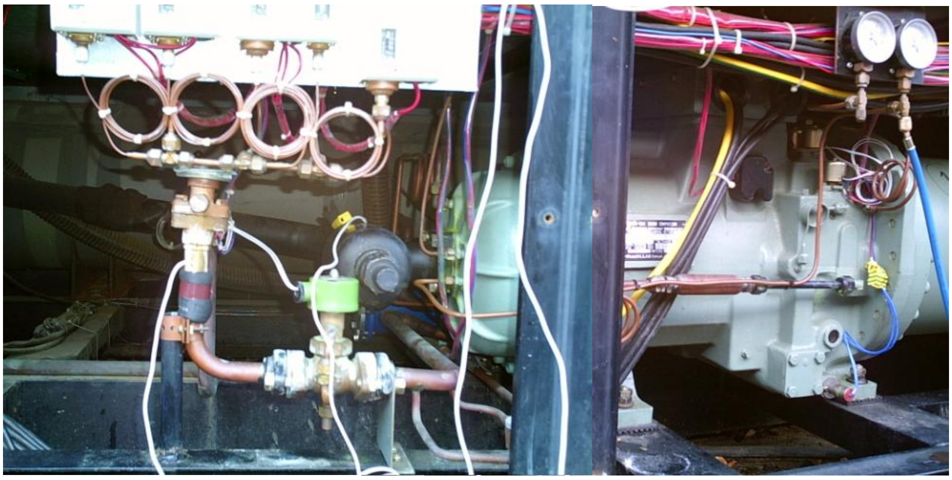
CASE STUDY

HITACHI WATER CHILLER CONVERSION TO DUPONT ISCEON® MO99 (R438A)

Introduction

The system under investigation was a Hitachi water chiller with an air cooled condenser, thermostatic expansion valve, a common evaporator with two other chiller circuits and a Hitachi 6002SC-H screw compressor. The oil used in the compressor was a specific oil supplied by Hitachi and reported to be a POE but this could not be confirmed.



The first retrofit to ISCEON® MO29 had taken place several months ago but there were concerns with the oil level in the compressor. After the retrofit the oil level in the compressor rapidly fell once the compressor switched on. Once the compressor switched off the oil level returned.

This first chiller was returned to operation with R22 and the oil levels were once again stable during operation. A second chiller was retrofitted to ISCEON® MO29 and the same observation with the oil was made and it was arranged for a DuPont representative to visit site.

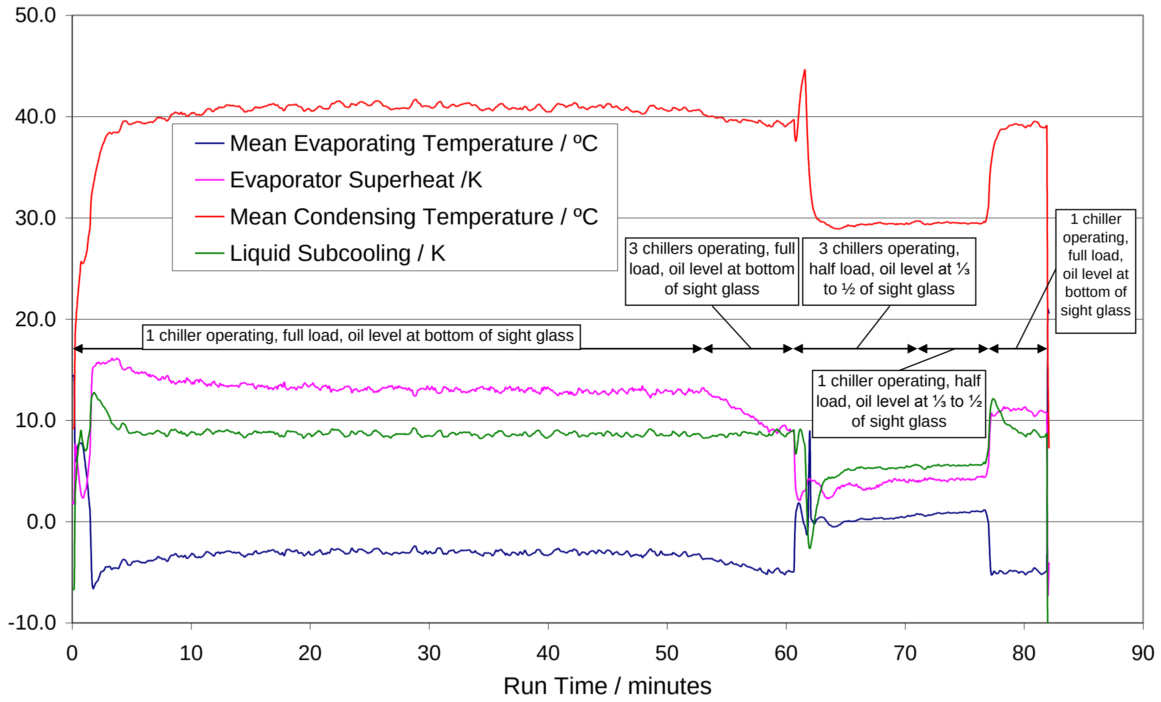
On arrival at the site the chiller was switched off and the compressor oil level completely filled the sight glass. The suction and discharge temperatures and pressures and liquid line temperature were monitored using a Climacheck performance analyser to help diagnose any system problems.

The observations of the oil level after retrofit to ISCEON® MO29 did not appear to be related to the system operating parameters. The fact that the oil level rapidly increased at part load and when switched off strongly indicated the oil was within the compressor and therefore not strictly an oil return problem.

Although alarming to see the oil level fall so quickly the level did stabilise, albeit at a low level, during compressor operation. This did not appear to pose a threat to compressor operation but it should be noted that the oil level does need to be high before the compressor is switched on.

The logged data (Figure 1) did show that the system was not operating at the optimum conditions to obtain the best performance. At full load the mean evaporating temperature was 4-5K too low and the suction superheat was 5-6K too high. Normally this would be an indication that the expansion valve required adjustment but an engineer on site reported that the expansion valve had already been opened 8 turns and was effectively fully open.

Figure 1 – Chart of logged system data with ISCEON® MO29



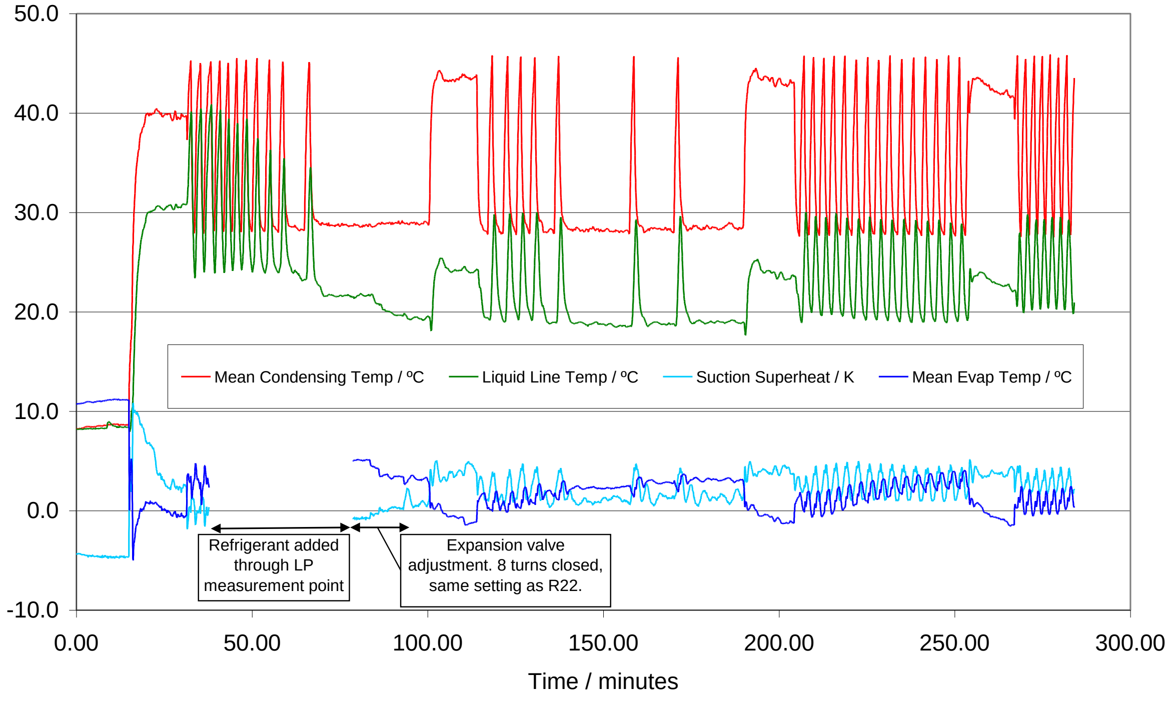
The results strongly indicated the expansion valve size was too tightly sized to the chiller capacity with R22 and was too small for use with ISCEON® MO29. This made this chiller an ideal candidate to trial ISCEON® MO99 to investigate if the use of ISCEON® MO99 could overcome the issue of a tightly sized expansion valve.

Investigation and Data Analysis

The system was changed to ISCEON® MO99 (36 kg initial charge) and the logging equipment attached before the system was switched on. On start-up, as before with ISCEON® MO29, the oil level rapidly dropped but this time to a minimum of ½ of the sight glass and then stabilised. The system ran at full load for 10 minutes before the compressor unloaded and the condenser fans started to rapidly cycle on and off resulting in very unstable conditions. It was thought this may be due to undercharging and therefore more refrigerant was added taking the charge to 50kg (nameplate charge with R22 40kg). The cycling stopped but later returned during the part load cycle with no obvious reason why the system was so unstable. Installation of variable speed fan controllers would remove this cycling problem.

During the charging of the additional refrigerant it was not possible measure the suction pressure as this port was also used as the charging point but once the charging had been completed the data revealed there was no suction superheat and it was remembered that the expansion valve was still 8 turns open from the ISCEON® MO29 retrofit. The expansion valve was slowly closed until the valve was back to the original R22 setting.

Figure 2 – Chart of logged system data with ISCEON® MO99



In order analyse the system performance and make a comparison with ISCEON® MO29 a stable period at full load (191 to 204 minutes) and a stable period at part load (141 to 157 minutes) were selected. A stable full load and part load period was also selected from the ISCEON® MO29 data for comparison purposes. The actual measured data for the selected periods are shown in figures A1.1 and A1.2 in appendix 1 and the calculated data derived from these shown in figures 3, 4 and 5.

In Figure 3 (full load operation) it can clearly be seen that the mean evaporating temperature of ISCEON® MO29 is significantly lower (2.5K) than that of ISCEON® MO99 despite the water in temperature being higher with the ISCEON® MO29. At the same water in temperature the difference in evaporating temperatures would be even larger (estimated 5.8K). It is also clear from comparison of figure 1 and figure 2 that the suction superheat is much higher (~12K) with ISCEON® MO29 than with ISCEON® MO99. This is a clear indication that the expansion valve size restriction experienced with ISCEON® MO29 is not occurring when using ISCEON® MO99.

Figure 3 – Comparison of ISCEON® MO29 and ISCEON® MO99 condensing temperature, evaporating temperature, water in temperature and evaporating temperature/water temperature difference at full compressor load.

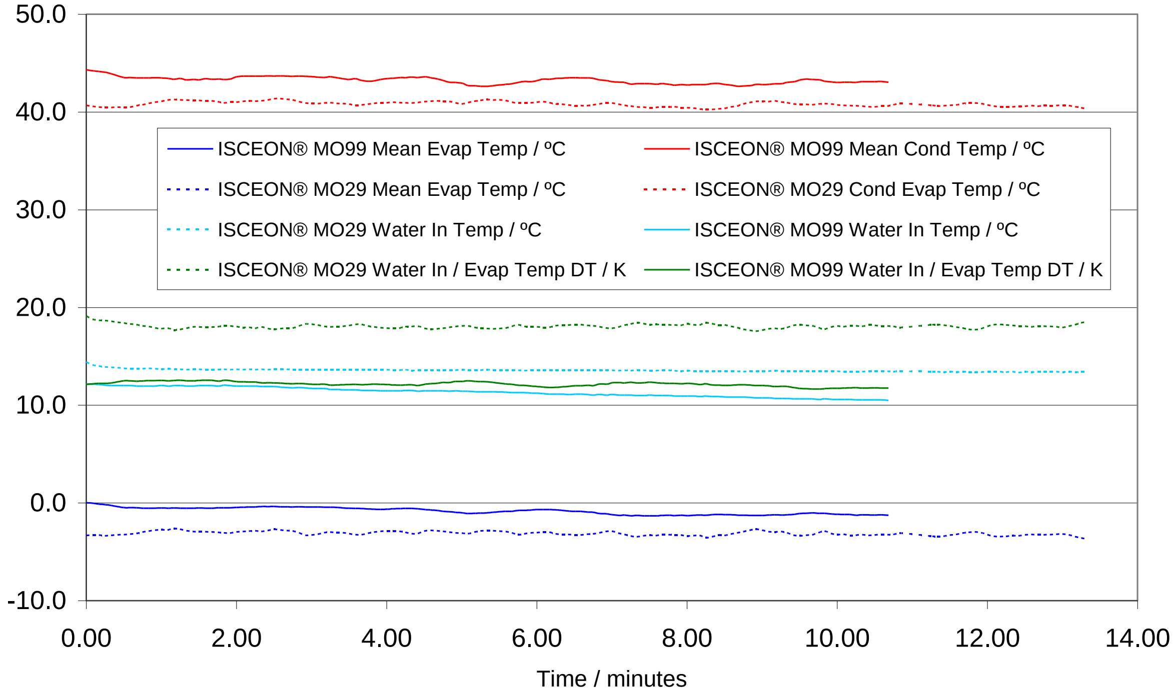


Figure 4 – Comparison of ISCEON® MO29 and ISCEON® MO99 condensing temperature, evaporating temperature, water in temperature and evaporating temperature/water temperature temperature difference at part compressor load.

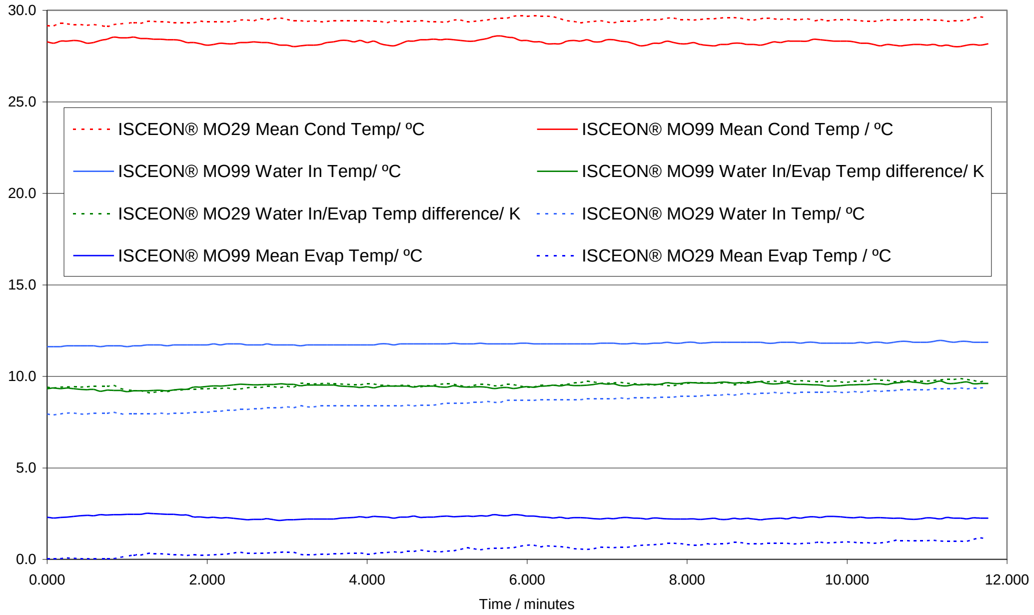
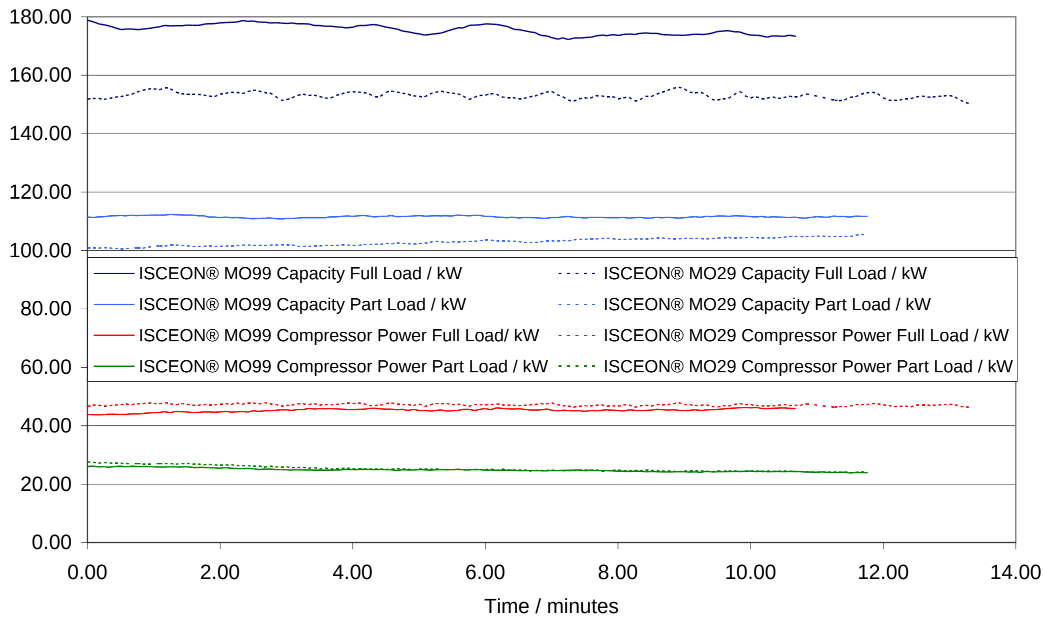


Figure 5 – Comparison of ISCEON® MO29 and ISCEON® MO99 calculated* cooling capacity and compressor power at full and part load.



* Cooling capacity calculated using 208 m^3/h compressor displacement full load & 112 m^3/h part load, 90% volumetric efficiency, 7% compressor heat loss and isentropic efficiency calculated from measured compressor discharge temperature.

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In Figure 4 (part load operation) at first glance it appears the evaporating temperature of ISCEON® MO29 is also lower than when operating with ISCEON® MO99, however the water temperature is also lower. The difference in temperature (DT) between the water in and the mean evaporating temperatures are almost identical with both refrigerants and it is therefore reasonable to assume at the same water temperature both refrigerants would have the same mean evaporating temperature. The suction superheat is only 1 K with ISCEON® MO99 which is lower than would normally be recommended but observation of the system during the monitoring period showed no evidence of any liquid refrigerant entering the compressor. Increasing the superheat setting at part load would have resulted in lowering the evaporating temperature at both the part load and full load operation which would also reduce system capacity. Having the benefit of the climacheck system it was decided these were the optimum settings for ISCEON® MO99. With ISCEON® MO29 at part load the superheat was 4K and the expansion valve appeared to be controlling the refrigerant flow i.e. operating within the valve control range.

Figure 5 shows the calculated comparative cooling capacities at full and part load operation. At full load at the measured conditions the capacity of ISCEON® MO99 is 13.5% higher than ISCEON® MO29 and at part load measured conditions 7.8% higher than ISCEON® MO29 however as previously mentioned the conditions with the two refrigerants are not comparable.

Tables 1 and 2 show the average values measured and calculated for ISCEON® MO99 and ISCEON® MO29 during the selected operating periods. Also shown are the values if the ISCEON® MO29 operating conditions are adjusted to the estimated operating conditions for the same water in temperature.

Table 1 – Calculated System Performance At Part Load Using Measured And Estimated Operating Conditions

	Part Load		
	ISCEON® MO99	ISCEON® MO29	ISCEON® MO29 adjusted to same water temperature (%Δ)
Ref Comp in (°C)	5.8	6.0	7.8
Ref Low press. (Bar(g))	4.15	4.16	4.46
Ref Comp out (°C)	53.2	51.8	52.9
Ref High press. (Bar(g))	10.35	11.22	11.22
Ref Exp. Valve in (°C)	18.7	22.6	22.6
Ref Evap. out (°C)	5.8	6.0	7.8
Mean Evap. Temp. (ºC)	2.3	0.6	2.3
Evaporator Superheat (K)	1.0	4.0	4.0
Mean Cond. Temp. (ºC)	28.2	29.4	29.4
Condenser Sub-cool (K)	7.0	5.4	5.5
Capacity (kW)	111.70	102.93	109.73 -(2%)
C.O.P.	4.53	4.08	4.09 -(10%)

Cooling capacity calculated using 112 m^3/h compressor displacement part load, 90% volumetric efficiency, 7% compressor heat loss and isentropic efficiency calculated from measured compressor discharge temperature.

Table 2 – Calculated System Performance At Full Load Using Measured And Estimated Operating Conditions

	Full Load		
	ISCEON® MO99	ISCEON® MO29	ISCEON® MO29 adjusted to same water temperature (%Δ)
Ref Comp in (°C)	5.8	11.4	8.1
Ref Low press. (Bar(g))	3.65	3.54	3.04
Ref Comp out (°C)	64.9	68.9	73.2
Ref High press. (Bar(g))	15.79	15.39	15.39
Ref Exp. Valve in (°C)	23.9	31.1	31.0
Ref Evap. out (°C)	5.8	11.4	8.1
Mean Evap. Temp. (ºC)	-0.6	-3.1	-6.4
Evaporator Superheat (K)	4.0	13.1	13.1
Mean Cond. Temp. (ºC)	43.3	40.9	40.9
Condenser Sub-cool (K)	17.2	8.7	8.7
Capacity (kW)	177.17	153.33	134.81 -(24%)
C.O.P.	4.02	3.27	2.74 -(32%)

Cooling capacity calculated using 208 m^3/h compressor displacement full load, 90% volumetric efficiency, 7% compressor heat loss and isentropic efficiency calculated from measured compressor discharge temperature.

At the same water in temperatures the calculated cooling capacity of ISCEON® MO99 is 24% higher at full load and just 2% higher at part load than the estimated values calculated for ISCEON® MO29.

Conclusions

It is very clear from the measurements made that when using ISCEON® MO99 at the full load condition the expansion valve size is not a limiting factor and has been estimated to give 24% more cooling capacity than ISCEON® MO29 at the same water in temperature with an estimated 32% higher energy efficiency.

The strange behaviour with the compressor oil level variation was still evident but to a much lesser degree than observed with ISCEON® MO29. Under the operating conditions observed the compressor discharge temperature with ISCEON® MO99 was slightly lower than ISCEON® MO29 at full load which proves this parameter was not fully responsible for the fluctuation and so this observation is still unexplained. Another parameter which may be a factor is the density of the discharge gas which is much higher with both ISCEON® MO29 (+31%) and ISCEON® MO99 (+18%) than with R22 at the measured full load conditions. This may effect the oil separator performance and hence the oil level observed in the sightglass.

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The system was not monitored with R22 so it is difficult to assess the system performance compared to R22 but it has been established that the use of ISCEON® MO99 provides a greatly improved performance over ISCEON® MO29 at the full load condition without the need for any changes to the expansion valve.

Date of Conversion December 2008

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