

An aerial photograph of a large agricultural field, likely a cornfield, showing distinct rows of crops. The top half of the image is dominated by a bright yellow color, while the bottom half is a vibrant green. The rows of crops create a strong sense of perspective and depth, receding towards the horizon.

APPLICATIONS OF TRANSCRITICAL

CO₂

Part 2

Chapter 3



An overview

Transcritical CO₂ technology has been deployed in a variety of applications across the world for many years. From traditional supermarket applications to convenience stores and industrial cold storage applications; even on cruise ships and for ice rinks – there are hundreds of examples of successful installations globally.

The following pages showcase examples of a multitude of different transcritical CO₂ installations, varying in size and location, categorized by type of application. Whether in a small, convenience store type of installation, or the more conventional commercial retail one; even industrial projects – transcritical CO₂ is worth considering when designing an HVAC&R installation. Here is how others have done it...

INDUSTRIAL APPLICATIONS



REFRIGERATED WAREHOUSING/ COLD STORAGE

¹⁶U.S.: Hannaford, a Scarborough, Maine-based division of Ahold Delhaize, is one of the first U.S. grocers to employ a transcritical CO₂ system in a refrigerated warehouse. Hannaford's CO₂ warehouse also contains one of the world's largest refrigerated spaces (250,000ft²; 23,226m²) to use a transcritical system. The warehouse supplies 85 of Hannaford's approximately 190 stores in New York, New Hampshire, Vermont and Massachusetts.

Four transcritical racks are planned in what is a replacement of the warehouse's original, almost 30-year-old R22 system. Three of the racks are medium-temperature, two-stage, intercooled systems, while the low-temperature rack (the first installed) is single-stage, with ejector defrost.

¹⁷Japan: Japanese cold storage operator Hamamatsu Itaku Soko reduced energy use by up to 35% at one of its facilities after replacing an R22 system with a transcritical CO₂ system. In 2018, Hamamatsu Itaku Soko replaced a 22-year-old R22 system at its Yonezu Cold Center facility with the transcritical system. The cost of the installation

was supported by Japan's government subsidies for natural refrigerant systems. The old R22 unit was reaching its lifetime end after running for 22 years.

The R22 unit in 2017 consumed 854,898kWh [244,257RTh]. By contrast, in 2018, the CO₂ unit consumed 553,842kWh [158,241RTh], a drop of 35%, and in 2019, 562,417kWh [160,691RTh], a 34% reduction.

¹⁸Japan: Fukuoka-based Yoshio Ice Manufacturing & Refrigeration (Yoshio Ice) installed three Japanese-manufactured CO₂ transcritical systems at one of its cold storage facilities in April 2018. The region experiences some of Japan's hottest and most humid climates with temperatures sometimes reaching 35°C [95°F] during the summer months.

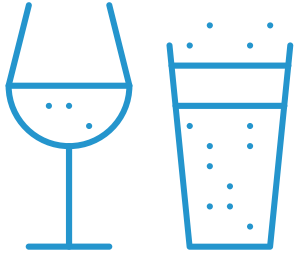
The three CO₂ transcritical systems service one 4,700m³ [133ft³] frozen storage room (at -25°C [-13°F]), as well as a 3,700m³ [105ft³] cold room (at 5°C [41°F]) and a 4,700m³ [133ft³] loading area (at 5°C [41°F]). The power consumption for the period from April to December 2018 was 27kWh/m³ [0.22RTh/ft³]-

less than what was predicted (around 35kWh/m³ [0.28RTh/ft³]), and far less than Japan's industry annual average of around 61kWh/m³ [0.49RTh/ft³].

¹⁹Australia: South Coast Stores, an Australian wholesaler in the remote town of Nowra, New South Wales, has opted for a transcritical CO₂ system that uses solar energy and employs the waste heat from the refrigeration system for hot water and heating requirements. The cold-storage component was commissioned in January 2019, followed by the retail space in February. Other refrigeration options, including ammonia and HFCs, were rejected.

The commercial viability of an ammonia plant versus a CO₂ plant with solar PV was found to be unattractive, and therefore a full CO₂ plant with booster and parallel compressors and an adiabatic gas cooler was chosen as the lowest-cost option. The CO₂ system provides 256kW [55.8TR] of total cooling capacity.





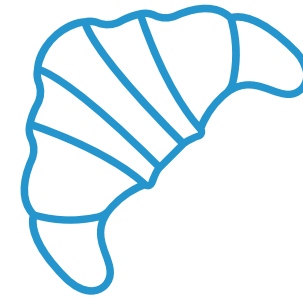
WINERIES AND BREWERIES

²⁰**Japan:** In Japan, transcritical CO₂ is experiencing an expansion into the sector of food production and food processing. Companies such as Asahi Breweries, which makes one of Japan's most well-known lagers, along with margarine production facilities and packaged ice manufacturers, are currently installing transcritical CO₂ refrigeration systems.

²¹**Europe:** High up in the picturesque mountains of South Tyrol, northern Italy, at the nine-centuries old Abbazia di Novacella/Kloster Neustift, two CO₂-based water-brine chillers serve a high-efficiency CO₂ transcritical system with gas coolers and heat recovery. Each of the chillers, installed in August 2017, has a cooling capacity of 60kW [17.1TR]. The two units are used to cool must when it increases in temperature

during the fermentation phase; at the same time, heat recovery produces sanitary water at 90°C [194°F] for cleaning the wine barrels. In the system, the water chiller, depending on the cooling load request from the air-conditioning system, generates cold water.

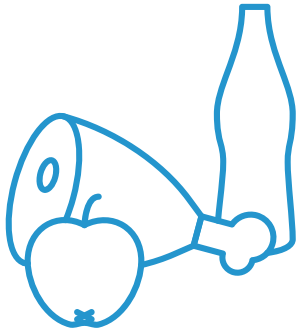
It can operate in several ways. In the first operating mode, it rejects the heat into the ambient air. A second operating mode is used when hot water is required. A three-way valve transfers the available heat to a water cylinder, and the mass flow of refrigerant bypasses the condenser/gas cooler. A third option is to reheat the water in the cylinder. Here the CO₂ passes through both the heat recovery heat exchanger and the condenser/gas cooler. In this manner, it is possible to produce sanitary hot water almost for free.



BAKERIES

²²**Europe:** The site of BACU Bakery in the Netherlands was equipped with its first transcritical flooded chiller. The cooling capacity is 550kW [157.1TR], the evaporation temperature is 1°C [34°F]. Propylene Glycol is used in the chiller and heat recovery is deployed for heating water.

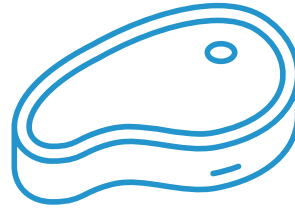
FOOD AND DRINKS PROCESSING



FOOD PROCESSING

²³**South Africa:** To meet an increase in the demand for their popular range of Mediterranean Delicacies branded products, BM Food Manufacturers opted to completely revamp their 18-year-old plant in Cape Town. The interior of the 1,200m² [12,916ft²] building, with its simplex R22 refrigeration units, was totally gutted. The new plant needed to meet EU standards, be energy efficient, and have minimal impact on the environment. In the processing of ready-to-eat soups and prepared meals, the refrigeration plant consumes the largest portion of power.

The new CO₂ plant has a trans-critical booster pack with parallel compressors. The pack has seven semi-hermetic compressors, all fitted with variable frequency drives (VFDs) for capacity control. Three compressors operate on the medium temperature (MT) circuit (-7°C [19°F]), two on the low temperature circuit (-32°C [-26°F]), and two provide parallel compression on the MT. The MT circuit maintains the temperature (0–4°C [32–40°F]) in five cold rooms, three double-blast chiller tunnels, and a blast chiller. Heat recovery is used to heat water to between 40°C and 45 °C [104°F and 113°F]. The LT circuit has a blast freezer that can also operate as -25°C [-13°F] cold room.



MEAT PROCESSING

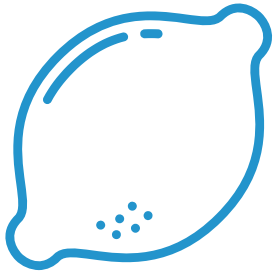
²⁴**U.S.:** The world's largest transcritical CO₂ refrigeration system has been installed and commissioned at Yosemite Foods, a California-based pork and meat supply company. With a total cooling capacity of 4MW [1,137TR], it is the largest transcritical CO₂ refrigeration system installed globally. The company Yosemite recently relocated and expanded to the city of Stockton, where it opened a new 200,000ft² [18,580m²] meat processing facility.

It is here where five transcritical CO₂ refrigeration racks power the cooling needs for the facility's quick chiller, process water chiller and cold/freezer rooms. The system also employs heat reclaim to produce process hot water. In order to mitigate reductions in energy efficiency due to the plant's location in central California, where ambient temperatures can be high, the system uses adiabatic condensers and parallel compression.

²⁵**South Africa:** The new Meat World production facility in Springs boasts an energy efficient, state-of-the-art trans-critical CO₂ refrigeration plant that will raise the technology standard in South Africa. The heat load for

the system consisted of amongst others between 80 and 160 tons [79 imperial tons and 158 imperial tons] of fresh meat as well as 1,000 tons [984 imperial tons] of frozen meat passing through the facility daily. This all added up to a combined heat load of 840kW [240TR] for both the medium and low temperature applications. Additionally, the client required that the system could supply 10,000l [2,200gal] of hot water per hour as well as 2,000l [440gal] of chilled water for various factory and processing functions.

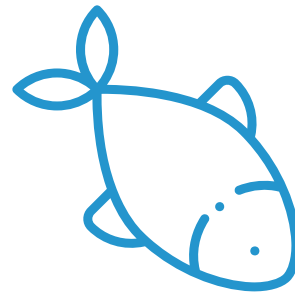
The final equipment offered and installed for the CO₂ system were as follows: Two outdoor multiple compressor rack plant rooms each handling half of the overall load to keep the system balanced. The following are specifications for each plant room: Racks capable of delivering 431kW [123.1TR] each to serve both medium and low temperature applications, each rack consists of eight compressors all equipped with service valves on the suction, discharge and oil side to allow for isolation if required, as well as pressure relief valves. Furthermore, the system is quipped with a vapor multi ejector.



FRUIT PROCESSING

²⁶**South America:** One of the leading fruit processing companies in Peru was recently supplied with a transcritical CO₂ system. Friopacking – an engineering and construction company specializing in food processing plants – was in charge of the installation, which took place in the city of Trujillo. The fruit-processing operator could not be identified without its permission.

The transcritical system serves 1,750m² [18,837ft²] of refrigerated storage, with a low-temperature capacity of 54TR [189.0kW], and a medium-temperature capacity of 21TR [73.5kW]. The control package keeps the system's COP at maximum levels at all times.



FISH PROCESSING

²⁷**Europe:** DFDS Logistics Ltd., a logistics and freight shipping company headquartered in Copenhagen, Denmark, announced in October 2019 that it had purchased 50 CO₂ refrigerated shipping containers to use in its short-sea (coastal) shipping service.

In addition to being in line with sustainability initiatives, the CO₂ shipping containers are helping shipping companies mitigate future business risks related to environmental regulations and technology phase-outs. According to the statement issued, DFDS has emblazoned each of its new 45ft [13.7m] containers with the slogan 'Naturally Chilled: No synthetic refrigerants – kinder to the environment'.

²⁸**U.S.:** Global Seas, a private fisheries management company based in Seattle, Washington, has installed

a CO₂-based refrigeration system using recirculated seawater on its F/V Northern Defender trawler. The system was chosen for its compactness and cost-effectiveness. The Northern Defender was built in 1979, and the original synthetic refrigeration system had become outdated, and needed replacing.

The Northern Defender, a 45m trawler fishing in the Bering Sea, off the Alaskan coast, needed a system that could keep up to 308,443kg [680,000lbs] of pollock fresh on the several days' journey back to port. For this, Highland Refrigeration built a 500kW [142.2TR] recirculated seawater (RSW) system that chills the catch with 0 to -1°C [32 to 30°F] seawater. The system had to fit into a space only 8m [26.2ft] long, 1m [3.3ft] wide, and 2m [6.6ft] high.

NICHE APPLICATIONS/ OTHER



ICE RINKS

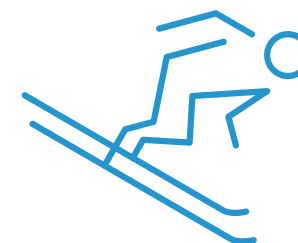
²⁹**Canada:** A transcritical CO₂ system for an outdoor ice trail was installed at the College Park section of Toronto, Canada. Opened in December 2019, the Barbara Ann Scott Ice Trail is an oval-shaped, 5m (16.4ft)-wide path that doubles for a walking loop in the summer.

The system's capacity is 50TR [175.0kW], which is enough HP to maintain the ice surface in all conditions, yet the piping and the CO₂ pumps are much smaller and more efficient than standard rink systems. According to the manufacturer's website, the system costs roughly half as much to operate as other options. In part that is because the CO₂ system is a direct system, making it more efficient than a secondary system. Instead of removing

heat at multiple steps, the refrigerant in this system goes straight to the ice floor, removes the heat from it, then uses the same refrigerant to carry it and remove it.

³⁰**China:** The Beijing 2022 Organizing Committee has officially announced its plan to use CO₂ refrigeration systems for several ice venues in the Beijing 2022 Winter Olympics. This will be the first time the technology is used in China and at the Olympic Games.

CO₂ systems will be used in «the Beijing 2022 speed skating, figure skating and short track venues, as well as the ice hockey training venues. R449 will be used in the ice hockey and curling venues.



SKI SLOPES

³¹**Europe:** In January 2020, Norway's first year-round indoor ski arena, named SNØ, opened in Lørenskog, just east of capital city Oslo. The snow for the venue is cooled by natural refrigerant CO₂. The arena is fitted with three transcritical racks and delivers 3.1MW [885TR] of cooling in what is the largest CO₂ transcritical installation in Norway.

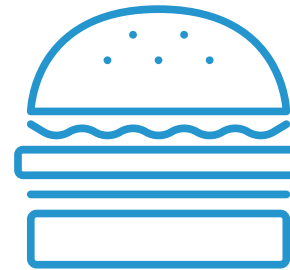
The platform will maintain temperatures at -4°C [25°F] and be able to deliver temperatures as low as -12°C [10°F]. It integrates modulating vapor ejector technology as a standard feature to improve energy efficiency. It is asserted that the platform can deliver energy savings of up to 30% on an annual basis compared to standard transcritical CO₂ systems.





CRUISE SHIPS

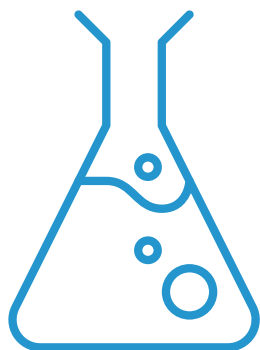
³²**China:** Two cruise ships in China are going to be equipped with a transcritical CO₂ refrigeration system. All food and beverage on the ships will be refrigerated with this system. They are the first two cruise ships ever to be built in China, according to the manufacturer of the CO₂ system. The first ship will be delivered in 2023.



FAST FOOD

³³**Europe:** U.S. fast food chain Burger King has chosen a transcritical CO₂ system as preferred condensing units for its restaurants in Spain. It marks the first time that Burger King has used CO₂ and it has since ordered more.

Spain has a warm climate throughout the year with temperatures reaching above 40°C [104°F] and so having the right and reliable refrigeration solution was essential. This system is designed to operate in warm temperatures and is using components that can handle 80 bar [1,160psi] service pressure and it can operate with ambient temperatures reaching up to 43°C [109°F].



PHARMACEUTICAL PROCESSES AND LABORATORIES

³⁴**Europe:** At the site of multinational biotechnology group in Basel, Switzerland, transcritical CO₂ is used for cold storage rooms for pharmaceuticals. A transcritical CO₂ double-stage system serves two cold rooms where most of the products are stored at -20°C [-4°F]. The cooling capacity is two x 71kW [20.2TR], with four compressors. The compressor capacity is 12.5kW [3.6TR]. A total of 110kg [242.lbs] of CO₂ per chiller are used. The system primarily runs in subcritical mode, harnessing groundwater to cool the CO₂ and improve the efficiency.



PRODUCT TESTING

³⁵**U.S.:** A new innovation/technology centre in Downtown Minneapolis where Jack Link's Beef Jerky tests new products has been kitted out with a transcritical CO₂ system. The system delivers a low-temperature capacity of 36.4K BTU/hr [10.7kW; 3.1TR] and a medium-temperature capacity of 575.5K BTU/hr [16.9kW; 4.8TR] to the 10,000ft² [929m²] processing area.

The transcritical system leverages heat reclaim to create hot water used to preheat the water required for the wash down of the processing area. A unique aspect of the Jack Link's project is that the CO₂ discharge gas is cooled in a heat exchanger by chilled (40°F-50°F/ 4.4°C-10°C) water provided via underground pipes by Clearway Energy's Energy Centre. The cooled water prevents the CO₂ system from ever entering transcritical mode, in which high ambient temperatures prevent the gas from condensing.



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