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Improving the energy efficiency of carbon dioxide commercial refrigeration systems

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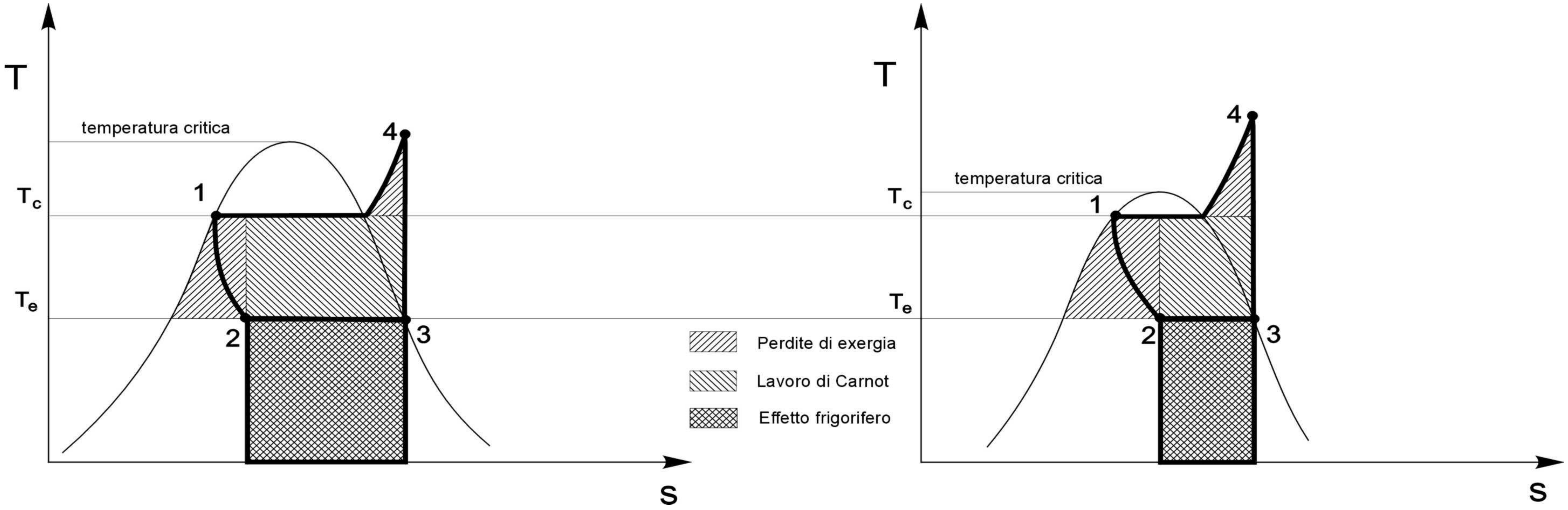
SCM FRIGO refrigerating systems

- SCM FRIGO SPA is located in Italy, near Venice (25 miles) MADE IN ITALY
- We are leading OEM manufacturer of CO2 systems, with more than 1800 Transcritical racks installed in 25 countries
- Co2 Running plants in Europe, South America, Africa, Australia **(2)**, New Zealand **(6)**
- 110 People, 7% R&D
- In 2017 we expect to deliver 450 CO2 racks plus more than 500 CO2 condensing units
- SCM FRIGO is a Beijer Ref company, we export CO2 systems to all the world BEIJER REF

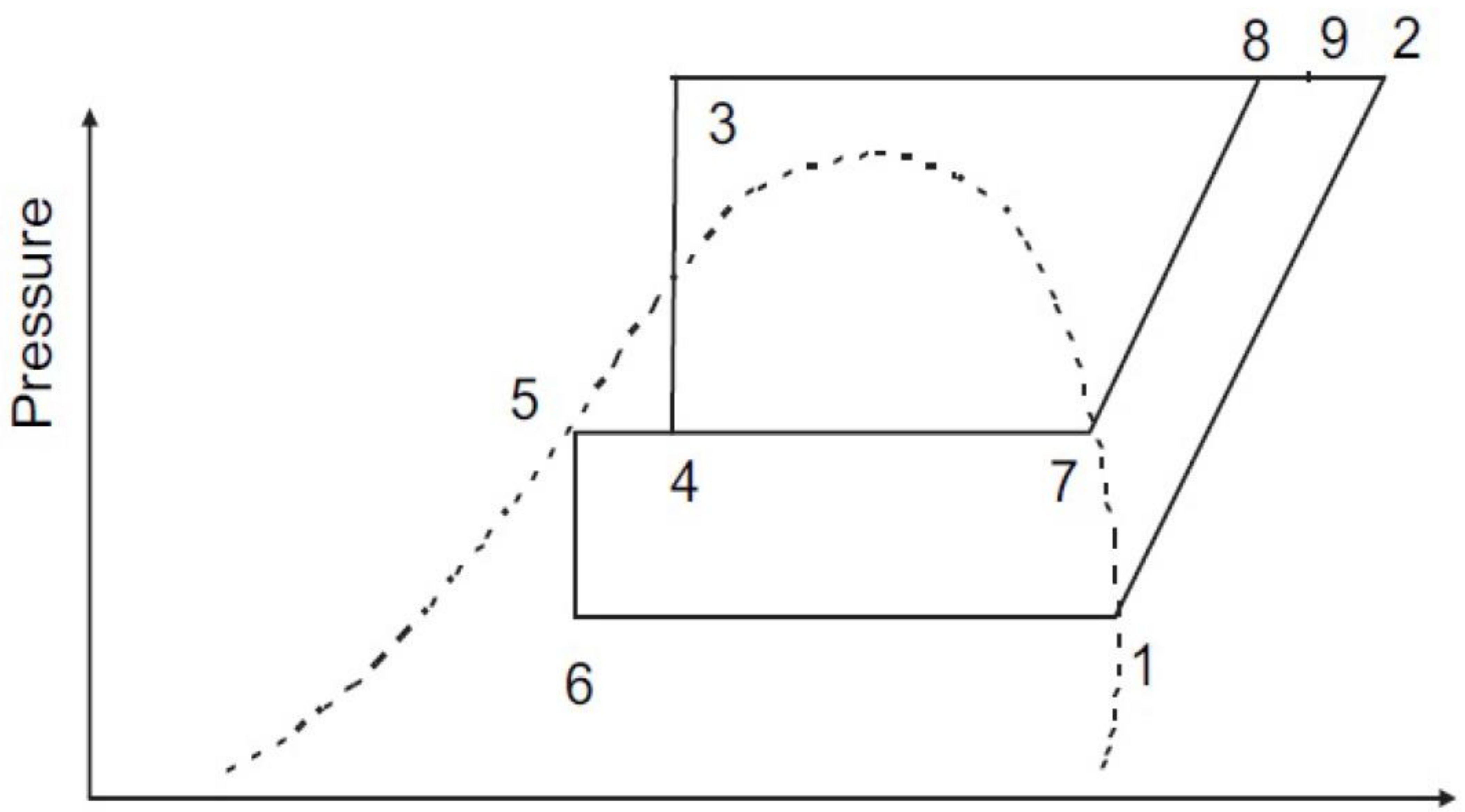
Transcrtitical Cycle

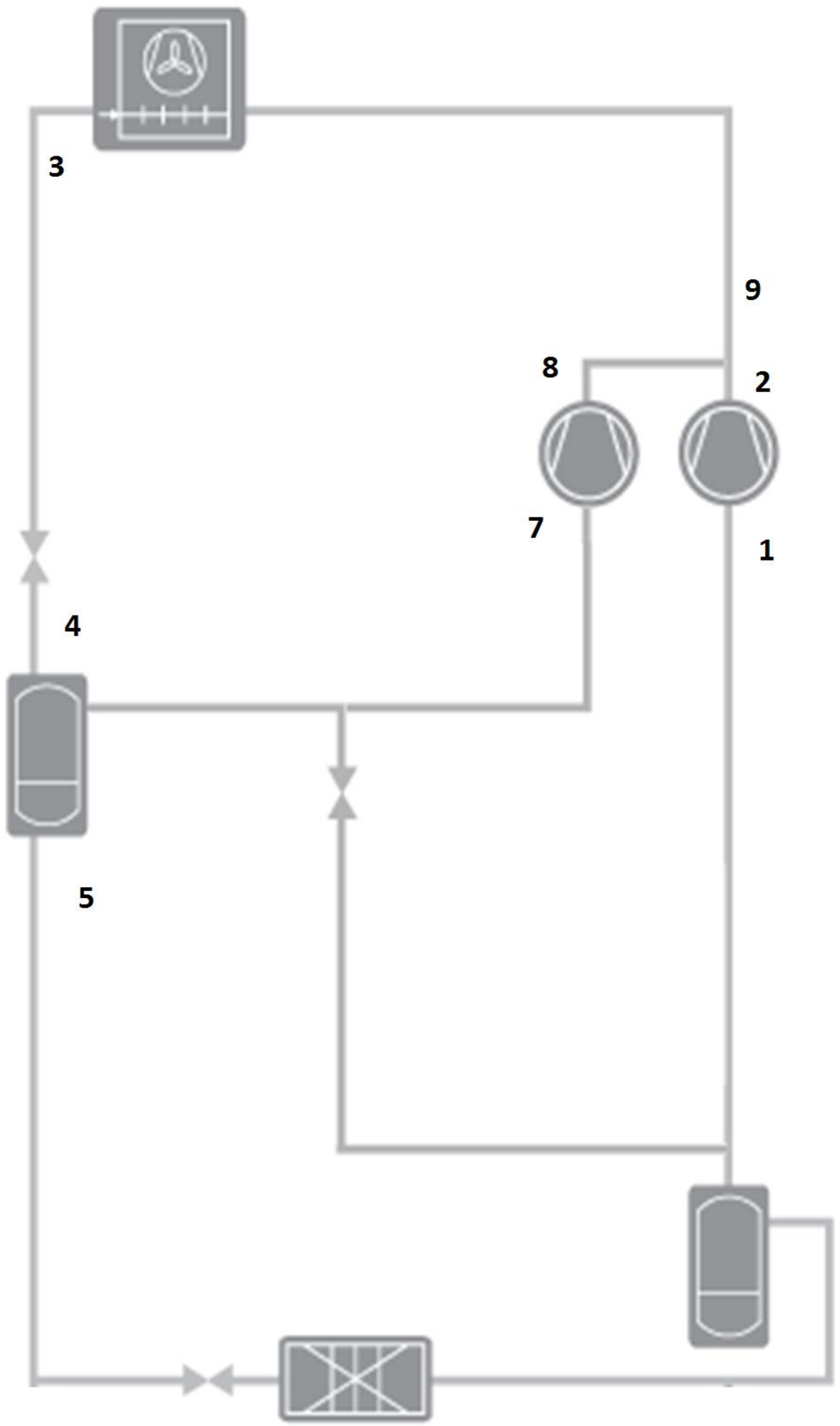
The use of CO_2 as the sole refrigerant has been mainly limited to temperate climates; as a matter of fact, both efficiency and refrigeration capacity of the transcritical single compression cycle undergo a rapid deterioration in hot climates.



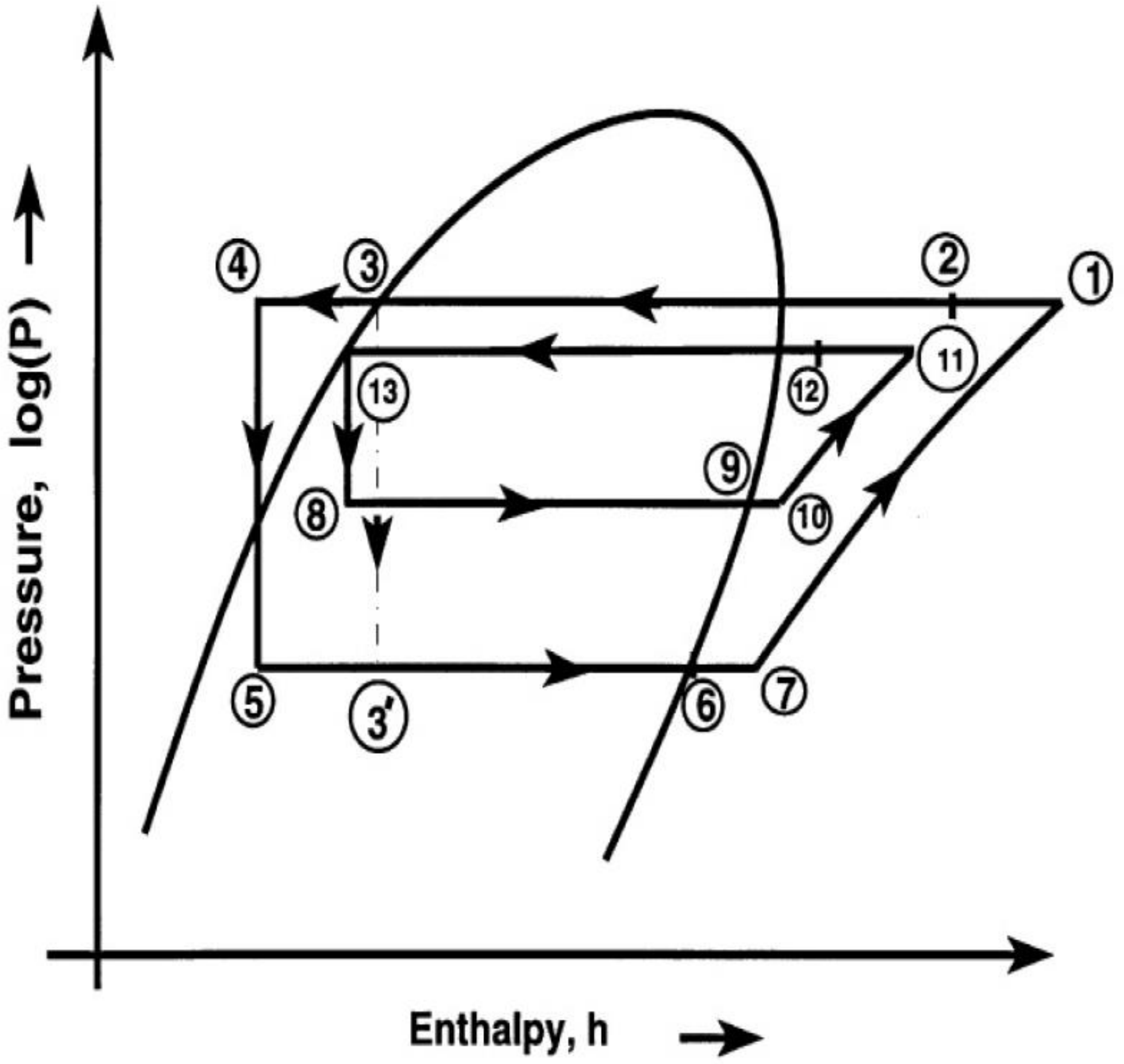
Improved cycles have been proposed to enhance efficiency and cooling capacity at high ambient temperature mainly reducing exergy throttling losses.

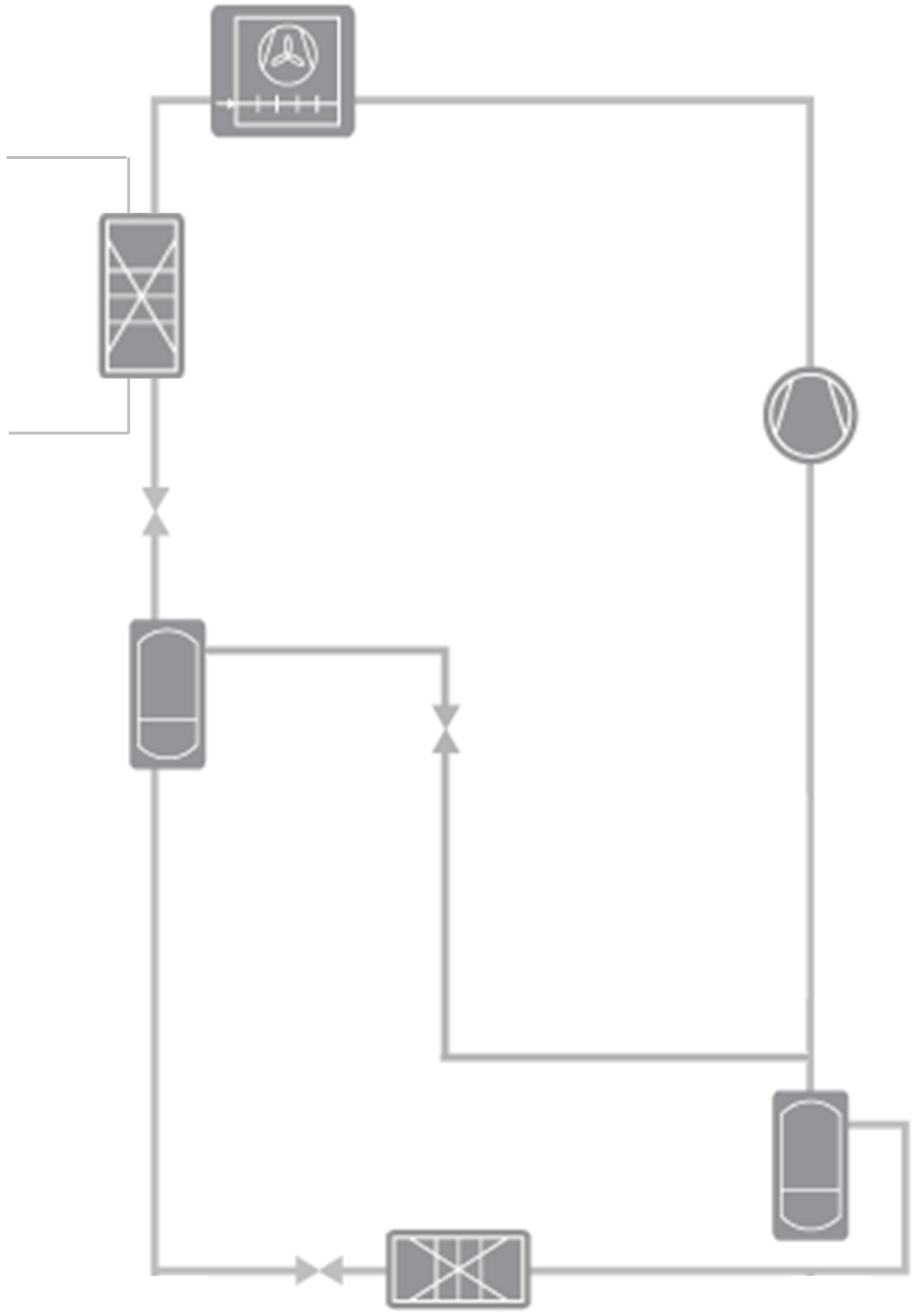
Reducing throttling losses: Parallel compression



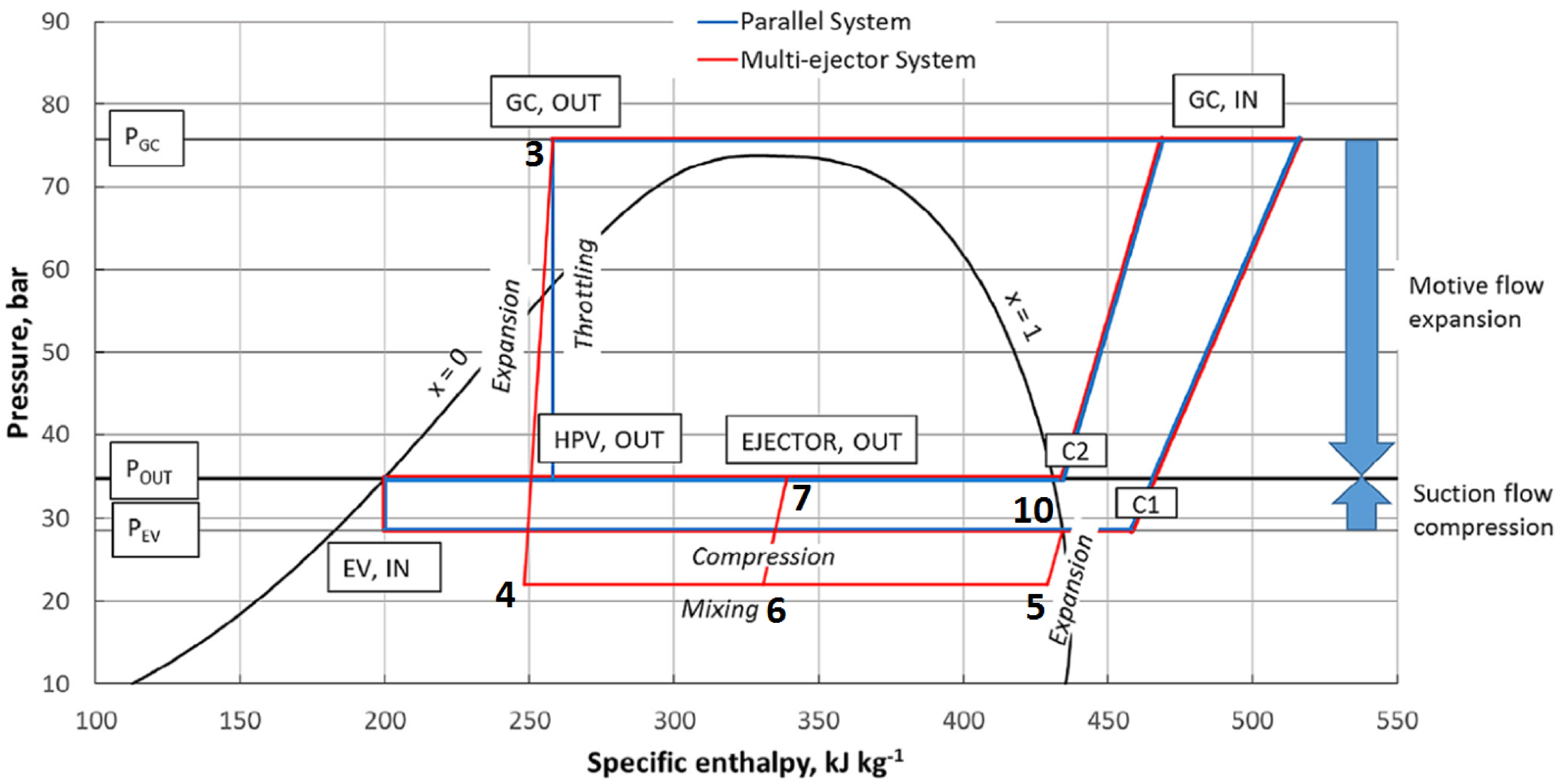


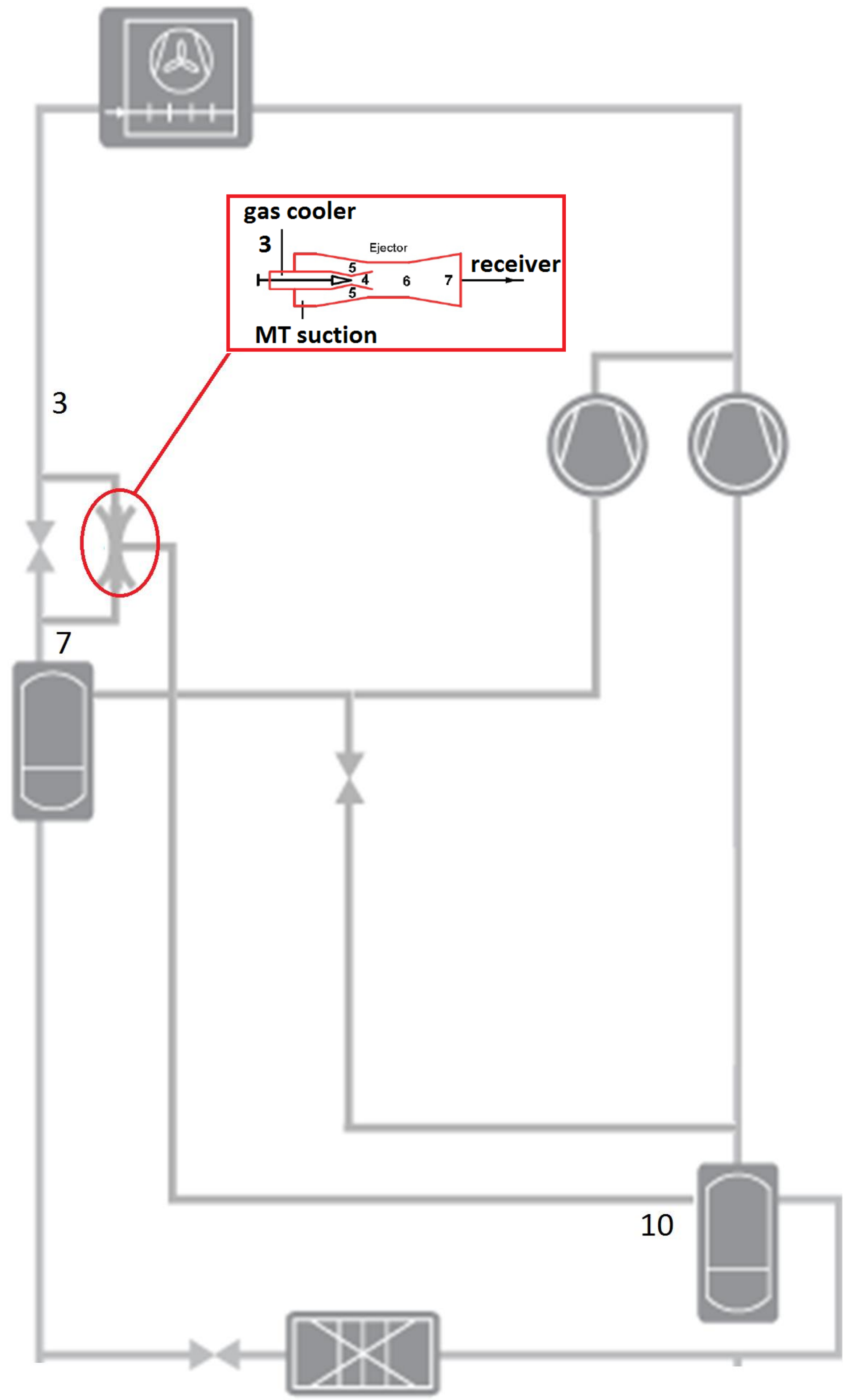
Reducing throttling losses: <u>Mechanical Subcooling</u>





Reducing throttling losses: Vapor Ejector





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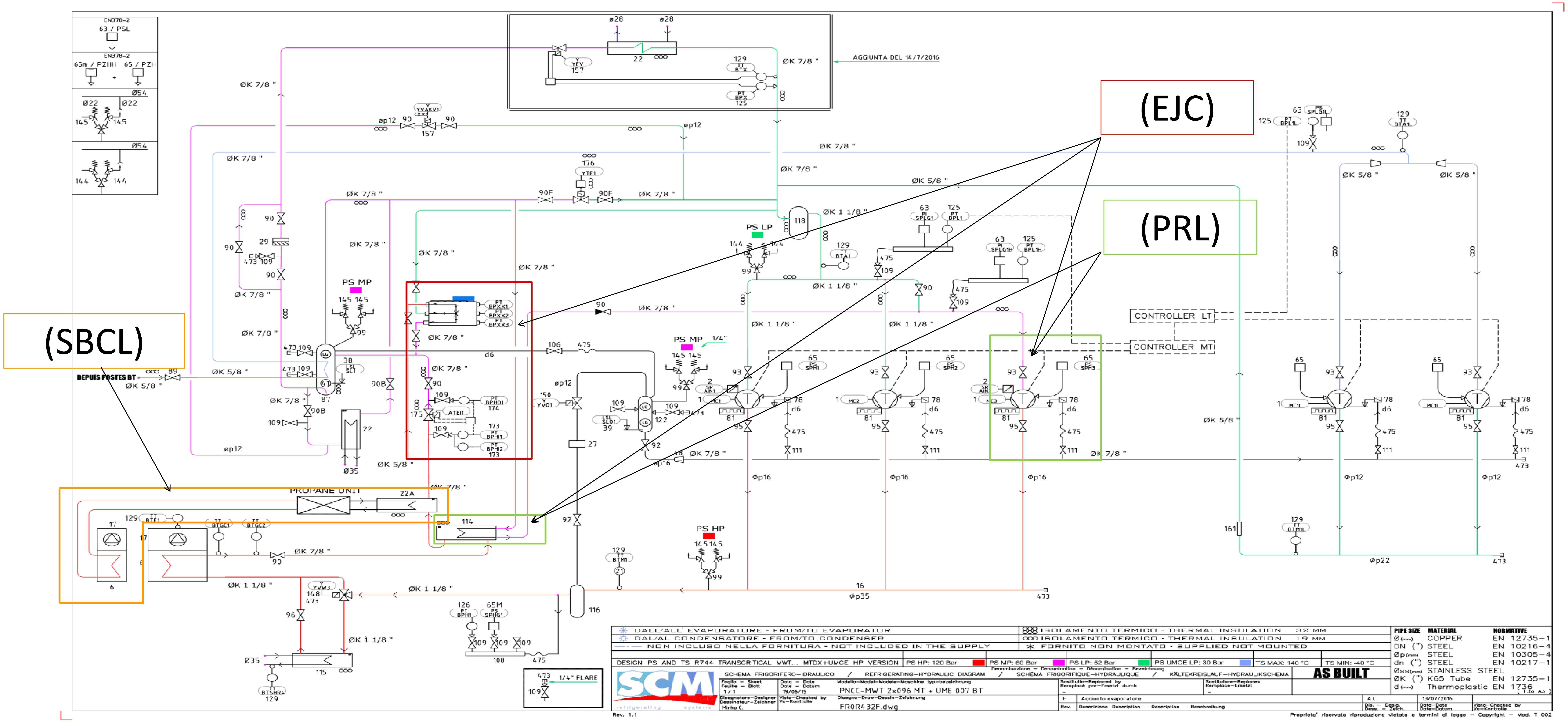
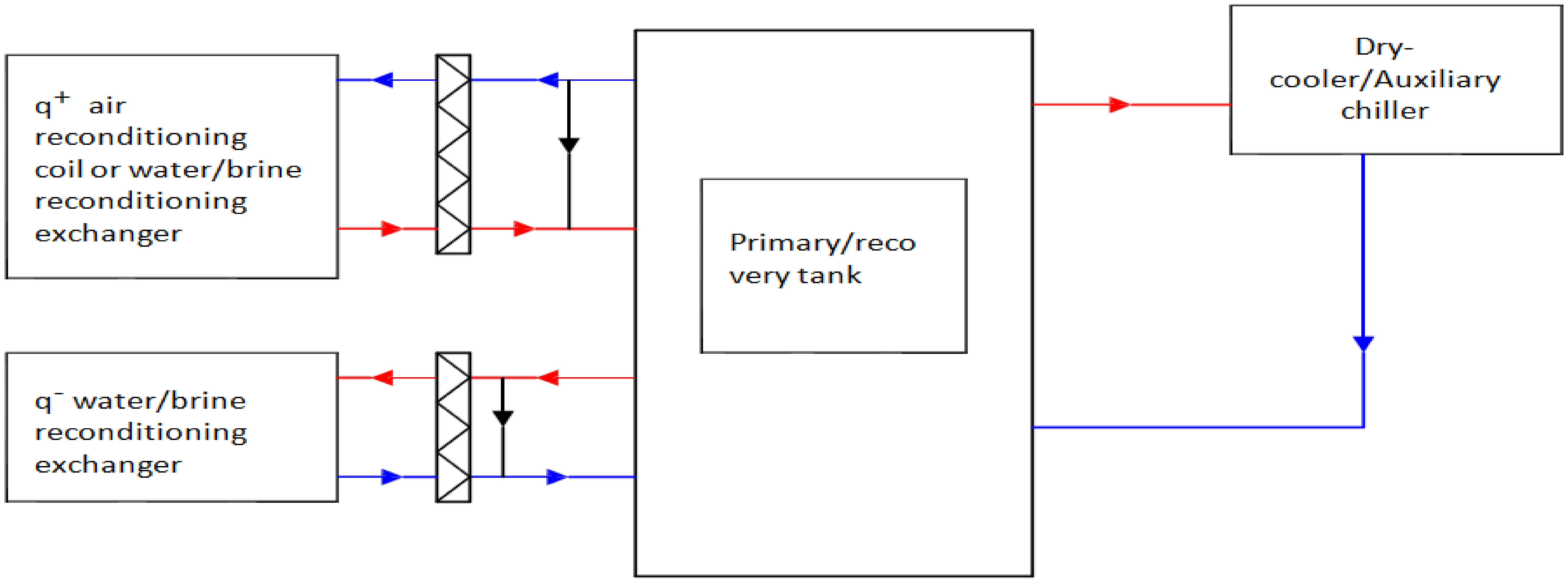
SCM FRIGO Tested Unit Configurations



Test facility

Experimental tests were carried out in the IMQ laboratories located in Amaro (UD) - Italy.



Functional scheme of the chiller chamber recovery system

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Test facility

Measured variables and the test facility measuring instruments

Measured variable		Measuring instruments	
Electrical quantities		Lem instruments	
Air	Dry bulb temperature	Platinum RTD	
	Wet bulb temperature	Rotronic M23	
	Barometric pressure	Vaisala instruments	
Water	Temperature	Inlet	Platinum RTD
		Outlet	Platinum RTD
	Mass flow	Foxboro instruments	
	Pressure drop	Druck trasducers	
Refrigerant	Temperature	Thermo-couple K	
	Pressure	Trafag instruments	
Data logger		PXI National instruments	
PLC		National instruments	

The tests were carried out in compliance with the EN 14511:2013 “Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling.

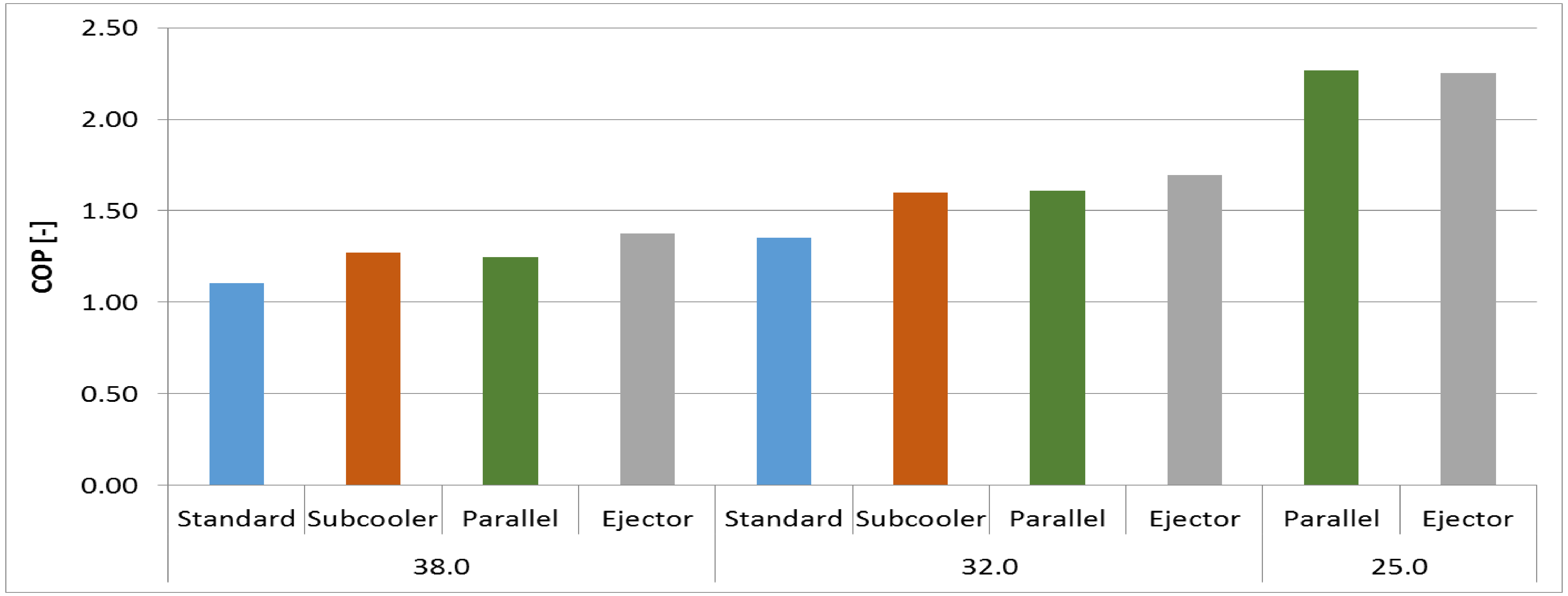
Test facility

Unit installation inside the environmental chamber

Experimental test results

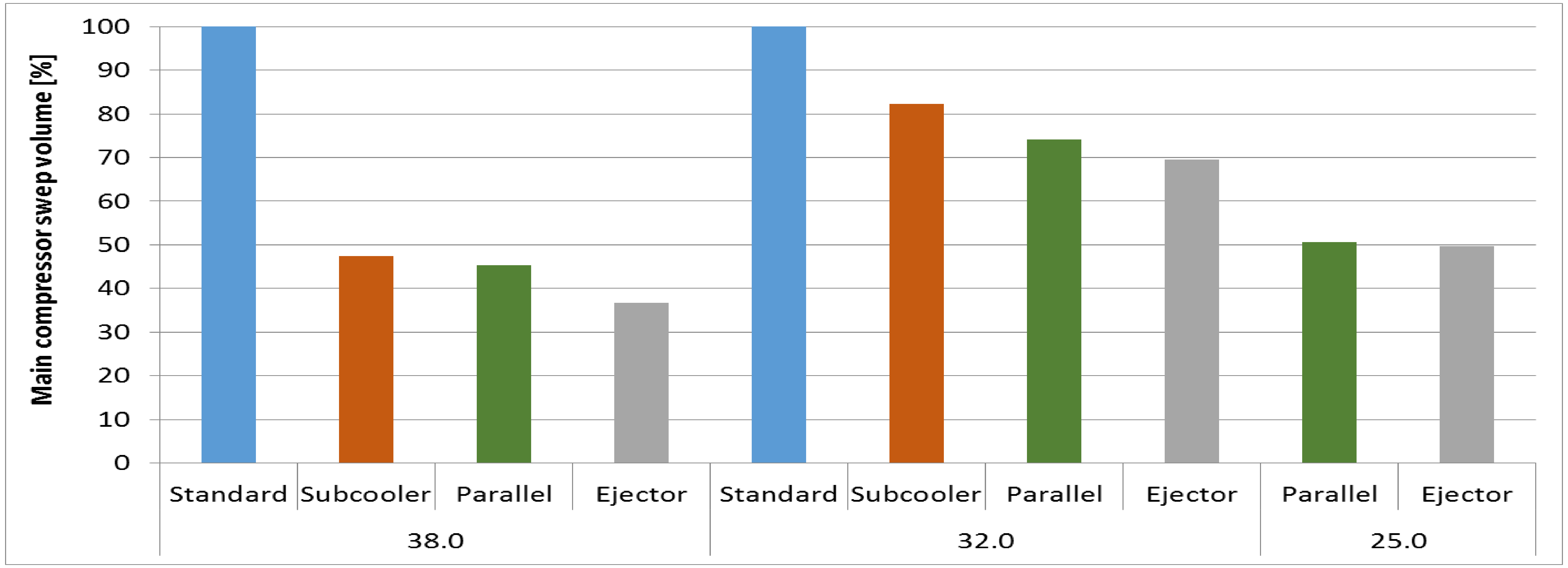
		STD	SBCL	PRL	EJC	STD	SBCL	PRL	EJC	PRL	EJC
Ambient air temp.	°C	38.0	38.0	38.0	38.0	32.0	32.0	32.0	32.0	25.0	25.0
Brine vol. flow rate	l/h	5217	5198	5121	5186	5606	5618	5630	5629	5631	5630
Brine inlet temp.	°C	-0.5	-0.7	-0.9	0.0	1.0	1.0	1.6	1.6	1.5	1.5
T_{ev}	°C	-7.7	-7.8	-7.8	-7.8	-7.7	-7.8	-8.0	-7.7	-7.7	-7.7
Q_0	kW	21.4	20.2	21.4	21.6	28.5	28.4	31.1	31.5	30.8	30.6
Main cpr capacity	%	100.0	47.5	45.4	36.8	100.0	82.2	74.2	69.6	50.7	49.7
p_{dis}	bar	90.9	90.8	91.0	88.8	86.0	84.9	85.6	85.9	72.1	74.7
p_{rec}	bar	41.0	39.9	37.2	37.5	41.0	41.0	37.1	37.3	36.2	36.8

Experimental test results - Efficiency



- For 38°C ambient air temperature conditions, the parallel compression and the subcooler aided systems over perform the standard booster system by +12.9 and +14.8%.
- The ejector system over perform the standard and parallel system by +24.7 and +10.7% at 38°C air temperature conditions. Both This depends on the ejector associated vapor mass flow rate entrainment from the low-pressure receiver to the intermediate pressure vessel. The ejector system energy efficiency increments varies from +18.9 to +6.2% against standard and parallel systems, respectively, when temperature ranges from 38 to 32°C. This is associated to the ejector entrained mass flow rate reduction with discharge pressure and gas cooler outlet temperature.
- The ejector effect at 25°C is negligible with respect to the parallel system.

Experimental test results- Swept volume



- At 38°, the parallel compression and the subcooler systems over perform the standard system by 54.6 and 52.5% in terms of available low-pressure side swept-volume. This maximum capacity increment is associated to the parallel compressor swept volume at intermediate pressure for PRL system and to the additional propane compressor subcooling capacity for SBCL system. At lower temperature the advantaged is reduced because of the reduction of the suction by-passed flash gas mass-flow rate in STD systems.
- The ejector system over perform the standard and parallel system by +63.2 and +18.9% at 38°C air temperature
- The ejector effect at 25°C is negligible with respect to the parallel system

Conclusions

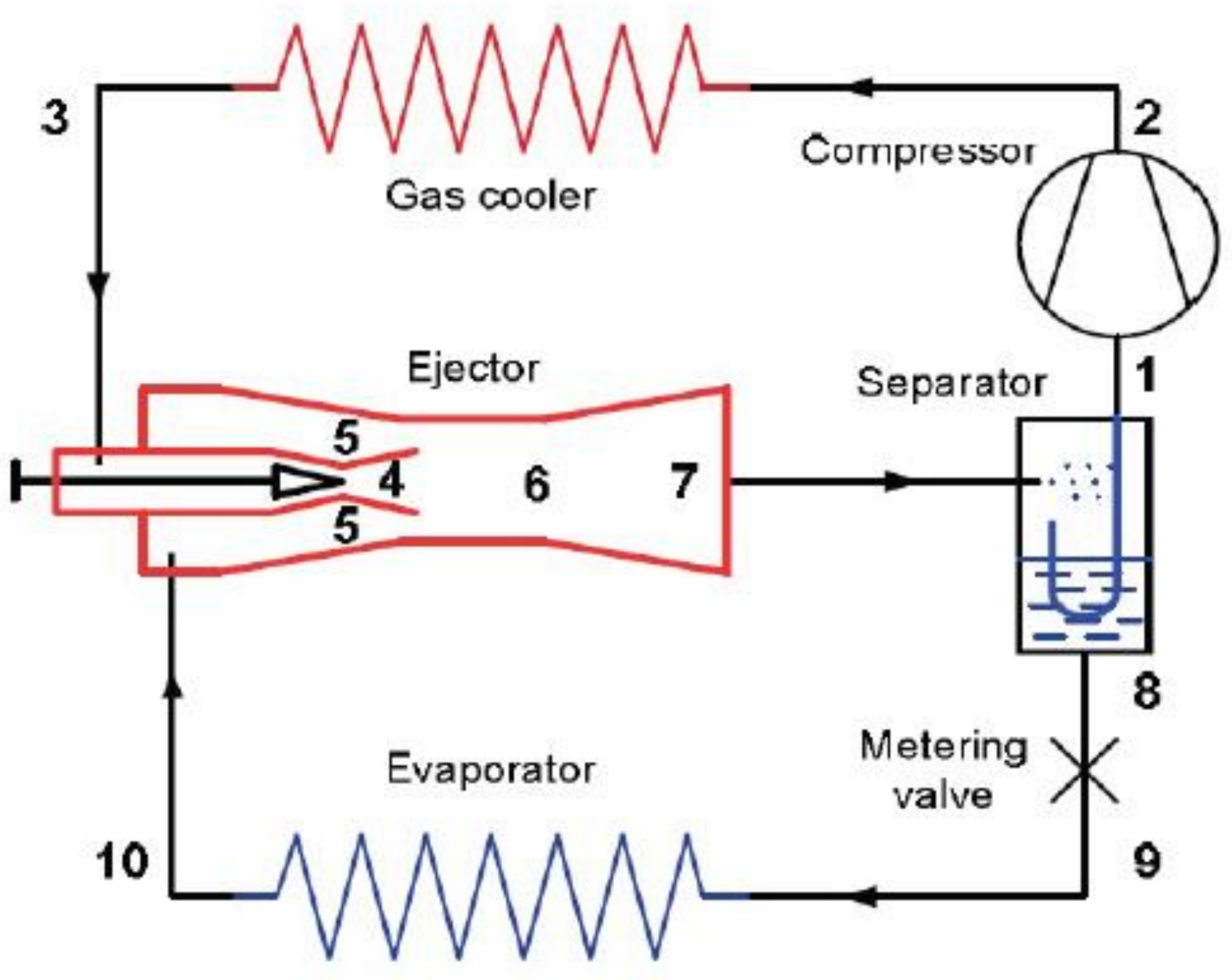
- Both parallel compression and mechanical subcooling appears convenient solutions for reducing commercial refrigeration CO_2 systems limits in warmer climates; where, as a matter of fact, both efficiency and refrigeration capacity of the transcritical single compression cycle undergo a rapid deterioration.

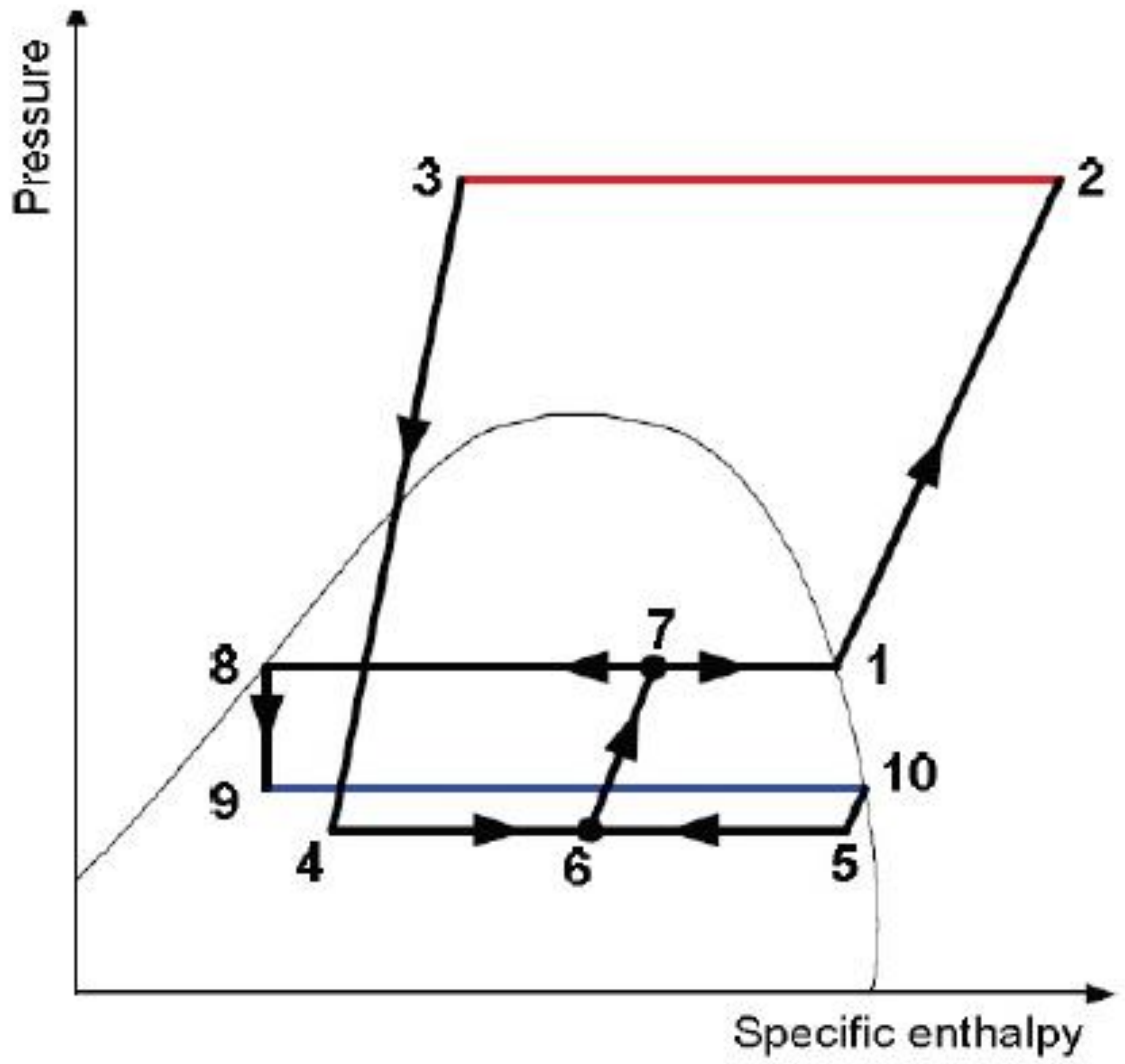
- The ejector system over perform the standard and parallel system by +24.7 and +10.7%, in terms of energy efficiency and by 63.2 and 18.9% in terms of available low-pressure side swept-volume at 38°C air temperature conditions because of the ejector associated vapor mass flow rate entrainment from the low-pressure receiver to the intermediate pressure vessel.

- Looking at the warmer climates countries as well as Australia we can say that CO_2 represent a real, efficient and reliable alternative to traditional HFC refrigerant without any restriction!

- Further improvement in the CO_2 technology will continuous to keep up the system efficiency

Next step of improvement: Vapour + liquid Ejector





Surce: Dott. Ing. Stefano Bissoli "Future CO2 Refrigeration System for hot climate" Padova University - July2015

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Thank you very much!