ClimaCheck onsite

COOL CHECK
measure • manage • save

Performance Analyses of Air-cooled chiller

Carrier 30RQ (0402-0193-PE)

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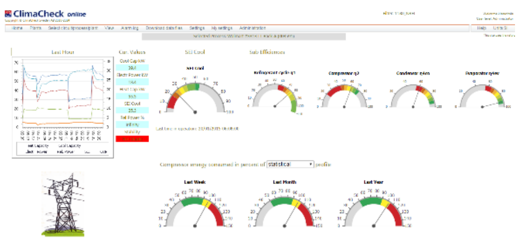
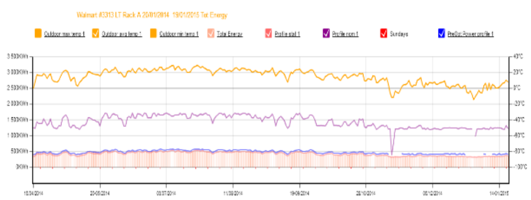
ClimaCheck Performance *onsite and online*





Analyses and visualisation of the process is done with ClimaCheck

Disclaimer

ClimaCheck Sweden has not had access to design data/specification for the chiller so analyses are done strictly based on an evaluation of the performance versus "good practice" in general and compressor software not versus specification for this particular site.

This review is done by ClimaCheck staff in Sweden without compensation and is only a demonstration to visualise capabilities of ClimaCheck online analysing system to analyse and optimise refrigeration and air conditioning systems.

Contents

1 Executive Summary

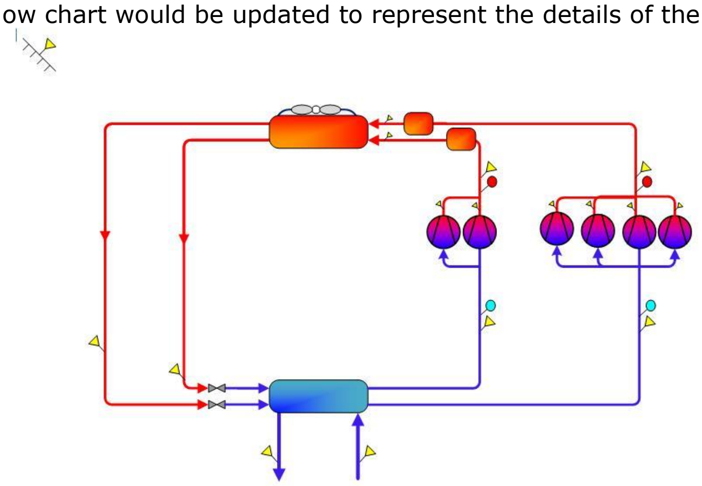
Compressors on the measured circuit has very much lower efficiency than showing from compressor software and condenser is showing poor performance. The systems should be checked so indication of low compressor efficiency is not caused by hot gas leaking backwards from some device/connection. If no external explanation can be found and rectified it is recommended that compressors are replaced before they fail as cost of failure is much higher than planned replacement.

The condensing temperature of 46°C at an outdoor temperature of 26°C indicate a poor condenser performance that will result in critically high condensing at high ambient conditions if dT remains. The system is likely to trip on high pressure at high ambient condition. The likely cause is high refrigerant charge as subcool is very high. A second possibility would be that control set-point of condensers fan is high but it would be unlikely to be set at so high pressure. The increase of energy recovered in desuperheater from operating at normal temperature would not justify the increase of energy and wear such an increase result in.

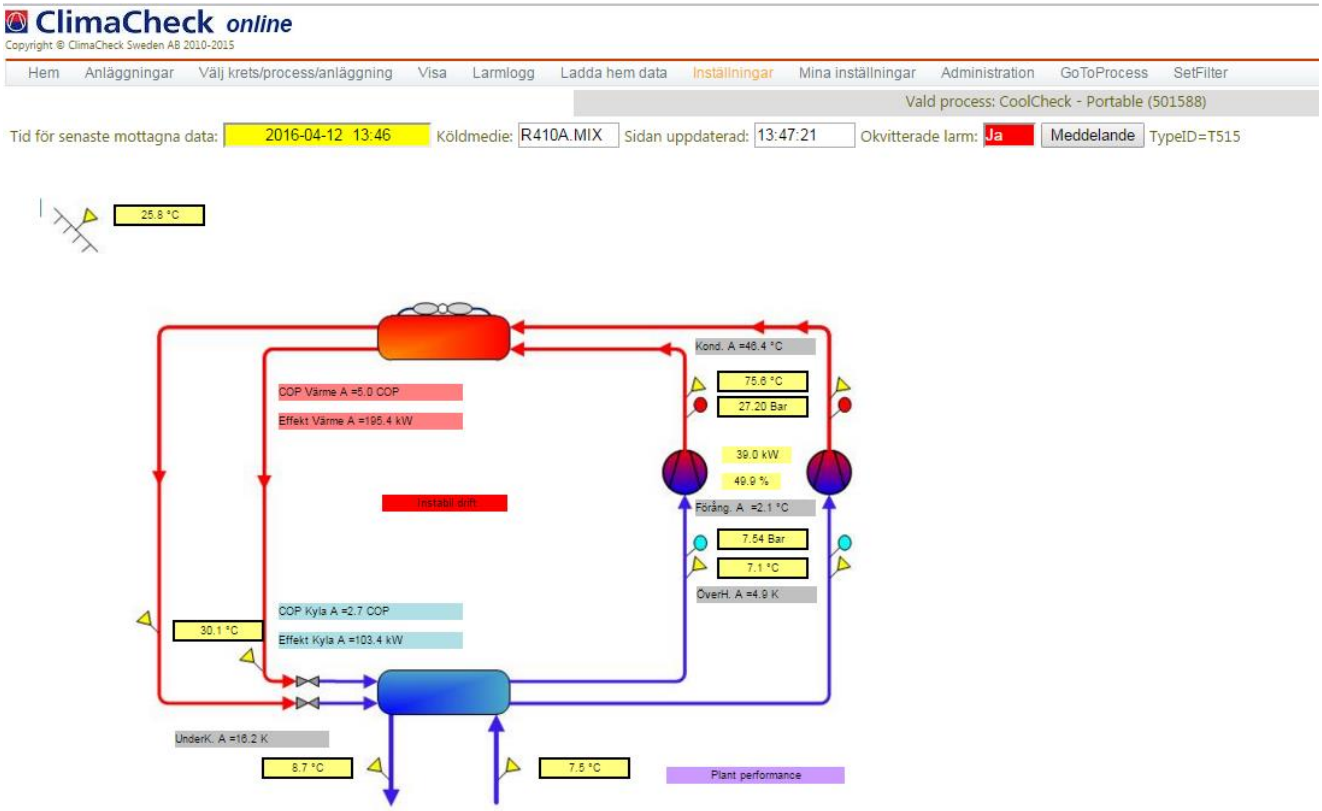
Performance		Measured	Desired	Comments recommendations	Estimated Annual impact
Total Efficiency SEI		21%	>40-45%	SEI is very low due to overcharged condenser and poor compressor efficiency.	**> 50%** higher energy consumption than expected
Cycle		85%	75-95%	Normally affected by design and refrigerant less of operation	
Compressor		50%	> 65%	Compressor performance is signifcantly lower than Danfoss data resulting. Before fianl conclusion validate no bypass from high to low pressure side around compressor (see comment under compressor section).	33% increase of energy consumption
Evaporator		83%	80-95%	System is operating at signifcantly lower cooling load due to high condensing and poor compressor performance so data is not fully relevant. Performance should be checked	
Condenser		65%	80-95%	20 K difference between incoming air and condensing is aproc double of what is expected from a styate of the art efficient chiller. Air flow and controls as well as liquid line driers should be checked for problems causing decreased condenser performance.	20% increase of energy consumption
Charge Subcool		Subcool 17 K	3-6 K	At full capacity system show clear signs of being overcharged with refrigerant. Refrigerant should be reduced in accordance with manufacturer charge recommendation.	
Superheat		5.5 K	4-7 K		
	Evaluation of factors affecting performance and relaibility				
Controls capacity		**Controls are acceptable at current day time loads measured but follow up should be done at low load/night before measuring is stopped.**			

2 System

The system is an air cooled Chiller in principle designed as shown below. Due to that the measurement is a short term demonstration the visualisation on ClimaCheck online is visualised as a simplified circuit. The calculation of desuperheater capacity is still done on server and all relevant parameters are available. For a normal project the flow chart would be updated to represent the details of the analysed plant.



The simplified flow chart show compressors as one and does not indicate the desuperheaters in the flow chart but sensors for analyses are applied and calculations done to fully evaluate chiller.



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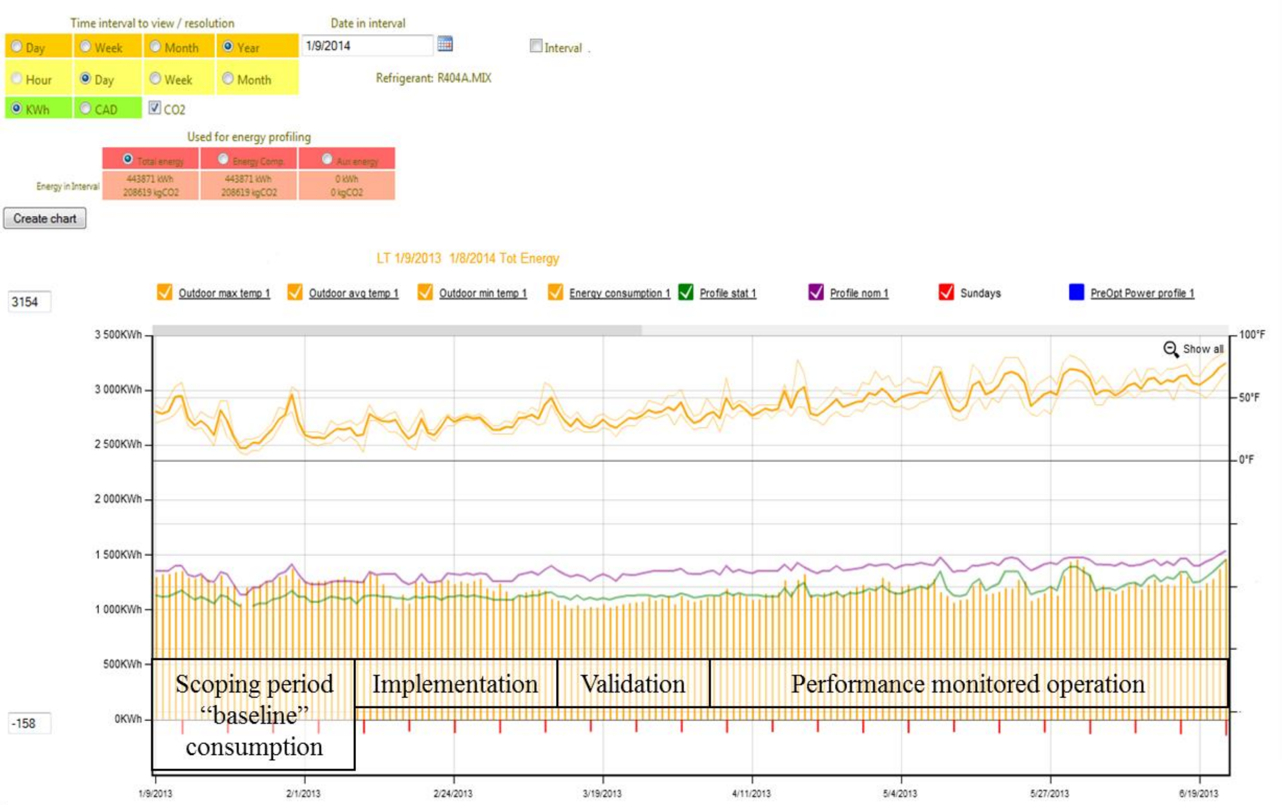
3 Energy

3.1 Power/Energy signature

Due to short measuring period and measuring of only one circuit of two the energy signature will not be applicable. To generate an energy profile the total power to a refrigeration load and the ambient temperature must be monitored over a range of ambient conditions.

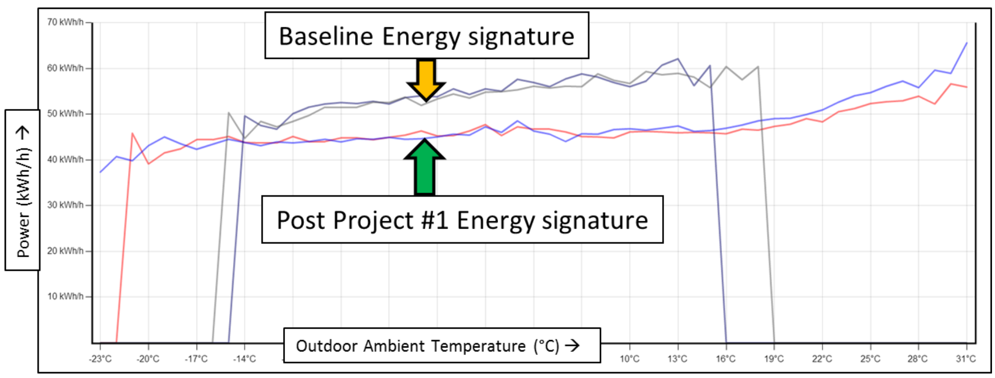
The energy signature is a powerful tool to optimise plants and monitor that they stay optimised.

Example of energy signature and energy statistics from typical plant is show below. This is not from this plant



Re-Commissioning - result of structured optimisation

The energy signature allows to compensate for differences in ambient conditions from baseline to post optimisation period.



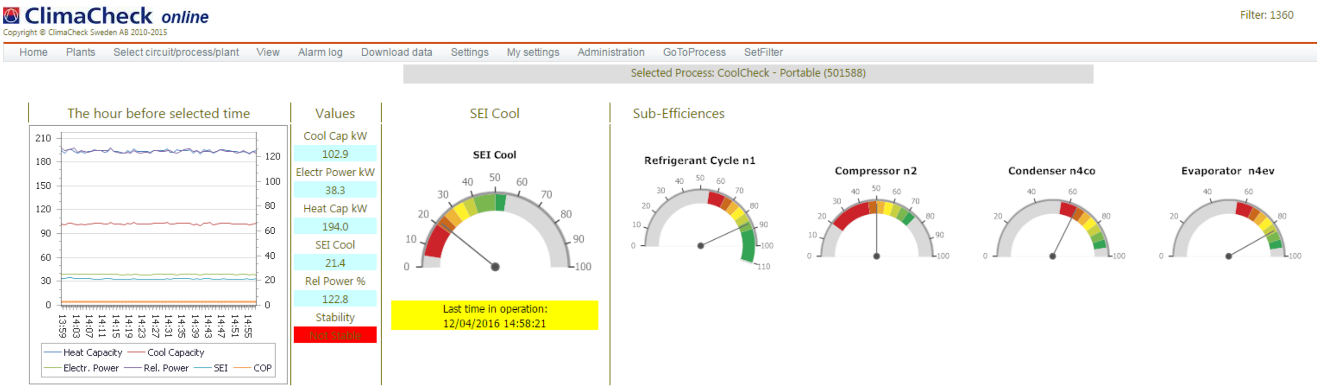
4 Performance

4.1 Full load performance – two compressors in operation

Performance of system is low for two reasons:

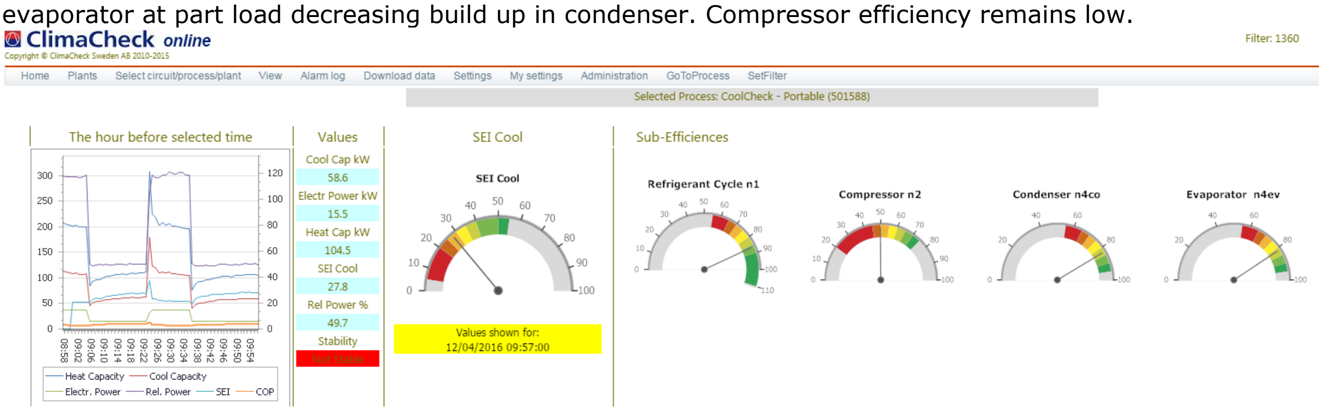
A. System is overcharged with refrigerant causing liquid build up in condenser. This is blocking heat transfer surface resulting in high condensing pressure and poor COP. This is assuming that the system is not intentionally forced to work at this in-efficient operation.

B. Compressor efficiency is low. It should be excluded that this can be leakages from high to low side outside compressor. If not external leakage is identified the compressors are severely damage. Regardless if cause is internal or external problems it has to be rectified to avoid excessive energy consumption and failure within short.



4.2 Part load performance with one compressor in operation

With one compressor only in operation influence of over charge is less as there is more refrigerant in evaporator at part load decreasing build up in condenser. Compressor efficiency remains low.



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4.3 Performance table

Performance is significantly lower than expected due to poor performance in condenser and compressor.

ClimaCheck *online*

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Filter: 1360

Welcome klasadmin
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Home | Plants | Select circuit/process/plant | View | Alarm log | Download data | Settings | My settings | Administration | GoToProcess | SetFilter | Help | Units SI

Selected Process: CoolCheck - Portable (501588)

This site uses the refp

Refrigerant: R410A.MIX   Unconfirmed alarms: Yes   Go To:

Date to show | No of values per page | Max-Min-Avg calculated on the last | Time Search | Search | Export functions

System settings active 12/04/2016 | 40 | 60 min | yyyy-mm-dd hh:mm | Page to XL | All to XL | Page to PDF

older data> oldest data>>

Time	SecC Evap in (°C)	SecC Evap out (°C)	Ref Evap (°C)	Ref Comp in (°C)	Super heat (K)	SecW Cond in (°C)	Ref Cond (°C)	Ref Exp. Valve in (°C)	Sub cool total (K)	Ref Comp out (°C)	Power input Comp. (kW)	COP Cool Ref	Cap. Cool (kW)	Cap. Heat (kW)	Amp Comp 1 (A)	Amp Comp 2 (A)	Amp Comp 3 (A)	Outdoor temp (°C)	SEI 1 cool (%)	Eff 1 Cycle (%)	Eff 2 Comp. Isen. (%)	Eff 4 Cond. (%)	Eff 4 Evap. (%)	Cap desup heat (kW)	Desup. water out (°C)	Energy Circ A (kW)	Power factor ()	Dig In
Max last 60 min	7.4	8.6	2.1	7.3	5.8	26.9	47.0	30.8	17.1	76.8	39.8	2.70	104.4	197.4	69.9	66.9	69.4	26.9	22.4	86.33	50.6	66.60	85.18	15.3	76.70	-23,272	0.84	00000000
Min last 60 min	7.0	8.3	1.3	6.8	4.8	24.7	45.1	28.4	16.0	75.3	38.2	2.58	100.3	190.1	67.8	64.7	67.2	24.7	20.8	85.05	48.6	64.19	83.53	14.3	76.00	-23,310	0.82	00000000
Avg last 60 min	7.2	8.4	1.7	7.1	5.3	25.5	45.9	29.4	16.5	75.9	38.8	2.64	102.4	193.7	68.8	65.4	68.2	25.6	21.3	85.80	49.5	65.19	84.32	14.8	76.20	-23,291	0.83	00000000
2016-04-12 14:55:21	7.1	8.3	1.4	7.1	5.6	25.1	45.3	28.7	16.5	75.6	38.2	2.65	101.3	191.4	68.2	64.8	67.6	25.4	21.2	86.07	49.2	65.42	83.77	14.3	76.10	-23,272	0.83	00000000
2016-04-12 14:54:21	7.1	8.3	1.5	7.1	5.5	25.4	45.7	29.0	16.6	75.9	38.6	2.64	101.9	192.7	68.4	65.1	68.2	25.3	21.3	85.96	49.4	65.43	84.12	14.6	76.10	-23,273	0.83	00000000
2016-04-12 14:53:21	7.1	8.3	1.5	7.0	5.5	25.3	45.7	29.1	16.5	76.0	38.9	2.63	102.2	193.4	69.0	65.6	67.8	25.0	21.1	85.88	49.2	65.18	84.05	14.7	76.10	-23,273	0.83	00000000
2016-04-12 14:52:21	7.1	8.3	1.5	7.1	5.6	25.0	45.5	29.2	16.3	75.9	38.6	2.63	101.5	192.1	68.7	65.0	67.8	24.7	20.9	85.75	49.2	64.72	84.00	14.5	76.00	-23,274	0.83	00000000
2016-04-12 14:51:21	7.1	8.3	1.4	7.2	5.8	24.7	45.1	28.4	16.7	75.6	38.4	2.66	102.2	192.9	68.0	65.0	67.7	25.0	20.9	86.25	49.1	64.75	83.64	14.4	76.10	-23,275	0.83	00000000
2016-04-12 14:50:21	7.1	8.3	1.4	7.1	5.7	25.0	45.4	28.9	16.4	75.8	38.7	2.64	102.2	193.2	68.7	64.9	67.9	25.0	21.0	85.93	49.2	65.00	83.78	14.6	76.10	-23,275	0.83	00000000
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2016-04-12 14:47:21	7.1	8.3	1.5	7.1	5.6	25.2	45.8	29.0	16.7	75.8	38.9	2.66	103.4	195.3	68.3	65.1	68.3	25.2	21.3	85.96	49.9	64.86	84.05	14.7	76.20	-23,277	0.83	00000000
2016-04-12 14:46:21	7.1	8.3	1.6	7.0	5.4	25.2	45.9	29.2	16.6	75.8	39.1	2.65	103.6	195.7	68.5	65.2	68.6	25.0	21.2	85.87	49.8	64.61	84.25	14.6	76.20	-23,278	0.83	00000000
2016-04-12 14:45:21	7.1	8.3	1.6	7.1	5.5	25.0	45.7	29.2	16.4	75.9	38.8	2.63	102.2	193.3	68.5	65.5	68.3	25.3	20.9	85.81	49.2	64.50	84.20	14.5	76.20	-23,278	0.83	00000000
2016-04-12 14:44:21	7.1	8.3	1.6	7.1	5.5	25.3	45.7	29.4	16.2	76.1	38.6	2.61	100.9	191.1	68.5	65.2	68.3	25.2	21.0	85.68	49.0	65.08	84.29	14.6	76.10	-23,279	0.83	00000000
2016-04-12 14:43:21	7.0	8.3	1.5	7.1	5.6	25.2	45.9	28.7	17.1	75.7	38.7	2.68	103.8	195.7	68.3	64.7	68.0	25.3	21.5	86.22	50.3	64.71	84.18	14.8	76.10	-23,280	0.83	00000000
2016-04-12 14:42:21	7.1	8.3	1.5	7.1	5.6	25.3	45.7	29.0	16.7	75.8	38.7	2.65	102.8	194.1	68.5	64.9	68.2	25.4	21.4	85.95	49.8	65.17	84.03	14.7	76.20	-23,280	0.83	00000000
2016-04-12 14:41:21	7.0	8.3	1.5	7.0	5.5	25.4	46.0	29.1	16.8	75.7	38.7	2.67	103.3	195.0	68.4	65.3	67.8	25.5	21.6	85.93	50.3	65.02	84.22	14.7	76.20	-23,281	0.83	00000000
2016-04-12 14:40:21	7.1	8.3	1.7	6.8	5.1	25.5	45.7	29.6	16.1	75.8	38.5	2.60	100.3	190.1	68.5	65.3	68.0	25.7	21.2	85.57	48.8	65.47	84.42	14.6	76.20	-23,282	0.83	00000000
2016-04-12 14:39:21	7.1	8.4	1.8	6.9	5.0	25.7	46.4	29.8	16.5	76.0	39.0	2.63	102.4	193.9	68.8	65.7	68.7	25.6	21.5	85.63	49.7	64.78	84.90	14.9	76.20	-23,282	0.83	00000000
2016-04-12 14:38:21	7.1	8.3	1.8	6.8	5.0	25.6	45.9	29.8	16.0	75.9	38.8	2.60	100.7	191.0	68.5	65.6	68.2	25.7	21.2	85.49	48.7	65.39	84.72	14.8	76.20	-23,283	0.83	00000000
2016-04-12 14:37:21	7.1	8.4	1.8	6.9	5.1	25.7	46.2	29.7	16.5	75.9	39.3	2.63	103.3	195.5	69.0	66.0	69.3	26.0	21.5	85.65	49.6	65.06	84.75	14.8	76.20	-23,284	0.84	00000000
2016-04-12 14:36:21	7.1	8.3	1.9	6.8	4.9	26.0	46.6	29.9	16.7	76.2	39.3	2.61	102.7	194.5	69.2	65.7	68.5	25.8	21.7	85.62	49.7	65.09	85.18	15.1	76.10	-23,284	0.83	00000000
2016-04-12 14:35:21	7.1	8.3	1.7	6.9	5.2	25.8	46.2	29.6	16.6	76.0	39.1	2.63	102.8	194.6	69.0	65.7	68.5	25.4	21.6	85.69	49.7	65.35	84.66	15.0	76.00	-23,285	0.83	00000000
2016-04-12 14:34:21	7.1	8.3	1.6	7.0	5.4	25.4	45.7	29.0	16.6	75.6	38.7	2.65	102.8	194.1	68.6	65.1	68.1	25.3	21.5	86.01	49.5	65.31	84.30	14.8	76.00	-23,286	0.83	00000000
2016-04-12 14:33:21	7.1	8.3	1.5	7.1	5.6	25.3	45.6	28.5	17.0	75.3	38.4	2.70	103.6	195.1	67.9	64.7	67.7	25.5	21.7	86.33	50.1	65.37	84.04	14.6	76.10	-23,286	0.83	00000000

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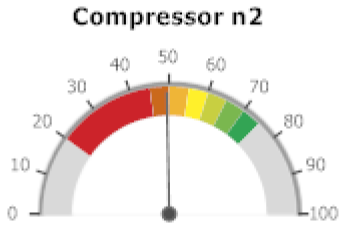
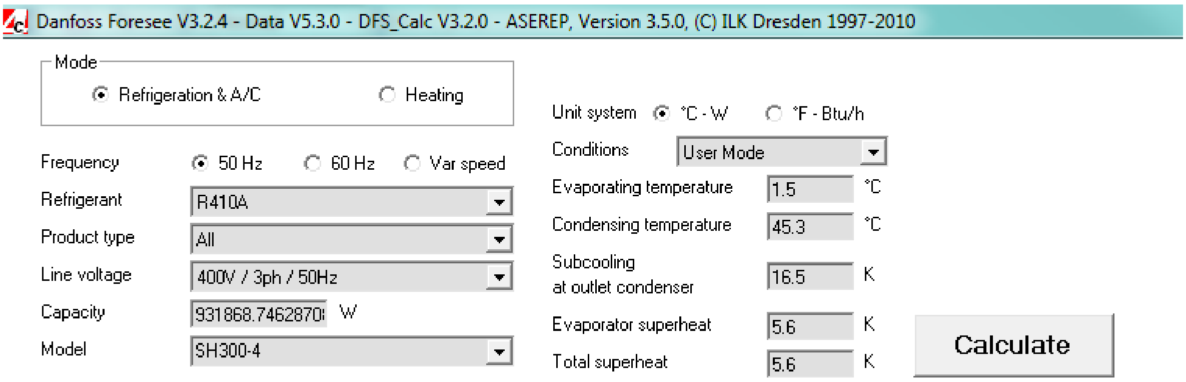
4.4 Compressor Performance



Compressor performance with an efficiency of 50% is significantly lower than expected 65-70% for a good compressor. The compressor is a hermetic scroll Danfoss SH300.

With same condition as measured entered in Danfoss software is showing much higher performance than measured 14:55:21 at stable conditions. Note that measured performance is total of two compressors.

Time	SecC Evap in (°C)	SecC Evap out (°C)	Ref Evap (°C)	Ref Comp in (°C)	Super heat (K)	SecW Cond in (°C)	Ref Cond (°C)	Ref Exp. Valve in (°C)	Sub cool total (K)	Ref Comp out (°C)	Power input Comp. (kW)	COP Cool Ref	Cap. Cool (kW)	Cap. Heat (kW)
Max last 60 min	7.4	8.6	2.1	7.3	5.8	26.9	47.0	30.8	17.1	76.8	39.8	2.70	104.4	197.4
Min last 60 min	7.0	8.3	1.3	6.8	4.8	24.7	45.1	28.4	16.0	75.3	38.2	2.58	100.3	190.1
Avg last 60 min	7.2	8.4	1.7	7.1	5.3	25.5	45.9	29.4	16.5	75.9	38.8	2.64	102.4	193.7
2016-04-12 14:55:21	7.1	8.3	1.4	7.1	5.6	25.1	45.3	28.7	16.5	75.6	38.2	2.65	101.3	191.4
2016-04-12 14:54:21	7.1	8.3	1.5	7.1	5.5	25.4	45.7	29.0	16.6	75.9	38.6	2.64	101.9	192.7
2016-04-12 14:53:21	7.1	8.3	1.5	7.0	5.5	25.3	45.7	29.1	16.5	76.0	38.9	2.63	102.2	193.4


Danfoss Foresee V3.2.4 - Data V5.3.0 - DFS_Calc V3.2.0 - ASEREP, Version 3.5.0, (C) ILK Dresden 1997-2010

Mode: (•) Refrigeration & A/C ( ) Heating

Frequency: (•) 50 Hz ( ) 60 Hz ( ) Var speed

Refrigerant: R410A

Product type: All

Line voltage: 400V / 3ph / 50Hz

Capacity: 931868.7462870 W

Model: SH300-4

Unit system: (•) °C - W ( ) °F - Btu/h

Conditions: User Mode

Evaporating temperature: 1.5 °C

Condensing temperature: 45.3 °C

Subcooling at outlet condenser: 16.5 K

Evaporator superheat: 5.6 K

Total superheat: 5.6 K

Calculate

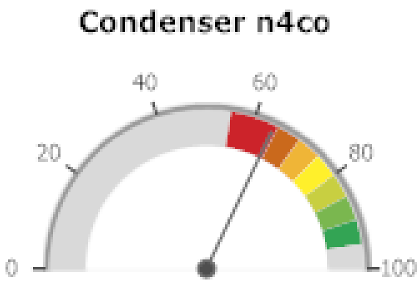
Technology	Model	Freq. (Hz)	Speed (rpm)	Refr.	Voltage	Cooling capacity (W)	Power input (W)	COP	Current (A)	Inlet compressor mass flow (kg/h)
Scroll	SH300-4	50	2900	R410A	400V/3ph/50Hz	75 936	19 209	3.95	33.36	1 504

COP at full performance should be 3.95 whereas of the measured system the performance is only 2.65.
The decrease of the compressor performance represent an increase of energy consumption of 33%.

Before final conclusion on compressor status is made it should be validated that hot gas cannot leak through from discharge side to suction gas side between suction line temperature sensor and compressors as this would give save symptoms as a defect compressor.

If the suction line sensor is placed before 4-way valve and this valve is leaking the symptom would be the same as internal leakage and then the problem is related to the valve.

4.5 Condenser performance



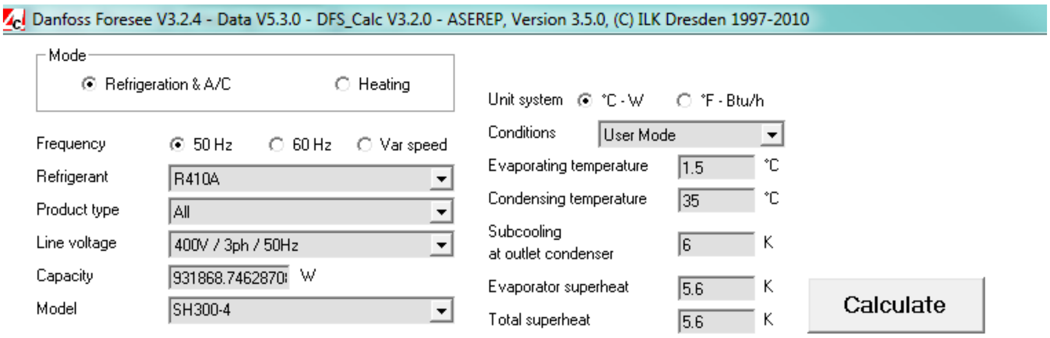
No design information for this particular chiller was available when writing this report so evaluation is based on best practice.

At full load the condenser performance is poor resulting in 20 K difference between condensing and ambient air where for a high efficiency condenser 10 K is achievable. At the same time the subcool is high 16 K instead of normal 4-6. All indicating most likely problem being an over charge of refrigerant but alternative problems can give similar synmptoms.

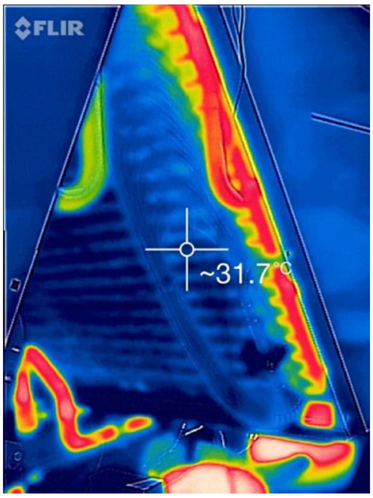
The air flow and potential fouling of condenser should be checked as well as problems in liquid line and filter causing problems. Restrictions are less likely as the expansion valve is not negatively affected.

4.6 Performance with expected condensing temperature at 25°C ambient.

With an expected subcool of 6 K and condensing 35°C (10 K above ambient temperature) the COP according to Danfoss software should be 4.89 which wold be achievable with a high efficiency condenser.



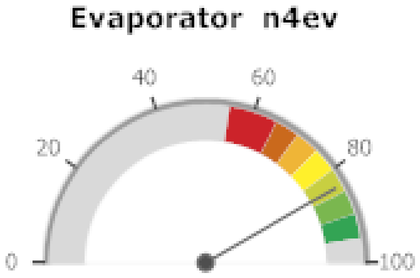
Technology	Model	Freq. (Hz)	Speed (rpm)	Refr.	Voltage	Cooling capacity (W)	Power input (W)	COP	Current (A)	Inlet compressor mass flow (kg/h)
Scroll	SH300-4	50	2900	R410A	400V/3ph/50Hz	77 139	15 774	4.89	28.98	1 531



Manufacturer specified subcool at different operating conditions should be documented in connection with Chiller for future service/monitoring.

The condensing temperature of 46°C at an outdoor temperature of 26°C indicate a poor condenser performance that will result in critically high condensing at high ambient conditions. The system is likely to trip on high pressure at high ambient condition. The likely cause is high refrigerant charge as subcool is very high. A second possibility would by fan setting pushing up the condensing pressure but it would be unlikely to be set at so high condensing.

4.7 ,Evaporator performance

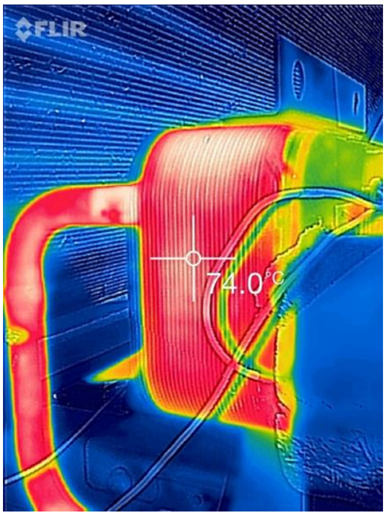


Evaporator is operating with acceptable performance but is not fully loaded due to problems in condenser and compressor.

With current superheat and high water flow that cause a low dT on the water the dT evaporation and water cannot decrease significantly as the incoming water is aprox 1 K above suction gas.

Manufacturer specified superheat at different operating conditions should be documented in connection with Chiller for future service/monitoring.

4.8 Desuperheater performance



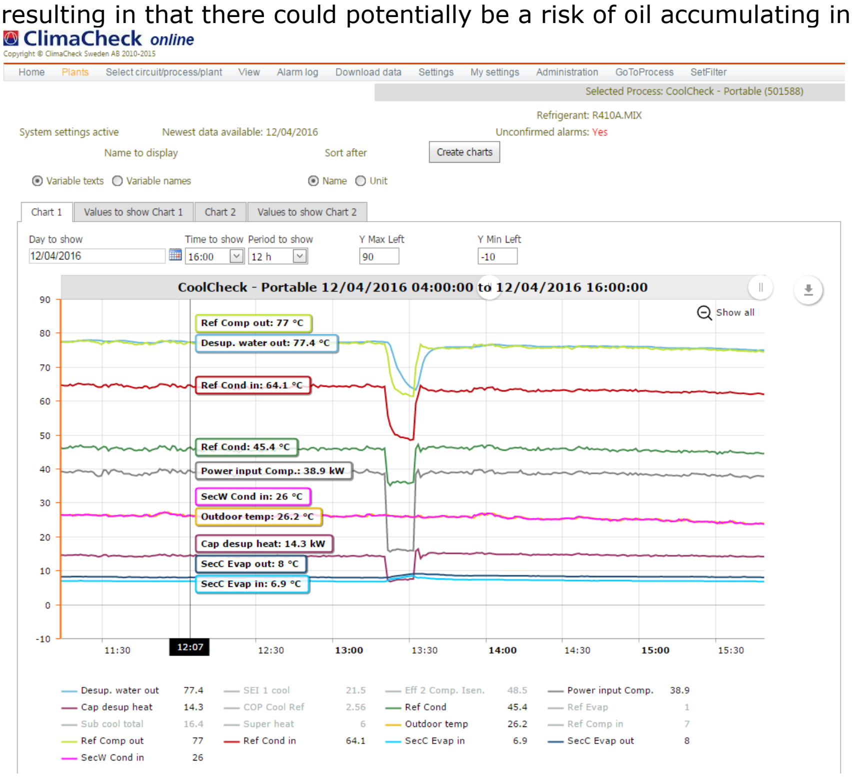
Desuperheater is recovering approximately 15 kW of the total 190 kW rejected in condenser and desuperheaters.
Existing water temperature is close to discharge temperature indicating that desuperheaters either has satisfied the demand or that flow is low (inlet water not measured due to that available sensors were used).

A higher water flow could increase heat recovery.
With a normal condensing temperature discharge temperature would decrease and available heat to recover. Maximum water temperature on recovery system would decrease.

Refrigerant temperature out of desuperheaters indicate that incoming water is quite high.

No design data or information on heat load was available when this report was done so no recommendation on optimum setting can be done.

Desuperheater is mounted in an unconventional way "laying down" resulting in that there could potentially be a risk of oil accumulating in heat exchanger below outlet port.



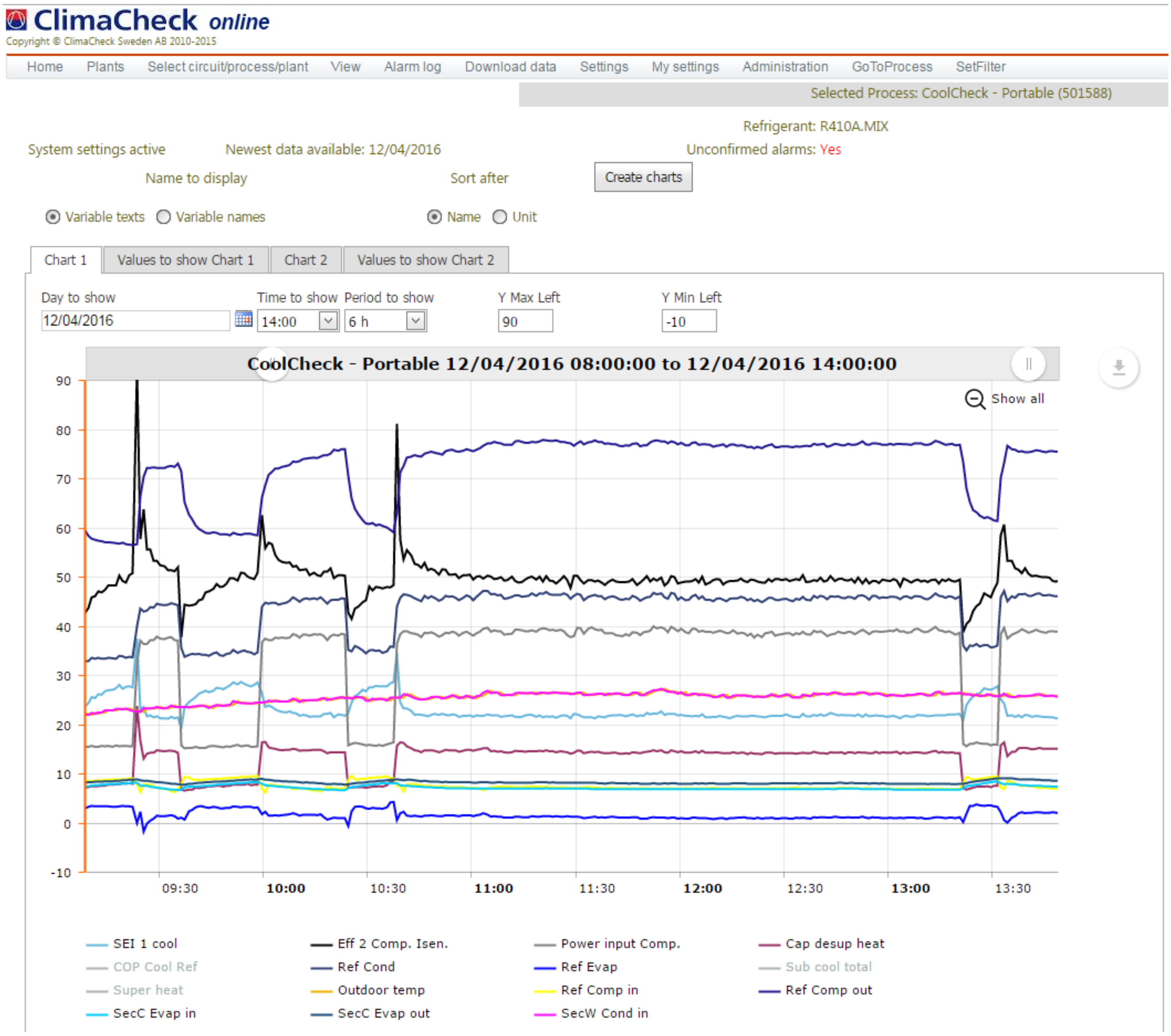
4.9 4-way valve

The 4-way valve is a potential risk for bypass from high side to low side of compressor. By checking suction gas temperature before and after this the amount of leak can be quantified.

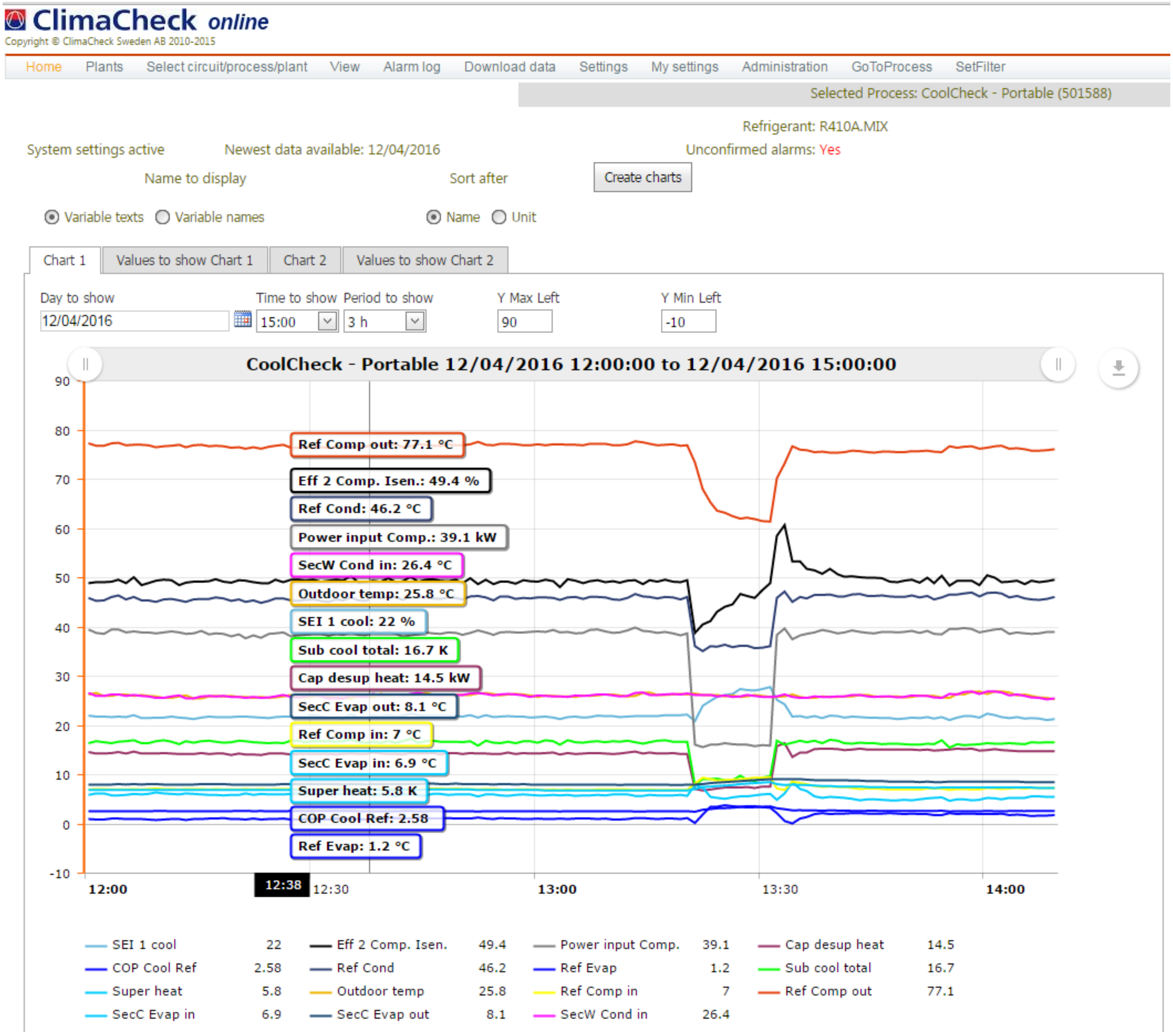
ClimaCheck

5 Operation - controls

Controls at the current out door day conditions are consistent. Minimum operation/stand still time is 10 minutes which is acceptable.
At night the cycling is increasing and some further evaluation is recommended.



Sequence below show operation of two compressors to the left and to the right and with one compressor 13:20-13:30.


ClimaCheck online
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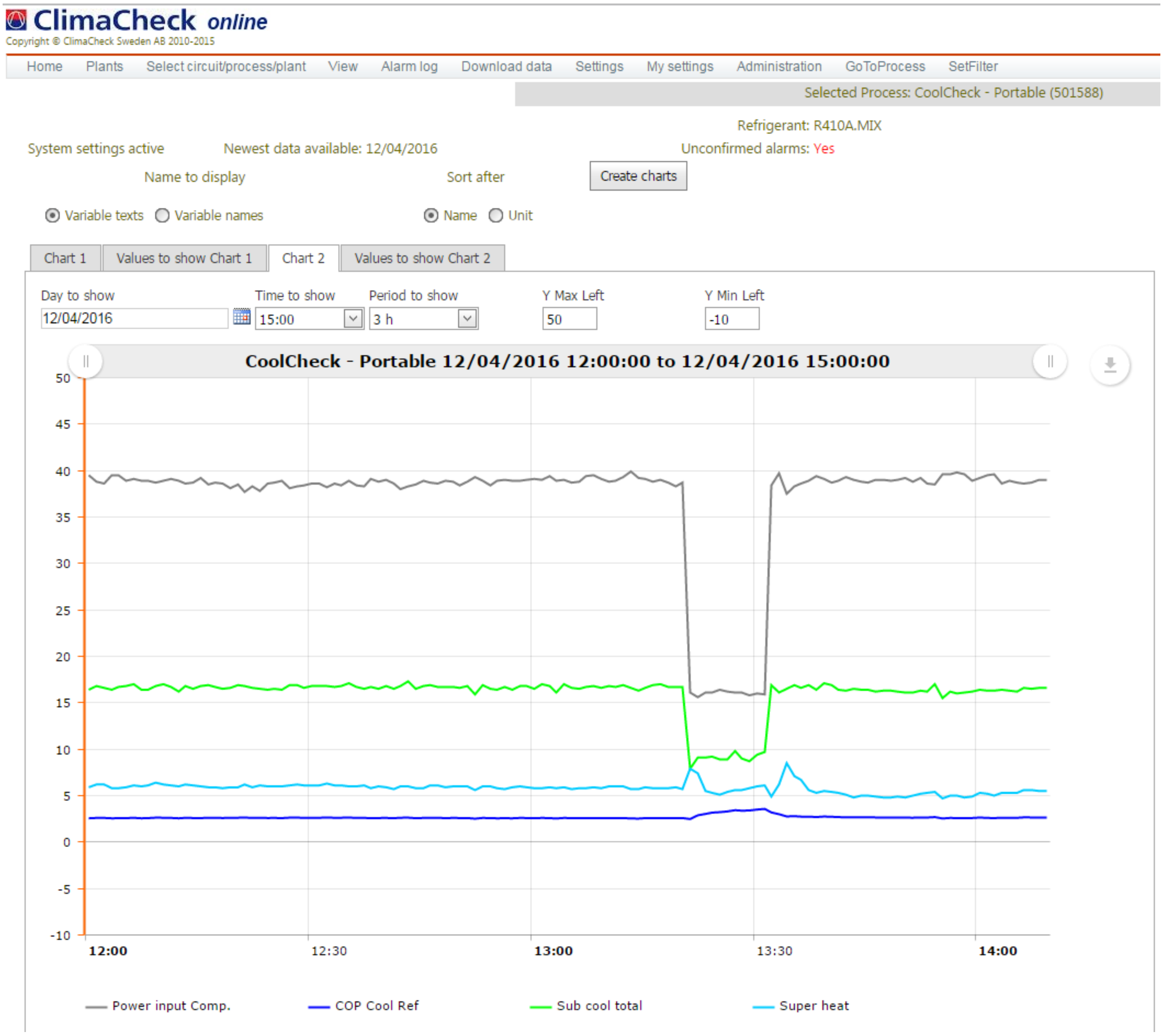
Home Plants Select circuit/process/plant View Alarm log Download data Settings My settings Administration GoToProcess SetFilter
Selected Process: CoolCheck - Portable (501588)
Refrigerant: R410A.MIX
System settings active
Newest data available: 12/04/2016
Unconfirmed alarms: Yes
Name to display
Sort after
Create charts
Variable texts
Variable names
Name
Unit
Chart 1
Values to show Chart 1
Chart 2
Values to show Chart 2
Day to show
12/04/2016
Time to show
15:00
Period to show
3 h
Y Max Left
90
Y Min Left
-10
CoolCheck - Portable 12/04/2016 12:00:00 to 12/04/2016 15:00:00
Ref Comp out: 77.1 °C
Eff 2 Comp. Isen.: 49.4 %
Ref Cond: 46.2 °C
Power input Comp.: 39.1 kW
SecW Cond in: 26.4 °C
Outdoor temp: 25.8 °C
SEI 1 cool: 22 %
Sub cool total: 16.7 K
Cap desup heat: 14.5 kW
SecC Evap out: 8.1 °C
Ref Comp in: 7 °C
SecC Evap in: 6.9 °C
Super heat: 5.8 K
COP Cool Ref: 2.58
Ref Evap: 1.2 °C
90
80
70
60
50
40
30
20
10
0
-10
12:00
12:38
12:30
13:00
13:30
14:00
SEI 1 cool 22
COP Cool Ref 2.58
Super heat 5.8
SecC Evap in 6.9
Eff 2 Comp. Isen. 49.4
Ref Cond 46.2
Outdoor temp 25.8
SecC Evap out 8.1
Power input Comp. 39.1
Ref Evap 1.2
Ref Comp in 7
SecW Cond in 26.4
Cap desup heat 14.5
Sub cool total 16.7
Ref Comp out 77.1

5.1 Superheat, subcool and COP graph

Operation with two compressor indicate an overcharged system as sub cooling increase significantly to 16 K this pushes the condensing up to 20 K above ambient.

At part load subcool is below 10 K so problem will not be as noticeable.



6 Appendixes

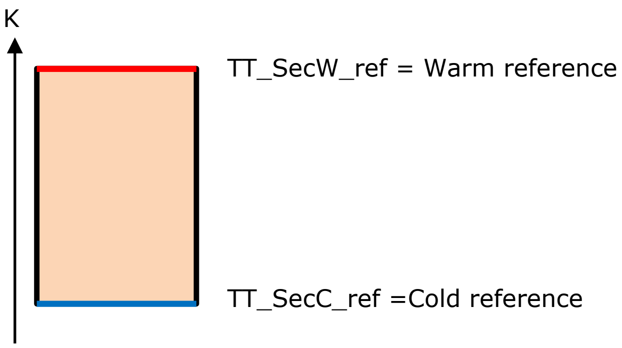
6.1 SEI Introduction

6.1.1 ClimaCheck Implementation of SEI and Sub efficiencies as a trouble shooting and benchmarking tool

System Efficiency Index – SEI an Innovative benchmarking parameter for evaluation and optimization.
Everybody who has worked with commissioning, inspections or evaluation of air-conditioning, refrigeration and heat pump systems in the field has encountered the problem of system not operating at design conditions and the challenges to compare a measurement with design data.
The commonly used performance indicators COP/EER or chiller efficiency (kW/RT) are totally dependent on the operating conditions and are challenging to use for evaluation of real life systems that rarely work at design conditions which is typically an extreme condition that occur the coldest or warmest day of the year.

The key performance indicator **System Efficiency Index**, SEI, is the efficiency for a refrigeration, air-conditioning or heat pump system compared **to a 100 % efficient (loss free) unit at the operating condition it is measured**. The ideal loss free process is defined as the "Carnot efficiency" based on using the "reference temperatures relevant for the analysed system.

These are called "reference temperatures" and must be defined with care to correctly reflect the performance of the system. With defined "reference temperatures" the "Carnot COP" is the ideal process at these conditions.



Carnot COP cool
for reference conditions

$$Carnot\_COPc\_ref = \frac{TT\_SecC_{ref}}{TT\_SecW_{ref} - TT\_SecC_{ref}}$$

SEI cool

$$SEIcool = \frac{COPmeasured}{Carnot\_COPc\_ref}$$

6.1.2 Reference temperatures

Benchmarking of systems require the definition of Reference temperatures that are relevant for the analysed system. These references are different for i.e. a water cooled and air cooled chiller as the mean temperature is the relevant parameter for chilled water for both types but on the warm side the mean temperature on the water cooled is relevant but the exiting air is not a relevant parameter for the air-cooled where only inlet air is relevant. To generate SEI and condenser efficiency comparable the reference temperature for "free blowing" air evaporators and condensers are set based on inlet air with an assumed fixed dT of 10 K. This allow optimisation based on heat exchanger design and fan power resulting in that highest efficiency and SEI represent most efficient system. Benchmarking should be limited within categories of systems with the same reference temperatures although useful conclusions can be drawn between different systems as sub-efficiencies are often comparable. The following reference temperatures have been found useful and are recommended (work on further categories/guide lines is ongoing).

Cold reference temperature

Water/brine systems with liquid	> Mean temperature
Free blowing air evaporators	> Inlet air -5 K
Multi evaporator systems (air)	> lowest set-point -5 K

Warm reference temperature

Water/brine systems with liquid	> Mean temperature
Free blowing air condenser	> Inlet air +5 K
Multi condenser systems (air)	> highest set-point +5 K

6.1.3 Limitations of SEI envelope.

To establish a Carnot COP there need to be positive difference (Warm temperature difference – Cold temperature difference). This limits the possibility to use SEI i.e. for air-conditioning or refrigeration with air-cooled condensers used when ambient temperature is 5 K below cold reference (this would basically correspond to when free cooling is possible) and thus making no compressor power required.

6.1.4 SEI benchmark

The specification of suitable categories and establishing of benchmarking levels is on-going. SEI is easy to use to compare two systems with similar applications i.e. two water-cooled chillers and this can be done on unit or system level (e.g. unit power only or including auxiliary loads). To establish what state of the art is, good and bad SEI require that the applications are defined as a low temperature chiller will not reach the same SEI as a high temperature chiller due to that state of the art performance compressors do not reach the same performance for low temperature as high temperature compressors. Relevant categories must be defined with consideration to application and it is obvious that good is a relative term as a large centrifugal chiller with flooded evaporator running in a hot climate has a totally different economical/technical design than a small hermetic chiller with dry expansion in a temperate climate. Also the secondary system will limit the freedom to reach the highest SEI as flow and temperature requirements restrict freedom to operate chiller. But the SEI will rate chillers versus the ideal and show the impact of measures in percent making it possible to understand impact with a minimum of technical background. It is very easy for anybody to build their own SEI scale to rate the systems they are working whereas care should be taken in using them as global values due to the huge number of system designs.
Indicative levels for chillers are
High efficiency chillers with flooded evaporators reach 45-55% (full load of compressor)
High efficiency chillers and water to water heat pumps with expansion valve reach 40-50% (full load of compressor).

Figure 1, State of the art chiller with flooded evaporator

6.1.5 Sub Efficiencies

The measured COP divided by the "Ideal=Carnot COP" is the SEI and the losses in each step of the process can be defined allowing the sub efficiencies to be established. The possibility to identify and benchmark weak points contributes to making the SEI concept a powerful tool for fault detection and communication. The most interesting sub efficiencies for most application are:
Cycle efficiency – this shows the losses caused by the refrigerant process deviation from an ideal cycle with a 100% efficient compressor. This will i.e. be affected by the refrigerant and factors such as sub cool and superheat and if the system has economizer.
Compressor efficiency – show the losses in the compressor e.g. the isentropic compressor efficiency this include all losses inside compressor and motor.
Condenser efficiency – Show the difference of measured COP with that of the same system with an ideal condenser (indefinite surface).
Evaporator efficiency - Show the difference of measured COP with that of the same system with an ideal evaporator was used (indefinite surface).
As the sub efficiencies and SEI is in principle independent of the operating condition it proves to be a very practical benchmarking parameter.

Further efficiencies related to i.e. pressure and heat losses can also be defined if so desired. In many applications these are be considered as part of the evaporator and condenser efficiencies. For some analyses it other sub efficiencies than those above can be relevant to evaluate separately.

In a project financed by the Swedish Energy Agency SP Technical Research Institute of Sweden a measurement methodology to measure SEI for cooling and heating have been developed with system boundaries at four levels. For liquid/liquid units with a system boundary, including the refrigerant process, laboratory and field measurements have been evaluated and a report is available* as download on internet. The result shows that SEI is a useful indicator for analysis of heat pump and air conditioning systems.

*Method and guidelines to establish System Efficiency Index during field measurements on air conditioning and heat pump systems, 2014, SP Technical Research Institute of Sweden.
http://effsysplus.se/wp-content/uploads/2012/02/EP18-Slutrapport-20140630rev0704.pdf

6.2 The ClimaCheck method for performance analyses.

The performance analyser based on the "Internal Method" is an innovative technology that has the potential to revolutionise the industry's approach to commissioning, trouble-shooting, service and energy optimisation of refrigeration and air conditioning systems.

Figure 2, ClimaCheck Performance Analyser in portable and fixed versions

It enables engineers in the field to cost-effectively in real time determine the performance of the refrigeration process, its actual COP, capacity, and other vital performance parameters without hours of tedious calculations of a highly skilled engineer. This vital data is presented dynamically in charts and tables, enabling the engineer and/or end user to gain an immediate picture of the actual performance of the system. Suggested optimisation measures can be validated.

Figure 3, Visualisation in flow chart, graphs and tables that easily can be customised.

The performance is documented in an un-biased way without inputs of manufacturers of system or components. **The method is based purely on fundamental thermodynamic properties and the first law of thermodynamics e.g. energy cannot be destroyed only transformed.**

6.2.1 Accuracy of results

It accurately determines a working system's performance:

- Coefficient of Performance (± 5%)
- Cooling and heating capacity (± 7%)
- Power input (± 2 %)
- Compressor isentropic efficiency (± 3%)

The accuracies stated above are based on ClimaCheck PA Pro data acquisition system, standard ClimaCheck sensor accuracy mounted in accordance with ClimaCheck's manuals and good measuring practice on a standard refrigeration process with a semi-hermetic or hermetic compressor as shown below.

6.2.2 Accuracy of sensors

Error calculations are based on the below stated accuracy of input sensors.

- Pressure sensor, ± 1% FS
- Temperature sensors PT1000 Class A
- Electrical Energy power meter ClimaCheck EP Pro, Class B
- Current transformers (20-120% of rating), ± 2%

6.2.3 Innovative approach – how it works

The system uses ten easy to apply sensors that are attached at strategic points around the system. This is 7 temperatures, 2 pressures and active power as shown in Figure 3.

A technician/engineer can hook up the equipment in 20-30 minutes. From the information gathered the key operating parameters that pinpoint the system's actual performance can be determined independent of any supplier data.

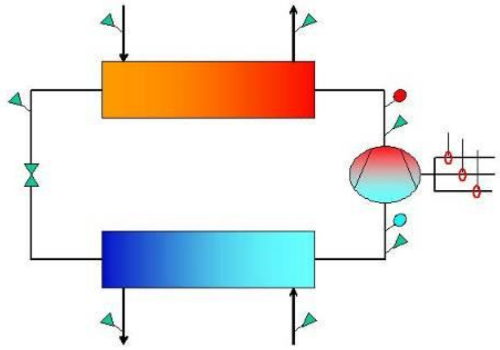


Figure 4, Sensors required and their location to establish performance of a standard refrigeration system.

Required measuring points for a standard systems is:

- Temperature and pressure at entrance of compressor.
- Temperature and pressure at compressor exit.
- Liquid refrigerant before expansion device.
- Active electrical power.

For reference of operating condition and heat exchanger evaluation the temperature of air/liquid entering and exiting condenser and heat exchanger are measured. IN total 10 measurements that are easy to apply to almost all systems in the field.

At the heart of the performance analyser is the energy balance over the compressor and a series of algorithms, based on the thermodynamic properties and operating characteristics of the refrigerant in use.

The heat losses are low relative the total input power limiting the impact of variation as documented by (Asercom, 2003) and (Naumburg, 1987). So equation (1) will give a good accuracy of mass flow of refrigerant.

The losses varied in documentation and tests between three and ten percent in hermetic and semi-hermetic compressors without external cooling representing the vast majority of compressors on the market. For open drive and compressors with cooling the same methodology can be used by adding a model of the amount of energy not introduced in the refrigerant flow. When the net energy to the refrigerant flow calculated as the measured electrical power – heat losses are known the mass flow is also known through equation (1) and (1a).

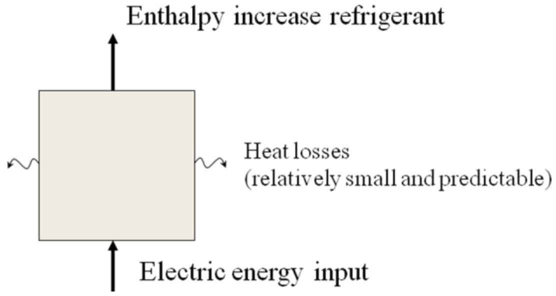


Figure 5, The energy balance with consideration of heat losses over the compressor allows calculation of mass flow.

$$\text{Mass flow} = \frac{\text{(electrical input-heat losses)}}{\text{Enthalpy difference}} \quad (1)$$

$$\text{Massflow} = \frac{(\text{Electrical power} * (1 - \text{rel.heat loss})}{(h1 - h2)} \quad (1a)$$

From the above described energy balance and these enthalpies all data required can be derived including COP, Capacities, and the compressors total isentropic efficiency. Method described in more detail by i.e. (Berglof, Methods and Potential for Performance Validation of Air Conditioning, Refrigeration and Heat Pump Systems, 2004), (Berglof, Methods and Potential for on-site Performance Validation of Air Conditioning, 2005), and (Fahlén, Methods for commisioning and performance checking heat pumps and refrigeration equipment., 2004).

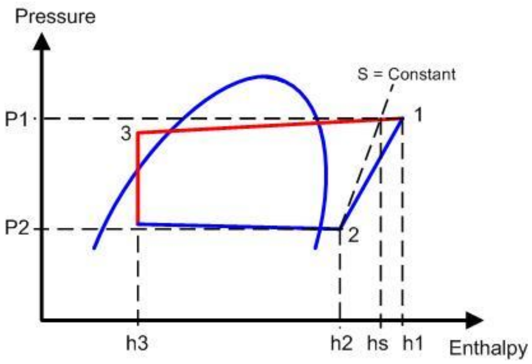


Figure 6, Pressure – enthalpy graph of "standard" refrigeration process.

$$\text{Cooling Capacity} = \text{Mass flow} * (h2 - h3) \quad (2)$$

$$\text{Heating Capacity} = \text{Mass flow} * (h1 - h3) \quad (3)$$

$$\text{Isentropic Effic} = \frac{(hs - h2) * (1 - \text{rel.heat loss})}{(h1 - h2)} \quad (4)$$

6.2.4 Well proven method

The method and technology was first developed in Sweden 1986 and validated by SP the national Swedish testing institute (Fahlén, Capacity measurements on heat pumps - A simplified measuring method, 1989). More than 40 manufacturers and 300 contractors in 20 countries have introduced the "Internal Method" as a tool to improve their development, production and aftermarket activities. Examples of world leading companies in the industry that has validated and use the Internal Method to document the performance of their products and optimise the systems are Carrier, Trane, Johnson Control, Copeland, Bitzer, Gea, Danfoss Heat pumps and DuPont.

6.2.5 Practical benefits

All data required for a full evaluation of the system are available as soon as sensors are connected - most of the time without requirement to stop the system. With the information provided, engineers can identify plant performance problems, including among many others:

- refrigerant shortage or over-charge
- incorrect superheat setting
- compressor damage or wear
- fouling of heat exchangers
- oil logging in the condenser/evaporator
- fan/pumps underperformance, Flow problems on secondary medias (air/water/brine)
- control problems

The system identifies irregularities in compressor, component performance that could result in future impairment of performance – or even plant breakdown, enabling pre-emptive maintenance and energy optimisation.

Armed with this vital information, engineers can address the issues identified, optimising system performance. The result is huge potential savings in power consumption and carbon emissions over a plant's lifetime.

Without an effective method and an efficient tool, these problems normally go unrealised, with the plant continuing to perform inefficiently – or eventually breaking down with potentially catastrophic consequences for refrigerant loss and stock damage.

Whenever required a modem can be connected to the data collection unit and information in real time transferred to an Internet server where calculations are done and made available to any expert in the world who is given access through user name and password for validation and advice on best actions to take.

6.3 Used Symbols in table overview

	Correct function and performance
	Incorrect function and/or performance
	Unclear function and/or performance Could not be measured or reference values to benchmark not available
	Warning – issue or suspected issue that can result in serious problem/failure. It is recommended that issue is addressed without delay.
	Maintenance or repair is required
	Further investigation is required

Note that when savings on several areas occur they cannot be added for the total saving. The total saving is better estimated by multiplying the factors in the following way.

Relative energy consumption after optimisation = (1-saving in % measure 1)*(1- saving in % measure 2)*……..