Background

Winter sports fun all year round, thanks to natural refrigerants

Ammonia and carbon dioxide for ice rinks and indoor skiing slopes

Ice skating, ice hockey or skiing: winter sports are extremely popular with young and old. And fans don't have to wait for the winter to enjoy their favourite sports. Ice rinks and indoor skiing slopes offer winter sports fun every day of the year.

But the operators of sporting facilities in need of refrigeration are facing new challenges. According to the EU regulation on substances that cause degradation of the ozone layer, as from 2010, only reconditioned HCFCs may be used in refrigerating and air-conditioning systems. This period then ends in 2015. From then on, all HCFCs are prohibited in refrigerating and air-conditioning systems.

"This is forcing the branch to act", says Monika Witt, Chairwoman of eurammon, the European initiative for natural refrigerants. "One possible solution for modernizing the systems consists of natural refrigerants, such as ammonia, carbon dioxide or hydrocarbons, with convincing properties such as sustainability and economic efficiency. Ammonia for example is acknowledged to be the most efficient refrigerant, as reflected in the low operating costs for users. In addition, ammonia systems relieve the pressure on the environment, as the refrigerant does not make any contribution to the greenhouse effect."

Making intelligent use of waste heat

The "Curl Aberdeen" ice rink in Summerhill, Aberdeen, is one of the centres for Scotland's traditional winter sport of curling, and is an example of how such facilities can benefit from the advantages of the natural refrigerant ammonia. The ice rink has a total ice surface of around 1,350 square metres and is also used for public ice skating.

In order to cut back on the increased operating and maintenance costs, the operator instructed the company Star Refrigeration to plan and install an efficient system running on natural refrigerants. With close to 40 years experience, Star has provided high efficiency cooling solutions to around 70% of the UK’s ice and curling rinks.

For "Curl Aberdeen", Star Refrigeration designed a refrigerating system to provide cooling to the rink floor. This includes a critical charged refrigeration plant with a mere 80 kg of ammonia and a glycol circuit which is connected to the refrigerant circuit by means of an evaporator. The system has a refrigerating capacity of 253 kW to cool the secondary refrigerant glycol to -10℃ before it is pumped through a network of pipes integrated in the floor of the rink. In this way, the cooling system fulfils the high demands made of the ice surface in terms of constant quality, hardness and temperature.

The main components of the refrigerating machine that is pre-assembled in the factory include two reciprocating compressors, an accumulator on the intake side, two glycol pumps, two drive motors and an electronic control panel. A desuperheater on the high-pressure side makes thermal use of the compression heat of the refrigerant. The energy recovered in this way is used for the underfloor heating of the remaining facilities apart from the ice rink itself. The refrigerating system is also equipped with an external evaporative condenser which condenses the refrigerant; this unit is accommodated on separate grounds next to the main building.

Skiing in the desert

A similarly designed system has been installed in the world's third largest indoor snow park "Ski Dubai". As the main attraction of the Mall of the Emirates shopping centre in Dubai, "Ski Dubai" offers a wide range of winter sporting activities for up to 1,500 visitors on premises covering 22,500 square meters. The snow park offers five skiing slopes, covered with more than 6,000 tonnes of snow. Energy-efficient cooling of the snow is provided by an ammonia refrigerating machine with a capacity of 2,600 kW.

The snow is cooled by a glycol circuit which is connected to the refrigerant circulation of the machine by two Alfa Laval plate heat exchangers. At an evaporation temperature of -22℃, the ammonia cools the secondary refrigerant to -15℃. The glycol is then transported through a piping system 100 km in length that runs through the building floor under the layer of snow which is one metre thick. This ensures that the snow foundation remains frozen.

In addition, the glycol circuit feeds the 29 air coolers in the ceiling of the building, which keep the temperature in the snow park at a level of -1 to -2℃ during opening hours. After midnight, the air temperature is lowered to -8℃ for production of 30 tonnes of new snow, which happens every night. Water is cooled down to 1℃ in a water chiller and then pumped to the snow canons. These inject the water into the cold air in the building, where it crystallizes and forms snowflakes.

The heart of the refrigerating machine consists of three Grasso screw compressors. A computer control system adjusts the output of the compressors exactly to the refrigerating demand, thus reducing their energy consumption. Further potential for saving energy is offered by the insulation which turns the snow park into a giant cool box. Walls that are five metres thick warrant that the generated cold remains in the building, keeping the snow park at low cost at temperatures below freezing point. In this way, energy accounts for less than ten percent of the total operating costs.

The whole refrigeration process also benefits the adjoining Mall of the Emirates: the 30 to 40 tonnes of "old snow" which are replaced by new snow every night in "Ski Dubai" are recycled to water in a melting pit. The cold water is then used for air-conditioning in the shopping centre and for irrigation of the adjoining gardens.

Environment-friendly modernization of the ice stadium

Tingvalla Ice Stadium in Karlstad, Sweden, is Europe's largest open air stadium with an ice rink measuring 65 x 180 metres. It is used for bandy, a version of ice hockey that is popular in Scandinavia and Russia. The stadium's refrigerating system has been completely renewed to safeguard the refrigeration concept for the years to come. Francks Kylindustri was instructed to plan and carry out the work.

The task facing the contractor consisted in safeguarding operation at outside temperatures of 12°C, keeping the ice temperature at a constant -4°C. Further demands made of the refrigerating machine included high energy efficiency and low operating costs, together with minimum maintenance.

The Swedish solution was designed with a cascade system using 1.3 tonnes of ammonia as refrigerant and 16 tonnes of carbon dioxide as secondary refrigerant with partial evaporation. The refrigerant cools the carbon dioxide at an evaporation temperature of -12°C. The carbon dioxide is stored in four accumulators which are connected with the ammonia system by heat exchangers. This condenses the secondary refrigerant which comes back partially evaporated from the four separately switched cooling circuits measuring 65 x 45 m, installed underneath the ice surface.

Cold production on the ammonia side is generated by three one-stage screw compressor combined sets with a total refrigerating capacity of around 2,300 kW and a pumping volume of 4,100 m^3 per hour. Altogether, ten open screw compressors by Bitzer are used: two of the combined sets have three compressors each, the third set has four.

Each compressor is directly coupled to a drive motor with a rated output of 110 kW. The motors are in the highest energy efficiency class. Each set is equipped with a multi-stage oil separator with a separating volume of 700 dm^3. To cool the oil, each set is connected to a joint ethylene glycol circuit by means of a plate heat exchanger. The ethylene glycol is pumped to a central recooler on the roof of the machine house where it cools down against air.

The combined sets drain the ammonia evaporator through a central intake pipe; the evaporator works in flooded mode for the highest possible thermodynamic efficiency. Three wet cooling towers connected in parallel positioned outside next to the machine house are responsible for condensing the ammonia.

Equipped for the future

"In the context of climate change and increasing energy prices, operators are finding it increasingly important to have environment-friendly refrigerating systems that make efficient use of energy," explains Monika Witt from eurammon. "This is why we encourage system operators to opt for natural refrigerants, in view of the HCFC phase-out. Natural refrigerants constitute a viable future solution in refrigerating technology which puts operators on the safe side already today."

Annex

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.

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.

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	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 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).

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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