative to its nominal torque:

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$$\frac{T}{T_n} = 0.9 \cdot \frac{\lambda}{\lambda_n} \cdot \frac{\eta_{c,n}}{\eta_c} \cdot \frac{\omega_n}{\omega} \qquad (8)$$

The part load performance, described by the dependency between part load index and energetic efficiency, can be derived quite easily from the compressor performance data. By combining Equation (8) with interpolation of motor and drive performance data, deriving the part load efficiency of the motor and drive as a function of the part load index is also possible. Figure 4 shows an example of the relation between the part load index (λ) and the energetic efficiency (η).

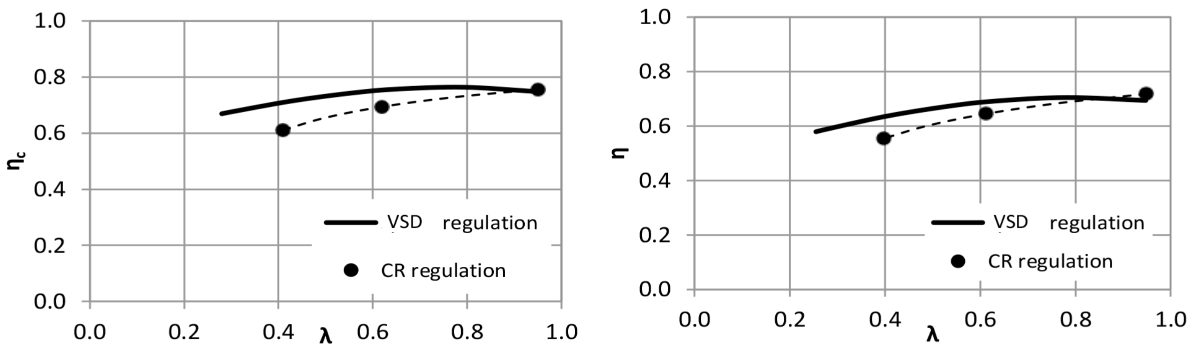

Figure 4. Energetic efficiency as a function of compressor part load index for compressor only (left) and complete system (right).

Comparison of Different Solutions

This section compares the part load performance of different compressor package solutions. The most basic compressor regulates solely with a slide valve. The next step is to add a VSD and finally to use multiple compressors. Simulations of many different solutions were done to map the different combinations.

All comparisons are done for the same total maximum capacity. For easy comparison, the values for part load index were scaled (indicated by λs) to be exactly one at maximum capacity. The effect of size, where larger machines tend to have better efficiency, is accounted for by using actual performance data from appropriate sizes of compressors, motors, and drives. The effect of size and the effect of using a VSD become evident when looking at the nominal maximum load efficiency. Multiple smaller compressors will have a slightly lower maximum load efficiency when compared with fewer larger compressors. Solutions with VSD will have a slightly lower maximum load efficiency than comparable size compressors without. The losses in a VSD on multiple compressor systems naturally only affect the one compressor with VSD.

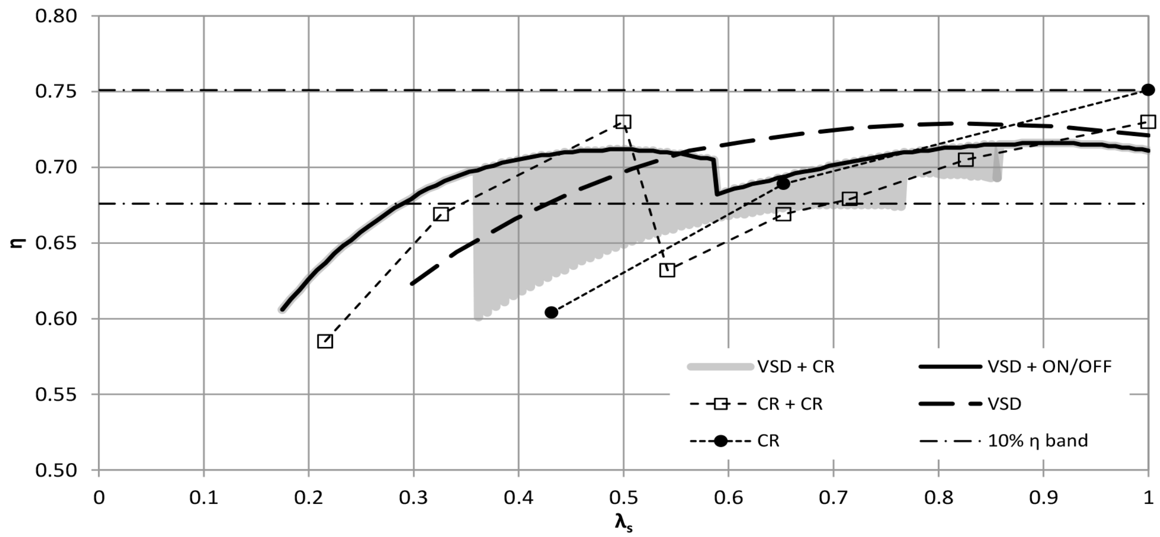

Figure 5. Comparison of part load efficiency for package with one or two compressors.

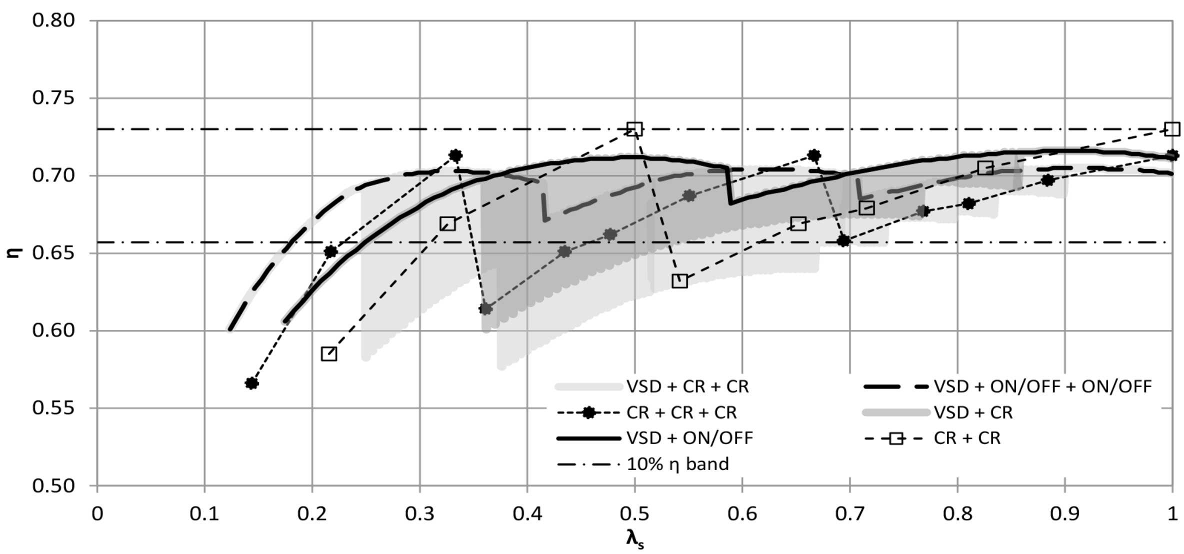

Figure 6. Comparison of part load efficiency for package with two or three compressors.

Figure 6 compares a solution with either two or three compressors. Again, solutions with VSD evidently have a constant high efficiency. The solution with three compressors (one VSD) can even keep very high efficiency down to approximately 17% capacity. Furthermore, a three-compressor solution with only slide regulation (CR) has a high efficiency down to approximately 23% capacity, except from a minor load area around 37– 43%.

The analysis of the different scenarios was done for operation at a fixed operating condition (T_0/T_c = +5/+35 °C / +41/95 °F). The results will change depending on the operating conditions, which should be considered when searching for the optimum solution. The results for low-temperature operation are not elaborated here, but will have a tendency to show lower maximum efficiency and larger drop in efficiency at part load. This is basically due to the relatively larger increase in losses

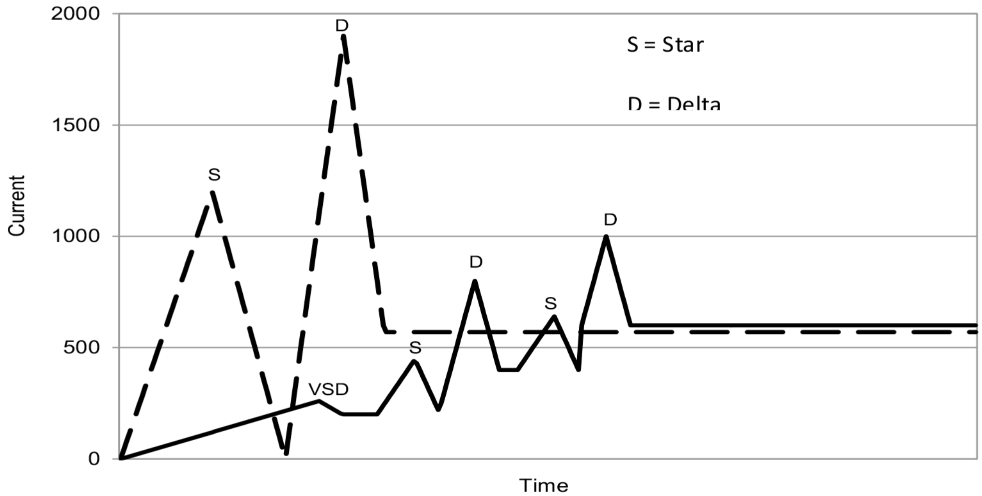

Figure 7. Comparison of typical starting current for three-compressor package versus one single compressor.

Reliability through Redundancy

The simplest configuration of a multiple compressor pack, with two parallel compressors (without VSD), already offers full redundancy on the complete compressor-motor unit. Both can operate independently and provide the ability to service one compressor-motor unit, while the other continues to operate and deliver 50% of the maximum cooling capacity. The three-compressor variant naturally offers an even higher level of redundancy. The redundancy offered by multiple compressor-motor units is expressed in terms of

- Pack design that enables the exchange of a complete compressor-motor unit, without stopping the other(s).
- Multiple use of smaller compressors and motors. These compressors, motors, starter equipment, etc. are typically more feasible in terms of cost and are more readily available than the comparable larger ones. This means lower cost in case of stocking spare parts for unforeseen cases or typical shorter delivery times.
- Redundant sensors on critical positions. Each compressor can come with its individual set of pressure and temperature sensors. The oil management system can also be equipped with redundant oil pressure and temperature sensors.

For even higher reliability the redundancy can be increased by adding more compressor-motor units, or by using two parallel units (each with two compressors) instead of, for example, one pack with four compressors. The parallel units will give internal volume ratio; the oil return system; and other related functions. The separate distributed module philosophy can also be used for other main components in the system, like oil management system and switch board.

The distributed modules must all be able to work independently to ensure maximum redundancy. At the same time, the communication among the individual modules increases the potential to optimize the use of each individual component and to ensure maximum efficiency of the entire system.

Figure 8. Control system with distributed module layout.

Conclusion

Parallel compressors, where one is optionally fitted with VSD, provide high redundancy and high efficiency over a wide capacity range. The three-compressor package offers the highest level of redundancy and high part load efficiency over the widest capacity range. More than three compressors, however, do not add much regarding part load efficiency. Maximum efficiency will drop slightly, and a wider capacity range is seldom needed. A pack with two compressors provides basic redundancy, which naturally increases with more compressors. A control system with distributed modules fits the potential parallel operating compressors offer. The control system must ensure that the compressors and related components are operated in an optimum way under all circumstances with respect to efficiency and reliability.

Nomenclature

COP	Coefficient of performance	[-]
CR	Capacity slide regulation position	[%]
η	Total energetic efficiency of the compressor package	[-]
η_c	Isentropic efficiency of the compressor	[-]

Nomenclature

COP	Coefficient of performance	[-]
CR	Capacity slide regulation position	[%]
η	Total energetic efficiency of the compressor package	[-]
η_c	Isentropic efficiency of the compressor	[-]
ω	Shaft rotational speed	[rad/s]
n	Subscript to indicate nominal values at maximum load	[-]

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