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CONDENSER

Are Natural Refrigerants Breaking Climate Change?

IIAR'S STANDARDS AND THE EVOLVING GLOBAL COLD CHAIN

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SUMMER 2025

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PRESIDENT'S MESSAGE

BY GARY SCHRIFT

It's membership renewal season at IIAR, and while it's tempting to put aside the messages we've been sending you until there's time to think about it, the next five minutes is all you need. Still with me? There are only two things to know this year.

First, the IIAR products available at no additional charge with your membership are increasing again. As an IIAR member you'll get access to the entire refrigeration training series plus two Academy of Natural Refrigeration courses when you become a member. And second, if you're considering group membership, the cost advantages and benefits are better than ever. After you register 25 members for your group, the per member cost is only $100 per person added to the group. In addition, your group will get access to a powerful recruitment tool, our new internship and entry level job boards.

Meanwhile, individual membership is always one of the best ways to get involved, and more training resources than ever are available to help you accomplish your professional goals.

As an IIAR member, we all depend on you to take that essential first step to participate in the activism and advocacy of our industry by keeping your membership current. Whether that means getting involved in the work of one of our committees or laying the groundwork for future success, here are some of the key benefits:

Professional Development and Education: IIAR offers a variety of training programs, including workshops, seminars, and certification courses designed to enhance the skills and knowledge of refrigeration professionals at all levels. As part of the enhanced benefits, members have access to all of the IIAR Training Videos. Additionally, members get two free Academy of Natural Refrigerants courses per year. Additional training is available with a member discount.

Technical Papers, Bulletins, and Standards: IIAR members receive free online access to bulletins and industry standards via IIAR's e-library. Members can view documents in eBook format using their Bookshelf account through VitalSource/eVantage, making them portable.

Annual Conference & Exhibition: IIAR's annual conference is a premier event for ammonia refrigeration professionals, and members receive a discount on attendance. The conference provides a platform for individuals to connect with others in the industry, share knowledge, and explore the latest industry innovations.

Webinars and Editorial Content: Access to all IIAR webinars is free for members, and the webinars are recorded for those who don't attend live.

Regulatory Advocacy: IIAR represents the interests of its members by engaging with regulatory bodies and policymakers. The organization advocates sensible regulations that promote safety without imposing unnecessary burdens on our industry.

MEMBERSHIP PRICING

IIAR has created several different membership tiers to meet a wide range of needs. Individual Company membership is a single membership class where a member is registered under their company of employment.

If additional employees from the company would like to join, companies can upgrade to a Group Membership, which includes up to 25 members. If companies would like to add more than 25 employees, they can do so at a significantly discounted rate, only $100. If a company has dozens of technicians or a lot of people in the plant that can use training, the value proposition is that you get significant benefits for a much lower cost.

IIAR also offers special membership at a discounted rate to affiliates, such as regulators and first responders, academics, students, and retirees.

As always, I encourage everyone to participate in IIAR on our various volunteer committees, and to take advantage of the many member benefits. When you belong to the IIAR Community, your voice adds impact to our Industry. I'm looking forward to working with you again this year, and I invite you to renew your membership today.

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Are Natural Refrigerants Breaking Climate Change?

IIAR'S STANDARDS AND THE EVOLVING GLOBAL COLD CHAIN

As climate goals and efficiency become the central focus behind cold chain decisions, both at the individual and government level, natural refrigerants are becoming a global movement, increasingly unencumbered by regional political landscapes.

In Latin America, a surge in CO_2 systems is happening, while in Europe, focus is growing on a policy-driven adoption of refrigerants like ammonia and hydrocarbons.

The global regulatory landscapes remain uneven, but in many places, the tide is turning. Natural refrigerants are outgrowing national constraints, propelled by international climate agreements, evolving technologies, and a (in many cases, profit-driven) drive towards sustainability and efficiency.

Meanwhile, global issues like reducing food waste and shoring up regions vulnerable to famine are, increasingly, urgent problems that natural refrigerants are well-suited to help solve, earning them attention from global policy leaders.

These factors shape the way the International Institute of All-Natural Refrigeration (IIAR) seeks to work on the global standards scene, where IIAR's standards, alliances, and educational efforts are helping shape the adoption of natural refrigerants.

"There's a massive movement in Europe, Latin America, and other regions toward natural refrigerants," said IIAR's Vice President – Education, Outreach and Events, Yesenia Rector. "We're seeing expansion into heat pumps, CO_2 systems, hydrocarbon systems, and ammonia in non-conventional applications. It's taking relevance globally."

IIAR's credibility as a standards-setting body is no longer confined to the U.S. market. "We've solidified our position over the last decade," said EVAPCO Vice President Kurt Liebendorfer, who is currently serving on IIAR's board. "Our standards are now adopted into the International Code Council and enforced through building codes. We've long been the go-to for ammonia, and now we're seeing CO_2 and hydrocarbons follow suit."

That credibility is exportable, said Leibendorfer. "IIAR is living proof of an industry that has successfully self-governed through technical excellence. Along with IIAR members, we've managed the intersection between the desire to use ammonia for all its benefits and the safety concerns that come with it. If we hadn't, ammonia use wouldn't be growing, but it is."

In Latin America, where many countries have not developed their own standards, IIAR's best practices are being adopted to shape national frameworks. "These partnerships are helping build not just regulatory capacity but entire supply chains," Leibendorfer said. "It's no longer just about standards—it's about infrastructure, technology, and market maturity."

In 2023, IIAR's International Committee launched a far-reaching research initiative to catalog the standards and codes governing industrial refrigeration systems – especially those using ammonia and other natural refrigerants – across key international markets. The goal: to create a comprehensive global reference that supports IIAR's mission to promote safe and sustainable refrigeration worldwide.

The resulting dataset spans 14 countries across Latin America, Europe, Asia, and Oceania, offering insights into regulatory frameworks, adoption levels of IIAR standards, and relationships between national authorities and IIAR's global partners. It's a milestone in IIAR's international engagement, said Rector, and a strategic tool for advancing natural refrigerant adoption.

Among the findings:

- Colombia has adopted IIAR Standards 1, 2, 3, and 4 through ICONTEC.
- Costa Rica, in partnership with CIEMI, used IIAR Standards to develop national refrigeration norms.
- Brazil's ABNT is translating IIAR Standards into Portuguese for future adaptation.
- Chile and Paraguay are in the early stages of adopting safety standards.

These developments underscore a broader trend, said Rector, IIAR Standards are no longer just technical references, they're becoming code documents themselves, recognized in international model codes like the IBC, IFC, UMC, NFPA, and ASHRAE 15.

From a North American perspective, the rise of natural refrigerants in heat pump applications is one of the most significant shifts underway. "We're seeing ammonia and CO_2 being used as heat pumps as part of the broader electrification movement," said Dave Malinauskas, President of CIMCO Refrigeration. "Natural gas boilers are being eliminated in favor of heat pump solutions. Ammonia makes sense for a lot of reasons—it's cheaper, more efficient, and better for the environment."

Malinauskas pointed to the potential for high-grade heat recovery as a game-changer. "Instead of rejecting heat to the atmosphere, we can reuse it. By increasing compression ratios, we can get higher temperatures—ammonia can reach 180 to 185°F, compared to most synthetic refrigerants that top out around 140°F."

This shift is especially relevant for institutional campuses and district heating systems transitioning from steam to hydronic infrastructure. "Higher process temperatures provided by ammonia is a must for facilities that are moving from steam to hydronic heating."

Latin America is emerging as one of IIAR's most dynamic regions. "The cold chain economy there is important to the U.S.," said Eric Smith, IIAR's Vice President and Technical Director. "Multinational end users and manufacturers want consistency in refrigeration design and operation—primarily for safety, but also for reliability."

Smith emphasized that IIAR's early efforts to make educational materials available in Spanish were pivotal. "It wasn't just outreach—it was a mutually beneficial arrangement. They understood the value of natural refrigerants, and we were ready to support them."

The region's growth is visible in participation metrics. "In the last ten years, we've seen significant growth in manufacturers, contractors, and end users engaging with IIAR," said Max Duarte, IIAR's International Committee Chair. "Our events are packed, our courses have high participation, and our chapters are promoting IIAR's goals with real depth."

Duarte also noted the importance of staying neutral in the market. "We work with many people in each region. As we've grown, our members see that we're all in this together; it's not about supporting one company's interests over another, it's about a collective move toward natural refrigerants for the good of everyone."

IIAR's international strategy relies on active chapter engagement, education programs, and strategic alliances with peer organizations and regulatory bodies. These relationships – often formalized through Memorandums of Understanding (MOUs) – enable advocacy, training, and technical exchange.

Key IIAR partners include:

- CIEMI (Costa Rica)
- ACAIRE (Colombia)
- Chilean Chamber of Refrigeration
- ASHRAE, UNEP Cool Coalition, GCCA, EIA, RETA, and others

The research initiative that was started in 2023 is now informing technical training, standard harmonization, and future MOUs. IIAR is working to regularly update the international standards matrix and provide members with detailed country-by-country summaries, said Rector.

IIAR's relevance may soon extend beyond refrigeration. "There's a huge opportunity in the use of ammonia as a fuel," Leibendorfer said. "The maritime shipping industry and others are piloting ammonia-based energy systems, and they've reached out to IIAR and its partners to help develop safety standards."

That outreach is a testament to IIAR's reputation. "We've gotten where we are by managing risk very successfully, which has facilitated the expanded and diverse use of ammonia. ," he added. "And we're going to get even better. We have a robust industry ecosystem, and we're staying more relevant as an industry than other competing [technologies]."

The global movement toward natural refrigerants is not just technical – it's human. "If we can promote the safe use of natural refrigerants," Duarte said, "it benefits everyone. These communities, these markets, this planet."

> "We're seeing expansion into heat pumps, CO_2 systems, hydrocarbon systems, and ammonia in non-conventional applications. It's taking relevance globally."

As IIAR completes new research efforts and global climate agreements are put in place, multinational demand for natural refrigerants is rising.

"The industry itself is redefining in a way that is making natural refrigerants the most viable global solution," said Rector. "Natural refrigerants are driving growth, technology availability, and climate agreements."

"Initiatives promoting natural refrigerants – that limit and help with climate change – are very much becoming global policy," said Rector. "It's energy savings, and it makes business sense to use natural refrigerants; the technology is there, and it's getting better by the day."

"There are larger forces at work, said Rector. "Business interests and small governments alike are transcending local political discourse on climate change. And this is happening on a global scale."

IIAR EXHIBITORS PLAN FOR 2026 San Antonio Conference

The International Institute of All-Natural Refrigeration will host its largest-ever Natural Refrigeration Conference & Expo from March 15 – 18, 2026, in San Antonio, Texas—featuring a packed exhibit hall, approximately 30 educational sessions, including technical papers, white papers, workshops and panels as well as educational programming for students and end users.

Rym Omniewski, IIAR's Meetings, Conference & Expo Coordinator, said three new factors, introduced this year, are attracting interest from the event's exhibitors and attendees. First, IIAR's NRF Lounge will include a sponsored recruiting station in 2026, where recruiting companies will be connected directly to individuals looking for jobs. Also new this year, IIAR's education program session schedule will see an expansion to two morning sessions and one in the afternoon, for both Monday and Tuesday, with committee meetings scheduled for Sunday. Meanwhile, social opportunities like the NRF Lounge will see an expansion with new games and activities, while IIAR's Monday night social event features a live Rodeo at the Pedrotti's Ranch.

The exhibit hall continues to be a major draw for IIAR attendees and exhibitors alike, said Omniewski. "We hear from exhibiting companies that they generate dozens of high-quality leads and make successful partnerships during exhibitor hours - and during the social activities that we have planned, like our golf and Monday night events."

"One of the things that makes this meeting valuable to everyone is that we have so many opportunities to network and meet with each other," she said. "People come ready to talk business, to talk solutions, to hire the next generation of talent. Our exhibiting companies see firsthand how valuable it is to meet face to face."

General registration for IIAR's 2026 Conference & Expo will open in November, but IIAR exhibit space is filling up quickly and sponsor opportunities are still available, said Omniewski, adding that interest in exhibit and sponsorship opportunities, as well as attendance, has ballooned in recent years.

"The growth over the past couple of years has been strong," she said. "We consistently grow members and exhibitors for this event. Since 2022, general registration has jumped by over 500 attendees, and this year our exhibit space has sold faster than ever." Omniewski attributes the growth to the "need to meet up in person to really, effectively, conduct business," a need she says IIAR has responded to by expanding exhibitor capacity – up to 158 exhibitor spaces available in 2025, from 122 in 2022.

IIAR president Gary Schrift agreed with Omniewski that IIAR's event has become the standard place to network and grow business. "We've increased the number of educational sessions, expanded our exhibit hall, and created new tracks to meet the needs of both seasoned professionals and newcomers," said Gary Schrift, IIAR president. "This year's conference is bigger and more inclusive than ever."

One of the more popular networking events, the IIAR exhibitor product showcase, which allows exhibitors to show off new products and services during dedicated presentation time on the exhibit hall floor, has grown in recent years, said Omniewski.

"These product showcase slots have been sold very quickly," she said. "It makes sense because people who are interested in your equipment or services are already there in the exhibit hall, looking to make a decision. There's a high attendance for those showcases." The exhibitor product showcases will be scheduled for Monday and Tuesday, and during extended exhibit hall hours in 2026.

In general, the IIAR conference is well worth the effort to attend because nothing replaces the kind of conversations you can have on the exhibit hall floor, said Omniewski. "The facetime with engineers, policy makers, students, and colleagues is invaluable."

Exhibiting with IIAR includes two full conference registrations for every 100 square feet of exhibit space reserved, and includes a company listing in the online and print conference guide as well as the conference app. But the most popular exhibitor benefit remains the attendee list, which exhibitors get two to three weeks before the conference.

"The attendee list is really a priority for our exhibitor because a presence at IIAR is not just about brand awareness, but it's a real return on investment as well," said Omniewski.

Part of that return on investment is an investment in the next generation of workers in refrigeration, a responsibility IIAR has taken even more seriously this year with

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an expansion of the NRF lounge and the addition of a networking event for the conference's growing population of students and companies looking to employ them.

"This year we'll have an even more fun NRF lounge with different gaming spaces," said Omniewski. "And the new NRF networking event is really exciting. Companies that are hiring will have a presence in the NRF lounge where people who are interested in looking for a job can get information about the companies that are hiring - and then go to the exhibit hall floor and, in many cases, talk to the hiring manager."

Meanwhile, for attendees, the 2026 conference will blend technical depth with strategic networking, offering attendees a chance to shape the future of natural refrigerants through committee work, peer exchange, and direct engagement with industry leaders.

IIAR's 2026 educational program will span six distinct tracks: system design, system safety, decarbonization, facility management, heat pumps, and refrigeration fundamentals. The latter, dubbed "Refrigeration 101," is designed to support students and early-career professionals.

Technical papers and workshops will cover safety, efficiency, and emerging technologies. All sessions will offer professional development hours and be recorded for on-demand access throughout the year.

"You can attend sessions live and revisit others later," said Yesenia Rector, IIAR's director of meetings and international programs. "Recordings will be free for all members and attendees."

The conference will open with the Natural Refrigeration Foundation's (NRF) Golf Tournament on Saturday, March 14, followed by IIAR committee meetings on Sunday.

Networking events will include the Chairman's Reception, a VIP dinner for board and committee members along with other VIPS and the Monday night social event and the exhibitors reception on Tuesday evening in the exhibit hall. The NRF Networking Lounge will offer a quiet space for conversation, coffee, and collaboration near the technical program rooms. "The lounge is a place to recharge between sessions or meet with colleagues," Rector added.

IIAR will continue its commitment to student engagement by offering free registration to university and technical college students, including NRF scholarship recipients, IIAR said. Students will have full access to the conference and be paired with mentors to help navigate the exhibit hall and technical sessions. First-time attendees and end users will also receive discounted registration at IIAR member rates, regardless of membership status.

Committee meetings on Sunday will provide IIAR members with updates on ongoing initiatives and opportunities to contribute to the organization's technical and policy work. To encourage broader participation, meeting times have been shortened to one or two hours.

With expanded education, strategic networking, and inclusive programming, IIAR's 2026 Annual Conference & Expo promises a dynamic experience for engineers, end users, policymakers, and students alike. To view the full schedule and register, visit IIAR's official conference website.

Applying Psychrometrics in Refrigeration

Psychrometrics isn't just a chart on the wall – it's the language of air. And for many facility or production issues, speaking that language often means looking beyond refrigeration as the only option available to solve moisture control problems.

Tom Peterson, founder and CEO of Climate by Design International (CDI), has spent more than three decades building custom desiccant dehumidification systems for facilities where dry air needs go beyond what can be accomplished with refrigeration alone. By applying the science of psychrometrics to a few common facility problems, "we're not just moving air," Peterson said. "We're controlling the environment."

"Refrigeration can only solve your moisture problem to a certain point, whereas with a desiccant, you can go way beyond what refrigeration alone can do," said Peterson. Many people don't think of applying psychrometrics as a solution to the problems they encounter because they're just not used to a thought process that might involve beyond-the-refrigerant reasoning, he added.

"Not everyone has that experience factor [that would lead them to consider psychrometrics]. They may have been taught to think only in tons of refrigeration, because our industry is so focused on refrigeration alone," he said. "But there are limits to how dry you can get with just refrigeration before you start dealing with things like frost, sequential defrost, and other problems."

Peterson applies a desiccant air handling unit to help solve most of these problems. Inside the unit is a wheel filled with desiccant that continually turns, rotating slowly between two airstreams. " The airstream we are conditioning is moisture-filled. That airstream goes into the wheel and the wheel adsorbs that moisture. To then remove the moisture from the wheel it turns into another airstream where the moisture is then ejected to atmosphere."

Many people don't know there is a solution to many of their common moisture problems, or generally speaking, they accept the management of moisture issues because they don't know they have a viable solution to the problem, said Peterson. "Once people find out what a desiccant is, they start finding many places where dry air can be their friend."

Peterson said there are four main areas where applying psychrometrics can take the guesswork out of solving the moisture-related production issues that get the most attention:

1. WASH DOWN RECOVERY

Wash-down recovery in protein rooms can turn into a significant moisture problem quickly. When wash down occurs in a typical 45 degrees processing room, and 140-degree hot water is used for sanitation, "condensation on cold surfaces is dripping everywhere, and so you have to recover that room and get it back to condition before you can start production again, said Peterson. "After sanitation, it takes time to get that room back down to temperature and a moisture level below the point where it can condense. Using a desiccant air handling unit can increase by a 4- to 10-fold factor the amount of drying that can be done. You get that room back faster."

2. LOADING DOCK SAFETY ISSUES

The second most common place moisture-related issues can crop up is the cold storage loading dock, said Peterson, where issues come either from a potential safety risk, i.e., slippery floors, or from a maintenance issue when evaporator fans collect frozen vapor and become unbalanced, bearings and motors then fail. Providing a desiccant unit to dry the air in the vestibule – so that moisture from outside air can't get into a freezer or cooler in the first place – is a preventative solution.

3. PRODUCT ISSUES

A third common area where moisture control can become important is in the more product-related processes, where moisture in the air is an issue that impacts the product itself. Too wet of an environment can cause moisture-regain in the product itself. This issue commonly crops up in applications where a product is meant to be dry. It must be prevented from absorbing moisture, like in pharma applications where moisture can affect the precision of pressing out pills, or in food applications where a crispy texture is needed, where moisture might cause a product to stick to itself or the packaging.

4. IMPROVING ENERGY EFFICIENCY

Sometimes, controlling moisture with a desiccant might simply be an easy way to improve energy efficiency in freezers or coolers, said Peterson. "There can be an energy payoff to paying attention to psychrometrics. Most of the time, the financial rewards come in increased productivity and increased safety, but there can also be operational benefits like improved energy efficiency as well."

When it comes to applying psychrometrics to solve these problems, "we have to look at all of the factors affecting moisture-in-air as interrelated," said Peterson. "We need to construct a comprehensive understanding of all of them in a given situation and understanding the psychrometric chart allows us to be able to know any two conditions and then understand all the others.."

Peterson is the presenter of the IIAR Webinar "Psychrometrics, The Science of Moisture in Air," available to IIAR members through IIAR's educational resources.

During the webinar, he reviews several important principles for decision making including how he uses seven factors to determine an overall picture of a given facility's psychrometrics, including: 1) vapor pressure; 2) dew point; 3) relative humidity; 4) wet bulb; 5) dry bulb; 6) enthalpy, and 7) the density of air.

Tony Lundell, IIAR's Senior Director of Standards and Safety, said the webinar covers an often-overlooked strategy for managing moisture. "Where moisture needs to be removed from the air below the freezing point, an air handling unit with a desiccant wheel in it is a great option."

"Managing moisture so it helps your product, prevents wasted energy, and reduces maintenance, is where the payoff for paying attention to psychometrics comes in – in the science of moisture in air," said Peterson.

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GOVERNMENT RELATIONS

BY LOWELL RANDEL, IIAR GOVERNMENT RELATIONS DIRECTOR

DEPARTMENT OF LABOR
Advances Regulatory Reforms

As the Trump Administration enters the second half of its first year, efforts continue to reform the structure and operation of the federal government. President Trump signaled deregulation would be a priority for his administration early in his term with the signing of an Executive Order entitled "Unleashing Prosperity Through Deregulation". In his first term, President Trump implemented aggressive deregulation efforts by mandating that two federal regulations be eliminated for each new rule issued. The President has directed federal agencies to take an even bolder step by eliminating ten existing regulations for every new rule. Since the signing of the order, federal agencies have begun the process of identifying regulatory changes.

The Department of Labor is undertaking efforts to reduce the regulatory burden on industry, including several actions specific to the Occupational Safety and Health Administration (OSHA) that could impact the industrial refrigeration industry. On July 1st, Secretary of Labor Lori Chavez-Deremer announced the Department's initial deregulatory efforts, which aim to cut regulatory burdens, spur job creation, and fuel economic opportunity for American workers and businesses. The Department's plan includes 63 deregulatory actions aimed at reversing costly and burdensome rules. By comparison, the Department of Labor took 37 deregulatory actions in President Trump's first term.

The 63 actions taken by DOL cover a wide variety of policy areas, and many will require completing the notice and comment rulemaking process, which can be lengthy. Other actions can go into effect immediately.

While none of the actions are specific to the industrial refrigeration industry, below are several actions that could be of interest to IIAR members:

Revising Respiratory Protection Requirements – OSHA has also proposed a rule that would remove medical evaluation requirements for filtering facepiece respirators (FFR) and loose-fitting powered air-purifying respirators (PAPR). In justifying the proposal, OSHA has made a preliminary determination that using a respirator may place a physiological burden on employees that varies with the type of respirator worn, the job and workplace conditions in which the respirator is used, and the medical status of the employee. Medical evaluations are currently required for all respirators.

Withdrawal of OSHA 300 Log Proposal – OSHA has withdrawn a proposed rule to amend the OSHA 300 Log by requiring employers to record work-related musculoskeletal disorders. The move signals a departure from focusing on ergonomics. Other aspects of the OSHA 300 Log and reporting requirements would not change.

Limiting General Duty Clause Violations – OSHA is proposing to clarify its interpretation of the General Duty Clause to exclude from enforcement known hazards that are inherent and inseparable from the core nature of a professional activity or performance. If finalized, the new rule would codify the principle that the General Duty Clause does not authorize OSHA to prohibit, restrict, or penalize inherently risky activities that are intrinsic to professional, athletic, or entertainment occupations. While the rule is focused on industries other than industrial refrigeration, it is worth noting the potentially broader implications for how the agency may approach the General Duty Clause moving forward.

Rescinding Construction Illumination Rule – Another proposed rule would rescind OSHA's construction illumination requirements (29 CFR 1926.26 and 1926.56), which require construction areas,

OSHA has also recently updated its guidance on penalty and debt collection procedures in the Field Operations Manual in an effort to minimize the burden on small businesses and increase prompt hazard abatement.

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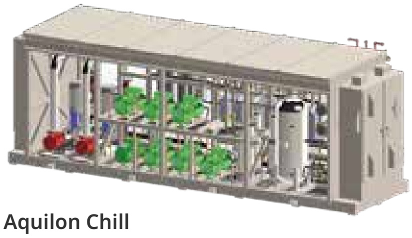

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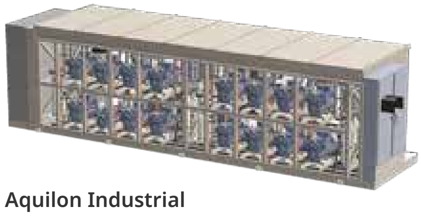

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aisles, stairs, ramps, runways, corridors, offices, shops, and storage areas where work is in progress to be lighted with either natural or artificial illumination. OSHA said it is proposing this removal because it "does not reduce a significant risk to workers."

In addition to the deregulatory actions, the Department of Labor and OSHA are taking other actions to reduce burdens on employers. On June 2nd, the Department announced the launch of its opinion letter program, which is intended to provide meaningful compliance assistance that helps workers, employers, and other stakeholders understand how federal labor laws apply in specific workplace situations. The effort will impact various parts of the DOL, including OSHA, Wage and Hour Division, and the Employee Benefits Security Administration. Opinion letters provide official written interpretations from the Department's enforcement agencies, explaining how laws apply to specific factual circumstances presented by individuals or organizations. DOL has stated that opinion letters are an important tool in ensuring workers and businesses alike have access to clear, practical guidance.

OSHA has also recently updated its guidance on penalty and debt collection procedures in the Field Operations Manual in an effort to minimize the burden on small businesses and increase prompt hazard abatement. The new policy, outlined in the Penalties and Debt Collection section of OSHA's Field Operations Manual, increases penalty reductions for small employers, making it easier for small businesses to invest resources in compliance and hazard abatement. Under past policies, only businesses with 10 or fewer employees were eligible for a penalty reduction level of up to 70 percent. The new policy will expand eligibility to include businesses that employ up to 25 employees. Employers who immediately take steps to address or correct a hazard would be eligible for a 15 percent penalty reduction.

Additionally, the updated policy expands the penalty reduction for employers without a history of serious, willful, repeat, or failure-to-abate OSHA violations. Under OSHA's revised policy, employers who have never been inspected by federal OSHA or an OSHA State Plan, as well as employers who have been inspected in the previous five years and had no serious, willful, or failure-to-abate violations, are eligible for a 20 percent penalty reduction.

The DOL and OSHA actions are just a part of the Trump Administration's efforts to advance regulatory reforms across the federal government. IIAR will continue to actively monitor deregulatory actions and opportunities and keep members updated on developments.

In addition to the deregulatory actions, the Department of Labor and OSHA are taking other actions to reduce burdens on employers.

Momentum Builds for CO2 at District Energy Conference

Nearly 900 district energy professionals from 30 countries convened in Minneapolis, Minnesota, for the Annual IDEA District Energy Conference and Trade Show, held June 2–5, 2025, where the International Institute of All-Natural Refrigeration (IIAR) was invited to attend and contribute to IDEA's business meeting.

The meeting with IIAR was organized to explore ways for IIAR members and equipment manufacturers to expand the use of natural refrigerants—particularly in heat pumps and chillers—across the district heating and cooling industry. While the broader discussions covered natural refrigerants in general, Robert Croghan, CEO of Cascara Energy, said he was especially pleased to see momentum building for CO_2 as a potential district energy vector fluid, offering an alternative to water in certain applications.

Organized under the theme "Aggregate, Integrate, Innovate," the event showcased how centralized thermal systems are evolving to meet the demands of a decarbonizing, digitalizing, and increasingly electrified world.

"Aggregation, integration, and innovation are a combination of qualities that are unique to district energy," said Rob Thornton, IDEA President and CEO. "Together, these three capabilities enable the technology's ability to deliver resilient, efficient, reliable, and sustainable energy solutions for cities and communities worldwide."

IIAR represented natural refrigerants on the IDEA exhibit hall floor, where Croghan noted that CO_2 heat pumps and chillers are rapidly gaining momentum across the refrigeration and HVAC industries. "We're seeing adoption across all scales—from single-family homes to large-scale industrial systems of 50 MW and above," he said.

"Everyone is coming out with a heat pump solution now, and CO_2 as a natural refrigerant is being adopted quickly," Croghan continued. "We're looking closely at how people are customizing CO_2 applications, and it's an important area to focus on because the technology is rapidly maturing."

Croghan added that the equipment and infrastructure needed to make CO_2 heat pump and chiller-based district energy systems feasible "is available now, whereas it wasn't before," thanks to the convergence of three trends: the widespread adoption of CO_2 in the heat pump and chiller markets, the growth of carbon capture and utilization projects, and the presence of established large-scale CO_2 pipeline networks already in operation.

"This combination means we now have both the technology and the transport infrastructure to enable large-scale CO_2 district energy systems. The environment for carbon capture, use, storage, and transport is well established, and CO_2 is already present within the property line of many customers, making it a far more practical and cost-effective option for district energy."

"In the past, the cost of building dedicated CO_2 pipelines was prohibitive," said Croghan. "Today, with established infrastructure, available equipment, large-scale compressors, and the necessary pipe systems already in place—and with clear IIAR standards—the pathway to deployment is much more practical."

Croghan said he was especially encouraged to see IIAR in attendance at the IDEA event because the regulations and standards that have been developed around CO_2 are accelerating the adoption of heat pumps and chillers using natural refrigerants.

"It's encouraging to see IIAR at IDEA, as they are a leading resource for CO_2 standards and play a key role in establishing its credibility as a large-scale refrigerant. Expanding education around CO_2 supports

industry progress," he said, adding, "Large-scale district cooling can benefit greatly from CO_2-based systems, given their efficiency, environmental advantages, and growing regulatory support."

Wayne Barnett, Head of Public Policy and External Affairs at Cordia Energy, who facilitated the business development meeting where IIAR representative Tony Lundell was invited to speak, said his interest in IIAR was in how the two organizations could collaborate to extend IIAR's educational resources into new markets.

The event showcased how centralized thermal systems are evolving to meet the demands of a decarbonizing, digitalizing, and increasingly electrified world.

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"We've had good conversations and follow up with IIAR and we're having discussions around expanding this effort," said Barnett. "Our core business is thermal district heating and cooling, which makes IIAR a natural partner. As a recognized part of the regulatory and standards framework, IIAR is well-positioned to extend its educational resources on CO_2 and other natural refrigerants into broader policy and commercial discussions and to build awareness among stakeholders well beyond the industry, supporting both best practices and decarbonization goals."

Tony Lundell, IIAR's Senior Director of Standards and Safety, said IIAR was able to bring information about natural refrigerants—such as challenges and best practices—to the IDEA conference, where many attendees were exploring the new possibilities presented by natural refrigerant use in district heating and cooling.

"This was an exciting event for IIAR because it was a chance for us to extend our years of rigorous standards development and natural refrigerant knowledge to a new audience," said Lundell. "Now, as these new applications for natural refrigerants are emerging, it's a good time to think about how we can work together and advocate together going forward."

The integration of diverse energy sources, including renewables, waste heat, combined heat and power, and even data center thermal loads, earned focus at the event.

The District Thermal Energy Networks Workshop examined how utilities and municipalities are coupling thermal systems with electricity, natural gas, and wastewater networks to create flexible, low-carbon infrastructure. Meanwhile, the District Energy and Data Centers Workshop explored the convergence of two rapidly growing sectors: digital infrastructure and urban thermal systems. With data centers proliferating to meet global demand, their need for firm power and constant cooling—and their production of massive volumes of low-grade heat—makes them ideal candidates for district energy integration, said IDEA in a statement.

Speakers from global data center operators and government agencies discussed heat export programs, co-location strategies, and regulatory frameworks for grid infrastructure. Technology providers showcased innovations in CHP, thermal storage, and energy optimization, positioning district energy as a key enabler of sustainable digital growth, said IDEA, adding "data centers and district energy go better together."

The conference also featured plenary panels with CEOs from leading district energy companies, an Innovation Awards ceremony, and technical tours of Cordia's Main Plant and District Energy in St. Paul, Minnesota. Keynote speaker Joseph Majkut of CSIS offered a perspective on energy security and climate resilience, framing district energy as critical infrastructure in an era of extreme weather and shifting federal mandates.

Know Your Incident Timelines

BY KEM RUSSELL

Like a good science fiction plot, any ammonia-related incident has two parallel timelines. Making sure you're aware of both of them, even before anything happens, can make the difference between a public relations and operational horror story and a good outcome.

Take one incident where the lack of awareness by facility staff led to a lot more chaos than should have been expected. It was a normal work shift when several employees coming into a process area smelled a very strong, irritating odor.

Several of them knew that the refrigeration department had just a short time earlier been working on the refrigeration system in the area. But they didn't know, or remember, who to call about the strong smell. Panicking, more than one of them called 911 as they all rapidly exited the area to the outside.

Almost fifteen to twenty minutes later, someone finally remembered to call the facility safety manager, who quickly drove to the site. When he got there, he found several ambulances, fire department engines, police and sheriff department cruisers, and, of course, the media. As the safety manager approached the scene, he also noticed what appeared to be several employees lying on the ground, some seemingly convulsing. In the safety manager's words, "It was chaos!"

In this particular event, the employees did not remember who was supposed to be called or what the facility's emergency plan was. The safety manager quickly contacted the refrigeration department and began investigating the incident.

It was soon learned that this was not an ammonia release, or even any other kind of release. What the employees had smelled turned out to be a cleaning agent used for the sanitation of the process equipment in the area.

Nevertheless, the damage was already done. In a very short time, news of this incident quickly spread through the media. One regulatory agency called the safety manager, asking why they had not reported this serious ammonia release. From the quick investigation, the safety manager was able to explain there was "not an ammonia release."

A lesson learned from this event is that there are two timelines that should always be considered. One is a timeline that should begin well in advance of any incident. The other timeline begins at the moment of the event. And both are very important to always keep in mind.

The "before event" timeline is concerned with what might be done to prepare employees for any type of incident. This means companies should train all employees on several things, which can include: the emergency plan (action or response); what specific actions should be taken when an event occurs (these may vary depending on the emergency); what the chain of command is and who should be notified within a company; how to properly evacuate all areas in a facility; where a pre-determined gathering point is outside of the facility; what areas within the facility could be used for shelter-in-place; how to identify a chemical; how to perform basic first-aid; and who should talk to the media. Training drills that prepare employees to better respond when an event occurs are essential to the "before event" timeline.

The event described above would have likely unfolded much differently, with less of an impact on the company, if "before event" training had established a reflexive employee response. At the least, employees would not have made several separate 911 calls, indicating that there was a large emergency.

In this case, the correct facility personnel would have been contacted, and the facility would have been exited in a safe and organized manner. In the end, the panic experienced by some of the employees was not from a physical effect of a chemical, but a psychological effect that caused "panic attack" symptoms, including minor convulsions.

Meanwhile, the second timeline begins the moment the event occurs. In this scenario, several actions should take place during a very short time period. To illustrate this timeline, let's look at another event of an ammonia release occurring outside of a refrigerated facility and examine some of the approximate times that events occur as the incident unfolds.

In this case, a 150-psig relief valve on a surge drum released. The estimated wind speed was approximately 7 mph, which was normal for the area. But in these few minutes, two minutes to be exact, the wind carried the ammonia over 1000 feet, which was well past the facility property line.

During the first couple of minutes, the ammonia could be smelled outside of the facility's property line. There was no plan in place to determine how to rapidly notify or alert the public of what to do if an ammonia release occurred. In this event, it was actually someone outside the facility's property who called 911. The 911 dispatcher quickly notified responders, which in this case included members of the fire department and police department. Once the call arrived at the fire department, the responding fire company engine quickly prepared, left the station, and in about seven minutes was on site at the facility. A police unit arrived shortly after that.

A lesson learned from this event is that there are two timelines that should always be considered.

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Once the fire department arrived, it took a few more minutes for the engine captain to determine what the event was, the status of the facility employees (they were all accounted for and safe), and where to set up exclusion areas.

With the identification and confirmation that this was an ammonia release, the fire captain radioed fire-dispatch to request the hazmat team to respond. It would be over another 30 minutes before the hazmat team arrived. State Patrol (in this particular state, the designated incident commander for hazmat events) was also contacted by the fire department to coordinate what was happening. The local ambulance service also sent an aid unit, which arrived a few minutes after the fire engine.

In the follow-up to the ammonia release, it was stated by the Office of Emergency Management that whoever owns the chemical is responsible for notifications, including alerting the public of the emergency. This was not new information, but the lesson learned was potentially how little time was available to accomplish the notification of the people and businesses around the facility or in the potentially affected area.

As was found in this event, the ammonia smell went over 1,000 feet in the first few minutes of the release, which meant there was not sufficient time to make phone calls to all potentially affected off-site people or businesses. The proper response would have required a plan to have been developed and coordinated with local agencies on how to rapidly notify the surrounding area. This plan would also involve informing and educating the surrounding population prior to future events.

Another lesson learned was that since this particular facility had an "emergency action plan" and would rely on outside emergency responders, the length of time it would take to have the properly trained and equipped hazmat responders on the scene was well past the first 30 minutes of the event.

Analysis of the event timeline turned out to be an eye-opener for facility personnel, illustrating the importance of close coordination with local emergency responders and possibly a local refrigeration contractor to improve the means and methods of dealing with an ammonia release in a timely, safe, and effective manner.

These two events illustrate lessons that can be learned to improve some of the actions and responses to emergencies. The first event shows the importance of doing proper training in a timeline well in advance of an incident, and that properly trained people should both be able to safely evacuate and be able to communicate to the right people, agencies, and media.

The second incident shows the importance of developing an emergency plan that takes into account the rapid timeline of actions that should occur during an ammonia event. Also, the importance of coordinating with local responders in developing an overall action or response plan that will provide the most effective, efficient, and timely actions.

Have you considered the timelines before and during an emergency at your facility?

Have you considered the timelines before and during an emergency at your facility?

IIAR Releases CO_2 Fact Sheet

In response to growing demand for accessible, technically sound guidance, the International Institute of All-Natural Refrigeration (IIAR) has released a new CO_2 Refrigeration Fact Sheet—a concise overview of the use of CO_2, including safety considerations, system guidelines, and design considerations. Additional fact sheets for ammonia and hydrocarbons will follow.

IIAR Marketing Committee Chair, Stephanie Smith, said her committee was responsible for producing the fact sheets to help business owners choose which natural refrigerant applications may fit best for them.

"With more information available, it's more important than ever to be able to summarize and keep it simple," said Smith. "These IIAR fact sheets come with easy and basic information that IIAR is uniquely suited to provide to end users who are trying to make a decision, or to the general public who are trying to learn more about natural refrigerants."

IIAR's first goal, as always, is the creation of safety standards that promote more widespread adoption of ammonia, CO_2, and hydrocarbons. But with an extensive library of standards and technical handbooks, refrigerant-specific fact sheets can help experts and laypeople quickly compare refrigerants.

"IIAR decided to develop these fact sheets because there's a need for a broader understanding of IIAR standards, with the increased use of hydrocarbons and CO_2, especially," said Smith. "Highlighting the benefits of each refrigerant in a one-pager is a great resource. It gives anyone who's interested quick, easier access to IIAR's wealth of information."

Carbon dioxide has long been recognized for its environmental advantages—zero ozone depletion potential and a global warming potential of just 1. But its adoption has been slowed by the absence of unified safety standards and building code recognition. The inclusion of IIAR's CO_2 standard into the ICBC framework changes that equation.

The ANSI/IIAR CO_2-2021 Safety Standard for closed-circuit carbon dioxide refrigeration systems was formally integrated into the International Code Council's Building Codes (ICBC) in 2024 – a move that signals growing institutional support for low-GWP refrigerants and the infrastructure needed to deploy them safely.

Now, architects, engineers, contractors, and code officials have a clear, codified reference for designing and inspecting CO_2 systems. This reduces regulatory ambiguity and accelerates adoption across commercial and industrial sectors.

But it has also broadened the interest in CO_2 generally, beyond the industrial refrigeration industry into applications like district heating and cooling, where the wealth of IIAR standards and information may prove useful.

And within the world of industrial refrigeration, CO_2 is growing more attractive for factors like its lower energy consumption, said Smith. "The next step is getting this information, like the energy efficiency payoff of CO_2, into an easier format to use and then provide it to others."

"IIAR's fact sheets are a good place to start if you don't know where to start and you need basic information on refrigerants," she added.

The release of IIAR's fact sheet is a timely addition to IIAR's resources, said Smith. With regulatory pressure mounting, industry professionals are seeking natural refrigerants that balance performance, safety, and sustainability. CO_2 fits the bill, but its unique thermodynamic profile and operating characteristics require specialized knowledge.

IIAR's fact sheet bridges the gap between technical depth and practical accessibility. It's tailored for engineers, technicians, facility managers, and policymakers who need a reliable snapshot of CO_2's capabilities and constraints—without wading through dense standards or textbooks.

Here's what readers will find most useful:

Refrigerant Profile

- Chemical name: Carbon Dioxide (CO_2)
- ASHRAE designation: R-744
- Ozone Depletion Potential (ODP): 0
- Global Warming Potential (GWP): 1 (benchmark value)
- Safety classification: A1 (non-toxic, non-flammable)
- Thermodynamic Characteristics
- Operates at high pressures, especially in transcritical systems
- Excellent heat transfer properties, enabling compact system designs
- Requires specialized components rated for CO_2 pressures

System Types

- Subcritical systems (often cascade with ammonia or HFCs)
- Transcritical systems (common in supermarkets and heat pumps)
- Secondary loop systems (CO_2 as a fluid in indirect systems)

Advantages

- Environmentally benign: no ozone depletion, negligible climate impact
- Readily available and inexpensive
- High volumetric cooling capacity

Challenges

- High operating pressures demand robust system design
- Efficiency can drop in warm climates without proper optimization
- Requires training and familiarity with CO_2-specific safety protocols

The fact sheet also references IIAR's CO_2 Safety Standard, the first of its kind, which outlines best practices for system design, installation, and operation. This standard complements the fact sheet by offering deeper guidance for facilities transitioning to CO_2 or expanding its use.

The fact sheet is more than a technical summary, said Smith, it's more of a strategic tool. As CO_2 adoption accelerates across food retail, cold storage, and industrial processing, stakeholders need clear, credible information to guide investment and training. IIAR's fact sheet helps normalize CO_2 as a mainstream refrigerant, reinforcing its role in a low-GWP future.

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IIAR STANDARDS UPDATE

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

IIAR Suite of Standards Update:

IIAR 5, 6, & 7 2025 Revisions Approved, IIAR 4, 8, & 9 Now Opened for Review for Next Revisions, IIAR CO2-Addendum A and IIAR HC Nearing Completion

The International Institute of All-Natural Refrigeration standards revisions presently has IIAR 2 under review for its targeted 2026 revision. Standards IIAR 4, IIAR 8, and IIAR 9 are currently open for review as well, and IIAR 5, IIAR 6, and IIAR 7 revisions were ANSI "approved" in July 2025. Meanwhile, IIAR's first hydrocarbons standard is targeted for an ANSI approval in 2025, while the ANSI/IIAR CO2-2021 Safety Standard for Closed-Circuit Carbon Dioxide Refrigeration Systems is finalizing an Addendum A soon and will sequentially be opened for its targeted 2026 revision.

This article provides a status report on the IIAR suite of standards. Behind each update is a network of subcommittee chairs, staff facilitators, and consensus body members working to ensure the standards reflect current safety practice, regulatory clarity, and cross-document consistency. Don Faust is currently the IIAR Standards Committee Chairman.

IIAR 1: ANSI/IIAR 1-2022 Standard for Definitions and Terminology Used in IIAR Standards is presently in effect. It will be opened up for review starting in mid-2026 for its next revision, with a targeted completion with ANSI approval in 2027. Jake Denison will serve as the IIAR 1 subcommittee chair for this next revision, and Tony Lundell, senior director of standards and safety at IIAR, will serve as the IIAR staff facilitator. An IIAR 1 future revision considerations (FRC) list has captured suggestions and considerations for its next revision.

IIAR 2: ANSI/IIAR 2-2021 Standard for Design of Safe Closed-Circuit Ammonia Refrigeration Systems is presently in effect. It is presently opened now for review for its next revision, with a targeted completion with ANSI approval in 2026. Mark Bazis Jr. is the IIAR 2 subcommittee chair, and Matt Chojnacki is the IIAR staff facilitator, and Tony Lundell and Eric Smith are supporting facilitation from IIAR staff who have both facilitated previous IIAR 2 revisions. An IIAR 2 FRC list has captured suggestions and considerations for its next revision, which are being addressed at this time.

IIAR 3: ANSI/IIAR 3-2022 Ammonia Refrigeration Valves is presently in effect. It will be opened up for review starting in mid-2026 for its next revision, with a targeted completion with ANSI approval in 2027. Morton Juel Skovrup will serve as the IIAR 3 subcommittee chair for this next revision, and Lundell will serve as the IIAR staff facilitator. This standard provides minimum "performance criteria" requirements for ammonia refrigeration valves and strainers that are used in closed-circuit ammonia refrigeration systems. AN IIAR 3 FRC list has captured suggestions and considerations for its next revision.

IIAR 4: ANSI/IIAR 4-2020 Standard for the Installation of Closed Circuit Ammonia Refrigeration Systems is presently open for review for its next revision, with a targeted completion with ANSI approval in 2026. Brian Alleman is the IIAR 4 Subcommittee Chair. Chojnacki and Lundell are the IIAR staff facilitators. An IIAR 4 FRC list has captured suggestions and considerations for its next revision.

IIAR 5: ANSI/IIAR 5-2025 Standard for the Startup of Closed-Circuit Ammonia Refrigeration Systems was ANSI Approved on July 3rd, 2025. Nick Nechay served as the IIAR 5 subcommittee chair, and Lundell served as the IIAR staff facilitator. The revision addresses the standard to harmonize items with IIAR 2, IIAR 4, IIAR 6, and IIAR 7.

IIAR 6: ANSI/IIAR 6-2025 Standard for Inspection, Testing, and Maintenance of Closed-Circuit Ammonia Refrigeration Systems was ANSI Approved on July 7th, 2025. Jeff Sutton is the IIAR 6 subcommittee chair, and Lundell is the IIAR staff facilitator. The revision addresses the standard to harmonize items with IIAR 2, IIAR 4, IIAR 5, and IIAR 7. Appendix B, which was updated to include the old 109 Inspections, was removed from this 2025 Revision. An IIAR 6 Certificate Course, instructed by Tony Lundell of IIAR staff, with twenty-six (26) passing participants, occurred at the RETA 2024 Conference in Grapevine, Texas.

IIAR 7: ANSI/IIAR 7-2025 Standard for Operating Procedures for Closed-Circuit Ammonia Refrigeration Systems was ANSI Approved on July 7th, 2025. Lesley Schafer is the IIAR 7 subcommittee chair, and Lundell is the IIAR staff facilitator. The revision addresses the standard to harmonize items with IIAR 2, IIAR 5, and IIAR 6. Example Operating Procedures Templates, along with five (5) P&IDs, were included as Appendix D with this 2025 Revision.

IIAR 8: ANSI/IIAR 8-2020 Standard for Decommissioning of Closed-Circuit Ammonia Refrigeration Systems is presently open for review for its next revision, with a targeted completion with ANSI approval in 2026. Lesley Schafer is presently the IIAR 4 subcommittee chair, and Chojnacki and Lundell are the IIAR staff facilitators. An IIAR 8 FRC list has captured suggestions and considerations for its next revision.

IIAR 9: ANSI/IIAR 9-2020 Standard for Minimum System Safety Requirements for Existing Closed-Circuit Ammonia Refrigeration Systems recently had an Addendum A developed to address a scope change and an interpretation, provide a clear compliance deadline, address some simple edits, and provide an informative flow chart. Also, an IIAR 9 Checklist was developed as a tool. It is presently open for its next revision with a targeted ANSI approval within 2026. Eric Johnston is the IIAR 9 subcommittee chair, and Lundell is the IIAR staff facilitator. An IIAR 9 Certificate Course, instructed by Tony Lundell of IIAR staff, will occur during the RETA 2025 Conference in Spokane, WA. The initial evaluation and/or acknowledgement to meet compliance is due January 1st, 2026, for (older) existing closed-circuit ammonia refrigeration systems.

CARBON DIOXIDE (IIAR STANDARD):

IIAR CO2: ANSI/IIAR CO2-2021 Safety Standard for Closed-Circuit Carbon Dioxide Refrigeration Systems recently had an Addendum A finish its first (1st) public review receiving three (3) comments that are being addressed for Chapter 11, Pressure Relief Capacity Determination that focuses on the "C = fDL" equation to determine what is the "f" in the equation for covering subcritical and supercritical conditions (which is now not a constant). Once the Addendum A is completed and ANSI-approved, the full standard will be opened up for its targeted 2026 revision. John Collins is the IIAR CO2 subcommittee chair, and Lundell is the IIAR staff facilitator.

HYDROCARBONS (STANDARD IN DEVELOPMENT):

IIAR HC: IIAR HC-202x Safety Standard for Closed-Circuit Refrigeration Systems Utilizing Hydrocarbon Refrigerants is a standard presently in development. This standard pertains to utilizing "natural" hydrocarbon refrigerants that have zero ozone-depleting potential and ultra-low global warming potential. The committee reviewed and developed responses to one hundred sixty-one (161) public review #1 comments received, fifteen (15) public review #2 comments received, and two (2) (Informative) Appendix A comments received. Joseph Pillis is the IIAR HC subcommittee chair, and Lundell is the IIAR staff facilitator. With the public reviews completed, this standard in development is now being reviewed by the IIAR Standards Committee Voting Members, IIAR Consensus Body Members, and the IIAR Board of Directors for their votes to approve. Once the voting is completed/addressed/resolved, the standard is targeted for an ANSI Approval within 2025.

IIAR Represents North America at World Refrigeration Day

In a year defined by climate urgency and supply chain volatility, the International Institute of Refrigeration, IIR, said it convened a landmark event in Paris to mark World Refrigeration Day 2025.

With over 170 participants from 60-plus countries, IIR said the gathering spotlighted the global cold chain as the foundation of modern civilization and called on all countries to establish National Refrigeration Committees to take climate action.

“A cold chain system, the temperature-controlled supply chain for perishable goods, is the silent but indispensable backbone of modern human civilization, said Rokhmin Dahuri, former Minister of Marine Affairs and Fisheries of Indonesia.

“This is the decade where sustainable refrigeration will shape our societies. Let’s be visionary, let’s be disruptive, and let’s be inclusive,” said Yosr Allouche, Director General of IIR.

The IIR also announced the launch of a new report series, called the Global Refrigeration Outlook, to guide policy, science, and finance. Representatives from the International Institute of All-Natural Refrigeration, IIAR, and member companies, including Danfoss Climate Solutions and Mayekawa, were on hand to showcase new innovations in natural refrigerants and advocate for the policies and investment that will enable the long-term growth of natural refrigerants.

IIAR member and president of CIMCO Refrigeration, Dave Malinauskas, who represented IIAR at the IIR event, said IIAR's involvement as an industry partner represented "a huge opportunity [for both organizations] to collaborate in Europe."

“We were excited to attend the IIR event this year,” said IIAR president Gary Schrift, who said IIAR’s presence has helped the organization build support and expand global initiatives through relationships with IIR’s policy contacts and representatives.

The IIR event brought together policy makers, researchers, and engineers, said Malinauskas, adding that climate change, decarbonization, and finding ways to reduce global food waste in an increasingly hungry world were three main themes.

“We all know about climate change, but what doesn’t get as much focus is the idea that developed cold chains reduce food waste, and in turn save lives. Right now, 30 percent of the food we produce globally is wasted. That’s enough to feed 900 million people,” he said.

IIR conference presenter, Mustapha Abdullahi, Director General, Energy Commission, Nigeria, echoed that idea, saying refrigeration and particularly energy efficiency are important in Nigeria, where unusually hot temperatures pose unique challenges to a developing cold chain. "The major issue we're getting is really to preserve this food," he said.

The IIR meeting was a chance to tackle problems that developing cold chains face, and the event represents a unique opportunity for IIAR to help lead a global effort to solve these problems – by extending the deep technical resources and standards IIAR is known for, said Malinauskas.

"IIR sees themselves as facilitators, and IIAR, with its standards and technical resources, fits in at that same level," he said.

The IIR's main initiative at its World Refrigeration Day event was to propose the formation of national committees that IIR said would bring together ministries, academia, and industry to align policy, investment, and workforce development. "Refrigeration is no longer a side issue; it is core infrastructure," said IIR Director General Yosr Allouche in her keynote presentation.

Meanwhile, representatives for the Multilateral Fund for the Implementation of the Montreal Protocol emphasized the importance of early action in emerging sectors, particularly in developing countries, aligning with the Kigali Amendment's goals.

The event's emphasis on natural refrigerants and integrated cold chain solutions spotlighted technologies showcased by Carrier Transicold, Chereau, Danfoss, Mayekawa, and others attending the event to demonstrate the viability of low-GWP systems across transport, food processing, and healthcare.

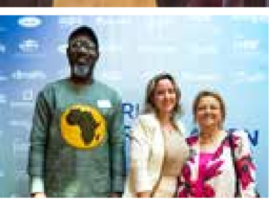
IIR and IIAR member Andy Pearson of Star Refrigeration underscored the need for cross-collaboration on a global scale, saying of the global refrigeration environment, "We must break down silos. Refrigeration touches everything, from vaccines to food to climate. We need integrated solutions."

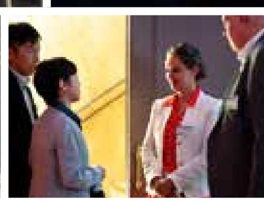
Miki Yamanaka of Daikin added, "We're seeing real momentum in applying low-GWP technologies. But we need enabling policies and predictable investment to scale."

The IIR event video and attendee interviews captured the energy and diversity of the event. Stephen Gill, founder of World Refrigeration Day, reflected on the sector's evolution: "We've gone from raising awareness to driving action. This year's event shows how far we've come—and how far we still need to go."

The IIR said it hoped its call for National Refrigeration Committees would be more than symbolic, adding that the idea is meant to be a blueprint for coordinated action. For policymakers, it offers a framework to align climate goals with economic development. For engineers and end-users, it signals a shift toward integrated, sustainable systems. And for sustainability professionals, it reinforces the role of refrigeration in achieving climate targets, IIR said in a statement.

Above all, the call for collaboration is a global, all-hands-on-deck moment for IIR. "We are witnessing the rebirth of the IIR, more relevant than ever, more united than ever," said Professor Min-Soo Kim, President of the IIR General Conference.





IIAR Peru Chapter Meeting Draws Full House, Focuses on Sustainability and Standards

The IIAR Peru Chapter's latest International Seminar, June 4-5, drew a packed house, with almost 300 attendees from over 14 countries and a high-caliber lineup of technical presentations, underscoring the region’s growing commitment to natural refrigerants and the standards that support them.

Held in Lima, the two-day event maxed out its registration capacity and delivered what organizers called “a great industry turnout” with strong engagement from engineers, end users, and government representatives.

“The presentations were extremely professional and covered a wide range of topics,” said IIAR’s Vice President – Education, Outreach and Events, Yesenia Rector.

Rector supported the IIAR Manager for Latin America, Federico Alarcon, who coordínated the event. “We saw a lot of interest in system comparisons, efficiency strategies, and especially in how our industry can stay sustainable in the face of global refrigerant regulations,” said Alarcon.

The meeting featured presentations on CO_2 cascade systems, hydraulic efficiency in pumped ammonia systems, ammonia system management, and comparative analyses of ammonia, CO_2 subcritical cascade, and CO_2 transcritical systems. One session focused on blast freezing efficiency for post-harvest applications – a key concern for Peru’s agricultural exporters.

But the unifying theme was sustainability. With HFC and F-gas regulations tightening worldwide, attendees explored how natural refrigerants like ammonia, CO_2, and hydrocarbons can meet both environmental and performance goals. “The main concern is the sustainability of refrigerants,” Rector said. “Peru trades heavily with Japan, China, and Europe, so systems need to align with global expectations.”

The success of the Peru Chapter International Seminar reflects a broader trend across Latin America: countries are increasingly turning to IIAR for technical guidance, training, and standards adoption. In the absence of clear national regulations for ammonia and CO_2 systems, IIAR’s standards have become the de facto reference.

We’re seeing more end users become group members after events like this,” Rector noted. “They’re looking for certificate courses, access to standards, and a community that can help them navigate the transition to natural refrigerants.”

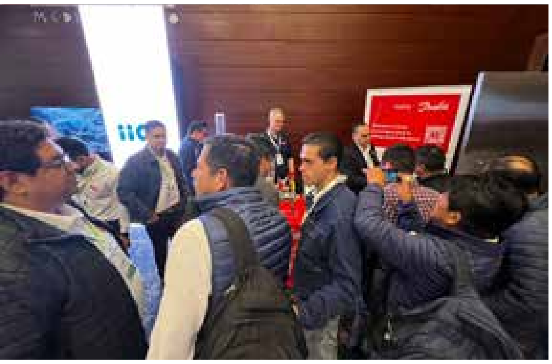
The momentum is what IIAR envisioned when it launched its Chapter initiative, said Rector. Since 2009, IIAR has hosted Industrial Refrigeration Seminars across Latin America to bring technical education to professionals who can’t easily attend

 (continued from page 30)

the annual IIAR Conference. The Chapter model builds on that foundation, enabling local members to organize regular meetings, collaborate with government agencies, and promote IIAR's mission in their own countries. The leadership and hard work of the volunteers who work in the IIAR Chapters has been key to the success of these international seminars.

IIAR Chapters are composed of members residing outside the United States and serve as regional hubs for education, standards adoption, and professional development. Through translated materials, volunteer support, and international partnerships, IIAR is expanding its reach—and its relevance—in the global refrigeration industry, said IIAR president, Gary Schrift.

According to Rector, the drive to adopt IIAR standards often comes from within an interested country. "We're usually approached by a government agency," she said. "They may reach out to a local IIAR Chapter, and then to us. There's a real desire here to align with IIAR's work."



TECHNICAL PAPER #9

Intelligent CO2 Compressors and Ejectors for Enhanced System Efficiency and Reliability in Industrial Applications

ALESSANDRO SILVA, SENIOR APPLICATION ENGINEER | BITZER US

ABSTRACT

Intelligent CO2 compressors and ejectors are emerging as highly promising solutions for industrial refrigeration systems. This publication highlights their expanding capacity and scale, demonstrating their suitability for various applications, including cold storage facilities, distribution centers, beverage and food processing plants, and ice rinks. The integration of intelligent CO2 compressors and ejectors within refrigeration systems offers multiple benefits, such as enhanced efficiency, reduced energy consumption, minimized machine room space, and improved safety and reliability compared to ammonia-based systems. In addition, these solutions have the potential to incorporate waste heat recovery technologies, enabling the capture and utilization of excess heat for other purposes within industrial facilities. By leveraging intelligent CO2 compressors and ejectors, overall energy efficiency is further optimized, while reducing the environmental impact of the system. This paper provides an overview of the applications and potential of intelligent CO2 compressors and ejectors for industrial use, positioning them as sustainable and natural refrigerant-based alternatives that complement ammonia systems rather than compete with them.

Introduction

Gustav Lorentzen's team developed modern CO_2 refrigeration technology in the late 1980s (Lorentzen 1992). Since then, CO_2 has found extensive application in transcritical CO_2 systems, with over 3,000 installations in North America and more than 70,000 in Europe, including grocery stores and industrial sites as stated in the ATMO Report (2023). The viability of CO_2 and the multitude of benefits it offers make it one of the best natural alternatives available for use today. Transcritical CO_2 has become more viable for installations of all types as new innovations have made it more viable. The industrial market has been experiencing rapid growth, with more and more transcritical CO_2 solutions being developed for large-scale projects as reported in Silva and Sanchez (2022). While ammonia remains an excellent all-around refrigerant for industrial applications, its usage is sometimes restricted in areas where concerns over toxicity or flammability arise. In these scenarios, CO_2's unique properties make it an appealing choice as CO_2 is non-toxic, non-flammable, and boasts favorable thermodynamic characteristics. Furthermore, CO_2 is a cost-effective refrigerant (priced at under US$2 per pound) with minimal leakage rates due to the use of stainless-steel pipes, especially in large systems. Beyond these advantages, CO_2 stands out for its environmental safety, with negligible global warming potential (GWP = 1) and zero ozone-depletion potential (ODP = 0). These attributes position CO_2 as a sound long-term investment in the fight against climate change, however, materials and components of CO_2 systems must be designed and manufactured to operate safely and efficiently with elevated pressures. In fact, the characteristic of CO_2's inherent operating pressures provide opportunities to incorporate waste heat recovery technologies into the facility as well as ejector technologies to make the system more efficient.

In recent times, industrial refrigeration systems utilizing 4- and 6-cylinder CO_2 compressors have proven successful in handling capacities amounting to 1,137 TR (4 MW). An example of such an installation can be found at Yosemite Foods, Inc., based in central California, where the OEM provided five modular racks with 13 semi-hermetic compressors each, totaling 65 compressors, according to Coolsys.com, which operate well at warm temperatures and generate considerable heat reclaim. These compressors, with a geometric displacement varying from 745 to 1628 CFH (21.1-46.1 m^3/h) at 60 Hz operation, are used for low and medium-temperature applications. The sizable number of compressors in this example highlights the potential for using larger displacement 8-cylinder compressors which facilitates fewer compressors and components, reducing the space in the machine room. However, it's crucial to recognize that merely designing large displacement compressors isn't sufficient for industrial-scale refrigeration. While modular concepts from the realm of commercial refrigeration are making their way into industrial applications, it doesn't imply a compromise in the high safety and efficiency standards expected from the industrial refrigeration sector.

The emphasis on operating costs has grown significantly, not only due to increasing energy prices but also in anticipation of longer component lifecycles. Given that compressors consume a substantial portion of a system's energy, enhanced energy efficiency is essential to minimize electrical demands and operating costs. Moreover, as the compressors and components are expected to last longer, ensuring operational reliability over extended lifecycles has become increasingly vital. Factors such as rising energy costs, system energy efficiency especially in warmer climates, the possibility of adapting the capacity to the required demand, and the ongoing technician shortages are driving the adoption of a growing array of smart solutions to mitigate these issues. Intelligent 8-cylinder CO_2 compressors with geometric displacements ranging from 2959 to 4204 CFH (83.8 to 119 m^3/h) at 60 Hz, and CO_2 ejectors with variable geometry are new advanced refrigeration technologies. They enhance system efficiency, and offer improved safety and reliability compared to ammonia-based systems.

This paper explores the potential applications of intelligent 8-cylinder CO_2 compressors and ejectors in industrial settings. Furthermore, this paper presents energy efficiency analysis using CO_2 system software, contrasting intelligent

8-cylinder CO_2 compressors with ejectors against the 4- and 6-cylinder CO_2 compressors without ejectors already in operation within the CO_2 booster systems at an existing grocery distribution center in Maryland.

Description of the Intelligent Eight-Cylinder CO_2 Compressor

Larger-capacity CO_2 compressors have been a major driver of CO_2's increasing use in industrial refrigeration. The new intelligent 8-cylinder CO_2 compressors, designed with large displacements for industrial-scale applications, were developed with a focus on high efficiency, capacity control regulation, low levels of sound pressure and vibration, and minimum oil carry-over rate (OCR), as detailed in Javerschek and Mannewitz (2021). These compressors are primarily intended for medium and high-temperature applications, covering a wide range of evaporating temperatures from -4 to 59°F (-20 to 15°C) and discharge pressures from 580 to 1595 psi (40 to 110 bar). The largest model 8-cylinder compressor we considered provides a nominal displacement of 4220 CFH (119.5 m^3/h) at 60 Hz and is equipped with a newly developed 140 HP asynchronous motor (ASM). Based on 60 Hz operating conditions of 14°F (-10°C) evaporating temperature, 18°R (10°K) superheat, 1305 psi (90 bar) discharge pressure, and 95°F (35°C) gas cooler outlet temperature, the 8-cylinder compressor delivers 909 kBTU/h (266 kW) of cooling capacity with a power consumption of 147.5 kW and a EER of 6.16 (COP of 1.81). In comparison, the largest 6-cylinder CO_2 compressor that we considered provides 324 kBTU/h (95 kW) of cooling capacity with 55.9 kW of power consumption and an EER of 5.80 (COP of 1.70). This results in more than 6.2% EER/COP for the 8-cylinder compressor compared to the 6-cylinder compressor.

The concept of CO_2 compressors with integrated intelligent modules and wired peripheral components brings various advantages to OEMs, contractors, and operators. The benefits include enhanced efficiency and reliability, as well as cost savings during installation and operation, as reported by Reichle (2019). The onboard intelligent module, along with wired accessories, as depicted in Figure 1, enables compressor centric control of the compressor functions such as capacity control, oil level management, oil pressure, discharge gas, and motor temperature. It also provides data logging and tracks the compressor's application limits through operating envelope monitoring, ensuring safe and efficient operation across the entire application range while enhancing system safety and run-time availability. The intelligent 8-cylinder CO_2 compressor can be operated effectively and reliably with a run command signal and 0–10 V capacity control from the system controller. Using this intelligent logic, the compressor capacity can be adjusted quickly to the cooling demands within a modulation range of 50%–100% of VFD operation from 30 to 60 Hz, minimizing pressure fluctuations on the suction side, preventing wet operations, and ensuring precise temperature control for products and processes. Additionally, this new concept can provide start unloading which reduces the energy consumption of the system in comparison to systems that have more basic compressor capacity control. In applications with highly fluctuating capacity requirements, such as in many industrial refrigeration settings, the intelligent 8-cylinder CO_2 compressors provides great economic and technical advantages. During operation, the compressors are minimized from starting and stopping, reducing wear of the moving parts, and increasing the compressors' service life. Using specific intelligent software, compressor operation data, counters, and statistics can be displayed graphically and listed in tabular form, making the operating concept safe, intuitive, and easy to understand.

Figure 1. Eight-cylinder CO_2 compressor equipped with built-in intelligent module and wired accessories (capacity control system, oil pressure control, oil level management, discharge gas temperature, oil heater, and motor PTC sensors, not shown).

Capacity Control System (VARISTEP) for CO_2 Compressors

As described by Javerschek (2008), controls may be used to vary compressor capacity in a quasi-stepless manner to fulfill the high part load requirements of systems in commercial applications. The 8-cylinder models, intended for large-scale applications, are equipped with four solenoid valves for capacity regulation and start unloading. In these compressors, controls are applied to vary the capacity between 50%, 75%, and 100%. Solenoid valves are activated effectively via the compressor's intelligent module which ensures the smoothest possible operation by providing an optimized activation sequence for the solenoid valves. This ensures efficient cooling of each cylinder head if the compressor is operated unloaded for an extended period. When the compressor operates with full load, all solenoid valves are de-energized (100% capacity). When unloading a cylinder bank, the coil is powered and high-pressure gas passes through a small channel inside the control piston and pushes the piston into a seat above the suction chamber (2). Subsequently, an internal bypass is opened and the pressure above the control piston is reduced to the suction pressure level. Consequently, the control piston is lifted and opens a bypass between the discharge (3) and the suction chamber (2) of the controlled cylinder bank, equalizing the pressure of the cylinder bank up to the check valve, as shown in Figure 2. The check valve, located on the valve plate, prevents any reverse flow from the high-pressure side of the system. This capacity control system presents a cost-effective alternative, especially when compared to VFD operations, particularly in the case of large compressors like the 8-cylinder models. The data logging and operating data as well as control parameters can be monitored or read out via the intelligent module software.

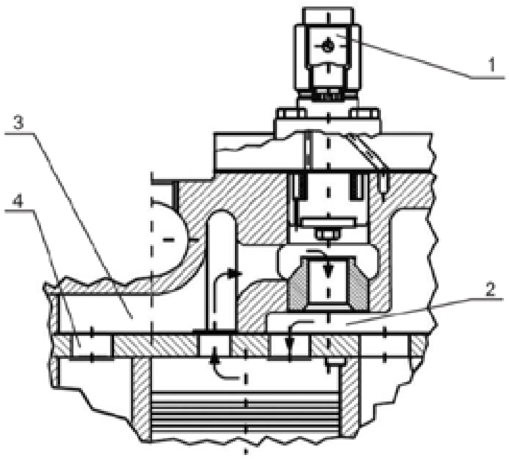


Figure 2. Structural design of the capacity control system used on eight-cylinder CO_2 compressor. (1- magnetic coil, 2- suction gas chamber, 3- discharge gas chamber, 4- check valve).

CO_2 Ejector Description and Operation

Compared to other refrigerants, CO_2 provides considerably higher throttling losses. This characteristic, however, offers the possibility of implementing devices like ejectors to recover expansion work. Hafner and Pardinas (2019) described that ejectors can significantly improve the energy efficiency of transcritical CO_2 refrigeration or heat pump systems, especially under high ambient temperatures. To achieve high energy efficiency within a system, ejectors must operate efficiently under a variety of conditions. The ejector design has a significant impact on the system's performance and energy consumption. Two-phase ejectors provide even better performance than traditional high-pressure control valves in reducing throttling losses and improving the overall system COP. An adjustable geometry ejector offers the flexibility to control the system's high pressure (like HPV) and maintain high system efficiency even during part-load operations. In contrast, a fixed geometry ejector may experience a significant drop in performance under part-load conditions when the operating parameters deviate from the design specifications the ejector was originally intended for.

An ejector operates like a jet pump, generating a pressure below the suction level based on the Venturi principle, consisting of key components: a motive nozzle, suction nozzle, mixing chamber, and diffuser, as reported by Javerschek et al. (2022). The ejector functions by accelerating refrigerant from the high-pressure side, often leaving the condenser or gas cooler outlet, through the motive nozzle, which increases its kinetic energy while decreasing the fluid's pressure as shown in Figure 3. The ejector harnesses the potential and kinetic energy inherent in the refrigerant from the gas cooler outlet to draw in a suction mass flow and elevate it to a higher-pressure level. As depicted in Figure 4, the ejector is linked to the evaporator outlet, where it compresses the evaporated refrigerant to the flash gas tank's pressure level. The high-pressure CO_2 [2], leaving the compressor, gains velocity in the ejector nozzle [4] followed by cooling in the gas cooler [3]. This causes a drop in static pressure, resulting in the flow pressure leaving the nozzle [5/6] being lower than the evaporator's suction gas pressure [9]. This differential pressure enables the selective extraction of both gas and liquid from a low-pressure level [9]. These partial flows merge in a mixing chamber [6] located ahead of the diffuser [7]. Within the diffuser, the flow decelerates, leading to an increase in pressure to the intermediate pressure level [7]. Beyond the diffuser, the mixture is directed into the flash gas tank, where the gas phase [1] is separated from the liquid and then compressed to a high-pressure level [2]. Meanwhile, the liquid [8] proceeds to the throttling valve and subsequently enters the evaporator [9].

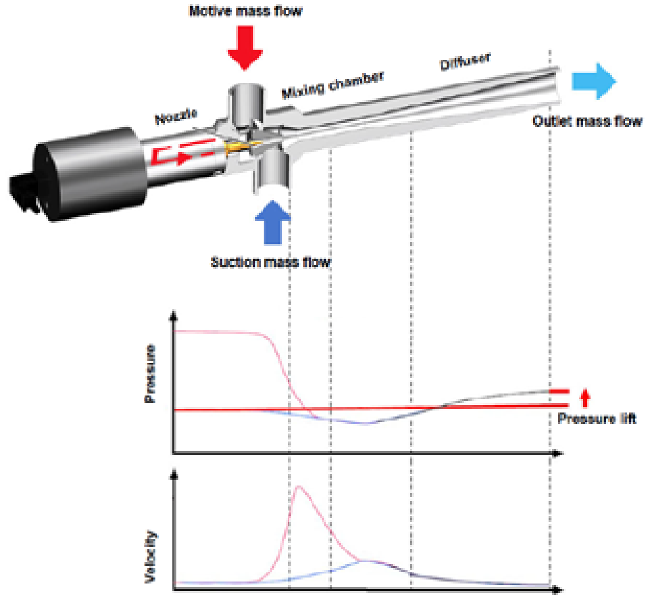


Figure 3. Controllable high-pressure ejector with pressure and velocity curves of the mass flows.

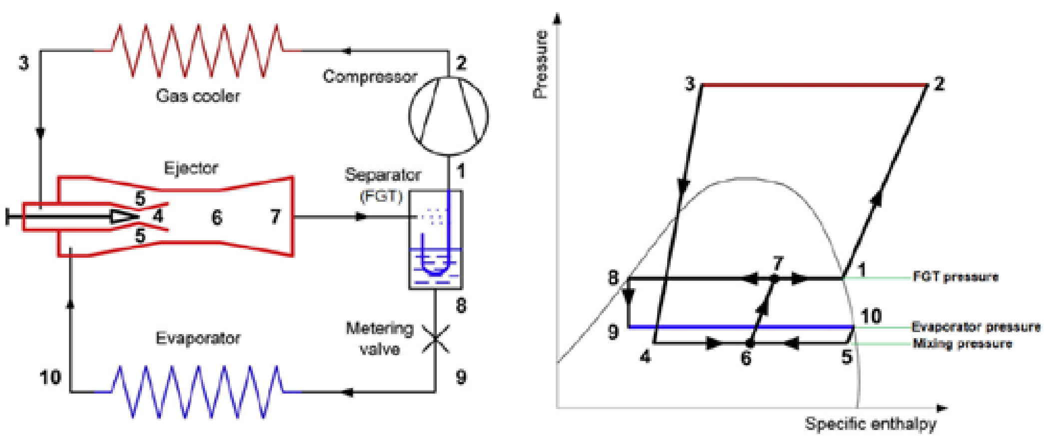


Figure 4. Transcritical CO_2 refrigeration cycle using a two-phase ejector for expansion work recovery and corresponding pressure-specific enthalpy diagram.

CO_2 Ejector Characteristic Values

Elbel (2011) reported that various parameters are utilized to evaluate the performance of the two-phase expansion ejector. These parameters encompass the pressure ratio, pressure lift, mass entrainment ratio, and ejector efficiency. Optimal ejector performance is achieved when a significant pressure lift is combined with a high suction mass flow rate. The pressure ratio, as defined in Equation (1), represents the ratio of the ejector's outlet pressure to its suction pressure. It quantifies the amount of pressure lift that the ejector can impart to the entrained fluid. The pressure lift, outlined in Equation (2), corresponds to the difference between the mixed stream pressure at the ejector outlet and the suction nozzle pressure, indicating the extent to which the suction mass flow pressure has been elevated to the outlet level. The mass entrainment ratio, as expressed in Equation (3), is defined as the ratio of the suction mass flow rate to the motive mass flow rate. This equation measures the ejector's capacity to entrain or pump refrigerant mass. The ejector efficiency, presented in Equation (4) and defined in Figure 5, is the ratio of the energy gained by expanding the ejector's motive mass flow to the work performed by the pressure lift of the motive mass flow and the suction mass flow at the ejector outlet. These calculations assume isentropic expansion and compression, along with superheated and dry saturated vapor conditions.

$$\Pi = \frac{P_{diff,\,out}}{P_{suction}} \tag{1}$$

$$\Delta_p = P_{diff,\,out} - P_{suction\ mass\ flow,\,on} \tag{2}$$

$$\phi_m = \frac{\dot{m}_{suction}}{\dot{m}_{motive}} \tag{3}$$

$$\eta_{ejector} = \frac{\dot{m}_{suction}}{\dot{m}_{motive}}\ x\ \frac{\Delta h_{compression}}{\Delta h_{expansion}} \tag{4}$$

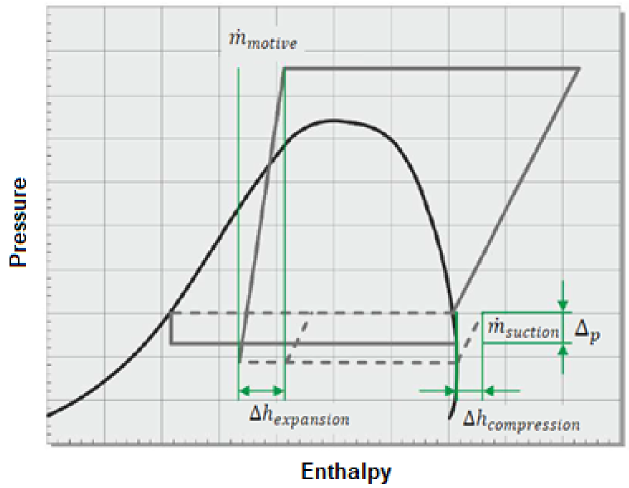


Figure 5. Pressure-enthalpy diagram illustrating ejector efficiency [AT-744-2 Application Guide for the use of R744, 2023].

Simon et al. (2022) reported that, depending on the operating conditions, mass flow through the motive nozzle may be limited by choking, and a converging-diverging nozzle can even accelerate the refrigerant to supersonic speeds. If the pressure at the motive nozzle exit is lower than the suction pressure, it induces a secondary flow of refrigerant, typically from the evaporator, drawn in through the suction nozzle. The secondary mass flow might also be limited by choking. These primary and secondary flows combine in the mixing chamber, often generating shockwaves and causing an instantaneous pressure increase. At the diffuser, the kinetic energy of the refrigerant mixture transforms into potential energy, raising the pressure. The ejector's outlet pressure then falls between the pressures at the motive and suction nozzle inlets. Two critical features of the ejector are the pressure hub, which is the pressure difference between the ejector outlet and the suction nozzle inlet, and the mass entrainment ratio, described as the ratio of suction nozzle mass flow compared to motive nozzle mass flow. The ideal ejector maintains a high-pressure hub and a high entrainment ratio for optimal performance.

Ejectors for Low and High Lift Applications

In low lift applications, ejectors aim to achieve the maximum possible mass flow. Their primary role is typically to recover the entire evaporated mass flow within the system and return it to the intermediate pressure vessel as shown in Figure 6 (a). In this application, the MT compressor operates as a parallel compressor controlling the intermediate pressure vessel, which is higher than the MT evaporator pressure. The critical factor in this context is the mass flow itself, which dictates the ejector's capability to boost pressure or determine the upper limit for intermediate pressure, allowing for efficient refrigerant return. The flash gas tank serves to separate the liquid and gas phases. The gas phase is drawn by the compressor, constituting the motive mass flow. Meanwhile, the liquid phase remains accessible to supply the evaporator and constitutes the suction mass flow. Ejectors in low lift applications function as robust "refrigerant pumps" with the ability to handle gas-liquid mixtures. This capability facilitates operations with flooded evaporators, eliminating the need for a superheat section and enabling higher evaporating temperatures without risking harm to the compressor.

In high-lift applications, ejectors are employed to achieve the maximum possible pressure increase while maintaining a reduced delivery rate. As depicted in Figure 6 (b), the ejector is used to load the parallel compressor and unload the MT compressor. Not necessarily the entire suction mass flow must be taken in. Depending on the medium pressure level and the resulting entrainment, the ejector elevates the pressure of a portion of the suction mass flow. This scenario requires a delicate balance between pressure lift and the desired suction mass flow, aiming to optimize system efficiency. Ejectors in high lift applications are typically used for transporting superheated gas only, as they do not handle the entire evaporated mass flow. In addition, a portion of the mass flow continues to be extracted by medium-temperature compressors. The ejector transports this portion of the mass flow back to the intermediate pressure vessel, which is maintained at a higher-pressure level compared to low lift configurations. The gas is now extracted from the intermediate pressure vessel by the parallel compressor. The advantage of this setup lies in the pre-compression of a portion of the evaporated refrigerant, resulting in a load redistribution to the parallel compressor, which operates at a lower pressure ratio, leading to increased overall efficiency. In a semi-flooded system, a separator, also known as a suction accumulator, is employed to allow the operation of MT evaporators with minimal superheat. In this scenario, the ejector functions as a liquid ejector, directing the surplus liquid from the MT evaporators/suction accumulator back into the flash gas tank. An oil return line must be installed to return the oil to the compressor from the suction accumulator.

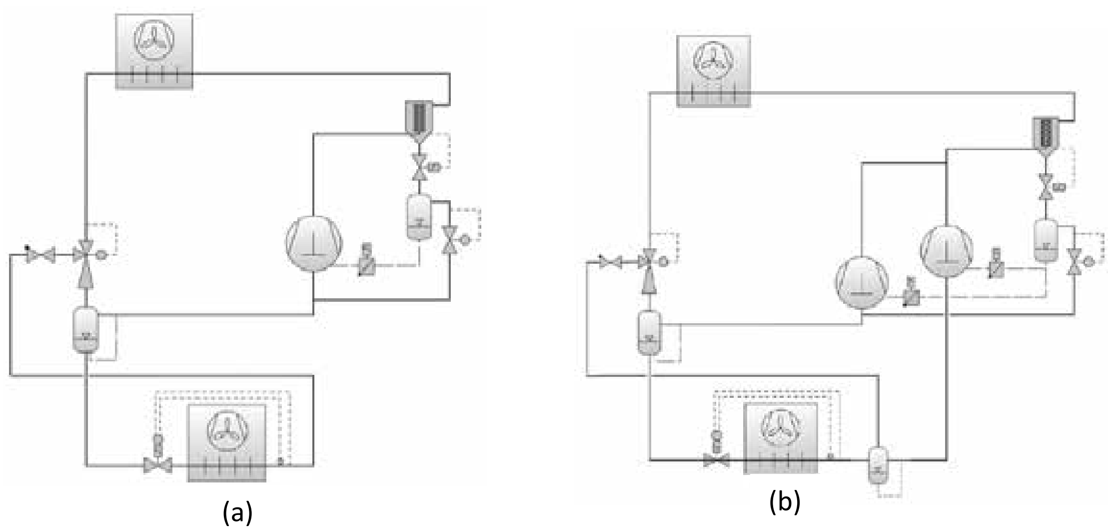
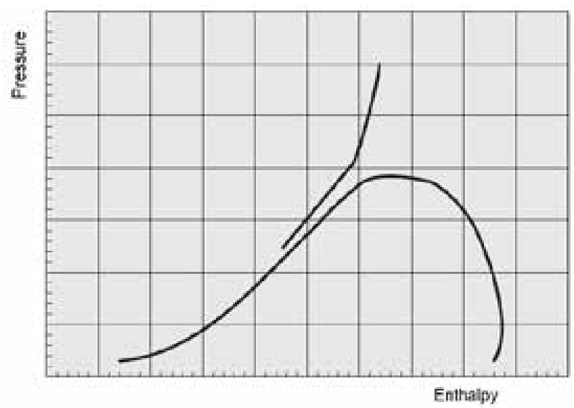


Figure 6. (a) CO_2 ejector in low lift application, (b) CO_2 ejector in high lift application (simplified representation).

Ejector Control Characteristics

High pressure is optimized by the ejector's control characteristic as shown in the Figure 7. This is accomplished through a control characteristic determined by the control deviation between the measured high pressure and the target high pressure. As a result of this signal, the ejector's stepper valve is actuated, changing the cross-sectional area of the ejector's nozzle, which affects the mass entrainment ratio and the high pressure. This relationship needs to be considered when planning and designing systems for low lift/liquid ejectors to avoid stall effects, especially at low pressures.

Depending on the ejector application there may be different operating conditions, such as an open or closed suction line. These conditions are activated by factors such as the gas cooler outlet temperature and motive mass flow inlet temperature. In some cases, however, relying solely on the gas cooler outlet temperature may not provide sufficient information about the cooling points' load requirements. Additional criteria may be factored in based on the manufacturer and type of system controller. Among the variables that can be analyzed are the opening degree of the flash gas bypass valve, the opening degree of the high-pressure control valve, the operation feedback from the compressors, and the alarm messages.



Ejectors for Industrial Large-Scale Transcritical CO_2 Systems

CO_2 ejectors can provide the most significant energy efficiency gains in high ambient temperatures by reducing compressor power consumption while minimizing system platform complexities. CO_2 ejectors with variable geometry offer a nominal mass flow range spanning from 1764 lb/h to 20.948 lb/h (800 kg/h to 9500 kg/h) at inlet conditions of 87.8°F (31°C) and 1334 psia (92 bara). The largest ejector used here delivers 977 kBTU/h (286,4 kW), making it compatible with the 8-cylinder CO_2 compressor designed for large-scale applications. These ejectors effectively manage mass flow through their motive nozzles using a needle valve, enabling precise control of the transcritical pressure at the gas cooler outlet. They offer accurate regulation of the gas cooler's optimal discharge pressure across a broad range of applications, effectively replacing high-pressure valves. Closing the needle valve reduces the motive nozzle throat area. The needle valve's position, controlled by a stepper motor, is referred to as "utilization," where 100% utilization corresponds to a fully open needle valve. It is possible to employ a combination of different sized ejectors to achieve additional improvements in the system's COP, enhancing performance not only at full load but also at part load conditions. Figure 8 shows A cut-away view of a variable-geometry CO_2 ejector.

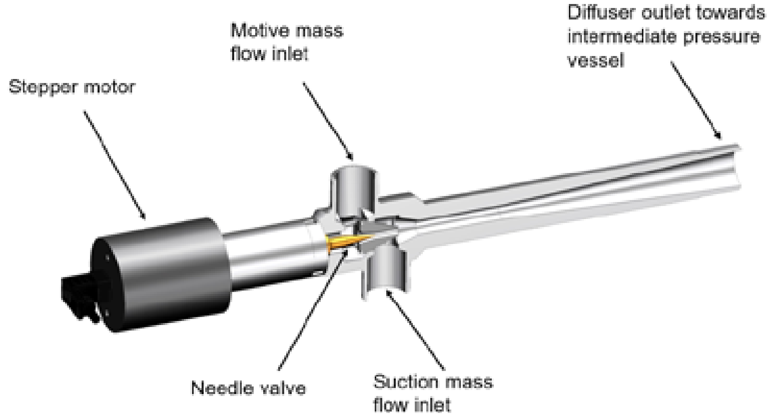


Figure 8: A cut-away view of a variable-geometry CO_2 ejector.

Energy Efficiency Analysis: CO_2 Refrigeration System with Eight-cylinder Compressors and Ejectors in Grocery Distribution Center

The analysis was conducted using Bitzer CO_2 system software version 7.0 to compare 8-cylinder compressors with ejectors to existing 4- and 6-cylinder compressors without ejectors in operation at a grocery distribution center in Maryland. The facility features one of the world's largest CO_2 refrigeration systems, with a cooling capacity of 1,328 TR (4.67 MW). This capacity includes 1,022 TR (3.87 MW) for medium temperature (MT) applications at 21°F (-6.2°C) SST and 227.5 TR (0.8 MW) for low temperature (LT) applications at -21°F (-29.44°C).

The distribution center houses five transcritical CO_2 refrigeration racks employing parallel compression technology. These racks incorporate 57 compressors with 4- and 6-cylinder configurations. In this facility, each rack operates independently, with loads distributed among them so that each refrigerated space has a backup. The existing CO_2 racks are designed with adiabatic gas coolers to maintain the gas cooler outlet temperature at 85°F (29.4°C) during the summer.

The analysis refers to the existing CO_2 flash gas system with parallel compression as the FGP system, and the system with 8-cylinder CO_2 compressors and ejectors, as an FGE system. Based on the parameters outlined in Table 1, the COP is examined for both full- and part-load operations. Assuming the adiabatic gas coolers maintain the outlet temperature at 85°F (29.4°C) at point A (highest ambient temperature), and at points B and C the temperature difference between the gas cooler outlet and ambient temperature is targeted to be 4°R (2.2K). The superheat of the evaporator and the suction line for all systems was set at 9°R (5K), and to prevent wet operations, internal heat exchangers (IHXs) were incorporated in all systems. Additionally, desuperheaters were installed on the compressor discharge lines for the low-temperature stage (LT-stage) to prevent high suction gas superheat on the medium-temperature stage (MT-stage). The discharge pressure was maintained at 1116 psi (80 bar) at all three operating points to optimize the ejector efficiency. A heat recovery of 455 TR (1.6 MW) was assumed for various purposes such as domestic hot water, space heating, warming glycol for under-slab radiant heating, and hot water used in washdowns. A simplified diagram of the FGE and FGP system is shown in Figure 9.

Operating Point	A (full load) 100%	B (part load) 85%	C (part load) 75%
Cooling Capacity	1,328 TR (4.67 MW)	1,128.8 TR (3.969 MW)	996 TR (3.503 MW)
Ambient Temperature	91.4°F (33°C)	77°F (25°C)	59°F (15°C)
Gas Cooler Outlet Temperature	85°F (29.4°C)	81°F (27.2°C)	63°F (17.2°C)
Discharge Pressure	1116 psi (80 bar)	1116 psi (80 bar)	1116 psi (80 bar)

Table 1. Cooling load demands and operating data for the COP analysis.

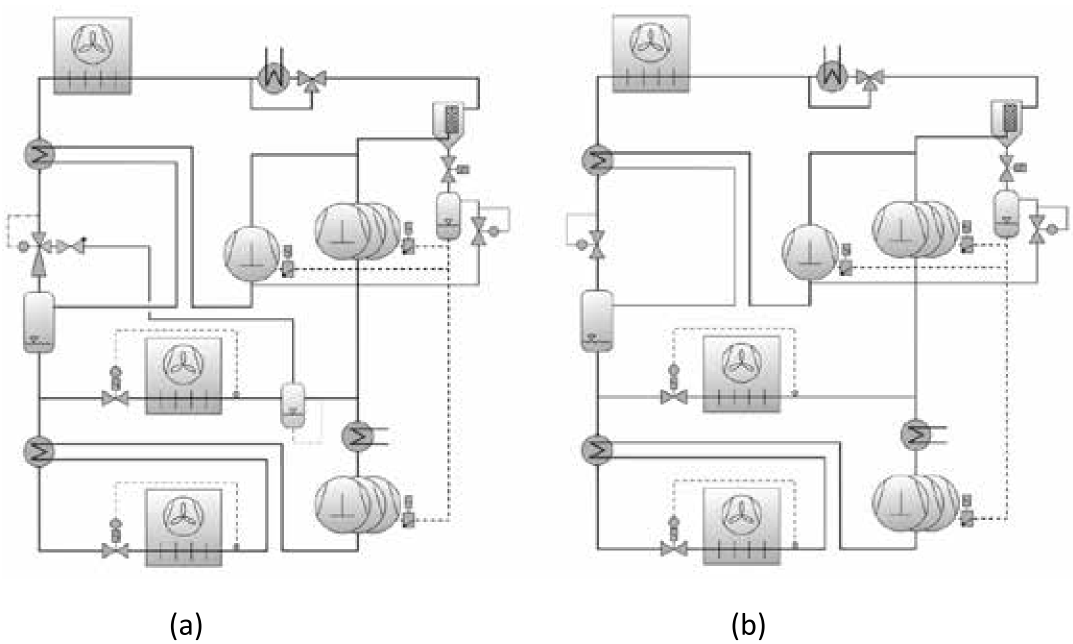


Figure 9. Simplified diagram of the (a) FGE system and (b) FGP system.

The intermediate pressure of these systems is optimized to achieve the highest coefficient of performance while utilizing the minimum number of compressors across operating points. At full load operation (operating point A), the FGE system requires five 6PME-40K compressors for the LT-stage, six 8-cilynder compressors for the MT-stage, ten additional 8-cylinder compressors for the parallel-stage, and eighteen ejectors. The FGE system's lead compressor in each suction group utilizes capacity regulation to adapt to the required mass flow. The FGE system employs 21 compressors, which is a significant reduction compared to the 57 compressors utilized in the existing FGP system. Figure 10 illustrates the COP comparison between the FGB and FGE systems under full- and part-load conditions.

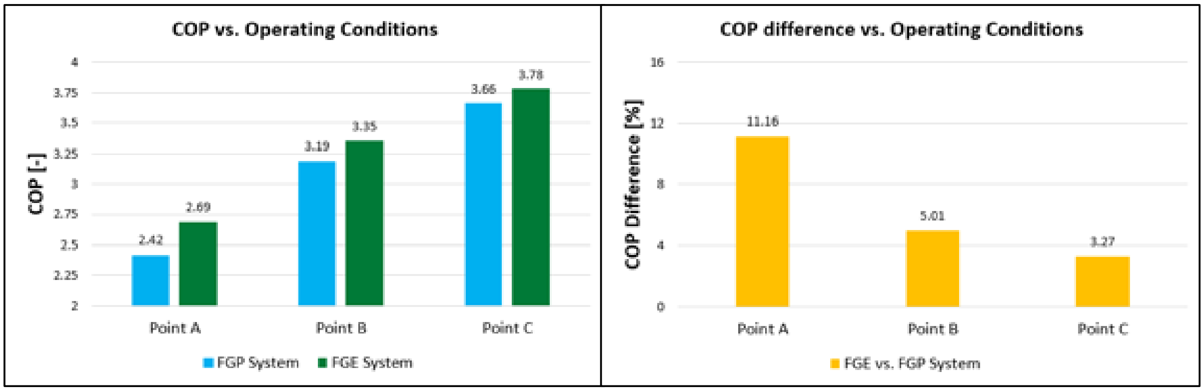


Figure 10: COP comparison between FGP and FGE system for different operating conditions.

The FGE system demonstrated a significant improvement in COP of 11.16% at point A, followed by improvements of 5.01% and 3.27% at points B and C, respectively, compared to the existing FGP system. The ejectors, particularly at point A, played a pivotal role in moving most of refrigerant mass flow between the MT evaporators and parallel compressors, contributing to the highest COP at that specific operating point.

Eckert et al. (2022) reported that while ejectors perform well under original design conditions, when deviations from these design conditions occur, ejector efficiency drops, resulting in a decrease in overall system efficiency. Under subcritical conditions, the ejector may operate with lower motive pressure and reduce the energy content of the refrigerant flow.

Analysis by Simon et al. (2022) on the COP of three different CO_2 systems designed for a central European distribution center, considered various operating conditions. These systems, all incorporating 8-cylinder CO_2 compressors, were configured with flash gas bypass (FGB system), parallel compressors (FGP system), and ejectors (FGE system). Their research revealed that the FGE system outperformed both the FGB and FGP systems, delivering a superior COP. The researchers underscored the importance of considering both full load and part load conditions when designing a CO_2 refrigeration system with ejectors. They highlighted that at higher ambient temperatures, the ejector input pressure and energy increase, leading to greater energy benefits and a higher COP. Conversely, lower ambient temperatures result in reduced energy benefits due to the decreased potential energy available to the ejector.

Conclusion

In recent years, there has been a notable shift in the adoption of transcritical CO_2 racks from traditional supermarket settings to the industrial sector. This paper highlights the potential of intelligent 8-cylinder CO_2 compressors and ejectors as highly efficient solutions for industrial applications. The growing capacity and adaptability of these technologies render them viable for diverse applications, providing advantages such as heightened efficiency, decreased energy consumption, reduced space requirements, low operating costs, and enhanced safety.

The energy efficiency analysis in this paper reveals that 8-cylinder CO_2 compressors and ejectors allow for a reduction in the number of compressors in large systems. In this study, the FGE system employs 21 compressors + 18 ejectors instead of 57 compressors without ejectors in the existing FGP system. The improved EER/COP is a result of better performance provided by the 8-cylinder CO_2 compressors, with ejector operation playing a major role in that improvement.

Intelligent 8-cylinder CO_2 compressors and ejectors are positioned not as competitors, but as sustainable alternatives to ammonia-based systems in industrial applications. By integrating these technologies, CO_2 systems operate efficiently in transcritical mode, resulting in a substantial increase in the COP especially in warm climates. This breakthrough addresses the historical challenge of CO_2 systems struggling to operate efficiently in higher ambient temperatures.

The removal of this efficiency barrier opens up possibilities for installing CO_2 systems for commercial and large-scale industrial applications worldwide. The versatility and performance enhancements brought by intelligent 8-cylinder CO_2 compressors and ejectors make transcritical CO_2 systems a viable and efficient choice.

Nomenclature

ASM	Asynchronous Motor	OCR	Oil Carry-Over Rate
BTU/h	British Thermal Units per Hour	OEM	Original Equipment Manufacturer
CO_2	Carbon Dioxide	SST	Saturated Suction Temperature
COP	Coefficient of Performance [-]	TC	Transcritical
CFH	Cubic Feet per Hour	TR	Tons of Refrigeration
EER	Energy Efficiency Ratio	VFD	Variable Frequency Drive
FGE	Flash Gas Ejector	Π	Pressure Ratio
FGP	Flash Gas Parallel	Δ_p	Pressure Lift
GWP	Global Warming Potential	ϕ_m	Mass Entrainment Ratio
HPV	High-Pressure Control Valve	$\eta_{ejector}$	Ejector Efficiency
IHXs	Internal Heat Exchangers	$\dot{m}_{suction}$	Suction Mass Flow
kW	Kilowatt	$\dot{m}_{motive}$	Motive Mass Flow
LP	Low Pressure	$P_{diff,\, out}$	Diffuser Outlet Pressure
LT	Low Temperature	$P_{suction}$	Suction Pressure
MT	Medium Temperature	$P_{suction\ mass\ flow,\, on}$	Suction Mass Flow Pressure
MW	Megawatt	$\Delta h_{compression}$	Performed Work
ODP	Ozone Depletion Potential	$\Delta h_{expansion}$	Expansion Work

References

Silva, A., Sanchez, J. 2022. Oil Management Design Considerations for Industrial Transcritical CO_2 Systems. IIAR Natural Refrigeration Conference & Expo, Savannah Convention Center in Savannah, Georgia from March 6–9, 2022. Technical Paper #5.

Javerschek, O. Mannewitz, J., 2021. Advanced Design for CO_2 Compressors in Industrial Applications. 9th IIR Conference on Ammonia and CO_2 Refrigeration Technologies, Ohrid, North Macedonia, 16-17 September, 2021. http://dx.doi.org/10.18462/iir.nh3-co2.2021.0009

Reichle, M. 2019. Mastering the Technology of Transcritical CO_2 Applications. International Refrigeration Seminar, BITZER SCHAUFLER Academy, Rottenburg-Ergenzingen, June 2019.

Javerschek, O. 2008. Commercial Refrigeration Systems with CO_2 as Refrigerant. 8th IIR Gustav Lorentzen Conference on Natural Working Fluids, Copenhagen. http://www.ammonia21.com/files/pdf_760.pdf

Hafner, A., Pardinas, A. 2019 refrigeration technology: Possible Innovations. 8th IIR Conference: Ammonia and CO_2 Refrigeration Technologies, Ohrid, 2019. http://dx.doi.org/10.18462/iir.nh3-co2.2019.0024

Javerschek, O., Mannewitz, J., Hegglin, A. 2022. The use of ejectors in industrial heat pumps. 15th IIR-Gustav Lorentzen conference on Natural Refrigerants, Trondheim, Norway. DOI: 10.18462/iir.gl2022.070

Elbel, S. 2011. Historical and present developments of ejector refrigeration systems with emphasis on transcritical carbon dioxide air-conditioning applications. International Journal of Refrigeration, 34(7), pp.1545-1561.

Simon, F., Pfaffl, J., and Javerschek, O. 2022. Introduction of an Ejector for Industrial Scale CO_2 Systems. International Refrigeration and Air Conditioning Conference. Paper 2493. https://docs.lib.purdue.edu/iracc/2493

Eckert, M., Kauffeld, M. and Siegismund, V. 2022. Natural refrigerants: Applications and Practical Guidelines. 2022 VDE VERLAG GMBH and Shecco SPRL (ATMOsphere).

ATMO Report, 2023. Natural Refrigerants: State of the Industry. Refrigeration in Europe, North America and Japan, Plus Heat Pumps in Europe. 2023 Edition. https://atmosphere.cool/atmo-market-report-2023/

Lorentzen, G., Pettersen, J. 1992. New possibilities for non-CFC refrigeration. IIR Int. Symp. on Refrigeration, Energy and Environment, Trondheim, Norway, June 22-24, pp.147-163.

BITZER AT-744-2 Application Guide for the use of R744, 2023. https://www.bitzer.de/shared_media/html/at-744/en-GB/index.html?P=/html/at-744/en-GB&N=index.html

BITZER CO_2 Software version 7.0 [Computer software], accessed on Dec 4th, 2023. https://www.bitzer.de/websoftware/calculate/CO2/?tab=results

Coolsys, 2023. https://coolsys.com/ [Coolsys webpage], accessed on Sep 22nd, 2023.

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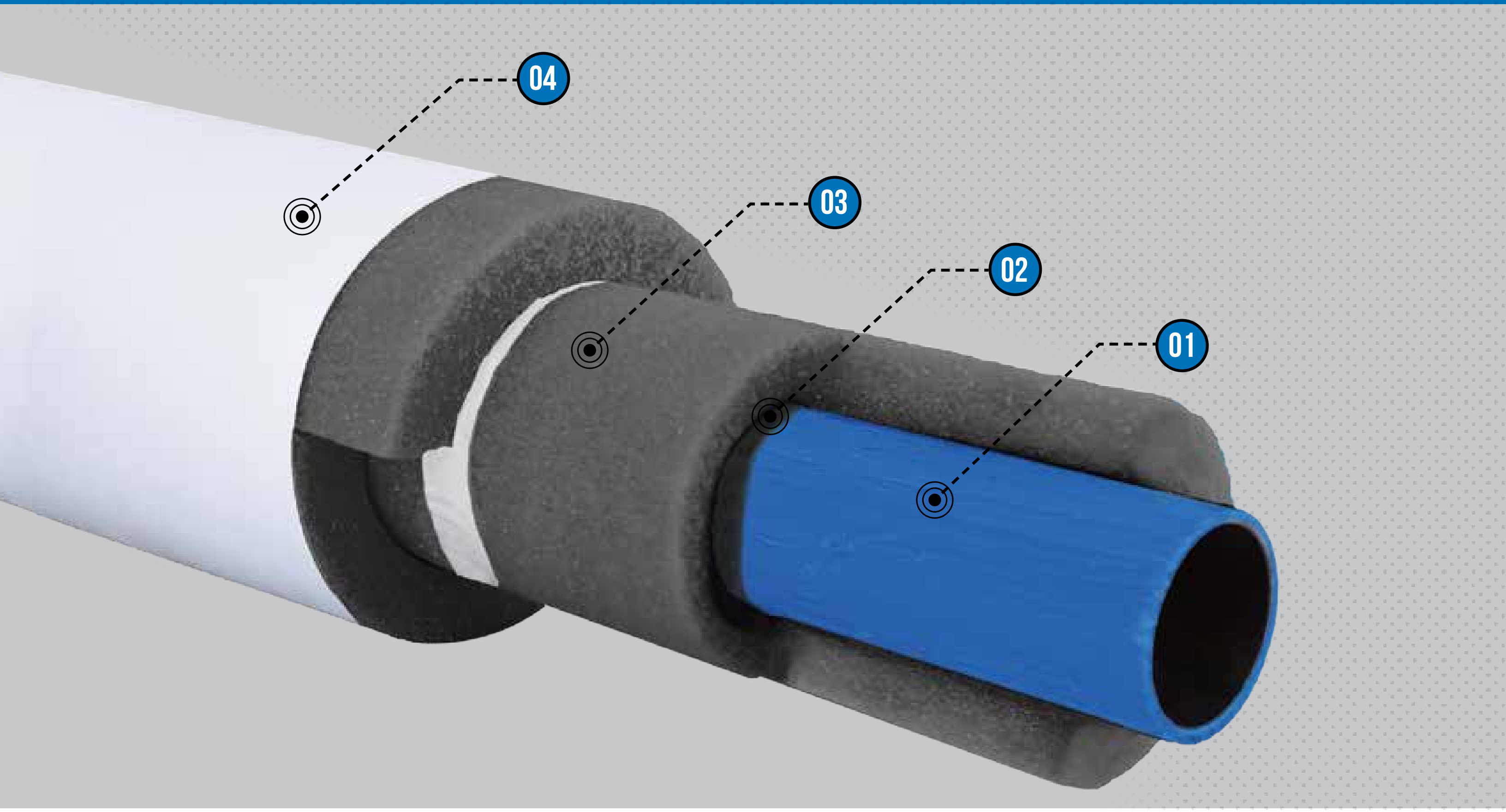

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