SUSTAINABLE
INDUSTRIAL REFRIGERATION
AIR CONDITIONING SYSTEMS
& HEAT PUMPS

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'NATURAL 5' LINE-UP.

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.

In the 'NATURAL 5' overview table the different solutions are summarized for each natural refrigerant from cryogenics, freezing, cooling, air conditioning up to heating.

FIELD CASES

NEWTON3000 (NH3 COMPRESSION REFRIGERATION + CO2 SECONDARY BRINE)

Mycom developed the 'NEWTON3000', a semi-hermetic compressor for use in industrial refrigerated warehouses, based on 2-stage screw compressors and IPM drive motor.

The design targets were :

- High efficiency
- Low charge (by use of direct expansion system and CO2 as secondary brine)
- Less leakage (by use of semi-hermetic motors)

The photo illustrates the compact NEWTON3000 with semi-hermetic compressor-motor built on the NH3 condenser, oil separator, NH3/CO2 cascade evaporator/condenser, CO2 receiver, control panel etc.

The benefits of the IPM motor are :

- 5 to 10% better in efficiency
- 40% smaller in size
- High rotation speed possible

The field reference is a Food Distribution Center installed in Japan using NEWTON3000 modules producing -30°C CO2 by evaporating NH3 at -34°C.

The case study shows that the power consumption and the CO2 emission were reduced with 30% for the NEWTON3000 compared to the conventional system.

NH3 COMPRESSION REFRIGERATION

An overview of most commonly used piston and screw compressors, by showing the theoretical gas displacement volumes, is given with range 15->1300 m3/hr for pistons and 200->15.600 m3/hr for screw compressors.

Page 13 shows an 80.000m3 Food Store Plant in France using for the freezing part NH3/CO2 secondary brine equipment producing 1200kW CO2 at -30°C. The machines are operating approx. 30.000 hrs.

Mycom compound screw compressors(4x) with individual NH3 circuit, each connected to their cascade NH3-evaporator/CO2-condenser(installed on top of the common CO2 receiver with liquid pumps) are equipped with variable speed control. Minimum NH3 charge is obtained by applying plate in shell type heat exchangers.

Page 14 shows an Ice Cream Factory with big size Mycom compound compressor units(part of the plant) installed since 2003 producing 3450 kW at -42°C with NH3 compression, having approx.28.000 hrs of operation.

NH3 HEAT PUMPS

The NH3 heat pumps are executed with high pressure compressors to cover the higher output temperature requirements.

The reciprocating compressor model N6HK is a 50 bar compressor, of which many compressors are operating in the field, covering a swept volume from 120 up to 200 m3/hr depending on the rotation speed controlled by means of a frequency convertor.

New higher pressure reciprocating compressor models N4HS and N6HS are available very soon.

For the 50 bar screw compressors, 3 models are available in the swept volume range of 400 to 3900 m3/hr depending on the rotation-speed with capacity range 190 kW up to nearly 10 mW depending on the required hot water outlet temperature.

HP field reference 1 is an over-compression HEAT-PUMP to produce 60°C hot water for meat factory process.

The plant scheme shows on the bottom side the refrigeration plant with heat produced at the condenser at condensing temperature of 40°C.

The heat pump plant is shown on the top side :

The heat pump compressor takes the gas from the high pressure side of the refrigeration plant at the refrigeration compressor outlet to the low pressure side of the heat pump compressor via a gas cooler and a suction gas liquid heat exchanger. The heat pump is compressing the ammonia gas from 40°C to 65°C and produces hot water of 60°C from the inlet water at 12°C by using the sensible heat exchanger and the suction gas/liquid heat exchanger.

With this combination of heat exchangers it is possible to achieve a coefficient of heating performance from 6.0 up to 9.0

The unit layout shows the compressor-motor set with the oil separator, the sensible heat exchanger, condenser and high pressure liquid receiver.

The photo's of the installation show the heat pump system installed at the machine room and the thermal stratification tank applied for the buffering of the hot water.

The plant is operational since 2008 and operated approx. 4000 hrs with a hot water output of 400kW at 60°C.

HP field reference 2 is an over-compression HEAT- PUMP to produce 77°C hot water for district heating.

The plant scheme shows on the bottom side the refrigeration plant with heat produced at the condenser at condensing temperature of 30 to 40°C taken from the low stage heat recovery evaporator.

The heat pump plant is shown on the top side :

The heat pump compressor takes the gas from the high pressure side of the refrigeration plant at the heat recovery vessel at the low pressure side of the heat pump compressor. The heat pump is compressing the ammonia gas from 30/40°C to 80°C and produces hot water of 77°C from the inlet water at 60°C.

With this system it is possible to achieve a coefficient of heating performance from 4.0 up to 5.2, with heating output capacity from 407kW to 1104kW depending on the intermediate ammonia temperature(30->40°C) and the system load (1800->3600rpm) per compressor. Two compressors are installed in this heat pump plant.

The unit layout shows the compressor-motor set with the oil separator.

The photo's of the installation show the heat pump system installed at the machine room with low stage compressors and heat exchangers.

CO2 TRANCRITICAL HOT WATER HEAT PUMP

Mycom developed the 'ECO-CUTE' with a semi-hermetic 150 bar piston type compressor for production of hot water or hot air by using transcritical CO2 compression.

The source can be water or air.

On page 19 an Industrial Hot water Production Package is shown with air-source (alternative water-sourced)

The field reference is a 90°C hot water supply installation for a company complex in Japan.

The 'ECO-CUTE' produces the water (which is available at maximum 65°C) up to 90°C which is than buffered in the Hot Water Storage Tank. The hot water production capacity is approx.90kW per hour. From the hot water storage tank the water is used at controlled temperature for the different purposes in the building.

The application targets for this hot water production unit are hospitals, hotels, welfare institutions, sport facilities, bathing facilities, facilities for boarding, food factories etc.

The case study shows that the power consumption and the CO2 emission were reduced with 62% for the ECO-CUTE compared to the conventional fuel boiler system.

CO2 COMPRESSION REFRIGERATION

Is used mostly in cascade systems where NH3 is used on the high stage.

Mycom produces several high pressure compressors (ref.NH3 heat pumps above) which can be used for the compression of CO2.

The schematic diagram shows the NH3 and the CO2 cycle, each with compressor, evaporator, condenser and expansion device. The NH3 evaporator/CO2 condensor functions as cascade heat exchanger between the 2 circuits.

Equipment for compression of CO2 for liquefaction purpose has been produced by Mycom for more than 40 years.

The field reference is related to a meat processing installation in Nederland installed in 2005.

On the low temperature CO2 side 5 high pressure compressors are installed on different temperature levels -51°C, -41°C and -31°C, which cover respectively 4200kW, 2600kW and 3000 kW plant performance.

1 compressor, with design pressure 50 bar, is used for defrosting of the freezers at +10°C.

On the NH3 high stage 7 screw compressors are installed.

The average operating hours per machine is approx. 38.000 hrs.

HYDROCARBON COMPRESSION

An Industrial Hydrocarbon Refrigerant Package is shown for Air-Conditioning and Heating.

The field reference is a 7°C chilled water production installation of 140 kW in Japan.

The application targets for this Hydrocarbon Refrigeration package are food factories, hotels and office buildings.

The case study shows that the power consumption and the CO2 emission were reduced with 16 to 14 for the 'HYDRO-CARBON' compared to the conventional R134A system.

ADSORPTION CHILLER

An Adsorption Chiller Utilizing Renewable Energy is shown for chilled water production.

Possible heat sources can be solar heat, waste heat, power station waste heat, boiler exhaust heat, process waste heat, etc.

The cooling is done by applying condenser (watercooled, evaporative type)

The field reference is a 9°C chilled water production installation of 350 kW in Japan.

The application targets for this Adsorption Chiller are factories, food factories, hospitals, shopping centers, offices etc.

The case study shows that the power consumption and the CO2 emission were reduced with 64% for the 'ADSORPTION CHILLER' compared to the conventional R134A chiller system.

AIR COMPRESSION REFRIGERATION

An AIR CYCLE Refrigeration System is shown for low temperature applications in the range of -50°C to -120°C.

The field reference is a -60°C Ultra Cold Freezing Storage of 5.000m3 in Japan.

The AIR CYCLE Refrigeration System is composed of 3 parts : an expander-integrated compressor (compression & expansion), a primary cooler (heat dissipation) and a heat-recovery heat exchanger.

The most suitable markets for this Ultra-low temperature refrigerators are tuna & bonito food factories and rapid freezers etc.

The case study shows that the power consumption and the CO2 emission were reduced with 54% for the 'AIR CYCLE REFRIGERATION SYSTEM' compared to the conventional R22 two-stage compression refrigerator system.

CONCLUSION

The main goal of this Roundtable on '**zero and low GWP HCFC alternatives**' has been achieved !

1. All 'NATURAL 5' REFRIGERANTS comply with a GWP between 0 and 3.

   (NH3,AIR,WATER : 0, HCO2 : 1, HYDROCARBONS : 3)

2. All 'NATURAL 5' REFRIGERANTS comply with an ODP = 0.

3. The examples from the field shown in this presentation,

   all result in significant reductions of CO2-emission and energy consumption :

NH3 NEWTON3000	:	-30%
NH3 hot water	:	-75%
CO2 hot water	:	-62%
HC chilled water	:	-14%
ADSORPTION chilled water	:	-64%
AIR ultra cold air	:	-54%.

   The shown results are taken from the field cases presented in this paper and do not represent in general every 'NATURAL 5' application as those need to be evaluated case by case.

   In any case the field cases results are based on real operational equipment.

   The results show attractive positive trends of improvements.

   Therefore good design praxis is vital to obtain similar or better results than shown in this paper.