Background

Eco-friendly brewing processes use natural refrigerants to produce cold beer for hot days

On hot summer days in particular, many of us appreciate a refreshing beer from our own fridge. However, even during the brewing process itself certain temperatures have to be maintained. For example, the fermentation temperature of top-fermented beer is up to 22°C, while for bottom-fermented beer it should not exceed 10°C. For the “amber nectar” to succeed, breweries need refrigeration solutions tailored to their processes and individual requirements. “Nowadays, these systems are not just energy-efficient. If they also use natural refrigerants like ammonia, they are also particularly environmentally friendly,” says Georges Hoeterickx, member of the board of eurammon, the European Initiative for Natural Refrigerants. “This is because natural refrigerants have no, or only very low, global warming potential.”

It is an accepted fact, that brewers had a mayor influence in regards to the development of refrigeration systems. Already in 1876 an ammonia system enabled a Bavarian brewery to produce beer at any time of the year. Due to the positive properties of natural refrigerants many breweries did not change over to synthetic refrigerants. In the following, some cases from recent years are introduced.

Brewery in England enjoys higher output and reduced energy costs

Since it was established in 1807, the Daniel Thwaites brewery, one of the top ten breweries in England, has been an independent, family-owned and operated company with headquarters in Blackburn. To improve its refrigeration capacity and to save energy costs, the company commissioned the cooling specialists from Star Refrigeration to optimise the existing refrigeration system. Heat exchangers and separator vessels had already been replaced in the course of previous projects. A newly installed GEA Grasso reciprocating compressor, featuring inverter drive and using the eco-friendly natural refrigerant ammonia, increases output from the previous 310 kW to 400 kW, while at the same time reducing operating costs. The improved energy efficiency is largely due to the use of the new inverter-driven reciprocating compressor instead of the original unit that ran constantly at the same speed, and to the installation of a new compressor control system. Energy measurements

show that the brewery is saving around 2,000 GBP (approx. 2,500 Euros) a week in electricity costs, and that the investment will pay for itself in less than 18 months.

Eco-friendly beer cooling with heat pump option

The “Herzoglich Bayerische Brauhaus Tegernsee” in the Alps is regarded as one of the oldest remaining breweries in Bavaria and produces around 120,000 hectolitres of beer every year. In 2010, industrial refrigeration specialists Th. Witt supplied an environmentally friendly refrigeration system for chilling the brewing water. Up until the rebuild, the wort chilling (four brews a day) had been done in the traditional way using an ice bank system. Due to the brewery’s planned increase in capacity to nine brews, a new refrigeration solution was required. The brief was to design a system that could be operated at almost constant capacity throughout the day. In addition, it was to incorporate the option of subsequently connecting a heat pump to the system so as to supply heat to adjacent buildings like the "Braustüberl” pub and restaurant. During the chilling process, 190 litres of brewing water have to be cooled down from +16°C to +2°C within two and a half hours. In the new system, cooling water consumption for the condensers was to be reduced as far as possible. Th. Witt installed a gravity-type NH_3 system with separator and plate evaporator. To assure the supply of cooling at all times, two reciprocating compressors were installed. While one compressor is in operation the second one is in standby.

To completely dispense with cooling water, the engineers designed the system with an air-cooled condenser for condensing the refrigerant. The system cools a secondary refrigerant loop with glycol to a temperature of -2°C. By means of a secondary plate heat exchanger operating with glycol and fitted with an outlet temperature controller, the brewing water is then cooled to the required temperature of +2°C and stored temporarily in an insulated basin. The system’s cooling capacity is 124 kW and it uses around 100 kg of ammonia as refrigerant.

Modern beer cooling using R723 – the refrigeration solution for the lower output range

The Ottenbräu Brewery from Abendsberg in Bavaria’s Hallertau region has been brewing beer since 1609, making it one of the oldest breweries in Germany. In 2011, owner and seventh-generation brewer Robert Neumaier decided to install a completely new state-of-the-art brewing plant. Although various parts of the equipment had been replaced from time to time, the last general overhaul had been carried out by his great-grandfather as far back as 1906.

The brewery commissioned HKT Huber-Kälte-Technik GmbH in Halfing to professionally implement the cooling system and equip brew house and malt store with state-of-the-art refrigeration technology. The new brewery can process two brews per day with a total of

4,000 litres, with the complete brewing cycle taking about eight hours. A plate heat exchanger performs the function of cooling the hot wort from its boiling temperature (95°C) to a yeast pitching temperature of 7°C in the fermentation tanks. The primary fermentation, where yeast is added at 7 to 9°C, lasts eight days. The beer is then matured for eight to ten weeks. About 2,000 hectolitres of beer are brewed annually using this process.
When designing the new brewery, the focus was on energy efficiency and sustainability. In view of the output range of between 3 and 15 kW with direct expansion at -8°C, the refrigeration solution opted for an ammonia and dimethylether mixture (R723) as refrigerant. Adding DME to the ammonia allows the discharge temperature to be reduced by up to 25 K and achieves oil solubility. As a result, it is possible to build reliable direct expansion refrigeration units with air-cooled condensers, even where ambient temperature is 35°C. In this specific case, due to the brewery's close proximity to its neighbours, the company opted for a very quiet stainless steel condenser supplied by Güntner with a sound pressure level of 36 dB(A) at 10 m, mounted on a special base frame above the compressors' suction side to avoid noise. The higher suction gas density of R723 results in a 3 per cent higher efficiency than using pure ammonia. This means that even cooling systems with an output of less than 20 kW are suitable for operation with a natural refrigerant. The brewery has achieved energy savings of around 40 per cent as a result of switching from bricked-in fermentation vats to free-standing directly cooled stainless steel fermentation tanks, changing the space cooling of the storage tanks to direct jacket cooling by glycol, replacing ice bank storage systems with single-stage plate heat exchangers with pre-cooled brewing water and using the natural refrigerant R723.

"The examples show that systems using natural refrigerants can now be used energy-efficiently and with minimal environmental impact in breweries of all sizes – even in the lower output range," says eurammon board member Georges Hoeterickx. "It always depends on the overall concept for a system, and the choice of refrigerant is one aspect of this."

<<Information box>>

- In Germany, the average per capita consumption of beer in 2010 was around 107 litres.
- A total 75,000 hectolitres of beer were served at the Munich Oktoberfest in 2011.

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About R723

The refrigerant known in refrigeration technology parlance as R723 (R = refrigerant) was developed as a result of several years of research. The designation derives from the mean

molecular mass of 23g/mol and the compound's categorisation as a natural refrigerant (700 series). However, it still does not have an official ASHRAE standard classification. R723 is a colourless gas liquefied under pressure and with a pungent odour. It is made up of 60 per cent by mass of ammonia (R717) and 40 per cent by mass of dimethylether (RE170) – a propellant similar to isobutane when used as a refrigerant. Due to its azeotropic boiling point the mixture can be handled like a single-component refrigerant. This means that there is no composition shift during evaporation and condensation. R723 has no ozone depletion potential (ODP = 0) and minimal direct global warming potential (GWP = 8). It offers the energy benefits of ammonia, which means that its contribution to indirect global warming is also comparably low. In respect of its toxic effects, the relevant safety guidelines for ammonia have to be observed. The dimethylether components have no known specific toxic effects.

Further information on R723 is available in eurammon information paper No. 12 on the Initiative's website[1].

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.

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

[1] http://www.eurammon.com/information-materials/information-papers/12-r-723-azeotrope-basis-ammonia

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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