



where

Carrefour Lombardy, Piedmont, Valle D'Aosta (northern Italy)

what

Carrefour supermarkets

- compressor racks by Enex
- installation by RefSystems – REF MILANO
- electronics by CAREL

why

Full-green solution

- natural refrigerant
- booster solution
- integrated parallel compression
- high efficiency heat recovery

when

2013-2015

Natural refrigeration: Carrefour on CO₂ with CAREL

Full-green compressor racks in Carrefour supermarkets in northern Italy

Thanks to the partnership between Carrefour, RefSystems and REF MILANO, Enex and CAREL Industries, around a dozen fully green supermarkets have been developed in northern Italy, using carbon dioxide as carbon dioxide as the refrigerant for cold food storage, and exploit the most advanced technologies for energy efficiency, such as parallel compression and heat recovery.

Carrefour has been committed to replacing its HFC systems, first with hybrid CO₂/R134a solutions (33 installations using subcritical CO₂), and then with refrigeration systems that only use CO₂. Since 2011, 18 transcritical CO₂ Supermarkets have been developed (either new or retrofit) by the Carrefour group, 16 of which exploit CAREL technology.

FORMAT	STORE	SQ.M SALES	YEAR	SYSTEMS	CAB-INETS	COLD RMS	Type of system	HEAT RECOVERY
HYPER	AOSTA	6150	2013	1	87	11	BOOSTER - 2 temperature levels	DOUBLE STAGE
MARKET	AOSTA	1150	2013	1	31	9	BOOSTER	SINGLE STAGE
HYPER	GALLARATE MALPENSA	3600	2014	1	63	12	PARALLEL COMPRESSION	DOUBLE STAGE
MARKET	MI CORSO LODI	2000	2013	1	49	9	PARALLEL COMPRESSION	SINGLE STAGE
MARKET	MI PZZA ANGILBERTO	900	2013	1	27	8	PARALLEL COMPRESSION	DOUBLE STAGE
MARKET	MI PZZA GRAMSCI	1100	2014	1	38	8	PARALLEL COMPRESSION	SINGLE STAGE
DOCKS	NICHELINO	6650	2015	2	94	22	PARALLEL COMPRESSION	DOUBLE STAGE
HYPER	CARUGATE	15400	2015	2	214	26	PARALLEL COMPRESSION	DOUBLE STAGE

Success Story



The main partner in this project is Enex, a company specialising in the design and development of high efficiency refrigeration systems operating on natural fluids. Enex was founded in 2004, and since the beginning has dealt with the development of efficient and advanced refrigeration systems, specifically using the CO₂. The experience it has acquired in over 600 transcritical installations has allowed Enex to become a leader in CO₂ refrigeration units.

Enex has brought many innovations to the refrigeration sector, introducing and perfecting the use of systems with auxiliary compressors, featured in most of the Carrefour installations in question. The purpose of parallel compression is to increase the efficiency of systems that use CO₂ refrigerant by up to 15%, and above all making CO₂ refrigeration systems also suitable for operation in warmer climates. Fundamental in the construction and installation of these systems was the work performed by RefSystems and REF MILANO, refrigeration system installation and maintenance companies, which managed and coordinated the changeover in technology and refrigerant.

RefSystems and REF MILANO are part of a group specialising in high efficiency food cooling solutions. Founded in 2009 (RefSystems) and in 2012 (REF MILANO) with the intention of creating dynamic new businesses at the cutting-edge in the field of refrigeration, the two companies are constantly focused on new technologies aimed at ensuring energy saving and care for the environment. Their teams comprise highly qualified technical personnel with decades of experience in the sector, allowing the companies to immediately establish ongoing partnerships with the main retail chains in Italy. RefSystems and REF MILANO can in fact develop cutting-edge systems

that exploit the best energy saving technology, respecting the environment and simplifying maintenance, with special emphasis on transcritical CO₂ systems with heat recovery and air-conditioning.

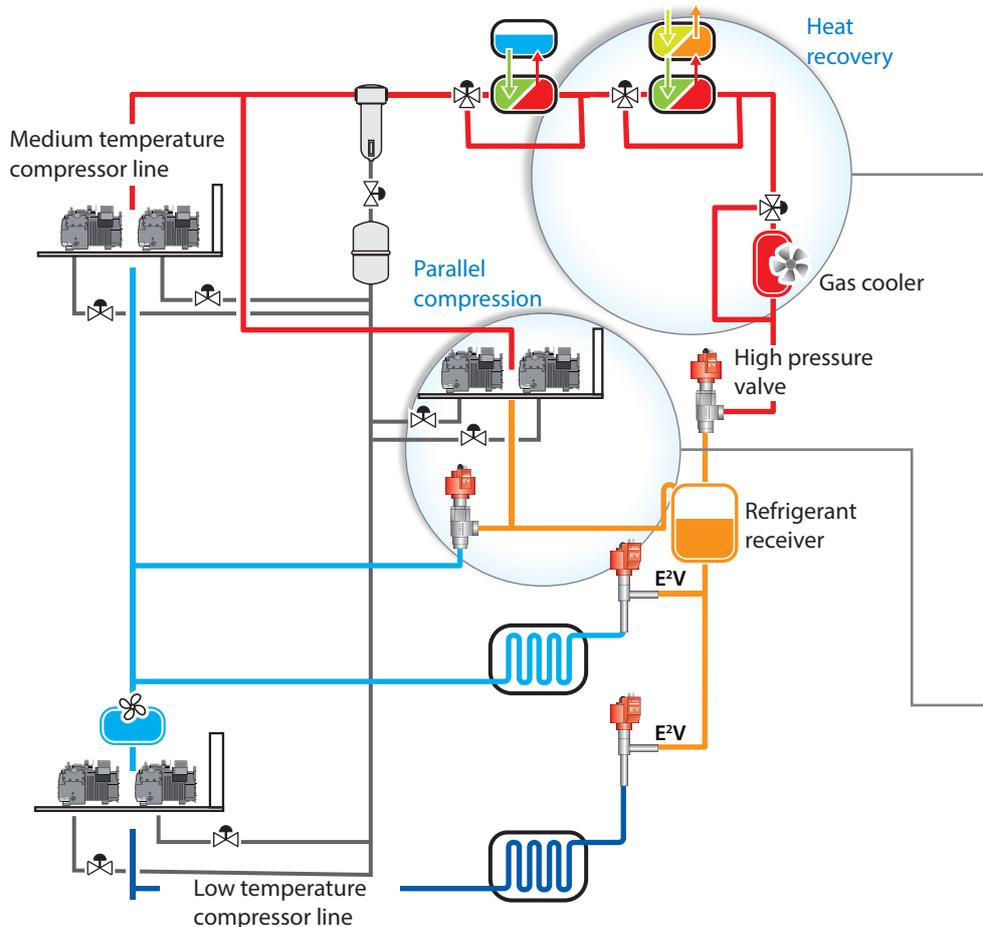
System description

The compressor racks are transcritical CO₂ booster systems, in which the low temperature (-35°C) compressor discharge is first cooled by an intercooler, and then delivered to the medium temperature suction line (-10°C).

The number of compressors on each line, managed by the CAREL pRack controller, can vary in the different systems, from a minimum of two to a maximum of six compressors.

The compressor discharge on the medium temperature line flows into the high pressure line, where a system of heat exchangers (up to three) provides for heat recovery in two stages, firstly for domestic hot water and secondly as room heating. Both stages are managed directly by the CAREL pRack board, at the same time calculating the heat recovery requirement, and controlling the opening of the 3-way valves and operation of the water circulating pump.

The CAREL pRack controller manages temperature control of the gas cooler, featuring EC fans. It does this by monitoring the heat exchanger outlet temperature, with the possibility to adjust the control set point based on variations in outside temperature (floating condensing pressure function) or based on the heat recovery requirement. The HPV valve is controlled based on pressure, with the set point calculated considering the gas cooler outlet temperature, aiming to



Heat recovery parallel compression focus inside a typical installation scheme (Transcritical CO₂ booster system)

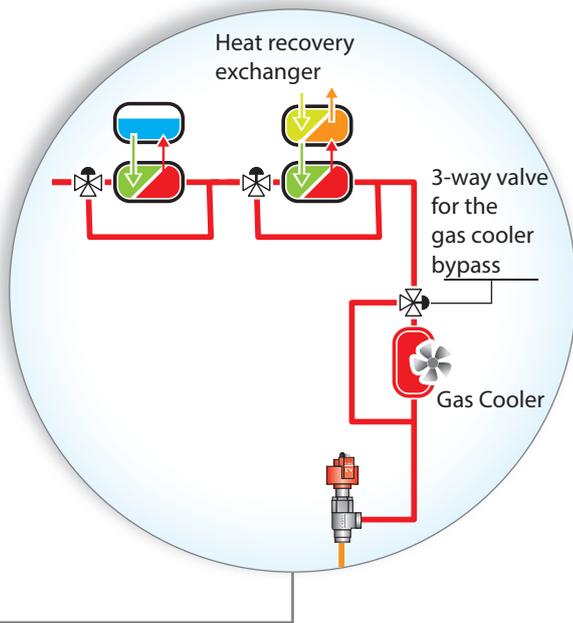
achieve the optimum pressure for compressor rack COP in transcritical conditions, or the ideal subcooling level in subcritical conditions, with the possibility to increase the minimum value of the set point if needed for heat recovery.

The liquid receiver normally works at around 35 barg (2°C) and the flash valve controls the pressure inside the receiver (safety valves calibrated at 45 bars).

In most of the systems developed, there is also an additional parallel suction line, able to compress the flash gas directly, starting from the intermediate pressure in the receiver, thus avoiding to need to expand

it at lower pressures. This action in fact reduces compression work at high ΔP that would otherwise be necessary, bringing energy benefits (in terms of COP) in typically demanding conditions (such as ambient temperatures of 30-35°C) of around 15%. The auxiliary compressor is therefore fundamental for compression of the flash gas in mild climates such as in Italy.

From the CO₂ liquid receiver, the lines branch off to the medium temperature and low temperature units (cabinets and cold rooms).



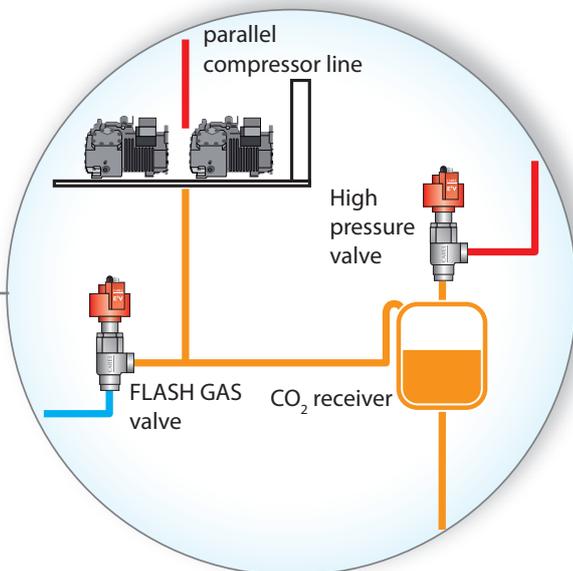
Details of heat recovery

In a CO₂ booster system, the heat recovery (or heat reclaim) function exploits the heat normally rejected by the gas cooler for domestic hot water production or space heating.

The CAREL controller for transcritical CO₂ solutions can manage two heat recovery functions at the same time (water or air), allowing the activation of two 3-way valves on the heat exchangers.

The same controller manages the flow of water (for a CO₂-water heat exchanger) by controlling pump speed and activation based on actual heat recovery requirement, rather than water outlet temperature.

For the purpose of energy efficiency, it is fundamental to be able to act on the high pressure valve set point and the effective gas cooler set point. The controller can also bypass the gas cooler through modulating control of a third 3-way valve. Once bypass is enabled, the controller determines the new temperature for controlling the gas cooler and consequently calculating the high pressure valve set point downstream of the 3-way valve.



Details of integrated parallel compression

In a transcritical CO₂ booster system, CO₂ receiver pressure control is fundamental, with the CO₂ in the liquid state at the bottom part of the receiver and in the gaseous state at the top. The excess gas is removed through the expansion valve, called the flash gas valve or RPRV (Regulating Pressure Receiver Valve), so as to keep a constant intermediate pressure (around 35-38 barg).

This valve will work with greater frequencies and at higher opening percentages in the warmer periods of the year and in temperate climates, such as in Italy, forcing the medium temperature compressors to work not so much to meet actual cooling demand as to maintain a stable pressure inside the CO₂ receiver.

The use of a compressor, or group of compressors, installed between the receiver and medium temperature compressor discharge line, offers the following advantages:

- reduced use of the RPRV valve;
- higher efficiency at high pressure in the gas cooler;
- higher efficiency at high outside temperatures.

Activation and regulation of the parallel compression function depends mainly on thermal load and on the working conditions thanks to a special algorithm.

Description of the pRack pR300T with built-in driver and E³V-C high pressure valves:

pR300T is the ideal controller for the management of carbon dioxide booster systems.

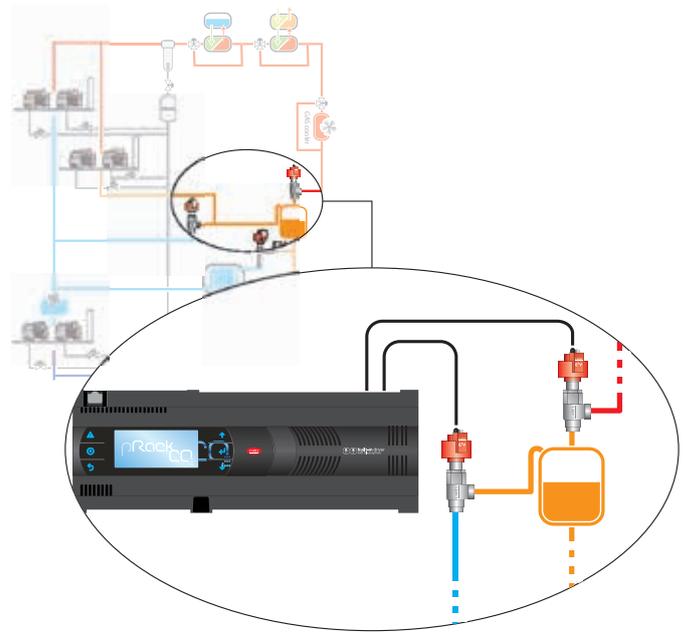
The new pRack pR300T platform offers the transcritical CO₂ market an extremely high performance product that assists the user managing intrinsically complex units:

- complete management of transcritical CO₂ systems on a single controller;
- simple and intuitive user interfaces (can be customised);
- easy access to supervisor systems;
- easy access to programming (USB host and device).

The main features that make CAREL controllers unique on the market are:

- integrated management of a third suction line for parallel compression;
- direct management of high pressure and flash gas valves.

Also fundamental for control is integration of the stepper expansion valve driver, meaning no external driver is needed to manage the valves. Ultracap technology, finally, maximises system safety.



Conclusions

In recent years, the main focus of supermarket chains has shifted to natural refrigeration systems, and Carrefour is certainly one of the pioneers and promoters of CO₂ in commercial refrigeration applications. RefSystems and REF MILANO have proven how the Italian market is ready to use this type of technology, even from a viewpoint of return on investment.

Cutting-edge compressor racks, such as those developed by ENEX, allow customers to invest and put their faith in refrigeration systems that use carbon dioxide refrigerant.

CAREL control technology is designed to achieve reliability and efficiency with this type of system, especially in climates with hotter temperatures than in northern Europe.

CAREL solutions can also help less expert users to interact with these types of systems, and are the most promising solutions in terms of reducing CO₂ emissions in the commercial refrigeration sector.



Headquarters ITALY

CAREL INDUSTRIES Hqs.
Via dell'Industria, 11
35020 Brugine - Padova (Italy)
Tel. (+39) 0499 716611
Fax (+39) 0499 716600
carel@carel.com

Sales organization

CAREL Asia Ltd.
www.carel.com

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