

Review of
**Performance inspection
Carrier 19XR
Water cooled centrifugal chiller**



Analyses and visualization of the process is done with
ClimaCheck *onsite*

ESG-Management Summary

The water-cooled chiller had **sufficient cooling output** but to confirm its performance efficiency it was measured for a short period (30 minutes) at stable conditions

The measured SEI (System Efficiency Index) reached 38% and falls short of the desirable 45%. This means that the performance only reached 85% of its expected efficiency at the measured conditions, resulting in a **15% efficiency loss** through electricity use.

With an average load of 60% around the year, the overall annual expected electricity consumption of this chiller is 3,9 MWh.

Based on mentioned 15% efficiency loss this chiller, although functioning well in terms of delivering the expected cooling, currently has an avoidable annual waste that is close to 600,000 kWh on electricity.

Monetary value of the avoidable waste:

- Electricity cost: 600,000 kWh @ US\$ 0.08: US\$ 48,000
- Carbon Tax: 233.4 MT CO2 @ US\$ 51/MT: US\$ 11,900 (PM)

NOTE: at the time of this report carbon taxes are not (yet) applicable and the rate indicated is based on expectations.








Main Recommendations for Efficiency improvement

This deviation is related to lower measured isentropic **efficiency of compressor** than expected.

Further the oil temperature 51°C is clearly above manufacturer operating manual 43°C which could be an indication of that lubrication/friction is not good.

It is recommended that the compressor is inspected by compressor expert with access to all manufacturer data.

Overview of Chiller and Component Performance

Performance	Measured Efficiency%	Desired	Symbol	Comments
System Efficiency Index (SEI)	38%	45% at full load good conditions		Clearly lower than expected than expected. Approximately 15% lower efficiency than expected due to compressor isentropic efficiency lower than expected.
Cycle Performance	89%	>80%		As expected
Compressor	58%	>65% at full load peak efficiency		Isentropic efficiency is clearly below (10% below) expected for this type of chiller. Also oil temperature is well above recommended level (in manual for 19XR chiller found on Internet).
Refrigerant Charge	Subcool condenser 3 K	1-5 K		Within expected range.
Expansion Device	Super heat 2.8 K	0.5-3 K		No indication of issues during the measurements
Condenser Performance	85%	>85%		Good
Evaporator Performance	88%	>85%		Very good

Internal Feedback (March 2020):

Within 2 weeks after this check the maintenance contractor was invited on site and made adjustments to the compressor vanes that were indeed positioned incorrectly. Cleaned oil line.

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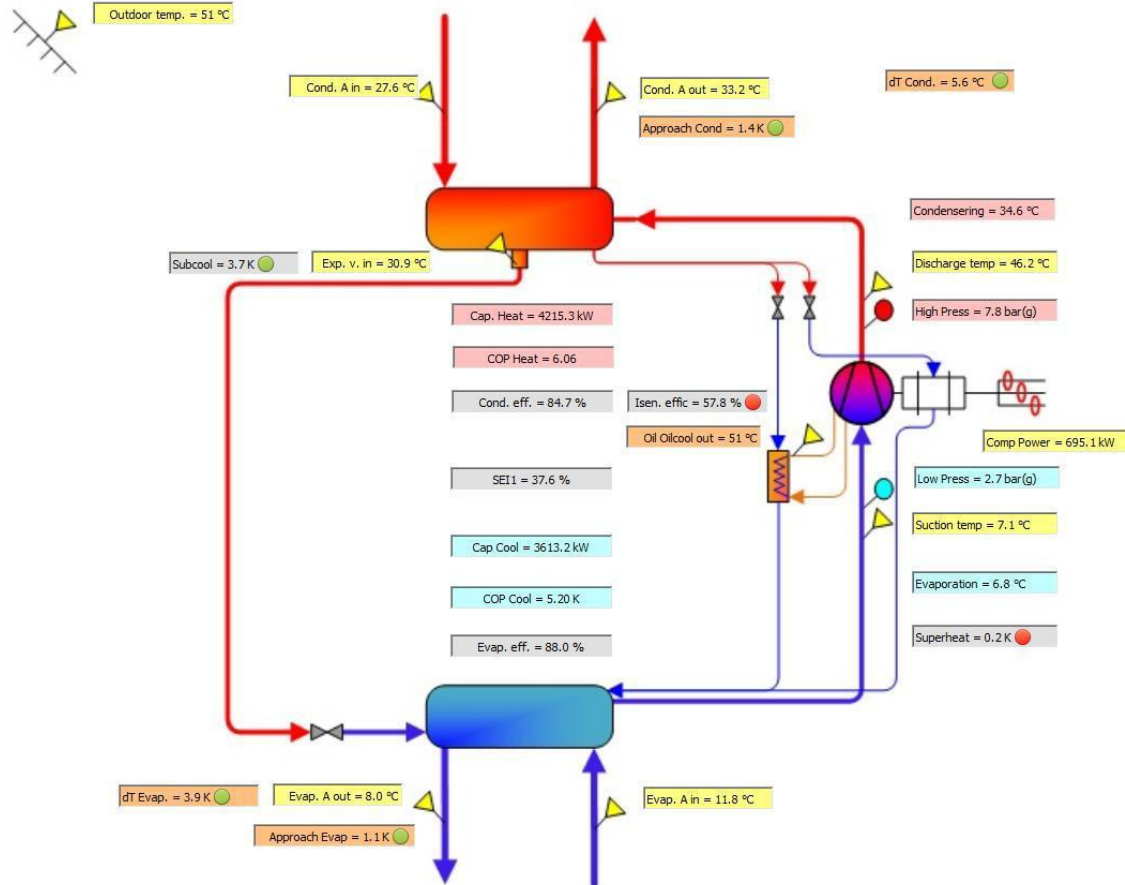
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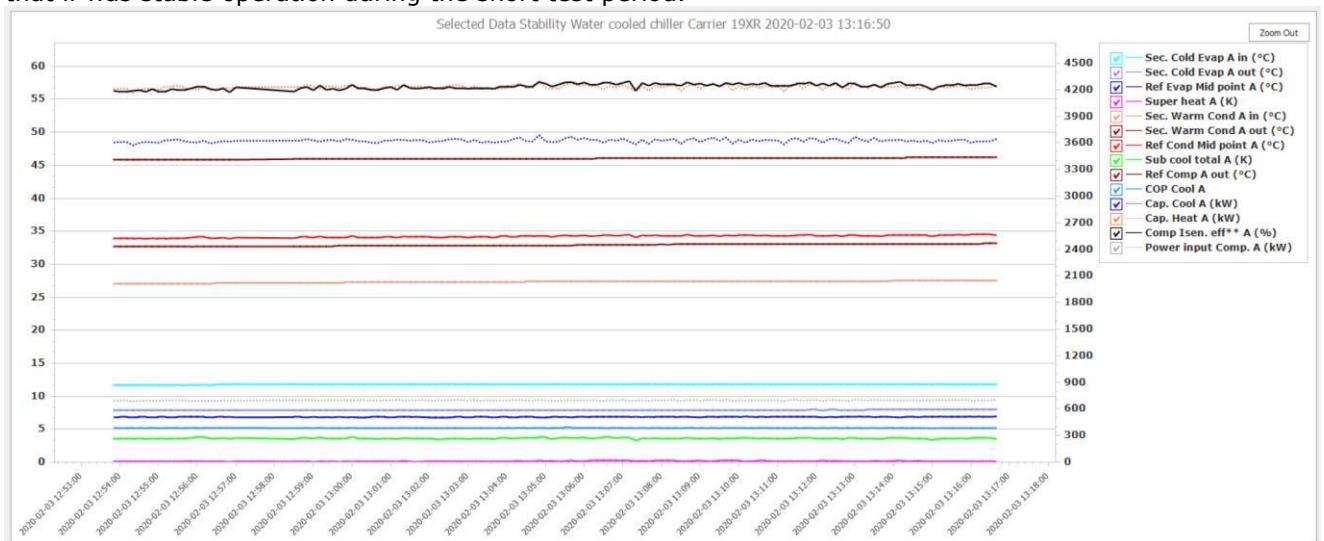
- A. SEI Introduction
- B. Methodology for the ClimaCheck Internal Measurement approach

1 System layout and operation

Carrier 19XR are water cooled centrifugal chillers with a straight forward design with refrigerant cooled motor and an oil cooler.



System was operating stable during the relatively short measuring sequence of aprox. 30 minutes so measurements does not give sufficient information to comment on controls and operating conditions beyond that if was stable operation during the short test period.

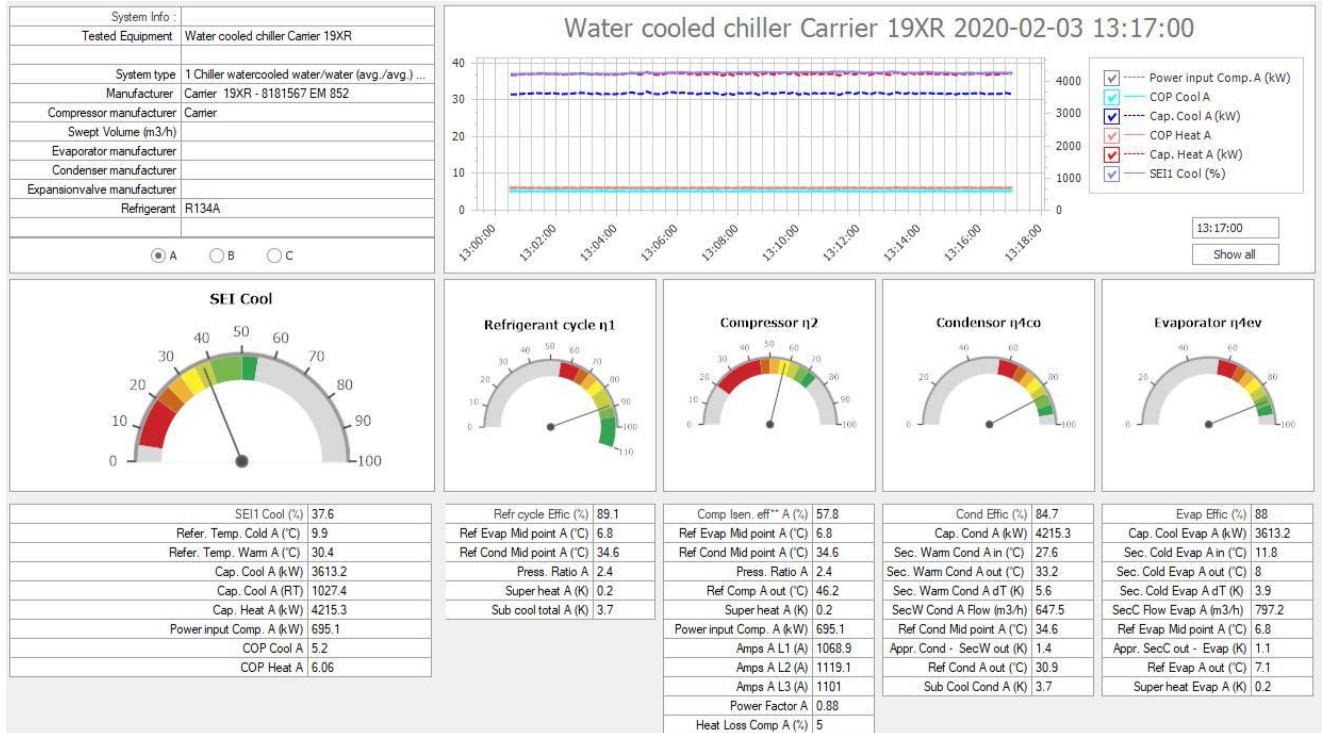


2 Performance of air-cooled chiller – System Efficiency Index (SEI)

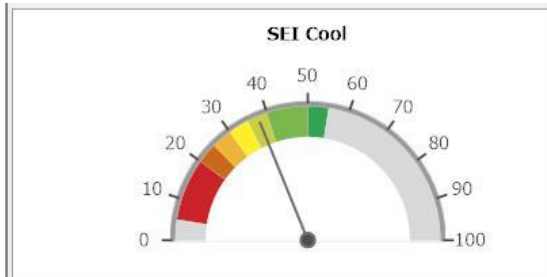
The chiller is not fully reaching the high efficiency expected for this type of chiller and the deviation is in the compressor isentropic efficiency.

The System Efficiency Index (SEI) that compare measured COP with a loss free process at the measured conditions is 38% whereas it with a state of the art compressor would reach 45%.

The difference in SEI represents an increase of power consumption with 18% versus the high efficiency expected of this chiller at the measured conditions. See details below.



3 Comparison of ClimaCheck measured performance with performance as stated



SEI1 Cool (%)	37.6
Refer. Temp. Cold A (°C)	9.9
Refer. Temp. Warm A (°C)	30.4
Cap. Cool A (kW)	3613.2
Cap. Cool A (RT)	1027.4
Cap. Heat A (kW)	4215.3
Power input Comp. A (kW)	695.1
COP Cool A	5.2
COP Heat A	6.06

The total **System Efficiency Index** (SEI) is 38% which is lower than expected of high efficiency chillers at peak conditions full load.

System is operating quite close to rated power input and capacity so efficiency would be expected to be higher.

The Carrier 19XR are known as efficient chillers but are available in different configurations.

The chiller is operating with a cooling capacity of 3613 kW (1027 RT) and an input of 695 kW.

According to nameplate nominal capacity is 3840 kW (1092 RT) and input kW 759 kW (at what rating conditions these values are given is not known as nameplate is only performance information that is available).

Cooling capacity is 94% and power input is 91% of rated

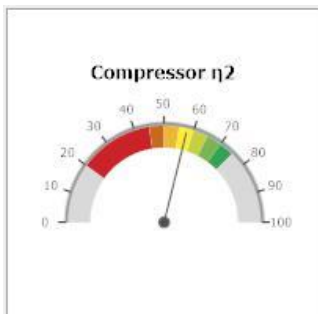
(rating conditions unknown).

Measured COP is 5.2 (0.677 kW/RT)

Rated COP is 5.05 (0.695 kW/RT)

This indicate that the rating conditions are quite different from measured as the compressor efficiency as discussed below also is significantly lower than normally found on the Carrier XR19.

3.1 Compressor



Comp Isen. eff** A (%)	57.8
Ref Evap Mid point A (°C)	6.8
Ref Cond Mid point A (°C)	34.6
Press. Ratio A	2.4
Ref Comp A out (°C)	46.2
Super heat A (K)	0.2
Power input Comp. A (kW)	695.1
Amps A L1 (A)	1068.9
Amps A L2 (A)	1119.1
Amps A L3 (A)	1101
Power Factor A	0.88
Heat Loss Comp A (%)	5

The compressors is operating with 58% isentropic compressor efficiency at stable operation were normal efficiency of these chillers are reaching around 70% at peak conditions and full load.

Compressor should be fairly close to full load as power input and capacity are not

Together with the indication of higher oil temperature than anticipated (see section below) the lower than anticipated compressor efficiency indicate that there is a potential issue in the compressor.

It is recommended that compressor is inspected by an expert to identify the cause of low isentropic efficiency and high oil return temperature.

Possible causes are e.g.:

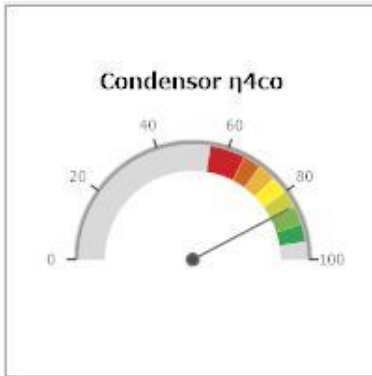
- Incorrect position of inlet Guide vanes, IGV
- Internal leakage
- Increased friction

Deviation is clearly outside what is expected as normal measuring errors.

3.2 Condenser

The condenser efficiency is 85% which represents a good performance. An approach of 1.4 K is good. The dT of the cooling water is 5.6 K which reflects that flow is within expected range.

It should be noted that if there is a decreased performance in compressor the capacity is slightly lower than design and this would put a lower load on heat exchanger.



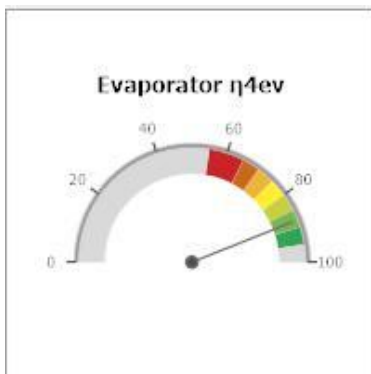
Cond Effic (%)	84.7
Cap. Cond A (kW)	4215.3
Sec. Warm Cond A in (°C)	27.6
Sec. Warm Cond A out (°C)	33.2
Sec. Warm Cond A dT (K)	5.6
SecW Cond A Flow (m3/h)	647.5
Ref Cond Mid point A (°C)	34.6
Appr. Cond - SecW out (K)	1.4
Ref Cond A out (°C)	30.9
Sub Cool Cond A (K)	3.7

3.3 Evaporator

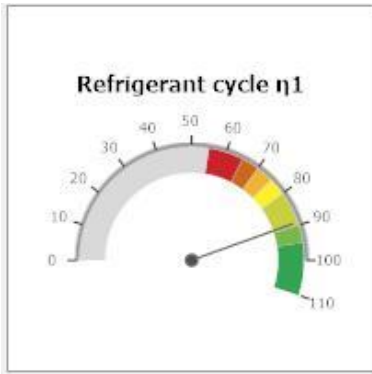
The evaporator efficiency is 88% and approach is 1.1. K which represent high performance.

The dT on the chilled water is 3.9 K which reflects that flow is within expected range

It should be noted that if there is a decreased performance in compressor the capacity is slightly lower than design and this would put a lower load on heat exchanger.



Evap Effic (%)	88
Cap. Cool Evap A (kW)	3613.2
Sec. Cold Evap A in (°C)	11.8
Sec. Cold Evap A out (°C)	8
Sec. Cold Evap A dT (K)	3.9
SecC Flow Evap A (m3/h)	797.2
Ref Evap Mid point A (°C)	6.8
Appr. SecC out - Evap (K)	1.1
Ref Evap A out (°C)	7.1
Super heat Evap A (K)	0.2



Refr cycle Effic (%)	89.1
Ref Evap Mid point A (°C)	6.8
Ref Cond Mid point A (°C)	34.6
Press. Ratio A	2.4
Super heat A (K)	0.2
Sub cool total A (K)	3.7

3.4 Refrigerant cycle

The refrigerant cycle is a standard cycle without economisers or sub coolers which reach the measured performance.

3.5 Charge

The subcooling (3.7 K), superheat (0.2 K) and approaches all show that refrigerant charge is well adapted to the current operating conditions.

3.6 Expansion device

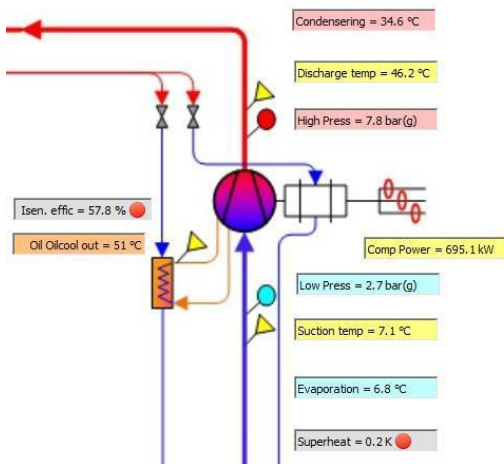
System is operating with low superheat and approach and expected subcooling at stable conditions which then indicate that at the measured conditions the expansion device offer a good control.

3.7 Oil Cooler and oil temperature

The oil return temperature is measured to 51°C which is higher than anticipated which together with the lower measured isentropic efficiency of the compressor is an additional indicator that the compressor need to be checked.

The following paragraph is from page 51 in Carrier manual for 19XR (<http://www.carrier.co.th/m/19xr-6ss.pdf>) – downloaded from Internet – might not be the correct manual for this particular chiller but it represent normal oil return temperatures experienced.

This could indicate that there is a bearing/lubrication problem.



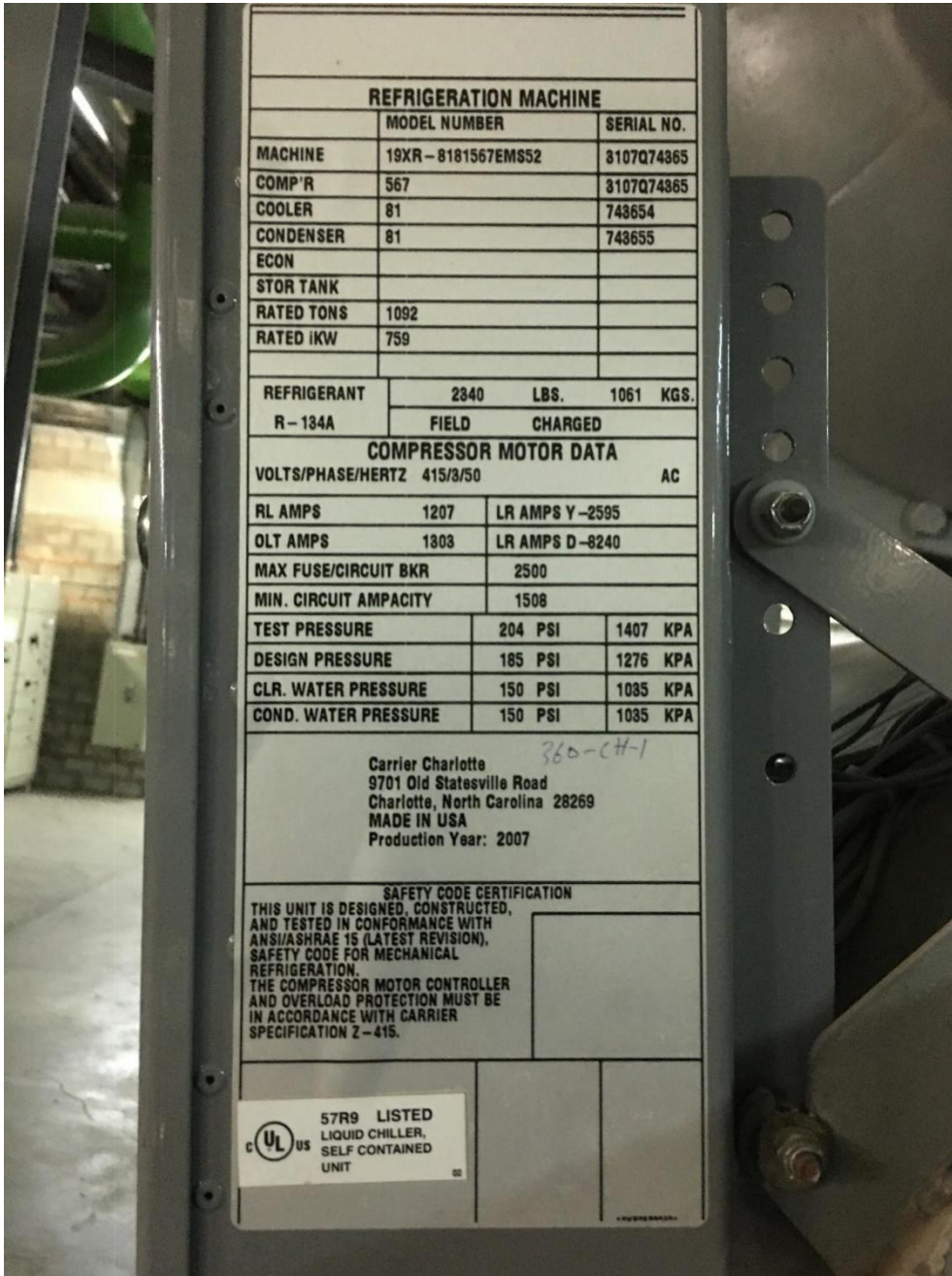
It is recommended that the compressor is inspected by compressor expert with access to all manufacturer data.

"Oil Cooler — The oil must be cooled when the compressor is running. This is accomplished through a small, plate-type heat exchanger (also called the oil cooler) located behind the oil pump. The heat exchanger uses liquid condenser refrigerant as the cooling liquid. Refrigerant thermostatic expansion valves (TXVs) regulate refrigerant flow to control the oil temperature entering the bearings. The bulbs for the expansion valves are strapped to the oil supply line leaving the heat exchanger, and the valves are set to maintain 110 F (43 C). NOTE: The TXVs are not adjustable. The oil sump temperature may be at a lower temperature during compressor operations."

5 Equipment design conditions

Unknown.

5.1 Chiller name plate



5.2 Site pictures

