Climate change: melting glaciers, diminishing water resources, trapped sunrays increase global warming

LARGE TRANSCRITICAL CO2 COMPRESSOR

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LARGE TRANSCRITICAL CO_2 COMPRESSOR FOR BIG COOLING CAPACITIES

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Abstract

The use of carbon dioxide is nowadays considered one of the most suitable mainstream solution to avoid the use of high GWP refrigerant.

However, while is adoption in commercial refrigeration application is already widespread, this refrigerant is not yet considered as a standardized solution for larger equipment such as refrigerated warehouses, process cooling, light industrial applications, etc.

One of the main reasons for this is the lack of adequate components, including compressors. This work deals with new CO_2 compressors ranges which have been developed starting from commercially-sized compressor platform, but providing much larger capacities to cover those applications where industrial compressors have been adopted in so far.

Keywords

CO_2, Carbon dioxide, industrial refrigeration, low GWP, natural refrigerants.

1. Introduction

Semi-hermetic commercial piston compressors have emerged on the market for some peculiarities that make it easy to install such as: the presence of the electrical motor and the compressor in the same casing makes it easy to contain eventual leaks even with high operating pressures typical of applications with CO_2, cooling down the electrical motor with the suction gas allows for obtaining high specific powers, the lubrication system is included in the same body, no motion transmission elements are required since all the components are mounted solidly on the same shaft, they are easy to install in parallel on a rack, do not require any special procedure for startup or stop.

At the same time, they maintain the performance over time and require minimal maintenance: the elastic iron piston rings are able to provide excellent grip even with high differential pressures and allow to compensate the cylinder wall wear even after many hours of operation, valves are controlled only by pressure forces, do not need adjustments or regulations over time, and there are practically not subject to wear.

The use of CO_2 compressors is characterized by high operating pressures and higher discharge temperatures than those of synthetic refrigerants, in addition, the high volumetric refrigerating capacity dramatically limits the displacement. All these peculiarities of CO_2 bring decisive advantages in the use of piston compressors in comparison with other technologies like screw and scroll.

2. State of the Art

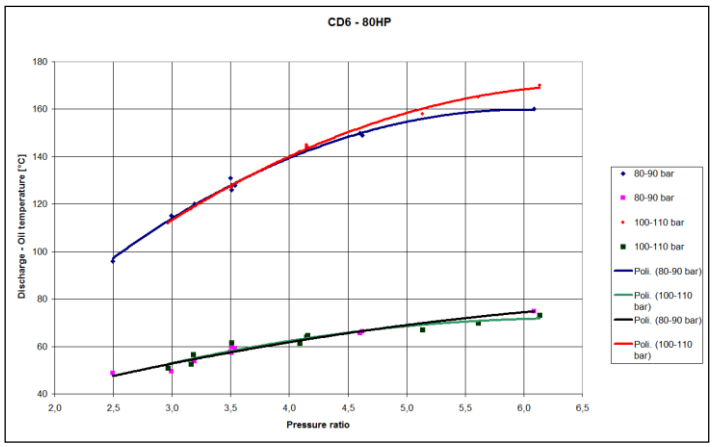
Over the last 7-8 years, the most important semi-hermetic compressor manufacturers have developed their own range of CO_2 compressors. Starting from typical powers of commercial refrigeration, the potential of CO_2 compressors has gradually increased, up to today, when we can find available compressors on the market with up to 50 HP nominal power and displacement volumes <40 m^3/h @50 Hz. This situation involves a limitation in racks construction with an impressive number of compressors needed and with high installation costs. Below one of the most recent case studies is taken as an example.

It is a cold warehouse where a cooling capacity of 1,1 MW is required at MT (medium temperature -5 to 0°C). These are systems in which the thermal load varies very slowly over time and does not require too much seasonal load variations. With the CO_2 compressor models, available now on the market, it is necessary to build two refrigeration racks with a total of 10-12 compressors, depending on the volume selected. With the new range of CD500 6-cylinder transcritical CO_2 compressors developed by DORIN, we can cover the same cooling capacity with one single rack and only 6 compressors, with obvious benefits in terms of space requirement and installation costs.

3. Large Transcritical Co_2 Compressors for Big Cooling Capacity

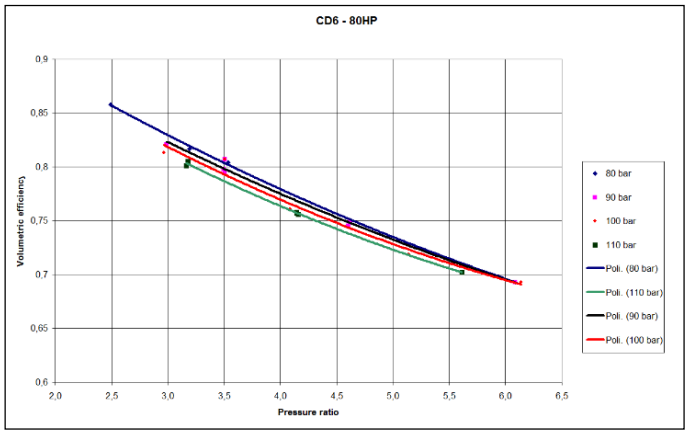
The increase in the swept volume and the high differential pressures involved, led to the need to switch from 4 cylinders to 6 cylinders in order to avoid having to use too large boreholes. As with the actual DORIN transcritical CO_2 range of compressors, it was decided to confine the refrigerant after compression, to a generously sized discharge plenum outside the compressor casing, that acts like a buffer before discharging the high pressure CO_2 (Figure 1). This limits the heat transfer between the high temperature zone and the rest of the compressor; and it was proved by inhouse functional tests. Moreover the validation of the project have confirmed that this solution allows to maintain the overall thermal level and the temperature of the lubricating oil at acceptable values even under high compression ratios.

Figure 1 - External plenum to permit optimum heat rejection



The diagram in Figure 2 shows the oil temperature curves and the discharge temperature when changing the compression ratio and the evaporation pressure.

Figure 2 - Oil and discharge temperature at different pressure ratio

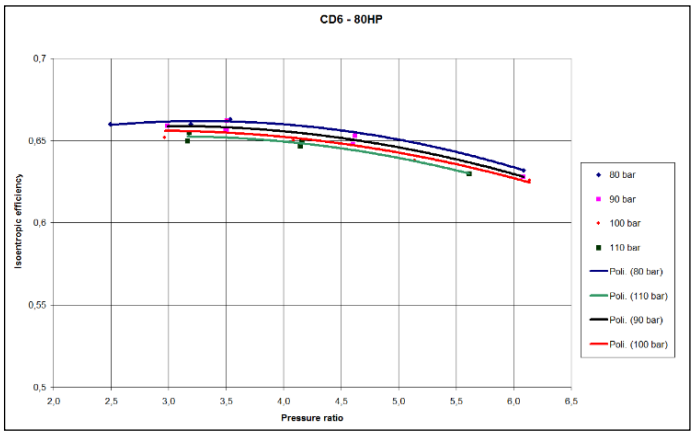


Functional checks have also shown that compressors with the typical commercial refrigeration structure can also be applied up to 100 Hp electrical motors, with values of volumetric and isentropic efficiency comparable to actual CO_2 transcritical compressors on the market. Diagrams 3 and 4 show values measured on an 80 HP model.

Figure 3 - Volumetric efficiency

The compressor design has also privileged the standardization of external pressure parts on an extended range of cylinders with suitable project not only for refrigeration but also for heat pumps. Considering the installed power, the size of the compressors is quite small, allowing a considerable saving in space allocation and relative costs.

Figure 4 - Isentropic efficiency



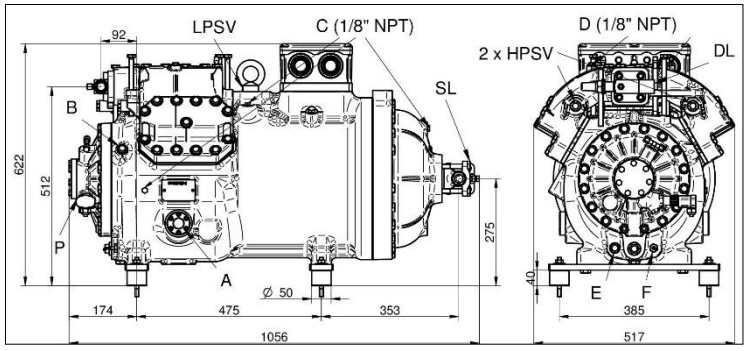


Figure 5 shows the overall dimensions of CD500 range of CO_2 compressors. In table 1 we have the entire CD500 range with nominal HP values and displacement volume at @50 Hz.

Figure 5 - CD500 overall dimensionancy

4. Conclusions and Further Developments

Range Serie	Model Typ	Displacement Fördervolumen 50 Hz [m^3/h]	HP
CD 500	CD6 500-40B	39,85	50
	CD6 600-40M	39,85	60
	CD6 700-40H	39,85	70
	CD6 500-45B	45,34	50
	CD6 700-45M	45,34	70
	CD6 800-45H	45,34	80
	CD6 500-53B	53,21	50
	CD6 800-53M	53,21	80
	CD6 800-59M	59,53	80
	CD6 700-99B	98,58	70

Table 1 - CD500 displacement and nominal HP

Nowadays the first few dozens of the new CD500 range have been in operation since some months; results from the field show extreme compressors quietness and smooth operation, leading end users to look at CO2 as a very interesting alternative for light industrial applications (capacities up to 1.5 MW*). Nevertheless, the very large specific capacity featured by CO2, makes it possible to develop even larger compressors platforms, still pertaining to commercial refrigeration sector, but ending up in capacities up to 200 kW* per compressor. As a matter of fact, Officine Mario Dorin is already developing such kind of models which will soon be qualified and field tested.

(* Data at typical MT conditions, -10°C / 90 bar / 35°C T_{GCOUT}).