CHEMSTATIONS 2005 SALES MEETING

BATCH REACTOR REFRIGERATION SYSTEM MODELLING

Contents

Appendix

1.0 INTRODUCTION

The refrigeration process is used extensively in the process industries to carry out a wide range of below ambient cooling duties. These applications include low temperature condensation, to minimise volatile organic compound emission, heat removal on low temperature reactions and a variety of product separation and stability applications.

Chlorofluorocarbons (CFCs) are extensively used as refrigerants. CFCs have been identified as a major cause of ozone depletion, due to their breakdown when exposed to strong ultra-violet light, releasing chlorine atoms. Refrigeration processes have been undergoing a major program to replace CFCs with non-ozone depleting blends.

This technical note is based on refrigerant R407C which is the replacement for R22. Chemstations has demonstrated that CHEMCAD provides excellent data fit for the new refrigerant blends when using the Peng-Robinson-Stryjek-Vera(PRSV) equation of state.

The conventional refrigeration cycle is reviewed and CHEMCAD is used to model a novel refrigeration system architecture which allows system operation from 0 to 100% duty with the compressor running continuously at full load without using unloading valves.

The CHEMCAD Excel Add In feature has been used to develop a model Graphical User Interface (GUI). The refrigeration process is characterised by a complex interaction of process parameters and the GUI provides the user with powerful facilities to test the sensitivity of these process variables.

Models developed in this format, opens up the use of CHEMCAD to a wide range of technical disciplines providing a user friendly flexible facility for the sales, design optimisation and operational functions.

2.0 PHYSICAL PROPERTY DATA

2.1 Refrigerant R407C Properties

The information in this section has been provided by David Hill of Chemstations, Houston.

R407C is a non-ozone depleting blend used as a replacement for R-22 (HCFC-22) in existing medium-temperature refrigeration systems. R407C is a blend with a temperature glide and is not recommended for use in chillers with a flooded evaporator. It is not a drop-in replacement as mineral oils used with R-22 are immiscible with R407C. Consult the original equipment manufacturer for the recommended lubricants and retrofit guidelines.

Relative to R-22, there is little to no capacity decrease with R407C, however, some loss of efficiency may occur and some equipment modifications will be required when retrofitting these systems.

Refrigerant R407C Composition			
Component	Refrigerant	CHEMCAD ID	Composition w/w
difluoromethane	HFC 32	645	23%
pentafluoroethane	HFC 125	1231	25%
1,1,1,2-tetrafluoroethane	HFC 134a	1802	52%

Refrigerant blends are typically zeotropic mixtures. A zeotrope is a mixture which has a very narrow phase envelope. The saturated liquid and saturated vapour pressures for a zeotrope are very close; a zeotrope is typically difficult to separate. This narrow phase envelope is a quality for a heat transfer fluid. A mixture with a wide phase envelope will change composition during service, causing a change of transport properties.

The properties of the new zeotropic blends are somewhat different than the traditional refrigerants. Zeotropic blends shift in composition during the boiling or condensing process. As the blend changes phase, more of one component will transfer to the other phase faster than the rest. This property is called fractionation. The changing composition of the liquid causes the boiling point temperature to shift as well. The overall shift of temperature from one side of the heat exchanger to the other is called the temperature glide.

Zeotropic blends cannot be defined by a single pressure-temperature relationship. The temperature glide will cause different values for temperature at a given pressure, depending on how much refrigerant is liquid and how much is vapour. The most important values for checking superheat and subcool are the end points of the glide or the pressure-temperature relationship for saturated liquid and saturated vapour.

Typically refrigerant blends are highly non-ideal. As such, it can be difficult to accurately model the mixture's behaviour without using special mixing rules and parameters.

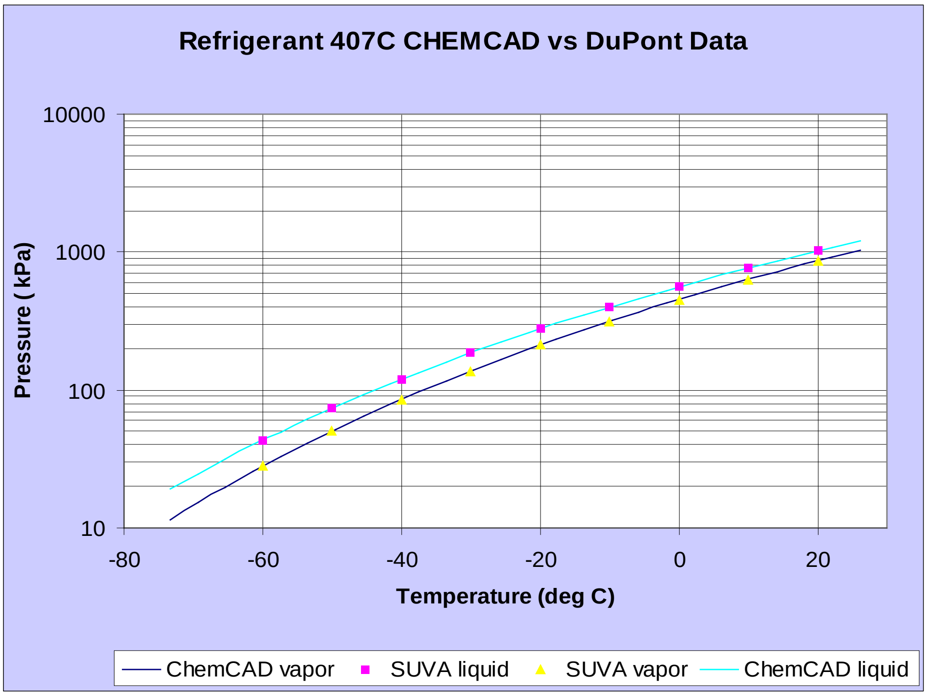
There are two options for modelling a blended refrigerant model the system as a 'pure' component with properties from the system or model the system as a mixture.

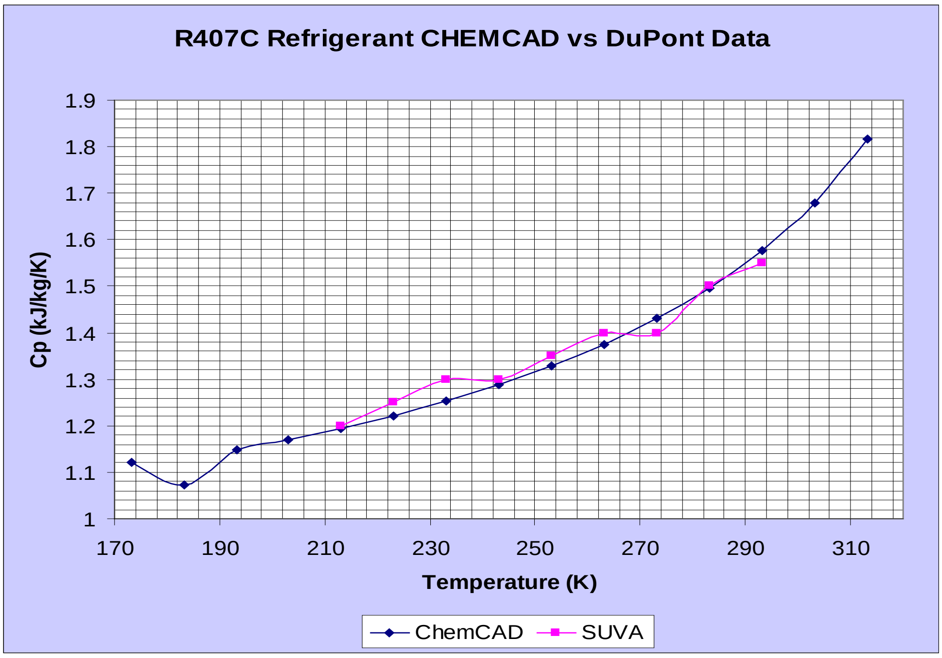
To model a refrigerant blend as a single pseudocomponent with properties which are representative for the blend has the problem that the pseudocomponent will not have a narrow phase envelope; it will only having a saturated boiling curve. A second problem is that if an equation of state is used to calculate compressibility of the component, the liquid heat capacity will not be extremely accurate. For an equation of state, liquid heat capacity is calculated from the vapour and critical properties.

2.1 Refrigerant R407C Properties (Cont.)

Dupont publishes values for its SUVA line of refrigerants with mixing parameters to be used in the Peng-Robinson-Stryjek-Vera(PRSV) equation of state. Modelling the blends as separate components allows the user to see the zeotropic behaviour. Also, the liquid heat capacity more accurately reflects data from the vendor.

The curves below demonstrate that CHEMCAD accurately reproduces the bubble-dew point curves on a PT diagram and the liquid heat capacity for the blends is also consistent with vendor data.

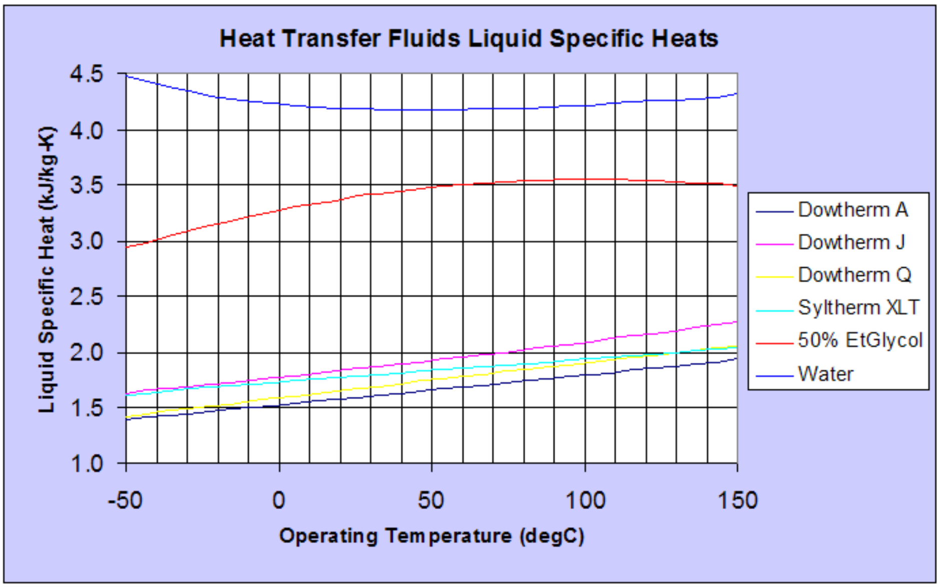




2.2 Heat Transfer Fluid Properties

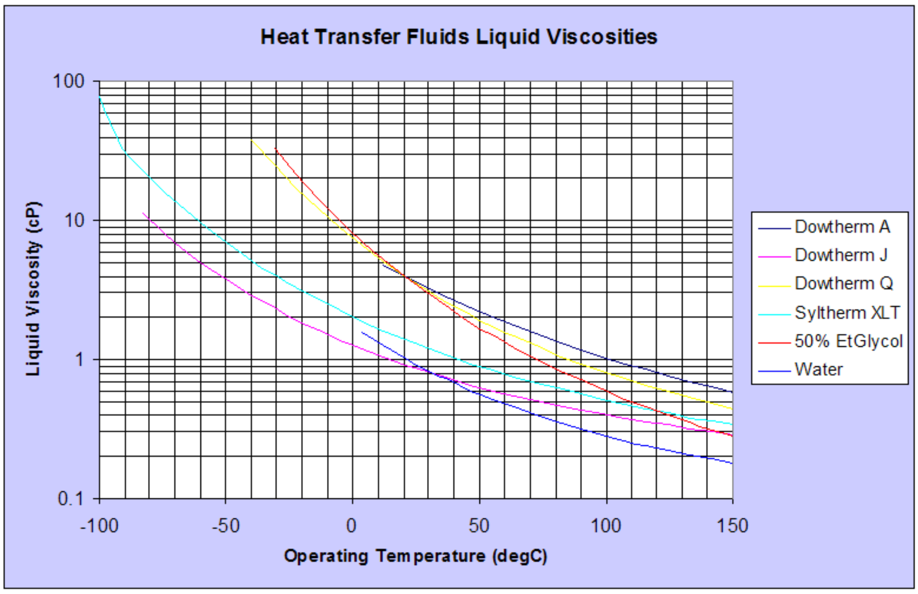
The relative merits of the heat transfer fluids, under consideration, are evaluated by study of key property data group component plots generated using CHEMCAD.

The liquid specific heat plots for common heat transfer fluids show a significant difference between water and organic based thermal fluids.



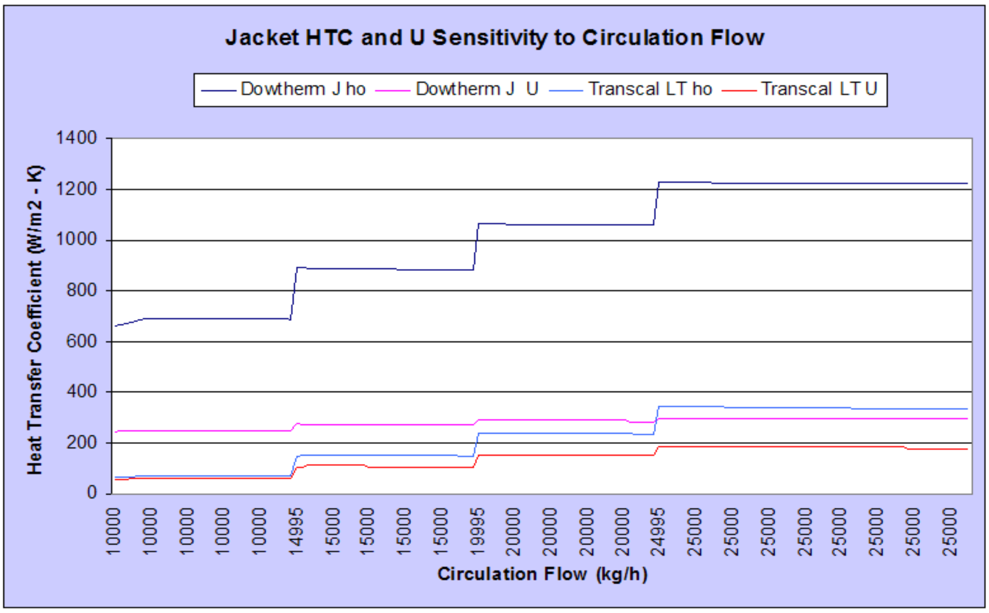
The heat removal capability using water, at constant temperature difference, is greater than that achieved with organic fluid flows in proportion to the ratio of the specific heats. In consequence, heat transfer fluid distribution systems are significantly more expensive to install, due to the increased pipe size and pumps required, over that for water systems.

The liquid viscosity of the selected fluid throughout the operating temperature range is the key parameter in the selection. Viscous conditions can result in laminar flow in the cooling circuit with resulting poor heat removal capability leading to instability for exotherms.

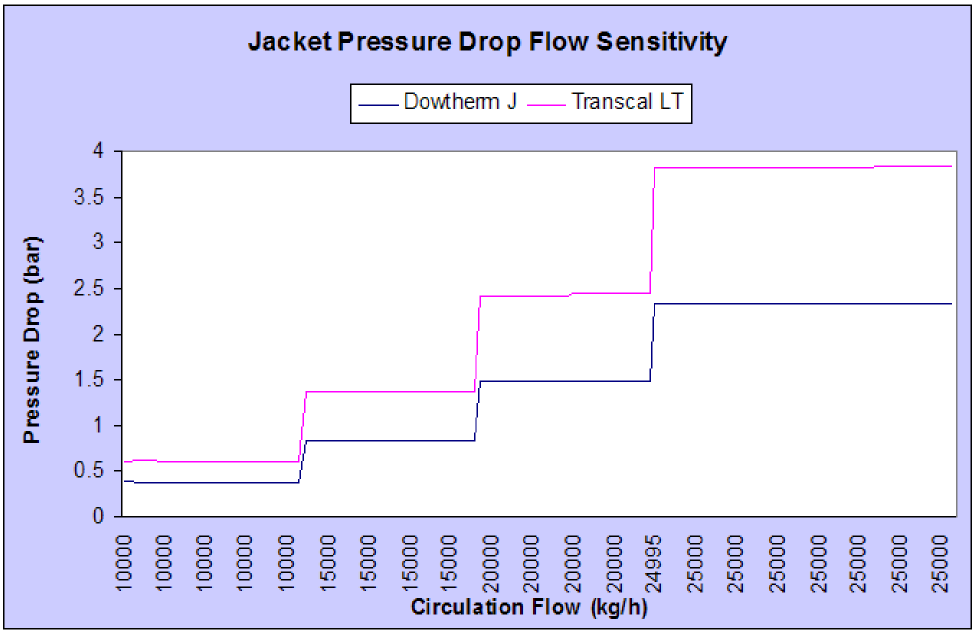


2.2 Heat Transfer Fluid Properties (Cont.)

CHEMCAD provides a powerful tool to demonstrate the implications of incorrect heat transfer fluid selection. An application using Dowtherm J or the more viscous Transcal LT is considered. for a 4.5 m^3 glass lined jacketed reactor, with three mixing nozzles fitted, carrying out an exothermic reaction in the range 100 to 110 °C.



Circulation flow change results in the U for Dowtherm J varying from 252 to 295 W/m^2 °K and for Transcal LT varying from 62 to 181 W/m^2 °K.

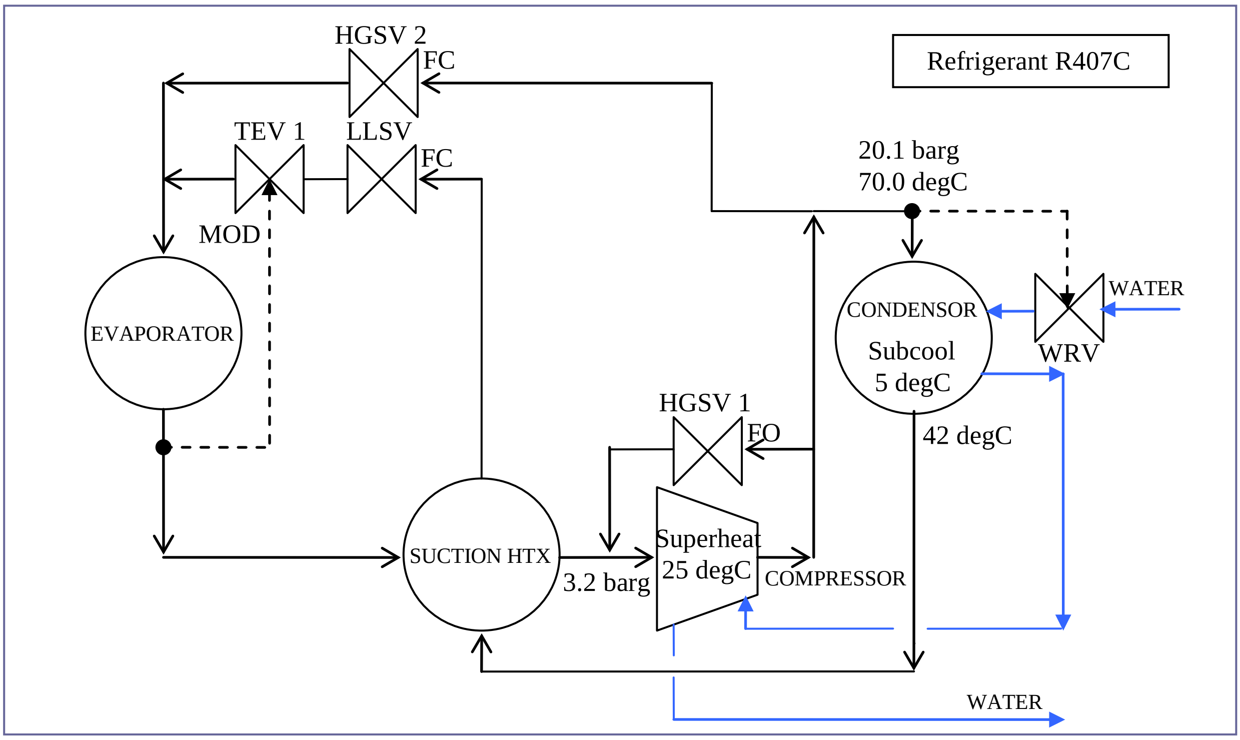


Circulation flow change results in the jacket pressure drop for Dowtherm J varying from 0.37 to 2.3 bar and for Transcal LT varying from 0.6 to 3.8 bar.

3.0 REFRIGERATION SYSTEM CYCLE

3.1 Typical Refrigeration Cycle Description

These systems are frequently used for temperature control of batch reactors with operating temperatures in the range of -40°C to 150°C. Heat transfer fluid is circulated through the evaporator with the result that refrigerant temperatures leaving the evaporator vary significantly, resulting in extreme temperatures that approach the operating temperature range limits. The diagram shows a typical architecture used in industry for a process requiring cooling below ambient temperature.



The evaporator inlet temperature is controlled by using the thermo-expansion valve TEV1 and the hot gas bypass valve HGSV2. The evaporator(coil) pressure is set for the refrigerant to give the desired temperature.

The thermo–expansion valve is a precision device designed to regulate the rate of refrigerant liquid flow into the evaporator in exact proportion to the rate of evaporation of the refrigerant liquid in the evaporator. The amount of refrigerant gas leaving the evaporator can be regulated since the valve responds to the temperature of the refrigerant gas leaving the evaporator and the pressure in the evaporator. This controlled flow prevents the return of refrigerant liquid to the compressor and controls the flow of gas by maintaining a pre-determined superheat.

When operating at sustained low temperatures the evaporator is prevented from freezing or liquid from reaching the compressor suction by using a feature known as hot gas bypass. During low load conditions the hot gas bypass valve HGSV2 imposes a false load on the evaporator by allowing some hot discharge gas to bypass it's normal route to the condenser and enter the evaporator inlet.

The diverted hot gas (HGSV 1) can be routed to the suction line after the evaporator, however it is considered a better option to tie in after the TEV1 (HGSV 2). In this case the evaporator serves as a mixing chamber for the bypassed hot gas and the liquid/vapour mixture from the expansion valve. TEV1 responds to the increased superheat of the vapour leaving the evaporator and will provide the liquid required for desuperheating. Oil return from the evaporator is also improved since the velocity in the evaporator is increased by the hot gas. A solenoid valve is also required in the hot gas line to prevent the possibility of liquid migration back to the compressor during the off cycle.

To control the condenser inlet(head) pressure water regulating valve (WRV) controls the flow of water through the condenser. When refrigeration is off there should be no water flow. When refrigeration starts, the WRV modulates the flow of water to maintain a pre-set head pressure. The sensing line is hooked up to high side refrigerant pressure. If the head pressure starts to rise above normal, the increase in pressure causes the valve to allow more water flow reducing the head pressure. The valve reaches an equilibrium and maintains a pre-set head pressure. The WRV should be located on the water inlet side of the condenser. It is also uni-directional which means flow should be in the direction indicated by the arrow on the valve body. High head pressure causes high discharge pressures and increased amperage draw. High discharge temperatures break down refrigerant oil

LLSV prevents liquid from filling the evaporator when the compressor stops and prevents backflow(siphoning) into the condenser and compressor.

Typical settings and readings in a conventional refrigeration system using refrigerant R407C are shown in the Table below.

	R407C REFRIGERATION CYCLE PROCESS PARAMETERS			
Location	Parameter	Units	Estimated Values	
Compressor Suction	Pressure	bara	4.82	6.66
Evaporator Superheat	Temperature	°C	0	0
Compressor Inlet (SST) t_o	Temperature	°C	-5.0	5
Compressor Inlet Superheat	Temperature	°C	20	20
Compressor Inlet	Temperature	°C	15	25
Compressor Discharge	Temperature	°C	70	70
Condenser Inlet(Head)	Pressure	bara	20.65	23.33
Condenser Dewpoint (SDT) t_c	Temperature	°C	35	40
Condenser ΔT	Temperature	°C	36	31
Condenser Subcool	Temperature	°C	1	1
Liquid	Temperature	°C	34	39
Compressor Output	Flow	kg/h	541.1	775.6

The pressure-temperature (PT) chart is used to check proper system operation. For a blend, such as R407C, simply read the saturated temperature next to the pressure in the vapour (dew point) column of the chart. PT charts are most often used:

- To set a coil pressure so that the refrigerant produces the desired temperature.
- To check the amount of superheat above the saturated vapour condition at the outlet of the evaporator.
- To check the amount of subcooling below the saturated liquid condition at the end of the condenser.

3.2 Modified Refrigeration Cycle Architecture

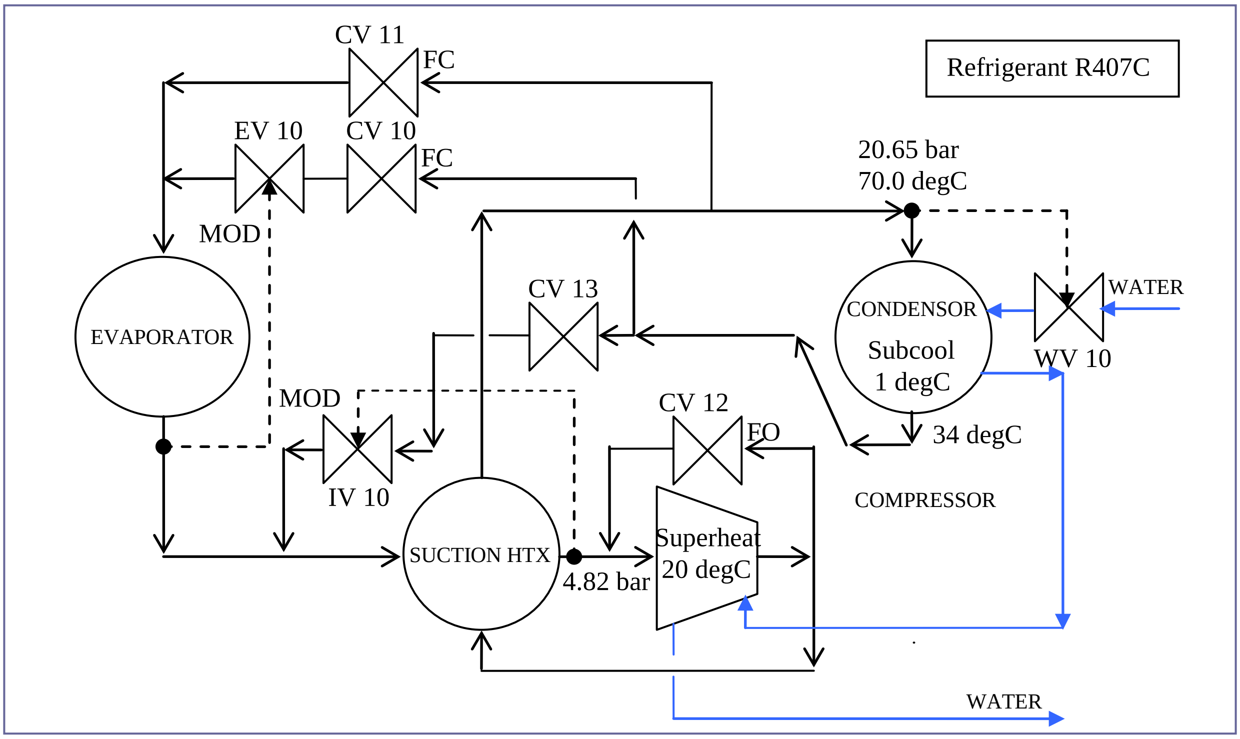
This architecture has been developed to allow system operation from 0 to 100% duty with the compressor running continuously at full load without using unloading valves.

The hot gas bypass valve CV 11 is located on the evaporator inlet. When operating at sustained low temperatures the evaporator is prevented from freezing or liquid from reaching the compressor suction by using hot gas bypass. During low load conditions the hot gas bypass valve CV 11 imposes a false load on the evaporator by allowing some hot discharge gas to bypass it's normal route to the condenser and enter the evaporator inlet. This feature has been described previously.

Hot gas bypass valve CV 12, a normally open valve, is used to stop surge during compressor start up. It closes when the star/delta starter timer switches to delta mode and remains closed until the compressor is shut down.

The condenser inlet pressure water regulator valve WV 10 controls the flow of water through the condenser to control the head pressure as described previously. Condensor relief valves are set at 24 barg which is equivalent to an SDT of 43°C.

The compressor discharge is routed through the suction heat exchanger. Liquid injection valve IV10 directs liquid to the inlet of the suction heat exchanger to allow for some desuperheating of the suction gas.. Thermal expansion valve IV 10 maintains an acceptable superheat for compressor suction conditions.



The application being modelled uses a 50% Ethylene Gycol/Water mixture as the heat transfer medium being circulated at 10000kg/h through a 250L glass lined jacketed reactor.

3.2 Modified Refrigeration Cycle Architecture (Cont.)

The evaporator inlet temperature is controlled by using the thermal expansion valve EV 10 and the hot gas bypass valve CV 11. The evaporator pressure is set for the refrigerant to give the desired temperature.

The thermo–expansion valve fitted has a nominal capacity of 32.9 kW for R407C refrigerant. Nominal capacities are based on 38°C condensing temperature(dew point 22.2 bara), 4°C evaporating temperature and 1°K liquid subcooling at the inlet to the expansion valve. Correction factors have to be applied for different operating conditions. The upper limit of the evaporating temperature range is 14°C (bubble point 8.7 bara).

The liquid injection valve IV10 provides an additional feature for superheat control, namely to desuperheat the suction gas. The valve selected has a nominal capacity, Q_n, of 4.0 kW and desuperheat setting of 13°K for refrigerant R407C.

For desuperheating of suction gas in conjunction with hot gas bypass regulation the required bypass capacity $\mathbf{Q_{Bypass}}$ is calculated from:

$$\mathbf{Q_{Bypass} \, x \, k_{ti} = Q_n}$$

Where
$\mathbf{Q_n}$ nominal valve capacity and
$\mathbf{k_{ti}}$ is the evaporation temperature correction factor

The correction factors are based on 20°K superheat at the compressor inlet and discharge temperature 28°K above the isentropic compression and 1°K subcooling.

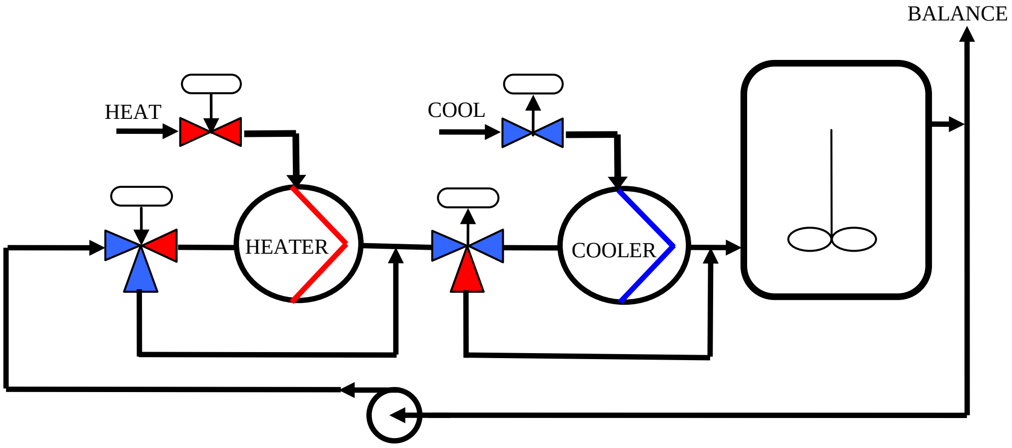
Correction Factor k_{ti} for R407C refrigerant								
Condensing Temperature °C	Evaporating Temperature °C							
	10	5	0	-10	-20	-30	-40	-50
50	0.41	0.45	0.49	0.58	0.69			
40	0.32	0.35	0.39	0.46	0.55			
30	0.25	0.28	0.31	0.37	0.45			
20	0.19	0.21	0.24	0.30	0.37			

Refer to Appendix I for the compressor and condensor performance data.

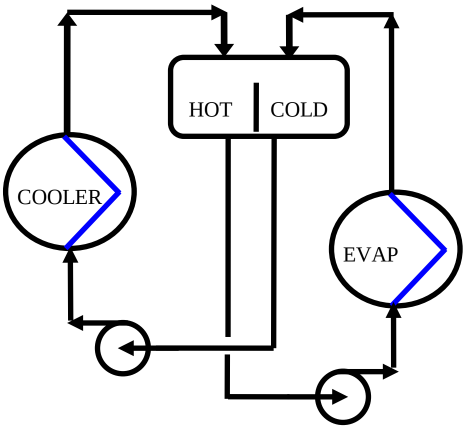
4.0 OPERATIONAL CONSIDERATIONS

4.1 Reactor Temperature Control

Reactor temperature control is typically achieved by circulating a heat transfer fluid via a Temperature Control Unit (TCU) through the reactor jacket at a flowrate suitable for turbulence and at the required temperature. The scheme below comprises a heating unit, a cooling heat exchanger and circulating pump.



For operation below ambient, the refrigeration system evaporator can be inserted into the circulation loop or alternatively an additional heat exchanger / three way valve combination is used with the refrigerant circulating in a secondary loop as shown below.

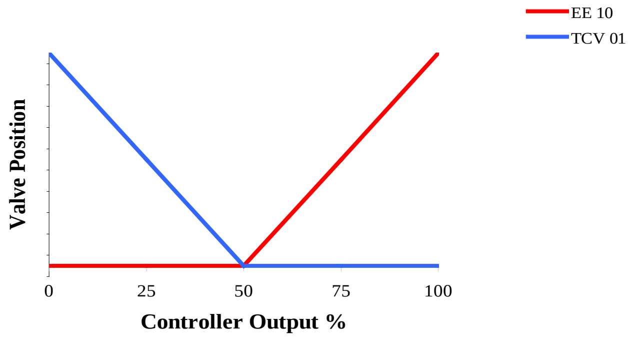


This arrangement protects the refrigeration system from the high jacket return temperatures that occur during initial reactor cooldown and is the preferred option on multiple reactor facilities. However on a single reactor system, it is expensive and resulted in the development of the modified refrigeration system architecture, described previously, eliminating the need for the balance tank, circulating pumps and additional heat exchanger.

4.1 Reactor Temperature Control (Cont.)

Normal Mode

The heat transfer medium is circulated through the reactor jacket via the heating unit and cooling heat exchanger, which are controlled in split range applying heating or cooling as appropriate. Circulation through the refrigeration system evaporator is continuous but the refrigeration system is disabled in this mode. The system expands or contracts via the pressurised head tank.

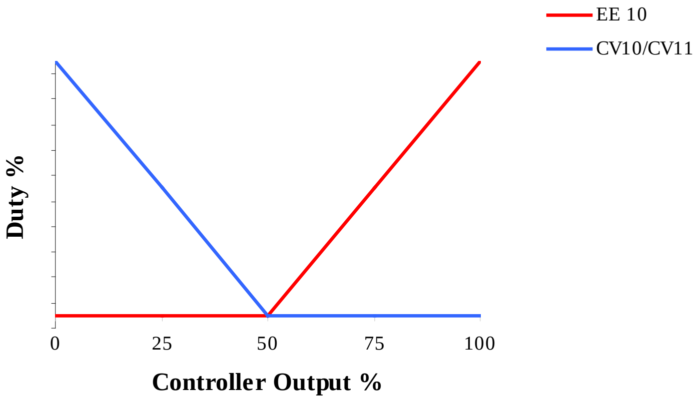


Chill Mode

This is used for operation of reactor contents at below ambient temperatures up to 30ºC, by running the refrigeration system at a temperature determined by the control system. The heating unit is available in this mode. This mode is used to achieve final target temperatures when the cooling exchanger would be operating in a region with only small temperature differences.

Refrigerant temperature is controlled operating CV10 and CV11 by pulse width modulating over a 6 second cycle time. For 100% cooling duty CV 10 is open and CV 11 is closed. For 0% chilling duty CV11 is open and CV10 is closed. For 50% duty CV10 is open for 3 seconds and CV11 is open for three seconds.

The circulation pump runs continuously circulating the heat transfer medium, via the heater and evaporator, through the reactor jacket. The heating unit and refrigeration control valves (EE 10 / CV 10 & CV 11) also operate in split range.

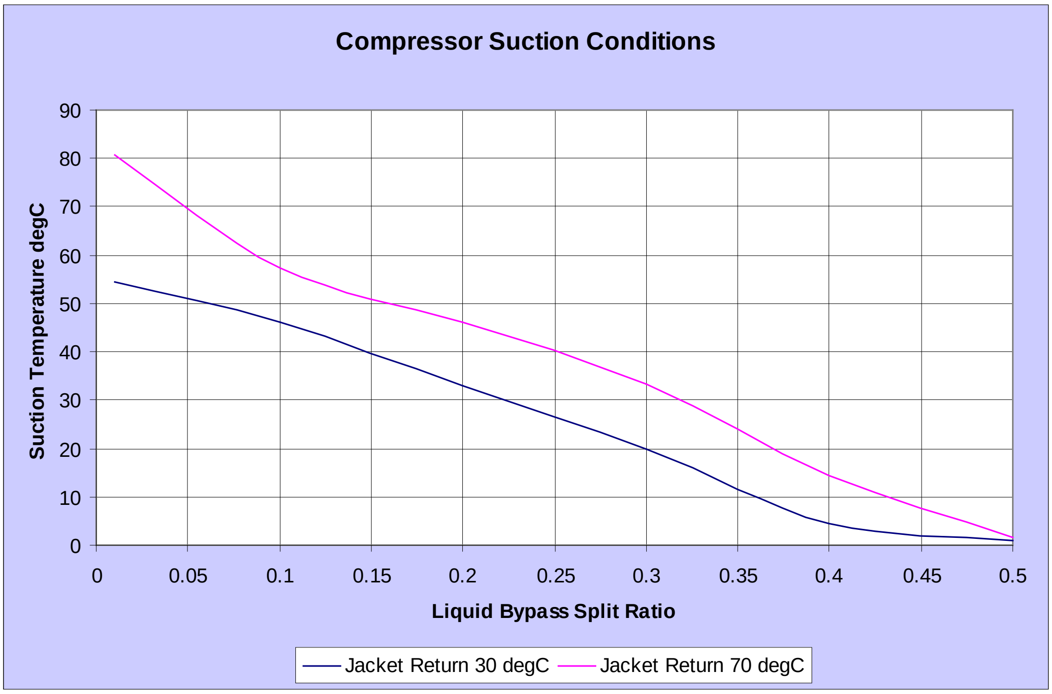


5.0 CHEMCAD MODEL AND SIMULATION RESULTS

The modified refrigeration cycle is modelled using CHEMCAD as shown in Appendix III. The simulation is run from an Excel GUI using the data mapping tool in CHEMCAD as shown in Appendix IV. This allows the user to readily study the interaction of the process parameters.

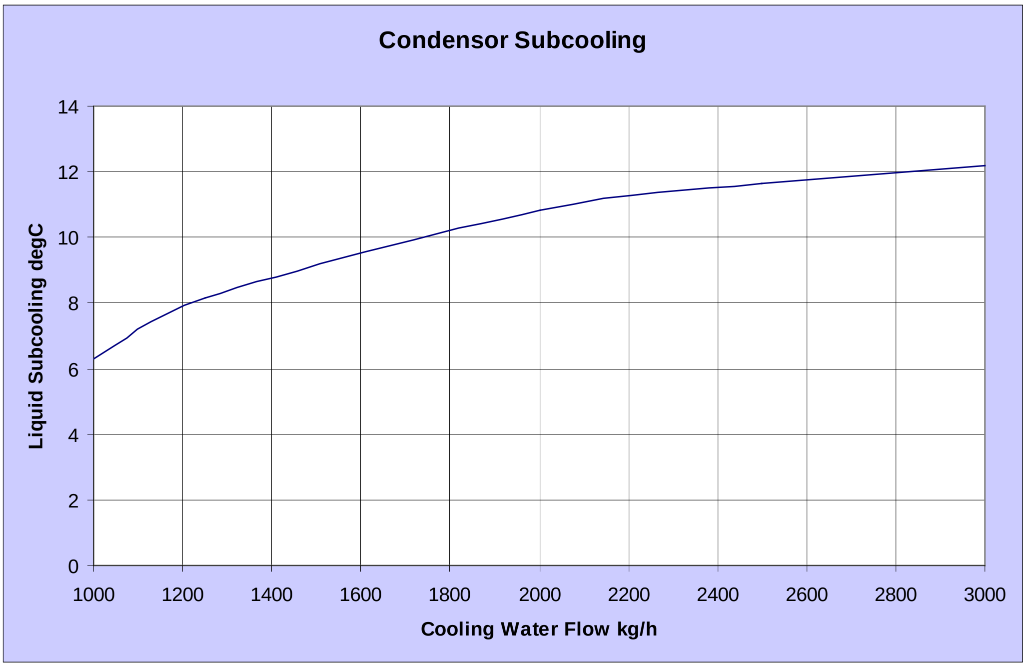
5.1 Compressor Suction Conditions

The compressor suction conditions are critical for satisfactory compressor operation. Excessive superheat conditions or the presence of liquid will result in compressor damage. The plots below shows the sensitivity of suction temperature to the jacket return temperature and the liquid bypass split.



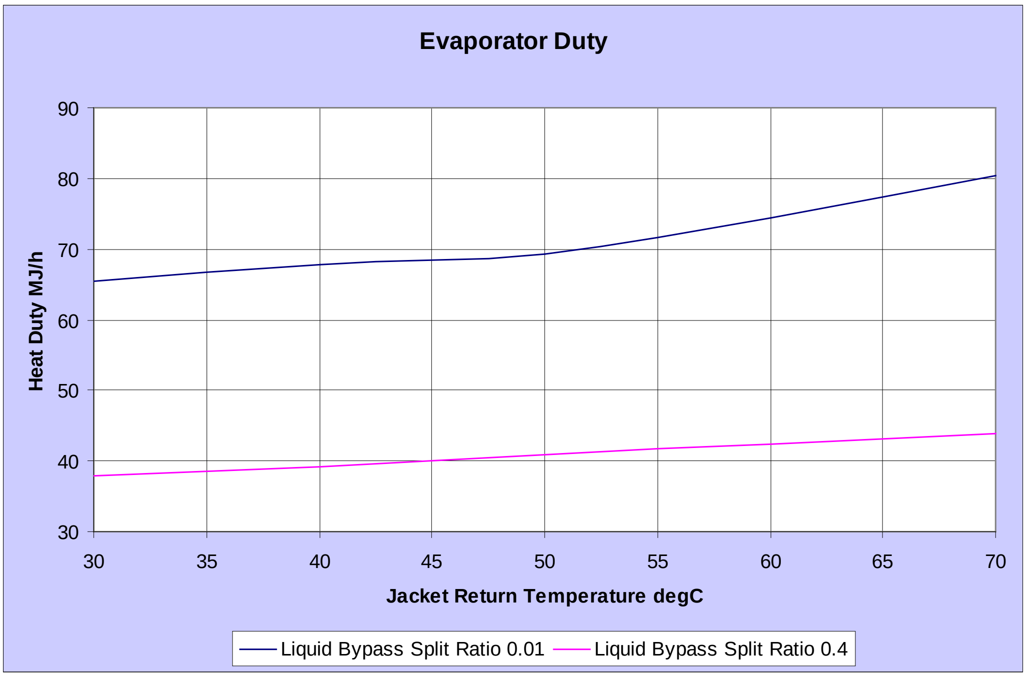
5.2 Condensor Subcooling

The condensor cooling water flow is adjusted to maintain a constant head pressure and results in condensate subcooling.



5.3 Evaporator Duty

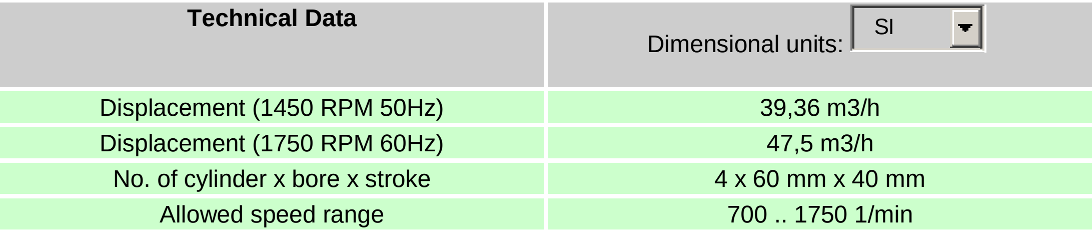
The evaporator duty is determined by the reactor jacket return temperature and the liquid bypass split ratio as shown in the curves below. It can be seen that the heat challenge to the refrigeration system is limited by the bypass split ratio.



APPENDIX I

EQUIPMENT PERFORMANCE DATA

Bitzer Compressor W4T2Y

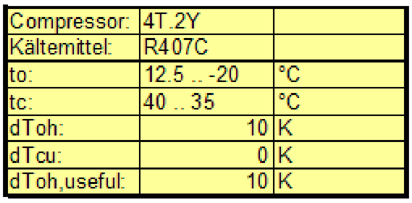


Technical Data	Dimensional units: SI
Displacement (1450 RPM 50Hz)	39,36 m3/h
Displacement (1750 RPM 60Hz)	47,5 m3/h
No. of cylinder x bore x stroke	4 x 60 mm x 40 mm
Allowed speed range	700 .. 1750 1/min

The compressor heads require a minimum cooling water flow of 150 l/h with a target temperature difference between 5 and 10 K and a maximum allowable outlet temperature of 50 degC. Alarm at 40 °C and shutdown at 50 °C.

The performance data for R407C refrigerant with the W4T2Y compressor installed is shown below.

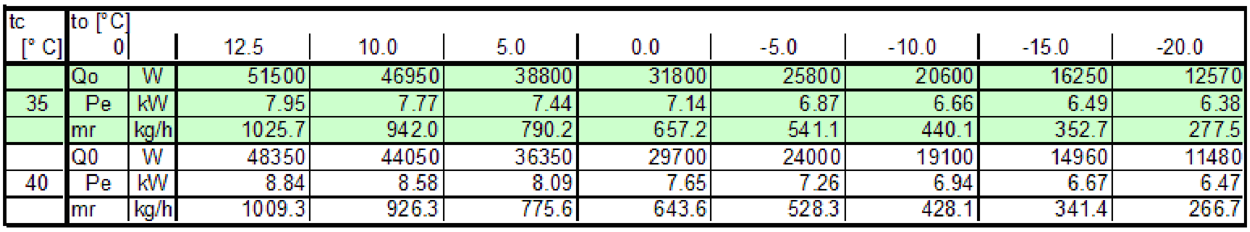
Performance Data



Compressor:	4T.2Y	
Kältemittel:	R407C	
to:	12.5 .. -20	°C
tc:	40 .. 35	°C
dToh:	10	K
dTcu:	0	K
dToh,useful:	10	K

τχ	[°Χ]	Χονδενσινγ ΣΔΤ
το	[°Χ]	Εϖαπορατινγ ΣΣΤ
Θο	[W]	Χοολινγ Χαπαχιτψ
Πω	[kW]	Σηαφτ Ποωερ
μ	[kg/h]	Μασσ Φλοω

ΣΔΤ Σατυρατεδ Δεωποιντ Τεμπερατυρ
ε



tc [° C]	to [°C]	0	12.5	10.0	5.0	0.0	-5.0	-10.0	-15.0	-20.0
	Qo	W	51500	46950	38800	31800	25800	20600	16250	12570
35	Pe	kW	7.95	7.77	7.44	7.14	6.87	6.66	6.49	6.38
	mr	kg/h	1025.7	942.0	790.2	657.2	541.1	440.1	352.7	277.5
	Q0	W	48350	44050	36350	29700	24000	19100	14960	11480
40	Pe	kW	8.84	8.58	8.09	7.65	7.26	6.94	6.67	6.47
	mr	kg/h	1009.3	926.3	775.6	643.6	528.3	428.1	341.4	266.7

Listed performance data are based on calculations and measured data.
Under worst conditions given values might differ from our common tolerances.

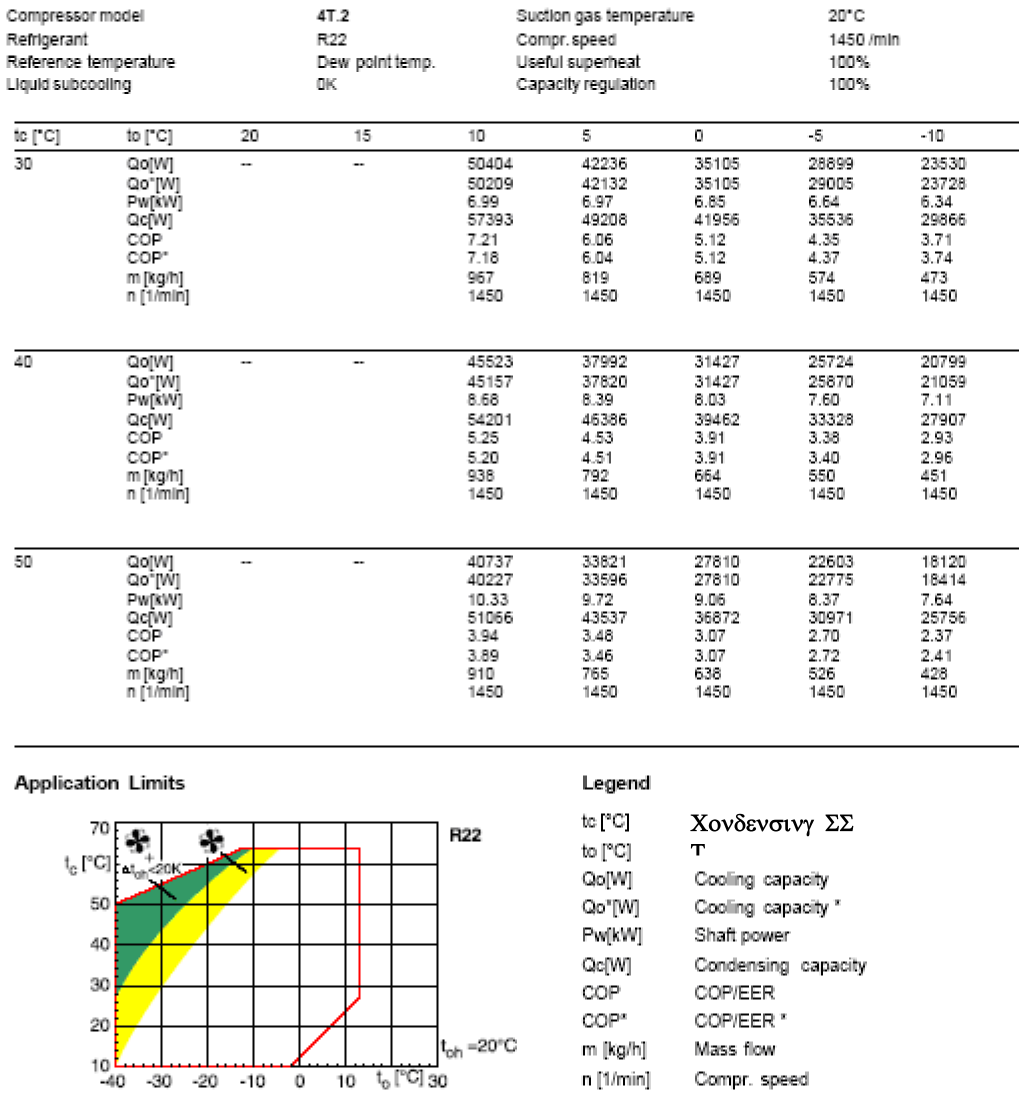
Bitzer software version 4.1 does not have data for the R407C refrigerant so R22 data was used to check for the maximum allowable compressor suction temperatures. The software indicates that at the higher condensing SDT no superheat is allowed.

APPENDIX I

EQUIPMENT PERFORMANCE DATA

Bitzer Compressor W4T2Y

Compressor Model: 4T.2 Refrigerant: R22 Reference Temperature: Dew point		
Suction gas temperature	**40°C**	**50°C**
Evaporating SST	12.5°C	12.5°C
Condensing SDT	40°C	50°C
Liquid subcooling	5K	5K
Cooling capacity	51.8 kW	47.5 kW
Cooling capacity *	49.2 kW	43.9 kW
Evaporator capacity	51.8 kW	47.5 kW
Shaft power	8.79 kW	10.62 kW
Condensing capacity	58.8 kW	56.3 kW
Mass flow	993 kg/h	937 kg/h
Operating mode	Coupling (1:1)	Coupling (1:1)
Compr. speed	1450 /min	1450 /min
Motor required	11.00 kW	15.00 kW



Compressor model	4T.2	Suction gas temperature	20°C
Refrigerant	R22	Compr. speed	1450 /min
Reference temperature	Dew point temp.	Useful superheat	100%
Liquid subcooling	0K	Capacity regulation	100%

tc [°C]	to [°C]	20	15	10	5	0	-5	-10
30	Qo[W]	--	--	50404	42236	35105	28699	23530
	Qo*[W]			50209	42132	35105	29005	23728
	Pw[kW]			6.99	6.97	6.85	6.64	6.34
	Qc[W]			57393	49208	41956	35536	29866
	COP			7.21	6.06	5.12	4.35	3.71
	COP*			7.18	6.04	5.12	4.37	3.74
	m [kg/h]			967	819	689	574	473
	n [1/min]			1450	1450	1450	1450	1450
40	Qo[W]	--	--	45523	37992	31427	25724	20799
	Qo*[W]			45157	37820	31427	25870	21059
	Pw[kW]			8.68	8.39	8.03	7.60	7.11
	Qc[W]			54201	46386	39462	33328	27907
	COP			5.25	4.53	3.91	3.38	2.93
	COP*			5.20	4.51	3.91	3.40	2.96
	m [kg/h]			938	792	664	550	451
	n [1/min]			1450	1450	1450	1450	1450
50	Qo[W]	--	--	40737	33821	27810	22603	18120
	Qo*[W]			40227	33596	27810	22775	18414
	Pw[kW]			10.33	9.72	9.06	8.37	7.64
	Qc[W]			51066	43537	36872	30971	25756
	COP			3.94	3.48	3.07	2.70	2.37
	COP*			3.89	3.46	3.07	2.72	2.41
	m [kg/h]			910	765	638	526	428
	n [1/min]			1450	1450	1450	1450	1450

Application Limits

Legend

tc [°C]	Χονδενσινγ ΣΣ
to [°C]	Τ
Qo[W]	Cooling capacity
Qo*[W]	Cooling capacity *
Pw[kW]	Shaft power
Qc[W]	Condensing capacity
COP	COP/EER
COP*	COP/EER *
m [kg/h]	Mass flow
n [1/min]	Compr. speed

APPENDIX I

EQUIPMENT PERFORMANCE DATA

Blitzer Condenser K373H

R407C refrigerant has a large temperature glide so that a reduction in performance can happen in special cases as a result of de-mixing of the low boiling component. As condensing takes place only at higher pressures, they can block a part of the heat transfer surface. Should this take place the condensing pressure will rise up until a stabilisation of the operation behaviour.

<table>
<tr><th colspan="4">Condenser Type K373H (4 Pass)
Refrigerant R407C Coolant Water Fouling 0.00004m²K/W</th></tr>
<tr><th>Condensing temperature</th><th>35°C</th><th>40°C</th><th>45°C</th></tr>
<tr><td>Water inlet temp.</td><td colspan="3">20°C</td></tr>
<tr><td>Water outlet temp.</td><td>30°C</td><td>30°C</td><td>35°C</td></tr>
<tr><td>Liquid subcooling</td><td colspan="3">5K</td></tr>
<tr><td>Condensing capacity</td><td>31.0 kW</td><td>47.8 kW</td><td>51.8 kW</td></tr>
<tr><td>Allowed max. capacity</td><td colspan="3">63.5 kW</td></tr>
<tr><td>Volume flow</td><td>2.68 m³/h</td><td>4.13 m³/h</td><td>2.99 m³/h</td></tr>
<tr><td>Vol.flow min.</td><td colspan="3">1.07 m³/h</td></tr>
<tr><td>Vol.flow max.</td><td colspan="3">5.36 m³/h</td></tr>
<tr><td>Flow rate</td><td>1.25 m/s</td><td>1.93 m/s</td><td>1.40 m/s</td></tr>
<tr><td>Pressure drop</td><td>0.23 bar(a)</td><td>0.51 bar(a)</td><td>0.28 bar(a)</td></tr>
<tr><td>LMTD (uncorrected)</td><td>9.09</td><td>14.4</td><td>16.4</td></tr>
<tr><td>UA</td><td>3410 W/m2</td><td>3319 W/m2</td><td>3158 W/m2</td></tr>
</table>

Cooling water flow to the condenser at maximum duty is 5.36 m3/h, dP 0.78 bar. Normal duty will probably be around 2500 kg/h, dP 0.2 bar.

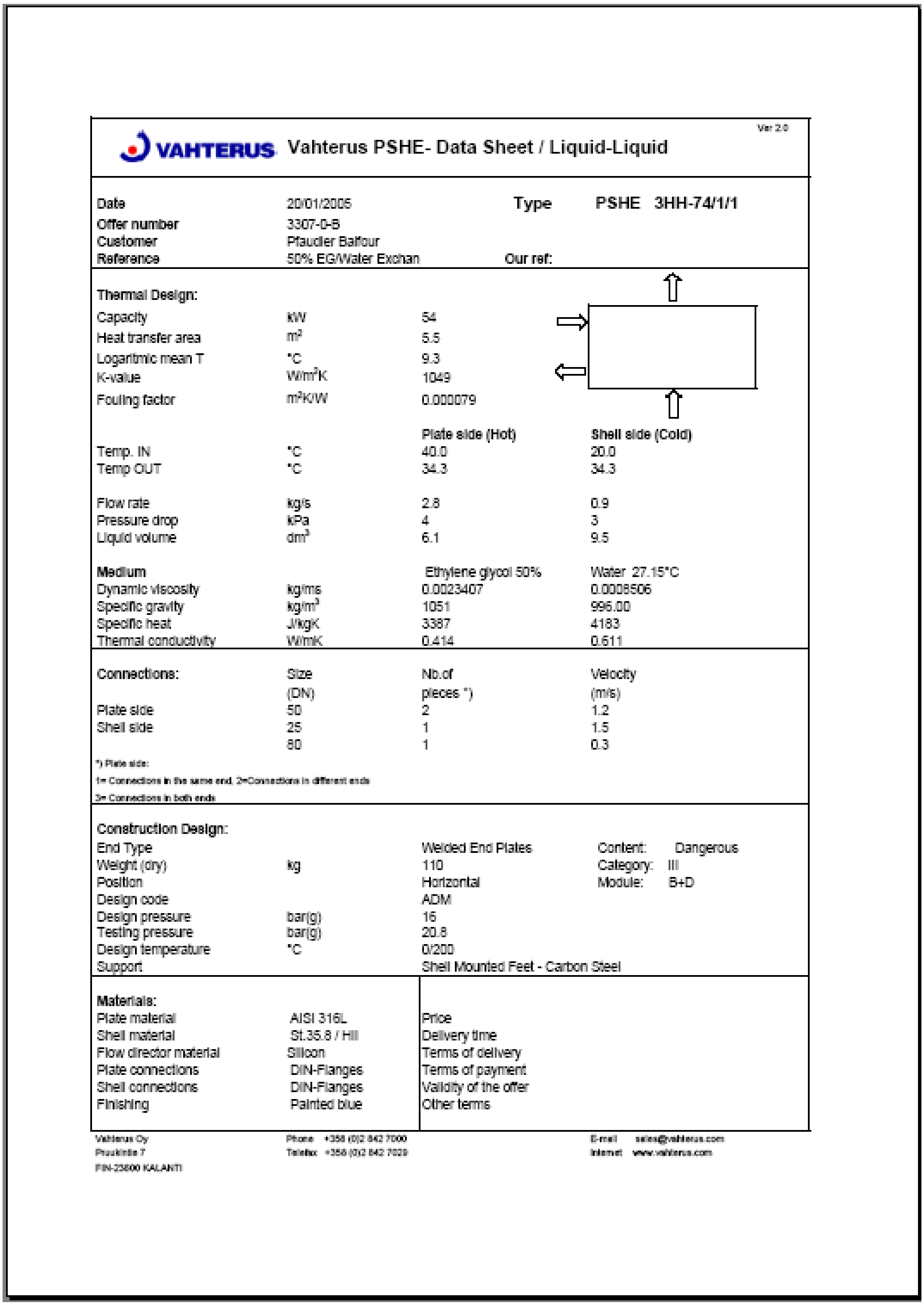
Cooling heat exchanger HE10A cooling water requirement will be a nominal 3000 kg/h.

The pressure drop in the 25mm branch connection from the 100mm main at 2500 kg/h will be an estimated 0.4 bar and at 5000 kg/h will be an estimated 1.35 bar.

APPENDIX II

EQUIPMENT SPECIFICATION

Vahterus Shell and Plate Heat Exchanger



Ver 2.0

VAHTERUS Vahterus PSHE- Data Sheet / Liquid-Liquid

Date	20/01/2005	**Type**	**PSHE 3HH-74/1/1**
Offer number	3307-0-B		
Customer	Pfaudler Balfour		
Reference	50% EG/Water Exchan	**Our ref:**	

Thermal Design:

Capacity	kW	54
Heat transfer area	m^2	5.5
Logaritmic mean T	°C	9.3
K-value	W/m^2K	1049
Fouling factor	m^2K/W	0.000079

		Plate side (Hot)	**Shell side (Cold)**
Temp. IN	°C	40.0	20.0
Temp OUT	°C	34.3	34.3
Flow rate	kg/s	2.8	0.9
Pressure drop	kPa	4	3
Liquid volume	dm^3	6.1	9.5
Medium		Ethylene glycol 50%	Water 27.15°C
Dynamic viscosity	kg/ms	0.0023407	0.0008506
Specific gravity	kg/m^3	1051	996.00
Specific heat	J/kgK	3387	4183
Thermal conductivity	W/mK	0.414	0.611

Connections:	Size (DN)	Nb.of pieces *)	Velocity (m/s)
Plate side	50	2	1.2
Shell side	25	1	1.5
	80	1	0.3

*) Plate side:
1= Connections in the same end, 2=Connections in different ends
3= Connections in both ends

Construction Design:

End Type		Welded End Plates	Content:	Dangerous
Weight (dry)	kg	110	Category:	III
Position		Horizontal	Module:	B+D
Design code		ADM		
Design pressure	bar(g)	16		
Testing pressure	bar(g)	20.8		
Design temperature	°C	0/200		
Support		Shell Mounted Feet - Carbon Steel		

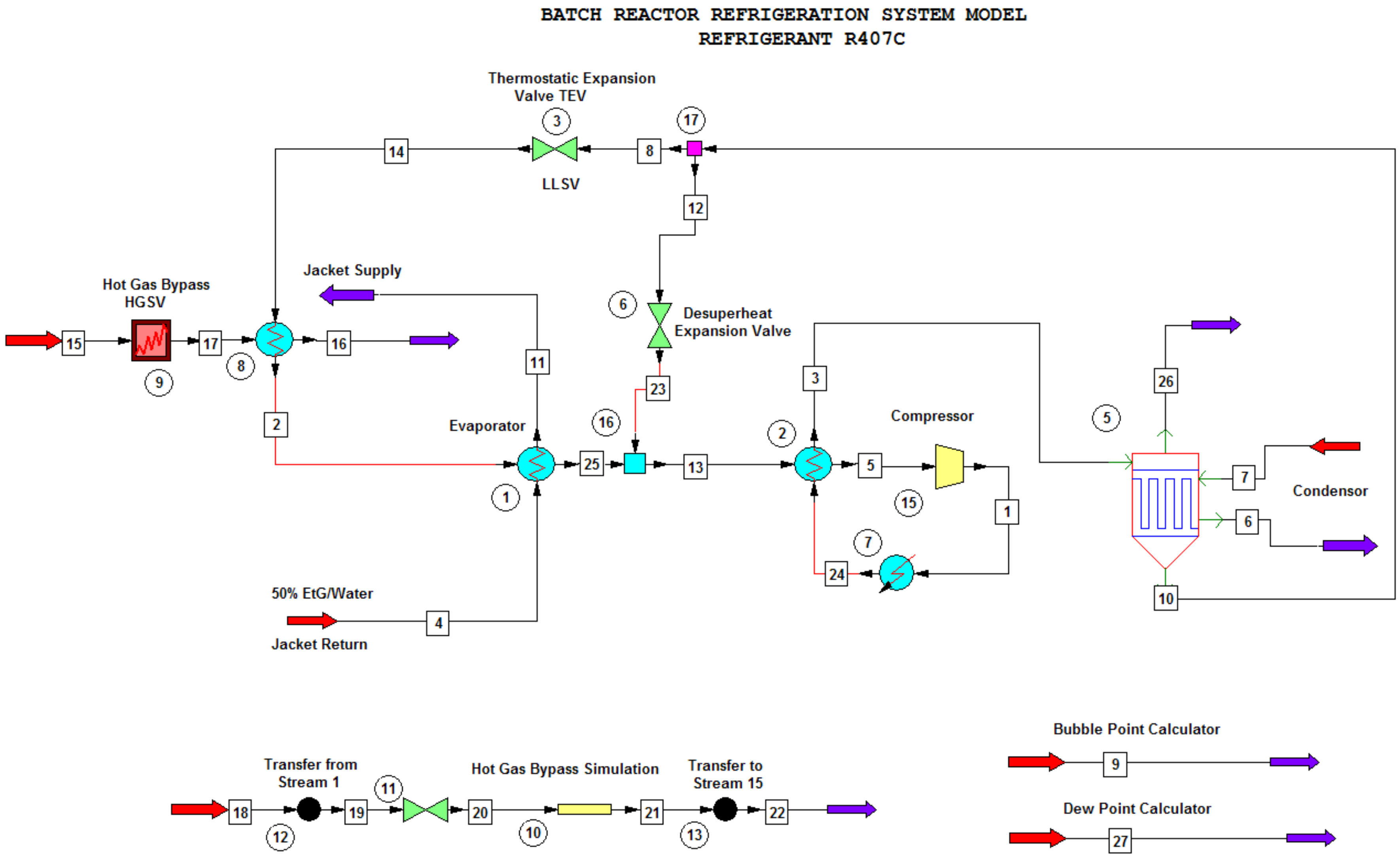
Materials:		
Plate material	AISI 316L	Price
Shell material	St.35.8 / HII	Delivery time
Flow director material	Silicon	Terms of delivery
Plate connections	DIN-Flanges	Terms of payment
Shell connections	DIN-Flanges	Validity of the offer
Finishing	Painted blue	Other terms

Vahterus Oy
Pruukintie 7
FIN-23600 KALANTI

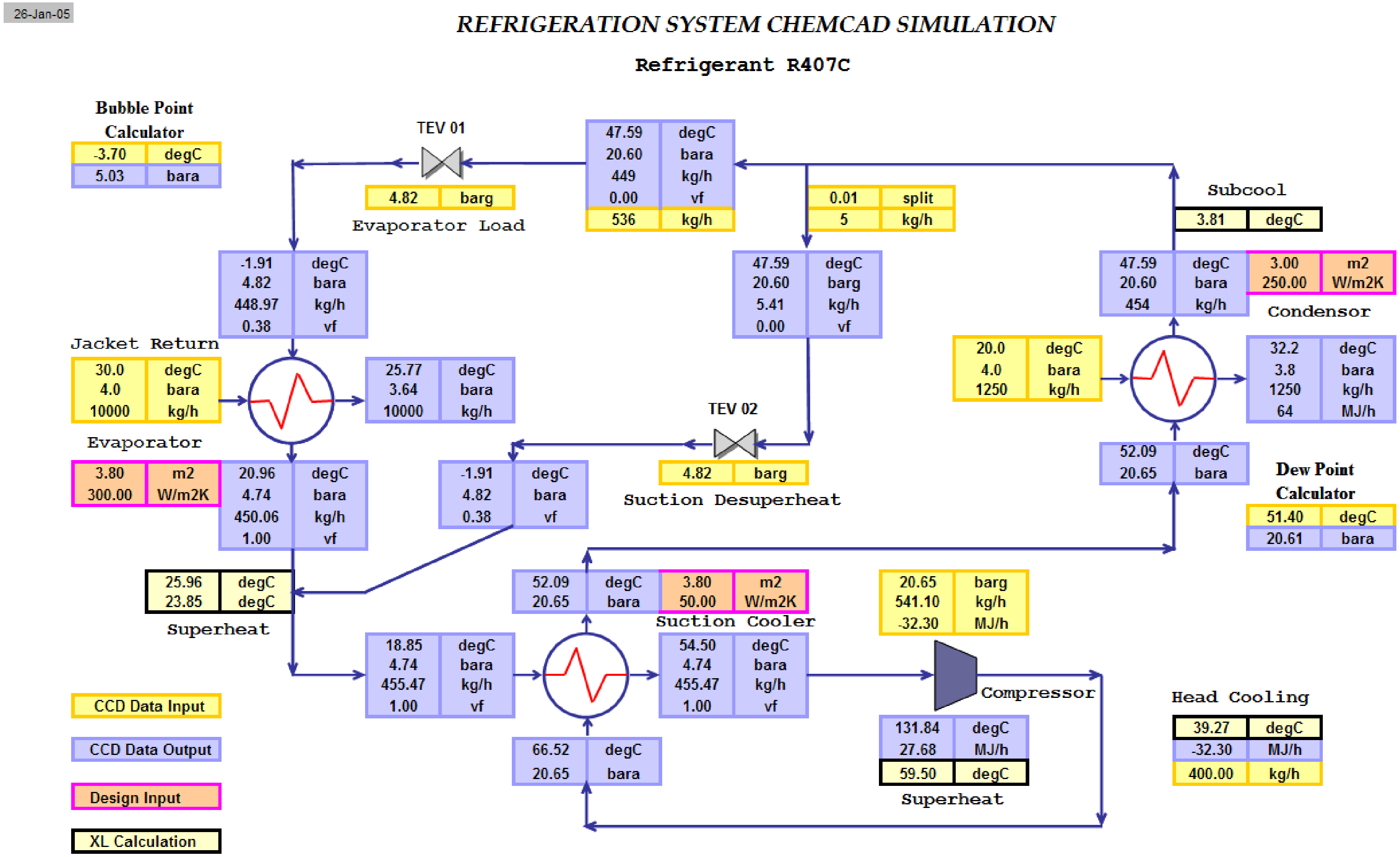
Phone +358 (0)2 842 7000
Telefax +358 (0)2 842 7029

E-mail sales@vahterus.com
Internet www.vahterus.com

APPENDIX III – CHEMCAD MODEL



APPENDIX IV EXCEL CHEMCAD MODEL GUI



26-Jan-05

REFRIGERATION SYSTEM CHEMCAD SIMULATION

Refrigerant R407C