NATURAL REFRIGERANTS

with high pressure compressors in Industrial plants

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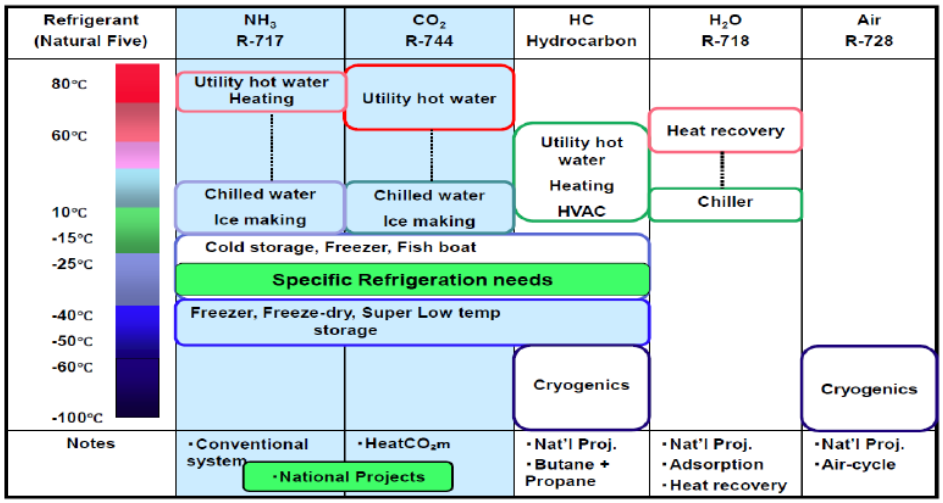
LINE-UP OF 'NATURAL 5'.

Mayekawa was founded in 1924 and is to-day one of the world's largest industrial refrigeration companies. It actively promotes the 'NATURAL 5' refrigerants, including ammonia, CO2, hydrocarbon gasses, air and water. Mayekawa is active in ammonia compressors for more than 85 years, for hydrocarbons and CO2 for more than 40 years.

The 'NATURAL 5' refrigerants cover the full application range -100°C/+100°C from cryogenics, freezing, cooling, air conditioning up to heating.



As it is our tradition to bring as much as possible information from the field we have choosen this time for high pressure compressors in Industrial plants.

The need of higher pressure compressors is increasing with the new applications :

such as CO2 refrigeration - including defrosting,

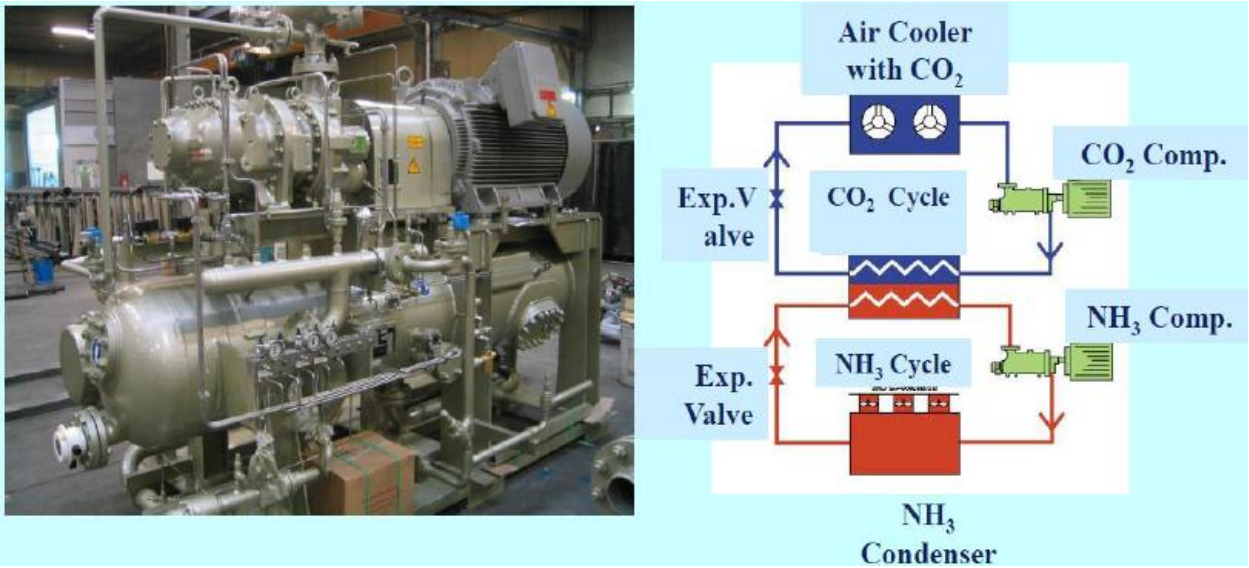
and the intensively expanding heat pump applications at higher output temperatures and capacities.

CO2/NH3 CASCADE COMPRESSION REFRIGERATION.

The field case of to-day is an industrial low temperature refrigeration plant using a CO2/NH3 cascade system with CO2- and NH3 compressors as is illustrated in the scheme.

The CO2 cycle is shown on the top of the scheme with CO2 compressors, -air cooler, expansion valve and cascade CO2 condensor/NH3 evaporator.

The NH3 cycle is shown on the bottom.



The unit picture shows a 50 bar oil injected screw compressor typical for use with low temperature cooling (-40°C to -52°C with CO2) including also defrosting mode (+10°C at 45bar).

FIELD CASE.

The plant belongs to an international group of companies active in traditional bakery products for bakeries, food service operations, supermarkets and industrial customers, installed by the contractor AXIMA REFRIGERATION GDF SUEZ in France.

INTRO

The starting point for the plant was to realize a freezing plant for bakery products requiring -35°C product temperatures for approx..3000kW to be realized in 2 phases.

The choice was made to apply for a CO2/NH3 cascade which is a main trend for low temperature refrigeration in food industry where CO2 of -40°C, still at very usefull pressure of 10 bara, to obtain -35°C product temperature.

The CO2 is natural and can be used direct in the freezers.

CO2 can also be used for defrosting of the freezers with the high pressure compressors

The high stage of the cascade can be done with the natural refrigerant NH3 with limited charge only for the high temperature side in the NH3 machineroom and condensors.

The realization of the plant was done in 2011 for phase 1 followed by phase 2 in 2013.

EQUIPMENT

LOW TEMPERATURE SIDE CAPACITIES (kW)			
CO2 T°(°C)	C160GHSx1	C6HKx4	C6HSx1
FREEZING T°-40°C	741	1196	940
DEFROSTING T° +8°C	606	696	
HIGH TEMPERATURE SIDE			
NH3 TE (°C)	N250VLDx3		
-12	3502		

The table shows the overview of the installed compressors for the low temperature - and the high temperature side of the cascade plant.

The CO2 evaporating temperature is kept at -40°C and the freezing is realized by using 6 compressors :

1 pce 50 bar screw compressor performing 741kW(-40°C) freezing and 606kW(+8°C) defrosting,

4 pieces 50 bar piston compressors performing 1196kW(-40°C) freezing(total) and 696kW (+8°C) defrosting (total).

1 piece 66bar piston compressor performing 940kW(-40°C) freezing.

All CO2 compressors are condensing at -8°C, while the NH3 compressor evaporate at -12°C with evaporative condensors designed at +35°C.

3 pieces 26 bar screw compressors performing 3502kW (-12°C) evaporating are taking the total heat rejection from all CO2 compressors.

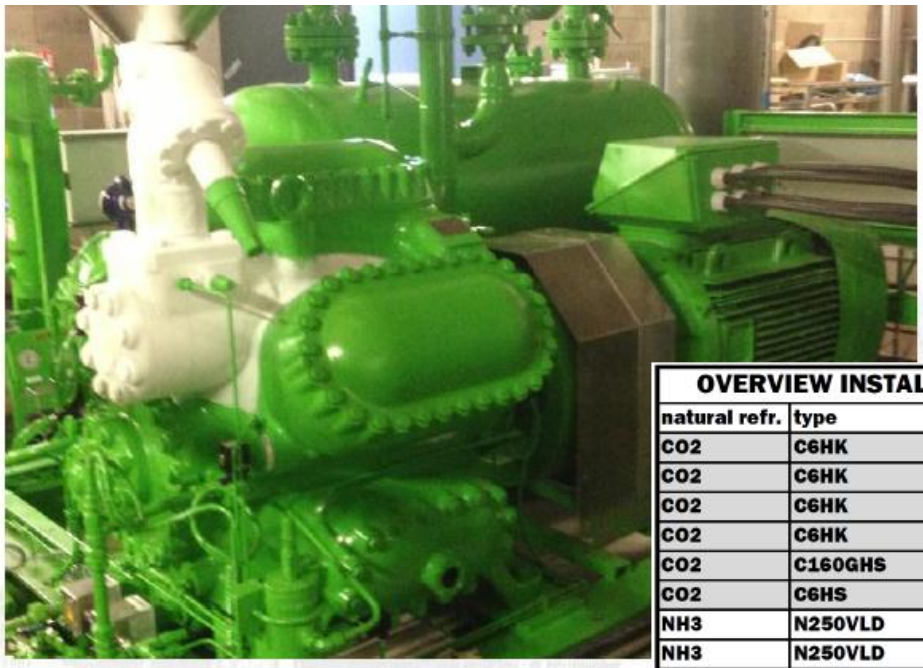
The picture shows the 50bar screw compressor freezing/defrosting (right side picture)

and the 66 bar piston compressor.

All mentioned compressors are equipped with frequency drive convertors so that speeds can be reduced from maximum to minimum speed by keeping the highest

efficiency. This avoids that mechanical part loading needs to be done so that the highest COP's can be mainted.

The overview table shows the installed units with installation dates and the actual total number of operating hours for each machine.



OVERVIEW INSTALLED COMPRESSORS :				
natural refr.	type	unit	date	hours
CO2	C6HK	C1	2011	7997
CO2	C6HK	C2	2011	1664
CO2	C6HK	C3	2011	5444
CO2	C6HK	C4	2011	877
CO2	C160GHS	C5	2011	71
CO2	C6HS	C6	2013	1871
NH3	N250VLD	CV1	2011	19895
NH3	N250VLD	CV2	2011	5107
NH3	N250VLD	CV3	2011	5603

EFFICIENCY ANALYSIS

An overview of the cascade plant COP-c is made based on the initial design conditions and compared to the average obtained operation.

The basis for the calculation is operation 24 hours per day, 5 days per week, 50 weeks on year basis at 80% plant load, what means 4800 hours per year.

The table shows the freezing capacities, absorbed power at the compressor shafts, total heat rejection and the corresponding coefficients of performance (COP-c)

For the low temperature CO2 side and the high temperature NH3 side.

For a design condensing temperature of 35°C the final COP of the cascade plant is 1,68.

DESIGN

CO2/NH3 CASCADE		RT	BKW	THR	COPc-each	COPc-total
TE=-40°C	TC=+35°C	kW	kW	kW		
CO2 LS	C160GHS	741	200	941	3,7	
	C6HK	1196	289	1485	4,1	
	C6HS	940	212	1152	4,4	
	total	2877	701	3578	4,1	
NH3 HS	N250VLDx2	3502	1006		3,5	
	N250VLD					
TOTAL		2877	1707			1,68

AVERAGE

CO2/NH3 CASCADE		RT	BKW	THR	COPc-each	COPc-total	
TE=-40°C	TC=+29,5°C	kW	kW	kW			
CO2 LS	C160GHS	741	200	941	3,7		
	C6HK	1196	289	1485	4,1		
	C6HS	940	212	1152	4,4		
	total	2877	701	3578	4,1		
NH3 HS	N250VLDx2	3575	825		4,3		181 kW
	N250VLD						
TOTAL		2877	1526			1,88	12%

Based on the average condensing temperature of 29,5°C on year basis it is possible to reduce the power consumption on the NH3 high stage compressors by 181 kW per hours, which results in a total cascade plant COP-c of 1,88 which is 12% higher than design.

This 12% COP-c improvement represents a yearly saving of 4800 (hrs) x 181(kW)

or 868.800 kWh. At an average electricity cost of 70 €cent per kWh this represents an energy saving amount of 608.160 € per year!

This electricity saving reflects also directly on the equivalent CO2 emmision saving.

CONCLUSION

It is clear that natural refrigerants are the main trend for industrial refrigeration in food industry !

CO2 proves its advantages with :

direct use in the freezing equipment

low temperature refrigeration at usefull pressures (-40°C 10bara)

defrosting mode operation availability (10°C 45bara, 20°C 58bara in f(compressor design)

design optimizing COPc 1,68->1,88 by applying lowest average condensing temperature 29,5°C, resulting in saving of 870 mW electricity per year or 608 k€/year.

Low energy consumption

Low CO2 emmision

low cost (smaller size equipment)

less risc for food safety

cascade with minimized NH3 charge

low insurance cost

COMBINED NH3 CHILLER/HOT WATER HEAT PUMP.

The next system exists of a 2 stage NH3 compressor system mounted on 1 skid as a closed system.

The low stage is used as a water-chiller and the high stage, using a high pressure piston compressor, is used as an over-compression hot water heat pump.

The picture shows :

The low stage compressor with drive motor and discharge piping to the oil separator in the front on the left side.

The insulated suction line is visible on the left side of the compressor with the PHE evaporator and NH3 separator on the left in the back side.

The high stage compressor with drive motor and insulated discharge piping to the insulated oil separator on the front of the right side.

The with Armaflex insulated suction line connected to the heat source flash tank on the right side,

and the insulated discharge piping connected to the insulated condenser on the back side.

The table shows the compressor models with cooling/heating outputs, compressor shaft power inputs, the corresponding COP's.

CHILLER		
compressor model		piston N8M
cooling output		
water temperature	°C	1,5
capacity	kW	1000
bkw	kW	250
COP-c		4,0
HOT WATER HEAT PUMP		
compressor model		piston N6HS
heating output		
water temperature	°C	90
capacity	kW	1500
bkw	kW	250
COP-h		6,0
COP-total		**5,0**

The package produced 1000kW chilled water of 1,5°C (NH3 evaporation at 0°C)

and 1500kW hot water of 90°C (NH3 condensing at +92°C).

The total COP-(c+h) of 5,0 is achieved.

The first plants have been delivered this year.

SPECIAL THANK-WORD.

For Mr.Lucas, the contractor AXIMA REFRIGERATION from France, who installed the CO2/NH3 cascade plant for bakery products and gave us access to all details of this heat pump plant.