R32 REFRIGERANT FOR AIR CONDITIONING CHILLERS

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INTRODUCTION

R410A which has a GWP of 2088 is the main refrigerant used as working fluid in commercial air conditioning and heat pumps for residential and commercial systems. It was introduced several years ago because of its good thermodynamic and thermo-physical properties.

The EU regulation phase-down is impacting the availability of R410A.The long-term scenario of the phase-down based on today consumption shows that the average GWP value of the refrigerants shall fall below 400. R32 is a candidate to replace R-410 in commercial comfort. It has a GWP of 675, good properties making it suitable to meet the minimum efficiency performance standards.

1 MAIN SECTION

Thermodynamic Properties

The R32 refrigerant has comparable properties to R410A. The normal boiling point and the critical temperatures are -51.7 °C and 78.1 °C. Table 1 shows the simulated refrigerant performance for both R410A and R32 at 5°C evaporation and 50°C condensing. For the same displacement compressor, the R32 mass flow is 31% lower. The cooling capacity and absorbed electrical motor power are respectively 13 and 8 percentage points higher, thus R32 efficiency is 4% superior.

	Displacement	Delta H	Mass Flow	Cap.	Power	EER	Discharge Temp.
R410A	100%	100%	100%	100%	100%	100%	-
R32	100%	155%	69%	113%	108%	104%	+ 22 K

Table 1 - Simulated Performance Comparison

1.1 Main drivers for R32

1.1.1 High system efficiency

Zilio et al. (2015) have theoretically studied the performance of a 74 kW reversible R410A chiller unit with R32 for both cooling and heating modes. Figure 1 summarizes the results of the unit when operating in cooling mode at the standard conditions as referred in EN14825. The R32 capacity is in the range of +6 % and the seasonal efficiency about +3%.

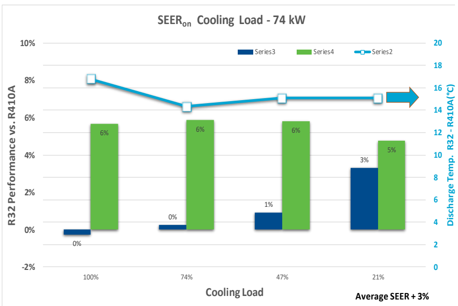

Figure 1 - System Performance

1.1.2 Lower GPW and system charge

Figure 2 shows a comparison of a 70-kW chiller with two different condenser geometries. The unit with a standard condenser tube 5/16” charged with R410A is the baseline. The same chiller unit was modified by replacing the condenser with a microchannel heat exchanger. As a consequence, the refrigerant charge decreases by more than 22%. When tested with R32, the charge of the same unit decreases by another 19%.

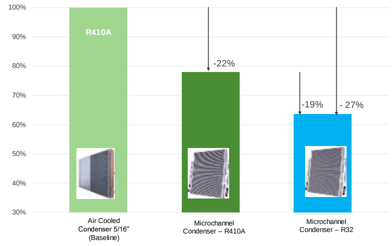

Figure 2 - Charge Reduction

1.1.3 Lower pressure drop

With the same cooling capacity, the lower mass flow rate of the R32 caused by the lower density induces less pressure losses. The figure 2 shows the measured pressure losses on a condenser finned-tubes air heat exchanger tested with R32 and R410A. These help to reduce the internal dimensions of the heat exchangers and potentially the pipes. This is associated with a lower refrigerant charge for a further reduction in the cost of the system, in both cooling and heating applications.

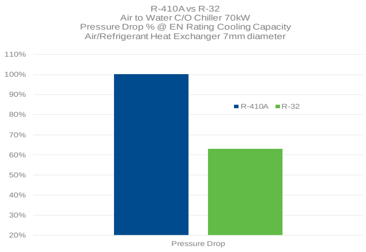

Figure 3 - Pressure Drop

The total equivalent CO_2 reduction with R32 is about 74% due to the lower GWP (-67%) and system charge (-20%). The applied cost of an R32 chiller should be lower than an R410A one as a consequence.

1.2 Main design changes

The properties of R32 related to pressure, cooling capacity, electrical motor power, discharge temperature and density require an optimisation of the scroll design as reported in the table 2. Therefore, the optimisation of the scroll compressor with R32 is necessary:

- to meet the R410A operating envelope,
- to improve the efficiency to meet the performances required by the Eco Design regulation EU 813/2013 and 2016/2281

R32 Properties changes	Design Features Impacted
Higher absorber Power	• Motor Torque
Higher Pressure	• Motor Torque & Bearing • Axial & Radial Compliances
Higher Discharge temperature	• Operating Map (Heating application)
Lower Mass flow	• Efficiency

Table 2 – Design features impacted by R32 properties

The main constraints limiting the application of a scroll compressor on the upper left corner of the map (figure 4) are:
- motor torque,
- scroll strength,
- discharge temperature,
- oil management,
- scroll compliance.

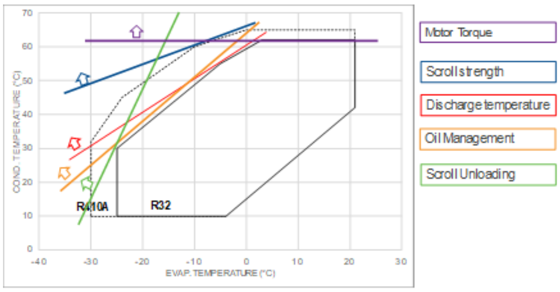

Figure 4 - Design Map Constraint

1.2.1 Oil injection

The oil quantity sucked inside the scroll with R32 is very low, which means the compressor runs with a very limited quantity of oil. This is a source of refrigerant leakage during compression, which leads to an increase of the discharge temperature and consequently to a drop of the compressor performances.
Figure 5 reports the discharge temperature at different rating conditions with oil injection and without.

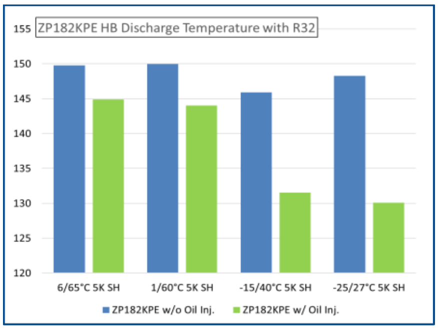

Figure 5 – Discharge Temp.

1.2.2 High built-in volume ratio (BIVR)

The discharge temperature at high pressure ratio increases with a small built-in volume ratio due to under compressed conditions. Figure 6 shows how the discharge temperature limit moves up with a higher built-in volume ratio. The efficiency with a high BIVR drops at low pressure ratio, thus the optimisation at low pressure ratio is mandatory to meet seasonal efficiency requirements.

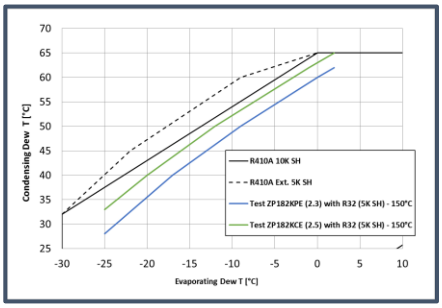

Figure 6 - Built-in Volume Ratio Influence

1.2.3 Variable volume ratio (VVR)

The Variable Volume Ratio is a configuration enabling multiple built-in volume ratios. A valve is used to enable the gas in the compression chamber to exit when it reaches the system discharge pressure. This is an important feature to achieve the seasonal efficiency required by regulations. Figure 7 shows the efficiency improvement at low pressure ratio with the VVR and at high pressure ratio with BIVR.

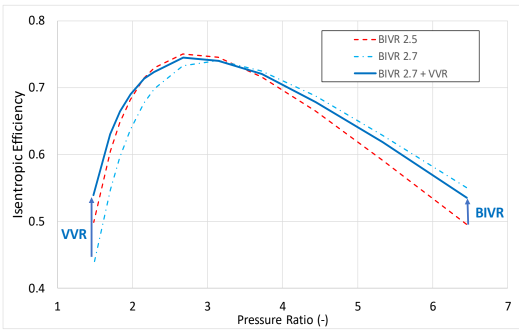

Figure 7 - VVR Impact on Scroll Efficiency

1.3 Results

1.3.1 Scroll compressor performance

Figure 8 summarises the COP of YP192, an optimised R32 scroll compared with ZP192 R410A scroll. The efficiency is better with R32. It is important to highlight the gain of efficiency at high pressure ratio.

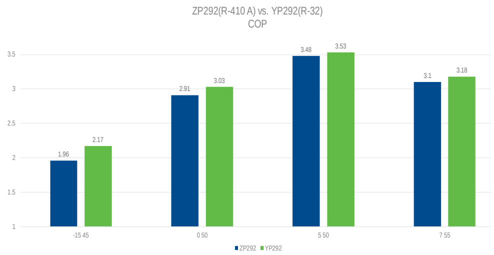

Figure 8 - COP of R32 and R410A Scroll

1.3.2 Map extension with discharge temperature control

The operating map for heat pump applications at extreme conditions can be further extended with the control of the discharge temperature. The discharge temperature is controlled by managing the suction superheat temperature by acting on the evaporator electronic expansion valve. The discharge temperature is limited to 145 °C with a tolerance of 5K for the high compression ratio, as shown in figure 9. This solution helps further extend of the operating map for the extreme conditions in heat pump applications.

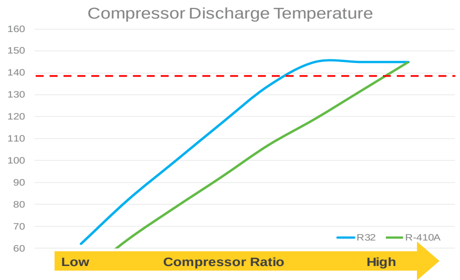

Figure 9 - Discharge Temp. Control

CONCLUSIONS

- R32 system efficiency is better due to thermodynamics properties.
- The low pressure drop and the lower system charge contribute to reducing the applied cost of a chiller designed for R32.
- The total reduction in CO_2 equivalent is approximately 74%.
- The high discharge temperature for R32 is manageable with a design optimisation of the scroll compressor. The control of the discharge line temperature helps to extend the map for extreme heat pump working conditions.
- The compressor efficiency with R32 is better than R410A.
- R32, for commercial chiller, is a low GWP solution in both cooling and heat pump applications.

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