Commercial Refrigeration Applications

Italian supermarkets:
R744 multi-ejector enhanced parallel compression system

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SINTEF - A contract research organization based in Trondheim, Oslo, Bergen, Stavanger and Tromsø

• SINTEF is one of the largest independent research organisations in Europe.

Social perspective
SINTEF wishes to contribute to the creation of value and to a society in healthy sustainable development.

Business concept
SINTEF sells research-based knowledge and related services to Norwegian and international clients.

Fundamental values
Honesty, Generosity, Courage and Unity

SINTEF has 2145 employees, 1600 situated in Trondheim and 430 in Oslo.

Application of an innovative expansion work recovery system with multiple ejectors for energy performance improvement in the R744 refrigeration installations for supermarkets

Direct Objectives

• Test campaigns for two supermarkets (Trondheim and in Italy)

Long-term aspects

• Making the ejector-equipped CO$_2$ refrigeration systems thermodynamically, operationally, and economically competitive with the HFC systems over the whole range of operating conditions (high $t_{amb}$).
Multijet – pilot supermarket SPIAZZO (TN), ITALY
Near Trento / Verona
Multi-Ejector Rack

Photo: Enex srl  www.enex.it
Multi-Ejector block

• Compact design, made in cooperation with Danfoss
• Six fixed geometry nozzles
• 6-100 kW cooling capacity

Photo: Enex srl  www.enex.it

6+12+6+12+25+50
System configuration (Simplified)

Pgc Reference: 82.0Bar
Pgc Pressure: 82.6Bar
Sgc Temp: 18.5°C

Pc Pressure: 82.8Bar
Po Temp: 1.5°C

COP MT: -1.0
COP Ideal MT: 41.8
COP LT: 0.0
COP Ideal LT: 0.0

HP1expansion: 316-50: u24 Valve OD % 0%
HP2expansion: 316-51: u24 Valve OD % 27%
Two hours
P separator

<table>
<thead>
<tr>
<th>Name</th>
<th>Interval</th>
<th>Min</th>
<th>Max</th>
<th>Average</th>
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<tbody>
<tr>
<td>MTpack-PC781-11: Prec</td>
<td>1 min</td>
<td>34.03</td>
<td>41.35</td>
<td>38.15</td>
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<td>MTpack-PC781-11: Po Temp</td>
<td>1 min</td>
<td>-4.11</td>
<td>-2.67</td>
<td>-3.04</td>
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</tbody>
</table>

Evaporation temp
3.5 hours

Ejector pressure lift

<table>
<thead>
<tr>
<th>Name</th>
<th>Interval</th>
<th>Min</th>
<th>Max</th>
<th>Average</th>
</tr>
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<tbody>
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<td>18</td>
<td>35</td>
<td>24.21</td>
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</table>
Evolution of R744 Commercial Refrigeration

**R744 simple Booster**
- Simple
- Many units in the market
- Flash gas bypass
- Low cost (below HFC in Scandinavia)
- COP baseline for moderate – cold ambient temp.

**Parallel Compression**
- Advanced system
- Higher investment cost
- Flash gas (auxiliary) compression

**Ejector System**
- Advanced system
- Flooded evaporators:
  - possible
  - simple (no pump)
- Pre-compression
- Higher load on Auxiliary compressors

COP + 10%  
COP + 10-20%
# Ejector system ≠ Ejector system

## Classic Ejector
- High pressure control with needle in motive nozzle
  - High eff. at design point
- Part load operation challenges
  - Low motive flow rate and
  - Large mixing chamber
- Requires oil return strategy
- Ejector off (low pumping ability) – superheat operation of evaporators
- Discontinues operations

## Liquid Ejector only
- Enables flooded evaporators all year
- Applicable for booster and parallel compression system
- Simple on/off control
- Requires low pressure accumulator

## Ejector supported parallel Compression
- Fixed nozzle ejectors: designed for pumping liquid and pre-compressing vapour (Multi-Ejector block)
- Enables flooded evaporators all year, requires low pressure accumulator
- Higher load on auxiliary compressors.
- Pressure lift can be adapted to provide efficient AC

### Venturi type
- Part load challenges
Summary & Outlook

- Commercial refrigeration is currently in an innovative period.
- The so-called 'CO₂ equator' has reached Africa!
- High system flexibility, efficiency, and performance can be achieved applying smart ejector technology.
- Various ejector systems may enter the market depending on the end-user demand and efficiency expectations.
- Cost- and energy efficient implementation of AC, etc. will open up for additional markets outside EU.