Maturing and dissemination of new Refrigeration technologies with CO$_2$ as refrigerant

Århus
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About ADVANSOR

- The World’s largest producer of transcritical booster-systems
- Production of 4-6 systems per week
- Uses CO₂ to fight the global CO₂ problem (Global warming)
- Production area: 2000 m²
- Employees: 25 (+20 at sub contractors)
- Production 2010: 200 systems
- Production capacity max. 400 systems per year
- Reference list: 250 systems operating in 7 countries
- Turnover 10/11: €10 mill.
About ADVANSOR - history

- 2006 2 engineers from Danish Technological Institute founds Advansor
- 2006/07 Development and testing in laboratories
  Establishment of production
- 2007 Prototypes of supermarket rack, chiller and HP
  put into operation
- 2008 Series production of supermarket racks
  Series of 3 racks (1 rack per week)
- 2009 Company growth to 12 employees and moving
  into new production facilities
- 2010 Scaling up production, volume based production
  4-6 racks per week, cost reduction
- 2011 Capacity: 8 rack’s per week
  Production in 2 other European countries
Another 6 system on it’s way to England
Products
ADVANSOR’s products

**compSUPER: Refrigeration applications**
Advansor offers refrigeration systems (compressor rack’s) for supermarkets and other commercial/industrial applications. The units work with as the only refrigerant. Main focus are placed on reliability, ease of service and low energy consumption.

**compHEAT: CHP – combined heat and power**
Advansor develops heat pump solutions dedicated to power plants operated by either gas motor or gas turbines. The heat pump produces hot water up to 90 °C which enables direct pipe connection to the external pipe work with no interference with the motor and piping.

**compBINE: Combined heating and cooling**
Combined heating and cooling - produce hot water up to 100 °C and get ice water for free or counter wise. Advansor’s product line is highly suitable in connection with pasteurisation, CIP systems and other application in food industry where coinciding demands for heating and cooling exist. Combined heating and cooling saves both capital investment and energy cost.

**compFORT: Chiller applications and AC systems**
Advansor offers highly compact air cooled chillers and AC systems in the range from 100 to 400 kW. With natural refrigerant, no toxic risk and no flammability this is a safe and economical feasible choice.
### compSUPER – supermarket models

<table>
<thead>
<tr>
<th>Model</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>XS 2x0B CC</td>
<td>(35 kW)</td>
</tr>
<tr>
<td>XS 2x1B CC</td>
<td>(35/5 kW)</td>
</tr>
<tr>
<td>XS 2x0B</td>
<td>(35 kW)</td>
</tr>
<tr>
<td>XS 2x1B</td>
<td>(35/5 kW)</td>
</tr>
<tr>
<td>S 2x2B 1x 70 liter</td>
<td>(42/8 kW)</td>
</tr>
<tr>
<td>S 2x2B 1x 140 liter</td>
<td>(55/10 kW)</td>
</tr>
<tr>
<td>S 3x2B - 1x 140 liter</td>
<td>(61/14 kW)</td>
</tr>
<tr>
<td>S 3x2B - 1x 140 liter</td>
<td>(90/20 kW)</td>
</tr>
<tr>
<td>S 4x3B 2x140 litres</td>
<td>(120/30 kW)</td>
</tr>
<tr>
<td>S 5x3B 2x140 litres</td>
<td>(140/40 kW)</td>
</tr>
</tbody>
</table>

**Standard:** Elec.panel, AKD, Danfoss controllers, Bitzer  
**Options:** Gascooler, EC Fans, service switches  
Heat recovery system  
40/ 60 bar
compSUPER
compSUPER XL 8x6B (180+70 kW)
compHEAT 4-IKV
1.000 kW heat production
compFORT 8x0B
National arena in Copenhagen – AC with CO2

Luftkonditionering: 3xcompFORT S 8x0
Anlægstype: Gas-by-pass, DX
Kapacitet: 3 x 300 kW
Fordampertemperatur: 7-8°C
Lufttemperature: 15°C
Økonomi: 20% besparelse på installationen
Energibesparelse: ca. 15% sammenlignet med de bedste HFC-chillere

| Udeluft °C | COP HFC luft/yard | COP CO₂ luft/luft | DRY antal timer T/udeluft | Koldydelse kW | HFC kWh | CO₂ kW | Energiforbrug
|------------|-------------------|------------------|--------------------------|---------------|---------|--------|----------------
| 32         | 3,10              | 3,10             | 1                        | 360           | 116     | 116    |                |
| 28         | 3,50              | 3,46             | 10                       | 360           | 1,029   | 1,040  |                |
| 25         | 3,80              | 4,00             | 49                       | 360           | 4,542   | 4,410  |                |
| 20         | 4,20              | 5,40             | 351                      | 360           | 30,086  | 23,400 |                |
| 15         | 5,00              | 6,90             | 1,490                    | 360           | 107,280 | 77,739 |                |
| 12         | 5,70              | 9,10             | 2,723                    | 360           | 171,979 | 107,723 |                |
| ESEER      | 3,77              | 4,12             | 315,131                  | 214,429       | kWh/år  |        |                

European Seasonal Energy Efficiency Rating – Eurovent Certification Programme
Market Development
Market growth - compSUPER

Advansor transcritical CO2 booster

2007 2008 2009 2010 2011
Business Strategy and Partners

- Advansor cooperates with few but large leading companies

<table>
<thead>
<tr>
<th>Country</th>
<th>Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway</td>
<td>2</td>
</tr>
<tr>
<td>Sweden</td>
<td>2</td>
</tr>
<tr>
<td>Denmark</td>
<td>3</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1</td>
</tr>
<tr>
<td>Germany</td>
<td>1</td>
</tr>
<tr>
<td>Bennelux</td>
<td>2</td>
</tr>
<tr>
<td>Switzerland/Austria</td>
<td>3</td>
</tr>
</tbody>
</table>
Market Strategy
Business Strategy and Partners

- Advansor is specialized in producing systems but not in installing systems
  - Advansor needs the strongest possible partner in each country
- Advansor cooperates with few but leading installers
  - Interested in working with 1-3 partners in the Top 5 of each country
  - Requirement of education in the CO₂ technology
What does Advansor Offer our Partners?

- The Worlds best transcritical CO$_2$-systems
  - Highest quality at the best price
  - Sales support (why should the end-user by green technology)
  - Influence "the decision makers" and end users directly

- Consulting
  - Design of supermarket systems
  - Practical experience regarding installation
  - Calculation of the energy consumption

- Education
  - Training seminars at Advansor
  - Sales/ technical seminars

- After-sales
  - Start up help
  - On-line support
  - Spare parts
Test and training system at Advansor
Why CO$_2$ and why Advansor?
Advantages of CO\(_2\) as refrigerant

- **High level of security**
  - Safety valves and switches
  - Production and assembly approved
  - CE-labelled in accordance to PED cat. IV
  - High level of documentation

- **Reliable operation**
  - Well known tested components (compressors, exchanger, control)
  - Optimal and easy controls and monitoring
  - Resistant against compressor failure (oil handling, IHX, accu)
  - Secure handling of stand still pressure
  - High safety at service (pump-down, easy access)

- **Easy installation**
  - Only one refrigerant – CO\(_2\) / DX and copper piping
  - Optimized design: cobber, small pipes, hoses, and oil handling
  - No brine nor water pipes
  - Can be installed anywhere, no limits to the loc. of the condenser

- **Low installation and operating costs**
  - Low energy consumption
  - Low cost refrigerant
  - Easy and quick service
  - Availability of all components (standard)
  - 200% extra heat recovery
  - Cooling with termosyfon
  - Stabile temperatures
Point of Sale (CO2 vs. HFC) pros./ cons.

- Pros.:
  + No global warming effect
  + CO₂ is safe and non-toxic – no restriction against the use of CO₂
  + Tax on HFC (CO₂ is an insurance against big refrigerant loses)
  + Pressure from NGO’s on bigger supermarket chains
  + Low average outside temperatures => low energy consumption
  + Better possibilities of heat recovery with CO₂
  + Only one refrigerant, simple system, few components
  + Low maintenance costs

- Cons.:
  ÷ No legislation against HFC and no taxes
  ÷ Long experience with cascade systems and indirect systems
  ÷ The transcritical CO₂ systems are more expansive than HFC systems
Systems Available for Supermarkets – transcritical vs. cascade

Brine-anlæg

Kondensator

Tænkåler

Kælekompresor

R134a

Kaskade anlæg

Kondensator

Tænkåler

Kælekompresor

R134a

CO₂ anlæg

Kondensator

HT-ventil

CO₂

GBP-ventil

Kælekompresor

CO₂

Frost}

Brine (glykol)

Brine pumpe

Käl

Frost

Kælekompresor

Frostpumpe

Käl
Systems from Advansor

- Reliable systems (250 systems operating in 7 countries)
  - Optimal and robust design and thoroughly tested components
  - Oil management and protection against liquid
  - Optimal controls and monitoring easy to access and operate
  - Well known and readily available components
- Better handling of stand still pressure
  - UPS – secure shutdown in case of power failure
  - 90 bar receiver for application during maintenance and controlled shutdown
  - Strategic controlling during power failure
- Low operating costs
  - Low energy consumption (optimized components and controlling)
  - Low maintenance costs (easier to perform maintenance)
  - Optimal heat recovery
- Better documentation and training
  - User’s and maintenance manual
  - Training seminar at Advansor
Properties of CO$_2$ as Refrigerant
Characteristics of CO$_2$

Properties in general:
- Level II (L1) with ODP = 0 + GWP = 1 (NH$_3$ = L2, R290 = L3)
- No imitations in terms of location or application
- Temperature and pressure: -55 -> +31 °C (5.5 -> 73 Bar)
- Heavier than air, is a dense gas

Advantages:
- Small piping dimensions and minor pressure losses
- Improved efficiency of compressors high volumetric cooling capacity
- Improved heat transfer – especially by “pool-boiling”

Challenges:
- Higher working pressure (up to 130 bar)
- Higher stationary pressure
- Application of safety valves
- Separation of oil/liquid drops from the CO$_2$-gas
- System COP security at high temperatures
- Price of components
Principles of the cycle – booster + gas-by-pass

Log(p)-h diagram
Technical Properties
System Design

- Transcritical booster system with CO$_2$ as refrigerant
  - Medium pressure receiver with gas-by-pass
  - Highest level of safety

- Materials and assembly
  - Sturdy welded frames
  - Welded piping system - P235GH steel
  - Conical threaded – proof against leaks

- Noise and vibrations
  - Balanced solution with heavy frame results in low level of vibrations
  - Low level of noise with Bitzer compressors
  - Low gas pulsation and no electrical noise

- Reliable
  - Oil system, dry filters and dirt filters
  - Exchanger and suction accumulator on low temperature
  - Pressure levels, pump-down, UPS
Design and layout
(depth = 780 mm)

Electrical board
Heat rec. HX
LT comp
Suction acc. LT
Gas-by-pass valve (ETS)
HT comp
Filter dryer
HP valve (ICMT)
Oil separator
Receiver (90 bar, 130 l)
Liquid filter
UPS – closes HT-valve + ETS-valve

UPS

120 bar

90 bar

60/(75) bar

60/(75) bar

60/(75) bar

ADVANSOR
ENERGISYSTEMER
Energy Consumption and TEWI
Why CO$_2$ systems are low in energy consumption

- Low average outside temperatures in Northern Europe
- No heat exchangers – no extra temperature difference
- No pumps or other aux energy consuming surplus components
- Less pressure drop and better heat transfer
- Lower condensation temperatures allowed (until +5°C)
- Much higher potential heat exchange

- --------------------- and it keeps improving
- Better match of capacities of MT and LT (frequency control)
- Optimization compressors
- Optimization of control: capacity, suction pressure, condensation pressure, high pressure and receiver pressure
- Optimization of heat exchangers (gas coolers and evaporators)
Energy consumption (booster, indirect, cascade)
### Energy consumption for CO2/ HFC indirect/ cascade

<table>
<thead>
<tr>
<th>City</th>
<th>Transcritical [kWh]</th>
<th>HFC indirect [%]</th>
<th>Cascade (R134/CO2) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stockholm</td>
<td>200.272</td>
<td>+36</td>
<td>+20</td>
</tr>
<tr>
<td>Copenhagen</td>
<td>203.228</td>
<td>+36</td>
<td>+20</td>
</tr>
<tr>
<td>Oslo</td>
<td>201.309</td>
<td>+36</td>
<td>+20</td>
</tr>
<tr>
<td>Amsterdam</td>
<td>215.477</td>
<td>+34</td>
<td>+18</td>
</tr>
<tr>
<td>Berlin</td>
<td>223.761</td>
<td>+30</td>
<td>+15</td>
</tr>
<tr>
<td>Paris</td>
<td>233.269</td>
<td>+27</td>
<td>+13</td>
</tr>
<tr>
<td>Lyon</td>
<td>245.977</td>
<td>+23</td>
<td>+9</td>
</tr>
<tr>
<td>Madrid</td>
<td>271.159</td>
<td>+19</td>
<td>+6</td>
</tr>
<tr>
<td>Marseille</td>
<td>279.484</td>
<td>+17</td>
<td>+3</td>
</tr>
<tr>
<td>Barcelona</td>
<td>282.695</td>
<td>+16</td>
<td>+3</td>
</tr>
<tr>
<td>Rome</td>
<td>289.547</td>
<td>+14</td>
<td>+1</td>
</tr>
</tbody>
</table>

Source: DTU, Technical University of Denmark (IPU)
Measurements of energy consumption (FAKTA DK)

- 30 Transcrit CO₂ type 1
- 60 HFC DX systems

- 2-5% reduction in comparison to HFC
- 10-12% reduction in comparison to Type 1
- 20-40% reduction in comparison to cascade and indirect systems
Future Energy Consumption

- Design + reg.
- Design + EC-fans
- Opt. regulating
- SH
- AKD
  - P0 + PC Efficiency
- Design + reg.
Advantages of heat exchange in CO$_2$ systems

- Higher pressurized gas temperature
- Higher heat in pressurized gas
- Pinch point is situated further inside the exchanger
- Lower condensation pressure for the same quantity of heat
- COP during heat exchange
- Heat exchangers from ALFA LAVAL
Heat exchange from transcritical CO\textsubscript{2} systems

\begin{itemize}
  \item \text{COP (R404A)} = 1,8
  \item \text{COP (R744)} = 2,4 (85 bar)
\end{itemize}

- \text{Pinch point R404A}
- \text{Pinch point R744}
- \text{Higher discharge gas temp}

\begin{align*}
  t_{\text{vand,in}} &= 30 \, ^\circ\text{C} \\
  t_{\text{vand,ud}} &= 50 \, ^\circ\text{C} \\
  P_{\text{gk}} &= 22 \, \text{bar} \\
  m_{\text{dot,vand}} &= 0,8 \, \text{[kg/s]} \\
  t_{\text{gk,ind}} &= 70 \, ^\circ\text{C} \\
  t_{\text{ut,in}} &= 10 \, ^\circ\text{C} \\
  t_{\text{ref,intermediate}} &= 29,57 \, ^\circ\text{C} \\
  t_{\text{ut,ud}} &= 15 \, ^\circ\text{C} \\
  t_{\text{vGv,ud}} &= 32,15 \, ^\circ\text{C} \\
  m_{\text{dot,ut}} &= 1,364 \, \text{[kg/s]}
\end{align*}

- \text{Heat recovery unit}
- \text{Aircooled condenser}

- \text{Enthalpy steps [0=ref entrance/ 100 ref exit]}
  \begin{align*}
    Q_{\text{ut}} &= 7,5 \, \text{[kW]} \\
    A_{\text{VGV}} &= 13,62 \, \text{[m}^2\text{]} \\
    U_{\text{VGV}} &= 8,174 \, \text{[kW} \cdot \text{m}^2\text{]} \\
    Q_{\text{vand}} &= 67,2 \, \text{[kW]}
  \end{align*}
Heat recovery system

Tap water

Heat recovery heat exchanger A

+60°C

+15°C

Gas-by-pass valve

Heat recovery heat exchanger B

+50°C

+30°C

Ventilation/ space heating

+25°C

Aircooled condenser

Fans

Intermediate pressure receiver

HP valve
Keywords on success with development and dissemination
Keywords on maturing/ development

- Work closely together with your suppliers and costumers
- Focus on reliability – one change give other problems

- Make it easy

- Use “home market”

- Do your homework
  - Open minded
  - Continuous improvement

- Next step: optimisation
Dissemination with success

- **Built up confidence!!!**
- Have a clear strategy on each market (both to you and your customers)

- Use “open” and understandable components
- Use components that are “available” to everyone
- Select partners really interested
- Develop calculation tools for easy access to knowhow
- Users manuals – quick start

- Ease of maintenance
- Educate your partners (sales and technical)