iiar
THE OFFICIAL MAGAZINE OF THE NATURAL REFRIGERANT INDUSTRY ■ JUNE 2015

CONDENSER

Standardizing a Customized Industry

THE MARKET FOR PACKAGE SYSTEMS AND THE FUTURE OF REFRIGERATION

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contents

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8 COVER STORY Standardizing a Customized Industry

The move towards lower charge has spurred demand for products like standardized package systems that promise solutions to at least some of the industry's biggest problems. But exactly how those products will develop, and who will take them to market is yet unclear.

IIR Holds Sixth Refrigeration Technologies Conference

The International Institute of Refrigeration, IIR, said its sixth Ammonia and CO_2 Refrigeration Technologies Conference clarified future uncertainties regarding both the Montreal and the Kyoto Protocols and environmental regulations applicable to natural refrigerants.

The conference, which was held April 16 – 18 in Ohrid, Macedonia, focused on natural refrigerants, specifically ammonia, carbon dioxide and hydrocarbons used in various refrigeration applications worldwide.

IIR said conference participation increased, from approximately 100 individuals in the past to 140 participants this year, attracting a wide scope of key industry stakeholders, ranging from manufacturers, end users to research institutions.

In light of the intense debate on the F-Gas regulation and its implementation worldwide, as well as proposed amendments to the Montreal Protocol for the phase-down of HFCs, the conference provided the ideal forum for the exchange of knowledge on ammonia and CO2 technologies, and their combination, as the most viable option in future, IIR said in a statement.

IIAR Vice President and Technical Director, Eric Smith attended the event as one of five keynote speakers, delivering a speech entitled "Navigating the regulatory environment and opportunities for new technologies in the U.S."

Smith gave a detailed overview of the regulatory climate in the United States, delivering a speech on the U.S. legislative process and outlining the ways the industrial refrigeration industry works to inform that process through standards development and other advocacy activities. He also gave an overview of opportunities for new technologies in the U.S.

In a region where ammonia was, and still is, a traditional refrigerant, the event provided the perfect opportunity to introduce CO_2 as a refrigerant and focused on the greener alternatives represented by natural refrigerants, the advancing future of green technologies and the economic benefits of these technologies, the IIR said in a statement.

During the closing ceremony Professor Risto Ciconkov, president of the conference Organizing Committee, expanded on that idea, saying that "Instead of being occupied with a phase-down of HFC gases, drop-in refrigerants, retrofit of systems, environmental taxes, restrictions, calculations of F-gas quotas, let's start with a new approach: a PHASE-IN of natural refrigerants." ■

chairman's MESSAGE

THOMAS LEIGHTY

This month marks one of the most productive and interesting times of the year for IIAR. The March annual meeting is behind us, and we're at the beginning of the organization's new leadership cycle. That means it's time to build on all the momentum we created in the last year, and at the same time look ahead to a few new goals.

Our first priority this year is to keep you informed of the growth and change that our industry is undergoing, as well as the role IIAR is playing in several key arenas.

Our first priority this year is to keep you informed of the growth and change that our industry is undergoing, as well as the role IIAR is playing in several key arenas.

First, we are excited to report that this year's Industrial Refrigeration Conference – always a major event that reinforces the vibrancy and growth of our industry – again saw record-breaking numbers of attendees and exhibitors.

We exceeded and surpassed expectations primarily because of the dedication and hard work of our members. On behalf of me and the Board of Directors, we would like to extend special thanks and appreciation to all who contributed their time and financial support to make IIAR's 2015 show one of our best conferences yet.

We are moving forward with an emphasis on educational and training programs and a continued focus on standards. That theme was on display at this year's conference, where we again devoted a Sunday afternoon session to specific training.

In the coming year, one of our first priorities is to expand on that Sunday afternoon training effort. Throughout the year we will be developing additional training where our members need it the most – like instructional webinar series and other materials addressing the technical side of our industry.

And of course, no discussion about training is complete without a look at IIAR's continuing standards development effort. Currently, we're right on the brink of publishing IIAR-2. This standard has been several years in development, and will represent a major step forward for our industry; the creation of the first comprehensive safety standard dedicated entirely to ammonia. Alongside the release of IIAR-2, we'll also be completing the publication of our suite of eight standards.

IIAR's standards program is perhaps one of the most important functions of this organization, so this year we will be very focused on advancing the influence of our standards that our volunteer members worked so hard to create.

Our efforts to promote our standards and pursue code adoption will continue to strengthen our relationships and help us expand our circle of influence within the industry. We see this as a method of continuing support with our relationship organizations like RETA and GCCA, where common advocacy goals exist.

Meanwhile, we're embarking on an aggressive CO_2 educational campaign. As a technology that is seeing increasing application, both in the commercial and industrial world, CO_2 is an important area of consideration for IIAR and our members.

In the coming year, our existing CO_2 committee will begin to look at opportunities for IIAR to provide additional educational resources for this natural refrigerant. And…IIAR's standards committee is already evaluating potential opportunities for standards creation.

On the internal organization front, IIAR is in solid financial condition and growing when it comes to the educational and standards programs we've mentioned, but several other new initiatives are on the horizon for us this year and years to come.

Your Board of Directors is putting together a long-term strategic plan for the organization that is focused on membership growth, not just here in the U.S., but internationally. The international chapters program started last year has already been successful, with several new active chapters around the world.

Another exciting program is our support for the Ammonia Refrigeration Foundation scholarship initiative which will kick off this year. We hope each member will consider financial participation in this program. This tuition reimbursement program is directed at students with the potential goal of attracting qualified candidates to our industry – a much needed addition.

We are looking forward to accomplishing several goals, and as your Chairman this year, I would like to remind you that none of these things would be possible without your gift of financial support and your time. As members, your ongoing participation makes all of our activities possible. Thank you for continuing to enrich our industry! ■

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president's MESSAGE

BY DAVE RULE

Throughout this edition of the Condenser, you'll see a common theme: change. New technologies are opening the door to new types of customers and applications for ammonia and other natural refrigerants.

The next decade will bring new markets, new regulations and new reasons that participating as an IIAR member is one of the most important things you can do for your business and your industry.

I couldn't be more excited about where this organization is heading, and I'm going to use my column here this month to issue a challenge to the IIAR membership. If you are already an IIAR member, I encourage you to take a new look at the wide range of membership benefits you're receiving and get involved in actively recruiting your friends and colleagues who are not yet a part of IIAR.

As an IIAR member, it is your involvement and input within this industry that is the sole force that moves us all forward. Whether it's exploring new technology or new practices, increasing communication with regulatory agencies or developing cutting edge resources like safety training and standards, we can't do any of it without you.

For non-members reading this column, your decision to become an IIAR member strengthens the voice of our community and gives you a way to put your vital experience to work. IIAR is already taking the lead in the regulatory activities and standards development that will ultimately define the safety and efficiency of our technology, and we need you to get involved.

As a community, we're made up of companies and individuals that use ammonia and other natural refrigerants in food production and cold storage; manufacturers and distributors who supply products for the industry; academics; and engineers who provide essential design and support services.

I'm confident that IIAR members are better equipped than any other group to advance our common goals and define a new business and regulatory landscape in the years to come.

Regardless of the group to which you belong, if you are a member of the natural refrigerant community, you have an opportunity and a responsibility to utilize all the resources available to ensure that your refrigeration systems are designed and maintained with the highest safety standards available and in compliance with the industry and regulatory standards.

Each dollar invested in IIAR membership represents an investment in our industry. As an IIAR member, you are providing the support needed for your association to continue to develop the safety standards, technical publications, training materials and regulatory advocacy programs upon which we all depend.

If you don't already have a library of IIAR publications in your office, now is a good time to take another look at the extensive resources we've produced over the years. Meanwhile, IIAR will continue the momentum started this year at our conference with several new member tools and services.

For the end-user and regulatory communities, our designated website portals will be expanded to include a new webinar safety training series and access to essential industry standards and training materials. And to facilitate easy website access for all IIAR Members, I'm excited to announce that a new IIAR member app will be introduced in just a few months.

As an industry, our passion and dedication for what we do easily translates into the kind of "can do" attitude that affects real change in our world.

That attitude is always on display at our annual conference, but it's just as evident in the hard work of our committees and the increased level of participation between IIAR and regulatory agencies like OSHA, EPA and DHS.

The bottom line when it comes to IIAR membership is simple: your voice matters. As an IIAR member, you are closest to the operations and procedures that define how we all do business.

I'm confident that IIAR members are better equipped than any other group to advance our common goals and define a new business and regulatory landscape in the years to come.

I'll end this month's column with a challenge to IIAR members and non-members alike. This year, become your industry's best advocate by taking an active role in the work of your IIAR organization.

It's never been a more exciting time to be a part of IIAR. As your president, I'm looking forward to new projects and a new level of participation during this membership year. With your help and hard work, IIAR and our industry is poised for unprecedented growth. ■

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BY: ANDREA FISCHER

The move towards lower charge has spurred demand for products like standardized package systems that promise solutions to at least some of the industry's biggest problems. But exactly how those products will develop, and who will take them to market is yet unclear.

As contractors, manufacturers and end users begin to answer those questions, a new model is evolving with the potential to reshape relationships that have long defined how business is done.

"The single biggest issue facing package systems is not the technology, it's the business model. That will determine how this industry will translate the technology to the end user," said Gerard Von Dohlen, President of Newark Refrigerated Warehouses. "These systems work for end users, and the demand is there, it's the adoption of a new model that will determine whether or not the industry is successful in meeting that demand."

"We've been using low charge packages for a while now, in fact, we're packaging pretty much everything," said Bob Czarnecki, Program Manager of Refrigeration for Campbell Soup Company. "We design our own packages and have them built. I'm using packages on every job I do and I'm doing that industrially."

Czarnecki added that most of Campbell's package systems are centralized, designed for minimum charge and range in size from 75 to 600 tons of refrigeration.

"Very few companies are manufacturing standard packages, I would much rather buy a catalog package than design my own," he said. "It's an evolving field with a lot of different players and all these things are up in the air. Everyone is looking at this. The industry needs to develop full [package] ranges to meet different needs."

But where and how the variability of those different needs will be addressed in an industry that has traditionally demanded highly customized approaches to design remains to be seen.

For proponents of natural refrigerants, plug-and-play style systems seem the obvious choice to replace synthetics in new commercial markets dependent on traditional HVAC contractor service arrangements.

But for large industrial applications, where package systems have not yet evolved to meet the capacity and cost

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THE MARKET FOR PACKAGE SYSTEMS AND THE FUTURE OF REFRIGERATION

thresholds that would make them attractive to a critical mass of customers, the industry is still reliant on a traditional design build model.

Between those two extremes, two seemingly conflicted forces are at work. The demand for project customization is strong as ever. But the need for product standardization is growing.

"Commercial equipment manufacturers are now expected to provide natural refrigerant solutions in markets that haven't demanded them before … One of those solutions is readily available pre-engineered equipment packages using small charge technology designed for ammonia and CO_2."

While project design has traditionally remained the realm of the industry's contractor base, equipment suppliers are beginning to see the opportunities to design full ranges of standardized packages.

"Complete package systems have a great potential to be a disruptive technology for the industrial refrigeration market," said Kurt Liebendorfer, Vice President of Taneytown, Maryland, equipment manufacturer, Evapco, Inc. "Manufacturers are taking on package systems for the food and beverage industry," where they haven't before.

Typically, package systems have been engineered after a customer specifies a project, he said. "But we've spent a year-and-a-half engineering them to 100 percent. Now we're asking 'What's your application and how does it fit your need?' It's the difference between building a custom engineered package to fit a particular job and pre-engineering a family of products to fit industry-wide."

While total product line standardization may meet at least some of the demand for package systems, there is also a growing reliance on design build contractors to apply standardized design in more specific ways, which could lead to a model that depends more heavily on semi-customizable package products, said John Collins, Industrial Sales Manager for Zero Zone Inc., a Waukesha, Wisconsin-based equipment manufacturer.

"The market is changing, and the expectations for manufacturers to change with it are high," he said.

Collins added that his company has focused its efforts on providing semi-customizable packages based on a standard design platform. "We have developed our system concepts over decades of experience serving the commercial sector with synthetic refrigerants," he said. "Commercial equipment manufacturers are now expected to provide natural refrigerant solutions in markets that haven't demanded them before."

One of those solutions, he said, is readily available pre-engineered equipment packages using small charge technology designed for ammonia and CO_2.

"The systems we have running with natural refrigerants show that they are a real solution for retail and other commercial applications. These customers expect an engineered system that operates with minimal user interface, and does not require on-site maintenance staff," said Collins.

Minimizing user interface and on-site maintenance takes a high level of communication between engineering and customer groups, he added. "That is not high-tech but it will always be the key to successful projects. The need for highly qualified contractors is a critical part of this picture. End-users are focusing in-house resources on their core business functions and are looking to consultants and contractors to handle most other technical and operational issues. With the shortage of engineers and designers in our industry, a standardized package system is a good solution."

As companies that are not manufacturers assess their role in the design, distribution and service of prefabricated package systems, the degree to which they will be customizable is emerging as

a defining factor in decisions to adopt, or not adopt a new business model.

"We design, build and install systems in-house because we're very particular about where we want these systems installed and operated as we want to be able to control the design criteria associated with that," said Eric Brown, President of Peachtree City, Georgia, design build contractor, ALTA Refrigeration. "We design and install systems that meet our customer's specific needs while trying to maintain consistency and reliability."

Brown said ALTA's packages are built based on several models the company has designed and currently maintains, and added that it would be unlikely that ALTA would use other package systems on projects.

Brown said ALTA, which also builds large central industrial ammonia systems, has developed a package that uses a synthetic refrigerant to meet the demands of its distribution warehouse customers.

"We see design build constructors as being the closest thing to package designers," said Brown. Despite the standardization available "you can consider everything in our industry custom to some degree. Reputable design build constructors are the closest to the demands of the project, so they're the best choice to come up with the design and carry out the installation of a project."

Evapco's Liebendorfer echoed that sentiment, pointing out that many contractors will prefabricate system design. "Contractors have long been involved in designing custom package systems because field built systems are very labor intensive. So packaging for them has been an option on specific projects, to deal with labor and cost issues in the field."

While manufacturers may be taking on a greater role in package development, the proliferation of catalog-type systems also presents new opportunities for contractors, he said.

"We have a heavy reliance on contractors to install the package systems and provide service and maintenance. However disruptive the new packaged solutions are to them, this is how we go to market with 90 percent of our customers. Helping them become a part of that adoption is essential to everyone's success."

Liebendorfer said standardized package systems in general will carry with them new service and maintenance requirements that manufacturers will depend on contractors to help them meet.

"We're committing heavily to refrigeration contractors. This path will not be a success without them," he said, adding that his company is launching a service partner provider program to support its package product offerings.

Nevertheless, contractors will likely avoid such a service model despite a greater demand for standardized packages, instead taking projects that make greater use of their design capabilities for clients, said Walter Teeter, CEO of design build contractor Republic Refrigeration in Monroe, North Carolina.

"We see design build constructors as being the closest thing to package designers. Despite the standardization available you can consider everything in our industry custom to some degree."

"I don't see the average contractor taking on a role that is strictly service provider for a manufacturer. The majority of the design work of the industry is being done by the contractor base. As long as they have business doing something else – like design and field installation work – they will not be in that role."

As more and more companies enter the market for package systems, the variety of standardized systems available, and the opportunities to support their design, maintenance and installation will grow, said Derek Hamilton, Business Development Manager for San Francisco, California, package manufacturer, Azane Inc.

"There are a variety of systems out there already, and more and more companies are using them to enter new markets in different ways. Along with that, there will be different levels of contractor involvement needed to support those systems, and varying levels of involvement in their installation," he said. "I do think that the advent of package systems is going to change how contractors as well as manufacturers operate on these types of projects, but we're in a phase at the moment where the industry is learning about what that will look like."

Meanwhile, end users will be watching – and waiting – for a model to emerge that can deliver the kind of standardization that will help them reduce charge, address a growing shortage of engineering talent and allow them to focus more on their own core business, rather than the business of refrigeration.

"I need big packages, small packages and everything in between," said Campbell's Czarnecki. "Every design build contractor will make you a package, but that's a one-off project. The question is what companies are out there making [standardized or standardize-able packages], and the answer is not that many."

"The bottom line is that package systems are the prevailing technology for us," said Newark's Von Dohlen. "They will help end users who are not in the refrigeration business to get out of it, and focus on our core business." ■

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IIAR Shatters Attendance Records, Sets New Goals at Annual Conference

The International Institute of Ammonia Refrigeration drew record attendance again this year at the 37th Annual IIAR Conference & Exhibition, an event that marked a variety of transitions and new initiatives for the association this year.

IIAR members and conference attendees took advantage of the technical knowledge and resources available on the exhibition hall floor and at technical program presentations over the three days of networking and industry sponsored events.

"This year's conference was very successful on so many levels," said IIAR Conference Chairman Mark Stencel. "We saw another record turnout and boasted our largest exhibit floor to date."

"I would like to thank each and every company who provided the important financial support for IIAR through their participation at this conference and to send a special thank you to all the companies that encourage and support the essential volunteer work of our members."

The conference, which was held in San Diego, March 22 – 25, drew over 1,500 attendees, many of whom were new to the event.

IIAR President Dave Rule said the organization saw a continued increase in international attendance at this year's event, illustrating the growing momentum of natural refrigerants around the world.

"The IIAR conference draws refrigeration professionals from all across the United States and increasingly from around the world," said Rule. "This international gathering of the key decision-makers in our industry is the perfect opportunity to network and learn from colleagues from all corners of the globe."

In support of that growing international presence, the conference featured an international program with technical paper presentations in Portuguese, Spanish, and Mandarin.

In addition, all technical papers presented in English were offered with simultaneous interpretation in Spanish and all international language presentations were given with simultaneous interpretation in English.

Meanwhile, the international presence and the growing diversity of technology in the industry could be seen on the exhibit hall floor, where a number of new companies, new technologies, equipment and services were on display.

"The exhibit hall floor was very impressive this year in terms of the quality and diversity of the products on display," said Rule. "Our industry is growing and evolving to meet the needs of new customers, new markets and new demands on efficiency."

That theme was also on display throughout IIAR's technical program, which featured presentations, experiential workshops, and interactive panels on topics ranging from global refrigerant trends to low charge ammonia systems.

"I want to extend a special thanks to our members whose participation and collaboration in exchanging information, experience and expertise made this conference such an incredible learning event," said Rule. "The paper authors, workshop presenters and panel participants who develop these presentations are all an integral part of making this such a great event."

Continuing the tradition of offering a special Sunday afternoon training session, IIAR this year introduced the *IIAR CO_2: Design and Application in Industrial Refrigeration* educational program. The condensed learning experience was designed to instruct attendees on the basic engineering principles needed to design a variety of energy efficient CO_2 systems.

"CO_2 is getting a lot of attention these days. So much new technology is being developed in this area. From new designs in valves to applications in new markets, we felt that the March conference represented the perfect opportunity to focus on this area of our industry and offer new training resources," said Stencel.

A focus on CO_2 and low charge systems, one of the always popular subjects being discussed at this year's conference, underscored a growing conversation about efficiency and charge levels.

"Many new components and systems are changing the industry and making it more efficient, and that will grow ever more important in the coming years as the industry looks for ways to control energy costs and minimize the impact the regulatory environment can have on operations," said Rule.

In fact, the central message of this year's event is that the world is moving toward natural refrigerants, he added.

"It's an exciting time in our industry, a time of change. As regulations and technologies evolve at a breakneck pace, we're seeing new opportunities and applications like never before. We are truly an industry in transition."

During his keynote address to IIAR members, Rule said three central trends are having an impact on the business environment in the natural refrigerants sector.

First, CO_2 technologies, long considered something of an outlier from a technology perspective, are moving into the mainstream and opening the door in new commercial arenas, such as supermarkets.

Second, low-charge systems are expanding the natural refrigerants marketplace by introducing new industrial and commercial applications for ammonia.

And finally, the phase-out of R-22 in the United States, and the broader F-gas phase-out underway in the European Union, is starting to influence decision processes in the commercial and industrial markets.

In the coming years, IIAR will evolve with these trends by guiding the industry in standards development and code adoption, activities Rule called central to the mission of the organization.

He added that IIAR has recently completed and released for publication the IIAR-4 standard, covering system installation, and IIAR-8, which covers system decommissioning. The IIAR-2 standard on ammonia safety design has been in development and is expected to be released for ANSI approval and publication within a few months.

Meanwhile, IIAR is in the process of creating several new member tools and services, including a dedicated website portal to deliver access to customized IIAR information and resources to the end-user community; a regulatory website portal to provide easy access to essential industry standards, guidelines, and training materials; and a member app designed to facilitate easy access to technical publications and services.

Along with the new initiatives, IIAR said it is continuing its strong commitment to advocacy and education, re-committing to a five-year formal alliance with the Occupational Safety and Health Administration, or OSHA, and partnering with the Refrigerating Engineers and Technicians Association, RETA, to identify ways to grow the industry's pool of new talent.

Rule said that the renewal of the alliance with OSHA and the organization's new work with RETA will help IIAR more closely coordinate industry activities to help inform the regulatory process.

"Our relationships with regulatory agencies like OSHA, EPA and DHS as well as our many strong ties with other organizations within this industry are invaluable," he said, adding that all three agencies participated in IIAR's 2015 conference as guest panelists on a special regulatory panel.

Looking forward, this year's conference set IIAR up to pursue a number of exciting projects and work goals, thanks in no small part to the hard work of its staff and membership, said Rule.

We're thankful for "the talents and resources that our members bring to this organization, especially the effort of all of our staff in making such a large event a great success," he said.

"We're getting ready for another great show in Orlando next year," he said. "And we're excited to carry the energy of our sponsors, exhibitors and members into the next IIAR event."

IIAR's 2016 Industrial Refrigeration Conference & Exhibition will be held March 20 - 23 in Orlando, Florida.

IIAR Award for Presentation Excellence Winners Recognized for Technical Paper Contributions

Chris Combs, IIAR, Gabriel Guttierez, Colmac Coil Manufacturing, and Mark Stencel

Eric Smith, IIAR, Andre Patenaude (on behalf of Rajan Rajendran), and Mark Stencel

The IIAR Awards for Presentation Excellence at the 2015 IIAR Industrial Refrigeration Conference & Exhibition were presented this year to Gabriel Guttierez of Colmac Coil Manufacturing, Inc. and Rajan Rajendran of Vilter Manufacturing. The Awards for Presentation Excellence are determined based on the results of the technical paper evaluation forms completed by those who attend technical paper sessions. Rajendran won the award for his paper, *Refrigerant and Regulatory Developments: Changes Impacting the Opportunities of Natural Refrigerants.* The purpose of the paper was to give an overview of the regulatory action governments around the world have taken to reduce the use of synthetic hydrofluorocarbons, or HFC's, in most common applications. The paper then gave an overview of the technologies and applications that are available to meet the demand for environmentally friendly refrigerants.

Meanwhile, Guttierez won the award for his Spanish language presentation of *Optimizing Evaporator Runtime and Defrost Frequency.* The paper gave guidance on how to properly select evaporators for a given frost load. The paper quantified the rate of moisture removal as a function of SHR and illustrated the effect of frost accumulation on evaporator airflow and cooling capacity.

IIAR Names Member of the Year

IIAR recognized past board member and former ARF Executive Director, Tim Facius, by naming him Member of the Year in 2015. The Member of the Year award is usually given to one recipient a year in recognition for outstanding service to the organization. "Tim has been an incredible asset to IIAR, serving this organization with his time and dedication, and making a large contribution to the success of so many of our initiatives, especially those of the Ammonia Refrigeration Foundation," said IIAR president Dave Rule.

Facius was recognized for his years of service to IIAR, especially his role as ARF Executive Director, where he provided exceptional leadership during a time when the foundation's endowment increased from $1.3 million to $2 million. In addition to expanding ARF's activities and fundraising, Facius has been a motivating factor in the foundation's growth, said ARF past Chairman, Bob Port.

IIAR 2014-2015 Chairman Marcos Braz (right) and President Dave Rule (left) present Tim Facius (center) with IIAR's Member of the Year award.

"Tim gave the foundation direction, leaving it in an extremely healthy condition. He is a great example of the kind of volunteer leader that really drives the success of our organization," said Rule. "Tim is passionate about this industry and passionate about the mission of ARF and IIAR, so we are honored to recognize him for all of his work."

The Member of the Year award is given to individuals who make outstanding contributions to the ammonia refrigeration industry through their service to the association over the preceding year.

Our volunteer membership is so dedicated to the pursuits and projects of this industry that it's hard to choose just one person to recognize every year," said Rule. "We chose Tim this year to recognize his substantial work in service of ARF, but also to thank him for the many years he has worked in service of this organization."

2015 BOARD OF DIRECTORS

First Row Seated (left to right): John Gay, Linda McDaniel, Harold Streicher, Marcos Braz, Tom Leighty, Mark Stencel, Walter Teeter, Michael Lynch, Dave Rule

First Row Standing (left to right): Delmar Lehman, Adolfo Blasquez, Don Stroud, Wayne Wehber, Jeremy Klysen, Martin Timm, Eric Johnston, David Blackhurst, Dave Schaefer

Second Row Standing (left to right): Don Hamilton, Michael Chapman, Brian Marriott, Dave Malinauskas, Trevor Hegg, Bruce Nelson, Bent Wiencke, Doug Reindl, Bob Czarnecki

Congress Tackles Regulatory Reform

iiar government **RELATIONS**

BY LOWELL RANDEL, IIAR GOVERNMENT RELATIONS DIRECTOR

The November 2014 elections resulted in a significant shift in control of Congress. Republicans gained control of the Senate and widened their majority in the House of Representatives. As a result, efforts to reform the regulatory process are seeing renewed interest this year. Bills that have been approved by the House in the past, but didn't see action in the Senate are now moving in both chambers, setting up opportunities for Congress to send multiple pieces of regulatory reform legislation to the President. This article will examine some of the regulatory reform bills getting the attention of this Congress.

REGULATORY ACCOUNTABILITY ACT

Central to the regulations that impact the ammonia refrigeration industry is the foundational process by which regulations are developed. The federal regulatory process, rooted in the Administrative Procedure Act, has not been updated for over 60 years. In recent years, federal agencies have been very active in promulgating numerous significant regulations using the outdated processes afforded by the APA. Many of these regulations have resulted in high compliance costs and uncertainty leading to negative impacts to businesses. The Regulatory Accountability Act would modernize the APA process by which federal agencies promulgate regulations and improve accountability and the integrity of the rulemaking process.

Some of the major provisions in the legislation are:

Mandating agencies to assess the costs and benefits of proposed rules and to consider alternatives. Giving these requirements the force of law ensures that they cannot be rolled back without congressional action and provides the basis for judicial review of agency compliance.

Subject "independent" agencies, which are outside the direct control of the President, to the same rulemaking requirements as other federal agencies. Independent agencies are responsible for a large and growing share of regulations but are not subject to many of the procedural requirements placed on other agencies.

Require major rules, those with $100 million in impact or more annually), have an advance notice of proposed rulemaking be released to solicit public comment before they are proposed. This provision is meant to prevent agencies from making tentative policy decisions before the public has an opportunity to comment.

For rules with $1 billion in impact or more annually, agencies would be required to hold an oral evidentiary hearing involving all affected parties with a full opportunity for cross-examination of witnesses from all sides. The hearing will provide more complete information on which regulators can make decisions.

Status: The Regulatory Accountability Act passed the House in January 2015 by a vote of 250 – 175. The House passed bill has been referred to the Senate Committee on Homeland Security and Government Affairs. President Obama has threatened to veto the legislation.

SUNSHINE FOR REGULATORY DECREES AND SETTLEMENTS ACT

Another procedural issue complicating the regulatory process is the practice of "sue and settle." In these situations, organizations sue federal agencies and seek to compel them to take specific actions, such as issuing new regulations. In many cases, agencies will negotiate with organizations to develop consent decrees or settlement agreements that result in agencies developing regulations or compelling specific timelines for action. These negotiations take place in a non-public way leading to a lack of transparency in federal policy making. The Sunshine for Regulatory Decrees and Settlements Act would reform the "sue and settle" process by improving transparency and making agencies more accountable for their actions. Provisions of the bill include:

Providing for greater transparency by requiring agencies to publicly post and report to Congress information on sue-and-settle complaints, consent decrees, and settlement agreements;

Requiring that consent decrees and settlement agreements be filed only after interested parties have had the opportunity to intervene in the litigation and join settlement negotiations, and only after any proposed decree or settlement has been published for at least 60 days to provide for notice and comment; and

Requiring courts considering approval of consent decrees and settlement agreements to account for public comments and compliance with regulatory process statutes and executive orders.

Status: In the House, the Sunshine for Regulatory Decrees and Settlements Act was approved by the House Judiciary Committee on March 24th. It is now awaiting consideration by the full House. In the Senate, the bill has been referred to the Senate Judiciary Committee but has yet to receive a vote.

Toxic Substances Control Act (TSCA) Modernization

In addition to fundamental regulatory procedures, Congress is also considering reforms specific to particular issues and industries. For example, the Toxic Substances Control Act, passed in 1976, is the primary law that the Environmental Protection Agency uses to regulate the safety of chemical products. TSCA gives EPA the authority to review and regulate chemicals in commerce.

TSCA was designed to ensure that products are safe for intended use. While the law originally perceived as creating a strong system of regulations, over time, confidence in EPA's regula-

continued on page 18

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tion of chemicals has eroded. As a result, individual states have established their own laws and regulations related to chemical products. In some cases, these laws have been based more on the concerns of activists than on science.

This has led to a patchwork of laws and regulations that can be confusing and sometimes contradictory as companies deal with multiple state policies. To help improve this situation and provide more consistency and predictability, federal legislation has been drafted and is currently under consideration in Congress.

The TSCA Modernization Act of 2015, introduced in the House, and the Frank R. Lautenberg Chemical Safety for the 21st Century Act, introduced in the Senate, would both provide important updates to the Toxic Substances Control Act. These bills would:

Create a new system for EPA to evaluate and manage risks associated with chemicals already on the market. Either EPA or a manufacturer (who is willing to pay the cost) may designate a chemical for risk evaluation. The risk evaluation must stand up to rigorous scientific standards set out in the legislation. If unreasonable risk is determined, EPA must immediately draft a rule to manage the risk.

Set deadlines for EPA to take action. Risk evaluations must be completed within 3 years. Risk management rules must follow completion of risk evaluations by 90 days.

Ensure user fees paid to EPA for specific purposes are used just for those purposes. User fees will be deposited in a separate fund in the Treasury, and the fees charged and collected will match the cost of carrying out the specific purposes.

Provide limited preemption of state law. Once EPA makes a final decision on a chemical, either a new rule or a determination that it poses no unreasonable risk, EPA action would apply in all states. Prior state laws that do not conflict with TSCA, and private rights of action under tort or contract law, are preserved.

Maintain protection of confidential business information. Certain state, local, and tribal government officials and health care professionals will have access. Confidentiality claims must be reclaimed after ten years. Exemption from CBI protection for health and safety studies does not include disclosure of confidential chemical formulas.

Status: Both the House and Senate bills enjoy bipartisan support. The Senate's bill was approved by the Environment and Public Works Committee on April 28th. The House legislation was approved on May 14th. The next step in the process will be consideration by the full House and Senate.

Legislative efforts such as those profiled above, should they be enacted, could provide improved transparency and additional certainty to the regulated community. Many hurdles still remain, including veto threats, but with Republicans now controlling both the House and Senate, regulatory reform will continue to be high on the agenda. ■

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IIAR Searches for New ARF Executive Director

The International Institute of Ammonia Refrigeration is looking for a new executive director for the Ammonia Refrigeration Foundation to lead the non-profit research and education organization toward continued growth and expansion.

"This is an exciting time for ARF, and this new opening presents a great opportunity for any IIAR member who would like to take a more active role in the leadership of this industry," said ARF chairman Marcos Braz.

He added that the Foundation will be reaching its goal for the ARF endowment fund in the next two years and emphasized that the leadership of a new Executive Director will shape how the Foundation uses that endowment to fund research and scholarships.

ARF's mission is to support research and educational efforts in industrial refrigeration, particularly in the area of ammonia and natural refrigerants. ARF also funds industry scholarship programs and recognizes outstanding contributors to the industrial refrigeration profession.

"We've unveiled a new scholarship program and we've reached a level of financial support that will allow us to commit to ongoing research projects, which will make that a much more sustainable activity than it ever has been," said Braz.

Tim Facius led ARF as executive director for the past two years, providing exceptional leadership during a time when the foundation's endowment increased from $1.3 million to $2 million. In addition to expanding ARF's activities and fundraising, Facius served as an invaluable resource for IIAR and was a motivating factor in the foundation's growth, said ARF past Chairman, Bob Port.

"The foundation is in an extremely healthy condition," said Facius. "Our $2 million endowment gives us a solid base and the flexibility to pursue the kind of research projects we feel are important. There are also a lot of exciting things happening on the education side. We want the scholarship piece to be a bigger part of our overall work. We're unveiling a new scholarship program, which means we'll have more of a balance between scientific research and bringing in young talent to the industry."

Facius said he is proud to have installed structure, discipline, procedures and documentation in the operations of the foundation during his term. "It positions us for a smooth hand-off to new leadership," he said.

"The leadership is really multifaceted, from the chairman to the board to the trustees to my part as executive director, to the support IIAR has provided," he said. "It's all that coming together as a team that has made the foundation what it is today.

"For me, it's been a very rewarding experience and an exciting way to give back to the industry for such an important cause. The concept of funding research and drawing in new talent is a real and tangible way that IIAR and ARF can better the industry that we're working in."

ARF said in a recent report that it hopes to have a new executive director in place by early July.

IIAR members interested in the ARF Executive Director role should contact Marcos Braz, ARF Chairman at 817-444-7858, via email at marcosbraz@mr-braz.com or IIAR President Dave Rule at 703-312-4200, via email at dave_rule@iiar.org.

Ammonia Refrigeration Foundation, Unveils New Scholarship Initiative

The Ammonia Refrigeration Foundation, ARF, and the International Institute of Ammonia Refrigeration, IIAR, has unveiled a new scholarship initiative, open to any undergraduate engineering student interested in the thermal sciences and attending an accredited four-year engineering school.

The Ammonia Refrigeration Foundation is a non-profit research and education foundation organized by members of the IIAR to promote educational and scientific projects related to industrial refrigeration and the use of ammonia and other natural refrigerants.

The new ARF scholarship initiative addresses one of the Foundation's primary goals – to support students that have an interest in this field of study and would like to pursue a career in the industrial refrigeration industry.

"This is an incredible opportunity to get involved in shaping the next generation of our industry," said IIAR president Dave Rule.

Under the new program, ARF said it will work to attract new engineering talent to the industrial refrigeration industry by awarding three two-year scholarships. The base scholarship package provides $1,000 per semester for four semesters after the student has completed a minimum of 60 hours towards an engineering degree.

The scholarship also includes a fully funded pass to the 2016 IIAR Industrial Refrigeration Conference & Exhibition in Orlando, FL with an incentive bonus scholarship for attending.

For scholarship instructions and application information, please visit the ARF web page at: http://nh3foundation.org/. ■

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2015 International Committee Meeting Highlights Industry

BY CHRIS COMBS

IIAR brought together more international members than ever before at the 2015 Industrial Refrigeration Conference & Exhibition in San Diego this year. And IIAR's International Committee gathered members and delegates from around the globe to give a picture of the trends that are shaping the refrigeration industry worldwide.

Among the reports given at that meeting were in-depth overviews of energy cost and efficiency. Discussion also centered on political challenges in Australia and cold chain development in India and China, where environmental, regulatory and safety issues are often barriers to natural refrigerant adoption.

In Australia, solar energy use is booming. According to Stefan Jensen, the International Committee's Regional Vice Chair for Australia and Oceania, nearly 40 percent of homes in that region now have solar panels. In Australia, where the unit price per kilowatt-hour of grid power continues to rise, homemade solar power – which represents only one third the cost of power from the electricity grid – has become a viable option for the country's energy consumers.

As a result, consumption of electricity from the grid is dropping fast. And according to one large Australian cold storage company, that means that carbon neutral cold stores could become a reality within two- to five-years as battery cost falls and cold stores begin to see photovoltaics as an economically superior choice.

While investments in higher efficiency natural refrigerant systems pick up as energy unit prices climb, ammonia may begin to look like the most attractive option. To illustrate that point, Jensen cited an example where – assuming an estimated energy cost of 20 cents per kilowatt-hour – a $2 million dollar ammonia system installation would yield a return on investment in only five years.

Nevertheless, in Europe, energy is still too cheap to drive interest in efficiency in the same way it is driving the Australian market. Upgrading the power grid is a bigger priority now in Europe, where solar and wind energy sources are widely used, especially in Germany.

And the potential increase in energy efficiency alone has become a hard sell for ammonia-based systems, given the expectations for a short return on investment. Technology evolution is also making efficiency a less talked-about issue because most system components on the market in Europe are already extremely efficient.

Instead, the European market is taking a more holistic approach to efficiency, focusing on the entire system. For example, optimization at full load design conditions, optimization for part load conditions and the use of smart controls.

And comprehensive approaches such as these are gaining attention elsewhere, including in Australia, where the Australian Refrigeration Association and other organizations launched a seminar series promoting the concept of Integrated Energy Efficiency Engineering in 2014. That series covered refrigeration and non-refrigeration costs and encompassed measurement, selection, design, integration, commissioning, operation maintenance and end of life system management.

Meanwhile, natural refrigerants face a number of political challenges to adoption in Australia, India and China where the technology offers some of the most efficient solutions for the cold chain.

In Australia, the current government eliminated its carbon tax and the associated levy on synthetic refrigerants, raising the hopes of proponents of natural refrigerants in that country and around the world.

But confused legislation, an inconsistent regulatory environment, mixed signals and lack of support from the government regarding the HFC phase down – as well as outdated standards –continue to plague Australia's natural refrigerants market.

Other obstacles include the lack of technical expertise on low GWP refrigerants among educators and HVAC&R stakeholders and the promotion of synthetic refrigerant technologies by industry wholesalers.

Taken together, Jensen commented that these factors could mean that Australia is falling behind in terms of international efforts towards the HFC phase out.

In large developing countries like India and China, public policy continues to play a critical role in overcoming regional food industry challenges and in facilitating the development of the cold chain infrastructure.

In India, the government is increasing its support for the cold chain, but obstacles still remain for natural refrigerants. Although ammonia has been used for 100 years in the country, it is now banned in many urban areas due to safety concerns.

In addition, the country's regulatory agencies and inspectors lack awareness about ammonia refrigeration. Complicating that issue, the country's current standard for ammonia refrigeration, originally created in 1963, is out of date. However, progress on improving safety is being made. The Association of Ammonia Refrigeration in India, AAR, is now proposing a new ammonia standard based on IIAR standards as well as local input.

While some hurdles to natural refrigerant adoption remain in place, the Indian government does seem committed to developing the cold chain. That government's 2014 and 2015 budgets targeted the agricultural and food chain sectors, and almost $800 million dollars were allocated in the 2014 budget for cold chain and warehousing

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development. A plan is also in place to allow for food production areas that are closer to cities to facilitate faster cold chain distribution.

Other 2014 items in the Indian budget that have the potential to benefit the cold chain include: rural power supply and transportation initiatives; new agricultural universities; almost $12 billion U.S. dollars for developing ports; subsidies for solar power development for refrigerated warehouses; and even the creation of a new TV channel to cover agricultural and cold chain development issues.

This year's budget includes a number of tax reforms and incentives and other initiatives that should pave the way for increased investment in the cold chain as well as funding for a skills development program in India. Samir Shah, IIAR's Regional Vice Chair for India and South Asia, commented that some of these initiatives should create more opportunities and tolerance for ammonia as a refrigerant.

As developing countries, India and China are advancing at breakneck speed, thanks to economic development and rising levels of affluence. Yet the barriers to natural refrigeration adoption are specific to each country.

China is also struggling with cold chain construction, yielding a high demand for efficient, low cost and environmentally friendly cold stores. But that demand is often stymied by local governments that are still reluctant to adopt ammonia in large projects.

Safety concerns surrounding ammonia are clearly part of that issue. A number of high profile ammonia incidents in 2013, which led to public hearings in 2014, have raised concerns about ammonia safety.

One byproduct of the heightened awareness around the safety issue is that CO_2 could gain an edge over ammonia for future cold chain development, according to Guy Cloutier, the International Committee's Regional Vice President for China.

Like India, China has a cold storage safety code, but it remains behind developed country standards. And complicating the safety issue, China's enforcement of the safety code is lacking.

Nevertheless, the government has indicated it will address both of these issues with standard adoption and development.

The incentives for cold chain improvement in China are great. Due to the distances and lack of cold chain infrastructure, China's agricultural production suffers from post-harvest losses exceeding 45 percent, which is much higher than the loss rate in India.

In addition, food safety has become a major concern in China as its population of consumers grows more sophisticated and gains more spending power.

Big challenges remain for China's industrial refrigeration industry, not least of which is a paradoxical approach to natural refrigerants. China now clearly aims to develop a green economy and build a sustainable cold chain – where natural refrigerants could play a central role – but the country is still producing R-22 and has often prioritized economic development over the environment.

Taken together, the largest issues facing natural refrigerants in developing countries like India and China fall into three main categories: safety, energy efficiency and environmental sustainability.

The goal of IIAR's International Committee in the coming year is to help address those issues by finding effective ways to reach relevant officials and agencies in those countries to facilitate positive developments in the cold chain through our chapters, alliances and other international programs. ■

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Routine Rooftop Maintenance Creates Requirement for Fixed Industrial Stairs

Increased regulatory scrutiny and the growing emphasis on process safety management have spurred a steady relocation of equipment from production room floors, freezers and coolers to facility rooftops. The reasons for the transition have been practical. Moving equipment to a roof allows a facility to expand by taking advantage of the "free real estate" offered by a building's rooftop footprint. And safety benefits – like eliminating the potential for pipes to be struck by handling equipment or minimizing exposure – limit liability in an era marked by federal oversight initiatives like OSHA's national emphasis program.

While facilities may be doing everything right when it comes to moving equipment to the roof, they may be overlooking a seemingly innocuous detail that OSHA has begun to focus on: the methods of egress.

When equipment on a roof requires any kind of routine maintenance, fixed industrial ladders, which have commonly been used by the industry to provide access to the roof, are no longer sufficient.

And in most cases, relocation of equipment to a rooftop has created the need for routine maintenance, leaving facilities that have only fixed ladders vulnerable to OSHA citations.

"We've always had equipment on the roof, but in the past, it hasn't been equipment that requires routine maintenance," said Bryan Haywood, PSM consultant and president of the Safety Engineering Network. "Now that equipment on the roof has grown in volume and complexity, the situation is different. IIAR and every RAGAGEP out there require that routine maintenance be performed, so the question becomes: how do you configure stairs and ladders to accommodate that maintenance?"

OSHA's answer, it appears, is simple: where routine maintenance is required, so are fixed industrial stairs.

"Most people know that fixed industrial stairs are a good idea, but not many people know that there is an OSHA standard that actually requires them," said Peter Jordan, president of MBD Risk Management Services. "If you have personnel on that roof once a day, you'd have a hard time reading the OSHA standard and saying you don't need fixed stairs."

"The bottom line is that if you have equipment on the roof that requires routine maintenance, OSHA is paying attention to this issue. They're going to see it."

The issue of egress is most likely to come up with OSHA during a routine PSM inspection, and, ironically, the relocation of equipment to the rooftop – which in turn creates a requirement for fixed stairs – is most often driven by a desire to meet a PSM program. However, the OSHA standard that requires fixed industrial stairs is not a PSM requirement.

"The citations we're seeing from OSHA are not being made under PSM, they are made under 1910.24(b), the agency's standard for industrial stairs," said Haywood.

To better understand what this may mean to a facility, Haywood suggested a thorough study of standard 1910.24 "Fixed Industrial Stairs," and its requirements, as follows:

1910.24(b) states…

"Where fixed stairs are required." Fixed stairs shall be provided for access from one structure level to another where operations necessitate regular travel between levels, and for access to operating platforms at any equipment which requires attention routinely during operations.

"As you can see, it is pretty clear that a process that places its piping and other components that require attention routinely during operations on a roof will be required to have fixed industrial stairs for access to their roof areas," said Haywood, adding that if the first portion of the section is not convincing enough, the second part provides more examples of when fixed industrial stairs are required…

Fixed stairs shall also be provided where access to elevations is daily or at each shift for such purposes as gauging, inspection, regular maintenance, etc., where such work may expose employees to acids, caustics, gases, or other harmful substances, or for which purposes the carrying of tools or equipment by hand is normally required. (It is not the intent of this section to preclude the use of fixed ladders for access to elevated tanks, towers, and similar structures, overhead traveling cranes, etc., where the use of fixed ladders is common practice.)

"I am sure someone could argue at some point that their processes do not meet any of these requirements," said Haywood. "However, if your facility has daily or shift rounds to be made (normal practice in PSM/RMP processes) we need industrial stairs to access the roof. Even if we do not make daily or shift rounds, but workers have to go up on the roof to operate valves or perform maintenance on a regular basis, then we are required to have fixed industrial stairs."

Haywood also pointed out that 1910.37 requirements come into play . . .

1910.37(a)(3) Exit routes must be

continued on page 28

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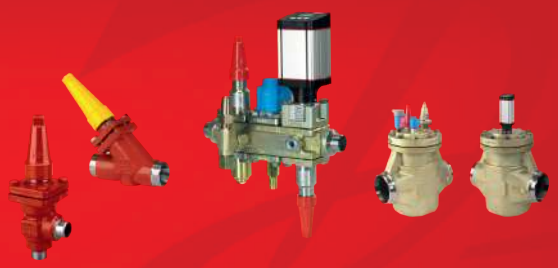

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free and unobstructed. No materials or equipment may be placed, either permanently or temporarily, within the exit route. The exit access must not go through a room that can be locked, such as a bathroom, to reach an exit or exit discharge, nor may it lead into a dead-end corridor. Stairs or a ramp must be provided where the exit route is not substantially level.

Fixed ladders that meet 1910.27 may be used for "emergency egress" in some situations, said Haywood, who added that he refers to OSHA's Standard Directive "STD 01-01-012 - Application of 29 CFR 1910.27, Fixed Ladders Used in Emergency Situations (6/20/1983)" to help explain when fixed ladders can be used as a means for emergency egress. In that directive, OSHA states…

This instruction provides performance criteria for fixed ladders used only as a means of access for fire fighters and other emergency personnel, or escape for employees in fire and other emergency situations.

1. Employers must establish and implement adequate administrative controls such as barricades and signs to prevent nonemergency use of fixed ladders which are meant for fire fighter use and emergency escape only.

2. In the event the employer does not provide adequate administrative controls such as barricades or signs and employees use an emergency ladder for other than its intended purpose, the employer may be appropriately cited under 29 CFR 1910.27.

3. Fixed ladders not equipped with cages, landing platforms, ladder safety devices, or other forms of employee protection, in some situations may be allowed as a means of access for fire fighters and other emergency personnel, or escape for employees in fire and other emergency situations. These guidelines are provided because it may be more hazardous to comply with 29 CFR 1910.27 than not to comply.

Regardless of where and how specific OSHA regulations surrounding stairs apply to an individual facility, the bottom line is that fixed stairs are almost always required when a large volume of equipment is on the roof, said Haywood.

"Moving equipment to the rooftop is safer for our equipment, but it also increases the risks to the workers who have to routinely access the equipment and perform high-risk activities with limited means of egress. Emergency egress is nothing to sneeze at, and it becomes doubly important when we have workers on a rooftop with highly hazardous chemicals."

And that, he said, should be the biggest consideration for a business that is considering moving equipment to a roof, or already has equipment in place. "If they've made this change, or if they're thinking about making this change, they may need to revisit their project in light of the OSHA requirement to ensure they have not created an egress issue," he said.

IIAR will be introducing a series of webinars to address facility daily or shift rounds as part of the IIAR website end-user portal. Look for this webinar series later this summer. ■

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Smaller Facilities Shouldn't Overlook Safety Planning

from the technical **DEPARTMENT**

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

When it comes to safety, prevention is the most important factor in avoiding potential consequences. Whether a facility is working with 900 pounds or 90,000 pounds of ammonia, the risks of an incident are similar.

And although the severity of a potential problem could be smaller with a smaller facility, the risk is still there.

As the industry sees more and more systems built to reduce charge levels, in some cases to get below regulatory thresholds, and in other cases to replace synthetic refrigerants, the question of which guidelines to follow for smaller systems – or those under 10,000 pounds – becomes more and more important.

IIAR-developed industry safety practices, like the Ammonia Refrigeration Management Program, or ARM, go a long way in protecting the reputation of smaller facilities. The program helps small facilities develop a good safety plan focused on prevention.

The refrigeration industry continues to experience an increase in enforcement activities that utilize OSHA's General Duty Clause, specifically in facilities with less than 10,000 pounds of ammonia, where OSHA expects process safety-like standards to be in place.

IIAR-developed industry safety practices, like the Ammonia Refrigeration Management Program, or ARM, go a long way in protecting the reputation of smaller facilities. The program helps small facilities develop a good safety plan focused on prevention.

For example, a smaller facility may not see the level of off-site consequences an incident at a larger facility would see, but it would certainly face on-site consequences, an outcome no company can afford, especially when such an incident could prompt local news media coverage.

Given those challenges, how should a small ammonia refrigeration facility determine the practices that are the most efficient for its own operations in the face of so much conflicting and often redundant information about safety practices – that may or may not actually apply to smaller operations?

Traditionally, larger ammonia refrigeration facilities – with charges greater than 10,000 pounds – have been required to comply with OSHA's Process Safety Management Program and EPA's Risk Management Program requirements.

In part because of those regulations, in place since the 1990s, the most common misconception among smaller facilities has been that they are exempt from compliance issues because the size of their charge is less than 10,000 pounds. But nothing could be further from the truth.

In addition to the safety and public relations considerations, there is a regulatory compliance issue for smaller facilities. The general duty clauses of OSHA and the EPA, cover every refrigeration facility, including those with less than 10,000 pounds of ammonia. These regulations can be found in 29 USC 654(a)(1) (OSHA) and the Clean Air Act Section 112(r)(1) (EPA). They set a minimum safety standard and place responsibility on employers to keep workers and neighbors safe from hazardous chemicals.

IIAR's ARM program is one tool any small facility can use to meet the challenges posed by a regulatory environment – an environment that often delivers non-prescriptive specifications for safety. Drawing on the cumulative experience of the industry, ARM helps companies and facilities identify the specific safety practices they should pursue, answering the common question: What basic safety processes should small ammonia refrigeration facilities observe and how should they build a safety program that is suited to their unique operations?

While safe and efficient operation has always been a driving force behind the innovations of the industry, even larger companies with multiple small facilities are turning their attention to safety programs as they increasingly expand their operations beyond a central, large facility, to facilities with less than 10,000 pounds of ammonia.

As we continually evolve to meet the demands of a complex regulatory environment and fast-paced supply chain, the need to develop and implement ARM programs at small facilities is indeed a challenge faced by everyone in the industry.

The ARM program is a streamlined version of the Institute's PSM/RMP compliance guidelines. It addresses topics such as the management system, documentation, contractors, mechanical integrity, and emergency response, and simplifies the record keeping and program maintenance elements of the more complex PSM and RMP requirements. ■

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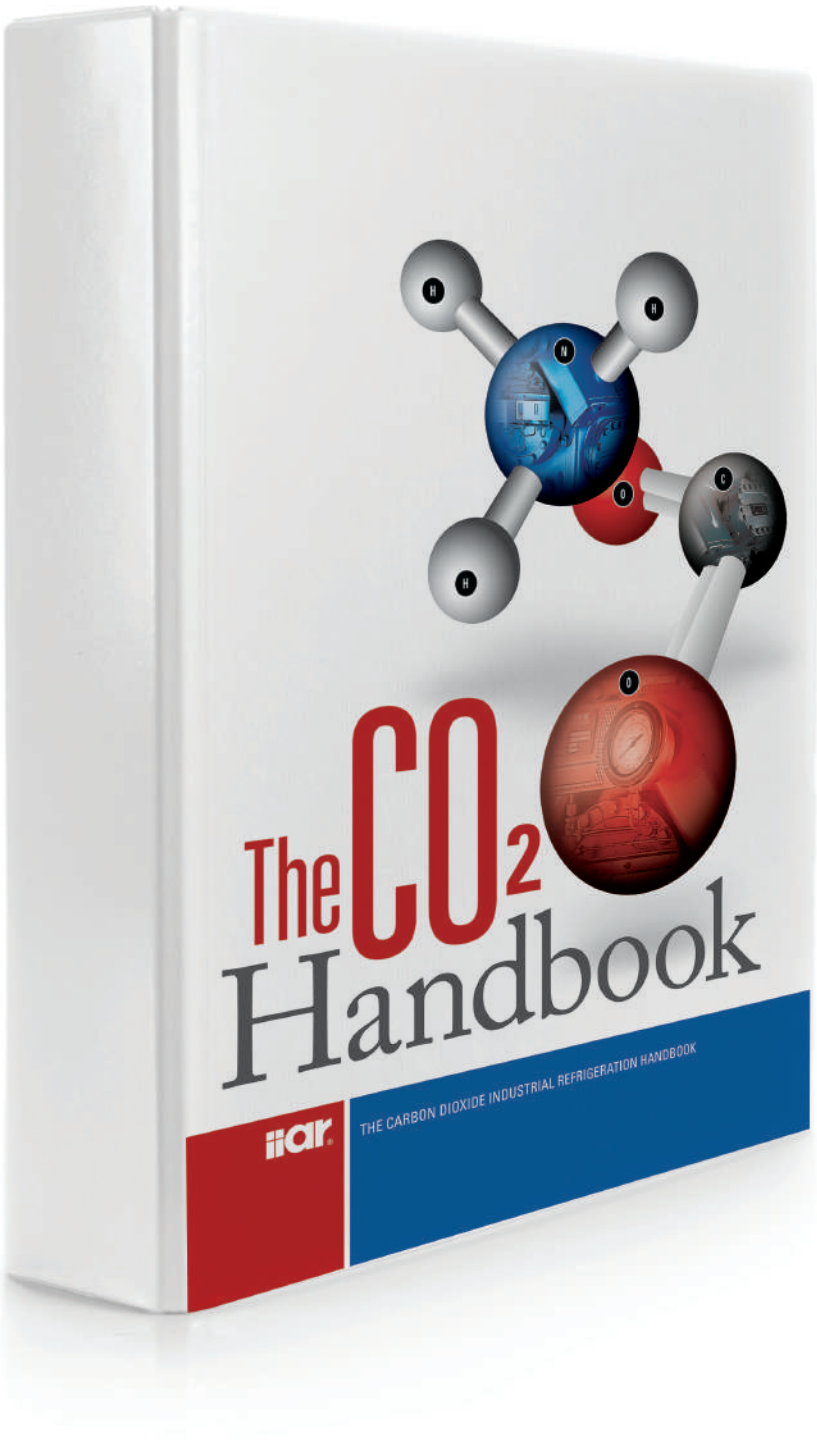

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REFRIGERANT AND REGULATORY DEVELOPMENTS:

CHANGES IMPACTING THE OPPORTUNITIES FOR NATURAL REFRIGERANTS

By Rajan Rajendran, Ph.D., Emerson Climate Technologies

Editor's Note

As recently as five years ago, air-conditioning and refrigeration applications were dominated by a handful of refrigerants – ammonia in large industrial systems, HFCs like R404A and HFC-134a in stationary and mobile refrigeration and air-conditioning, and R410A in stationary air-conditioning applications. Meanwhile, the use of HCFC-22 was declining as it was being phased-out by the Montreal Protocol agreement. In Europe, especially in domestic refrigeration, hydrocarbons like isobutane and propane had already become quite common. Today, CO2 as a refrigerant in stationary refrigeration has grown in usage and acceptance in Europe and Australia and is making inroads in North America and elsewhere. The use of R290 in small charge systems and even some large units is increasing across Europe and is being tried out in other parts of the world. In response to this demand for lower GWP fluids, refrigerant manufacturers are introducing and will continue to release new fluids over the next few years. So what might we expect ten years from now? In this paper, author Rajan Rajendran poses a few answers to that question, examining the changes to the refrigerant landscape and the resurgence of natural refrigerants as one of the best options in addressing climate change.

In the years since the Montreal Protocol went into effect in 1989, the global refrigeration and air-conditioning industry has met the challenge of phasing out ozone depleting chemicals and adapted well to achieving increasing efficiency for their equipment using synthetic hydrofluorocarbons, HFC's, in most common applications. In large industrial applications, ammonia has become the standard refrigerant of choice, even though HFCs are used in some installations. In recent years, the alarming growth and emissions of HFCs into atmosphere has caused concern that, if left unchecked, these HFCs could become a major contributor to global warming gases in the atmosphere. Starting with some European countries, and followed by Australia and eventually the rest of Europe, governments have started taking action to curb this growth and emission of large quantities of HFCs. More recently, the United States Environmental Protection Agency (EPA) announced proposed rules to remove some of the HFCs by application from their approved list of refrigerants. The refrigerant landscape has changed significantly and continues to evolve as these factors come into play. In response to a demand for refrigerants with lower climate impact, natural refrigerants have seen resurgence, made possible in large part due to the advent of electronics and software to make natural refrigerant systems more efficient. New synthetic refrigerants have also been developed, more efficient than existing HFCs and having less impact on the climate. We are looking at a future with more options than we have ever had before – which means that we have to be careful in how we make our choices to minimize or eliminate unintended negative consequences.

MONTREAL PROTOCOL AND ITS IMPACT

The Montreal Protocol was agreed to by all the countries in September 1987, and went into effect on January 1, 1989[1]. Since that original document was approved, the protocol has been adjusted several times to make allowance for new technical information that became available. The Montreal Protocol was born out of concern for the development of the "ozone hole" (the protective ozone layer is needed in the upper atmosphere to prevent harmful ultra violet rays from the sun reaching the earth's surface) caused by chemicals in the stratosphere reacting with the ozone and depleting the useful protecting layer. One family of chemicals eliminated from use is the chlorine containing chloro-fluro carbon refrigerants or CFC as they are commonly known. These CFCs were used in nearly all air conditioning and refrigeration applications worldwide, due to their high efficiency and low toxicity and non flammable characteristics. Since 1989, first Europe and then the other non Article 5 countries [1], like the United States and later Article 5 countries like China and India, have banned the use of CFCs and embarked on the path of phasing out the use of hydro chloro-fluro carbon (HCFC) refrigerants like HCFC-22. At the time of writing this paper, HCFCs have been phased out in Europe, soon will be in the United States, and the process of phasing out of HCFCs in Article 5 countries has begun. Figure 1 below shows these various stages of the phase-out process of HCFC-22, used in nearly all refrigeration and air conditioning equipment until recently.

The effect of the elimination of these gases that deplete the ozone layer has been the beginning of the process of "healing of the ozone hole". According to a recent report on the effect of the Montreal Protocol, titled "Assessment for Decision-Makers – Scientific Assessment of Ozone Depletion: 2014", the ozone depleting substances have started decreasing steadily in the last fifteen years. Figure 2 below shows the steady increase in equivalent chlorine in the stratosphere through the last two decades of the 20th century, followed by a stabilizing period and then a gradual decline, clearly due to the effect of the Montreal Protocol.

The report also documents that this stabilization and decline of ozone depleting substances has led to an increase in the ozone content as shown in Figure 3. The solid blue line is the measured data compared to the model, indicating that the ozone layer is indeed healing, thus leading to their conclusion that ozone levels will reach 1960 levels in the year 2100.

One of the benefits of the phasing out of CFCs is that the Montreal Protocol eliminated a whole family of gases that have high global warming potential (GWP). Global Warming Potential is a measure of the climate impact of a gas measured relative to that of carbon dioxide, which is given a reference value of 1. Global warm-

Figure 1 Montreal Protocol agreement on HCFC-22 phase-out for various countries

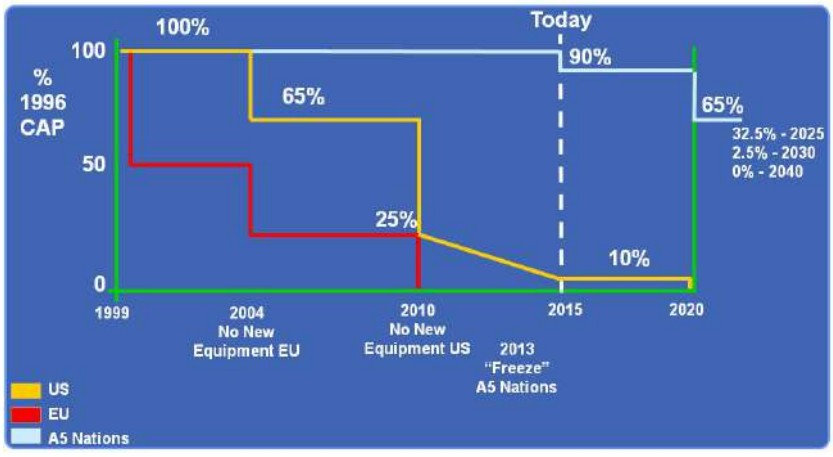

Figure 2 Equivalent effective stratospheric chlorine is showing a decrease [2]

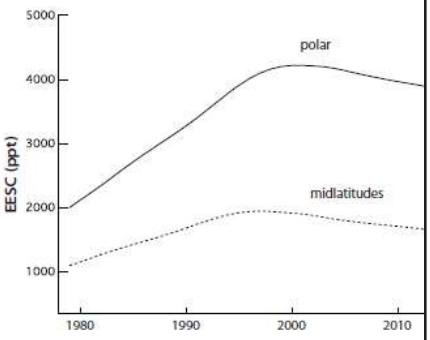

Figure 3 Modeling results and actual measurements of stratospheric ozone [2]

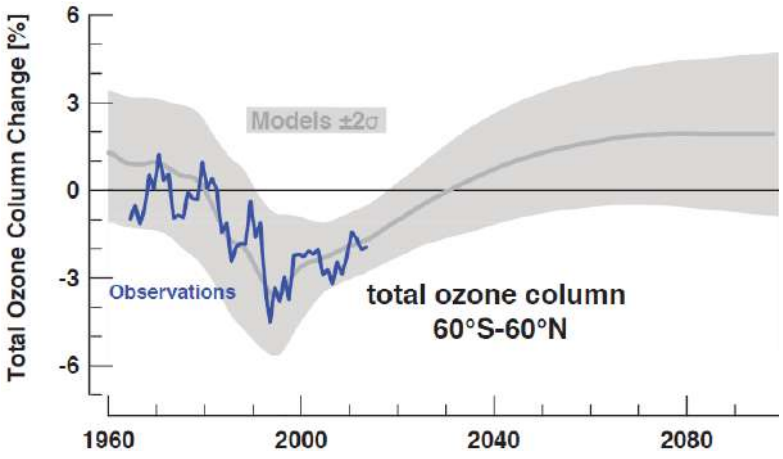

Table 1 Global warming potential of common chemicals referenced to CO_2 [3]

Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	Radiative Efficiency (W m^{-2} ppb^{-1})	Global Warming Potential for Given Time Horizon			
				SAR[1] (100-yr)	20-yr	100-yr	500-yr
Carbon dioxide	CO_2	See below[a]	[b]1.4x10^{-5}	1	1	1	1
Methane[c]	CH_4	12[c]	3.7x10^{-4}	21	72	25	7.6
Nitrous oxide	N_2O	114	3.03x10^{-3}	310	289	298	153
Substances controlled by the Montreal Protocol							
CFC-11	CCl_3F	45	0.25	3,800	6,730	4,750	1,620
CFC-12	CCl_2F_2	100	0.32	8,100	11,000	10,900	5,200
CFC-13	$CClF_3$	640	0.25		10,800	14,400	16,400
CFC-113	CCl_2FCClF_2	85	0.3	4,800	6,540	6,130	2,700
CFC-114	$CClF_2CClF_2$	300	0.31		8,040	10,000	8,730
CFC-115	$CClF_2CF_3$	1,700	0.18		5,310	7,370	9,990
Halon-1301	$CBrF_3$	65	0.32	5,400	8,480	7,140	2,760
Halon-1211	$CBrClF_2$	16	0.3		4,750	1,890	575
Halon-2402	$CBrF_2CBrF_2$	20	0.33		3,680	1,640	503
Carbon tetrachloride	CCl_4	26	0.13	1,400	2,700	1,400	435
Methyl bromide	CH_3Br	0.7	0.01		17	5	1
Methyl chloroform	CH_3CCl_3	5	0.06		506	146	45
HCFC-22	$CHClF_2$	12	0.2	1,500	5,160	1,810	549
HCFC-123	$CHCl_2CF_3$	1.3	0.14	90	273	77	24
HCFC-124	$CHClFCF_3$	5.8	0.22	470	2,070	609	185
HCFC-141b	CH_3CCl_2F	9.3	0.14		2,250	725	220
HCFC-142b	CH_3CClF_2	17.9	0.2	1,800	5,490	2,310	705
HCFC-225ca	$CHCl_2CF_2CF_3$	1.9	0.2		429	122	37
HCFC-225cb	$CHClFCF_2CClF_2$	5.8	0.32		2,030	595	181
Hydrofluorocarbons							
HFC-23	CHF_3	270	0.19	11,700	12,000	14,800	12,200
HFC-32	CH_2F_2	4.9	0.11	650	2,330	675	205
HFC-125	CHF_2CF_3	29	0.23	2,800	6,350	3,500	1,100
HFC-134a	CH_2FCF_3	14	0.16	1,300	3,830	1,430	435
HFC-143a	CH_3CF_3	52	0.13	3,800	5,890	4,470	1,590
HFC-152a	CH_3CHF_2	1.4	0.09	140	437	124	38
HFC-227ea	CF_3CHFCF_3	34.2	0.26	2,900	5,310	3,220	1,040
HFC-236fa	$CF_3CH_2CF_3$	240	0.28	6,300	8,100	9,810	7,660
HFC-245fa	$CHF_2CH_2CF_3$	7.6	0.28		3,380	1030	314
HFC-365mfc	$CH_3CF_2CH_2CF_3$	8.6	0.21		2,520	794	241
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	15.9	0.4	1,300	4,140	1,640	500
Perfluorinated compounds							
Sulphur hexafluoride	SF_6	3,200	0.52	23,900	16,300	22,800	32,600
Nitrogen trifluoride	NF_3	740	0.21		12,300	17,200	20,700
PFC-14	CF_4	50,000	0.10	6,500	5,210	7,390	11,200
PFC-116	C_2F_6	10,000	0.26	9,200	8,630	12,200	18,200

ing potential numbers are reported by the Intergovernmental Panel on Climate Change (IPCC), a United Nations organization and Table 1 shows the global warming potentials of some commonly used chemicals [3].

Commonly accepted values are those for the 100-year time horizon. On this scale, CFC-12 or R12 as it is also known, has a GWP of 10,900 and when phased out by the Montreal Protocol, was rapidly replaced by HCFC-22 or HCFC-22 at a GWP of 1810, an 83% decrease. The effect of this dramatic change was the positive impact that the Montreal Protocol had on climate change.

A recent article in The Economist, titled "Curbing Climate Change", dated September 20, 2014 [4], highlighted this "unintended consequence" of the Montreal Protocol through a dramatic comparison of the various efforts to mitigate global warming. The figure from the article that is reproduced as Figure 4, clearly shows that the elimination of CFCs had the most significant impact on global warming.

At 5.6 billion tones of equivalent CO_2, the phase-out of CFCs has been the single largest positive influence on reducing gases that impact climate change.

CLIMATE CHANGE CONCERNS

The replacement gases to R12 and HCFC-22, called hydrochlorofluorocarbons have a lower GWP than R12 (and some HFCs' GWP are lower

Figure 4 Emissions reductions by policies and actions [4]

Emission reductions by policies/actions, bn tonnes CO_2 equivalent

Policy/Action	Cumulative emissions	Period	Annual emissions*
Montreal protocol[1]	135.0bn	1989-2013	5.6bn
Hydropower worldwide[2]	2.8bn	2010	2.8bn
Nuclear power worldwide[2]	2.2bn	2010	2.2bn
China one-child policy[3]	1.3bn	2005	1.3bn
Other renewables worldwide[2]	600m	2010	600m
US vehicle emissions & fuel economy standards†[4]	6.0bn	2012-25	460m
Brazil forest preservation[5]	3.2bn	2005-13	400m
India land-use change[6]	177m	2007	177m
Clean Development Mechanism[7]	1.5bn	2004-14	150m
US building & appliances codes[4]	3.0bn	2008-30	136m
China SOE efficiency targets[8]	1.9bn	2005-20	126m
Collapse of USSR[9]	709m	1992-98	118m
Global Environment Facility[10]	2.3bn	1991-2014	100m
EU energy efficiency[11]	230m	2008-12	58m
US vehicle emissions & fuel economy standards†[4]	270m	2014-18	54m
EU renewables[11]	117m	2008-12	29m
US building codes (2013)[12]	230m	2014-30	10m
US appliances (2013)[12]	158m	2014-30	10m
Clean technology fund[13]	1.7bn	*project lifetime*	*na*
EU vehicle emission standards[14]	140m	2020	*na*

CATEGORIES:
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than HCFC-22 as well), yet, with rapid increase in economic activity worldwide, the contribution of these HFCs as global warming gases is expected to grow at a rate of 7% per year for the foreseeable future [2].

The effect of this continued growth in HFC consumption and emission could, if left unchecked, lead to significant increase in HFC contribution to global warming [5]. Figure 5 shows the possible growth in HFCs in developed and developing nations. In Figure 6, Velders et al show that the growth in HFCs, particularly in developing countries, could more than offset all the gains made in emissions through the Montreal Protocol.

These concerns for climate change impact due to growth in HFC consumption and emissions have prompted many countries to take actions on their own. Starting with countries in northern Europe that placed a GWP based tax on HFCs, Australia followed suit and, most recently, the rest of Europe approved the changes to the F-gas regulation. Since the F-gas regulation changes have the most impact in Europe, we will briefly review the key elements of those changes here.

EUROPEAN F-GAS REGULATION

The European Fluorinated Gas rule, called simply the F-gas rule, was first adopted in 2006 and regulates the use of refrigerants in various industries across Europe [6]. The F-gas rule was recently amended in March 2014 to include stricter rules on the use of HFCs. Table 2 summarizes the key elements of the revisions of the F-gas rule that affect the air-conditioning and refrigeration industries.

The most important impact of the F-gas directive is on the refrigeration industry and supermarket applications

Figure 5 Projected HFC growth in developed and developing nations [5]

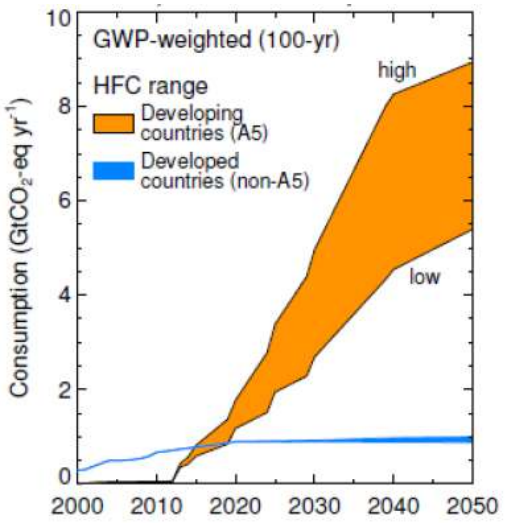


Figure 6 HFC growth could reverse emissions gains achieved by Montreal Protocol [5]

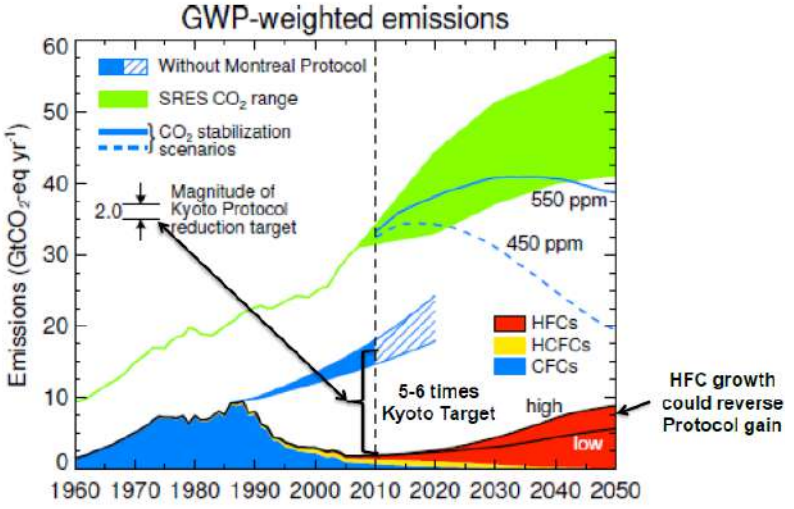


Table 2 The F-gas directive effective as of January 1, 2015

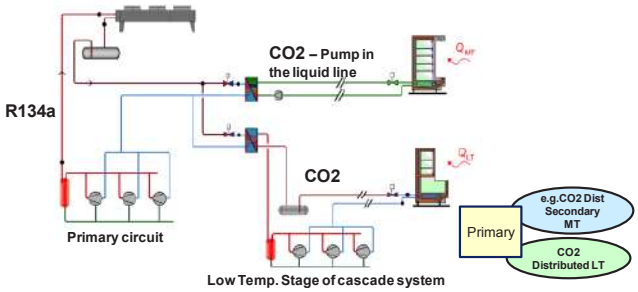
Service and maintenance ban for refrigeration equipment	GWP	Timing
Unless below >40 tonnes of CO2 charge or below -50 deg C product cooling, or for military purposes – recycled or reclaimed allowed until 2030	2500	Jan '20
'Placing on the market' (new equipment) bans		
Domestic refrigerators and freezers	150	Jan '15
Refrigerators and freezers for commercial use (hermetically sealed systems)	2500	Jan '20
	150	Jan '22
Stationary refrigeration equipment (except equipment for temperatures below -50 deg C)	2500	Jan '20
Multipack centralized refrigeration systems for commercial use with a capacity of ≥ 40 kW (140 kBTU/hr) (except in the primary refrigerant circuit of cascade systems, where fluorinated greenhouse gases with a GWP of less than 1500 may be used)	150	Jan '22
Movable room air-conditioning appliances (hermetically sealed equipment which is movable between rooms by the end user, includes window units)	150	Jan '20
Single split air-conditioning systems containing < 3 kg charge	750	Jan '25

with R404A or R507A in particular. New equipment bans for supermarket applications that go into effect in January of 2022 will drive large stationary refrigeration systems to using less than 150 GWP fluids except for cascade or hybrid systems. A typical example of a cascade system is shown in Figure 7 where CO_2 is used in the low temperature part of the refrigeration system which condenses using a HFC like HFC-134a (less than 1500 GWP) in the medium temperature primary circuit. This implies that the medium temperature cooling has to be carried out by a secondary pumped fluid like CO_2 or glycol.

Domestic refrigerators and hermetically sealed commercial refrigeration systems will be restricted further to refrigerants with GWP less than 150, beginning in January 2015 and January 2022, respectively.

In addition to the bans, the F-gas rule also implements a phase-down on the GWP based consumption of HFCs. This HFC phase-down mechanism is shown in Figure 8 along with the key elements of the specific application bans. The net effect of this HFC phase down will be to force applications to move to a weighted average GWP that is significantly lower than what it is today.

Figure 7 Cascade of hybrid supermarket refrigeration system



System Type	R134a primary; Secondary MT (e.g. CO2) / cascade CO2 DX LT
System Temperature	MT and LT
Refrigerant	Primary: R134a, LT: CO2, MT Secondary (e.g. CO2)
Capacity	100 kW
Charge	20 kg in primary circuit
Ban?	Allowed, LT cascade, <150 GWP in DX circuit, MT secondary circuit and <1500 in primary (A.III 13)

THE NORTH AMERICAN PROPOSAL FOR PHASE-DOWN OF HFCS

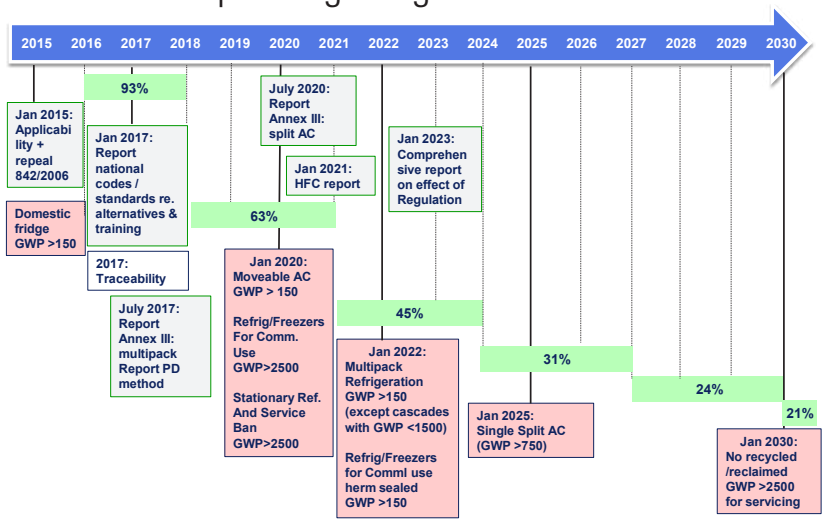
The United States, Mexico and Canada, the three North American countries, have proposed the highly successful Montreal Protocol be amended to include a global HFC phase-down. This proposal shown in Figure 9 has been presented and debated for five years without success. The European Union's F-gas HFC phase-down is also shown here for reference. The proposal envisions two phase-down paths, one for Article 5 countries like China and India and another more aggressive step down for developed countries like the United States. The Article 5 countries like China and India have been the main resistance to such an amendment, based on the grounds that it was not the intent of the Montreal Protocol to curb greenhouse gases but ozone depleting chemicals. However, since 2013, there has been a gradual shift in public comments made by both countries which indicate that perhaps such a global agreement might indeed be possible in the coming year or two [7,8].

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY'S PROPOSAL TO DELIST REFRIGERANTS

As we have seen earlier, even as the United States was leading the effort (with support from many countries including those in the European Union) to implement a global phase-down of HFCs, Europe's F-gas rule has gone into effect curbing the use of many high GWP HFCs. In the United States, on June 25th 2013, President Obama announced a Climate Action Plan [9] to curb the emission of many short-lived greenhouse gases. One of those gases listed were HFCs and executive action to reduce the impact of these gases was promised. In the subsequent months, the EPA held several industry stakeholder meetings and published two Notices of Public Rulemaking (NOPR) in 2014. The first of the two, published on July 9, 2014, listed new refrigerants, uses and revised venting prohibitions, and is summarized below [10]:

- Stand-alone commercial refrigerators and freezers: R600a, R441A (150 g)
- Household refrigerators and freezers: R290 (57 g)
- Vending machines: R600a, R290 (150 g)

Figure 8 GWP weighted HFC phase down in European F-gas regulation



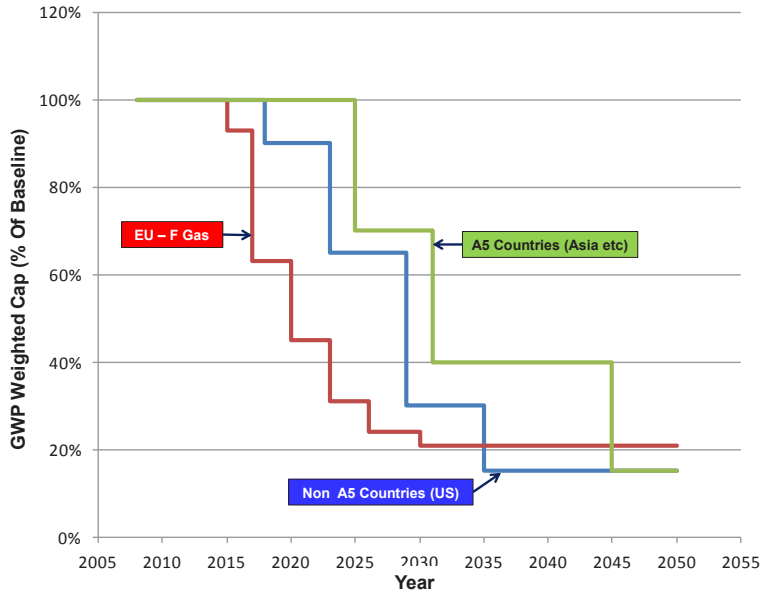
- Self-contained room AC, PTACs, PTHPs, window AC and single-room portable AC: R290, HFC-32, R441A (subject to UL 484 limits)

This rulemaking is important as it is a precursor to several more promised by the EPA in an accelerated process of approval.

The second NOPR that was published in the Federal Register on August 6, 2014 is a delisting of several high-GWP HFCs in various applications [11]. This delisting proposal is summarized in Table 3 (some applications are not shown on the table).

Since this proposal was published, there have been several meetings within the industry and between various stakeholders and the EPA to discuss on comment on this rulemaking. By the time of publication of this paper, it is likely that the final rule would have already been published by the EPA after review of all the comments. In general, the timing is extremely aggressive and for the self contained application, for example, the lack of alternatives to meet all their needs will pose serious issues. We can expect that the comments will reflect upon all of these points and ask for fewer candidates to be delisted (or not at all) and where a refrigerant is delisted, the industry be given sufficient time to research, develop, test and market the alternatives.

Figure 9 North American Proposal (NAP) for a global phase-down of HFCs



SEARCH FOR ALTERNATIVES, SAFETY AND LIFE CYCLE CLIMATE PERFORMANCE (LCCP)

The search for alternatives to high GWP refrigerants began several years ago with industry and other stakeholders engaging in research into different options. As will be seen in the next section, the known alternatives to HFCs and the new candidates being developed have some characteristic or another that makes them a challenge to be adopted universally in all applications everywhere. The principles to be followed in the search for alternatives, is shown in Figure 10.

Beginning with safety (toxicity, flammability, high pressure), the alternate's performance in an actual system, the economics, which includes both first cost and cost of ownership, as well as the impact on the environment have to be taken into account. Not doing so will lead to unintended negative consequences that we will have to deal with at a later date.

Alternatives to high GWP HFCs raise the issue of safety to a very high level – ammonia has toxicity and flammability, CO_2 has high pressure, and propane has flammability as risks that have to be mitigated. Standards are only now being developed around the world to accommodate these and other flammable refrigerants in various applications. Figure 11 shows a snapshot in time of a sampling of the standards and other work that needs to follow in order to fully absorb the alternatives to HFCs into the mainstream. Optimistic estimates place this date for completion of the safety work across the world and in all applications, somewhere beyond 2020.

Performance of an alternative refrigerant in an actual system, instead of

Table 3 EPA proposal to delist certain refrigerants by application in some end uses

Refrigerant	Supermarket*		Condensing Units* (field charged)	Standalone Self Contained Comm. Ref. Eqpt* (factory charged sealed systems)	Vending Machines*	Foam	Auto AC
	Direct	Sec.					
R404A/507A	Jan 2016	Jan 2016	Jan 2016	Jan 2016	Jan 2016		
HFC-227ea, R-407B, R-421B, R-422A, R-422C, R-422D, R-428A, R-434A	Jan 2016	Jan 2016					
R407A, R407F				Jan 2016 (New)			
R134a				Jan 2016 (New)	Jan 2016 (New)	Jan 2017	2021 Model (New)
Various Blends, GWP 600-3990**				Jan 2016 (New)			
Various Foam Refs**						Jan 2017	
Various Auto Blends**							2017 Model (New)

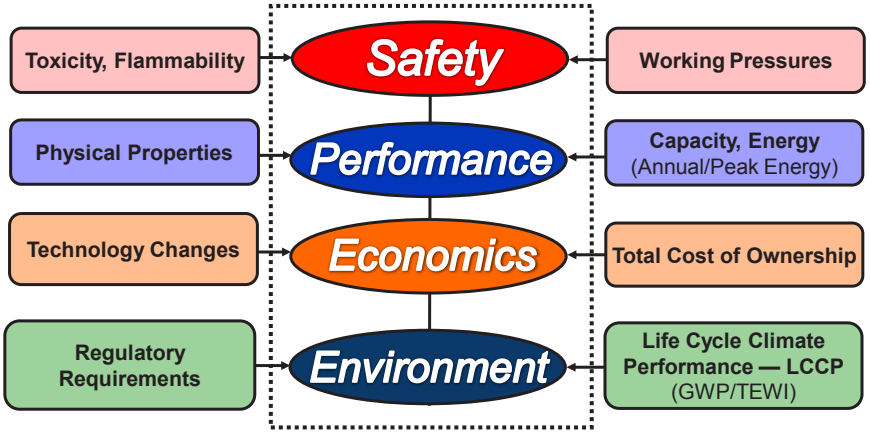
* New And Retrofit Only, Service Is Allowed
** Check EPA Documents For Details
Aerosol Application Not Shown In Above Table
Industrial, Ice Making Heads, Warehouses and Transport Applications Are Not Included In This NOPR But Comments Have Been Requested

just in a component is the next most important variable in the selection of a refrigerant. Often alternatives are evaluated in multiple ways and using different standards makes it difficult to compare one to another. In order to have a uniform method of comparison, the Air conditioning, Heating and Refrigeration Institute (AHRI) started and completed Phase 1 of a Low GWP Alternative Refrigerant Evaluation Program in 2012/2013 and a conference was held in New York in January, 2014 [13]. Twenty one companies participated in the testing, with six refrigerant producers supplying thirty eight different candidates resulting in forty one reports that are available to the public on the AHRI website. The outcome of the evaluation and the conference was an awareness that many new alternatives were available and with component and system optimization, it should be possible to achieve same or better performance than the current HFC refrigerants. Cost was not addressed in this study. A Phase II of the study is now in progress and is expected to be complete in late 2015.

Performance in a system and the environment impact of a refrigerant are connected. When considering the impact of a system on the environment, it is common to think about the effect of the refrigerant leak, which is called the "direct" impact. There is another, called the "indirect" impact of the system on climate that is due to the energy consumed by the equipment and the source of energy. The indirect impact, which can be as much as 95% of the total, when taken together with the direct, is called total equivalent warming impact and often approximated to the life cycle climate impact or LCCP. Figure 12 is a simple representation of this life cycle approach to calculating climate impact. Unfortunately, there is no single model for LCCP that is widely accepted as a standard, though effort is underway to change this. Emerson Climate Technologies has a web based software that enables a user to compare different refrigeration systems using an LCCP approach [14].

As one evaluates the different alternatives to replace high GWP HFCs in various applications, it is important to keep all of the above factors in mind in making comparisons. Even if alternate refrigerants are available, and standards for safety are in place, there is considerable effort required to research, develop and produce components that are compatible with these new refrigerants. Refrigerant and component availability precede equipment development, testing and qualification, where the qualification is for performance to minimum efficiency standards and reliability. Any effort to phase down HFC consumption has to take all of this into account to minimize negative impact on the industry, the economy and user.

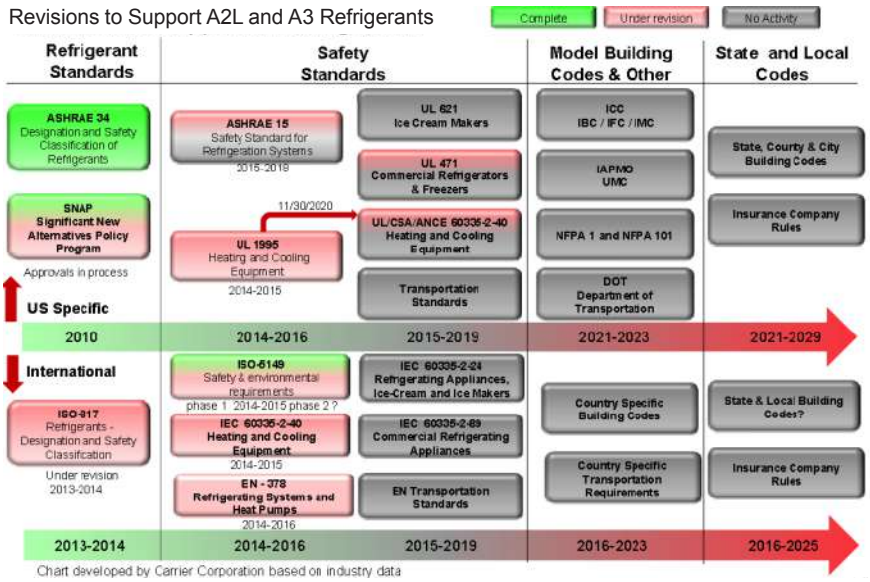
Figure 10 Holistic approach to selection of alternatives



ALTERNATIVES AVAILABLE FOR REPLACING HIGH GWP SYNTHETIC REFRIGERANTS

The two most common refrigerants that are being targeted for delisting or bans are R404A and R507A. R404A is used mostly in low temperature and often in medium temperature refrigeration applications. It is what is classified as a "medium pressure" refrigerant in the Figure 13 at a GWP of around 4000. The non flammable, non toxic (ASHRAE classification A1) refrigerant that is available now to replace R404A is R407A (and R407F in some systems). These refrigerants are less than 50% of the GWP of R404A and perform less efficiently in low temperature systems, but slightly more efficiently in medium temperature. Over 50% of the new supermarket stores in the United States have already

Figure 11 A sampling of the various safety standards, building and local codes [12]

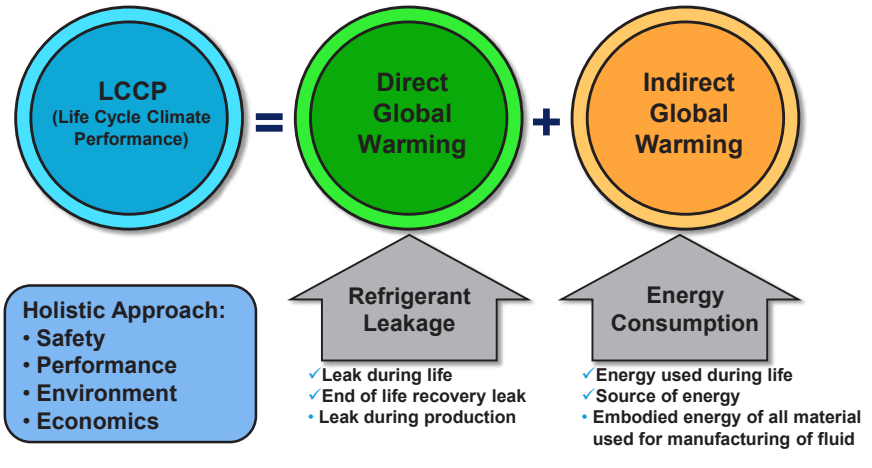


switched to R407A from R404A.

Replacing R507A is more of a challenge in some applications. R507A exhibits very low "glide", a characteristic of the blend that causes the saturated evaporation temperature to vary as the composition of the refrigerant changes in the evaporator. Typically, flooded evaporator systems use refrigerants with little to no glide as refrigerants with glide will cause the refrigerant composition to be different than specified at the exit of the evaporator (and inlet of the compressor). Systems that use R507A because of its low glide cannot use R407A as an alternative.

To the left of R407A in Figure 13, at around 1300 GWP, two new refrigerants are listed, R448A and R449A. These are A1, lower GWP candidates that are being tested by component and equipment manufacturers to replace R404A, especially in Europe where a refrigerant less than 1500 GWP is required in the future. It is expected that these refrigerants would be available for use in 2015.

Figure 12 Life Cycle Climate Performance view of equipment performance



The other HFC that will come under pressure due to the HFC phase down is HFC-134a, first in Europe, and later elsewhere. Two new A1 refrigerants, R450A and R513A are being developed to replace HFC-134a, at a GWP less than 600. Mildly flammable refrigerants like HFO 1234yf and HFO 1234ze will also become options in the future for replacing HFC-134a.

The other A1 refrigerant that is available to the refrigeration industry is CO_2, at a GWP of 1. This is not a direct drop-in replacement, but one that involves complete redesign. It is becoming increasingly popular in supermarket applications and is expected to grow in the industrial applications as well.

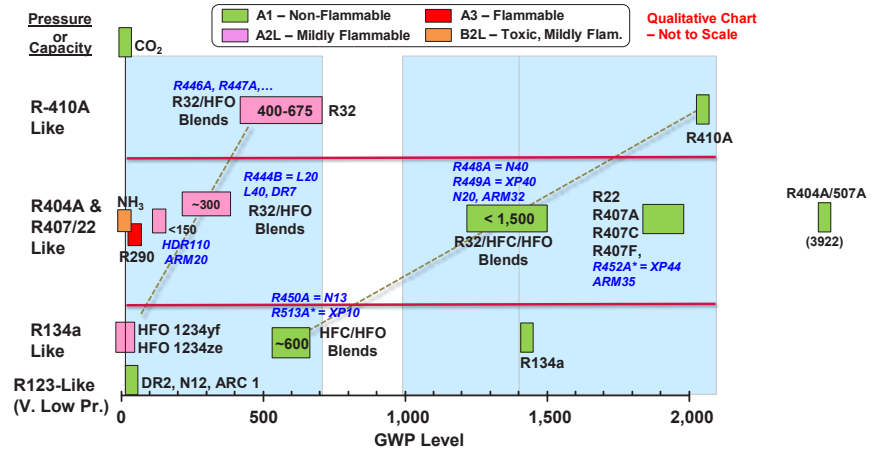
In Figure 13, to the far left at a GWP of around 8, propane, a hydrocarbon refrigerant is growing in acceptance in small self contained applications and even in larger secondary applications. Ammonia, an excellent refrigerant that is both toxic and flammable (mildly flammable, B2L classification), is common in large industrial applications. In Europe, Ammonia is also finding application in commercial comfort cooling applications where smaller charges and safety methods make it possible for its use near populated areas. A couple of supermarket chains are trying this refrigerant in secondary systems and this too has potential for growth, especially in Europe. This is discussed in greater detail in the section on carbon dioxide systems.

CARBON DIOXIDE AS A REFRIGERANT

Starting with northern Europe, and then Australia, carbon dioxide is making a comeback as a refrigerant in many large refrigeration applications, particularly in supermarkets. There are two major types of system architectures being employed in these applications. The more common system is called a hybrid or a cascade CO_2 system and is shown in Figure 14.

CO_2 is used as a direct expansion refrigerant in a low temperature system (heat transfer takes place directly from the refrigerant to the air in the refrigerated space) but condenses at a temperature that is closer to what is typically called a medium temperature system. The heat from the low

Figure 13 Alternative refrigerants being developed to replace high GWP HFCs.



temperature system is rejected into the medium temperature system, and hence the term "cascade" to describe this architecture. The medium temperature system is typically a HFC, mostly HFC-134a, which absorbs heat from the low temperature CO_2 system condenser and the various medium temperature evaporators in the supermarket and typically, rejects it to the atmosphere. Because these systems are a combination of a natural refrigerant and an HFC, these are called "hybrid" systems. Cascade hybrid CO_2 systems are more complex than a traditional supermarket system, but they can be equally efficient in any climate zone.

Another variation of the cascade system is one where the medium temperature primary refrigerant is an HFC like HFC-134a, but the actual medium temperature cooling is through a secondary fluid like CO_2 that is pumped through the refrigerated cases. This type of a system is shown in Figure 7 and uses very low charge of HFC usually confined to a "machine room", which makes this architecture ideal for different low GWP primary refrigerants, be they A2L, B2L or even A3.

The second type of CO_2 system is a "trans-critical booster" CO_2 system where both the medium and low temperature cooling is through direct expansion use of CO_2 as a refrigerant. The compressors from the low temperature circuit discharge the compressed gas into the suction of the medium temperature part of the system. The discharge of the medium temperature compressors is into a condenser which, when the outdoor ambient is close to or above the critical temperature of CO_2, operates as a gas cooler in the trans-critical mode. This type of system is more complex than a cascade hybrid CO_2 system, but, it is an "all natural" solution. Because a standard trans-critical CO_2 system is not as efficient as a comparable HFC based system, trans-critical CO_2 systems tend to be more common in those areas wherethe transcritical operation is limited or its impact is not significant enough to make it an issue. Research is ongoing to find competitive ways to improve the efficiency of the CO_2 system in the transcritical region as well as reduce the impact of the system operating in this mode.

As mentioned earlier, both types of CO_2 systems are increasing in popularity, mostly in Europe and Australia, but increasingly in Canada, the United States and elsewhere. While first cost and maintenance of the systems are important factors, the energy consumed and the LCCP of a refrigeration system need to be considered in making the right choice. Figure 16 shows the analysis for a basic standard R404A supermarket refrigeration system (both medium and low temperature) compared to a cascade CO_2 system with HFC-134a in the medium temperature primary with pumped CO_2 (similar to Figure 7) and a booster trans-critical CO_2 system for Boston, MA.

It is clear that from a climate impact point of view, a CO_2 based system is better than a HFC R404A based system in a cool climate region like Boston, MA. While the same could be said for the annual energy consumption, the peak power consumed on those warm summer days, indicate that there is a penalty to pay when a simple trans-critical CO_2

Figure 14 A simple cascade or hybrid CO_2-HFC system

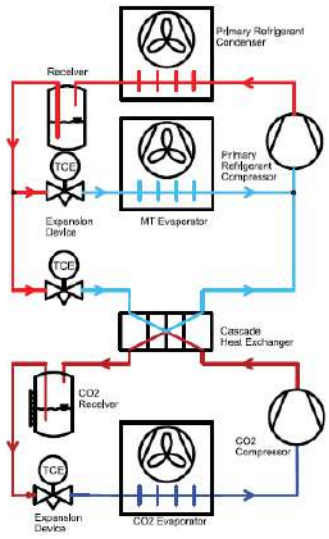


Figure 15 A simple trans-critical booster CO_2 system

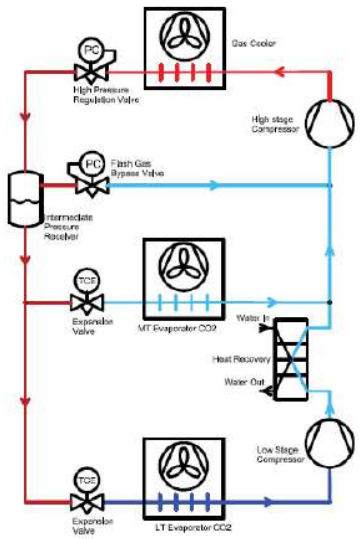
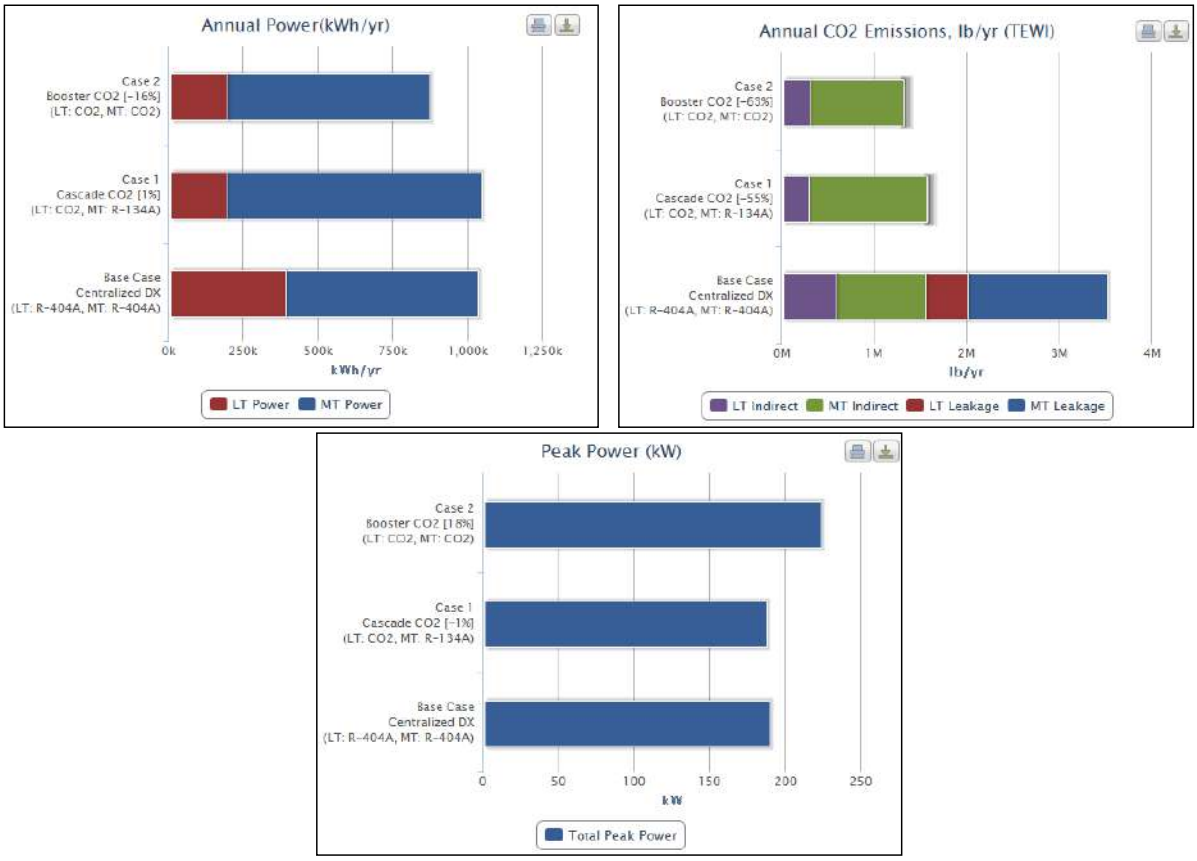


Figure 17 Climate impact analysis for simple cascade CO_2 and a trans-critical CO_2 system compared to a typical HFC R404A system in a supermarket application in Boston, MA [14].



booster system is employed. Note however that the cascade CO_2 system shows good performance all around.

A similar analysis done for a warmer region like Dallas, TX shows a different picture, as seen in Figure 17. While the CO_2 emissions for the cascade CO_2 and trans-critical booster CO_2 system are much better than that for R404A, annual power is slightly higher while the peak power in the summer is significantly higher. Several laboratory and field trials are underway to develop novel ideas to improve the CO_2 system efficiency without significantly increasing the first cost of the system but these will take a few years to see widespread use.

LOW GWP SYNTHETIC ALTERNATIVES

Synthetic fluids that are considered lower GWP can be classified as non flammable (A1) and mildly flammable (A2L). They can be further subdivided into three classes of refrigerants for the purposes of discussion – R410A-like, R404A/HCFC-22-like and HFC-134a-like. There could be a lower pressure classification, but for the purposes of this paper, we will not be including that list of refrigerants. Table 4 lists some of the synthetic lower GWP alternates available or in development right now. It should be noted that this is not meant to be an exhaustive or complete list of all candidates being developed. For a more complete listing of alternates being offered by the various chemical manufacturers, the reader is referred to the Low GWP Alternative Refrigerant Evaluation Program by the AHRI [13].

For the most part, these synthetic blends try to mimic the performance characteristics of the refrigerant they are trying to replace. While they are close in theoretical capacity and power, many of the replacements (R446A, R447A, R407A, R407F, R448A, R449A, N20, ARM32, R444B, L40, DR7, HDR110, DR3, ARM20) exhibit the phenomenon called "glide" due to their blend characteristics [15]. In addition many of these replacements have higher heat of compression and could have discharge temperature issues at the compressor – which often is mitigated by lowering the superheat at the suction of the compressor or using liquid or vapor injection. These are not insurmountable issues, however, any timeline to eliminate the use of refrigerants like R404A and replace it with its alternates has to consider the fact that compressor and other component testing and development takes months and years to complete. Figure 18 shows some of the performance data that was presented by the refrigerant suppliers at a recent meeting [16].

WHAT MIGHT THE FUTURE LOOK LIKE?

As recently as five years ago, the air-conditioning and refrigeration

Table 4 Some synthetic refrigerants in various stages of development and availability

Today's Refrigerant	Non Flammable – A1	Mild Flammable – A2L	GWP
R410A-Like		R32, R446A, R447A	<700
R404A/R22-Like	R407A, R407F		<2100
	R448A, R449A, N20, ARM32		<1500
		R444B, L40, DR7	<300
		HDR110, DR3, ARM20	<150
R134a-Like	R450A, R513A		<600
		HFO1234yf, HFO1234ze	<1

CO_2 will play a major role in supermarket refrigeration, especially in cold climates where the periods of trans-critical operation are limited to a few days in the year. The cascade refrigeration system will also become quite common.

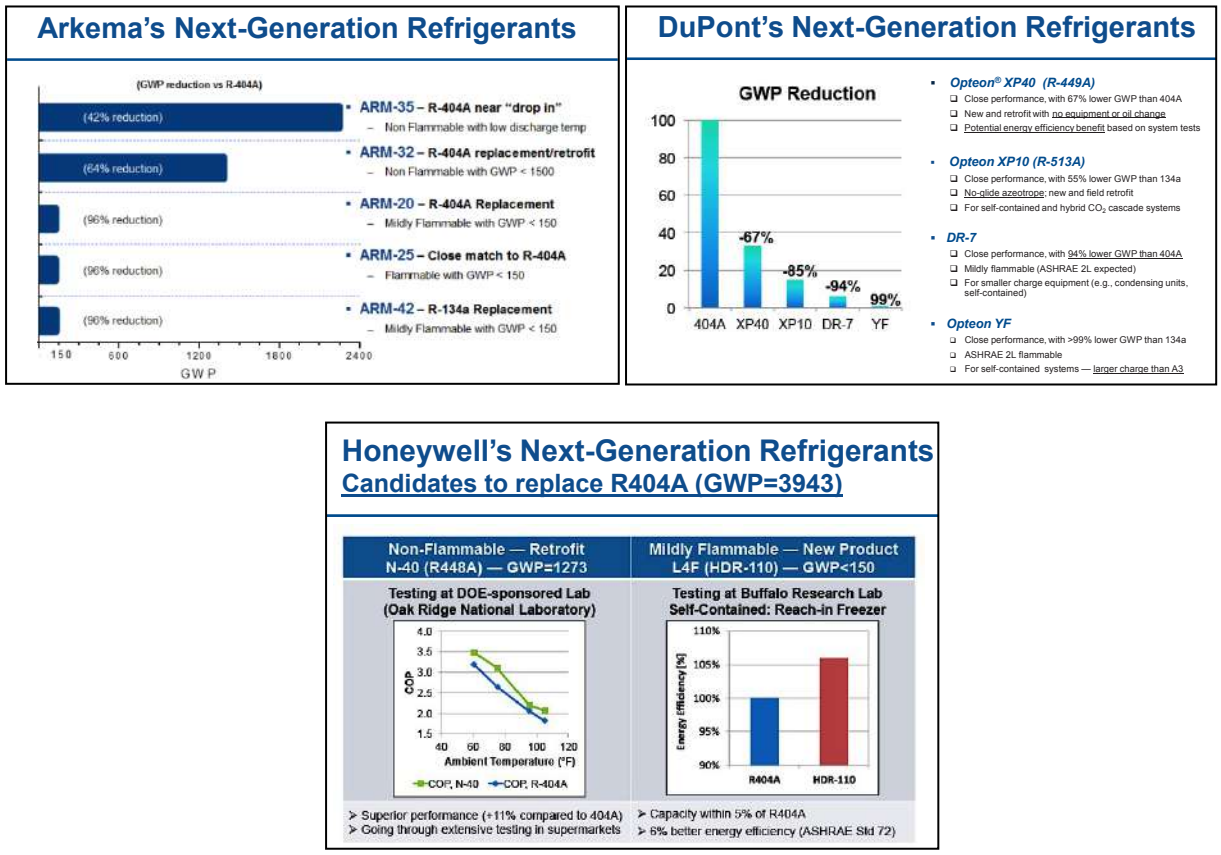
applications were dominated by a handful of refrigerants – ammonia in large industrial systems, HFCs like R404A and HFC-134a in stationary and mobile refrigeration and air-conditioning, and R410A in stationary air-conditioning applications and use of HCFC-22 declining as it was being phased-out by the Montreal Protocol agreement. In Europe, especially in domestic refrigeration, hydrocarbons like isobutane and propane had already become quite common. Today, CO_2 as a refrigerant in stationary refrigeration has grown in usage and acceptance in Europe and Australia and is making inroads in North America and elsewhere. The use of R290 in small charge systems and even some large units is increasing across Europe and is being tried out in other parts of the world. In response to this demand for lower GWP fluids, the refrigerant manufacturers are introducing and will continue to release new fluids over the next few years. So what could we expect ten years from now?

CO_2 will play a major role in supermarket refrigeration, especially in cold climates where the periods of trans-critical operation are limited to a few days in the year. The cascade refrigeration system will also become quite common, with synthetic fluids like HFC-134a and R407A yielding to lower GWP candidates like R448A, R449A and eventually candidates with less than 150 GWP as the HFC phase-down in Europe begins to take effect. Cascade refrigeration systems with CO_2 as a pumped secondary fluid in medium temperature and CO_2 as a compressed refrigerant in low temperature can be expected to be popular in southern Europe and warmer climates where use of HFCs will be restricted. Small refrigeration systems will see a mix of CO_2 (vending machines), hydro carbons, and HFCs and HFO blends as regulations permit. In these applications, even more so than in larger systems, synthetic fluids with less than 150 GWP will become common. Ammonia will continue to play a dominant role in industrial refrigeration and in those applications where it could be used as a primary refrigerant in a large refrigeration system, the use of ammonia will grow. In industrial applications, the use of HFCs will decline following the trends in the supermarket industry, giving way to similar architectures and fluids. The growth of CO_2 in supermarket applications will spill over into the industrial sector, and CO_2 as a pumped fluid and as a direct refrigerant will increasingly be common, especially in smaller industrial systems. All of the different CO_2 system architectures, but more importantly, the cascade system will grow in popularity in smaller industrial systems.

Air conditioning applications will continue to be dominated by R410A well into the foreseeable future, with refrigerants like HFC-32 and its blends with HFOs growing in use in Asia in the next few years. The shift from non flammable to flammable refrigerants in air conditioning systems will depend entirely on the safety standards and codes being developed around the world and their timeliness of adoption. Starting with Europe, other regions could evaluate and accept ammonia in limited commercial comfort cooling applications as secondary systems (chillers are already in use in these applications).

It is safe to say that we are in a period of flux right now, with several ideas competing with each other to establish themselves as mainstream. As applications move in the direction of lower GWP fluids, the choices confronting us are many – only the more efficient, safe and lower life cycle cost options can be expected to outlast the race. Not-in-kind technologies defined as non-vapor compression cycle systems for cooling are not discussed here, but are a growing area of interest worldwide. We have to be careful that attempts at regulations to pick winners and losers could force a solution that may not be the optimum. In an ideal world, we would set a goal for climate impact and let the market and applications find the best answer. ■

Figure 18 New synthetic lower GWP alternatives from three different companies [16]



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