NEW R744 102m^3/h TRANSCRITICAL COMPRESSOR: IMPROVING CO_2 PRESENCE INTO LARGE COOLING AND HEATING SYSTEMS

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ABSTRACT

The Dorin R744 transcritical compressor features the following technical solutions; the new compressor operates on 6 cylinders and boasts a 100/150 bar standstill pressure platform with max motor nominal power of 180 hp and 102.4 m^3/h displacement at 50 Hz. The design and materials allow for discharge temperatures up to 160°C, the use of both PAG or POE oils (subject to system design), and a generous application envelope with extended pressure ratios. Use of this new platform pairs the environmental benefits of using CO_2, a natural refrigerant, with a reduction in the number of compressors required to run larger systems.

Figure 1. The new compressor platform: up to 102 m^3/h and 180 hp

1. INTRODUCTION TO THE PAPER

R744 has increased worldwide due to the excellent heat transfer properties and high volumetric capacity. R744 is considered a long-term, economic, environmentally sustainable solution in large refrigeration systems and heat-pumps. The purpose of this study is to demonstrate the mechanical technologies adopted in the new machine. Innovative solutions never previously seen in the refrigeration industry that offer clear advantages to the use of R744 in large applications. Below is just an example of how R744 Heat Pumps can make an environmental difference in highly efficient heat pumps in the future:

SYSTEM DATA

compressor model: Dorin CD6 180 102H		
Evaporating temp:	-5	°C
Gas-cooler pressure	110	bar
Gas-cooler out T	45	°C
Disch. Temp	119	°C
super-heating	10	K
Cooling Capacity	205,2	kW
Gas Cooler Heat Rejection (heating power)	350,9	kW
Power input	143,8	kW
COPr	1,43	
COPh	2,44	

EFFICIENCY ANALISYS

GAS heating boiler general efficiency	90%	
Electric production efficiency (turbogas-cogenerative)	62%	
GAS POWER USED FOR PRODUCING 350kW		
GAS BOILER SYSTEM	389,8	kW
R744 HEAT PUMP SYSTEM	231,9	kW
ENERGY SAVING WITH R744 HEAT PUMP	-40,5%	

references
https://www.theheatinghub.co.uk/boiler-efficiency-guide-and-energy-saving-tips
https://www.ge.com/power/about/insights/articles/2016/04/power-plant-efficiency-record

2. COMPRESSOR DESIGN SPECIFICATIONS

2.1 6 CYLINDERS

The 6 cylinders solution is minimizing the number of components in the compressor and reducing the length of the shaft for optimum lubrication and mechanical stress. The 6 cylinders pattern is ideal for balancing the masses in motion as we have pumped gas every 60° on the shaft. Minimizing the number of components was critical for the MTBF analysis; fewer components mean less components possible failures, yielding longer MTBF values. The 6 cylinders technology has also decreased the ratio between the areas with friction and swept volume when compared to compressors with more cylinders, similar displacement and smaller cylinders diameters.

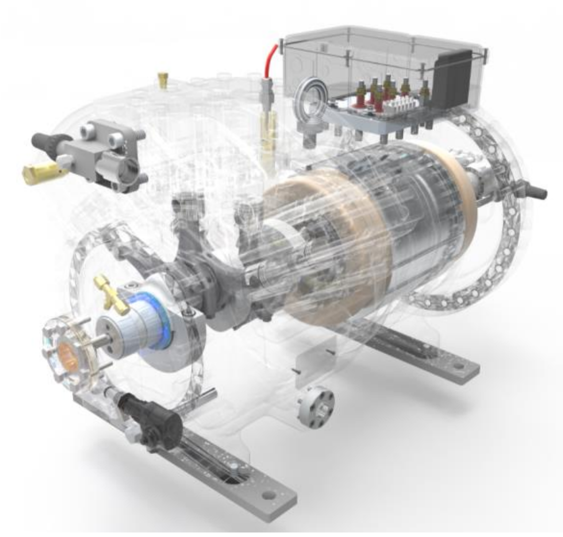

Figure 2. 6 cylinder new platform: less components, longer lifetime

2.2 EXTERNAL MANIFOLD

Typically, refrigeration compressors feature an internal discharge manifold, which is physically inside the compressor housing. The heat from the discharged gas is exchanged to the oil sump and the oil is washing the hot internal surfaces. This is bringing to a reasonable increment of the oil temperature in the oil sump.

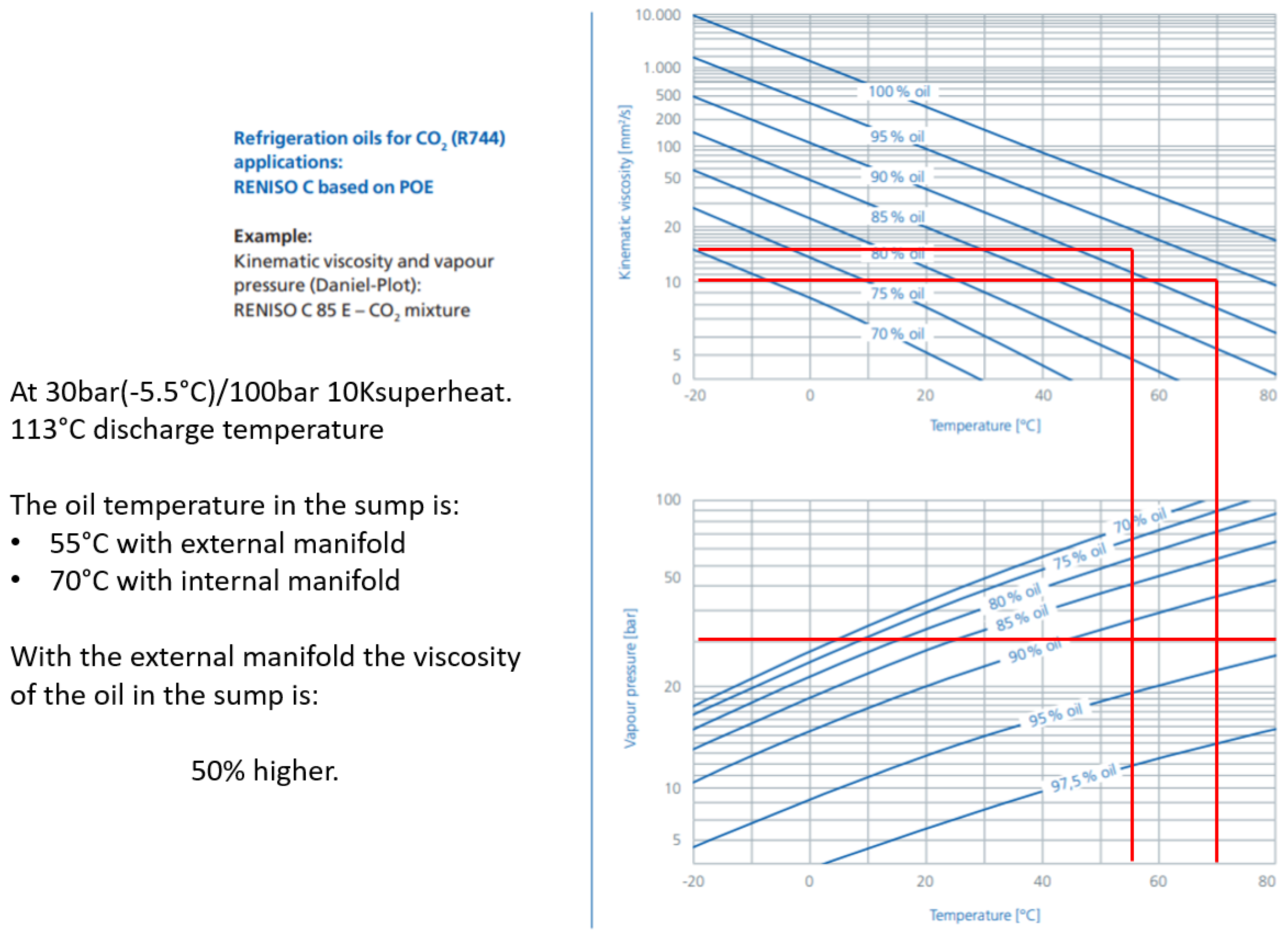

Figure 3. @30/100 bar the viscosity of the oil is double with the external discharge manifold
References for the Daniel chart: Fuchs Reniso C 85 E. Reference Dorin Lab and:
https://www.fuchs.com/fileadmin/schmierstoffe/Prospekte/Brochures_EN/Product_brochures_industry/Refrigeration-Oils.pdf

The external discharge manifold allows the unit to keep reasonable oil temperatures and viscosity even when discharge temperatures are high, which in our case can reach 160°C. The external manifold plenum is larger and helps to eliminate pressure pulsations in the discharge line. The main advantages secured by the external discharge manifold are:

- Higher pressure ratios allowed
- Higher oil viscosity
- Longer compressor lifetime
- Larger application envelope
- Less gas pulsation in the discharge

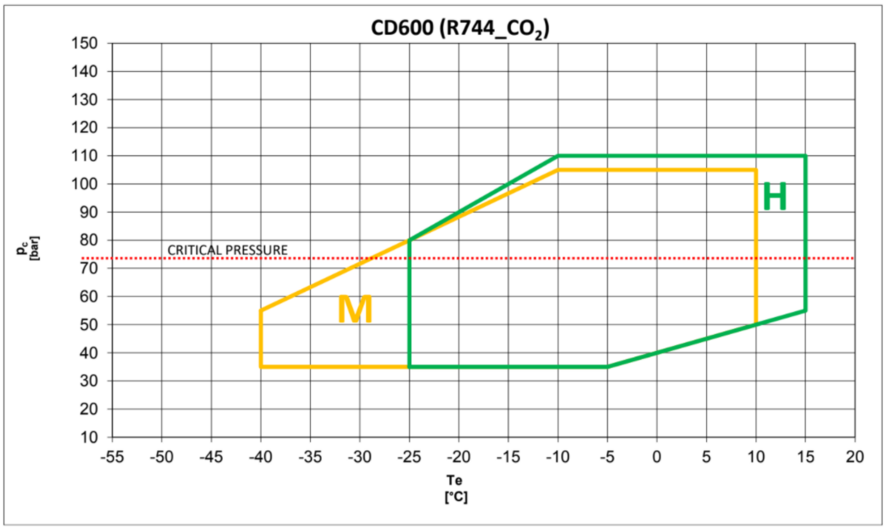

Figure 4. The application envelope from Dorin Selection Software

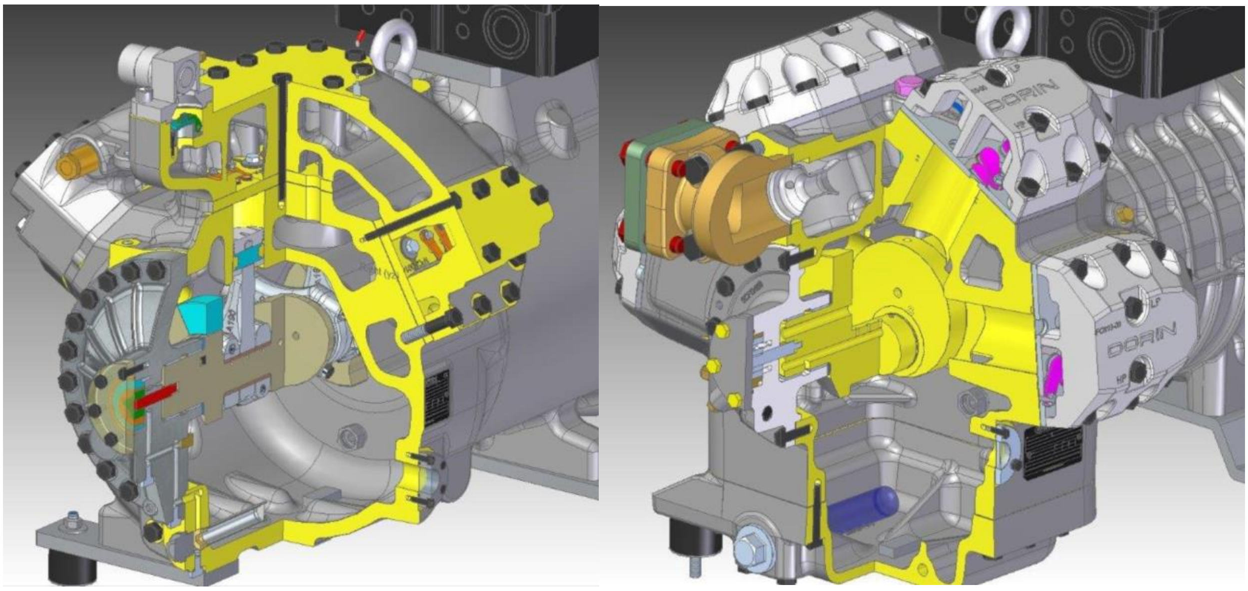

Figure 5. Benefits of the external manifold (left) compared to a standard design (right). Dorin property

2.3 PISTON AND CONNECTING ROD

When using R744 with high pressure ratios, like in refrigeration or heat pumps applications, pistons can easily reach 100-150°C temperatures. We chose to manufacture our pistons in cast iron with surface treatment instead of aluminium, which is more widely used. Cast iron is having a thermal expansion coefficient that is about half that of aluminium. This is granting the correct gap between the pistons and the cylinders when running at high discharge temperatures. Additionally, cast iron is having an Brinell hardness coefficient of about 250 compared to the aluminium which is around 100; the outcome is a lower friction and reliability in case of high specific loads and scarce lubrication, i.e.: during temporarily drops of the oil viscosity during the compressor starts. Vibrations are not affected by this solution as the compressor bodies are generously sized and the shafts balanced individually.

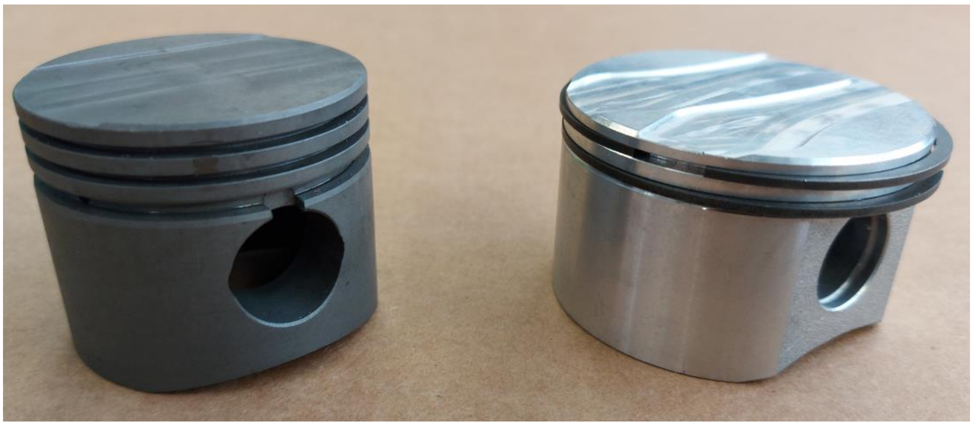

Figure 6. Cast iron pistons have about double the surface HB hardness of the Aluminium ones and expand Half due to the thermal expansion. Photo: Dorin property

2.4 LUBRICATION

Lubrication is done via a volumetric pump pressing the oil through the lubrication channels allowing high specific loads up to the piston pin. Additionally, a patented oil containment system is engineered on the shaft for virtually eliminating the oil throw to the suction side. According to laboratory analysis we have seen that the new patented oil containment system allows a discharge oil throw reduction that is varying from the operating conditions, oil type (POE or PAG) and compressor age and it is up to -80% when compared to the same compressor without the new pattern.

2.5 CONCLUSIONS

The new compressor pattern and size allows the use of R744 in large refrigeration and heat pump systems; indirectly it permits to increase the efficiency of heating and refrigeration systems by the use of a natural, not toxic, not flammable refrigerant fluid. The compressor mechanical features, presented in this paper, permit to work with high differential pressures values and ratios, high discharge temperatures and with a reduced oil carry over. The new large compressor size allows to reduce the number of compressors in large R744 applications making the new solutions economically more viable.