NATURAL REFRIGERANTS
IN DIFFERENT
INDUSTRIAL HEAT PUMP PLANTS IN NORWAY

Jan Boone

MAYEKAWA EUROPE S.A.,Leuvensesteenweg 605, 1930 Zaventem, Belgium

Tel. 32-2-757-9075, Fax. 32-2-757-9023, e-mail : jan.boone@mayekawa.eu

‘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

DICTRICT HEATING OF TECHNOLOGY AREA

The contractor THERMA INDUSTRI AS received the request to install 2 hot water heat pumps producing each 1350kW hot water at 77°C.

The plant is an energy station of a technology area.

The cooling plant is used to produce ice-water for office cooling and cooling of data-center.

The heating is used to produce hot water of maximum 82°C for district heating.

As heat source the heat rejection from the cooling plant needed for office and process cooling shall be used with priority depending on the available capacity. An extra heat source is available from sewage water system if necessary.

The minimum load is 600kW and can grow to maximum 5 MW.

For the temperature of 80°C the most suitable natural refrigerant is NH_3 with corresponding pressure of 39,6 barg to obtain 77°C hot water.

NH_3 is a standard refrigerant for THERMA INDUSTRI in Norway.

The project started in 2008 and installation was finalized in 2009.

The NH_3 heat pump compressors are used as overcompression stage on the refrigeration plant.

(P.9) The heat normally rejected to the condenser will be used as heat source for the heat pumps.

In case of insufficient cooling demand in the offices, as is the case during the winterseason, the heat will be taken from sewage water available from the water-treatment station in the neighbor.

(P10) The compressor model N160GHS-V, which is a 50 bar execution, and drive motor, which is size 315kW with frequency drive, are mounted on the oil separator, which is insulated, with complete oil system and control system.

(P11) The heating performances (RT=heat source, BKW=power input, QC=heat output) and –coefficients (COP-h) are shown in the table for the different heat source temperatures (NH_3 at 30°C or 40°C) and the different compressor speeds (1800rpm to 3550rpm) obtained by the frequency controller (30Hz to 60Hz).

The maximum heating performance of 1366kW is obtained at 3550rpm (60hz) and 40°C NH_3 heat source temperature with a corresponding heating performance coefficient of 5,2.

On 2-10-2012 the heat pumps have operated 15.470 hrs (VP1) and 12921 (VP2).

(P12) The graphs show logging data during the starting up cycle of the heat pump (approx.time span of 2 hours).

Left top : water outlet temperature from 65°C to 80°C.

Left bottom : heat pump compressor suction pressure at 10 to 12barg and discharge pressure from 27 to 40 barg.

Right top : compressor speed from 1800 to 3550rpm.

Right bottom : heat pump oil supply temperature (60 to 70°C), condensing temperature (65 to 80°C), oil tank temperature (85 to 105°C), heat pump discharge gas temperature (85 to 108°C).

The plant produced approx. 10GWh of energy in 2010 which increased to 13 GWh in 2011.

The design heating performance coefficient in in the range of 3,7 to 5,2 depending on the plant load.

The yearly overall heating performance coefficient was above 3 for the first 3 years of operation.

(P13) The heat source-heat output-heating performance coefficient overview shows an operating scenario in winter where only the minimum cooling load of 600kW is produced for the data center.

For the production of the maximum heating of 2732kW it is necessary to use an extra heat source capacity of 1360kW from the sewage water. This is realized by operation of the extra compressor model N200VL-L providing 1360kW heat source capacity with an additional power input of 246kW.

This brings the total power input to 772kW for a heating output of 2732kW, corresponding with a heating performance coefficient of 3,5.

The equipment is operating following load programs which must be covered by the heating plant, which is fulfilled.

The machines are equipped with frequency convertor for speed control at part load operation to maintain the best heating performance coefficient.

Barriers faced with in this project and solutions :

As this plant was one of the first realized in Europe, supply and availability of high pressure components has been one of the faced bottle necks.

Thanks to the customer who gave full confidence and made strong investment in this new technology to THERMA INDUSTRI it was possible to succeed and realize this plant with success!

Psychological barriers were not experienced as customer fully relied on the capability of THERMA INDUSTRI and MYCOM.

Safety and legislative barriers have all been covered as plant/system was build fully in compliance with CE-PED.

Lessons learned from the project and how can this be applied to other projects using natural refrigerants :

For the cooling and heating plant the customer will choose for the same solution as demonstrated by this field case which is already running nearly 15.000hrs with full satisfaction.

Planning about similar projects and recommendations for natural refrigerants :

Continue in the same line !

THERMA INDUSTRI has more than 25 industrial NH_3 heat pump plants in operation which have been installed since 1998 !

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

In any case the field case 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.

HOT WATERPRODUCTION IN SLAUGHTERHOUSE

The plant is a Norvegian slaughterhouse chain existing since 1950 with about 30 plants in operation.

In 1987 a centralization and modernization of the sites took place with NH3 as preferred refrigerant.

Since 1989 NH3 compression heat pumps are used for production of 50°C water for a capacity of 1200 kW.

In 2007 a hybrid heat pump was installed for 500 kW.

As there was an important need for more hot water because of production extension, it was decided to increase the hot water production with an additional 2400 kW.

The contractor THERMA INDUSTRI AS received the request to install 2 sets MYCOM NH3 overcompression heat pump screw compressors.

The customer has choosen for natural refrigerant NH3 because of strong argumentation :

'VERY EFFICIENT', 'CHEAP', 'EXPERIENCE SINCE 1950'.

NH3 has a pressure of 23 barg with condensing temperature of +57°C to obtain hot water of 52°C.

NH3 is a standard refrigerant for THERMA INDUSTRI in Norway.

The project started in 2009, followed by some budgeting period, and was realized in 2011.

It took 1 week to build-out the old equipment and after 8 weeks the plant was completed.

Heat pumps were started-up in October 2011.

The customer received 900.000 NOK fundings from ENOVA, the Norwegian Energy Organisation.

This new heat pumps save 1,6 GW fuel per year corresponding with approx. 210.000 liter.

The funding is only valid on condition that savings are realized and proved to ENOVA.

After 7 months of operation is was already visible that the 1,6 GW was going to be realized easily.

The heart of the heat pump plant are 2 screw compressors model N170JM-L, of 36 bar execution, driven by frequency-controlled motors complete with oil system and all necessary controls,

Producing NH3 at 57°C (saturated condensing temperature) from NH3 heat source at 20°C (saturated evaporating temperature) to produce hot water of 52°C.

This hot water is than further heated by other nequipment to 84°C and buffered in a 200.000 liter tank.

A modulating control valve is installed for controlling the suction pressure of the heat pumps at 7,5barg (20°C) representing an important saving of energy on the refrigeration plant :

Cooling performance coefficient improves with at least 50% when comparing between :

1) TEc/TCc=-10/+35°C RT/BKW/COPc=353kW/105kW/3.36
2) TEc/TCc=-10/+20°C RT/BKW/COPc=381/73/5,21

Were abbreviations stand for :

TEc : cooling plant evaporating temperature

TCc:cooling plant condensing temperature

RT:cooling capacity

BKW:absorbed motor power

COPc:coefficient of cooling performance.

This means up to 256MW power saving on 8000 hours of operation.

Priority is given to the heat pumps so that normally the condenser is not active.

The screw compressors are equipped with frequency convertors which result in no reactive power, saving 8.000 NOK monthly (or 96.000 NOK per year).

The frequency convertor driven engines are more expensive but quickly payd back.

'THIS WAS A BONUS'

(P.22) The heat pump compressor units in the machine room with the vertical heat source flash tank on the back side.

(P23) The heating performances (RT=heat source, BKW=power input, QC=heat output) and –coefficients (COP-h) are shown in the table for heat source temperature of 20°C and the different compressor speeds (1500rpm to 3400rpm) obtained by the frequency controller (25Hz to 57Hz).

The maximum heating performance of 1157Kw is obtained at 3400rpm (57hz) with a corresponding heating performance coefficient of 6,2.

On 2-10-2012 the heat pumps have operated 5.155 hrs (VP1) and 7.842hrs (VP2).

The panel monitor gives the complete overview of the operating conditions.

(P24) The panel condenser sub-menu shows the water-inlet temperature of 45,9°C and hot water outlet of 54,8°C covering sufficiently the requirement.

(P25) Efficiency analysis shows :

The design heat performance coefficient is in the range of 5,7 to 6,2 depending on the plant load.

The average heat performance coefficient in praxis was at 5,5 for the first 11 months of operation.

The table shows the weekly average heating output for the different compressor speeds,

i.e. 134 MWh at 1500rpm till 319 MWh at 3400rpm for 276 operating hours per week

(value taken from total number of operating hours 12.997 on 3-10-2012 after 11 months operation).

The real energy input and heat output is weekly recorded by the customer.

The table shows that in January 2012 232MWh was produced with an energy input of 41,55MWh, or heat performance coefficient of 5,6.

In May 2012 the results show 190 MWH heat output with 35MWh energy input, i.e.COP-h 5,4.

(P26) Process of measuring efficiency :

The total power input and heat pump plant output are checked weekly and taken up in the monthly energy cost per ton of produced meat which is the basic indicator for the process.

The block diagram shows the monthly energy input for 2011 and 2012.

It is clear that the overall energy consumption per ton produced meat has been reduced between 4 to 18% as shown on the graph.

Cost analysis :

This installation represents a value of 3.500.000 NOK including NH_3 heat pump installation, condenser, subcooler, waterpumps etc.

The cost saving can be summarized :

1,6 GW fuel (216.000 liter equivalent 1.200.000 NOK)

Cooling plant condensing temperature +20°C (up to 256 mW/yr or 288.000 NOK)

Frequency controlled drivers (96.000 NOK/year).

The savings done in this plant :

Heat recovery as overcompression heat pump uses cooling plant heat rejected to the condenser, including oil cooler heat rejection.

High efficiency drive motors as IE2.

Frequency controllers on main drive motors and waterpump.

Energy-saving condensers.

Potential savings in the future :

Improvement is possible by increasing the NH_3 condensing temperature from 57°C to 62°C, requiring a 30 bar safety valve setting on the heat pump unit.

With the old heat exchangers drain water heat is recovered in the 45°C water buffer. In the future this heat exchanger can be replaced with a more efficient execution.

The forecast succeeded the expectations and the customer is absolutely happy with the plant.

Barriers and solutions :

Thanks to the customer who gave full confidence and made strong investment in this new technology to THERMA INDUSTRI it was possible to succeed and realize this plant with success !

Psychological barriers were not experienced as customer preferred NH_3 as natural regrigerant since long time and fully relied on the capability of THERMA INDUSTRI and MYCOM for the heat pump technology.

Safety and legislative barriers have all been covered as plant/system was build fully in compliance with CE-PED.

Lessons learned from the project and how can this be applied to other projects using natural refrigerants :

For the cooling and heating plant the customer will choose for the same solution as demonstrated by this field case.

Planning about similar projects and recommendations for natural refrigerants :

Continue in the same line, but with higher safety valve set pressures to enable use of the compressor at full pressure-range to allow operation with higher water output temperatures.

THERMA INDUSTRI has more than 25 industrial NH_3 heat pump plants in operation which have been installed since 1998 !

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

In any case the field case 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.

CONCLUSION : NATURAL REFRIGERANTS – SOLUTION FOR EUROPE :

THIS PROVEN FIELD EXAMPLE SHOWS THAT THE SUCCESS OF THE NEW TECHNOLOGY IS MUCH DEPENDING ON THE QUALITY OF THE PREPARATIONS DONE ON BEFOREHAND FOLLOWED BY THE INSTALLATION AND COMMISIONING WITH OPTIMAL FINE TUNING,

FROM COOPERATION BETWEEN ALL PARTIES INVOLVED :

MANUFACTURER : MAYEKAWA JAPAN/ MAYEKAWA EUROPE

CONTRACTOR : THERMA INDUSTRI.

Thanking word :

To the audience,

And much appreciated thanks to the contractor of the fieldcases :

THERMA INDUSTRI AS

NORWAY

Mr.Stein Terje Brekke (stein.brekke@therma.no)

Mr.Stein Johnsen (stein.johnsen@therma.no)