Refrigerant CO_2 in the ready meal-production

Air cooler with connected textile air socks for draft-free air distribution in the processing room

Line of Business:	Industrial Refrigeration
Application:	Food Cooling
Country / City:	Germany / Würselen
Fluid:	CO_2, R507
Product:	Wall/ceiling unit cooler GHN, Wall/ceiling air cooler GGHN, Condenser GVH

For the production and storage of ready meals for air passenger catering, the Frankenberg GmbH, domiciled in the German city of Würselen near Aachen, needed a new building for production, storage and administration. The refrigeration and air conditioning equipment for the new facilities was selected in close cooperation with the company York Deutschland GmbH. Together, they developed a refrigeration concept in which CO_2 is used as refrigerant for production frosting and deep-freeze storage and R507 is used in the area of production cooling.

In order to develop an economically reasonable and at the same time environmentally friendly equipment for the new facilities of the Frankenberg GmbH, the company firstly con-

ducted conversations with different refrigeration plant engineers and discussed different solutions based on the following consumption scenarios: To find a long-term reliable solution, the company developed a concept comparison between the different refrigeration concepts in cooperation with YORK Deutschland GmbH. Apart from the technical requirements, there were other conditions to fulfill in addition to the target of an exceptionally cost-effective investment. Thus, the company wanted:

- maximum waste heat utilisation / heat recovery and good overall COP-value
- production frosters should have pump circuits, refrigerant NH_3 or CO_2
- no NH_3 coolers in processing rooms / workplace regulation
- no refrigerating system that is subject to authorization in accordance with BImSchG (federal law for the protection against emissions)
- cost-effective investment

Comparison of system concepts

During a joint project cooperation of three to four months, the overall concept was examined from different angles. This approach was mandatory, as the refrigerating system plays an important role in the scope of the necessary investment (approx. 15 % of total investment) as well as in the current operating costs; besides, it was intended for a period of use of 20 to 30 years. Three different refrigeration concepts were compared in detail:

- NH_3 system, two-stage, with brine system for processing
- NH_3/CO_2 cascade refrigerating system with brine system for processing
- $R507/CO_2$ cascade refrigerating system with R507 direct evaporation in -processing

Moreover, in the scope of these concepts, the use of reciprocating compressor aggregates and screw compressor aggregates respectively were examined and compared with regard to investment requirements and maintenance costs as well as sound emissions.

Decision pro cascade refrigerating system

Finally, it was decided to use an $R507/CO_2$ refrigerating system, as it is an economically as well as ecologically wise solution. CO_2 is a common and established refrigerant and can be used in refrigerating systems in many areas of food refrigeration and deep freeze storage. The cascade refrigerating system with SABROE reciprocating compressor aggregates includes the following main components:

- 3 CO_2 reciprocating compressor aggregates
- 2 CO_2 condensers
- 1 CO_2 receiver
- 1 CO_2 pump separator
- 3 R507 reciprocating compressor aggregates
- 1 R507 separator
- 1 R507 HD receiver
- 1 evaporative condenser
- 1 R507 plate heat exchanger for condensation
- 1 horizontal R507 pressure gas desuperheater
- 1 air-cooled R507 condenser
- 1 R507 heat exchanger for brine cooling of continuous pass-through cooking machine
- 3 froster valve stations for CO_2 pump operation
- 13 deep freeze storage coolers CO_2-DX-operation
- 22 room coolers R507-DX-operation
- 1 air conditioning water chiller plate heat exchanger

Equipment with many advantages

The decision to use this equipment was based on numerous advantages:

- good partial load behaviour due to use of reciprocating compressor
- high total COP-value: 1.42 (incl. pumps/fans and auxiliary drives)
- in comparison to NH_3 two-stage or NH_3/CO_2 cascade system, more favorable investment by about 100 - 150 thousand

- no NH_3 components in processing areas / production
- high froster efficiency due to CO_2 pump operation
- reduced piping due to DX-R507 operation
- BImSchG approval not necessary
- good sound situation

In addition, this solution made it possible to reconstruct without problems an existing Samifi production froster for CO_2 pump operation.

Successful operation

Air cooler with "down-gust"-operation in a deep freeze store

After a construction period of 5 months, the new Frankenberg plant has been in continuous operation since the beginning of March, and during the summer, it has already proven itself at exterior temperatures of +35 °C.

		temperatures	capacities
cold water for air conditioning		+12 °C/+6 °C	80 kW
brine cooling for cooking facilities		±0 °C/-5 °C	280 kW
freezing facilities (CO_2)			
spiral freezer I		-40 °C	410 kW
spiral freezer II		-40 °C	200 kW
spiral freezer III		-40 °C	190 kW
frozen food store I	room temperature:	-25 °C	90 kW
frozen food store II	room temperature:	-25 °C	128 kW
frozen food store III	room temperature:	-18 °C	5 kW
temporary storage I	room temperature:	-18 °C	17 kW
temporary storage II	room temperature:	-18 °C	40 kW
food freezer (CO_2)			35 kW
room cooling (R507):			
loading ramp I	room temperature:	+12 °C	36 kW
loading ramp II	room temperature:	+5 °C	24 kW
cold room I	room temperature:	+5 °C	7 kW
cold room II	room temperature:	+5 °C	13 kW
temporary storage I-VII	room temperature:	+5 °C	je 15 kW
garbage	room temperature:	+5 °C	15 kW
hot meal filling	room temperature:	+18 °C	90 kW
blast chiller	room temperature:	+2 °C	2 x 40 kW

- Installierte Verdichterleistung HD (to = -8 °C) 1.500 kW
- Installierte Verdichterleistung ND (to = -40 °C) 1.000 kW

Wärmerückgewinnung aus

- Druckgas HD 100 kW/+48 °C Warmwasser
- Frischlufterwärmung/Kondensation 550 kW/+25 °C Zuluft
- Frischwassererwärmung/Kondensation 245 kW/+22 °C Frischwasser

Frankenberg: "Warm meals for specific needs"“

The Frankenberg GmbH, domiciled in the German city of Würselen near Aachen, specialises in developing, producing and distributing ready meals for air passenger catering. These "hot meal" and "ready meal" products depend on supreme quality and availability. As a business partner of many international airlines, particularly the smooth and flexible production is an important cornerstone of the company's success.

Refrigerant CO_2

Carbon dioxide has been used as a refrigerant since 1850 and has a long tradition in refrigeration engineering. Considering the process to

abandon the production and use of CFCs and the associated mounting relevance of so-called natural refrigerants, the economic advantages of using CO_2 in refrigerating plants are being rediscovered, too. Some important characteristics are:

Environment:

- low greenhouse warming potential (GWP = 1)
- nontoxic at low concentrations – ambient air = 330 ppm
  - limit of comfort = 1.000 - 1.500 ppm
  - MAC = 5.000 ppm (0,5 %, equals 9.000 mg/m³)
  - exhalation = 3-4 % vol.
  - IDHL = 40.000 ppm (4,0 % vol.)
  - benumbing effect at concentrations above 10 % vol. in the breathing air
  - instantaneously lethal at concentrations above 30 % vol.
- non-flammable (used as fire extinguishing agent)
- heavier than air

Refrigerating system

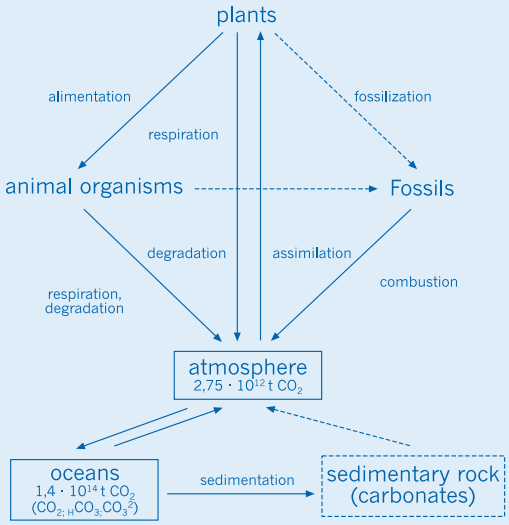
- high volume flow-related refrigerating capacity (5 to 7 times higher than ammonia)
  - low compressor cubic capacity + piping cross sections
- high refrigeration figure of merit at low temperatures
- low viscosity
  - low pressure losses
- pressure losses entail only small drops in temperature
- high operating pressures (e.g. 40 bar bei +5 °C)
- low pressure relations
  - high process efficiency of the compressors
- high overall heat transfer rates during evaporation and condensation (up to 60 % above that of HFC)
- good compatibility with common materials and machine oils for refrigerating systems
- triple point at 5.18 bar and -56.6 °C
- low critical temperature 31.05 °C
- max. condensation temperature 10 - 15 °C in 50 bar-systems

History of CO2 as refrigerant

1866/69	application by LOWE (dry ice)
1877	condensation by RAYDT (begin of use as technical gas)
1881/90	Design and construction of refrigerating systems by LINDE and WINDHAUSEN respectively
1887-90	strong development in refrigerating systems, especially in Great Britain and in the U.S.A.
1895	First vapor chart: MOLLIER
1904	first pressure-enthalpy-diagram by MOLLIER (TH Dresden)
1929	detailed p,h-diagram with solid phase: PLANK, KUPRIANOFF
1932	NH_3-CO_2 cascade systems for temperatures of down to -50 °C
1950	60 % of all refrigerating systems used on vessels and 10 % of all fractional and multiple horsepower refrigerating plants
1960-65	CO_2 is no longer used (‡ 0 %)
1989-93	rediscovery and first suggestions regarding plant design (LORENTZEN et al.)

CO_2 – a bonus for the environment

Carbon dioxide is primarily used in the beverage and food industry, for cooling during transportation, in water management, in metal processing and for fire fighting.


plants
alimentation
respiration
fossilization
animal organisms
Fossils
degradation
assimilation
combustion
respiration,
degradation
atmosphere
2,75 · 10^12 t CO2
oceans
1,4 · 10^14 t CO2
(CO2; H2CO3; CO3 2-)
sedimentation
sedimentary rock
(carbonates)