MIKE LYNCH

US Cold Storage’s CO₂ success proves skeptics wrong

Pega Hrnjak on Ammonia’s Plunging Charge

LA Cold Storage’s Low-Charge Invention

Canadian Warehouse_OPTS for CO₂ and Ice

Special

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SHAKING UP INDUSTRIAL REFRIGERATION

By branching out from ammonia-only systems to an ammonia-CO₂ platform, US Cold Storage has helped make CO₂ an acceptable refrigerant for warehouse operators

By Michael Garry
US Cold Storage’s 500,000-square-foot Bethlehem facility, opened in 2005, sits on a segment of the 300-acre site previously occupied by Bethlehem Steel Corp., once the second-largest steel maker in the world. In 1995 Bethlehem Steel, which produced the I-beams used to build many of Manhattan’s skyscrapers, shuttered its facilities after 140 years of production, the victim of overseas competition.

The force of change, in the form of globalization, overtook Bethlehem Steel. Change — in the form of stricter governmental oversight of ammonia refrigeration — is now sweeping over the industrial refrigeration industry, causing many companies to transition, or consider transitioning, to low-charge ammonia options.

Beginning in Bethlehem, US Cold Storage has learned how to manage change rather than be undone by it. Its Bethlehem plant, nearby the old steel mills, is a daily reminder of the need to confront current realities and not live in the past.

Rather than install a traditional two-stage pump-recirculated ammonia refrigeration system, with 20,000 to 40,000 pounds of ammonia, in Bethlehem, US Cold Storage opted for the NH₃-CO₂ cascade system, with 6,400 pounds of ammonia and 48,000 pounds of CO₂, something that was practically unheard of in 2005.

“When we started, people called us crazy,” said Michael Lynch, vice president — engineering for US Cold Storage, in a recent interview with Accelerate America at the Bethlehem warehouse. “Even equipment manufacturers were making presentations about why you shouldn’t use CO₂.”

But US Cold Storage stuck to its guns. To gain more experience with NH₃-CO₂ cascade systems, the company, which was acquired by U.K.-based Swire in 1982, sent some engineers to Europe to observe the technology in action there, where it was more prevalent. “The tour gave them insight and reassurance that we could take the technology and design a system that would work here,” said Lynch. At that time, Lynch, who became vice president — engineering in 2011, was more involved on the construction and installation side.

Since then, US Cold Storage — the third largest refrigerated warehousing and logistics provider in North America, with 233.5 million cubic feet of temperature-controlled space, according to the Global Cold Chain Alliance — has implemented ammonia-CO₂ systems at 10 more new locations in the U.S. (see map, page 26), including some that replaced outdated facilities. All together, US Cold Storage, based in Voorhees, N.J., operates 35 public refrigerated warehouses in 27 cities or towns across 13 states.

Of its 11 NH₃-CO₂ systems, 10 are cascade models, using high-pressure CO₂ compressors, while one, in Quakertown, Pa., is a critical brine unit that circulates CO₂ as a secondary coolant mostly to storage areas with a 35°F to 40°F temperature. The NH₃-CO₂ systems use between 5,000 and 8,000 pounds of ammonia and between 20,000 and 48,000 pounds of CO₂.

In a warehouse in Lumberton, N.C., US Cold Storage is installing an NH₃-CO₂ system in a second engine room to support new blast freezers — an add-on to a existing two-stage ammonia system. But the company does not plan to retrofit an entire existing ammonia system with the NH₃-CO₂ technology.
WHY CO2?

In 2005, US Cold Storage took a risk building one of the first NH3-CO2 systems in the industrial refrigeration industry. Why did the company do it?

Even then, ammonia regulations were taking a toll. “We saw that [stricter] regulations were coming, so we wanted to find a way to reduce our ammonia charge,” said Lynch, who joined US Cold Storage in 2000 after a decade as a refrigeration engineer for Nestle USA.

The biggest regulatory burden on cold storage facilities that use more than 10,000 pounds of ammonia refrigerant is complying with OSHA’s PSM (process safety management) and the EPA’s RMP (risk management plan) requirements. Using an ammonia-CO2 system, US Cold Storage stays below the 10,000-pound threshold, which removes filing protocols and puts its plants at less of a risk during an audit.

However, the company still voluntarily treats NH3-CO2 facilities as if the same regulations applied “because it’s the prudent and safe thing to do,” said Lynch. “And there’s still a general duty clause irrespective of the amount of ammonia you have.”

Equally as important as regulations, US Cold Storage wanted to reduce the risk of ammonia exposure to its employees and customers (delivery employees of packaged goods companies who warehouse products at US Cold Storage facilities). It could do that by taking ammonia out of the storage environment and confining it to the engine room – the scenario under an NH3-CO2 system.

While Lynch is not aware of any significant leaks at the ammonia-only plants, even in extremely small quantities like 15-20 PPM ammonia’s highly pungent odor is detectable to employees. “They know it’s dangerous so the slightest smell is alarming to them, and we respond accordingly,” said Lynch. With CO2, that stress is eliminated in storage areas.

Moreover, ammonia often carries a stigma in the areas where US Cold Storage operates, and authorities and communities regard a system with less ammonia as safer.

US Cold Storage’s customers have grown to appreciate the attention it has paid to the safety of their employees, as well as to the quality of their chilled and frozen food -- everything from milk shakes to chicken fillets, eggplant to cranberry concentrate -- which could be rendered unsaleable by exposure to ammonia. “We haven’t had a CO2 leak but the effect of CO2 on food would be benign,” said Lynch.

“Our customers like that; our insurance company loves it,” he added in a presentation at the 2015 IIAR Conference and Exhibition.

In fact, Lynch believes that the NH3-CO2 system has become a competitive advantage and "helped to grow our business."

Another factor that prodded US Cold Storage in the direction of an ammonia-CO2 platform was its partnership with M&M Refrigeration, which had experience with CO2 systems and exclusive rights to Sabroe’s reciprocating compressors in the U.S.

What clinched the decision for US Cold Storage was its determination that the capital cost of an NH3-CO2 system would be about the same as an ammonia-only system, within a margin of plus-or-minus 5%.

In addition, US Cold Storage’s ammonia-CO2 refrigeration system, including all compressors, condensers and evaporators, was found to be on average 5.8% more energy efficient than a conventional ammonia system, according to Lynch. The greater efficiencies of the low-temperature evaporators far outweigh the lower efficiency of the warmer-temperature units (at the docks, for example).

From a maintenance standpoint, NH3-CO2 requires more work in certain areas (reciprocating compressors and cascade condenser) and less in others (valves) than an ammonia system. On balance, Lynch thinks costs for maintenance, as well as for installation, are about the same for both systems.

Looking at the total cost of ownership, Lynch concludes that NH3-CO2 cascade systems are at minimum comparable to, and in some cases less than, traditional ammonia system. The 5.8% lower energy cost – as well as intangible benefits like safety, lower regulatory burden and competitive advantage – usually tip the balance toward the cascade system.

Locations of US Cold Storage’s NH3-CO2 facilities

Locations of US Cold Storage’s NH3-CO2 facilities

Voorhees, NJ
Fresno, CA
Turlock, CA
Syracuse, UT
Lebanon, IN
Omaha, NE
Bethlehem, PA
Hazleton, PA
Quakertown, PA
Lake City, FL
Dallas, TX
Covington, TN
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Rooftop ammonia evaporative condenser. Yellow pipes carry ammonia gas from engine room into the condenser; red pipes carry liquid ammonia to engine room.

CO₂ sensors are at waist level; ammonia sensors are on the ceiling.

Glycol is heated in the ammonia compressors and used to warm the subgrade under concrete to prevent frost heave.

Three brown containers are the cascade condensers, where liquid ammonia evaporates, cooling CO₂ gas into a liquid. Blue surge drums hold liquid ammonia at 11°F before it enters cascade condensers.
**CO₂ CHALLENGES**

Of course, US Cold Storage has had to clear some hurdles, with its CO₂ system, especially at the beginning. One was its in-house refrigeration technicians’ lack of experience with CO₂, though the primary difference between a two-stage ammonia system and the CO₂ cascade system is the presence of a cascade condenser.

“Knowledge transfer and training was a challenge, but we have been able to overcome that,” said Lynch. Self-education has also been important, as the company’s engineers conduct a post-mortem following every cascade project to discuss whether the system is operating as designed. Over the past decade the company has made “subtle changes” in equipment selection and design as part of a “continuous improvement” philosophy.

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Early on, US Cold Storage had limited options with respect to refrigeration contractors that could design and install CO₂ systems as well as to component suppliers who could provide high-pressure compressors and evaporators. Today, there are far more options on both scores “as more and more food and distribution companies embrace the technology,” said Lynch. “It’s gradually improving.”

From a technical perspective, the NH₃-CO₂ system presents certain challenges. Perhaps most important is preventing CO₂ and NH₃ from mixing in the cascade condenser and forming ammonium carbamate, a white, powdery salt with a penchant for clumping together and clogging pipes and valves. He uses a strainer to collect any ammonium carbamate and monitor its presence, so that it can be prevented from accumulating.

It would take several days to remove a collection of ammonium carbamate, compromising a plant’s operation, though that is not something US Cold Storage has experienced to date. “It’s what keeps me up at night,” Lynch said at the IIAR Conference.

Another technical imperative is eliminating moisture, which reacts with CO₂ to create carbonic acid that corrodes carbon steel. "Moisture management is critical," Lynch said. This includes using filter driers, leak testing with dry nitrogen, and evacuating the system down to at least 500 microns during maintenance.

The company is also relying more on acid-resistant stainless steel, which has become price-competitive with carbon steel. At its Lumberton, N.C., facility, the company is using only stainless steel in the new NH₃-CO₂ system.

**Other technical challenges:**

» A CO₂ system carries with it higher pressures and needs to be appropriately fitted with relief valves. But releasing saturated CO₂ gas produces dry ice, which can plug up pipes and valves. So US Cold Storage is careful to release saturated CO₂ directly to the atmosphere.

» Though CO₂, an odorless gas, is far safer than ammonia, it can be an asphyxiant in a closed space and "needs to be treated with respect," said Lynch at the IIAR Conference.

» To that end, US Cold Storage installs sensors (waist height) and alarms in all parts of the facility, as it does for ammonia (ceiling mounted). “Being odorless, CO₂ leak detection, especially small leaks, can be a challenge,” said Charlie Kulp, chief engineer at the Bethlehem facility.

» At the IIAR Conference, Lynch advised anyone using CO₂ as a refrigerant in industrial plants to coordinate closely with the CO₂ supplier to ensure that the supplier is equipped to interact with a refrigeration system, since that is a new application for many of them, and that they are supplying Coleman grade CO₂ with a purity of 99.99%.

» US Cold Storage can reuse the POE oil used in the CO₂ compressor (through oil rectification) rather than discard it, which is done with NH₃ compressor oil. The CO₂ and ammonia compressor oils don’t mix and have to be managed separately.

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When US Cold Storage decided to install an \( \text{NH}_3 - \text{CO}_2 \) cascade system in 2005, it was the only natural-refrigerant, low-charge alternative to all-ammonia systems for industrial applications. However, since then, low-charge self-contained ammonia units have also emerged as an option for end users. Would Lynch consider such a unit for US Cold Storage?

Possibly, but not right now, he said. “For a large industrial company like ourselves, we feel \( \text{CO}_2 \) cascade provides all the benefits we need. While low-charge ammonia systems offer benefits as well, he questions whether they are comparable from a capital cost, maintenance and efficiency standpoint. “We’re not sold on it yet.”

Still, there are times where a low-charge ammonia system might fit, he said, such as at a facility like the Lumberton plant that is adding an application but can’t fit it into an existing engine room. “Then a rooftop [low-charge] unit could be ideal.” Generally speaking, he believes smaller warehouses are better suited for low-charge units.

As for all-CO\(_2\) transcritical systems, Lynch believes they are “years down the road” in industrial settings, though they are gaining traction in supermarkets.

There are occasions when Lynch still opts for a traditional high-charge ammonia system. In a facility in Wilmington, Ill., that opened in 2010, he used a single-stage ammonia system for what is an “all-cooler” building that didn’t have any low-temp freezer or blast freezing for which \( \text{CO}_2 \) would be appropriate. “When you look at the life cycle costs, there are still times when traditional ammonia makes sense,” he said.

But Lynch plans to continue using ammonia-\( \text{CO}_2 \) systems as his primary platform in new facilities. Already two such warehouses are in the works – one in Sacramento, Calif., and one in Atlanta, Ga.

Skeptical about \( \text{NH}_3 - \text{CO}_2 \) systems in 2005, the industry has since caught up with US Cold Storage in accepting the technology as a low-charge option. The same suppliers that criticized the company are now selling \( \text{CO}_2 \) compressors and evaporators to end users that are installing cascade systems. IIAR, focused on ammonia, has incorporated \( \text{CO}_2 \) educational sessions into its conference agenda.

Lynch believes the tipping point came in 2010, when he saw “a change in thinking and acceptance,” which has been growing since then.

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**Business case for change**

In total cost of ownership, \( \text{NH}_3 - \text{CO}_2 \) cascade systems at United States Cold Storage are at minimum comparable to, and in some cases less than, traditional ammonia systems. The 5.8% lower energy cost – as well as intangible benefits like safety, lower regulatory burden and competitive advantage – usually tip the balance toward the cascade system.
LOOKING AT THE WORLD DIFFERENTLY

Lynch regards his job as personally gratifying on several levels. First, he enjoys overseeing construction of US Cold Storage buildings from conception to completion, and then watching them become profitable parts of the business. He is also responsible for the company’s environmental strategy, which includes installing NH₃-CO₂ refrigeration systems, and he finds that aspect fulfilling as well.

“As a parent” – Lynch is the father of three teenagers, two boys and a girl – “you look at the world differently,” he said. “You want a better environment for your kids. So being able to do my share in helping control how our company affects the environment is rewarding.”

Lynch has also been trying to influence the environmental direction of the industrial refrigeration industry as a whole through speaking engagements at industry events and consultations with customers. “I spend a lot of time enlightening our customers about CO₂ and how they can embrace it in their facilities,” he said. “That helps grow [CO₂ adoption] in the industry and increase awareness and demand.”

US Cold Storage’s customers include major brands like Unilever and Nestle that want to project a sustainable position to consumers by reducing their carbon footprint. Energy-efficient NH₃-CO₂ systems offer them one way to do that.

Moreover, since US Cold Storage is part of their supply chain, the company’s sustainability efforts can be incorporated into the brands’ own carbon calculation.

System Specs

At US Cold Storage’s public refrigerated warehouse in Bethlehem, Pa., the NH₃-CO₂ cascade refrigeration system has the following characteristics:

» M&M Refrigeration designed and installed the system
» Temperatures: 40°F (docks); -5°F (storage freezers). Other warehouses may include -48°F or below (blast freezer) and/or convertible freezer (40°F to -20°F)
» Capacities: Similar to those of an ammonia-only system.
» Charges: 6,400 pounds of NH₃; 48,000 pounds of CO₂
» Six freezer rooms, cooled by CO₂
» Vahterus three-part cascade condenser (plate and shell heat exchanger)
» Pump recirculated CO₂ system
» Four Sabroe high-pressure reciprocating compressors, plus one Frick high-pressure screw compressor, for CO₂
» Penthouse-mounted Guntner and Evapco CO₂ evaporators above each freezer room
» Two CO₂ receivers 19.4°F and -36.4°F
» Danfoss valve station on CO₂ evaporators
» Danfoss level controls on CO₂ receivers
» Four M&M high-temp screw compressors for NH₃
» Roof-mounted Evapco NH₃ evaporative condenser (air- and water-cooled)
» NH₃ controlled pressure receiver
» NH₃ surge drums
» Electric defrost (glycol and CO₂ hot gas used at other locations)
» The ventilated and monitored engine room is equipped with eye wash, an emergency shunt trip switch and remote emergency fan control outside control room