AMMONIA CHILLERS in Different Industrial plants in Switzerland.

Jan Boone
Mayekawa Europe S.A.,
Leuvensesteenweg 605, 1930 Zaventem, Belgium
tel: 32-2-757-9075, e-mail: jan.boone@mayekawa.eu

ABSTRACT

This paper presents the results of operation of CHILLERS with natural refrigerants in Switzerland.
PLANT 1 with a piston compressor to produce 367 kW cooling in a fruit & vegetable cold store with ethylene glycol at -6°C by using plate in shell type evaporator.
The plant started in the fruit-season 2012 and operated approx. 3716 hrs at an overall COP of 4 to 5.
PLANT 2 uses 2 piston compressors to produce 500kW chilled water at 6°C and 350kW glycol-water at -3°C in a coldstore by using a direct expansion type chillers.
The plant was started in 2010 and operated approx. 18000 hrs at an overall COP of 3~4,5.
PLANT 3 uses piston compressors to produce 250kW cooling in a fruit cold storage plant with ethylene glycol at -7°C by using combined plate in shell evaporators.
The plant started in 2011 and operated approx. 16000hrs at an overall COP of 2.9.

1. INTRODUCTION

Ammonia is one of the oldest refrigerants in industrial use today and its use will stay and always be of interest to engineers. This is because ammonia is a natural refrigerant with benign effect on the environment and has excellent thermal properties with a potential to offer systems with high COPs. In order to increase use of ammonia in industrial refrigeration applications, a lot of effort and development have been advanced to reduce refrigerant charge , increase safety and reliability.

2.AMMONIA PLATE IN SHELL CHILLER PACKAGE

2.1 COMPRESSOR

An 'M-Series' piston compressor type MYCOM N4M (bore/stroke=146/106mm) is installed in this chiller. (figure 1). This new serie of compressors is sold since 2009 on the market with higher efficiency and COP compared to the previous compressor-series, covering a bigger capacity range and wider operating range.

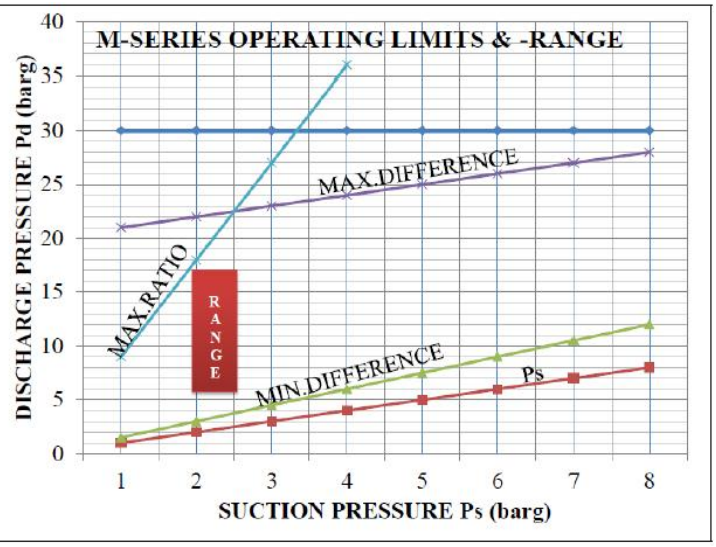
The compressor maximum capacity is in the range of 400 to 470kW at maximum speed depending on condensing temperature range 45 to 15°C (based on evaporating temperature -7°C) and minimum at 27% of these values at minimum speed and 50% cylinder-load. The COP-c of this compressor is 5 to 17% higher compared to the old piston compressors depending on the compressor rotating speeds.

The chiller is designed to produce 367kW chilled ethylene glycol-water at -6°C in the fruit/vegetable coldstores. Depending on the cold store load and the season it is possible to operate the plant in the capacity range of 100% to 25% by using frequency drive control between 1500 and 800rpm and piston bank control between 100 and 50%. (based on 0°C suction gas superheat and 0°C liquid subcooling). The operating

pressure range and limitations for this compressor is shown in graph 1.

figure 1

graph 1



In the machine room the compressor with drive motor type (LS-160kW 4P 400V IP23 mounting B3) is visible on figure 3 in the front with isolated suction line and suction separator(above evaporator) & oil system with oil pump(built-in compressor), oil filter and oil separator. The motor is controlled by a power drive type LS-MDS180T. Figure 2 shows the back side of the unit with oil separator and control panel.

figure 2

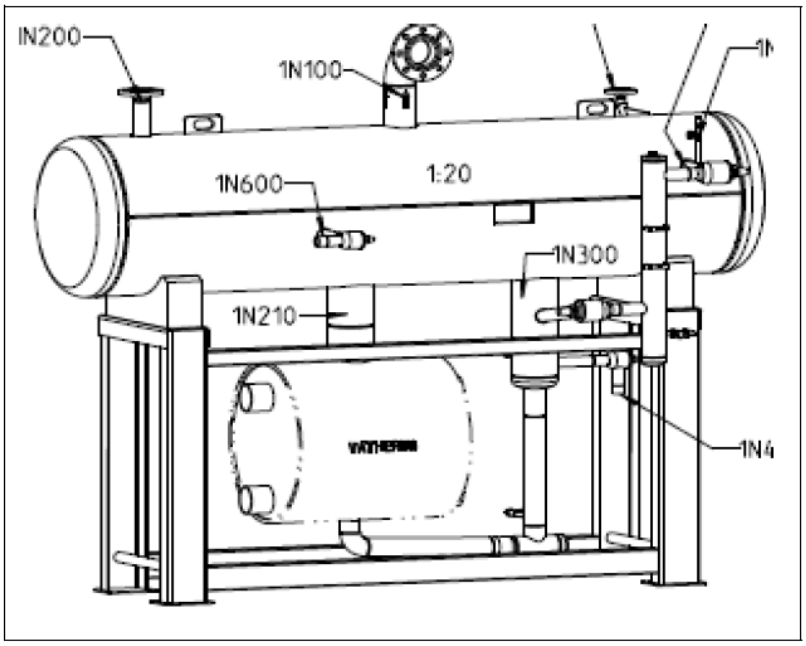
figure 3

2.2 EVAPORATOR

A plate in shell type heat exchanger evaporator is used in this chiller for producing 87,5 m3/hr glycol-water at -6°Cwith sizing as shown in figure 4. The PSHE is designed to be able to produce 440 kW of glycol-water if the outlet glycol temperature increases to -2,5°C (Tin 2°C, Tevap -5,5°C, 93,4m3/.hr).The fully welded plates are mounted in the shell which make the way for the refrigerant short with very small pressure drop (1kPa). The selected type is very suitable for natural refrigerant circulation with short distance between heat exchanger and separator mounted on top.

figure 4

CONDITION (EG 33%/water)	-6°C
TYPE	PSHE
MODEL	5HH-194/1/1
plate qty	194
RT	367
tw-in	-2
tw-out	-6
dt1	3
lmtd	4,60
dt2	7
TE	-9
HTS	50,3
k-value	1577
content	89



Abbreviations :

RT	evaporating capacity in kW
tw-in	glycol-water inlet temperature in °C
tw-out	glycol-water outlet temperature in °C
TE	evaporating temperature in °C
dt1	temperature difference (tw-out – TE) in °C
dt2	temperature difference (tw-in – TE) in °C
lmtd	logarithmic mean temperature difference in °K
HTS	heat transfer surface in m2
k-value	k-value in W/m2.K
content	total SPHE volume NH3 side in liter

2.3 CONDENSOR

An air-cooled condenser type Alfa Laval BNDLE1004CD is used in this plant as shown per figure 5.

figure 5 figure 6

2.4 EXPANSION VALVE

A high pressure float valve type HR3-S is used on this unit, as shown per figure 6, which is very simple and reliable with adapted NH3 charge on the unit.

2.5 FIELD EXPERIENCE

The chiller was installed by the contractor ZERO-C (contact: Mr. Pierre-Alain Giroud, www.zero-c.com) in August 2012 and has been operating until now approx.3716 hrs.(Charges: 102kg NH3, 40 liter OIL)

The COP has been calculated based on the operating condition range: evaporating temperature, condensing temperature and load (speed : maximum 1500rpm and minimum 800rpm, cylinder capacity control : maximum 100% and minimum 50%). The overall COP shown graph 2 (100% cylinder load) is based on the electrical consumption measured before the power drive and the cooling capacity measure by a magnetic flow meter and PT100 temperature probe on the glycol. We could estimate the overall efficiency of power drive and motor between 93% to 80% depending on the load. The COP varies between 7,8 and 3,2 at low speed for the defined operation pallet, and between 6,9 and 3 at high speed. This field case shows how COP-c can be maximized by using new compressor technology in a wide range of conditions by taking advantage of minimized condensing temperature.

Graph 2

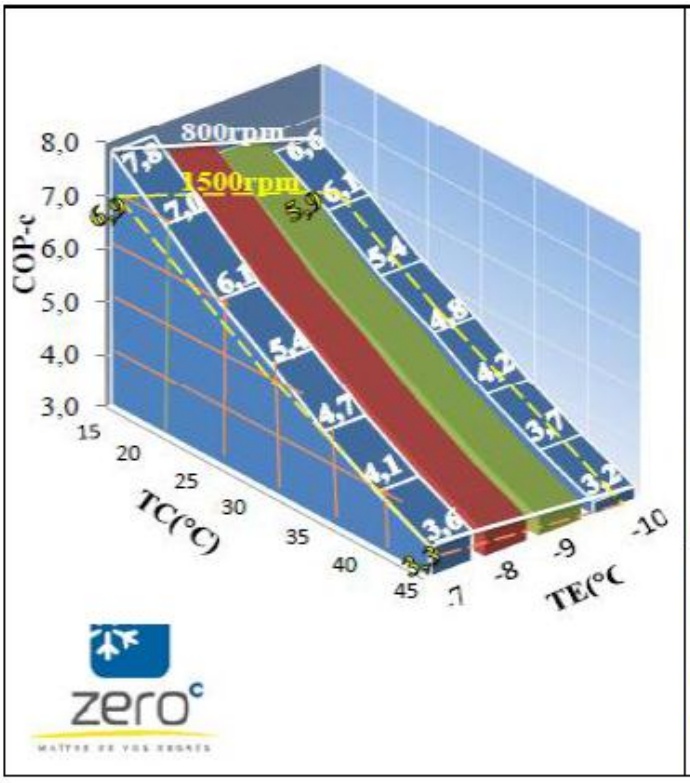


figure 7

OPERATION EVALUATION			
	FROM	TILL	
DATE	1/03/2013	25/03/2013	
TIME	0:00	0:00	
PERIOD HOURS DAYS		600	25%
OPERATING HOURS		283	47%
STAND-STILL HOURS		317	53%
MEASURED COP			
value	number of hours	time %	
>6	2,5	1	
5-6	32,7	12	
4-5	184,9	65	
3-4	62,9	22	
total	283	100	

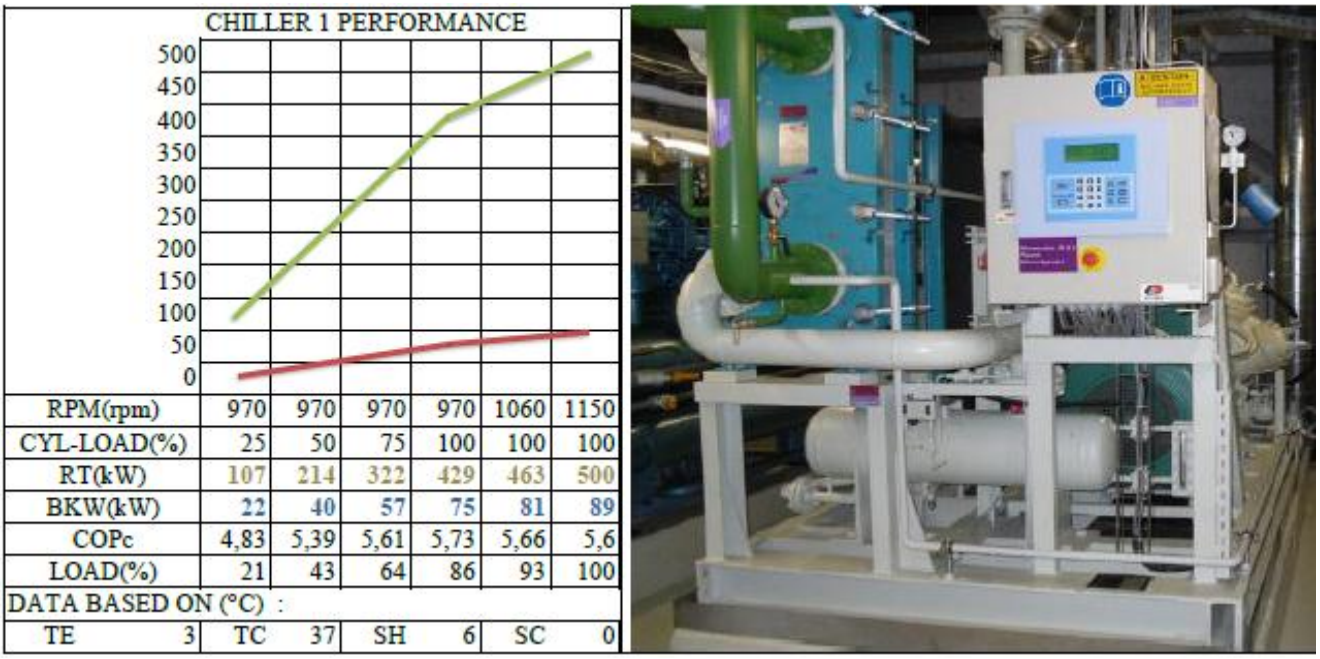
comparison 20/3/13 13:17hr
glycol- t° in/out: -0,3/-4,3°C
glycol flow : 59,2 m3/hr
te/tc: -5,8/18,6°C(2,45/7,21barg)
measured RT : 247 kW BKW:51,7kW
N4M 1438rpm 50%. COP-c = 4,79

3 AMMONIA DIRECT EXPANSION CHILLER PACKAGE

3.1 COMPRESSOR

The 'L-Series' piston compressor type MYCOM N8L(bore/stroke=115/90mm) is installed in each of the 2 chillers. Chiller nr 1 produces 500kW chilled water at 6°C which is used for obtaining temperatures of 13°C in the production rooms. Chiller nr 2 produces 350kW ethylene glycol at -3°C used for obtaining coldstore temperatures of +4°C.The compressors are open type oil lubricated with built-in oil pump and complete with oil system with oil filters, oil cooler and cyclonic type oil separator.
Both units have individual NH3 circuits and are equipped with water-cooled condensors.
All heat exchangers are plate type heat exchangers to obtain minimized NH3 charge.
The chillers have capacity control by using frequency control on the motor(nominal speed down to 970rpm) and cylinder bank control on the compressors (100-75-50-25%) allowing to cover a plant load from 100% down to approx..20% with capacities as shown per figures 8 & 9 for resp.chiller 1 & 2.

figure 8



RPM(rpm)	970	970	970	970	1060	1150
CYL-LOAD(%)	25	50	75	100	100	100
RT(kW)	107	214	322	429	463	500
BKW(kW)	22	40	57	75	81	89
COPc	4,83	5,39	5,61	5,73	5,66	5,6
LOAD(%)	21	43	64	86	93	100
DATA BASED ON (°C) :						
TE 3	TC	37	SH	6	SC	0

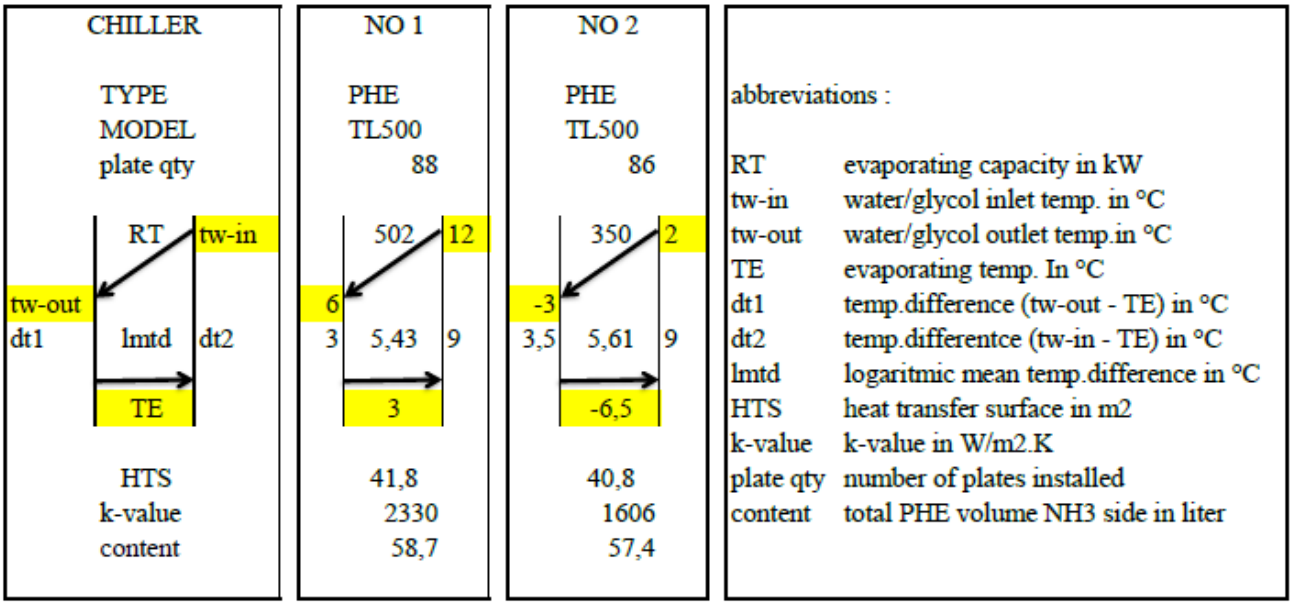
figure 9

RPM(rpm)	970	970	970	970	1072	1174	1276
CYL-LOAD	25	50	75	100	100	100	100
RT(kW)	69	138	207	276	300	325	350
BKW(kW)	21	37	53	69	76	83	90
COPc	3,31	3,75	3,92	4,02	3,96	3,91	3,87
LOAD(%)	20	39	59	79	86	93	100
DATA BASED ON (°C) :							
TE -6,5	TC	37	SH	6	SC	0	

Figure 8 & 9 show the plants room with backside view on condenser, liquid receiver & control panel, and with side view on compressor with drive motor.

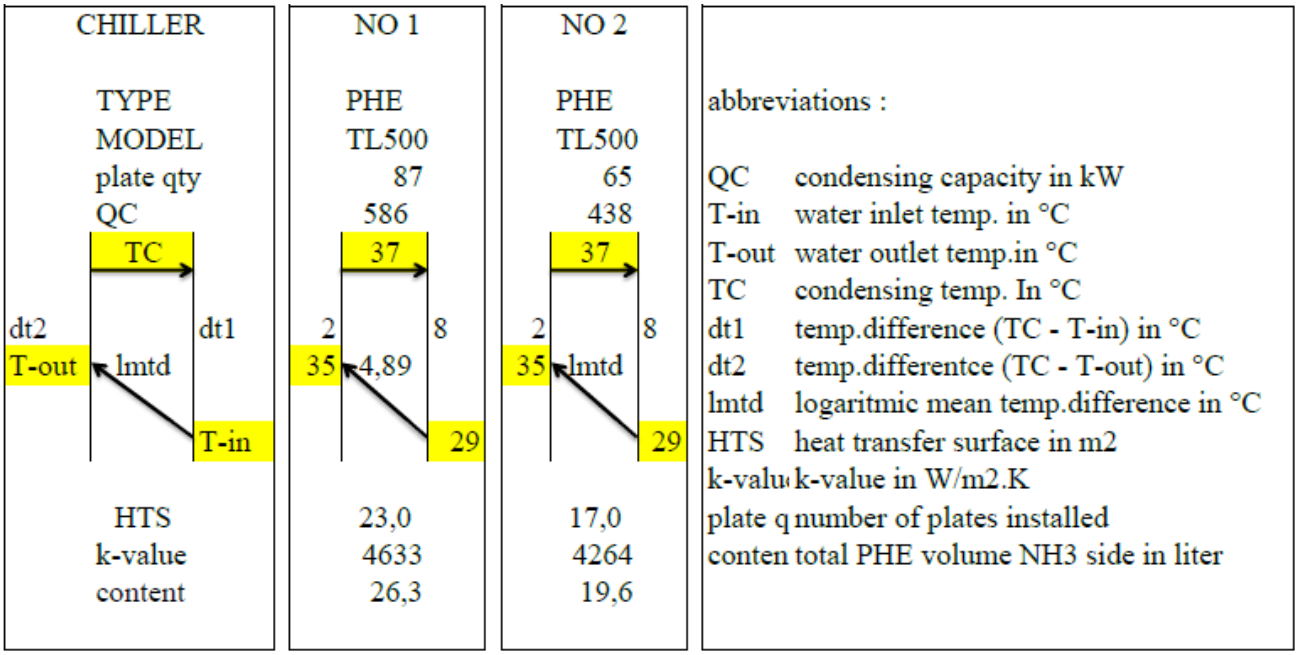
3.2 EVAPORATOR

Plate type heat exchangers are applied for the evaporators with sizing as shown in figure 10.
The PHE contains of a number of casettes, made by special shaped plates which are welded per 2 pcs, and sandwiched between 2 pressure plates. The NH3 is flowing in the cassette between the welded plates while the water/glycol is flowing outside the casettes.
figure 10



3.3 CONDENSOR

Plate type heat exchangers are applied for the condensors with sizing as shown in figure 11.
figure 11

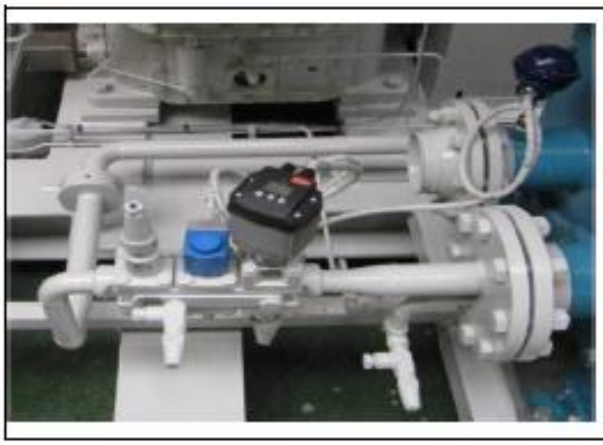


3.4 EXPANSION VALVE

Both chillers use an ICF valve combination, type ICF 20-6-5B, for direct expansion of the NH3 to the evaporator with electronic control. The compact valve set is complete with filter, liquid supply solenoid valve, electronic expansion valve with actuator and necessary service valves

The expansion valve controls the superheat on the NH3 gas outlet of the chiller, while the compressor capacity is controlled on the water/glycol outlet on the chiller.

figure 11



REFRIGERANT AND OIL CHARGES			
CHILLER		1	2
RT	kW	500	350
NH3 CHARGE	kg l g/kW	19,2 30 38	16,6 26 47
OIL CHARGE	l	30	30

3.5 FIELD EXPERIENCE

This plant was started in middle 2009 and have been in successful operation until to-day with actual number of operating hours for chiller 1 : 10192 hrs and chiller 2 : 8008 hrs.

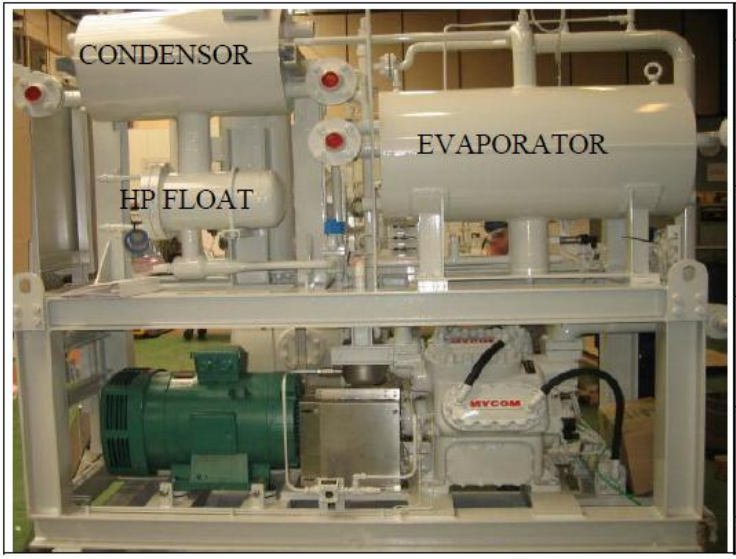
The overall COP-c of the system has been evaluated for chiller-1: 4~4,5, for chiller- 2: ± 3.

This field case shows minimized NH3 charge as main advantage of dx operation with no need of suction gas separators.

4. AMMONIA COMBINED PLATE IN SHELL CHILLER PACKAGE

2 chillers are installed in this fruit-vegetable coldstores to produce 133kW each of ethylene glycol at -7°C to obtain coldstore temperatures of 0°C using the open type compressor model N8K with B3 type mounted drive motor of 55 kW as shown in table 1 & 2.The 'K-Series' piston compressor type MYCOM N8K (bore/stroke=85/65mm) is used in each chiller.

figure12



NH3 CHILLER DATA (per chiller)		
compressor	N8K (rpm)	1450
	TE/TC (°C)	-10 / +36
	RT/BKW (kW)	133 / 37
	COP-c	3,6
evaporator	PSHE-4/3HH-328	combined
	EG/water 34/66%(°C)	-2 / -7
	flow (m3/hr)	24,5
condensor	PSHE-3HH-212	
	PG/water 30/70%(°C)	+26 / +33
	flow (m3/hr)	30,6
charges		
	NH3 (kg)	33
	OIL (l)	7
operation	HRS C1/C2(15/3/2013)	8500 / 7500

Evaporator and condenser are well known fully welded Plate & Shell heat exchangers.
The evaporator combines evaporator and separator functions in one shell
reducing the unit dimensions and also the refrigerant charge.
The vessel has an uncomplicated shape, no external piping and is easy to insulate
with high efficiency separator and small refrigerant charge (33 kg)
Not usefull areas can be filled up for reducing the refrigerant charge.
Design is made on practical tests.
Oil can be easily drained off

The expansion is controlled with a high pressure float valve type HS35-H
mounted under the condensor as visible in table 2.
The plant was started in May 2011 with successful operation and total running hours
given per table 2.

The fieldcase shows how compactness can be minimized when using combined evaporators.

figure 13

5. CONCLUSIONS

This paper reports on the operation of ammonia chillers that use different types of evaporators depending on direct expansion or flooded operation.
Compared to the conventional shell and tube evaporators with external separators as used in the past significant improvements have been achieved by the use of very compact plate in shell type heat exchangers and further integrated separator.
Units become much more compact and heat exchanger efficiencies have much increased.
With newer compressor technologies the COPs have been increased and load coverage has been much widened by applying frequency drive speed control in addition to mechanical part load of the machine.
In addition the optimizing of the operation at minimized condensing temperature contributes also to a very important reduction of the power consumption.
The introduction of hermetic main drive motors (figure 13) will contribute to further reduce environmental impact by improvement of efficiency, safety and reliability.