FURTHER ENHANCEMENTS IN THE APPLICATION OF MODULATING EJECTORS

SASCHA HELLMANN

NATURAL EVOLUTION

Carrier CO_2 technology status

More than 15 years of CO_2 projects

> 6500 CO_2 racks delivered[1]

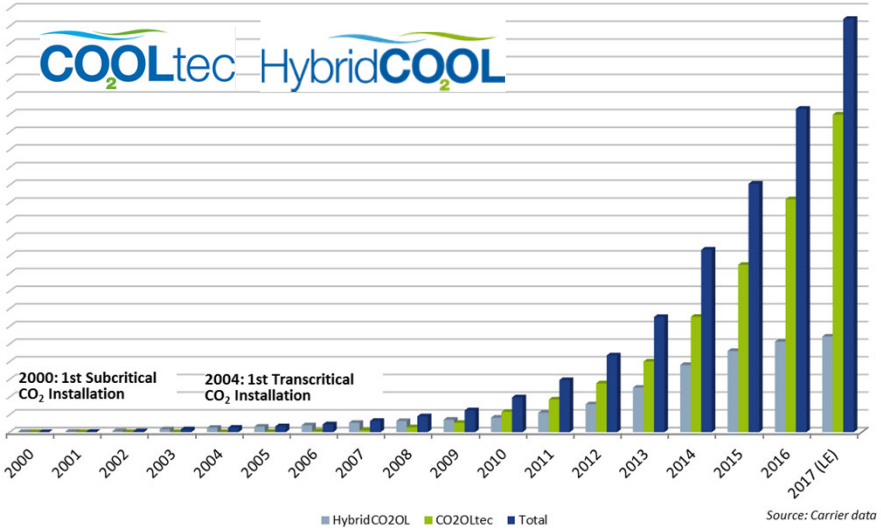
Sustained evolution, continuous improvement

Evolution of…

- **Technology**: HFC/CO_2 cascade → **full CO_2**
- **Applications**: Supermarkets → **all formats**
- **Climates**: Mild / cold → **all climates**

CO_2 refrigerant: Efficient, environmentally balanced, with A1 safety classification

Project Evolution: Carrier Commercial Refrigeration

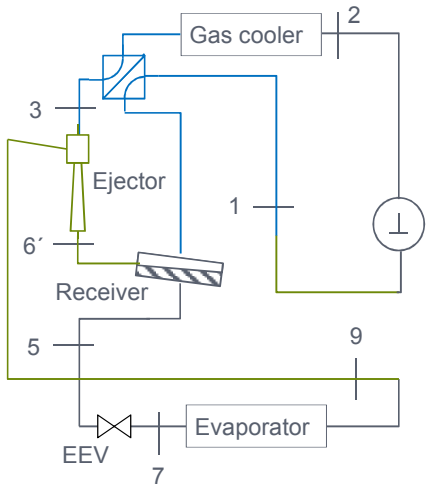


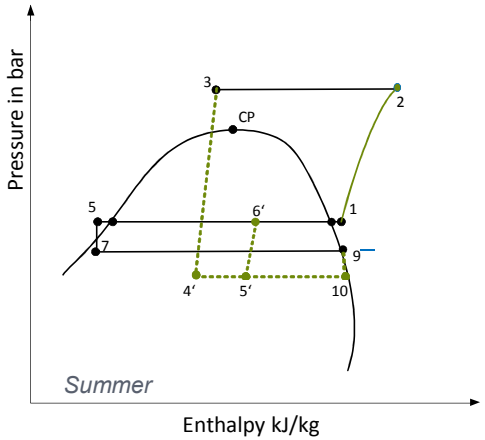
Source: Carrier data

[1]*Status as of end July 2017. Transcritical & subcritical, all brands*

HIGH EFFICIENCY TECHNOLOGIES

Initial solution: ejector system with economizer cycle





First applications of high-efficiency technologies:

- **Baseline standard transcritical CO_2 system**
- **Economizer cycle (parallel compression)**
  Additional compressor to compress flash gas at a higher pressure level
- **Carrier modulating ejector**
  Pre-compression of 100% of the MT suction flow

Annual rack energy savings up to 20%[1], vs. initial transcritical CO_2

Especially beneficial for warm climates

[1] *Rack only. Based on model store in warm climate. Compared to 1st generation transcritical system.*

INITIAL HIGH EFFICIENCY TECHNOLOGIES

Case studies 1 & 2

Location: Puertollano, Spain

Application: Supermarket

Solution: Modulating ejector
Economizer cycle

Commissioned: Q4, 2015

Efficient, trouble-free operation during recent extreme high temperatures

Modulating ejector

Economizer cycle

160 kW MT

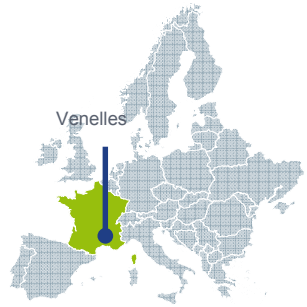
67 kW LT

Location: Venelles, France

Application: Cash & Carry

Solution: Modulating ejector
Economizer cycle

Commissioned: Q4, 2015



Full heat reclaim system w/ gas cooler bypass

Modulating ejector

Economizer cycle

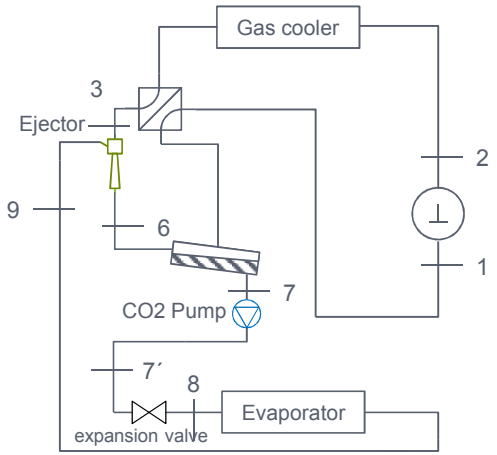
Heat recovery

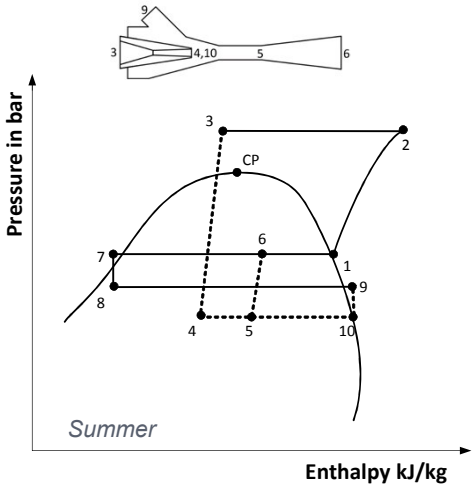
385 kW MT

47 kW LT

LATEST HIGH-EFFICIENCY TECHNOLOGY

Flooded system with ejector and CO_2 pump





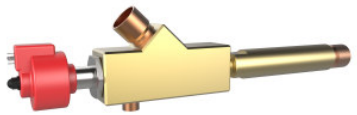
CO_2OLtecEvo baseline system:

- **Carrier modulating ejector**

  Reduced compressor work by pre-compressing the MT suction flow

  Optimal capacity-matching and part load performance across the entire range of operating conditions

  High entrainment / low pressure lift ejector; optimized to compress 100% of the MT suction vapor



- **CO_2 pump**

  Reduced energy consumption via full-year MT flooded operation

  Full-year flooded operation allows higher evaporating temperatures, delivering reduced energy consumption all year round

  No minimum high pressure is needed to operate the ejectors, so even the smallest pressure gains are utilized

CO_2OLtecEvo provides a simple, high-efficiency flooded solution for all climates

TAILORED EFFICIENCY, FOR ALL CLIMATES

Extended functionality

Heat recovery

AC cooling capacity

Heat pump

COOLtecEvo

Standard CO_2 refrigeration rack with add-on high-efficiency skid

Smaller capacities

Liquid ejector (flooded MT)

BPHX (flooded MT)

Improved efficiency

Modulating ejector

Economizer cycle

CO_2 pump (flooded MT)

Flooded LT

Mechanical subcooler

Adiabatic gas cooler

High efficiency compressor motors

A portfolio of high-efficiency solutions, to suit your specific project requirements

VALIDATED CUSTOMER BENEFITS

A new generation of CO_2 systems validated through pilots

Carrier's latest generation of advanced CO_2 systems is designed to deliver:

- ✓ Improved energy efficiency, up to 30%
- ✓ Optimized performance in all climates
- ✓ Solutions for multiple applications

CO_2OLtecEvo flexibly combines energy-saving features:

- **Based around modulating ejector technology**
- **Delivering ultimate solutions tailored to specific customer needs**

CARRIER Modulating Ejector Timeline:

2010: Ejector performance & qualification tests
2014: First installation
2017: Multiple sites operating across Europe

CASE STUDY 3

Makro Berverwijk

Location: Berverwijk, Netherlands

Application: Cash & Carry

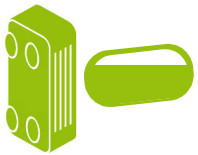
Solution: Modulating ejector
CO_2 pump
Flooded LT

Commissioned: Q2, 2016

Including low temperature flooded operation, for added efficiency

Modulating ejector

CO_2 pump (flooded MT)



Flooded LT

207 kW MT

79 kW LT

PROVEN ENERGY SAVINGS

Makro Bervervijk complete store with ejector and CO_2 pump

COOLtecEvo®

Energy measured for **complete store**[1]

Benchmarking via the independent VDMA "Quickcheck" tool, vs. average stores, per year[2]

CO_2OLtecEvo total store savings:

- -52% AEC[3] vs. average 2009 store
- **-38% AEC[3] vs. average 2012 / 2013 store**

[1] Complete store w/ CO_2OLtec®Evo plant (ejector / flooded MT / flooded LT), cabinets, cold rooms

[2] www.effizienz-quickcheck.org

[3] AEC = Annual Energy Consumption

CASE STUDY 4

Transgourmet Bremen

Location: Bremen, Germany

Application: Distribution center

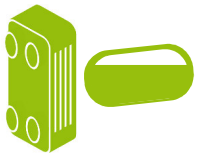
Solution: Modulating ejector
CO_2 pump
Flooded LT
Heat reclaim

Commissioned: Q3, 2017

Large-capacity semi-industrial installation, >1 MW.
Replacement of existing NH_3 & R404A systems.

Modulating ejector

CO_2 pump (flooded MT)

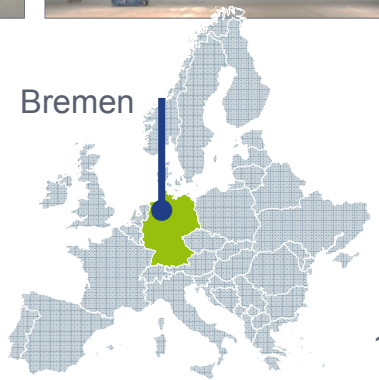


Flooded LT

Heat recovery

1260 kW MT

480 kW LT



NEW HIGH-EFFICIENCY STEP

Latest developments in Carrier CO_2 technology

Key drivers for a new generation of CO_2 systems:

- Further improved energy efficiency
- Suitable for all climates
- Suitable for multiple applications
- Reduced complexity of the main cycle
- Optimal energy gains via a configurable approach
- Tailored to specific customer needs & priorities

A range of tailored, high-efficiency solutions

- **Suitable no matter the application or climate**
- **No 'one size fits all' approach, to avoid performance compromise**

CO2OLtecEvo®

up to

30%

annual rack energy savings[1], vs. initial transcritical CO_2 (mild climate)

[1] Annual energy saving, for rack only. Based on model store in mild climate, compared to 1st generation transcritical system.

Thank you for your attention!

For further information, please come and visit us at our stand.