Exploiting CO₂

Packaged NH₃/CO₂ cascade refrigeration systems can serve large industrial applications

By André Patenaude
The large industrial refrigeration market is no stranger to the use of natural refrigerants. For decades, ammonia (aka NH₃ or R-717) has been the backbone of many cold storage applications. More recently, the increasing uptake of CO₂ (R-744) in commercial applications has led refrigeration manufacturers to look for ways to exploit this emerging natural refrigerant in industrial applications — and the technology to combine the benefits of both refrigerants and facilitate this transition is coming of age.

With excellent performance efficiency and ultra-low environmental impact, in many ways NH₃ is the closest thing to the perfect refrigerant. However, it has one major caveat: toxicity. In recent years, tightening regulations by the Occupational Safety and Health Administration (OSHA) has sought to improve the safety of NH₃ systems. Operators are now required to provide documentation for systems charged with at least 10,000 lbs of ammonia, per OSHA’s Process Safety Management of Highly Hazardous Chemicals standard.

For these reasons, operators and manufacturers alike began looking for ways to leverage ammonia’s efficiency while lowering system charges necessary to limit the potential for exposure to workers and product spoilage. Enter NH₃/CO₂ cascade technology, a system architecture that has been successfully deployed in many commercial applications with HFCs on the high side.

To make the transition to the large industrial market, manufacturers first needed to find a way to deliver high-tonnage refrigeration capacity while keeping ammonia charges low to help mitigate safety concerns, ease documentation requirements and, if possible, avoid the potential for exposure in any occupied spaces. They also needed to address other prevailing concerns about the use of NH₃/CO₂ cascade systems, including:

- Complexities related to installation, commissioning, operation and servicing requirements.
- Potential heat exchanger leaks of CO₂ and NH₃ that can mix and create ammonium carbamate, resulting in system failure.
- Maintaining uptime during the transition from a legacy system to a new cascade system.

Self-contained systems

Meeting high-tonnage, cold storage requirements while addressing the known operational challenges of ammonia and CO₂ meant that manufacturers have had to expand upon the existing cascade architecture. Among the leading solutions to achieve this is a self-contained system that integrates an entire NH₃/CO₂ cascade system into a modular refrigeration unit.

Designed to be located on the rooftop or next to a building of a cold storage facility, this modular refrigeration unit combines CO₂ and NH₃ compression technologies and electronic controls in a cascade system that contains two independent CO₂ and NH₃ circuits with separate condensers and evaporators (including a shared cascade heat exchanger).

The NH₃ portion of the cascade system provides the high stage of the refrigeration cycle, utilizing a small-displacement, very low-charge, single-screw compressor and a condenser that sits on top of the unit and uses ambient air to cool it; liquid ammonia evaporates in the cascade heat exchanger. This design meets the low-charge NH₃ requirement (fewer than 500 pounds) while keeping the NH₃ stage completely separate from conditioned space.

The CO₂ portion of the system utilizes high-pressure, reciprocating compressors and the cascade heat exchanger as a condenser, where the NH₃ chills and condenses the CO₂ into liquid. The liquid CO₂ cools air that is then pumped into the facility’s ductwork, keeping the NH₃ stage isolated on the roof and leveraging the non-toxic natural CO₂ to deliver high-tonnage refrigeration in the conditioned space. (The CO₂ may alternatively be pumped into an evaporator in the refrigerated space.)

To help alleviate potential ammonium carbamate concerns, the NH₃/CO₂ helix-style heat exchanger features stainless-steel

Operators and manufacturers alike began looking for ways to leverage ammonia’s efficiency while lowering system charges necessary to limit the potential for exposure to workers and product spoilage.

Enter NH₃/CO₂ cascade technology, a system architecture that has been successfully deployed in many commercial applications with HFCs on the high side.

Emerson modular rooftop refrigeration unit
construction, for corrosion resistance and long life. Multiple helical coils in a compact design allows for expansion and contraction of tubes during large changes in temperature and pressure with very low resulting strain and stress — thereby reducing the risk of failure and leaks while delivering a large heat transfer surface in a small volume.

The self-contained, modular unit essentially serves as the system’s mechanical room, enabling installation and efficiencies typically not found in traditional systems. Existing facilities can even install this system while their legacy system is still running. Installers simply position the unit at the desired rooftop location, connect the ductwork, and commissioning can potentially take place in as little as a few days. Then, as soon as the facility manager is ready, he/she can simply shut down the old system and let the new system assume refrigeration duties — minimizing or often eliminating any disruption in cold storage operations.

The simplicity of this drop-in, plug-and-play design also lowers maintenance requirements while improving serviceability throughout the lifecycle.

Addressing retrofit and greenfield challenges

From regulations and sustainability objectives to energy efficiency and operating costs, cold storage operators are faced with increasingly complex refrigeration decisions. Natural refrigerant systems such as the modular NH$_3$/CO$_2$ cascade unit help industrial cooling businesses address many of these challenges, regardless of their operational requirements.

Many brownfield facilities are facing retrofits in the near future, typically because they’re either using an aging high-charge ammonia system or an HFC-based system (such as R-22). New, all-natural systems provide opportunities to avoid the risk and documentation requirements of high-charge ammonia systems and help offer a seamless transition away from R-22 refrigeration and its associated challenges, including: the rising cost of refrigerant; known environmental concerns; and the global phase-out due in 2020.

New greenfield facilities seeking to completely avoid these complexities may find that these new NH$_3$/CO$_2$ cascade system architectures help meet many of their long-term operational requirements, including: low-charge ammonia; simplicity of a pre-designed, pre-packaged system; environmentally friendly and efficient; and compliance to future regulations; and market acceptance. For facilities simply looking to expand on their existing operations, a modular approach offers a no-fuss alternative without the complexity of trying to integrate a new refrigeration system into their existing one or expanding their current engine room.

Natural refrigerants driving innovation

The spread of natural refrigerant systems into industrial cooling is further proof of their viability across the gamut of refrigeration markets and applications. From low-charge propane in stand-alone systems to a variety of CO$_2$ architectures in food retail to the introduction of NH$_3$/CO$_2$ systems in cold storage, the market continues to seek the advantages that natural refrigerant systems can provide. As manufacturers continue to answer the call, look for naturals to be featured in more refrigeration system innovations in the coming years.

André Patenaude is director of food retail marketing and growth strategy, Cold Chain, Emerson.