ENGINEERING TOMORROW

Technical Article

Making the case for CO_2 refrigeration in warm climates

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For a decade or more, the potential of CO_2 in supermarket refrigeration has been recognized in Northern Europe. Thanks to its unique properties, notably the high heat transfer coefficients and the low sensitivity to pressure losses, CO_2 delivers high performance in supermarket applications.

In warmer climates, the advantages of CO_2 in food retail applications have been disputed. In recent years, however, the interest from forward-thinking retailers has fueled the invention of new technologies that make transcritical CO_2 systems in warmer climates both viable and profitable. New technologies are rapidly emerging as highly energy efficient solutions that help retailers reduce complexity and meet current and future regulation on traditional refrigerants.

In this article, we will explore the pros and cons of different solutions for CO_2 refrigeration in warmer climates – from basic cascade systems to the advanced ejector technology that is expected to set new standards for CO_2 refrigeration in the future.

CO_2 is one of the most environmentally friendly refrigerants with a GWP of only 1; it is widely available as a by-product in a number of industries, and the price of CO_2 is low.

CO_2 cascade systems – good performance but high complexity

CO_2 has played a role in warmer climates for several years, typically in subcritical cascade systems that enable CO_2 to perform at its best. A cascade system combines the benefits of CO_2 in the secondary loop with another refrigerant in the primary loop, providing high energy efficiency in warm climates. However, the first cost and complexity of cascade systems are high and constitute a barrier to more widespread use of CO_2 in food retail applications. This is particular evident in smaller systems where the complexity of cascade systems increases the first cost, to which smaller format stores are particularly sensitive to.

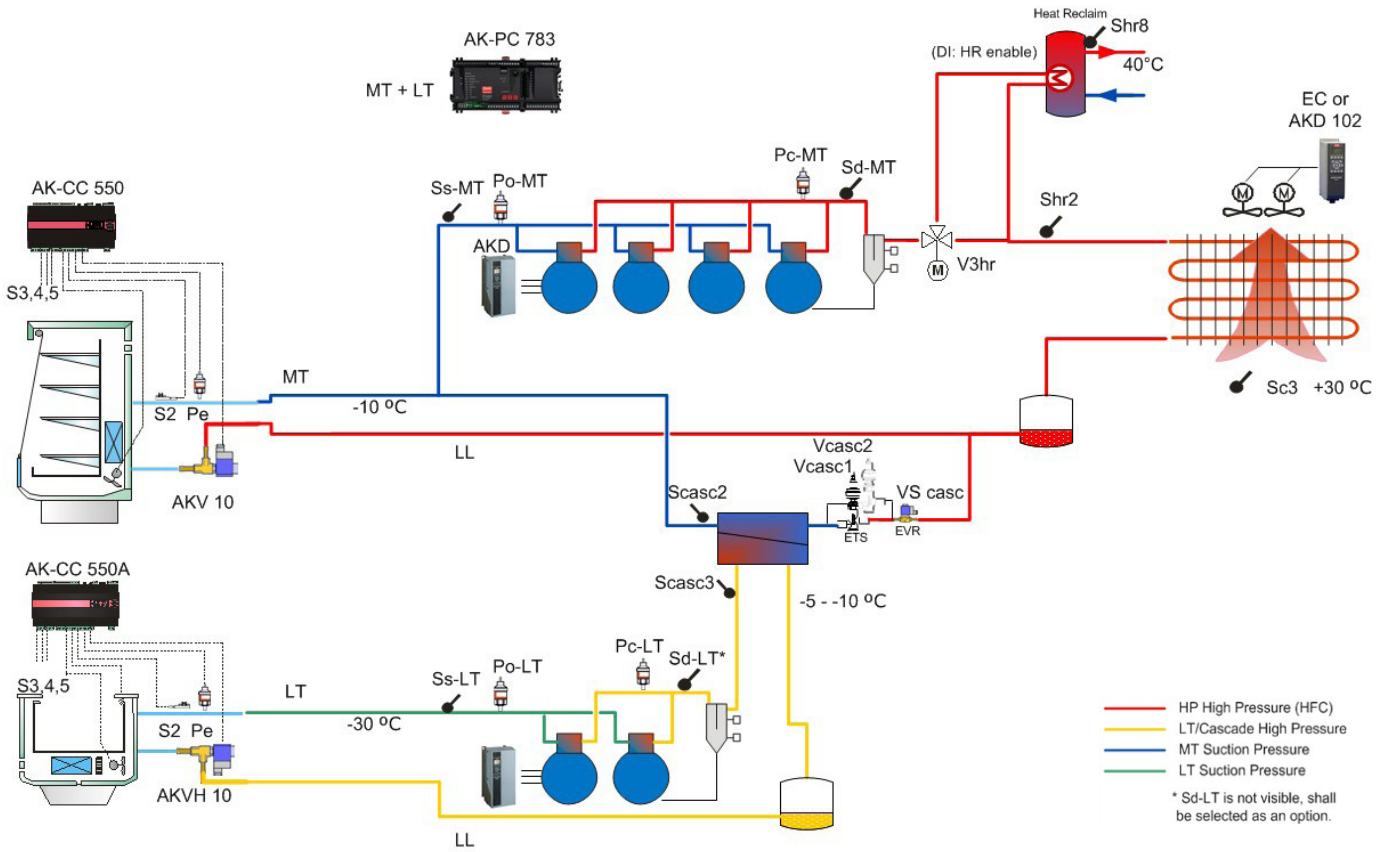

Figure 1: CO_2 Transcritical Booster Plant with Intermediate Compressor

Transcritical booster systems – industry standard today

The transcritical booster system has become the most common CO_2 solution today with more than 7,000 systems in place with Danfoss components alone. The system is particularly popular in temperate climates, whereas in warmer climates more development of the technology is needed in order to achieve similar or better energy efficiency than non-natural solutions. These technologies will be discussed in the following chapter.

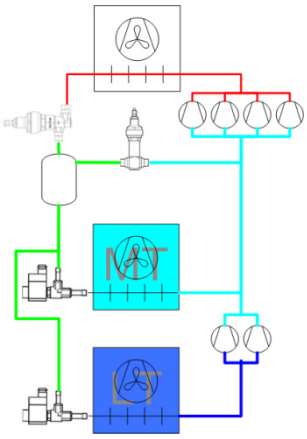

Figure 2: Outline of CO_2 transcritical booster system

Parallel compression – highly efficient in warm climates

In the pursuit of simplification and energy efficiency, other solutions have surfaced to allow CO_2 as the sole refrigerant in supermarket refrigeration. Parallel compression is the first step on the journey to make CO_2 an attractive solution in warmer climates, especially for larger installations. Parallel compression is therefore steadily advancing as a highly energy efficient CO_2 solution.

Parallel compression is a solution that compresses the excess gas at the highest possible pressure level to improve the energy efficiency. The solution yields significant improvement of COP in warm climates.

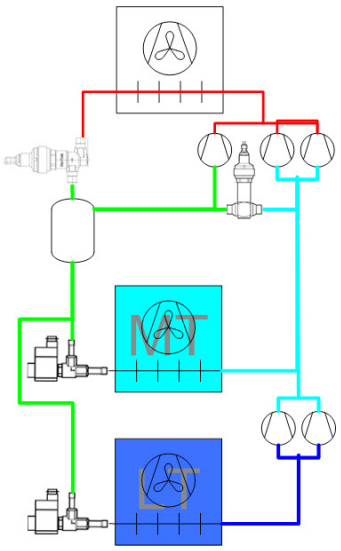

Figure 3: Parallel Compression

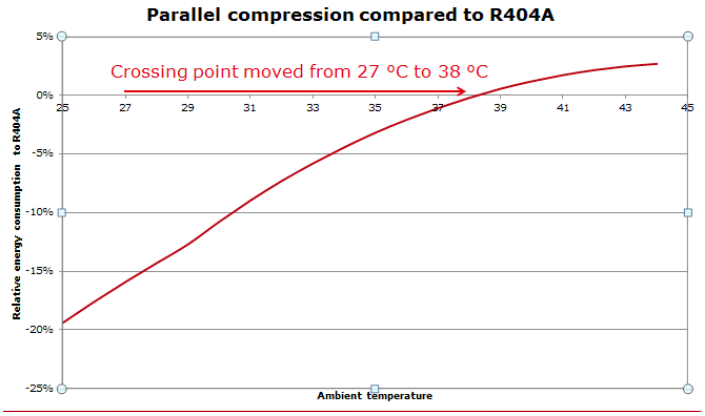

Figure 4: As long as the ambient temperature stays below 37° C, parallel compression saves energy compared to R404A.

Evaporative condensation and mechanical sub-cooling – local solutions for small systems

Evaporative condensation solutions use water to cool the gas in transcritical CO_2 applications. The solution is well-suited for small refrigeration systems and most attractive when it can be combined with AC systems on site. The energy savings returned by the solution are about 5-10 % in warm climates. Furthermore, it is possible to save up to 50% on the compressor capacity; however, the capacity is typically needed on the auxiliary cooling unit instead.

The solution is only applicable in areas with no restriction on water supplies. Besides, several markets have restricted the use of evaporative condensation due to the risk of legionella contamination from the water used in the application. Evaporative condensation is regarded as a temporary solution filling the gap in CO_2 refrigeration until other and safer solutions have matured.

Mechanical sub-cooling is yet another solution that has emerged in recent years in the quest to make transcritical CO_2 refrigeration viable in warmer climates. Mechanical sub-cooling uses a small mechanical vapor-compression cycle coupled to the main cycle at the exit of the condenser in order to provide sub-cooling to the main refrigeration cycle. The extra unit turns on only when the temperature exceeds a certain level and will therefore return energy savings during peak loads.

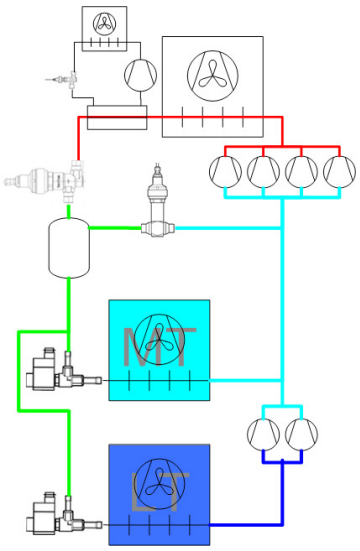

Figure 5: Outline of Evaporative Condensation unit for a small supermarket

Ejector – boosts the efficiency of parallel compression

Ejector is a well-known technology that has been used for more than 100 years in different applications, notably in water utilities, to retain the pressure in the system.

In close cooperation with SINTEF, Danfoss has devised new ways to use the ejector technology in refrigeration application to increase the energy efficiency of parallel compression.

Today, the current experiments with the ejector technology return promising results proving the viability of transcritical CO_2 system in warm climates. The high energy efficiency is achieved by recovering the energy taken out while reducing the pressure from the gas cooler to the liquid line pressure. The ingenious solution reduces the workload of the compressors, while still ensuring that the cooling demand is met at any time.

The ejector is still in the prototype stage, but the initial trial set-ups in more than 10 supermarkets in developed countries have shown that the simple ejector technology can increase the efficiency of the parallel compression system as much as when going from no parallel compression to parallel compression. The energy saving potential compared to traditional HFC systems is significant. Furthermore, the ejector technology allows smaller and more compact compressor packs to be installed, reducing the first cost of the installation.

Next step in the development of the ejector technology for refrigeration is a liquid ejector that allows the MT evaporators to be flooded. This means added savings resulting from a higher suction pressure. Combined liquid and gas ejectors have run in trial set-ups since 2013 yielding energy savings of 20-25 % compared to HFC systems. The first release of commercial liquid ejectors is expected within 2-3 years.

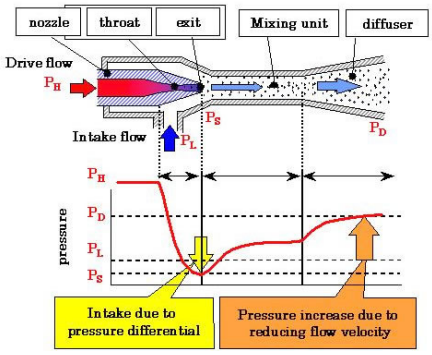

Figure 6: The ejector captures and boosts the pressure of the gas and reduces the workload of the compressors

CO_2 on its way to become industry standard in all climates

CO_2 is increasingly conquering the market for food retail applications as traditional HFCs are phased out and retailers are looking for ways to reduce their CO_2 footprint. Due to the fast technological development, CO_2 is today one of the best choices for supermarket refrigeration in all climates, allowing global food retailers to use similar solutions in all stores regardless of location. CO_2 offers high energy efficiency, excellent possibilities for heat reclaim and a low carbon footprint to promote a green image.

System	Energy saving VS. R404a	Compressor saving VS. Booster
Booster	-11%	0%
Parallel compression	7%	15%
Gas ejector	10%	18%
Liquid & gas ejector	22%	27%

Tabel 1: Potential energy savings by using parallel compression with gas ejector only or liquid & gas ejector. Comparisons are made at 32°C.

Danfoss leads the development of solutions and components for CO_2 refrigeration and offers a wide range of products specifically designed for CO_2 transcritical systems. Furthermore, Danfoss provides training, design tools and consulting services to promote the use of CO_2 and to support the development of forward thinking solutions in all parts of the value chain.