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SUMMARY REPORT

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Summary Report
International Workshop
San Francisco, CA, USA
June 18-19, 2014

ATMOsphere America 2014

Summary Report
International Workshop

The Westin Market Street,
San Francisco, CA, USA
June 18-19, 2014

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Natural refrigerants are coming

Marc Chasserot
Chairman, **ATMO**sphere America 2014
Managing Director, shecco

ATMOsphere America 2014 was the biggest and best ever ATMO, with 250 experts, 60 presentations across 13 different sessions to talk business and natural refrigerants. Simply put they are coming. And more US based companies see the competitive advantage of getting there first. The next 2-3 years will be an exciting time to watch these developments. ATMOsphere America will play its part to drive this change.

In the meantime, feel free to read the following summary report. You will hear from Target, Whole Foods, Walgreens, Delhaize America, Sobeys, McDonald's, The Coca-Cola Company and Redbull, as well as Genentech. Plus you will learn about the energy programs from PG&E, Southern California Edison, Bonneville Power Administration and EPRI. Not forgetting the latest regulatory updates from the US EPA, CARB and UL. And that's even before we talk about the 20+ technology case studies on Commercial Refrigeration, Industrial Refrigeration, HVAC, Heat Pumps and much more!

I'm already looking forward to ATMOsphere America 2015.

Thank you,

Marc Chasserot

About ATMOsphere America 2014

For the third consecutive year, ATMOsphere America 2014 gathered HVAC&R industry experts with the aim of supporting the adoption of natural refrigerant technologies across North America. Held for the first time in San Francisco from June 18-19, the conference attracted more participants than ever before and heard from over 60 speakers.

The specialized mix of nearly 250 attendees included system and component manufacturers, regulators such as Underwriters Laboratories (UL), the US EPA and the California Air Resource Board (CARB); energy providers including Electric Power Research Institute (EPRI), Southern California Edison (SCE), Bonneville Power Administration (BPA) and PG&E; as well as end users including McDonald's, The Coca-Cola Company, Red Bull, Walgreens, Target, Sobeys, Delhaize America and Whole Foods Market.

The event provided a unique platform to exchange information and best-practice in natural refrigerant-based technology through a combination of presentations, case studies, and ample networking opportunities.

Presentations from policy makers, energy providers and academics discussed the national and international legislative measures that could create opportunities for natural refrigerants and stressed the need for the industry to get more involved in the development of these new measures.

Presentations from end users spoke directly to manufacturers and the supply chain as a whole in order to clarify what is needed for end users to progress with a wider adoption of natural refrigerant technologies.

Case studies demonstrating technical data and energy efficiencies using CO_2, ammonia, hydrocarbons, and water as refrigerants in commercial and industrial refrigeration, air conditioning and heating, highlighted more installation examples in North America than ever before, as well as the very latest trends and technologies.

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Glenn Gallagher
California Air Resource Board (CARB)

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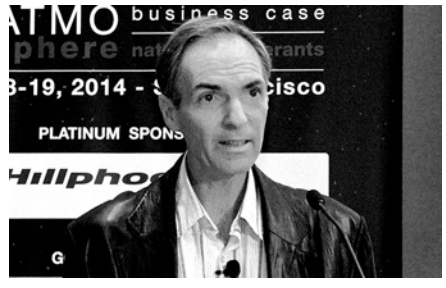


Barry Karnes
Underwriters Laboratory (UL)

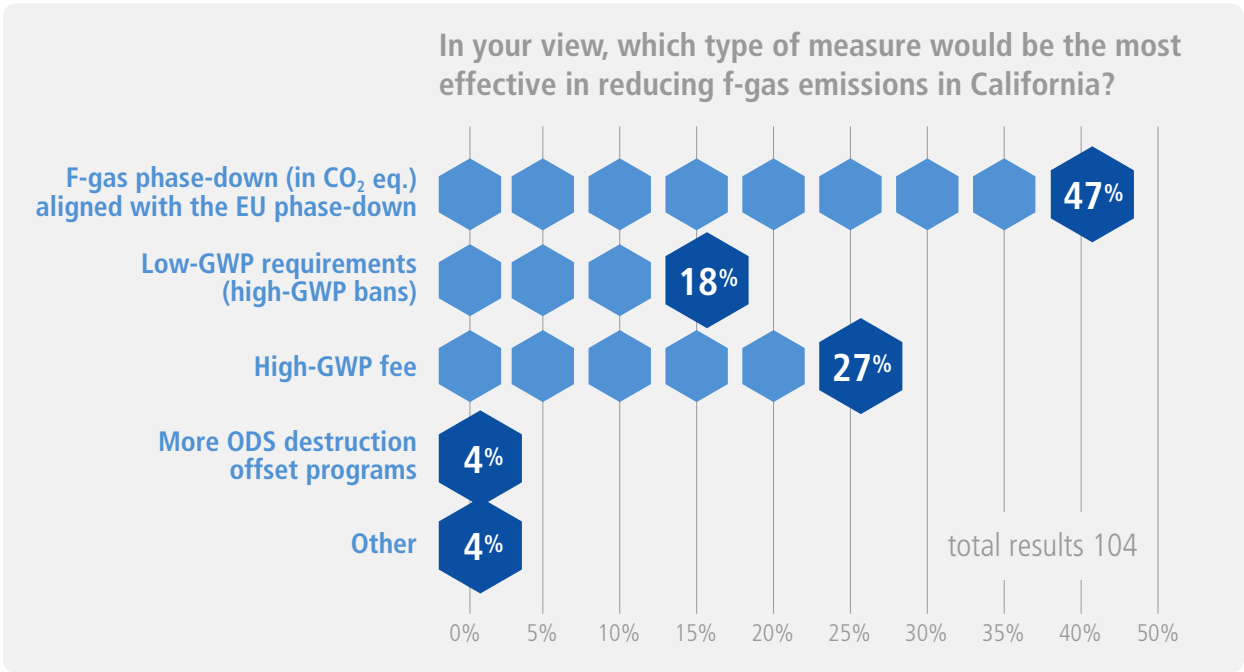
Alexandra Maratou
shecco

Moderated by Keilly Witman, shecco America's VP for Business Development, the regulatory session held on the second day of ATMOsphere America 2014 provided an overview of planned and recently adopted legislative changes that have a direct impact on the use of natural refrigerants in various applications in North America and other regions, especially Europe and Japan. The California Air Resources Board (CARB) brought to attention the possible measures to limit the use of high-GWP refrigerants currently under consideration in the state of California. At the national level, the US EPA is soon to publish a draft SNAP rule allowing the use of hydrocarbons in additional applications, while a second proposed ruling is expected to disallow the use of high-GWP refrigerants in equipment where natural refrigerant solutions have a great potential for wider uptake.

California to reduce HFCs by a minimum of 80% by 2050

The state of California, leader when it comes to the implementation of environmental legislation in North America, has committed to reduce the emissions of greenhouse gases by 80% by 2050. As pointed out by Glenn Gallagher, Air Pollution Specialist at the California Air Resources Board (CARB), actions to reduce short-lived climate pollutants (SLCPs) such as HFCs, by at least 80%, will be necessary in order to help accomplish the goal. To this end, CARB is currently considering a number of measures outlined in the recently published Scoping Plan that would limit the use of high-GWP refrigerants, such as an HFC phase-down, low-GWP requirements (high-GWP bans), a high-GWP fee and ODS destruction offset programmes.

In a poll asked to the conference participants, almost 50% thought that an HFC phase-down aligned with the one recently adopted in the EU under the F-Gas Regulation would be the most effective measure in reducing f-gas emissions in California. Close to 30% of the poll respondents believe that a fee on high-GWP HFCs would deliver f-gas emissions reductions most effectively.



Whilst the new f-gas legislation considered in California will not initially have an impact in other US states, Gallagher noted "most regulations that the Air Resources Board passes for clean air eventually tend to become national regulations."

Industry to be consulted on new California legislation

The CARB is currently working on a SLCP Draft Reduction Plan, which will outline details of the proposed measures that will eventually be adopted. The draft plan, to be published by 2015, will be prepared in close collaboration with the US Environmental Protection Agency (US EPA) and the European Union. Gallagher stressed that once publicly available, CARB will welcome industry comments and recommendations on the proposed measures.

Ed Cheng, Associate Professor at San Francisco State University, highlighted another opportunity for industry to provide input on the availability of low-GWP refrigerants and possible models to evaluate their benefits. The University has been selected by the CARB to conduct a cost benefit and feasibility analysis of low-GWP refrigerants in the sector of commercial refrigeration, which will be initiated in August 2014. Some of the major modeling challenges highlighted by Cheng include the difficulties in addressing impacts of varying climates on refrigeration system operation and the need for accurate input data or calculation methodology for refrigerant leak rates.

New EPA rulemakings to open up opportunities for natural refrigerants in the US

Tom Land who leads the EPA's Greenchill Partnership updated the ATMOsphere America participants on actions that the EPA is taking domestically and internationally to reduce emissions from HFC use. In addition to the recently published venting exemption for hydrocarbons in specific uses, the EPA is planning to issue two separate rulemaking proposals this summer, which will create opportunities for natural refrigerants in several new applications.

According to Land's presentation, one of the draft rules is likely to propose adding hydrocarbons as acceptable subject to use conditions in certain end-uses outlined in the table below. The table does not capture those cases for which some hydrocarbons are already considered acceptable (e.g. propane for stand-alone commercial refrigeration, iso-butane and R441A for household refrigeration).

Refrigerant	GWP	End use and application EPA is considering					
		Household refrigerators	Retail refrigerator stand-alone	Vending	Very low temperature refrigeration	Heat transfer	Household AC self-contained
Ethane	9				✓	✓	
Iso-butane	8		✓	✓			
Propane	3	✓		✓			✓
R441A	< 5		✓	✓			✓

Moreover, a second draft rule due to be published this summer will change the status of certain high-GWP refrigerants, meaning that these high-GWP refrigerants will no longer be listed as acceptable substances in vending machines, stand-alone reach-in coolers as well as multiplex supermarket systems, which will further influence the uptake of HC solutions.

UL realizes there is a need to increase HC charge limits, but needs supporting data from industry

Despite the new opportunities for hydrocarbon refrigerants that the US EPA is considering under the SNAP Program, industry participants raised concerns regarding the charge sizes allowed under Underwriters Laboratories (UL) standards, which limit the use of hydrocarbons to smaller equipment and are perceived as a major barrier in rolling out HC solutions on a wider scale. For instance, the maximum HC charge size in household refrigeration is 57g under the UL 250, whilst in Europe for the same type of equipment the charge limit is 150g.

Barry Karnes of UL noted that UL realizes the need to increase the charge sizes for A3 refrigerants. "At UL, like any other organization, we want to balance safety with environmental concerns and we are willing to look at new proposals and new data that would enable us to increase those limits," Karnes said. Nevertheless, he highlighted that industry stakeholders asking for an increase in the charge limits should increase their efforts to communicate to UL the rationale, testing data, and empirical information that would support such action.

"Give us something to work with; tell us why 57g is bad and tell us why 500g is good," he said. "We want to make sure that products are as safe as possible. Shifting from say 50 to 500g sounds like a good idea as far as the environment is concerned, but UL looks at it from a different perspective… What is offsetting that balance to make the 500g risk level as acceptable as that of 50g?" he challenged the audience.

> *At present, it appears that industry is moving towards the use of carbon dioxide as a refrigerant or as a circulating fluid within larger equipment, especially commercial refrigeration equipment. As a result several UL standards have been revised and now include requirements applicable to equipment using CO_2."*
>
> **Barry Karnes**
> Underwriters Laboratories (UL)

> *At UL, like any other organization, we want to balance safety with environmental concerns and we are willing to look at new proposals and new data that would enable us to increase those [hydrocarbon charge] limits."*
>
> **Barry Karnes**
> Underwriters Laboratories (UL)

Momentum building up for international action on HFCs

"We see a growing momentum globally for taking action on HFCs," said Alexandra Maratou, shecco's Deputy Public Affairs Manager. "There are increasing restrictions on HFCs, which means increasing demand for alternative refrigerants and natural refrigerants in particular.... This will reduce the cost of systems in North America," she added.

In her presentation she took participants away from previous discussions regarding developments in North America and gave an update on F-Gas legislation in Europe and Japan. In Europe it is not only the EU F-Gas Regulation driving the introduction of natural refrigerants, but also measures adopted by several countries at the national level, such as HFC taxes and grant schemes for natural refrigerants. Similarly in Japan, the new F-Gas legislation currently under discussion, which will introduce GWP targets for specific HVAC&R sectors, is expected to have a swift impact on the rollout of natural refrigerant solutions.

On top of regional and national activities, the possible amendment on HFC phase-down to the Montreal Protocol would also likely influence the refrigerant choice globally. "There is a lot of momentum building for the amendment proposal. This would significantly change the market for natural refrigerant, non-fluorinated substances in the United States, if agreed internationally," highlighted Tom Land during his presentation.

> *"There are increasing restrictions on HFCs, which means increasing demand for alternative refrigerants and natural refrigerants in particular.... This will reduce the cost of systems in North America."*
>
> **Alexandra Maratou**
> shecco

> *"There is a lot of momentum building for the amendment proposal. This would significantly change the market for natural refrigerant, non-fluorinated substances in the United States, if agreed internationally."*
>
> **Tom Land**
> EPA Greenchill Partnership

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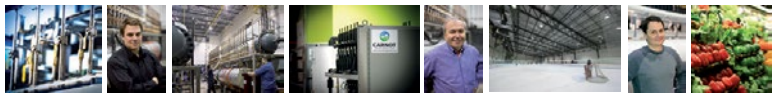

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Accelerating North American market uptake of CO_2 Commercial Refrigeration systems

Nina Masson
shecco

Scott Martin
Hillphoenix

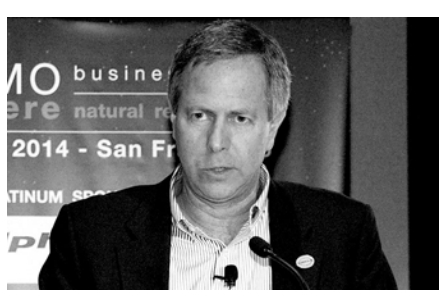
Kim Christensen
Advansor

Marc-André Lesmerises
Carnot Refrigeration

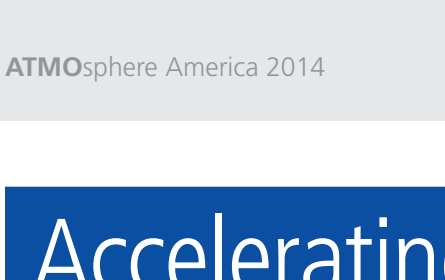
Masood Ali
Heatcraft Worldwide Refrigeration

Jeffrey Gingras
Systemes LMP

Mark Tomooka
Mayekawa USA



Harrison Horning
Delhaize America



Jason Robbins
Walgreens

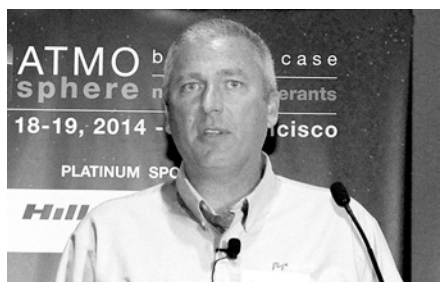
Rob Olden
GI Energy

Mike Ellinger
Whole Foods

Paul Anderson
Target

Ian Crookston
Sobeys

Richard Heath
Source Refrigeration



Chris Huffman
Neelands Refrigeration

Rob Arthur
CTA Architects Engineers

The very latest information on the increasing use of CO_2 refrigeration technology in North American supermarkets was captured in several ATMOsphere America 2014 sessions, including the State of the Industry Session and two Food Retail Sessions. Representatives from leading system suppliers, prominent supermarket chains, and contractors presented their experiences and market trend forecasts related to the use of natural refrigeration systems in the commercial refrigeration sector. Overall the market share of CO_2 in supermarkets in the US, Canada, and other regions, such as Europe and Japan, will be influenced by the level of collaboration between contractors, end users, regulators and system suppliers; by training; and by raising awareness among end users of the importance of total cost of ownership.

Nina Masson, shecco's Deputy Managing Director chaired the State of the Industry Session and gave an overview of the global perspective on natural refrigerant market trends, maintaining that "the market has become increasingly active," with European suppliers developing their business in North America, and North American companies expanding their operations in Europe. Masson also said that in the near future she expects Japanese companies to enter the European and North American markets.

Number of CO_2 stores set to grow exponentially

In his presentation, Masood Ali, Global Leader of Center of Excellence (COE) for Alternative Systems, Heatcraft Worldwide Refrigeration, said that the global number of CO_2 stores is "a drop in the ocean for the moment" since the percentage of CO_2 stores accounts for 4% in Europe, 0.4% in Canada and only 0.003% in the US. However, he anticipates that "the number will grow exponentially."

In agreement with Ali, Masson pointed out that "there is a huge potential in North America that is still untapped," with regard to CO_2 stores, and highlighted that Canada is more active when it comes to CO_2 transcritical systems while the US is more active when it comes to CO_2-HFC/secondary systems. Masson projected that by March 2015 we should expect more than 600 transcritical CO_2 stores in the Japanese market, a development that will make Japan the fourth country in the world in terms of total number of transcritical CO_2 stores.

According to Ali, the main factor constraining a wider global adoption of CO_2 stores is related to the lack of economies of scale, as the system cost is still perceived to be too high. However, he recognised that "when the demand goes up the cost will go down", resulting in substantial cost savings and in the creation of economies of scale. This will send a clear message to end users to stop focusing only on short-term costs since investing in CO_2 today represents a financial saving over the 15 year lifespan of an installation.

Things are going to change. CO_2 is the current choice in Europe and is definitely paving its way in North America."

Masood Ali
Heatcraft Worldwide Refrigeration

North American market shows increased interest in CO_2

According to Jeffrey Gingras, Vice President of Sales, Systemes LMP, CO_2 transcritical technology is becoming more popular in North America, with 65 installations in 2013 and at least 27 new installations planned for 2014, 21 of which are in Canada.

Marc-André Lesmerises, CEO & Co-Founder of Carnot Refrigeration noted that his company has built 39 CO_2 transcritical installations in 2013, including supermarkets, ice rinks and distribution centres. With a focus on improving technology, the number of Carnot installations has continued to increase in 2014 through an expansion into Western Canada and the US. The company is also looking to begin installations in Europe.

Hillphoenix's Director, Sustainable Technologies for the Refrigeration Systems Division, Scott Martin, also recognized that CO_2 secondary systems are increasing their market share in North America, with Hillphoenix experiencing a spike in its 2013/2014 CO_2 secondary systems production due to an increase in demand. According to Martin, Hillphoenix has so far received customer orders for 140 systems to be completed within 2014 compared to 90 systems completed in 2013.

Advansor expects close to 6,000 CO_2 transcritical stores annually by 2018 in Europe

According to Kim Christensen, Advansor currently has more than 1000 racks in 15 countries and has already installed 400 CO_2 transcritical racks since the beginning of 2014. Christensen highlighted that the European market expects to see significant growth in demand for transcritical CO_2 systems, estimating overall production to escalate from 1,700 CO_2 transcritical racks in 2014 to close to 6,000 racks in 2018.

Christensen focused his presentation on the European market and highlighted that recent EU F-Gas Regulation changes create clear scope for more investment in CO_2 transcritical booster systems and to some extent for HC plug-ins or HC chiller systems. Cascade solutions however, are expected to slowly disappear. Acknowledging that there is a need to reduce CO_2 transcritical booster first costs especially for smaller stores, he projects that first costs will soon fall to HFC related levels, as is already the case for larger store applications, according to data provided by retailers. He also pointed out that the market for all-inclusive racks is developing.

The message from Europe to North America today would be just go ahead. We already made all the mistakes, so it is safe way for you to invest. We believe that the basic technology is fully developed."

Kim Christensen
Advansor

Target officially announces shift to CO_2 hybrid systems for new stores

Following the system supplier presentations, representatives from Delhaize America, Sobeys, Target, Walgreens, and Whole Foods Market, presented promising energy use results from both pilot stores in the US, and CO_2 standard stores in Canada. In a session moderated by Tom Land from the US EPA GreenChill partnership, strong support for CO_2 refrigeration technology was voiced by all of the ATMOsphere America 2014 retailers, who were all in agreement on the need for retailers to look at total cost of ownership in order to prove the business case for natural refrigerant commercial refrigeration systems.

In the US the Target Corporation has trialled CO_2 systems in 5 stores to date, with each new store implementing lessons learned from its predecessors. Paul Anderson, Sr. Group Manager of Engineering, stated that initially, in terms of total cost of ownership, the CO_2 systems Target implemented were only advantageous with regard to one of the company's five total cost of ownership metrics - sustainability, improvements in energy consumption have since been achieved.

As a result, Target is officially changing its prototype for new stores from R404A to hybrid R134a/CO_2 systems, said Anderson, an announcement that was widely praised by ATMOsphere America participants. These new CO_2 systems have a carbon footprint 65% lower than previously used systems.

The comparatively high installation, equipment and maintenance costs, for example equipment costs are 25-30% more than for HFC systems, are expected to decrease in the near future.

Whole Foods achieves comparable energy efficiency and usage with CO_2

Whole Foods, the American supermarket chain specializing in natural and organic foods, has installed low temperature cascade secondary systems in three stores, CO_2 cascade systems in five stores, and a CO_2 transcritical system in what has been dubbed the 'greenest' supermarket in the United States. In addition, Whole Foods is investigating the use of high side ammonia/CO_2 systems. Joining the conference via a video link, Mike Ellinger, Global Maintenance & Refrigeration Coordinator, Whole Foods, stated that the company's ambitions are to reduce synthetic refrigerant charge, to reduce energy consumption and to achieve maintenance comparable to direct expansion systems.

Whilst Ellinger did not yet have data on the company's widely publicised CO_2 transcritical store in Brooklyn, he did briefly talk about the refrigeration electrical usage of the Whole Foods CO_2/R407A systems, which are comparable to that of an R407 system.

He also talked about the importance of properly trained technicians in making a CO_2 installation a success, as well as having a sufficient supply of refrigerant grade CO_2, which he said was not always readily available, which has meant Whole Foods needs to stock the refrigerant on-site. Lastly, Ellinger advised end users to partner with local regulators and involve them in projects early on in order to raise awareness of the workings of CO_2 systems and of their benefits.

Lower rack consumption for Delhaize America CO_2 transcritical pilot store

Besides Whole Foods, Hannaford is one of the only other US retailers with a CO_2 transcritical refrigeration equipped store. Harrison Horning, Director of Energy and Facility Services, North, Delhaize America, praised the system during his ATMOsphere presentation, saying that it has proven very reliable. "We are very impressed with the energy consumption," stated Horning.

Compared to DX R407a and DX R507 systems, the pilot CO_2 system has lower rack electric energy consumption, and unlike the HFC systems, features heat reclaim.

According to Horning, Delhaize America's long-term decisions regarding refrigeration will not be based on this single project; more CO_2 pilot stores are being planned as the company contemplates a phase-out.

CO_2 could be long-term, widespread solution for Walgreens

Walgreens, one of the fastest growing retailers in the US, deployed its first CO_2 transcritical system in Illinois, as part of the company's first "net zero" store, thanks to the help of GI Energy. Jason Robbins, Walgreens' Manager of Mechanical Engineering, explained that the decision to invest in CO_2 was part a wider initiative to trial a number of green technologies and define their scalability. According to Robbins an analysis of the impact of switching refrigerants found that the total cost of ownership is lower for the natural refrigerant systems.

Sobeys has seen 17% reduction in rack cost since 2011

In Canada, retailer Sobeys has defined transcritical CO_2 refrigeration systems as a national standard for its full-service format stores. To date the company has installed 58 systems, a number expected to grow to 64 by the end of 2014. Sobeys utilizes centralized booster systems with heat reclaim that can be used for domestic hot water and HVAC.

Ian Crookston, Manager, Energy Management at Sobeys, explained that the retailer has seen a 17% reduction in rack cost since 2011, although there are still significant differences in first costs.

> *We should be building stores that are expected to operate for at least 20 years. We need to keep this in mind when we actually design stores. Energy conservation plus natural refrigerants is the winning combination for customers, shareholders and the environment"*
>
> **Ian Crookston**
> Sobeys

Golden gateway to wider CO_2 uptake: OEM, end user, and contractor collaboration

Complementing the retailer presentations were those of leading contractors, who shared their unique viewpoint on how to accelerate the market for natural working fluids in commercial refrigeration.

Richard Heath, Sr. Director of Energy Optimization at Source Refrigeration emphasized the importance of operations and maintenance training. He stated that ignorance of operations and maintenance is a given when dealing with new technology, and operating and servicing new technologies requires new contractor and technician skills. While there is no one manual outlining all the maintenance needs of a CO_2 system – each one often being very different to the next, the industry can nevertheless learn from past mistakes and successes. This will be key to creating a strong business case for natural refrigerants amongst the original equipment manufacturers, the refrigeration engineers of record (EoRs), as well as the refrigeration contractors.

In addition to learning from experience and past CO_2 projects, the processes involved in these projects need to be clearly defined, meaning:

- Understanding design, installation and operation requirements
- Having proper tools
- Developing required skills
- Developing best practices

Scott Martin from Hillphoenix echoed many of these points, arguing that training is key to the success of any natural refrigerant system, and that the contractor determines the success of any refrigeration installation. Martin also emphasized that the most successful projects have been those in which every entity with a vested interest in the installation is in the same room and on the same page before construction begins.

Mark Tomooka, Director, Applied Technology Development at Mayekawa USA, said the same: "the best projects are those where everyone is collaborating and aligned with the same goal." For Tomooka, it is especially important to involve the manufacturer early in the planning process to ensure the system is optimized and designed specifically for its desired purpose. He noted that in order for this to occur, the following should be clearly defined:

- Equipment specification and operation requirements
- System integration points
- Sequence of operations
- Maintenance schedules

Tomooka highlighted the need to find the most suitable method to manage costs and risks as well as the importance of a post project evaluation. He offered an example from Mayekawa Japan, where predictive maintenance schedules for NewTon installations, using remote diagnosis, are being used to ensure all systems are operating efficiently. The practice of predictive rather than reactive maintenance reduces maintenance costs.

> *You can have everything perfect, but if your contractor is not on board with the technology and does not understand it, it is a recipe for disaster."*
>
> **Scott Martin**
> Hillphoenix

Preparedness and planning reduces costs

In his presentation, Neelands Controls Project Manager Chris Huffman also underlined training and preparedness as key messages. He noted several differences between HFC and CO_2 systems to be taken into consideration when planning a new installation. One key difference is that CO_2 systems are fully electronic, whereas HFC systems are electro-mechanical, which means contractors are transitioning from mechanical engineers to technicians.

As well as appropriate contractor training, end users need to maintain a close relationship with their contractor throughout the entire process of installation, and take into account in the project planning the availability of back up components, a point previously made by Mike Ellinger from Whole Foods.

Jim Armer, Assistant Director of Energy Services of CTA, reiterated the importance of preparedness, mentioning that "surprises can end up costing a lot of money, so the idea is to limit the unknowns and surprises." This requires stakeholder engagement, the establishment of benchmarks and reflection on previous projects. The practice of involving stakeholders and collaborators ensures that mistakes are not repeated and that new systems function in a cost-effective way.

Armer said contractors should act as conduits of information, and that no party should have more or less information than another during the design process. Through good planning, communication, training and education it is then possible to demonstrate repeatability, which in turn drives down costs. Stakeholders need to look at opportunities to learn and share.

Red Bull, McDonald's and The Coca-Cola Company choose natural refrigerants and talk future strategy

Paige Dunn
Red Bull

Jeffrey Hogue
McDonald's Corporation

Steve Cousins
The Coca Cola Company

Red Bull, McDonald's and The Coca-Cola Company shared their progress in the implementation of natural refrigerants and highlighted what is needed in order for them to move forward: innovation at cost parity and building a cohesive and sustainable supply chain. Out of the 2.7 million pieces of refrigerated equipment used by McDonald's, Red Bull, and The Coca-Cola Company 1.5 million have been converted to natural refrigerants, almost 500,000 of which use HCs.

Red Bull's 100% natural refrigerant goal

Red Bull's presentation at ATMOsphere America 2014 highlighted the company's ambitious target of 100% procurement of R600a coolers in its global fleet. As of May of 2014 Red Bull had already ordered 12,650 hydrocarbon coolers in the US, and the future order numbers are "aggressive."

CSR and Sustainability Project Leader Paige Dunn reported, "The team is very serious about reaching the 100% goal." Red Bull has placed an impressive 457,000 hydrocarbon ECO Coolers globally to date. The company's global cooler fleet encompasses 985,000 units.

The ECO Cooler using R600a received approval by the US EPA in 2013. Although the SNAP approval of hydrocarbon refrigerants was a significant step forward for the Austrian-based company, R600a was initially not approved in stand-alone units, a missing piece of the puzzle for Red Bull to be able to roll-out natural refrigerant units.

In addition to reaching 100% procurement, Red Bull reports that the company will be focusing on other ways "to do more" such as focusing on the end of life process, looking into foam and how they can refurbish coolers for a more sustainable overall outcome.

> *R600a was not initially approved because no one specifically asked. We [the industry] want to be more proactive and make sure this doesn't happen again. A year later, SNAP approval was granted in stand-alone units. The energy consumption of our cooler fleet has been reduced by 10% by using hydrocarbons. Regarding the roll-out of ECO Coolers in North America, they are coming."*
>
> **Paige Dunn**
> Red Bull

McDonald's: 13,000 pieces of natural refrigerant equipment and opportunities in green HVAC

In 2003 McDonald's opened its first 100% natural refrigerant restaurant in Vejle, Denmark, which utilises a CO_2 based HVAC system (transcritical), a CO_2/ R290 system for low and medium temperature storage, as well as hydrocarbon-based equipment in the kitchen. The main driver behind the convertion from f-gases was energy efficiency, considered by the company to be the second largest area for sustainability improvements, after sustainable beef sourcing (30% of global carbon footprint compared to 20% allotted to energy efficiency).

Currently 13,000 pieces of natural refrigerant equipment have been deployed using R290, R600a and CO_2, out of a total of 700,000 units of equipment used by McDonald's worldwide.

Jeffrey Hogue, Senior Director of Global CSR & Sustainability, commented that much more action is needed in the future.

Besides cost, other considerations for McDonald's include improved energy efficiency, and having a service infrastructure in place.

> *We proved this was possible, but need to work on building the supply chain. Natural refrigerant HVAC equipment is the biggest opportunity for McDonald's to switch to climate friendly refrigerants. We need innovations that are at cost-parity with current solutions, stating that the company is looking for pricing within 10% of the HFC structure. If we had all of our competitors side-by-side with us we could drive market innovation. We can't do this alone."*
>
> **Jeffrey Hogue**
> McDonald's Corporation

The Coca-Cola Company places 1.1 million CO_2 and HC coolers worldwide

The Coca-Cola Company has been a leader in HFC-free refrigeration, having set an ambitious goal in 2009 to phase-out HFCs in new cold drink equipment as of 2015. This goal is expected to take around 8 more years. To date around 1.1 million HFC-units have been placed globally, using CO_2 and also hydrocarbons, including 162 UL certified CO_2 vending machine models, representing around 80% of the purchase volume.

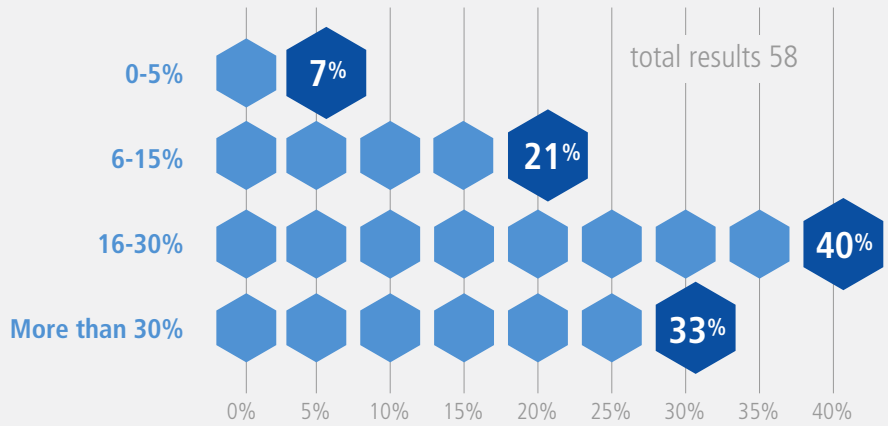
According to The Coca-Cola Company, some of the models placed have been up to 75% more efficient than what was used in 2010. What is more, The Coca-Cola Company aims to reduce its carbon footprint represented by "the drink in your hand" by 25%, from 2010 values.

With 12,354 CO_2 cabinets placed in North America (in other parts of the world hydrocarbons are used), natural refrigerants account for around 7-8% of the company's total fleet.

The Coca Cola Company, together with Red Bull, Unilever, Pepsico and with the support of UNEP and Greenpeace, collaborates with Refrigerants Naturally!, an organisation committed to phasing out f-gases in point-of-purchase refrigeration equipment.

In a poll asked to conference participants 40% thought that the market share of natural refrigerants in the US light commercial refrigeration sector would be 16-30% by 2020.

What will be the market share of natural refrigerants in the US light commercial refrigeration sector by 2020?



Last year we placed 40% more HFC-free cabinets than we did the year before, so we are starting to accelerate. To The Coca-Cola Company, HFC-free means natural refrigerants. The previous refrigerant used was R134a."

Out of the 162 certified models, 38 of them are meant for tropical, high temperature, high humidity environments. Specifically for North America, 18 cooler models out of this number will be available, including the 'freestyle' dispenser, which will be placed before year's end. To drive success we need the entire supply chain to work together; we need regulatory standards and we need greater efficiencies in technologies. This will allow us to purchase more CO_2 equipment."

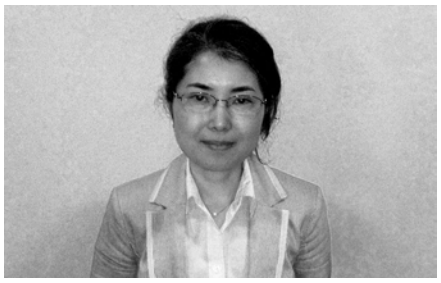
Steven Cousins
The Coca-Cola Company

Latest natural refrigerant technology case studies

Expanding market opportunities for natural refrigerant heat pumps in America

Marc Portnoff
Thar Geothermal LLC

Rolf Christensen
Alfa Laval



Maho Ito
Sanden International

Ken Eklund
Washington State University

Sam Gladis
Emerson Climate Technologies / Vilter

Pathways towards expanding the market for CO_2 heat pumps in America and the energy savings achieved thanks to an ammonia heat pump installation were discussed in parallel sessions held on the second day of ATMOsphere America 2014. Direct exchange geothermal design, integrated heating and cooling with water source CO_2 heat pumps, the design of heat exchangers for heat recovery, as well as progress towards introducing a CO_2 heat pump water heater tailored to the needs of the North American market were key topics.

Expanding the opportunity for geothermal heat pumps with R744

Despite their tangible benefits with respect to energy efficiency, reliability and water use, ground source geothermal heat pump systems are limited to 1-2% of the HVAC market. This can be attributed to persisting market barriers to the use of conventional geothermal systems, such as the high cost of the ground heat exchanger (GHX) installation (~50-75% of total system), the disruption associated with the GHX installation, as well as the cost and difficulty of evaluating the suitability of individual installation sites.

The use of R744, however, expands the opportunity for geothermal heat pumps according to the presentation by Marc Portnoff, General Manager, Thar Geothermal, LLC.

Thar Geothermal has drilled over 100 boreholes and has spent the last several years learning how to install a direct exchange geo-loop efficiently and effectively. It has worked towards successfully integrating its technology in the HVAC environment.

Demonstrations of a commercial scale (15-20 ton) geothermal system encompassing air side heat exchangers, as well as radiant floor & panels for both heating and cooling at Thar's 210,000 ft^2 (19,510 m^2) R744 Geothermal Facility in Pittsburgh, Pennsylvania have shown enhanced energy efficiency and reduced environmental footprint.

"By and large, we are 30% more efficient than a standard ground source geothermal system, which tends to be 40-60% more efficient than an air side heat pump," the presenter noted.

"We think we have a play here. We are not going to eliminate the market barriers for geothermal. We have a play by improving performance because CO_2 is an excellent refrigerant in this environment and by reducing the cost of installation so that the return on investment increases. Our goal is with our partners, that we will over time increase the market share from 1-2% in the HVAC market to 10%," Marc Portnoff concluded.

Less than 3-year payback time for Mayekawa's water source CO_2 heat pump system at 190-room hotel in Panama

A presentation by Troy Davis, Energy Manager, Mayekawa USA MYCOM, discussed the introduction of a Mayekawa ECO Cute water source hot water heat pump at Torres De Alba Hotel in Panama City. With a commitment to reduce energy costs and lower carbon emissions at his hotel property, the owner of the hotel recently installed the first ever integrated CO_2 refrigerant water source heat

> *R744 allows us to do a direct exchange design, because if you think about inserting synthetic refrigerants in and out of the ground there are a couple of problems, one is the cost, as the size of the charge gets larger - it is 10-fold more expensive than CO_2. Our oil management allows to separate the compressor oil from the refrigerant at the compressor skid, so we do not have to worry about compressor oil going into the ground heat exchanger. The other thing that R744 allows us to do is to design smaller diameter ground loops… The smaller diameter allows us to have much greater design flexibility in how we install the ground heat exchanger."*

> *What differentiate us is that we use recycled CO_2, safe natural refrigerant, that enables us to do commercial scale direct exchange geothermal design, and we have had successful demonstrations showing this technology works, providing enhanced energy efficiency and reduced environmental footprint. … The other thing that has enabled us to do this is an established supply chain. Without the R744 community and the established supply chain, we wouldn't have been able to make this accomplishment."*

Marc Portnoff
Thar Geothermal, LLC

pump heating and cooling system implemented in a hotel in Central America. The installation is in a luxury 190-room, three-tower hotel located in downtown Panama City in the El Cangrejo District. The hotel had already installed a solar thermal hot water heat pump for its laundry operations with much success; however it wanted to substantially reduce its reliance on butane hot water heaters that were used for hotel room hot water heating as well as the restaurant's kitchen. The goal was to install a system that would cover the majority of the hot water demand, covering the 24-hour cooling load required in this climate while simplifying the retrofit installation.

The hotel has three towers with guest rooms as well as a kitchen for the restaurant that were using standard butane hot water heaters located on the roof of each tower. On the third floor of the hotel was a chilled water plant consisting of three electric centrifugal water chillers for the air conditioning load. It was decided that the best location for the electric heat pump was the existing chiller mechanical room, which provided easy access to chilled water mains and the electrical distribution panel. In addition, there was space for an additional hot water storage tank next to the chiller mechanical room.

Working together GreeNRG - Latin America and Mayekawa USA designed an electric heat pump system for the hotel. The heat pump chosen was an Eco Cute electric-driven, water source, hot water heat pump that uses CO_2 as a refrigerant for water chilling and hot water heating all in the same unit. This Mayekawa CO_2 heat pump made its North American debut at the Somerston Wine Co. winery located in Napa Valley, US in 2010 and is backed by a proven record of performance and effectiveness in Japan and Europe, where there have been over 500 installations to date.

The heat pump provides 74 kW heating capacity at 75°F (23.9°C) inlet and 194°F (90°C) hot water outlet and 51 kW cooling capacity at 54°F (12.2°C) inlet and 44°F (6.7°C) chilled water outlet. It is more efficient than a standard hot water heater and in this application provides a 2.95 heating COP, 2.04 cooling COP and a combined 4.99 COP. In addition, by using a CO_2 heat pump instead of gas fired hot water heaters/boilers and HFC refrigerants, this system results in a 26% lower carbon footprint overall.

> *We have been using a butane gas system for heating water during the last 20 years. It works perfectly fine but our gas bill was almost $90,000 per year. With the Mayekawa heat pump system we will be saving around $60,000 per year (from the portion of gas used for water heating) plus the benefit of energy efficiency on the chiller side. Besides the savings, this technology will help us to be more efficient and at the same time environmentally friendly by eliminating almost 70% of our former use of butane gas."*
>
> Owner of Torres De Alba Hotel

By combining the hot water heating system with the chilled water cooling system using the Mayekawa water source heat pump unit, a higher COP is realized versus individual systems. This integrated system has been in operation since the summer of 2013 and the calculated payback period for the new heat pump system is less than 3 years.

Sanden's pathway towards introducing a US-tailored CO_2 heat pump water heater

Sanden has been participating in a CO_2 heat pump water heater project lead by the Energy Program of Washington State University and founded by the Bonneville Power Administration (BPA). According to a joint presentation by Maho Ito, CO_2 Product Manager of Sanden International USA and Ken Eklund, Building Science and Standards Team Leader at the Washington State University Energy Program laboratory, test results of CO_2 heat pump water heaters have shown an Energy Factor (EF) of 3.35 and Coefficient of Performance (COP) of 4.2 at an outside ambient temperature of 67°F (19.4°C), compared to an average electric resistance water heater with an EF less than 1.0 and an HFC heat pump water heater with an EF of 2.4.

This means that the CO_2 heat pump water heater are more than 3 times more efficient than the conventional electric water heater. "If electricity costs 10 cents per kilowatt hour and the average electricity use is 3,000 kilowatt hours, the average annual savings are $200," noted Ken Eklund. "If the system is used as a combination space and water heater the savings increase to over $1,000 per year."

Field test results of CO_2 heat pump water heaters installed in four single-family homes in North Pacific States encompassing different ambient temperatures are currently ongoing. "What we see is performance that is very similar to what we predicted from the lab test results with one difference, and that difference is that in a lab Energy Factor, the only impact one can measure is the tank loss." On the other hand, in field tests, there are also pipe losses, which are determined by how much time

> *The CO_2 heat pump water heater is more than 3 times more efficient than the conventional electric water heater. If electricity costs 10 cents per kilowatt-hour and the average electricity use is 3,000 kilowatt-hours, the average annual savings are $200. If the system is used as a combination space and water heater the savings increase to over $1,000 per year."*
>
> **Ken Eklund**
> Washington State University Energy Program

the water is sitting in the pipe - that also have to be taken into account. This makes the analysis difficult. To address this, Sanden and Washington State University are carrying out one-minute data collection, in which temperature readings are taken every single minute. At least 3 minutes of the same temperature are needed before the data can be used for calculating performance.

Sanden will also be participating in a Demand Response project to test how the CO_2 heat pump water heater can contribute to storing off-peak demand energy in order to control electricity peak demand.

Upon completion of field performance tests and Demand Response potential tests, lessons learned will be incorporated into next generation design & installation training, with a view to introducing a product tailored to the needs of the US in 2015.

For Jack Callahan, Senior Research Advisor, Bonneville Power Administration, who presented in the ATMOsphere America 2014 Energy Providers Session, there is a large opportunity to replace electric resistance heating technology with heat pumps. Whilst the BPA does not have a mandate to influence refrigerant choice, it does have a significant mandate for acquiring cost effective energy efficient resources. Transcritical CO_2 heat pumps, such as those being developed by Sanden, are an energy efficient resource that would provide and peak load improvements.

Design of heat exchangers for heat recovery in transcritical CO_2 systems

Rolf Christensen, Senior Product Portfolio Manager, Industrial Equipment, Alfa Laval, discussed the design of heat exchangers for heat recovery in transcritical CO_2 systems and water heating, the optimum operating pressure, the minimum approach temperature for different operating pressures, as well as the optimum COP.

According to Christensen, the balance between first cost and performance can be achieved by selecting appropriate operating pressure. Moreover, in order to attain successful transcritical CO_2 heat pump performance:

- The operating pressure must be chosen with consideration to the thermal duty
- The heat exchanger design cannot be based on the LMTD method
- A segmented model with local physical properties must be used
- Gas coolers should be long and slim, high-θ

Industrial ammonia heat pump in cheese processing

Industrial ammonia heat pump saves $435,600 (€320,000)

Sam Gladis, Business Director-Heat Pumps, Emerson Climate Technologies presented a case study of an ammonia based heat pump installation in a cheese processing facility, "PIZZA TOPPING", which converts 12 million lb (5.4 million kg) of milk to cheese. The installed ammonia refrigeration system has the following characteristics:

- Compressor load of 14,176 tons
- Condensing capacity of 13,319 tons

In the summer period the processing plant suffers from a shortfall in condensing capacity, which results in an increase in head pressure from 145 psig to 170 psig. In addition the facility is subject to cap and trade costs and water costs. The Emerson ammonia heat pump installation is able to offset some of this burden.

The configuration of the installation enables the heat pump to act in parallel as a condenser and to replicate the heating capacity of one the four steam boilers.

The heat pump installation's key advantages, as summarised by Gladis, are as follows:

- 581,000 therms fossil fuel savings
- 1.27MWh electric savings
- 100 HP boiler fan power savings
- More than 49 million liters water consumption savings
- Almost 25 million waste water savings and an increase in heating efficiency COP from 0.75 to 5.08.

In financial terms, the Emerson ammonia heat pump project resulted in approximately €320,000 ($435,600) overall utility cost savings and €37,500 ($51,000) cap and trade savings. It received a €520,000 ($707,000) utility incentive and had a 2.45-year simple payback.

State of the art low charge ammonia industrial refrigeration

Doug Schmidt
Embraco North America

Marek Zgliczynski
Embraco North America

Derek Hamilton
Azane / Star Refrigeration

Bruce Nelson
Colmac Coil Manufacturing

Carnie Marsh
Alfa Laval

Brian Dobbs
VaCom Technologies

The North American refrigerated warehouse industry has grown significantly in the past decade, resulting in an increased demand for innovative ammonia refrigeration systems with increased energy efficiency and reduced charges. The case studies in this chapter showcase some of the benefits of ammonia technology compared to fluorinated refrigerants, and looks specifically at the advantages of CO_2/ammonia cascade solutions, semi-welded plate heat exchangers with U-Turn, and direct expansion ammonia systems.

Switching from Freon to ammonia increases savings

Benoit Rodier, Director of Business Development at CIMCO Refrigeration, highlighted the advantages of an ammonia installation used to replace a Freon refrigeration system destroyed by fire at Viandes Meats, a 30,000 ft^2 (12,356 m^2) facility providing frozen products for restaurants and hotels. The replacement NH_3 installation, which has a capacity of 2,500,000 kW/hr, and provides 1,327 kW of heat, is comprised of:

- 1 spiral freezer at -40°F (-40°C)
- 5 blast freezers from -40°F to -10°F (-40°C to -23.3°C)
- 1 freezer at -10°F (-23.3°C)
- 24 medium temperature rooms from 36°F to 50°F (2.22°C to 10°C)
- 4 hygienic preparation rooms at 36°F (2.22°C)

The installation received a $500,000 (€366,800) grant from Hydro Québec, and saves:

- 260 kW of hot water heating
- 1,200 kW of electric heat
- 62 kW of air conditioning
- 200 kW of refrigeration system

Low charge ammonia - the natural replacement for R22

Derek Hamilton, US Business Development Manager for Azane, discussed the effects of the R22 phase-out in the US and in exploring alternative solutions argued that low charge ammonia systems represent an ideal alternative. Hamilton positioned himself against drop-in replacements and new HFC systems, arguing that the former face technical challenges regarding capacity, leakage rate and oil compatibility, whilst the latter face sustainability challenges. With the manufacturing of R22 no longer be possible in the US after 2020, Hamilton said non-action is not an option for end users. Non-compliance will necessarily result in financial penalties.

> *Natural refrigerant is the option!"*
>
> **Derek Hamilton**
> Azane /Star Refrigeration

Azane offers a low charge, air-cooled packaged ammonia chiller that is factory built and tested. According to Hamilton, these chiller packages dramatically reduce installation costs, as evidenced by an Azane installation at a Dairy facility in Puerto Rico. Azane worked in close collaboration with the dairy to design a 190 TR package consisting of a central cooling system, air-handling units and twin-screw compressors. Ammonia's excellent thermodynamic efficiency resulted in energy efficiency savings amounting of almost $41,000 (€30,000) per year.

Very low ammonia charge

In another presentation on low charge NH_3 solutions, John Scherer, Manager of Engineering at the Los Angeles Cold Storage Company, presented the NXTCOLDM™ Technology for ammonia refrigeration, which is suitable for warehouse storage. NXTCOLD™ requires less that 100 lb (45.36 kg) of ammonia per refrigeration system and features an Electronic Refrigerant Injection Control (ERIC).

Using direct expansion ammonia system to reduce refrigerant charge below 10,000 lb (4,500 kg)

Bruce Nelson, President of Colmac Coil Manufacturing introduced his presentation by discussing pumped ammonia systems, which historically have been very popular due to their simple operation and good evaporator performance over a wide range in load regardless of temperature. However, pumped ammonia maximizes the amount of refrigerant in the evaporators.

To address this issue, Colmac Coil manufactures Direct Expansion (DX) systems that reduce the charge in the evaporators by 30 - 50 times, and reduce the system charge by 4 - 5 times, allowing the ammonia charge to be kept below the 10,000 lb threshold (4,536 kg) for systems ranging between 1,500 TR and 1,800 TR. In addition, DX improves energy efficiency and lowers power consumption.

Explaining the benefits of the system, Nelson said that a DX ammonia system installed in a public refrigerated warehouse with a total area of 403,000 ft^2 (37,500 m^2), and with a total refrigeration load of 1,007 TR, had a $200,000 (€147,000) lower installation cost than for a pumped system. What is more, thanks to the Colmac Coil installation, which keeps the refrigerant charge below the 10,000 lb (4,536 kg) threshold, the facility will not be listed in the federal National Emphasis Program.

Ammonia refrigerant charge reduced by 2-3 times using semi-welded plate heat exchanger with U-Turn

In another example of an NH_3 technology that can help to reduce the ammonia charge, Carnie Marsh, National Key Accounts Manager at Alfa Laval, discussed the key features of Alfa Laval's upgraded semi-welded plate heat exchanger with a U-Turn ammonia flooded separator. The plate heat exchanger includes a new pressure design, a new gasket development for both refrigerants and a more compact, lower charge design flooded separator vessel. The semi-welded units can only exhibit external leakages, reducing the risk that ammonium carbonate will contaminate the system, as is the case in all-welded systems.

Rolf Christensen, Manager Product Portfolio Management from Alfa Laval, also discussed the U-Turn separators, whose low weight and compact design allows for high separation efficiency. The U-turn uses gravity separation and agglomeration, whereby surface tension keeps the liquid droplets trapped to the wall. Centrifugal forces are also at work.

Reporting on the energy consumption benefits of the U-turn, Christensen presented data from a 500 kW (142 TR), single stage system operating in San Francisco. He calculates that the U-turn can achieve savings of $10,000 (€7,348) annually, by reducing electricity consumption by 73 MWh.

In another installation at Homerton University Hospital in the UK, an existing R22 system was upgraded from 340 to 500 kW (from 97 to 142 TR). The charge dropped from 55 lb (250 kg) of R22 to 110 lb (50 kg) of NH_3 in the new system. As a result, the capacity was increased by 50% and the charge reduced from 5.7 to 0.77 lb/TR (0.74 to 0.1 kg/kW).

Low Charge CO_2/ammonia cascade system

In addition to discussing the U-turn, Alfa Laval's Carnie Marsh presented the advantages and disadvantages of CO_2/ammonia cascade systems. Cascade technology reduces the ammonia charge, lowers operational costs, and results in higher energy savings than conventional two-stage ammonia systems. This is true for low temperature CO_2 circuits operating at -58°F (-50°C) to 20°F (-6.67°C). However, it should be noted that such systems require higher working pressures at moderate temperatures, and typically electric defrost.

Marsh concluded his presentation with the findings of a comparative analysis of the ammonia charge of various cascade systems. The data, collected on the basis of a CO_2 low temperature system -58°F (-50°C) with a load of 1,380 MBH, with CO_2 condensing at 0°F (17.8°C) and flooded ammonia cooling evaporator at 73.8°F (23.2°C) revealed the semi-welded plate heat exchanger with a U-Turn separator requires the lowest charge among all systems: 26 lb (11.8 g).

Cascade CO_2/NH_3 tops R507 in terms of energy performance

In his ATMOsphere America 2014 presentation Brian Dobbs, Sr. Energy Engineer at VaCom Technologies compared the performance of an existing CO_2/NH_3 cascade system at a refrigerated warehouse in Fresno, California with a theoretical conventional NH_3 system and a theoretical conventional R507 system, from a real-time energy consumption and refrigeration capacity standpoint. The refrigeration system, installed in a 150,000 ft^2 (13,935m^2) warehouse, provides cooling at four separate pressure levels for: blast freezers (CO_2 -58°F/ -50°C), holding freezers (CO_2 -20°F/-28.8°C), coolers and docks (CO_2 +20°F/-6°C) and high side (NH_3 +11°F/ -11.7°C).

The comparative analysis, performed on the basis of power per unit of cooling produced during 2-minute intervals, showed that the CO_2/NH_3 cascade system results in:

- A higher energy efficiency due to the system configuration and the thermodynamic properties of the refrigerant
- A lower refrigerant charge
- Positive pressure in all system areas avoiding system contamination
- The potential to lower blast freezer temperatures
- A reduction in the TEWI (Total Equivalent Warming Impact) of almost 67%

Latest CO_2 technology innovations for centralized commercial refrigeration systems

Klaas Visser
KAV Consulting

Mirko Bernabei
SCM Frigo

Dan O'Brien
Zero Zone

Louis Morris
Parker

André Patenaude
Emerson Climate Technologies

Tom Wolgamot
DC Engineering

Michael Englebright
Carel

Jeff Newel
Hillphoenix

Xavier Marle
Systemes LMP

Peter Dee
Danfoss

ATMOsphere America 2014 held parallel case study sessions covering the latest in CO_2 innovation for centralised commercial refrigeration systems. The presentations summarised below by Hillphoenix, Systemes LMP, Carel, SandenVendo, Danfoss, SCM Frigo, Micro Thermo Technologies, Emerson Climate Technologies, KAV Consulting, Zero Zone, DC Engineering, touch on topics such as cost, technological improvements, serviceability and best practice; as well as give installation examples at major food retail stores and the latest performance results.

Small footprint CO_2 technology

Michael Englebright, Global Key Accounts Manager for Retail, Carel, discussed the evolution of CO_2 technology, which is rapidly becoming a mainstream technology in certain applications. Englebright estimates that CO_2 booster systems have almost achieved cost parity with traditional HFC systems, with only a 5% difference between the two. However, whereas the European market for CO_2 racks and plug-in and self-contained systems has evolved rapidly, for small footprint systems barriers remain in terms of initial upfront costs, usability for installers and system complexity.

Overcoming some of these barriers are smaller footprint CO_2 units developed on the basis of traditional condensing units, a technology already used in Japan. Roche pharmaceuticals in the US, offers an interesting example of successful CO_2 condensing unit installation. The technology was selected instead of a traditional CO_2 booster system because condensing units have a simple architecture that service engineers are familiar with. In total, Englebright said that 18 such systems were planned for completion before the end of 2014.

Other technological improvements include:

- Brushless compressors, which are increasing the efficiency
- Making systems more intuitive by creating one control system for everything
- High pressure valves such as receiver gas valves and gas cooler high pressure valves

Englebright concluded by emphasizing the importance of: standardizing equipment to aid serviceability and reduce costs; guidelines; sharing of best practice; having a proving ground of multiple units; enabling benchmarking and performance review; and integration with CO_2 systems.

From SandenVendo, Mike Weisser, VP Marketing and Sales also discussed the convenience store market and its significance in terms of the market opportunity for small footprint CO_2 refrigeration systems. For example in North America, retailer CVS has 150,000 stores, and is adding 5,000-7,000 stores per year, whilst store remodels can be expected every 15 years. Overall, this represents a market of 15,000 – 17,000 stores.

New technologies open door for efficient CO_2 use in hot climates

In an industry first time, Jeff Newel, Director of Research and Development at Hillphoenix, presented the company's pioneering installation of a CO_2 booster system in a warm ambient climate at a Sprouts Farmers Market store in Dunwoody Georgia. Here, a standard Advansor CO_2 booster system with 4 MT compressors and 3 LT compressors is installed together with an adiabatic gas cooler (operated dry in cooler weather and with wet pads for pre-cooling in warmer weather), minimizing the CO_2 temperature leaving the gas cooler and thereby reducing energy consumption by 6%. Newel highlighted the fact that water is used only when required, as a result of which the system only uses one third of the water a traditional evaporative condenser would use. What is more, no water treatment is required, and there is no wet coil so no scaling. The system also uses electric defrost, a technology more traditionally used in Canada than in the US.

From Systemes LMP, Xavier Marle, Director of Operations and North American Sales Representative, discussed the advantages of mechanical sub-cooling. This technology reduces energy consumption by 17%, improves the Energy Efficiency Rating (EER) by 35%, and decreases the number of refrigeration compressors needed to keep systems in a positive temperature mode. This lowers the energy costs associated with CO_2 transcritical systems, enabling them to operate efficiently at high ambient temperatures.

In addition to discussing Systemes LMP's patented mechanical sub-cooling technology, Marle pointed out that Systemes LMP has the most GreenChill certified platinum stores on the market.

Klass Visser, owner of KAV Consulting presented the application of CO_2 evaporative condensers and gas coolers. These technologies enable the efficient application of CO_2 anywhere in the world. Visser stated that evaporative CO_2 condensing out-performs all other refrigerants in hot climates, even ammonia, and with a surprisingly high Coefficient Of Performance (COP). Visser believes that CO_2 transcritical refrigeration can be used throughout the US when combined with an evaporative condenser and gas cooler. This combination provides a suitable alternative technology for the conversion of existing HFC/CO_2 cascade systems.

SCM Frigo's Technical Director Mirko Bernabei also presented on how natural refrigerant technology may be applied in a warmer climate conditions in a reliable and efficient manner. Bernabei looked at an installation in a meat factory in France, in a location with a similar climate to the US. The installation, comprised of a CO_2 booster MT and LT with parallel compression and total heat recovery, provides both cooling and heating in one unit. Parallel compression maximizes the efficiency of the system when the weather is hot or during heat recovery mode in wintertime, which decreases power consumption compared with a traditional booster unit. Not only does the CO_2 booster parallel compression system extend the efficient application of CO_2 technology to the southern US, the solution also has a much lower carbon footprint than traditional HFC systems.

Accurate CO_2 system controls

Peter Dee, Sales & Service Director, Danfoss North America discussed the benefits of CO_2 in supermarket systems, which include low climate impact, low life cycle cost, energy savings of 10-20%, 95% reduction in refrigerant cost, and the opportunity to combine heating and cooling in one system. Danfoss is one of several manufacturers that supply mechanical and electronic rack controls and case controls. The company was involved in one of the first CO_2 trancritical supermarket installations in the US, at a Whole Foods store in Brooklyn, New York. The 56,000 ft^2 (5,203 m^2) store features a CO_2 trancritical refrigeration system, Combined Heat and Power (CHP), and Air Handling Units (AHU) with hot and Chiller Water. One of the most significant successes of the project was strong industry collaboration and contractor training. Dee also presented the results of a retrofit project from 2010, whereby an 11,000ft^2 store (1,022m^2), was fitted with a CO_2 booster system with the following results: annual operating cost savings of $35,000 (€25,637), and 7% TEWI reduction thanks to added heat reclaim.

Also presenting on Whole Foods CO_2 were Tom Wolgamot, Principal Engineer / Branch Manager, DC Engineering, and Dan O'Brian, Vice President of Zero Zone, who talked about the retailer's Castro store. At this location a high side R407A system with medium temperature CO_2 overfeed and low-temperature CO_2 DX is installed.

Also speaking from the perspective a leading controller and component manufacturer was Louis Morris, Applied Engineering Manager at Micro Thermo Technologies a subsidiary of the Parker Hannifin Corporation. Micro Thermo Technologies has worked on 80 locations that use CO_2 as a refrigerant, collaborating with five different rack manufacturers and ten different grocery chains in Canada and the US, in addition to ice rinks and warehouses. The company focuses on providing a holistic, system approach that ensures none of an installation's heating and cooling systems are competing each other.

To illustrate this approach Morris described the way in which all of the subsystems in an IGA store in Terrebonee, Québec, Canada are interconnected, so that the condensers, RTU (rooftop units), lighting, racks and cases influence each other. The 40,000 ft^2 (3,716m^2) store has 105 cases, 15 coolers/freezers, one centralised CO_2 trancritical system with heat reclaim. The installed Micro Thermo Technologies control system collects all the data needed to provide efficient case control, such as ambient temperature, humidity, dewpoint, liquid temperature, and liquid pressure. In turn, the system enables the cases to provide important information to the interconnected systems relating to defrost and emergency situations. The goal is for the system to be predictive.

In a comparison between two stores, Morris showed that by using a system approach the predictive system meant that only two defrosts occurred instead of three, resulting 9% saving in refrigeration energy.

CO_2 booster system advantage versus R404A DX

In his presentation André Patenaude Director - CO_2 Business Development at Emerson Climate Technologies presented a Life Cycle Climate Performance (LCCP) comparison of a CO_2 booster system and an R404A DX system. Compared to the latter a CO_2 transcritical booster system has a 64.5% lower carbon footprint at 70°F (21°C). Patenaude also discussed the lower compression ratio of a 15 HP CO_2 compressors compared to a 15 HP CO_2 compressor: 2.9:1 versus 3.5:1, which is explained by the higher CO_2 suction pressures. Emerson manufactures a variety of compressor operating envelopes, all of which come equipped with CoreSense electrical controls, which reduces maintenance costs, increases system uptime, and records a history of all trips, alarms, and start ups.

Latest CO_2 technology innovations for transport refrigeration and in vending machines

James Taeckens
Carrier Transicold

Michael Weisser
SandenVendo America

CO_2 has significant market potential in the transport sector, as presented by James Taeckens, who discussed Carrier Transicolds' CO_2 refrigerated container, which has already successfully completed 27,500 operating hours. CO_2 is also successfully used as a refrigerant in vending machines, discussed by Mike Weisser from SandenVendo America.

James Taeckens, Senior Product Manager, Global Container Refrigeration for Carrier Transicold presented the company's CO_2 container transport refrigeration system. The NaturaLINE refrigeration machine is designed for ISO insulated containers and is able to transport virtually all perishable and frozen cargoes. Carrier decided to transition to CO_2 as a transport refrigerant because of factors such as performance, safety, availability, cost, and the refrigerant's low GWP. The average energy use of the NaturaLINE system is comparable to that of systems employing R134a. At part-load perishable set-points the NaturaLINE has superior efficiency.

To ensure the technology is operated and serviced correctly, Carrier offers CO_2 training for vessel crews covering: the fundamentals of refrigeration, how to work with refrigerants, how to operate the NaturaLINE unit, and servicing and troubleshooting.

NaturaLINE field trials began in 2008 and, to date, more than 120 shipments and 27,500 operating hours have been successfully completed. Taeckens announced that this technology will be moving into a commercial phase in 2014. In addition to marine trials Carrier Transicold has started to tryout its technology in refrigerated trucks and trailers for UK retailer Sainsbury's.

CO_2 refrigeration for vending machines

Providing another perspective on CO_2 refrigeration was Mike Weisser, VP Marketing and Sales for SandenVendo America, who talked about the company's CO_2 refrigerated vending machines, manufactured for The Coca-Cola Company (30 units deployed and an order for an additional 432 units received in June) and Dr Pepper Snapple (36 units deployed).

There are around 6 million vending machines in the US, and each one represents an essential tool in the marketing and sales arsenal of the end users that rely them. When one breaks the end user cannot sell their product, which can seriously impact the revenues of small business owners, such as those of 7-Eleven stores. Ensuring CO_2 system reliability and providing adequate maintenance and servicing training is therefore very important.

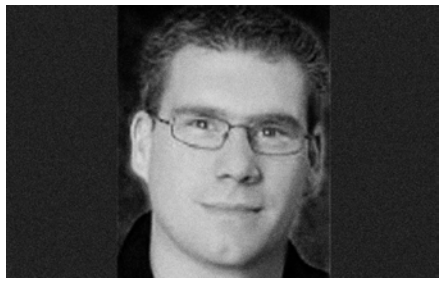
Like Steven Cousins from The Coca Cola Company, Weisser emphasized the fact that according to testing by DoE and Energy Star laboratories, CO_2 systems do not use more energy than R134a systems. What is more, due to the high-end and robust components required by customers and UL, SandenVendo is finding that the CO_2 refrigeration units are not breaking down. According to Weisser, the company has had excellent results from the field trials.

> *A CO_2 refrigeration system is essentially like a car that runs on trash, do people realize how amazing that is!"*
>
> **Michael Weisser**
> SandenVendo America

Hydrocarbons: "better for sustainability and for lower power consumption"

Doug Schmidt
Embraco North America

Marek Zgliczynski
Embraco North America



Eric MacGregor
Versatile Refrigeration

Embraco, one of the world's largest manufacturers of small hermetic compressors, presented during a lunchtime poster session the energy efficiency of R290 in commercial refrigeration with regards to the Department of Energy's (DoE) new recommendation for 2017. The encouraging future for hydrocarbons in the US as compared to two years ago was underlined, alongside what still needs to be done in order to ease implementation. In a second hydrocarbons-focused presentation, Eric MacGregor from Versatile Refrigeration International discussed the first installation in North America of a secondary refrigeration system using R1270 as the primary refrigerant.

In the spring of 2014, the Department of Energy (DoE) released a new recommendation for energy standards for 2017. Embraco saw this as an opportunity to spread the message about hydrocarbon refrigerants and the energy and cost benefits they offer to food retailers.

Energy efficiency comparisons from R404A to R290

Retailers with several thousand cooler units spanning the US hold a significant responsibility for energy consumption on the power grid. Using hydrocarbon cabinets can generate impressive annual savings, as demonstrated in three case studies that look at glass door merchandisers of approximately 26 ft³ (0.74 m³) using R290, compared to R134a or R404A. The results were as follows:

- In the first example the cabinet realized a 33% reduction in power consumption
- In the second example, the R290 cabinet, together with changes made to the lighting, the evaporator and condenser fan, resulted in a 30% reduction in power consumption, operating costs, and the amount of CO_2 emissions released
- In the third case study, the comparison was more direct as the only modification was the compressor and its associated refrigerant. From R404A to R290, the direct savings were 17% on power consumption

Versatile Refrigeration installs the first R1270 chiller in North America

Eric MacGregor, General Manager, Versatile Refrigeration International Inc focused his presentation on the first installation in North America of a secondary refrigeration system using R1270 as the primary refrigerant, at Auvil Fruit Co, Washington, USA. The chillers, designed to use hydrocarbon refrigerants (R290 and R1270), have higher efficiency and lower net weight charge. The project described by MacGregor comprises 11 controlled atmosphere (CA) rooms of various sizes, cooled from 32°F to 37.9°F (0°C to 3.3°C), and a package storage area at 33.8°F (1°C), designed to cool 15.4 million lb (7500 tons) of apples. The building is loaded in 10 days with 86°F (30°C) apples, and pulled down to 33.8°F (1°C) for ten months. The system COP varies depending on the time of the year (high load in warm temperatures and low in cold temperatures).

The cooling is provided by twin 260 kW Frigadon chillers, which cool the rooms via brine solution called Hycool, which circulates between the chillers and cooling coils in the rooms. In addition, the chillers are continuously monitored for any faults and are equipped with leak detecting sensors.

According to MacGregor, the building operators have reported that the system is simple and easy to operate, and requires less maintenance than the NH_3 systems at Auvil's other plants. The R1270-cooled AC rooms maintain excellent product quality with little water loss from the fruit.

The key factors that ensured the successful completion of the project, were the fact that Auvil Friot Co.:

- Worked with local partners
- Retained Intertek testing agency in order to obtain UL certification for the chillers
- Worked with Zurich as the underwriter and their local assessor to prove the safety and track record of the Frigadon equipment
- Provided training directly to the operating engineers responsible for building

> *By making the change to hydrocarbons, this particular manufacturer moved from an appliance which would not be allowed to be sold in the US two years from now, to one that is below the energy standard."*

> *Embraco's view is that although we believe in natural refrigerants, and we've explored CO_2 technology, we believe that hydrocarbons allow not only for better sustainability, but also for lower power consumption"*

Doug Schmidt
Sales Manager
Commercial Cooling Solutions Division
Embraco

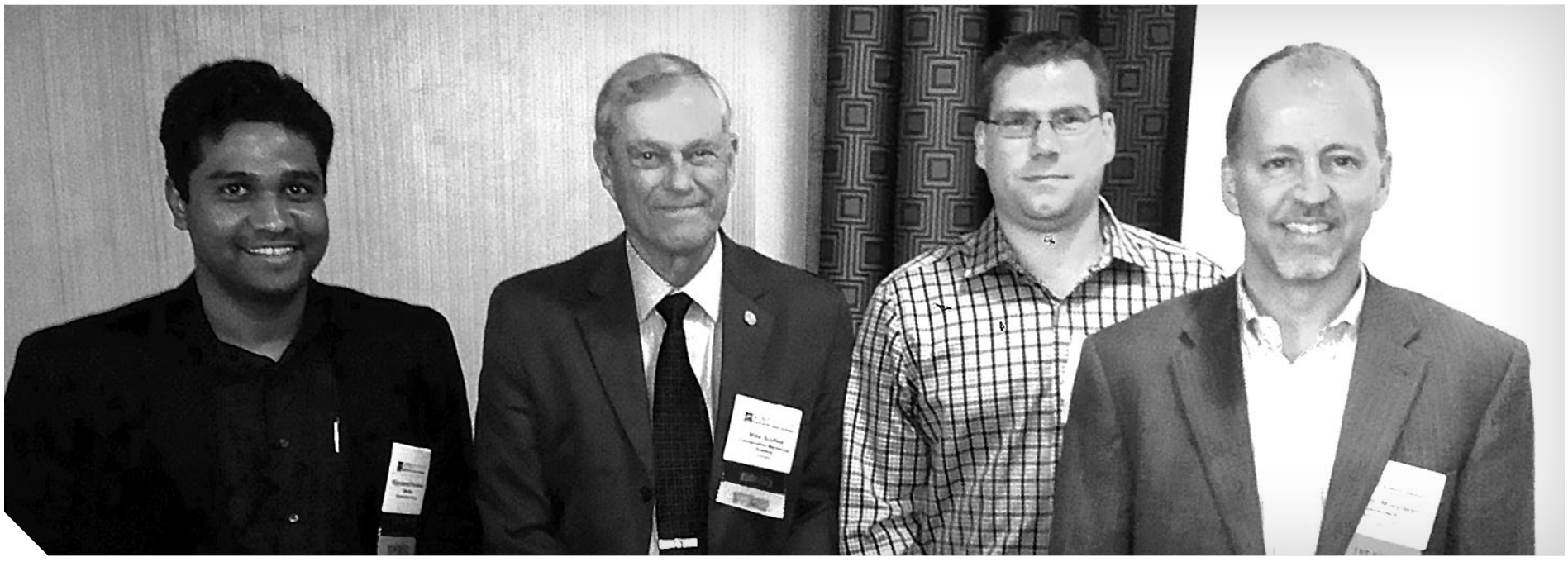
Water in cooling applications

Michael Morehead
Genentech

Mike Scofield
Conservation Mechanical Systems

Vijayanand Periannan
Munters Des Champs

In a session sponsored and moderated by leading biotechnology company Genentech, Conservation Mechanical Systems, Munters des Champs, and Genentech presented projects focused on using water to provide cooling in HVAC applications. The case studies covered a variety of topics, including the benefits of evaporative cooling, challenges for the industry, future trends, and more.



The parallel session dedicated to HVAC gave participants the opportunity to share experiences and knowledge on natural refrigerant uses in a new application area.

Absorption chillers using water as a refrigerant for 36-building campus HVAC system

Michael Morehead, Global Engineering, Mechanical Engineer at Genentech , presented a technology case study of a planned campus conversion to natural refrigerants, pointing out the potential economic benefits of such a project given pending the US HCFC and HFC phase out and phase down. The campus in question has 36 buildings and over 650 pieces of equipment including:

- 47 large units of over 100 tons
- 618 mid size units of below 100 tons
- 3,533 small units of fractional ton capacity

In addition to cold rooms, process cooling chillers, and large central chillers, Genentech relies on specialty equipment such as -80°C freezers and lysophilizers. Each application will require a different natural refrigerant technology. Whilst hydrocarbons could be used for the lysophilizers and process cooling chillers, and CO_2 for the walk-in cold rooms and freezers, absorption chillers using water as a refrigerant could be used to replace the large central chillers.

Morehead challenged the natural refrigerant industry to provide Genentech with solutions, by:

- Improving packaged CO_2 transcritical units,
- Developing CO_2 systems for the HVAC market
- Educating fire marshals about hydrocarbon refrigerant equipment
- Marketing hydrocarbon chillers in the US and developing a service network

Reduction in peak electrical demand of 20 to 30% thanks to UFAD and evaporative cooling

During his presentation, Mike Scofield, President of Conservation Mechanical Systems showed the difference between conventional overhead air distribution systems and Under Floor Air Delivery (UFAD) designs for air distribution, and discussed the benefits of the UFAD system on Indoor Air Quality (IAQ) as well as the marriage of this concept to a two stage evaporative cooling system. According to Scofield, as well as providing economic benefits the UFAD system reduces fan energy, increases free cooling economizer hours, and allows personalized climate control for occupants.

Scofield presented two case studies featuring the technology; one at the Dona Spring Animal Shelter project, where a two stage evaporative cooling design was used with an overhead delivery system to eliminate mechanical cooling, and a retrofit project of a 100 year-old building, using a direct evaporative cooling system combined with a UFAD design. According to Scofield, the benefits of evaporative cooling include a reduction in peak electrical demand of 20 to 30% compared to refrigeration design with air cooled condensing system.

EPX Heat Exchanger Technology for Dry Evaporative Cooling

Vijayanand Periannan, Regional Sales Manager Munters des Champs shared his experience on EPX heat exchanger technology for dry evaporative cooling. He argues that because evaporative cooling humidifies and cools, providing a constant wet bulb temperature, in warm weather a combined indirect and direct evaporative cooling (IDEC) system requires less refrigeration cooling than a 100% recirculation system. What is more, it provides better inside air quality, reduces energy costs and allows for a reduction of 29% in refrigeration load over 100% recirculation.

Periannan presented an annual energy consumption comparison of a 100% outdoor air IDEC variable air volume (VAV) system with a 25% outdoor air economizer VAV system in Sacramento. The IDEC design resulted in a significant reduction in peak demand charges and further peak kW reductions if combined with TES.

Energy Providers

Ammi Amarnath
Energy Power Research Institute (EPRI)

Paul Delaney
Southern California Edison(SCE)

Jack Callahan
Bonneville Power Administration (BPA)

Keith Forsman
Pacific Gas & Electric (PG&E)

In another ATMOsphere first, the programme featured a Session dedicated to Energy Providers, who shared with participants their unique perspectives on how natural refrigerant technologies can help utilities ensure that residential, commercial and industrial consumers use electricity as efficiently as possible.

Ammi Amarnath, Senior Program Manager of the Energy Efficiency & Demand Response, Electric Power Research Institute (EPRI) was first to speak in the Energy Provider Session. Amarnath provided an overview of EPRI, a breakdown of energy use in the residential and commercial sectors and explained that utilities should care about natural refrigerants because HVAC&R is an important segment, because of environmental impact, and because emerging technology using natural working fluids can help to increase efficiency and level loads. Within this context, Amarnath also discussed the implications of the US EPA Clean Power Plan, released June 2, 2014. The Plan centers on a process that is to be managed by states, which means states they have the flexibility to choose the most cost-effective approach to encourage use of renewable energy and improve energy efficiency.

Next to speak was Paul Delaney, Senior Engineer, Southern California Edison (SCE) who discussed evolving energy trends, which have shifted over the years to focus on improving energy efficiency. This has become particularly in important in California, which since 2008 has had a long-term energy efficiency plan, the "Energy Efficiency Strategic Plan", most recently updated in 2011. The plan has four goals, one of which is "New HVAC Technologies & System Diagnostics."

According to Delaney, there are various opportunities for energy efficiency improvements in different sectors. For example, in the residential AC sector current HVAC maintenance practices can be dramatically improved. Nearly half of the 5 million residential ACs in Caliornia, which represent 11% of electricity demand, are at least 10 years old, and 60% do not receive regular maintenance.

In the commercial sector, there are lessons to be learned from innovative projects like the Carpinteria Albertson's zero-net energy supermarket, which features energy efficient lighting, natural ventilation and a natural refrigerant NH_3/CO_2 refrigeration system. Thanks to the installation the store is saving about $100,000 (€73,000) every year, and its energy consumption has been reduced by 30%. Currently, SCE is working with EPRI to identify new technologies in refrigeration, focusing on natural refrigerants.

Lastly, in the industrial refrigeration sector, Delaney talked about the opportunities to improve the efficiency of refrigerated warehouses space. California relies heavily on refrigerated space with temperatures ranging from 40°F to – 80°F (4.4°C to – 62°C). He said that between 15-25% savings are possible using ammonia as opposed to HFC systems. NXTCOLD™ Technology can also yield significant savings.

Jack Callahan, Senior Research Advisor, Bonneville Power Administration (BPA), a wholesaler that sells to power utilities, also focused his presentation on energy efficiency goals in California, discussing in particular the role of heat pumps in the Pacific Northwest, where there is a large installed base of electric resistance space and water heating. Callahan emphasized the important role that heat pumps can play as energy efficiency measures. Although the BPA does not have any direct mandate to influence heat pump refrigerant choice, their mandate to incentivize energy efficiency does have an influence on refrigerant selection. With regards to CO_2 transcritical heat pumps, test results have yielded good performance. Callahan therefore sees a significant potential for this technology to flatten out loads, and yield energy savings.

Also talking about the role of heat pumps as efficiency measures was Keith Forsman, Customer Energy Services - Product Manager, Pacific Gas & Electric (PG&E), whose mission is to provide, safe, reliable and cost effective energy to the 15 million residents of Northern and Central California. For PG&E, it is cheaper to save energy than it is to produce more. To this end the company has a variety of programmes that support energy efficiency, covering: energy analysis tools and rate options, emerging technology, new construction, retrofits, retrocomissioning, codes and standards and workforce education and training.

Glossary

BPA: Bonneville Power Administration

CA: Controlled Atmosphere

CARB: California Air Resource Board

CO_2: Carbon dioxide

COP: Coefficient of Performance

CSR: Corporate Social Responsibility

DX: Direct Expansion

EF: Energy Factor

EPA: Environmental Protection Agency

EPRI: Electric Power Research Institute

EU: European Union

GHE: Ground Heat Exchanger

GWP: Global Warming Potential

HC: Hydrocarbons

HCFC: Hydrochlorofluorocarbons

HFC: Hydrofluorocarbons

HVAC&R: Heating, Ventilation, Air conditioning & Refrigeration

IAQ: Indoor Air Quality

IDEC: Indirect and Direct Evaporative Cooling

kg: Kilogram

kW: Kilowatt

kWh: Kilowatt hour

LT: Low temperature

MT: Medium temperature

NH_3: Ammonia

NR: Natural Refrigerants

ODP: Ozone Depletion Potential

ODS: Ozone Depleting Substances

PG&E: Pacific Gas & Electric Company

R290: R-numbering identification for propane

R600a: R-numbering identification for isobutane

R744: R-numbering identification for carbon dioxide

R717: R-numbering identification for ammonia

R718: R-numbering identification for water

R&D: Research & Development

SCE: Southern California Edison

SNAP: Significant New Alternatives Policy

SLCPs: Short-lived Climate Pollutants

TC: Transcritical

TR: Ton of refrigeration

UK: United Kingdom

UFAD: Under Floor A Delivery

UL: Underwriters Laboratories

US: United States

Presentation listing

INTRODUCTION & STATE OF THE INDUSTRY SESSION

Nina Masson - Natural refrigerants trends worldwide

Scott Martin, Kim G. Christensen - Market progress in natural refrigerant technologies

Marc-André Lesmerises - CO_2 technologies for your applications

Masood Ali - State of the industry

Jeffrey Gingras - State of the industry - challenges & growth. CO_2, a world of evolution

Mark Tomooka - Opportunity through adversity: natural refrigerants in North America

FOOD RETAIL PANEL - PART 1 (SUPERMARKETS)

Mike Ellinger - Whole Foods Market's experiences with natural refrigerant technologies

Harrison Horning - Natural refrigerants at Delhaize America

Jason Robbins, Rob Olden - Walgreens net zero with transcritical CO_2

Paul Anderson - Targets CO_2 experience

Ian Crookston - Reducing CO_2: present and future

POSTER SESSION

Marek Zgliczynski, Douglas Schmidt - How Embraco propane compressors can help you reach 2017

FOOD RETAIL PANEL - PART 2 (SUPPLIERS & CONTRACTORS)

Richard Heath - Installing & maintaining natural refrigeration systems

Scott Martin - Experiences with natural refrigerant systems

Mark Tomooka - A manufacturer's role in facilitating natural refrigerant usage

Chris Huffmann - CO_2 systems - installation considerations

Jim Armer - Planning & performance - natural refrigeration system design

PARALLEL TECHNOLOGY CS: COMMERCIAL REFRIGERATION SESSION

Xavier Marle - Mechanical sub-cooling - no climatic limit to transcritical applications

Peter Dee - Controlling transcritical CO_2 refrigeration for sustainable system design

Andre Patenaude - First North America built Copeland CO_2 booster transcritical rack

Louis Morris - The importance of taking a systems approach to CO_2 installations

Tom Wolgamot, Dan O'Brien - A case study of the CO_2 system at Whole Foods Market, Castro

Michael Englebright - Fast track and implementation of transcritical CO_2 refrigeration into Roche estate

Mike Weisser - An introduction to CO_2 refrigeration in Food and Beverage Marketing Equipment

Jeff Newel - CO_2 supermarket system - case study of a warm climate CO_2 booster system

PARALLEL TECHNOLOGY CS: HVAC SESSION

Michael Morehead - Genentech's project: Migrating away from HFC's

Mike Scofield - Indirect/Direct evaporative cooling in the arid West to eliminate mechanical cooling

Vijayanand Periannan - EPX heat exchanger technology for dry evaporative cooling

Eric MacGregor - Versatile Refrigeration International Inc., Successful installations of R1270 air cooled chillers

PARALLEL TECHNOLOGY CS: INDUSTRIAL REFRIGERATION & OTHER APP. 1

Marc-André Lesmerises - How CO_2 allows innovative processes? A comparative study on defrost technologies

Benoit Rodier - Moving from freon to natural refrigerant after a catastrophic fire

Derek Hamilton - Low charge ammonia - the natural replacement for R22

Bruce Nelson - Reducing ammonia charge in a large public refrigerated warehouse

Luke Facemyer - Food industry utilizes natural refrigerants for office HVAC

Carnie Marsh - Low Charge CO_2/ammonia cascade system

John S. Scherer - Very low charge ammonia

REGULATIONS & STANDARDS SESSION

Tom Land - Update on EPA actions

Glenn Gallagher - Regulation of high-GWP refrigerants

Ed Cheng - Modeling the greenhouse gas emissions impacts of refrigeration systems

Barry Karnes - Natural refrigerants and UL standards

Alexandra Maratou - Legislative update from the EU and Japan

ENERGY PROVIDERS SESSION: HEAT PUMPS AND REFRIGERATION

Ammi Amarnath - The Energy Providers Session - overview

Paul Delaney - Emerging technologies - alternative refrigerants

Jack M. Callahan - Bonneville Power Administration and Pacific Northwest Perspectives on energy efficiency and natural refrigerants

Keith Forsman - Heat Pumps and Refrigeration: A Utility Perspective

END USER PANEL

Paige Dunn - Red Bull & HC Refrigerants

Steven Cousins - Transition to HFC-free refrigeration

Jeffrey Hogue - McDonalds HFC-free journey

PARALLEL TECHNOLOGY CS: HEAT PUMPS SESSION

Marc Portnoff - Natural refrigerant enhanced geothermal heating & cooling solutions

Rolf Christensen - Design of heat exchangers for heat recovery in transcritical CO2 systems

Maho Ito, Ken Eklund - CO_2 heat pump water heater field test

Troy Davis - Introduction of Mayekawa's ECO Cute water source hot water heat pump at Torres De Alba Hotel

Sam Gladis - Industrial ammonia heat pump in cheese processing

PARALLEL TECHNOLOGY CS: INDUSTRIAL REFRIGERATION & OTHER APP. 2

James Taeckens - Efficient and practical container refrigeration applications using CO_2

Klaas Visser - The application of evaporative condensers for subcritical CO_2, condensing & transcritical CO_2 gas cooling

Brian Dobbs - Performance comparison of CO_2/NH_3 vs. R507 in an industrial refrigerated warehouse

Mirko Bernabei - CO_2 Booster MT and LT with parallel compression and total heat recovery in a meat factory

Rolf Christensen - Low charge energy efficient ammonia evaporator with separator vessel

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