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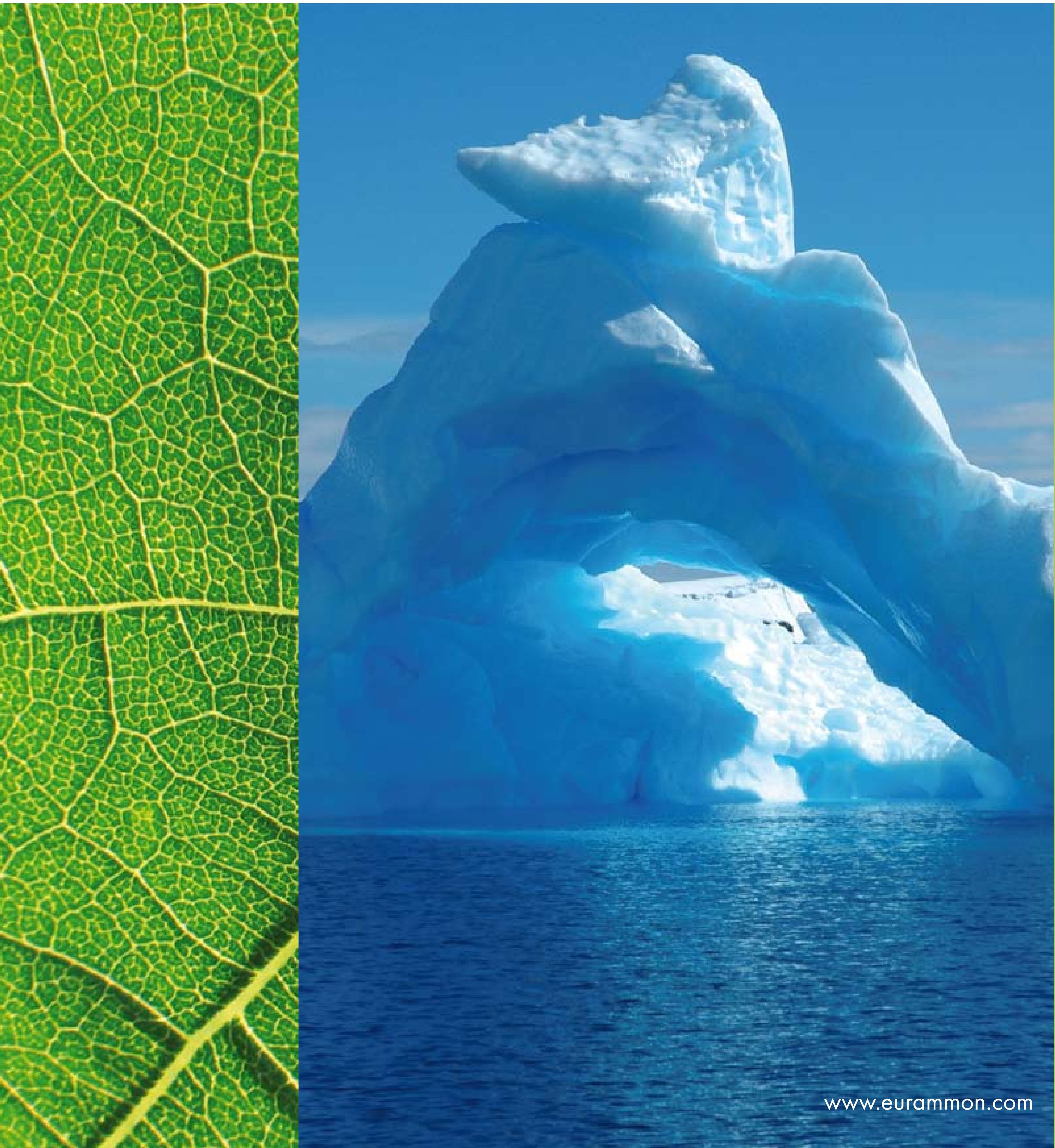
refrigerants delivered by mother nature

# Refrigerants by Nature

## eurammon magazine



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# Dear Readers,

The European refrigeration industry faces challenges. The EU directive on ozone depleting substances stipulates that from 2010, only recycled HCFCs may be used in refrigeration and air conditioning systems onwards. This period ends in 2015, after which all HCFCs will be banned from use in refrigeration and air conditioning systems. According to our estimates, over half of the refrigeration and air conditioning systems currently in operation in Europe are still using HCFCs. Reductions in HCFC production by refrigerant manufacturers mean that there will be less and less available in future.

So it makes good sense to retrofit or decommission old refrigeration systems depending on their age, remaining working life, overall condition and cost of operation. Either way, natural refrigerants are a good alternative. They are not only environmentally friendly – ammonia has zero global warming potential (GWP) and the GWP of carbon dioxide and hydrocarbons is negligible – but also energy efficient. For instance, the outstanding thermodynamic properties of ammonia have established it as the most efficient refrigerant available with the lowest primary energy input to produce a given refrigeration output. Refrigeration systems based on carbon dioxide and hydrocarbons have also been developed which are capable of very high levels of efficiency.

Industry has accumulated over several decades experience in the use of natural refrigerants, as these refrigerants were first used for refrigeration back in the mid-19th century, primarily in food manufacturing and storage. Ammonia in particular has a track record going back over 130 years in industrial refrigeration. Carbon dioxide on the other hand, another natural refrigerant with a tradition spanning over a century, was temporarily forgotten by the industry. It wasn't rediscovered until the early 1990s, when refrigeration experts realised its excellent potential as a refrigerant in the light of today's energy and environmental situation. Since then, researchers and users have developed numerous refrigeration systems for this natural refrigerant, and the future promises to introduce new technologies.

Our magazine "Refrigerants by Nature" presents outstanding projects involving natural refrigerants (see pages 6 to 35) from sectors including the food & beverage industry, logistics and process technology. We provide insights into new components and systems for ammonia refrigeration plants that aim to reduce the amount of refrigerant used and achieve even greater energy efficiency (page 36). An article on the international Montreal and Kyoto Protocols on climate protection and their implementation by the European Union outlines the political and legal framework within which the European refrigeration and air conditioning industry operates (page 38). And finally, you will find short information on natural refrigerants and their key properties.

We wish you an enjoyable, enlightening read!

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Dr. Karin Jahn
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Delivery of storage tanks for Kloster Andechs

# The future belongs to natural refrigerants

## Europe's brewers rely on ammonia

Beer is one of Europe's best-loved beverages. Connoisseurs know that it tastes best freshly pulled and well chilled. Even before it is tapped, however, the right temperature is crucial to the brew's later taste. As it is being manufactured, beer must be kept at precisely defined temperatures at each step of the production process. For instance, bottom-fermented beer "ripens" at between 4 and 10 °C. Refrigeration is also needed for storing the malting barley, during the malting, spicing, and chilling of the beer, and to cool the brewing water. Breweries traditionally rely on the natural refrigerant ammonia.

### Historic brands use ammonia

The Guinness brewery in Dublin planned to increase the production volume of its world-famous Guinness Stout beer to twelve million barrels a year. The enlargement of its production facilities also necessitated an extension of its existing ammonia-glycol refrigeration system. The extension was to be completed in six months, with a minimum impact on operations. Star Refrigeration installed a new facility that seamlessly adds 3.5 MW to the existing facilities' output. It consists of two compressor units, each with twin rotary screw compressors and high efficiency drive motors. A new suction-side collector and two gravity based plate heat exchangers were added to the four existing shell-and-tube evaporators. The refrigeration specialists also added three variable speed drive glycol pumps and increased the capacity of the condensers. A computer-based supervision system optimises all processes and monitors the temperature. The modernised facility now has refrigeration output of 8.9 MW at an evaporation temperature of -4.5 °C, without having increased the ammonia charge significantly.

In response to burgeoning demand for Andechser Kloster beer, the historic Bavarian brewery added four new tanks to its fermentation and storage cellars. Johnson Controls, a specialist in refrigeration facilities for brewers, hooked up the fermentation and storage tanks to the existing compression refrigeration facility. At the heart of the system, which is charged with 4,800 kg of ammonia, are two piston compressors with a combined output of 360 kW. The TÜV Süd Industry Service conducted the final inspection of the extension, among other things measuring the thickness of the anticorrosive coating, checking the thermal insulation and using a thermographic procedure to perform the five-yearly pipework inspection in accordance with §15 of Germany's occupational health and safety regulations (BetrSichV). The new construction was started up in 2006 and ensures that the Klosterbrauerei Andechs can continue to cold-ferment its beers and store them for up to six weeks in a two-tank process.

## Slurry ice to distribute cold energy

The Zipf Brewery, a Brau Union Österreich (Brewery Union of Austria) brand with annual production of around a million hectolitres, uses an ammonia facility with slurry ice to produce its cold energy. Originally built in 1965, the brewery's refrigeration facility worked with a pump and coolant system that circulated 3,000 kg of ammonia. To reduce the high energy consumption associated with this, the facility was to be hot-modernised. Austria's KWN Engineering was in charge of planning the project. They retained the existing refrigeration equipment, but replaced the refrigerant medium with slurry ice – a blend of ice, coolants and anticorrosive agents.

Slurry ice has excellent energy properties similar to those of a refrigerant that evaporates directly. The existing pipework was retained wherever possible, as were the heat exchangers on the beer tanks and in the refrigeration rooms. New installations included two 230 kW ice freezers, and air-coolers manufactured by Güntner. A 110 $m^3$ silo with a refrigeration capacity of 2,800 kW was designed to store the ice. The conversion allowed for reducing the ammonia charge in the refrigeration facility to 500 kg. At the same time, the necessary output was cut in half, from 1,300 kW to 670 kW.

Strakonice, a historic Czech brewery famous for beers like Nektar and Dudák, urgently needed to renew its aging refrigeration system. The system was prone to breakdown, difficult to maintain, and no longer met current operational safety regulations. So the brewery was looking for a new, environmentally friendly refrigeration solution with low maintenance costs. The company also wanted higher refrigeration output, as it was planning to expand its fermentation and storage tanks at the same time. The experts at Bohemiachlad built a central ammonia compression refrigeration facility comprised of eight refrigeration units, with a total output of 620 kW. The dry expansion design allowed for reducing the ammonia charge to 90 kg. Cold water is used to cool the tanks. Other components in the system include four speed-controlled compressors and two condensers. All of the engines are equipped with regulators which optimise operating costs by adapting their output as needed. The refrigeration system is easily controlled from a control centre.

## Recovery in breweries

During the production of beer, carbon dioxide is released. It is uneconomical to release the gas into the atmosphere so that it is recaptured. Flensburg brewery uses carbon dioxide to recover carbon

Slurry ice – a mix of ice, coolants and anticorrosives

Slurry ice production plant

dioxide – as refrigerant in an ammonia/carbon dioxide cascade system installed by Johnson Controls. As well as the ecological advantages of carbon dioxide, other aspects in favour of using it as a refrigerant in beer breweries include the fact that no beverage would be contaminated in the case of any leaks because this is technically generated carbon dioxide which is used as a standard feature in the brewing process anyway.

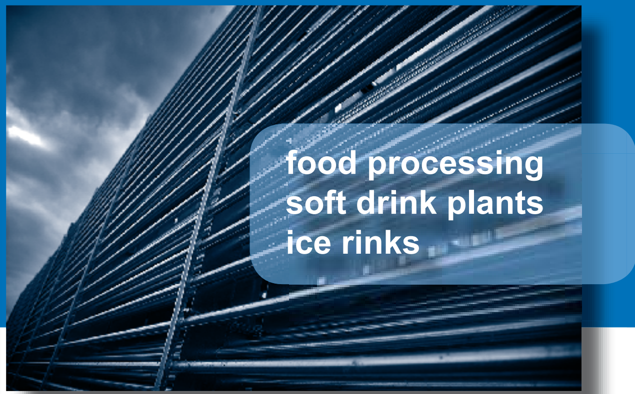
In addition to the already existing central ammonia refrigeration system, a low temperature carbon dioxide refrigerating circuit was installed in the new plant. This now allows for condensation at -42 °C and 10 bar instead of -30 °C and 16 bar, which is the case with ammonia. The changed working range increases the carbon dioxide volume flow in the process circuit, so that the dryer had to be rated in a larger size. Otherwise there are no additional costs and the operating costs are also similar to those incurred when using ammonia for condensation. However, at the same time the recoverable quantity of carbon dioxide increases from previously 2 kg per hectolitre beer to 3.5 kg per hectolitre, so that the use of carbon dioxide as refrigerant saves costs – not only for large breweries but also for companies concentrating on the bottling of non-alcoholic beverages. Ralf Zimmermann from Johnson Controls says: "Additional recovery of just one kilogram carbon dioxide per hectolitre can save total costs of € 20,000 p.a. already for an annual output of 200,000 hectolitres and a price of 10 eurocents per kilogram carbon dioxide."

Once the carbon dioxide has condensed, process evaporators take it out of the storage tank again and convert it into the required gaseous form under the influence of the evaporation heat. The carbon dioxide can now be fed to the beer again. The process evaporators have to be defrosted regularly, given carbon dioxide's low evaporation temperature of approx. -26 °C. To safeguard on-going operation during the defrosting phase, in most cases breweries use systems with two separate circuits for carbon dioxide recovery. It is thus possible for the plant control to switch evaporation over to the parallel circuit after every eight hours of operation with an output of 600 kg per hour. The warm ambient air then defrosts the decommissioned circuit.


Beer varieties of Kloster Andechs

## Ammonia ($NH_3$)

Ammonia has been successfully used as a refrigerant in industrial refrigeration plants for over 130 years. It is a colourless gas, liquefies under pressure, and has a pungent odour. Ammonia has no ozone depletion potential (ODP = 0) and no direct global warming potential (GWP = 0). Thanks to its high energy efficiency, its contribution to the indirect global warming potential is also low. Ammonia is flammable and is toxic to skin and mucous membranes. However, its ignition energy is 50 times higher than that of natural gas and ammonia will not burn without a supporting flame. Due to the high affinity of ammonia for atmospheric humidity it is rated as "hardly flammable". Ammonia is toxic, but has a characteristic, sharp smell which gives a warning below concentrations of 3 mg/m$^3$ ammonia in air possible. This means that ammonia is evident at levels far below those which endanger health. Furthermore ammonia is lighter than air and therefore rises quickly.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Newly built deep-freeze warehouse

# Quality and freshness throughout the cooling chain

## Operators opt for sustainable answers with natural refrigerants

Be it meat, fruit or vegetables – freshness takes top priority when dealing with food. One prerequisite for freshness is an uninterrupted cooling chain from production, storage and shipping through to the point of sale. Because this is very energy-intensive and therefore costly, energy-efficient refrigeration solutions are of great interest to food trading companies. The use of natural refrigerants can make a significant contribution: their high efficiency reduces power consumption and their global warming impact is either zero or is negligible.

### Refrigeration concept exploits waste heat

Galliker Transport AG, a national and international logistics company from Switzerland, opted for an environmentally friendly and energy-efficient refrigeration concept designed by the engineering firm SSP Kälteplaner for its new deep-freeze warehouse, which it built at its corporate headquarters in Altishofen.

The design brief was for three separate low-temperature cold stores with a total volume of 96,000 $m^3$ as well as a commissioning area with a volume of 20,000 $m^3$ that needed to be refrigerated. To meet these requirements, Axima Refrigeration installed an ammonia refrigeration plant with a cooling capacity of approximately 1,200 kW. Three economizer screw compressors made by Sabroe form the heart of the plant. Two unit coolers, each capable of generating 78,000 $m^3$ of cold air per hour with a cooling capacity of 180 kW, are installed in each of the three cold stores. Their ideal position and the best type of air inlet were determined by ILK Dresden in a detailed simulation during the planning stage. The commissioning area also uses two unit coolers, each of which blows 50,000 $m^3$ of cold air at about -31 °C into the commissioning area per hour. Air ducts directly below the ceiling, each with 50 air nozzles, ensure an even distribution of the cold air.

To re-cool the refrigeration system, ground water is used. This allows a low condensation temperature of 25 °C, which keeps the power consumption of the screw compressor down. The refrigeration specialists from SSP and Axima achieved additional energy savings by using the waste heat from the system for heating. To do so, a se-

Deep-freeze evaporator with defrosting flap

cond compression stage without an intermediate circuit or a heat exchanger was installed directly in the ammonia circuit. Two Sabroe reciprocating compressors with a total capacity of approximately 1,600 kW raise the condensation temperature to 67 °C, thus raising the waste heat level to 65 °C. The compressors can operate at pressures of up to 40 bar, which enables them to be used as high-pressure heat pumps. This makes it possible to extract about 6.5 kilowatt hours of thermal energy per kilowatt hour of electrical energy, which is used in winter for heating the entire Gäuerhof industrial estate as well as the neighbouring building, which houses the company Pan Gas.

## 62,500 square metres cooled at a constant level

Another company benefiting from the excellent properties of ammonia is Morrisons, the UK's fourth-largest supermarket chain comprising more than 360 stores. From its latest distribution centre, located on the outskirts of the town of Burton Latimer in Northamptonshire, central England, the company supplies its stores with fresh produce, meat and fish. To ensure the products reach the stores in peak condition, they are stored under chilled conditions before dispatch.

Maintaining the internal temperature of the 62,500 $m^3$, depot at a constant 2 °C is the job of two Alfa Laval semi-welded plate heat exchangers. The two units handle a total duty of 1,500 kW and are part of a central cooling system that feeds unit coolers to provide direct cooling to the main produce storage area and subsidiary sections for meat and fish. The cooling system uses glycol and ammonia and is fitted with a variable speed compressor to maximize efficiency and utilise potential energy savings in part-load operation. The system produces cooling by running glycol at -4 °C through the two heat exchangers, where it is cooled to -8 °C by ammonia which circulates there continuously at -12 °C. A top-up vessel installed above the heat exchangers maintains the ammonia at the correct level. From the heat exchangers, the glycol is pumped to the unit coolers which provide direct cooling in each of the key storage areas.

## An intelligent refrigeration solution cuts costs

The French trade association Système U, with its well known store brands Marché U, Super U and Hyper U, is among those benefiting from the advantages of natural refrigerants. This association of independent retailers unites approximately 850 supermarkets, making it the sixth largest retail group in France. Système U supplies all of its stores in the South of France from

Machine room with screw compressors by Sabroe

its distribution centre in Vendargues. As part of the enlargement of its distribution centre in 2006 and 2007, an 80,000 m$^3$ cold store used for food as well as a commissioning area with a total volume of 5,500 m$^3$ were to be supplied with refrigeration. At the same time, the energy consumption of the refrigeration equipment and the associated costs were to be cut. To come up to the retail group's exacting requirements, Axima Refrigeration opted for refrigeration technology using ammonia and carbon dioxide.

The refrigeration experts installed three refrigeration units with economizer screw compressors, each with a cooling capacity of 300 kW. They cool the 80,000 m$^3$ of storage space in the cold store down to -25 °C. Ammonia is used as the refrigerant while carbon dioxide serves as the coolant, circulating at -30 °C. To keep the adjoining commissioning area at a temperature of between 0 and 2 °C, Axima installed two more refrigeration units, each with a cooling capacity of 250 kW. These units also use ammonia as the refrigerant, but employ glycol as the coolant.

Not only is the solution selected by Axima exceptionally eco-friendly, but its high efficiency also cuts power consumption and thus costs. For instance, by using carbon dioxide as two-phase coolant for low-temperature cooling, the evaporation temperature of the refrigerant, ammonia, is raised. This increases the plant's coefficient of performance (COP) by about 20% over that of plants using a single-phase coolant.

The use of two-stage screw compressors equipped with economizers improves the COP by another 10% or so. In addition, the compressors, pumps and fans are all fitted with variable speed controllers to optimise performance and utilise potential energy savings when operating at partial load. Energy is also saved by heat recovery from the oil coolers and the condensers, and is then used, amongst other things, to defrost the housing of the air coolers and to heat offices. In sum, over the period the system has now been in operation, Système U has achieved a 30% cut in power consumption relative to typical consumption levels in the industry.

## Cooling distribution centres

The British supermarket chain Asda is benefiting from natural refrigerants as well. Asda has been using a carbon dioxide and ammonia cascade system at one of its major distribution centres in Lutterworth since 2007. This is the latest of a number of such systems that Asda has had installed since 2002 at its distribution centres by the refrigeration systems manufacturer Star Refrigeration. The goal of this long term modernization program is to replace all of the HCFC R22 based systems in use to date. To cool the entire cold store, which has a volume of around 270,000 $m^3$, Star Refrigeration installed a centralised refrigeration system consisting of two refrigeration circuits linked by a heat exchanger. This system has a charge of 1.6 tonnes of ammonia plus around 8 tonnes of carbon dioxide. It has a total refrigeration output of 3.2 MW and chills a frozen food cold store to -25 °C as well as several blast chilling rooms at temperatures of between 1 and 13 °C. For the cold store, carbon dioxide is used as the low temperature fluid in a vapour compression cycle, rejecting its heat, via the carbon dioxide condenser, to the ammonia circuit. The carbon dioxide is condensed at -5 °C and is then circulated as a high temperature volatile secondary refrigerant, providing cooling for a number of large chill rooms and for the building's air-conditioning system. The cooling capacity of the low stage carbon dioxide plant, which supplies liquid carbon dioxide at -31 °C to six air coolers in the cold store, is 820 kW. The volatile secondary refrigerant plant serves 20 air coolers in three chill rooms and has a capacity of 2,400 kW. The low stage carbon dioxide circuit incorporates two screw compressors, a surge drum and pump set, two plate and shell condensers and a high pressure receiver. The refrigeration system also comprises two separate high stage ammonia systems, each incorporating two screw compressors, a surge drum/evaporator unit and an evaporative condenser. The refrigeration system's special features are the computerised control systems and the ammonia and carbon dioxide detectors, designed to detect any leaks early on.

The food distributor Trio Invest uses a similar system at its new food distribution centre in Domodedovo, Russia. In the warehouse complex, which has a total capacity of 22,000 tonnes, the company aims to chill meat products, fish and poultry in an environmentally friendly way. Trio Invest wanted five cold stores at a temperature of -24 °C, and another five rooms were to be chilled to 0 °C.

The refrigeration systems manufacturer Johnson Controls installed a refrigeration system designed to meet these requirements using 2.9 tonnes of ammonia for the high-temperature level and 8.8 tonnes of carbon dioxide for the low-temperature level. The evaporating temperature of the coolant, carbon dioxide, is -32 °C. The system, which has a refrigeration output of 2,500 kW and involves five carbon dioxide piston compressors and four ammonia screw compressors, entered service in 2007.

## A system for efficiently distributing cold air

The refrigerated and deep frozen goods logistics provider Frigosuisse uses a pumped ammonia system at one of its deep freeze warehouses in the small Swiss town eurammon

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# Natural refrigerants

## Refrigeration engineering for the future

eurammon is a joint initiative of companies, institutions and individuals who advocate an increased use of natural refrigerants.

As a knowledge pool for the use of natural refrigerants in refrigeration engineering, the initiative sees as its mandate the creation of a platform for information sharing. The objective is to promote the use of natural refrigerants in the interest of a healthy environment, and thereby encourage a sustainable approach in refrigeration engineering.

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of Möhlin. The company expanded the existing three warehouses by adding another one to provide an additional 65,000 $m^3$ of storage space. Then, it was necessary to chill the new building to -28 °C in the deep freeze store and -10 °C in the adjoining automatic pick-and-pack plant. The engineers' office SSP Kälteplaner designed a pumped ammonia system with Eco mode, which was built by the refrigeration systems manufacturer Johnson Controls. The system, which started operation in June 2007, has a refrigeration capacity of 540 kW and a capacity of 2.1 tonnes of ammonia. The refrigerant is used for direct evaporation and is recirculated repeatedly, at an evaporation temperature of -40 °C. The main components used by the system are a screw compressor, evaporation condenser, a separator, an economizer, as well as an ammonia pump and aerial photographs. The coolers distribute the cold air vertically in the room, forming a "cold reservoir".

In the Swiss village of Neuendorf, Migros Verteilbetrieb AG, a company whose core business is deep freeze logistics for foods, was likewise looking for a solution to the problem of how to distribute the temperature in its deep freeze store. With a storage capacity of 167,000 $m^3$ this storage complex is the largest deep freeze cold store in Switzerland. The task was to ensure a constant temperature of -28 °C throughout the interior, which has space for 25,800 pallets up to a height of 29 m. To achieve this, the refrigeration systems manufacturer Johnson Controls installed a two-stage ammonia refrigeration system with a refrigeration capacity of 1,074 kW. A descending air system distributes the cold air and ensures that the temperature can only fluctuate by up to 1.9 °C. The benefits of this system are a drop of about 85% in the amount of power needed for the fan, which reduced the amount of cooling required by about 6%. This resulted in a 7% reduction in the total power used by the system, and investment costs have been cut by 25%. Since the mid-1990s, Johnson Controls has installed other, similar systems in 15 deep freeze warehouses. The warehouse in Neuendorf is by far the largest to date to have been fitted with a descending air system.

## Refrigerated warehouses the size of football fields

The Metro Group, one of the world's largest trading groups, is another company that relies on natural refrigerants. The company operates food distribution centres in Bremen and Hamm, both in Germany. Here, goods that are delivered directly by the manufacturers, are put into interim storage, and then shipped to Metro Cash & Carry, Real or Extra supermarkets. The centres are equipped with central ammonia refrigeration plants furnished by Axima Refrigeration.

The food distribution center in Bremen comprises 4,400 $m^3$, of refrigerated and deep-freeze storage. Forklifts and order pickers are remote controlled, and pallets are automatically loaded and removed. An air-cooled, two-stage ammonia refrigeration system ensures storage temperatures of between -24 and 12 °C. The refrigerant is compressed by two screw compressor units for each stage, which safeguard the reliable operation of the refrigeration system. The system is charged with 5,000 kg of ammonia. The ambient air is cooled by quiet, energy-efficient insulated air coolers. Air ducts integrated in the ceiling ensure a draft-less distribution of the chilled air in the warehouses by sending cold air "trickling down." The waste heat from the oil coolers is used to heat the service water. Because the facility is integrated in Axima Refrigeration's remote maintenance system, the plant manufacturer's customer service can view and optimize the operating data online. Axima Refrigeration was able to hand over the facility to Metro after a planning and construction period of just four months.

## Freshness wins

In southern Germany, a German food retailer operates one of Europe's largest logistics centres for frozen foods and fresh produce. The heart of the building is a central ammonia cooling plant, installed by Johnson Controls in four months. The mammoth facility comprises ten ammonia compressors and 140 air- and 25 insulated unit coolers in two stages: The low-

Cold store at Metro's distribution centre in Hamm

temperature stage provides direct cooling for frozen foods, using two low-pressure compressors with a combined output of 1,100 kW at -9 °C / -39 °C. Chilled brine is circulated in the high-temperature stage to cool the fruit and vegetables, the fresh produce department and the meat-processing rooms. Six high-pressure compressors generate a combined output of 5,400 kW at -11 / 45 °C. The brine is cooled in the corresponding plate units and conducted to the heat exchangers via two frequency-controlled pumps, using nine air-cooled condensers with a total output of 6,700 kW.

In addition to the two-stage refrigeration facility, Johnson Controls installed another brine loop that supplies cold energy to several meat-processing rooms and the fresh produce area. This loop consists of two compressors with a combined refrigeration output of 1,360 kW at -19 / 45 °C. Three air-cooled heat exchangers with a total output of 1,940 kW ensure that the brine returns the heat again. The condensers, like the insulated unit and brine coolers and heat exchangers, are manu-

Ammonia plant with ice water silo for Nordmilch

# Combating climate change with natural refrigerants

## The dairy industry relies on advance solutions involving ammonia and carbon dioxide

The quality standards for milk products like fresh milk, yoghurt, butter or ice cream are high: from processing to storage, these fast-spoiling products require rapid and seamless refrigeration chains. All this takes energy. And because energy prices are on the rise, dairy operators are looking for ways to save money. This is where natural refrigerants like ammonia, carbon dioxide or hydrocarbons come into play. Based on its thermodynamic properties, natural refrigerants require little energy to create a given refrigeration output. This advantage becomes particularly evident in dairies, with their enormous systems.

### Storing cooling energy in an ice bank

The German contractor Kältetechnik Dresen + Bremen GmbH built a single-stage pumped-ammonia refrigeration system with an ice water silo for crushed ice for the Nordmilch eG dairy. At the heart of the facility in Beesten, Lower Saxony/Germany, are two Grasso screw compressors, which are installed together as a so-called Duo-Pack on a shared frame. The entire cooling system is filled with 2,700 kg of ammonia and has a maximum refrigerating capacity of 1,200 kW for direct cooling of ice water or for making crushed ice. The coolant evaporating temperature is -2 °C for direct cooling and -6 °C for ice making. The condensation temperature is 35 °C. The ice is made at night and at off-peak times by three trickle coolers and is then stored as cooling energy in a silo, or ice bank. During the day, three pumps are used to pump ice water, that is about 0 °C to 1 °C in temperature, to where it is needed for the production processes, for example to cool the raw milk that has just been delivered. The chilled water, which by that time has been warmed up, is then cooled again in an ice water pre-cooler, before being returned to the ice bank. The trickle coolers are also used for direct water cooling as well as for ice making. Using the crushed ice bank, Nordmilch can, on the one hand, take advantage of the cheaper off-peak electricity and, on the other, reduce peaks in power consumption. A key advantage of this plant's method of using a crushed ice bank is the ability to attain a very high melting rate thanks to the high contact surface area of the crushed ice in the ice bank. Indeed, the operator has repeatedly confirmed that the ice water supply temperature never exceeds 1 °C, even though the load is


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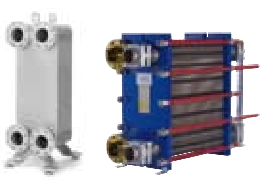

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The Sachsenmilch AG dairy was also seeking ways to save money by reducing the high power costs incurred by cooling and refrigeration. So Johnson Controls designed an ice water pre-cooling plant for its headquarters in Leppersdorf, Saxony/Germany. This allows the warmed water, returning from the cooling system, to be cooled to 1 °C before it is returned to the ice water tank, reducing the load on the system. A key component of the ice water pre-cooling system are Sabroe screw compressors, which have a refrigeration capacity of 2,400 kW each. They use ammonia, with a charge of less than 750 kg per unit. The evaporating temperature is -1.5 °C and the condensation temperature is 35 °C. The evaporator is a gravity-driven plate heat exchanger fitted with a separator. This improves the efficiency vs. direct expansion systems, which again cuts operating expenses. Other components include a 3,000 kW evaporative condenser as well as a heat dissipater and oil coolers for recovering waste heat. Complex PLC controls ensure that the temperature of the ice waters fluctuates by no more than 0.5 °C. So far, Johnson Controls has installed four such cooling systems for Sachsenmilch, with a total refrigeration output of 9,600 kW.

## World first carbon dioxide freezer

One of the first companies to opt for carbon dioxide as a natural refrigerant is the food and beverages giant Nestlé, which beyond mineral water, baby food and coffee, is especially well known for its ice cream products. Nestlé operates a large ice cream factory in Bangchan, Thailand. To meet the growing demand for Nestlé's brands, Nestlé Thailand needed to extend its Bangchan ice cream factory and

Ice water pre-cooling system for Sachsenmilch

## Carbon dioxide ($CO_2$)

Carbon dioxide has a long history in refrigeration, extending back to the mid-19th century. It is a colourless gas that liquefies under pressure, with a slightly sour odour and taste. Carbon dioxide has no ozone depletion potential (ODP = 0) and negligible direct global warming potential (GWP = 1) when used as a refrigerant in closed cycles. It is non-flammable, chemically inert and heavier than air. Carbon dioxide is narcotic and harmful to human health at moderately high concentrations. Because carbon dioxide has a lower critical temperature than other refrigerants, recent research has focused particularly on optimizing system design, and more and more effective refrigeration plants are being developed to close this gap. Carbon dioxide is available in abundance, and there is no need for recycling or waste disposal.

increase production capacity. This also involved the refrigeration units, which still used the synthetic refrigerant HCFC-22. In line with Nestlé's environmental sustainability policy, natural refrigerants were to be given preference. In cooperation with Johnson Controls Inc. and Gram Equipment A/S, Nestlé engineers installed the world's first commercial ice cream freezer using carbon dioxide. The freezer surpasses the efficiency of conventional freezing solutions. In addition to the new freezer, Nestlé also installed a new freezing tunnel, which is used to harden ice cream. The refrigeration required by the tunnel is provided by a compact cascade system containing an ammonia and carbon dioxide cycle. Nestlé put both of these new facilities into operation in 2005/2006, setting new standards for the use of natural refrigerants in the Asia-Pacific region: This is well ahead of what was required by the Montreal protocol for developing countries such as Thailand, where the HCFC phase-out is not due until 2040.

Unilever has built a high efficiency ammonia-based refrigeration plant in Prague, where the consumer goods manufacturer has its Czech headquarters, which encompasses numerous production and administrative buildings. Because the margarine and edible fats unit, which produces brands such as Rama and Flora, needed to expand, the company needed a new store at short notice. The aim was to minimise the refrigerant charge while maximising the cooling output. So the Czech contractor Bohemiachlad implemented a central dry expansion ammonia plant, which has a refrigerant charge of just 100 kg. Ammonia is only used in the machine room, while the chill store is refrigerated using water as a coolant. The chiller provides cold water at 3 °C, which warms to about 10 °C in the wake of the cooling process. Among the main components of the plant are three screw compressors, variable speed compressors, plate heat exchangers and condensers. The coolant evaporating temperature is 0 °C, and the condensation temperature is 35 °C. The two-megawatt chiller is one of the largest plants in Europe. All of its processes are centrally controlled and monitored by a computer-aided control system.

# Investing in the future

## Use of natural refrigerants on board of ships, less harm to the environment

Natural refrigerants are an environmentally friendly choice as they have zero (as in the case of ammonia) or negligible (as in carbon dioxide or hydrocarbons) greenhouse potential. Because natural refrigerants are also energy-efficient, economical and safe, they are spreading to new fields of application. One example is their successful use on large seagoing vessels.

### Shipping companies trust in natural refrigerants

Axima Refrigeration France supplied a refrigeration system which uses the natural refrigerant propane, for a ship operated by Phillips Petroleum that processes crude oil (Floating Production, Storage and Offloading, FPSO). These specialized FPSO ships collect the oil and gas from oil rigs, process it and store it until the raw materials can be transferred to a tanker or into a pipeline. The FPSO ship operating in the Timor Sea between Australia and East Timor has tanks for interim storage of propane and butane. Given the high ambient temperature of approximately 30 °C, it is necessary to constantly cool the crude oil: the propane to -39 °C and the butane to -7 °C. Four chillers with a total cooling capacity of 5 MW are used for this. To maximize the efficiency of the plant, the contractors connected the generators in cascade, which allows the propane refrigerant to be cooled down in two stages. The heat of condensation is then dissipated in the surrounding seawater. The main component of the refrigeration system is an oil-lubricated screw compressor with a volume flow of 8,000m$^3$/h. Very strict guidelines apply for operating technical plants off-shore. To protect the equipment against the aggressively corrosive salt water, Axima Refrigeration constructed all pipes and surge drums from stainless steel, while the plate heat exchangers, condensers and oil coolers are made of titanium. The fourth chiller is a backup to enable the ship's crew to maintain cooling and continue processing the oil, even in the event that one of the refrigeration systems is damaged. All of the screw compressors are identical to minimize the number of spare parts needed – an important factor in view of the limited space on board a ship. Atlantic Pelagic Seafood, an American international shipping company, commissioned Grenco B.V. Marine to fit the "American Freedom," a refrigeration ship for fish, with an environmentally friendly and large refrigeration system. Put into service at the end of 2006 and with a processing capacity of around 400 tonnes of sea fish per day, the "American Freedom" is one of the world's largest reefer ships. It operates as a mothership in under-fished regions of the Atlantic, i.e. serves as a base for trawlers which bring their catch of herrings and mackerels and pump them directly into its hold while at sea.

The contractor planned and built a cascade refrigeration system using ammonia and carbon dioxide. The high-pressure side uses four ammonia screw compressors with a total output of 4,500 kW. This circuit is charged with 1,500 kg of ammonia. The evaporating temperature is -6 °C; the condensation temperature is 36 °C. The low-pressure side uses four screw compressors with carbon dioxide, providing 2,000 kW of cooling capacity. The evaporating temperature on this side is -50 °C, and the condensation temperature is -2 °C. The fish is shock-frozen in 36 vertical plate freezers and then stored in cold stores in the hold, which are cooled with air coolers using carbon dioxide. The heated carbon dioxide is used to defrost the chillers, which eliminates the need for a conventional defrosting unit, resulting in additional energy savings. The low pressure circuit contains a total 10,000 kg of carbon dioxide. The ammonia circuit is part of the cascade, and also supplies two other chiller units that are used to cool seawater – this combination is an absolute novelty in ship-mounted refrigeration technology. All parts of the refrigeration system are monitored automatically and can be controlled from a central computer.

Propane refrigeration unit for Phillips Petroleum

## Hydrocarbons

Refrigeration plants using hydrocarbons like propane ($C_3H_8$) or butane ($C_4H_{10}$) have been in operation all over the world for many years. Hydrocarbons are colourless and nearly odourless gases that liquefy under pressure, and have neither ozone depletion potential (ODP = 0) nor significant direct global warming potential (GWP = 3). Thanks to their outstanding thermodynamic characteristics, hydrocarbons make particularly energy efficient refrigerants. They are heavier than air and have an anaesthetic and asphyxiating effect in high concentrations. Hydrocarbons are flammable and are capable of forming explosive compounds with air. However, with current safety regulations, refrigerant losses are near zero. Hydrocarbons are available cheaply all over the world; thanks to their ideal refrigerant characteristics they are commonly used in small plants with low refrigerant charges.

Screw compressor room with Danish Crown

# Cooling meat naturally

## Producers of meat products opt for ammonia

Be it beef, pork or poultry – meat is one of the most popular items on the menu in Europe. For instance, each citizen of the European Union eats about 90 kg of meat a year, on average – and the number is rising. In meat processing strict regulations concerning freshness, quality and hygiene exist to ensure that meat products meet high standards. Refrigeration plays a vital role in meeting these standards. The refrigeration equipment used has to be safe and reliable to cope with the cooling requirements of production and storage facilities. Increasingly, the meat processing industry is opting for refrigeration systems that use the natural refrigerant ammonia.

### 10,000 pigs a day, on average

Danish Crown, a meat specialist, is one company already reaping the benefits of using ammonia as a refrigerant. Since 2005, Danish Crown has operated the world's most modern pig abattoir near the little Danish town of Horsens, which is also one of the largest in the world, with a production area of about 75,000 m$^2$. Each day an average 10,000 pigs arrive here for slaughter. For the new plant, the refrigeration experts at Johnson Controls Denmark planned and installed a two-stage ammonia refrigeration system in cooperation with the company Güntner. To provide air conditioning for the staff rooms, an indirect refrigeration circuit containing glycol is connected to the system via a plate heat exchanger. The refrigeration system itself is charged with 48 tonnes of ammonia and cools the various processing and storage areas in the most efficient manner possible, through direct evaporation of the refrigerant. Via a network of pipes that is some 15 km long, a total of 175 valve stations distribute the ammonia to around 150 air coolers, which distribute the chilled air. The various temperature requirements around the plant are met using twelve screw compressors made by Sabroe, with a total capacity of approximately 14 MW. Four of the compressors generate a temperature of -3 °C, three cool to -10 °C, and the final five to -25 °C. The air supplied to various other parts of the plant such as the offices, the kitchen and the canteen is being conditioned as well. Because air channels could not be used for hygiene reasons, the system uses a large number of compact, soundproofed air conditioning units mounted on the roof to deliver the processed air precisely where it is needed.

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A total of 142 heat exchangers made by Güntner are used to cool the air, or heat it in case dehumidification is needed. These units are made of stainless steel and aluminium components and measure up to 2.5 x 4 m in size. Their dimensioning ensures that the evaporation temperatures are never unnecessarily low, and that all of the requirements are met while minimising energy consumption. Savings are also achieved through heat recovery, which is used to recover as much as 5 MW altogether from the oil coolers, from overheating the refrigerant and from the condensation heat. A 1.8 MW heat pump uses this heat energy to heat the process water for the abattoir.

## A consistently 'green' approach

The organic meat producer Mühlviertler Alm Biofleisch GmbH has also opted for an ammonia-based solution at its production facility in Unterweißenbach, Austria. All of the meat processed into sausage, ham and bacon here comes from organic farms. To ensure that the company can systematically adhere to its 'green' approach to meat production, engineering consultants KWN Engineering devised a water chiller charged with the refrigerant R723, which is an azeotropic blend of 60% ammonia and 40% dimethyl ether. Charged with 55 kg of this blend, the refrigeration system built by Frigopol and installed by Hauser provides cooling for the processing and storage rooms as well as air conditioning for the staff rooms, with a refrigerating capacity of about 111 kW.

Cooling is provided by absorbing the heat using a 38% mixture of water and propylene glycol, which is then taken away to the evaporator. There, the heat is transferred to the R723, which evaporates at -11 °C in the refrigerant circuit. Depending on the required cooling capacity, the gaseous refrigerant is then compressed using one or both of the open type reciprocating compressors. The heat is finally removed by the air-cooled condenser, which liquefies the R723 at a temperature of between 20 and 40 °C, depending on the outside temperature. It then flows back into the evaporator, where refrigeration oil that was carried by the R723 from the compressor into the refrigerant circuit is deposited. Due to the dimethyl ether the refrigerant is able to mix well with the oil and can carry it reliably through the suction line back to the compressor, where it lubricates the moving parts. For this reason, the use of R723 allowed Frigopol to do without a separate oil return system and keep the design of the refrigeration system simple. Apart from this, the comparatively low final compression temperature of the R723 – which is due to its alcoholic component – made it possible to use an air-cooled condenser instead of a water-cooled condenser for heat removal. Frigopol fitted the condenser with four fans to reduce the noise level of the system, which is mounted outdoors. The system also contains a 24 kW desuperheater to transfer the waste heat to the process water.

## Two-stage refrigeration

A refrigeration system with ammonia is used by the German retailing group Edeka in its new meat processing plant in Mecklenburg-Western Pomerania. The new two-storey "Nordfrische Center" complex which was completed in 2006 had become necessary for the company to expand both its production activities and its range. The refrigeration system, serving a number of cold rooms and deep-freeze rooms, had to meet all technical requirements while being both economical to run and low in price. The refrigeration engineering company Johnson Controls implemented a two-stage ammonia system designed by consulting engineers Lißner. It works with screw compressors producing an output of 5,500 kW with a refrigerant charge of 9,000 kg. The evaporator, air cooler and heat exchanger were supplied by Güntner. The secondary refrigerant to the consumers is 34% ethylene glycol.


Packaging room for poultry producer


Cold tunnel to cool down chickens

## 9,000 chickens per hour

A leading German poultry producer had a new cold tunnel installed in his Brandenburg facility for continuous cooling of chickens with spray humidifying. For subsequent processing of the products a modern production facility was built on a surface area of around 5,000 m². In order to supply the cold and production rooms with temperatures of -30°C to 7°C, the specialist engineers at Kältetechnik Dresen + Bremen erected a three-stage ammonia refrigeration system with a glycol circuit. Four screw compressors and one reciprocating compressor serve a system operating at a variety of temperatures. The total systems refrigerant charge is 2,850 kg ammonia. The deep-freeze store and quick-freeze rooms are provided directly with ammonia for a refrigerating capacity of 410 kW at -40°C. An ethylene glycol circuit with a feed flow temperature of -12°C cools the production rooms such as filleting, fresh stores and packaging rooms together with an integrated ventilation plant, with a total refrigerating capacity of 2,190 kW. This circuit also includes the cold tunnel with spray humidifying where around 9,000 chickens per hour are cooled down to a temperature of 2°C. One special feature of the refrigerating system is spray humidifying to avoid weight loss, with floating temperature control depending on product temperature. In the production rooms, the temperature is adjusted to 4°C by air coolers working in combination with a ventilation system. One particularly successful aspect consists of so-called "intensive dehumidifying" using the specially designed air coolers. In this way, the production rooms can be dehumidified and dried again very quickly after wet cleaning at a constant temperature.

## Making clever use of waste heat

A Swedish company of butchers operates numerous cold and deep-freeze rooms for the production and storage of its meat and sausages. For economical refrigeration, the company uses an ammonia system with an output of 4,000 kW – planned and implemented by the refrigeration and plant engineering company I. Johansson using Alfa Laval heat regeneration coolers. While the ammonia cools the production and storage rooms, at the condensing phase of the refrigeration cycle it reaches a temperature of about 70°C as it rejects heat, normally as waste, into the atmosphere. This waste heat is recovered in several stages, by means of a desuperheater, condenser and heat pumps and is used to heat water up to 67 °C for use in the heating system and other processes. The heat pumps with an output of 800 kW are directly connected to the refrigerating circuit for even greater efficiency. The company of butchers can save around 1,400 m³ of fuel oil p.a. by using the waste heat.

## Evaporators for every purpose

Meat and sausage specialist Herta also uses refrigeration systems with ammonia in its main factory in Herten/North Rhine Westphalia. In order to fulfil the strict demands for suitable storage of the products, the refrigeration plant engineer commissioned supplier Güntner to equip the cold store. At the moment, a high-bay cold store, a short-term cold store and a deep-freeze store are in use. The high-bay store consists of five cold cells for the storage of both unsliced and also sliced and ready packed sausage products. For example, the unsliced sausage has to rest for four days in the high-bay store before leaving the store again for further processing. The high-bay cold store is refrigerated by eight dual discharge ammonia evaporators by Güntner. These are fitted under the ceiling and guarantee constant room temperatures of 0 °C. Each evaporator has a capacity of 22 kW with a blowing range of 14 m on both sides; this corresponds to a circulation volume of 12,600 m³/h. The waste heat produced during the cooling process is used for low-energy defrosting of the evaporator. In the short-term cold store, four ammonia evaporators hold the room at -2 °C. These temperatures are necessary when the sausage products are sliced under strict hygienic conditions and then packed. The deep-freeze store is equipped with three evaporators. Herta's deep-freeze cells are kept at a temperature of -27 °C and filled with products primarily for large-scale consumers.

## Ozone Depletion and Global Warming Potential of Refrigerants

| | Ozone Depletion Potential (ODP) | Global Warming Potential (GWP) |
|---|---|---|
| Ammonia ($NH_3$) | 0 | 0 |
| Carbon dioxide ($CO_2$) | 0 | 1 |
| Hydrocarbons (Propane $C_3H_8$, Butane $C_4H_{10}$) | 0 | 3 |
| Water ($H_2O$) | 0 | 0 |
| Chlorofluoro-hydrocarbons (CFCs) | 1 | 4,680–10,720 |
| Partially halogenated chlorofluoro-hydrocarbons (HCFCs) | 0.02–0.06 | 76–12,100 |
| Per-fluorocarbons (PFCs) | 0 | 5,820–12,010 |
| Partially halogenated fluorinated hydrocarbons (HFCs) | 0 | 122–14,310 |

### Ozone Depletion Potential (ODP)

The ozone layer is damaged by the catalytic action of chlorine and bromine in compounds, which reduce ozone to oxygen when exposed to UV light at low temperatures. The Ozone Depletion Potential (ODP) of a compound is shown as an R11 equivalent (ODP of R11 = 1).

### Global Warming Potential (GWP)

The greenhouse effect arises from the capacity of materials in the atmosphere to reflect the heat emitted by the Earth back onto the Earth. The direct Global Warming Potential (GWP) of a compound is shown as a $CO_2$ equivalent (GWP of a $CO_2$ molecule = 1).


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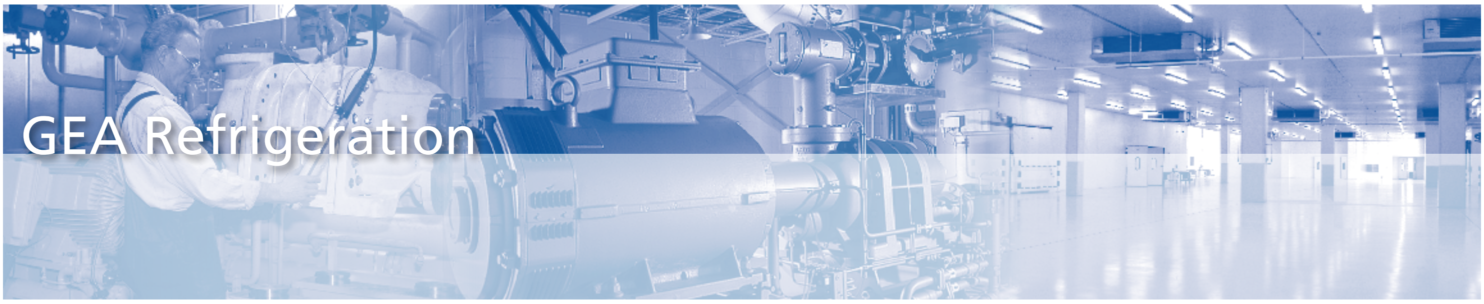


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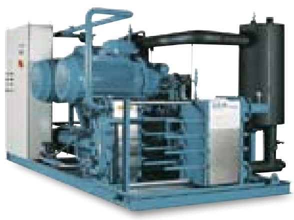

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Screw compressor unit for Bayer

# Keeping one's cool in production

## Sustainable approaches for process cooling using natural refrigerants

In process cooling, refrigeration facilities are closely interconnected with the production processes. Plant builders have to pay close attention to customer-specific needs, including norms and specifications, and use high-quality components. Therefore, this field of application requires a great deal of expertise.

Process cooling, i.e. the provision of cooling energy for industrial production processes, is primarily used in the liquefaction and purification of material flows. Cooling allows gases to be systematically condensed before they are secreted in a controlled way. Process cooling is also used in cooling chemical reactions.

Lately, natural refrigerants have increasingly been used in process cooling. Ammonia makes up the largest proportion – over 40 % – followed by carbon dioxide and hydrocarbons. Ammonia's important role is hardly surprising: For many users is energy efficiency the most important criterion in selecting the appropriate refrigerant. Because ammonia has proven efficient and effective, many companies choose to use this traditional natural refrigerant.

### A remote cooling system for economic refrigeration

The Bayer chemicals group, for instance, commissioned Johnson Controls' refrigeration specialists to build an ammonia-based refrigeration plant. The job was part of Bayer's extension of the remote cooling system at its primary plant in Leverkusen, Germany, one of the largest production plants in the world. Here, in roughly 600 buildings scattered on more than 3 $km^2$, Bayer manufactures pharmaceuticals, dyes, rubber, polyurethanes and organic and inorganic products.The heat generated by all production-related processes is dissipated via a remote refrigeration plant with several refrigeration centers. Three different temperature levels are available for this process: -5, -20 and -45 °C. Decentralized cascade chillers, also hooked up to the main supply, provide temperatures of -45 °C and below. Bayer uses the remote refrigeration plant, which comprises several large units, to economically generate cooling energy and ensure a steady supply. At the Johnson Controls refrigeration plant, two rotary screw compressor units provide cooling energy. The refrigerant, ammonia, is liquefied in condensers that are supplied with cooling water; the refrigerant is then fed into the liquid line via a subcooler and part-time jetting pumps as needed, to supply the consumer loads. The overheated ammonia gas returned by the network is cooled in a suction separator and then returned to the suction side of the compressor. The plant's refrigeration output exceeds 5 MW.

## Air-cooled ammonia-based plant

Lundbeck Pharmaceuticals, a Danish drug manufacturer, needed to expand its production capacity in Seal Sands, England, due to increased demand. The production processes requires adhering to precisely specified temperature gradients. There is a large variation in temperatures, from -85 to 260 °C. Lundbeck's requirement was for a cooling solution that is efficient, reliable and environmentally friendly – a challenge that Star Refrigeration was happy to take on.

The plant builders produced two factory built, skid-mounted air-cooled ammonia systems, that each supply one loop with cooling energy. Factory packaging significantly reduced onsite assembly and facilitated the production startup. The low temperature cycle at 5 °C cools 400 $m^3/h$ of the coolant Therminol D12. Its refrigeration output is 1.4 MW. The low low temperature cycle chills 50 $m^3/h$ of Therminol D12 to -25 °C, with an output of 220 kW. Both cycles use sound-proof rotary screw compressors and high-performance fully welded plate and shell evaporators, which assist in the design of a system with a very small refrigerant charge. The refrigeration systems have tanks for storing the secondary refrigerant, which helps to bridge downtimes and facilitates maintenance work. Star Refrigeration equipped the plant with modern controls, including ammonia detectors. Thanks to the modular design, the operator can easily and inexpensively expand the installation at any time.

## One-step process cooling and air-conditioning

Kältetechnik Dresen + Bremen, Germany, built an ammonia-based process cooling plant for a leading German sweets manufacturer. On its factory premises in German Halle/Westfalen, the company erected a new production building that required a system for cooling processes as well as air-conditioning the premises.

Following a detailed economic feasibility study that weighed the pros and cons from an installation engineering point of view, the operator chose an ammonia-based refrigeration plant. Dresen + Bremen's Norbert Hackmann sums up the deciding factors: "The plant uses a minimum of energy and is reliable thanks to its redundant structure. The additional investment compared to freon chillers pays for itself in four years. What's more, the operator benefits from the positive image of ammonia as a natural refrigerant."

Besides ensuring a controlled dissipation of heat during the production of chocolate, bonbons and gummy candies, the refrigeration system keeps the machines cool. At the heart of the centralized system there are four RPM-regulated rotary screw compressors. Two liquid cycles at temperatures between 5 and 11 °C supply cooling energy to the consumer loads: Cold water circulates in the process cooling cycle, while propylene glycol is used in the air conditioning. Plate heat exchangers handle the energy transfer, based on the principle of gravity feed evaporation.

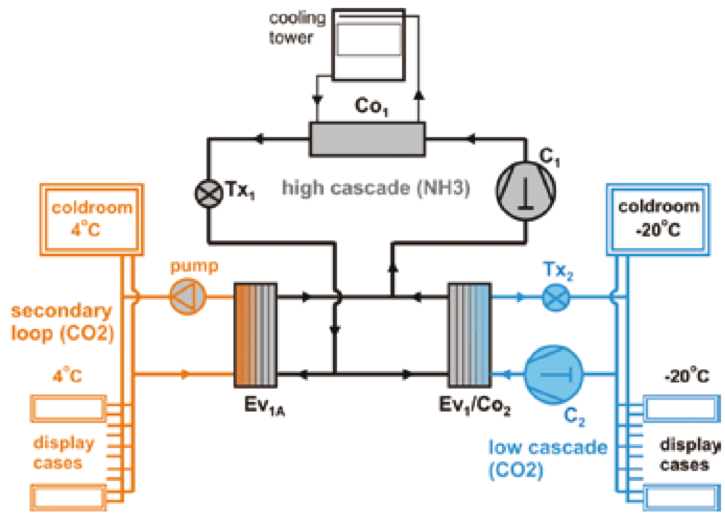
The evaporating temperature is 3 °C in each case, while the condensation temperature is 33 °C. The waste heat from the rotary screw compressors is used to heat the process water via a self-contained glycol cycle. The refrigeration plant is housed in a steel machine room on the roof of the production hall. Once the two-step system extension is complete, the refrigeration output will be nearly 2 MW in the production area, and nearly 3 MW for the air-conditioning.

Assembly of ammonia refrigeration plant

# New concepts of ammonia systems

## The industry aims at reducing the refrigerant charge

Ammonia is an excellent refrigerant which has been used for 130 years mostly for larger cooling capacities in refrigerating systems in food processing, cold storage and other industries. Its advantages are: environmental (ODP = 0, GWP = 0), high values for energy efficiency, excellent thermodynamic properties (high critical temperature, large latent heat and efficient for heat transfer), in vapor condition it is lighter than air, easily detected (warning) and low price.




Cascade refrigeration system with $NH_3$/$CO_2$ and indirect cooling

These advantages of ammonia and environmental public pressure (e.g. Montreal and Kyoto Protocols) have produced a lot of interest for increasing its use in the fields where HFCs are dominant, including in commercial refrigerating systems and air conditioning. Because the only disadvantage is its toxicity, a major goal of today's new developments is how to decrease the charge (quantity) of ammonia in refrigerating systems.

The new development is focused on dry expansion (DX) evaporators where the refrigerant charge is smaller. The refrigerant evaporates in tubes which require miscible oil, not commonly used mineral oil with ammonia. However, new developed oils are already available, such as Poly Alkylene Glycol (PAG) and Poly Alfa Olefine (PAO). DX shell-and-tube evaporators are already being built into new packaged liquid chillers and ammonia DX air coolers. In order to avoid superheating in the outlet (suction) connection, an electronic expansion valve is recommended providing sophisticated regulation.

### Plate heat exchangers

For several years plate heat exchangers (PHEs) have been introduced into ammonia systems as evaporators and condensers. Traditional brazing materials are not compatible with ammonia but technical developments in the past few years have brought new technologies with stainless steel welded plate modules (cassettes) and with nickel brazed exchangers. A new bonding technology has also resulted in the world's first fusion-bonded stainless steel PHE.

Ammonia PHE evaporators traditionally use a gravity fed system with a surge drum located above the evaporator. This takes more space and requires more refrigerant. The PHE evaporator is also designed for dry expansion. This solution requires electronic expansion valves and miscible oil. Compared to the shell-and-tube heat exchangers, the PHEs have higher energy efficiency, smaller fouling factor and dimensions. On the other side, shell-and-tube heat exchangers are cheaper and more convenient for mechanical cleaning.

Microchannel heat exchangers offer great promise in the near future with excellent possibilities of ammonia and $CO_2$. New designs in microchannel heat exchangers allow much smaller refrigerant charges than in conventional heat exchangers. Aluminium is a suitable material for manufacturing of this type of heat exchanger and it is compatible with ammonia.

Developments of hermetic and semihermetic compressors offer new possibilities for ammonia systems. These types of compressors greatly reduce the risk of leakage and increase system reliability. The ammonia semihermetic compressor is already available in the market, and the hermetic model is under testing period. High pressure ammonia compressors are also under development which opens the possibilities in heat pump applications where ammonia is very suitable.

## Secondary circuits

One of the ways of reducing the ammonia charge is the use of other secondary coolants. Ammonia is limited to the machine room, and the secondary coolants circulate in the spaces where the cooling is required. In addition to traditional secondary coolants (water, mixture with glycol, calcium-chloride, and sodium-chloride), new potassium acetate based coolants have also appeared on the market, with better characteristics for heat transfer. Very attractive results are also achieved with the application of $CO_2$ as a volatile secondary coolant, resulting in the dimensions of the piping and pumping power requirements several times smaller. In order to decrease potential places for ammonia leakage, new designs of compact packaged refrigerating units have been developed that are fully assembled and tested in factories. They typically have less than 50 kg of ammonia. Ammonia water chillers are already on the market and have in recent years been installed in larger numbers for air conditioning systems in commercial and public buildings. A large increase in the use of ammonia chillers for these applications is expected in the next few years. As the volume of units increases, the price will fall. In large industrial systems where there is a need for low temperatures (-30 to -54 °C) new concepts are already applied using cascade refrigerating systems with $NH_3$/$CO_2$. Here the ammonia charge is also limited to the plant room (high side of the cascade system), and $CO_2$ is circulated to the equipment and space that require cooling. This cascade concept has also been applied in supermarkets where HFC (and HCFC) refrigerants with large charges are dominant and where large volumes often leak into atmosphere.

Dr. Risto Ciconkov, University of Skopje

# Climate protection on the global agenda

## The Montreal and Kyoto Protocols: Milestones in the protection of mankind and the environment

As early as the mid-1970s, scientists began issuing warnings about the damaging effects of chlorofluorocarbons (CFCs) on the ozone layer – a warning that was confirmed a decade later by the discovery of the ozone hole. Since then, there has been growing pressure on politicians to act.

In 1987, 24 countries and the European Union finally signed the Montreal Protocol on Substances that Deplete the Ozone Layer. It came into effect in 1989, with the signatories committing to "take appropriate measures to protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer" (excerpt from the preamble).

Specifically, the signatories pledged to reduce and eliminate the emission of chemicals containing chlorine and bromine, which destroy ozone in the stratosphere, including CFCs, halons, bromides and tetrachloroethanes. The Montreal Protocol, which was binding under international law, marked the beginning of the end of global CFC production and use. Based on agreements reached at subsequent conferences, the use of CFCs was banned in industrialised nations after 1996, and the operation of new systems that use partially halogenated chlorofluorocarbons (HCFCs) has been prohibited since 2000. To date, 191 countries have ratified the Montreal Protocol and have reduced their total production output of ozone-depleting substances by 95 percent compared with 1987.

### Kyoto Protocol limits greenhouse gases

However, the alternative refrigerants used – primarily hydrofluorocarbons (HFCs) – soon came under criticism also. Because of their harmful effects on the environment, FCs and HFCs were included as greenhouse gases in the Kyoto Protocol resulting from the Kyoto Climate Conference. The Kyoto Protocol was adopted in 1997 as an amendment to the United Nations Framework Convention on Climate Change, which was passed at the United Nations Conference on Environment and Development, also known as the Earth Summit, in Rio de Janeiro in 1992. The Kyoto Protocol came into force in 2005, by which time it had been ratified by 55 nations which together accounted for more than 55 percent of total carbon dioxide emissions in 1990.

This protocol was the first ever binding agreement under international law to specify fixed emission targets for greenhouse gases, which are the main culprit behind global warming. The greenhouse gases specified include carbon dioxide, methane, dinitrous oxide, HFCs, perfluorinated carbons (PFCs) and sulphur hexafluoride. The Kyoto Protocol stipulates that industrialised nations reduce their greenhouse gas emissions by an average 5.2% from 1990 levels during the first commitment period, which runs from 2008 to 2012. The European Union, as a group of nations, has committed itself to an 8% reduction. To date, 182 nations have joined, ratified or formally approved the protocol.

### Europe commits to climate protection

In 2000, the European Union passed Regulation (EC) No. 2037/2000 on substances that deplete the ozone layer. It replaced Regulation (EC) No. 3093/94 from 1994, which implemented the Montreal Protocol, and came into immediate effect in all EU member states. Regulation (EC) No. 2037/2000 prohibits the bringing into circulation, use or import of CFCs for any type of system. From 2010 it will also apply to HCFCs, although for recovered HCFCs it will not come into effect until 2015. The use of fluorinated greenhouse gases has been controlled by Regulation (EC) No. 842/2006 since 2006. This EU F-gas Regulation mandates that all refrigeration and air conditioning systems be regularly checked for leaks and serviced by qualified personnel. Complete records of all servicing must be kept, and the F-gases must be recovered when the systems are disposed of. This Regulation does not prohibit the use of any specific greenhouses gases, but is aimed primarily at limiting and reducing emissions. Directive 2006/40/EC passed by the European Parliament and Council in 2006, relating to emissions from air-conditioning systems in motor vehicles, is to be implemented in national law by the EU member states. Its main provision is that as of 2011, new cars will not be allowed to use F-gases which have a global warming potential of more than 150. From 2017 this will apply to all vehicles.

### Natural refrigerants reduce environmental impact

The international protocols and the EU Regulations are of crucial importance for global climate protection. They also open up new prospects for natural refrigerants because these, due to their environmental friendliness, are not affected by the regulations. Natural refrigerants do not deplete the ozone layer and either have zero global warming potential, as in the case of ammonia, or negligible global warming potential, as with carbon dioxide or hydrocarbons. Natural refrigerants are already widely used in commercial air conditioning and in the food and beverage industry as well as in sports and recreational facilities, the chemical and pharmaceutical industries, and the automobile industry. For car air-conditioning systems in particular, carbon dioxide is an obvious eco-friendly choice in light of the European Directive.

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Natural refrigerants are environmentally friendly

# The European initiative eurammon

## eurammon advocates the increased use of natural refrigerants

eurammon is an association of leading, multinational companies in the refrigeration sector, as well as individuals and institutions in natural refrigerants, committed to advocating the increased use of natural refrigerants. eurammon is linked with international associations and institutions around the world through a network of cooperations and memberships. The industry initiative sees itself as a centre of expertise on the use of natural refrigerants and is fuelled by the strong personal commitment of its members.

Hence eurammon shoulders social responsibility in the interest of an eco-industrial policy. The initiative's members develop innovative, future-proof solutions and approaches and push ahead with their implementation. eurammon supports sustainable business practices in refrigeration and the use of energy-efficient systems. The initiative's mission is to promote the use of natural refrigerants across national borders.

### Climate protection the natural way

Recent worldwide efforts to step up climate protection have heightened people's interest in natural refrigerants, which have been used successfully in refrigeration technology for over 100 years. In the 1950s and 60s, they were displaced in new plants by synthetic refrigerants, touted by the chemical industry as so-called safety refrigerants. Since that time, numerous regulations were passed that unjustifiably restricted competition. However, thanks to technological innovations and thanks to their effectiveness, natural refrigerants have nevertheless become established as an efficient, safe solution for use in a wide range of industries. The most economically relevant among them are ammonia, carbon dioxide and hydrocarbons.

Natural refrigerants do not deplete the ozone layer (Ozone Depletion Potential, ODP) and either have no global warming potential – like ammonia – or only a negligible GWP. This puts them beyond comparison from a climate perspective. However, using natural refrigerants is worthwhile from an economic standpoint as well. The refrigerants themselves are inexpensive and available in vast quantities. The great efficiency of natural refrigerants and the plants that use them have a positive effect on operating costs. Ammonia, for instance, is acknowledged as the most efficient refrigerant of all. Add to that the inexpensive disposal of natural refrigerants once a plant has reached the end of its life.

### Refrigeration in the Future

Whether in the food and beverage industry, in air-conditioning, in sport and recreation facilities, the chemicals and pharmaceuticals industry or in automotives – refrigeration plants using natural refrigerants have proven themselves as an environmentally friendly, economical and reliable solution for producing cold energy. The European initiative eurammon puts its expertise at the service of opening up new areas of application for natural refrigerants and is open to anyone interested in refrigeration, the natural way.

eurammon
refrigerants delivered by mother nature

# There are plenty of good reasons to join eurammon

## For end users, being a eurammon member is well worth it because ...

1. the application of a refrigeration technology using natural refrigerants offering an energy-efficient, ecologically and economically sustainable solution, depends on the concerted action of refrigeration plant users.
2. eurammon is active throughout Europe and provides a platform for coordinated, joint actions.
3. eurammon assists in the long-term implementation of refrigeration strategies using natural refrigerants.

## For contractors, being a eurammon member is well worth it because ...

1. eurammon allows sharing experiences about sustainable and environmentally friendly refrigeration technologies in an international network.
2. eurammon members can cultivate personal relations at an international level, free from competitive concerns.
3. eurammon helps to efficiently put into practice today’s requirements for a better environment.

## For manufacturers and suppliers, being a eurammon member is well worth it because ...

1. eurammon acts as an active lobby above company and country borders to enhance the sharing of information and combined activities to promote the use of natural refrigerants.
2. eurammon provides comprehensive information about the latest developments in the field of natural refrigerants.
3. eurammon widens horizons by promoting and deepening contacts between manufacturers, plant builders and operators.

# Publications

## Information papers



## Directories

Product Directory English – German
Product Directory English – Russian
Product Directory English – Spanish

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### About eurammon

eurammon is a joint European initiative of companies, institutions and individuals who advocate an increased use of natural refrigerants. As a knowledge pool for the use of natural refrigerants in refrigeration engineering, the initiative sees as its mandate the creation of a platform for information sharing and the promotion of public awareness and acceptance of natural refrigerants. The objective is to promote the use of natural refrigerants in the interest of a healthy environment, and thereby encourage a sustainable approach in refrigeration engineering. eurammon provides comprehensive information about all aspects of natural refrigerants to experts, politicians and the public at large. It serves as a qualified contact for anyone interested in the subject. Users and designers of refrigeration projects can turn to eurammon for specific project experience and extensive information, as well as for advice on all matters of planning, licensing and operating refrigeration plants. The initiative was set up in 1996 and is open to European companies and institutions with a vested interest in natural refrigerants, as well as to individuals e.g. scientists and researchers.
www.eurammon.com

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# GEA Refrigeration. Your partner in refrigeration solutions.

To play a distinctive role in the refrigeration solutions market, it is key to continually innovate. In its 150 years existence, GEA Refrigeration acquired extensive know how in refrigeration applications. For example, the development of energy efficient solutions and the increasing application of natural refrigerants such as $NH_3$ and $CO_2$. GEA Refrigeration manufactures, designs, installs and maintains innovative key components and technical solutions for all customers for whom refrigeration is an essential part of their primary process.


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