WHITE PAPERS

INDUSTRIAL REFRIGERANTS

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INDUSTRIAL REFRIGERANTS SERIES

In this white paper, we address the pros and cons of the most popular industrial refrigerants and take a look at the myths surrounding CO2 and its use in cascade systems. As more food processing facilities explore the use of alternative refrigerants, we also examine Europe's stringent F-gas regulations and share successful implementation strategies of natural refrigerants within the European Union.

DISPELLING MYTHS OF CO2 REFRIGERATION

With HCFCs being phased out worldwide by 2030 due to harmful environmental impact, plant owners are searching for sustainable refrigerant alternatives. However, there is no one-size-fits-all solution.

CO2 is commonly used as a cryogenic refrigerant, but it has also been used as the working fluid in mechanical refrigeration systems as far back as the 1800s. Transcritical or subcritical CO2 refrigeration systems are common in Europe and Asia, and are gaining popularity in the Americas. In the northern US and Canada, transcritical CO2 systems have become a cost-effective choice in many food processing, cold storage and commercial facilities. Subcritical CO2 cascade and volatile brine systems are best used for low-temperature freezing and higher temperature secondary refrigerant applications.

Mechanical refrigeration using CO2 can be an attractive alternative to other refrigerants, but many have written off the refrigerant due to these common misperceptions:

MYTH #1: CO2 IS TOO DANGEROUS

Given the right conditions, all refrigerants have the potential to cause harm. Some of the characteristics that drive fear of CO2 are the same that provide its benefits. High operating pressure is "scary," but it is the feature that enables lower equipment costs and greater energy efficiency. With proper design, construction and commissioning, a mechanical CO2 system is just as safe as any other.

MYTH #2: CO2 REFRIGERATION REQUIRES LEAK DETECTION THAT OTHER REFRIGERANTS DON'T

Like many refrigerants, CO2 is a colorless and odorless vapor. Thus, it does require leak detection in the machine room as well as the cold rooms. However, leak detection instrumentation is required in unmanned machine rooms regardless of the refrigerant. In fact, many operators require leak detection for ammonia in the cold rooms too, despite its self-alarming odor. Cryogenic CO2 is widely used in processing facilities with ventilation and leak detection at the points of use. It is important to note that the right leak-detection technology is required with CO2 because of its presence in the human body. Instruments that only measure oxygen levels are not adequate.

MYTH #3: A CO2 SYSTEM IS MORE EXPENSIVE TO INSTALL AND OPERATE

In most cases, CO2 cascade systems are less expensive to install and operate than two-stage ammonia systems for low-temperature applications.

The unique physical properties of CO_2 provide an advantage when used as a secondary refrigerant for higher-temperature applications too. Its high vapor density and volatility combine to achieve much smaller piping and pumping requirements when compared to chilled glycol systems, thus reducing capital and operating costs. As a volatile brine, CO_2 can provide energy savings of up to 10-20 percent for high temperature systems and 20 to 30 percent for medium temperature systems.

When investing in a new refrigeration system, owners and operators should consider using CO_2 cascade or volatile brine systems. Whether looking to minimize ammonia charge, reduce carbon footprint, or both, CO_2 is often a viable and cost-effective option, providing:

- Cost-effective installation and operation
- Improved energy efficiency when compared to glycol
- Reduction in ammonia charge and PSM compliance costs
- Sustainability with 0 ozone depletion potential (ODP) and 1 global warming potential (GWP)

PROS AND CONS OF POPULAR INDUSTRIAL REFRIGERANTS

As R22 refrigerants are being phased out, many food processing facilities are re-evaluating their industrial refrigerants due to environmental concerns, legislative requirements and cost efficiency. In selecting a long-term refrigerant, it is important to consider your system's requirements and the operational considerations / limitations of each refrigerant. Equally important are the refrigerant's safety, impact on the environment, and performance.

Consider each of these factors when evaluating your plant's long-term refrigerant:

- Efficiency — operating pressure and range of temperatures
- Safety — toxicity and flammability
- Environmental impact — ideally you'll want to select a refrigerant with zero ODP (ozone depleting potential) and a low GWP (global warming potential)
- Thermophysical properties — high / low pressure levels and pressure ratio of the refrigerant in the application
- Chemical properties — material compatibility and miscibility with oil
- Cost — installation and long-term costs
- Availability

Here are the pros, cons and operational considerations of the most popular refrigerants in food processing:

Ammonia (NH_3)

Pros:

- Zero ODP and no GWP
- Widely available
- Highly efficient
- Low cost

Cons:

- Highly toxic with significant regulatory requirements

Operational concerns:

Ammonia is highly corrosive on copper so refrigeration lines must be composed of steel, which can increase upfront costs. Semi-hermetic (hermetically sealed) compressors are often preferred to help regulate the pressure of the gas. Ammonia has a low mass flow, which offers an advantage to large plants, but presents challenges for smaller ones. Ammonia systems have significant safety requirements.

Carbon dioxide (CO2)

Pros:

- Naturally occurring substance with zero ODP and a low GWP
- Nonflammable, low toxicity
- Widely available
- Very low cost

Cons:

- Less efficient
- High operating pressures

Operational concerns:

CO2 is not energy efficient at typical operating pressures. The critical temperature for CO2 is 88°F so systems are required to run in the transcritical range to achieve typical condensing temperatures. CO2 has better efficiency at lower temperatures and is best suited for cascade systems and as a volatile brine to replace glycol. Care must be taken to avoid the high pressures at ambient conditions if there is a system shutdown or loss of power.

Hydrofluorocarbons (HFCs)

Pros:

- No ODP, variable GWP*
- Safe, non-flammable
- Energy efficient
- Mixtures of HFCs can be designed to suit most types of applications

Cons:

- *HFCs with mid- to high-level GWP may be subject to new regulation. Some countries are considering implementing a tax on HFCs that reflects their GWP.
- High refrigerant cost

Operational concerns:

Because most HFCs are mixtures or blends, they can behave differently under certain operational conditions. HFCs are not miscible with non-polar oils such as mineral oil and thus require polyolester (POE) oil.

Hydrocarbons

Pros:

- Zero ODP and no GWP
- Widely available
- Highly efficient
- Low cost

Cons:

- Explosive
- Limits on usage

Operational concerns:

Hydrocarbons are gaining popularity as industrial refrigerants. Propane, isobutane, and propylene are among the most common, as well as blends containing ethane, propane and butane. The refrigeration properties of hydrocarbons — pressures, pressure ratios, and discharge temperatures — are similar to those of HCFCs and HFCs. Propane is very similar to R22 thermodynamically.

EUROPE IS SHAPING THE INDUSTRY IN THE UTILIZATION OF NATURAL REFRIGERANTS

European countries are at the forefront of efforts to reduce the use of industrial refrigerants that harm the ozone layer and lead to global warming. The Montreal Protocol on Substances that Deplete the Ozone Layer (link http://www.epa.gov/ozone/intpol/), called for phasing out the use of Chlorofluorocarbons (CFCs) and other Ozone Depleting Substances (ODS) like Hydrochlorofluorocarbons (HCFCs).

The European Union (EU) and its Member States have embraced this effort and established new regulations and mandates that go beyond the requirements of the Montreal Protocol. In 2006, The European Union adopted legislation, F-gas Regulation, to reduce the use of HCFCs and replace their use with other environmentally friendly alternatives. This legislation also included restrictions on marketing these substances and the use of certain equipment requiring HCFCs. By 2010, the EU had reduced its consumption of the main ozone-depleting substances to zero, 10 years ahead of its obligation under the Montreal Protocol.

Tighter F-gas regulations

In 2012, the European Commission proposed a revision to the 2006 F-gas Regulation to tighten its requirements. The new Regulation, (http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/envir/142190.pdf) adopted in April 2014, aims to reduce HCFC use by two-thirds by 2030 and ban use altogether when environmentally-friendly alternatives are readily available. This aggressive approach to eradicating ozone-depleting substances is further proof of the EU's commitment to leading this international effort.

While legislation has driven the conversion to natural refrigerants, many companies are making this choice proactively as sustainability ranks high among European corporate responsibility initiatives. Many industrial refrigeration users have made the move to safer alternatives, opting for ammonia, CO2 and hydrocarbons.

Change leaders

- Europe's commitment to reducing the use of these harmful gases has gone beyond simply eliminating their use, but has resulted in a push for the development of new technological innovations and alternative technologies. Some of the achievements thus far include:
- A vast majority of supermarkets across Europe have installed CO2 refrigeration systems
- Many predict that by 2020, market share of industrial refrigeration systems using natural refrigerants could top 20 percent
- Denmark already has a market penetration rate of close to 100 percent for facilities using natural refrigerants
- Nestlé recently announced that the company will only use natural refrigerants in its commercial freezers in Europe
- A recent research study revealed that three in five (63.6 percent) of food retailers in Europe are utilizing natural refrigerants

Many European companies are asking for political support to bring their innovative natural refrigerant-based solutions faster to market. Others are calling for new regulations that accelerate phase-out schedules, while some call for implementing taxes and financial incentives to accelerate the adopting of natural refrigerants.

U.S. companies doing business in Europe, such as Nestlé, are already making widespread changes based on the EU's more stringent regulatory requirements. The insights gleaned from those experiences in Europe will certainly have an impact on when and how U.S. companies will begin a more aggressive transition to natural refrigerants.

Industrial refrigerants series

Food processors and distributors are under constant pressure to produce more while spending less on operations. For plant owners looking for greener and more efficient secondary refrigerants, a carbon dioxide (CO2)/ammonia (NH3) cascade system is a viable option. In addition to providing 0 ozone depletion potential (ODP) and 1 global warming potential (GWP), CO2/NH3 cascade systems offer several benefits for food processing and low-temp distribution facilities including:

1. Lower operating costs – refrigeration systems are most efficient at 100% load. But the refrigeration systems in most processing and cold storage facilities don't run at full load for much of the time. During these times of partial loading, energy efficiency is more difficult to achieve. A CO2/NH3 cascade system uses less energy per ton of refrigeration when compared to other refrigeration systems at full load, but the difference can be even better at part load, especially when operating at evaporating temperatures of -35oF to -60oF.

2. Lower capital costs – using CO2 instead of ammonia for lower temperatures takes advantage of CO2's unique physical properties, resulting in smaller pipes, smaller pumps, less insulation, and less installation labor when compared to two-stage ammonia systems.

3. Ammonia charge reduction – a CO2/NH3 cascade system allows designers to limit ammonia charge to the machine room. Only CO2 is present in the processing and/or storage areas. For large low-temperature freezing systems, the reduction in ammonia charge can be significant.

Many owners are considering propylene glycol, a secondary refrigerant chilled by ammonia or another refrigerant, as a strategy to reduce ammonia charge for the higher temperature (above freezing) storage and process loads. For these applications, CO2 brine, often already part of the low-temperature cascade system, can be circulated to higher temperature storage loads serve as an efficient and less-expensive alternative to glycol.

4. Reduced compliance costs – in many cases, CO2/NH3 cascade systems can be designed with an ammonia charge below 10,000 pounds, giving owners the opportunity to reduce the costs associated with PSM and RMP compliance.

5. Constant positive pressure – because CO2/NH3 cascade systems always operate at a positive pressure, there is minimal concern about non-condensable build-up, and air and moisture cannot invade the refrigeration piping through vacuum leaks.

6. Quality and throughput improvements – frozen foods processors often seek lower process freezing temperatures to enable faster freezing, which optimizes food quality and enables increased throughput. With CO2/NH3 cascade systems, lower temperatures (and higher production yields) are achievable with less investment and less operating costs than conventional refrigeration systems.

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