Background

From producer to consumer: natural refrigerants in the cold chain

The European Union is the world's second largest market for frozen food. The consumption of refrigerated and frozen goods grows here by more than ten percent every year. Managing large quantities of food is no easy task for producers, storage logistic experts and retailers responsible for bringing the goods to their destination – the final consumer. In addition, companies have to ensure that the cold chain remains uninterrupted for the easily perishable goods with only a limited shelf life. Moreover, they are also making every effort to minimise the carbon footprint of their production and storage activities to counteract the progressing greenhouse effect.

In this context, great significance is attributed to the refrigeration of food with natural refrigerants. "The use of ammonia, carbon dioxide and hydrocarbons can make a major contribution to improving a company's environmental balance", explains Georges Hoeterickx, member of the Board at eurammon, the initiative for natural refrigerants. "Natural refrigerants are environmentally friendly, as they have either no (ammonia) or only a negligible global warming potential. In addition, refrigeration systems working with natural refrigerants are not only energy efficient, with a positive effect on the carbon balance: they also result in lower overheads." The following examples illustrate how companies use natural refrigerants to keep food cold and fresh.

Logistics company reduces operating costs by using natural refrigerants

With more than 60,000 employees in 900 sites spread across 100 countries, the Kühne + Nagel Group is one of the largest logistics companies in the world. The Group's distribution centre in Wellingsborough/England is responsible among others for the supply chain management of frozen and refrigerated goods for leading British food and drink wholesalers. The refrigeration design team from Star Refrigeration designed a high-efficiency refrigeration system for the Group that runs on ammonia (NH_3) as refrigerant; this system was installed in an existing warehouse building in the record time of just 23 weeks. The finished complete solution takes care of the chilling and deep-freezing sections of the warehouse, which among others has 17 truck loading ramps.

The refrigerating system with an output of 500 kilowatt keeps the deep-freezing section at a temperature of -25°C. The chilling section works at a temperature of +2°C generated by 650 kilowatt. The system consists of a two-stage ammonia plant with a hot gas defrosting system of the evaporators. NH_3 was chosen as environment-friendly natural refrigerant without any global warming and ozone depletion potential. The system comprises a two stage pump circulation ammonia plant with hot gas defrost to the evaporators. The compact and highly efficient system features two low and two high stage compressors, a high stage surge drum and two evaporative condensers. The innovative solution reduced Kühne + Nagel's operating costs by around £ 50,000 p.a. compared to a conventional pump system.

Fresh fruits all year round thanks to controlled atmosphere

For more than 125 years, Obst Gößl based in Puch/Austria has been trading fruit. The fruit wholesaler takes apples into "controlled atmosphere" storage straight after harvesting. To this end, the oxygen level is reduced in the cold cells of the CA (controlled atmosphere) warehouse. At the same time, the carbon dioxide level is raised and the apples are allowed to "hibernate" at temperatures of one to two degrees Celsius and high humidity levels. This storage technology ensures that apples can be supplied "fresh from the tree" all year round.

In 2009, the company started to plan an expansion of its storage capacities. The intention was to erect three additional CA warehouses each with a surface area of 100 square metres and measuring ten metres in height, to increase their controlled atmosphere storage capacity from 250 tonnes to altogether 300 tonnes. Furthermore, a new additional high rack warehouse was planned, that should offer space for about 6.000 large boxes, each of them providing a filling capacity for 300 kilograms of apples. This also entailed extending the existing refrigeration system. To this end, Johnson Controls installed a refrigeration system that started operations in 2010 with the natural refrigerant ammonia (NH_3). An ethylene-glycol-water mixture is used as secondary refrigerant. To warrant a constant temperature between one and three degrees Celsius maximum in the high bay warehouse, Johnson Controls installed brine circulation air chillers in the area of the warehouse ceiling panels. A double ventilation system consisting of two speed-controlled ventilators fitted under the roof permits free cooling in addition. Moreover, after ozonation, these ventilators are also responsible for purging the rooms and extracting the used air from the warehouse by means of negative pressure. Goods are taken into and removed from the warehouse by means of fully automatic conveyor systems at six openings in the building. At these access points, additional air curtains prevent the cold air from leaving the building, thus boosting the energy efficiency of the system. Two adiabatic glycol recoolers installed on the roof of the building are responsible for heat rejection for the whole system.

To ensure that the three new CA warehouses can be operated independently of each other, Johnson Controls fitted three brine/air coolers in every cold cell, each with its own brine circuit and own brine pump. Altogether eight brine/air coolers were also installed in the aisle zone between the warehouses and in the manipulation section in front of the warehouse. These brine/air coolers keep the temperature at a constant level of between two and four degrees Celsius, thus ensuring adequate chilling of the apples in all parts of the warehouse.

Highly energy-efficient with waste heat utilisation: natural temperature control in cold rooms for baked goods

Glockenbrot Bäckerei GmbH & Co. oHG produces baked goods in the industrial bakery "Backwerk Süd" in Bergkirchen near Dachau/Germany for around 1,100 REWE, Toom and Penny stores. Environmental protection aspects and a well thought-out energy concept were already central issues when the industrial bakery was being planned. This is why the company opted for a refrigeration system with an NH_3/CO_2 cascade system to cover refrigeration and deep-freeze requirements. The combined NH_3 system also chills the secondary refrigerants Temper-20 and iced water. The cold brine is applied to the Güntner air chillers in the pre-chilling rooms; it is chilled in the ammonia system by plate heat exchangers with an output of 700 kilowatt. The evaporators used in the deep-freeze rooms have integrated warm brine defrosting that uses the waste heat of the system, thus increasing its energy efficiency. This solution also saves the costs that would otherwise be generated in defrosting the deep-freeze evaporators and the air chillers in the refrigeration circuit, for example with electric defrosting solutions.

Waste heat not used for this process is dissipated with a Güntner recooler with a heat output of 100 kilowatt. The warm brine for defrosting is generated by the oil cooler. The system has six defrosting coils each with 22 kilowatt. Altogether 16 defrosting points are served. Temper-40 cold brine is used for the corresponding process in the deep-freeze section. The Güntner ammonia condenser has eight ventilators with step control and two with frequency control. The ventilators are regulated with a combination of step and frequency control at the adjusted minimum condensation temperature Tc_{min} = 32 °C.

Supermarkets save energy by opting for refrigeration with natural refrigerants with optimised part load

For 15 years now, the Danish Fakta supermarket chain and their suppliers Superkøl and Advansor have worked constantly at improving the energy efficiency of the refrigeration systems in its stores. Fakta changed over to carbon dioxide as refrigerant already in 2007, and has meanwhile installed 61 transcritical refrigeration systems in the altogether 378 stores. Another 40 of these state-of-the-art systems focused on optimised part load were

installed by the end of 2010. The relatively small systems operate with an output of 9 kilowatt in the deep-freeze range and 28 kilowatt in the medium temperature range. Today all systems are supplied as standardised five-unit combined solutions. They all have the same refrigeration appliances, packs and gas coolers; moreover, they all work with the same output. Only the type of installation can vary form one place to the next. All systems work with a booster system with gas bypass. They consist of two compressors, one with AKD inverter for the refrigeration range and two compressors without inverter for the deep-freeze range. They are controlled by the ADAP-KOOL pack controller system by Danfoss. A controller also checks the pressure in the gas cooler to reach the optimum COP in the system. An electric valve regulates the receiver pressure at the same time. A flexible chilling point and overheating regulator permits energy optimization of the whole system. Application-specific presets permit swift adaptation to different refrigeration appliances and rooms. More than one evaporator can be controlled depending on the application. A study of the energy consumption in the first ten installed state-of-the-art systems resulted in energy savings of around 10 percent compared to the HFC plants that were usually found in the stores through to 2007.

Contribution to environmental protection – also in the home

"Time and again, systems with natural refrigerants prove their efficiency as they can be used as an environment-friendly, energy-efficient solution for keeping food cool and fresh", says Georges Hoeterickx from eurammon. Natural refrigerants are also well established solutions for refrigerating food in the home. Today around 300 million refrigerators use isobutane.

<<Info box>>

The German Frozen Foods Institute (Deutsches Tiefkühlinstitut e.V.) put the average annual per capita consumption of frozen food in Germany at 40.2 kilogram in 2010. Given the current population of 81.5 million, this results in about 3.3 billion kilogram each year.

Annex

Ammonia (NH_3)
Ammonia has been successfully used as a refrigerant in industrial refrigeration plants for over 100 years. It is a colourless gas, liquefies under pressure, and has a pungent odour. In coolant technology, ammonia is known as R 717 (R = Refrigerant) and is synthetically produced for use in refrigeration. 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. 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/m³ ammonia in air possible. This means that ammonia is evident at levels far below those which endanger health (>1,750 mg/m³). Furthermore ammonia is lighter than air and therefore rises quickly.

Carbon dioxide (CO_2)
Carbon dioxide is known in refrigeration technology as R 744 and has a long history extending back to the mid 19th century. It is a colourless gas that liquefies under pressure, with a slightly acidic 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 has a narcotic and asphyxiating effect only in high concentrations. Carbon dioxide occurs naturally in abundance.

Hydrocarbons
Refrigeration plants using hydrocarbons such as propane (R 290, C_3H_8), propene (R 1270, C_3H_6) or isobutane (R 600a, 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. Hydrocarbons are flammable, however, with currently available safety devices, refrigerant losses are near zero. Hydrocarbons are available at low cost all over the world; thanks to their ideal refrigerant characteristics they are commonly used in small plants with low refrigerant charges.

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, propene C_3H_6, isobutane C_4H_{10})	0	<3
Water (H_2O)	0	0
Chlorofluoro-hydrocarbons (CFCs)	1	4680–10720
Partially halogenated chlorofluoro-hydrocarbons (HCFCs)	0.02–0.06	76–12100
Per-fluorocarbons (PFCs)	0	5820–12010
Partially halogenated fluorinated hydrocarbons (HFCs)	0	122–14310

Ozone Depletion Potential (ODP)
The ozone layer is damaged by the catalytic action of chlorine, fluorine and bromine in compounds, which reduce ozone to oxygen and thus destroy the ozone layer. The Ozone Depletion Potential (ODP) of a compound is shown as chlorine equivalent (ODP of a chlorine molecule = 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).

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.
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