Campbell Soup Company Extends Use of CO_2 Systems Into Their Operations

The Campbell Soup Company needed to expand their frozen operations at one of their Pepperidge Farm manufacturing plants in Pennsylvania with the addition of a new spiral freezer. From a refrigeration perspective, they had three main objectives. Given that physical restrictions would not allow the construction of a penthouse to contain standard ammonia coils, they wanted to avoid adding more ammonia (NH3) to their operation. They also did not want to expand the existing engine room or construct a new one. Lastly, Campbell wanted to continue to rely on an environmentally-friendly, natural refrigerant.

Limited space in the plant meant that taking a standard approach of constructing a penthouse for ammonia fan coils above the new spiral freezer, and outside of the production space, would not be an option. An alternative design to install the ammonia fan coils inside the spiral freezer, on the other hand, would not be ideal from a life safety perspective.

There were, as operators of ammonia plants know, good reasons for not wanting to add more. Although NH3 is an efficient, widely-used natural refrigerant in industrial applications, its high toxicity makes it considerably more challenging than most other refrigerants to use. Operations with more than 10,000 pounds of NH3, for instance, must have a process safety management (PSM) procedure in place as required for regulatory compliance. This, in essence, means specialized safety equipment, reporting, inspection and training requirements in order to facilitate its safe operation.[1]

Although the plant already had a large NH3 system in place, Campbell did not want to add more NH3 charge onsite. Something else they also already had, however, was a surplus quantity of low-temperature glycol capacity. A series of changes to the plant's operation over the years had left them with a certain amount of this glycol. But it was not enough to support the new spiral freezer refrigeration load.

Instead of adding more NH3 to accommodate the new spiral freezer, they found that the surplus glycol (in conjunction with their existing NH3 charge) could serve as one big condenser for a cascade-type system that would handle cooling the spiral freezer. Taking this path offered Campbell a number of advantages.

An Alternative Route

First, a compressor skid for a refrigerant other than NH3 offered the possibility of a more compact installation. That's because one particular natural refrigerant, CO2 at -40°F (the saturated suction temperature at which the spiral freezer evaporators would be running), is ten times denser than NH3, meaning that compressors that are ten times smaller can be used. As pointed out by Chuck Taylor of CRT Design, the consulting engineers who advised Campbell on the project, this enabled them to use a much smaller compressor skid in order to achieve an equivalent amount of cooling. By taking this path, Campbell could meet one of their other main goals for the project, eliminating the need to either expand the existing engine room or build a new one. The new cascade skid could simply be set in the existing engine room.

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[1] Because of the success of PSM, many operators including Campbell use it even when their charges are below 10k.

Sticking with NH_3 would have involved its own set of challenges even if Campbell's other goals weren't as important; cost was clearly a factor. The plant's operators were familiar with NH_3 since they were already using it onsite. But, expanding that use would have required Campbell to either build out the existing engine room or add another one. The project budget was not going to support either of these options.

Campbell of course had other factors beyond cost to consider. Environmental sustainability is a cornerstone of Campbell's approach to business. Campbell is committed to the Montreal Protocol and restricting the use of HFC and other high global warming potential (GWP) refrigerants, while at the same time improving energy efficiencies. Eliminating HCFCs and continuing to rely on natural refrigerants has been a major step in their commitment to sustainability.

Advantages of CO_2

CO_2 is an environmentally-friendly, highly efficient natural refrigerant. The operational benefits in efficiency of CO_2 come largely from its thermodynamic properties. CO_2 has a high coefficient of heat transfer making it very effective compared to most other commonly used synthetic refrigerants. Improved operational efficiencies with CO_2 systems provide an alternative to traditional HFC/HFCF industrial systems and were a key factor in Campbell deciding to use it.

In fact, Campbell was so convinced of the advantages of CO_2 that when they embarked on the project, they also chose to install another CO_2 system at their corporate R&D facility in New Jersey. For that installation they went with a different type of system, called a transcritical booster skid.[2] Instead of working in combination with another refrigerant, such as NH_3 like the cascade system in their Pennsylvania plant does, the New Jersey facility runs entirely with CO_2.

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[2] Booster systems using NH_3 in industrial applications are not uncommon. The main difference between these and CO_2 booster systems are the higher pressures CO_2 booster systems operate at which is why those systems are often referred to as transcritical.

Regardless of the type of system employed, using CO2 as a refrigerant has an added advantage involving the vapor compression cycle[3]—the heat of compression. The heat that is produced as a by-product of compression (in other words, wasted energy) can be felt and subsequently captured. The resulting heat reclaim adds to the list of benefits that CO2 can provide and that users in other applications, ranging from supermarkets to ice rinks, can likewise take advantage of.

Still, more gains result from when the CO2 reciprocating compressors are controlled with variable frequency drives (VFDs). This allows for greater energy savings under varying load conditions. The screw compressors typically used on NH3 systems can be also be controlled by VFDs but doing so offers less advantages than with CO2 reciprocating type compressors. The VFDs for the CO2 compressors on the cascade system's parallel skid enable them to better match refrigeration loads.

Choosing a hybridized CO2/glycol cascade system delivered more advantages to the company. Limiting the system's NH3 charge to the confines of the engine room contributed to a safer work environment that enabled them to avoid incurring any further PSM costs beyond those already in place. But the savings didn't end there. More cost advantages were realized during installation.

Key to the reduced installation costs of CO2 systems is that they, for the most part, use standard refrigeration components and materials. (CO2 booster systems involve some specialized parts that are required by the higher pressures at which those types of system operate.) But everything that is required for CO2 cascade systems, from piping to valves to controls, is readily available from refrigeration supply houses. The piping, in particular, needed for CO2 provides a big cost advantage in that smaller diameter pipe than is required for other refrigerants can be used. This again results from the excellent thermodynamic and transport properties of CO2 and adds to its installation cost savings. Consequently, the pipe running from the skid to the freezer's evaporators and back, was less costly than if another refrigerant had been used.

[3] The basic process by which most refrigeration systems operate in which a refrigerant undergoes changes in its state (generally from a liquid to a gas) that cause it to absorb heat from one location and to then reject (i.e., release) it to another when it changes back to its prior state.

Using experienced certified refrigeration contractors ensures that installations are done efficiently and on time. Since CO2 has been widely adopted throughout North America over the past decade, contractors working with CO2 are not hard to find.

One other factor in lowering installation costs is that, unlike a conventional NH3 system with costly individual screw compressors, the CO2 cascade skid came already fully-assembled, internally-piped and wired from the manufacturer. This, in essence, makes for the equivalent of a plug-and-play refrigeration system installation. Once in place, the rack needed only to be connected through its three plate-to-plate heat exchangers to the glycol supply on one side and through its two suction-liquid heat exchangers on the other side to the system's low-temperature loop. A field-installed desuperheater, wiring and external control connections are all that's needed to complete the setup.

Operational Benefits

Once the system is up and running, the use of standard widely-available parts and materials means that the costs for maintenance and repair will also be lower. Technicians do not have to wait on any specialized components or other items that might not be as easy to source. On top of that, CO2 (R744) is readily available and inexpensive. It typically sells for as little $1 per pound in some cases.

According to one estimate, CO2 compressors use approximately 40% less energy than conventional freezing systems.[4] When combined with the other benefits it provides, not the least of which is its lower impact on the environment with a GWP of 1 and an ODP (Ozone Depletion Potential) of 0, CO2 is an attractive alternative to other refrigerants. In fact, it has been described as a way to future-proof refrigeration given that there are no regulatory restrictions on its use, and since it's non-toxic and non-flammable, there are no limitations placed on the size charge that can be used in a single installation.[5]

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[4] http://www.mmrefrigeration.com/6-reasons-choose-co2-cascade-system-spiral-freezer/

[5] Future-proof NatRefs in ATMO Europe spotlight http://www.r744.com/articles/7865/future_proof_natrefs_in_atmo_europe_spotlight, ALDI US continues transcritical CO2 rollout http://www.r744.com/articles/8115/aldi_us_continues_transcritical_co2_rollout

The challenges facing industrial refrigeration make the rationale for moving to environmentally-friendly CO2 convincing. As Campbell has realized, CO2 cascade systems offer significant advantages. The design and operation of these systems makes them comparatively easy to install and operate. CO2 provides an alternative to traditional industrial refrigerants that place users on a path toward greater sustainability and higher levels of efficiency while at the same time ensuring safer, more manageable systems.

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