Energibesparelser i industrielle ammoniakkøleanlæg

Niels P Vestergaard
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Industrial Refrigeration

Industry Drivers

1. **Safety**
   - products and system design

2. **Reliability**
   - Automatic running

3. **Energy efficiency**
   - new and retrofit systems
   - Industriel heat pumps

4. **Global warming**
   - refrigerants focus, plays along with NH3 and CO2

5. **Cost**
   - primary growth in emerging markets with higher price pressure, TCO awareness

![Graph showing increased kWh drop at 0.07 bar pressure](image)

- **Cost**
- **Safety**
- **Reliability**
- **Energy efficiency**
- **Global warming**

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[Image of industrial refrigeration components]

- Refrigerant handling
- Oil separation

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[Image of industrial refrigeration systems]

- Industrial heat pumps
- Refrigeration systems
Ammonia
Industrial Refrigeration - Refrigerants

**Ammonia Facts**

- Natural refrigerant
- GWP=0
- ODP=0
- Environmentally friendly
- **High efficiency**
- Low Cost
- Widely available
- Self-alarming – by odour

Ammonia is the natural choice

- Ammonia is the dominant refrigerant in industrial systems.
- **Specific design requirements needed, do to ammonia’s classification as toxic and flammable fluid.**
Low Charge Ammonia system for cold storage

Mitigating risks

New innovative and compact ammonia system design opens the door for new applications

- No need for an engine room
- Roof-top based design
- "VLC" very low NH3 charge
- **Claimed to have up to 98% less ammonia than regular systems** (lowest charge < 100 g / kW)
- Fully automated, self-contained NH3 system
- Very fast installation

1. DX-system
2. LPR-system
3. Pump-system
Low charge ammonia system for cold storage

*New upcoming trend in the USA* - Cold storage with 8 self-contained, packaged units
Ammonia low charge systems

- Ammonia DX
DX in Ammonia low charge systems
Operation costs of pump circulation vs DX-systems

- Reduced evaporating temperature
- Reduced efficiency
5 [K] => ~11.5% increased kWh*)

*) (Ammonia @ -30 / +30)

- No superheat
- No reduction in evaporating temperature
- High efficiency
Enhanced Ammonia DX-system suction accumulator

**New method**, implemented in some prefabricated low charge ammonia units and in a few site-built low charge systems.
Ammonia low charge systems

Ammonia pumped systems with *regulated circulating rate*
Ammonia low charge pump circulating system with regulated circulation rate

New method, tests ongoing

Example based on:
Cold Store: 580 kW freezing @ -35 °C and 800 kW cooling @ -5 °C total 1380 kW
14 evaporators @ -35 °C and 22 evaporators @ -5 °C
Why regulated circulation rate?
Load variation in ammonia pumped systems
Pressure drop in DN 80 riser

Pressure drop in DN 80 riser
Ammonia - h=5 [m] @ -30 [°C]

$N_{circ} = 10$
$\Delta P = 0.05 \text{ bar} \Rightarrow \Delta T \approx 1 \text{ K}$
(approx. 3% additional compressor power)

Capacity [kW]

$N_{circ} = 3$

$N_{circ} = 1.5$

Constant Nc=3

Constant massflow

Constant Nc=1.5
Load variation in ammonia pumped systems
Effect of un-regulated circulation rate

100 kW evaporator & 5 m riser @ -30

<table>
<thead>
<tr>
<th></th>
<th>N=3</th>
<th>N=10</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>M_riser [kg]</td>
<td>1,0</td>
<td>3,6</td>
<td>3,5</td>
</tr>
<tr>
<td>M_evap [kg]</td>
<td>14,2</td>
<td>32,9</td>
<td>2,3</td>
</tr>
<tr>
<td>M_head_in [kg]</td>
<td>1,7</td>
<td>1,7</td>
<td>1,0</td>
</tr>
<tr>
<td>M_head_out [kg]</td>
<td>0,1</td>
<td>0,4</td>
<td>4,1</td>
</tr>
<tr>
<td>Total (header + evap) [kg]</td>
<td>16,0</td>
<td>35,0</td>
<td>2,2</td>
</tr>
<tr>
<td>Total [kg]</td>
<td>17,0</td>
<td>38,6</td>
<td>2,3</td>
</tr>
<tr>
<td>(All liquid (header+evap)) [kg]</td>
<td>123,7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Void correlation:
Zivi (evaporator + header out)
Yashar (riser)

Note: Liquid hold-up in the evaporator + riser is increased from 17 to 38,6 kg
Speed control of evaporator fans vs ON/OFF

**Note:**
Speed control of evaporator fans requires "regulated circulation rate" to efficient
Defrost
Air cooler performance vs. ice build-up on surface

45 kg ice on the surface reduce the capacity from 23,2 kW to 13,1 kW and increase the circulating rate from 3,9 to 7,0
Mass flow
Liquid drain method vs. Pressure control method

<table>
<thead>
<tr>
<th>Mass flow</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removing ice</td>
<td>Net effective hotgas energy [kWh]</td>
</tr>
<tr>
<td>Convection loss</td>
<td>Additional hotgas energy [kWh]</td>
</tr>
<tr>
<td>Saving potential</td>
<td>Total convection loss energy [kWh]</td>
</tr>
</tbody>
</table>

Pressure control

Liquid drain

- Removing ice
- Convection loss
- Saving potential

- Pressure control
- Net effective hotgas energy
- Additional hotgas energy
- Total convection loss energy

- Liquid drain
- Pressure control
- Hot gas bypass
- Evaporator as condenser
- To other evaporators
Energy distribution

Pressure control: 10 °C (50 °F)
Liquid drain: 15 °C (59 °F)

Coil heating & convection slightly larger for liquid drain

What you pay

What you get

Coil heating + Convection converted to electricity:
\[ E_{el} = 2 \times E_{heat}/COP \]  
\( \text{COP} = 3 \)
Our formula for efficiency:

✓ The Danfoss ICF Valve Station + ICFD Defrost Module = Superior defrost performance

It is a formula that unites the well-known benefits of the Danfoss ICF technology with the most efficient defrost method known into one state-of-the-art defrost solution for industrial refrigeration applications.
A formula that releases a state-of-the-art value creation

**Reduced energy consumption**
- Reduction of blow-by gas by up to 90%
- Less loading of compressors

**Improved job site efficiency**
- Easy installation due to a reduction in components and weldings plus no need to disassemble and re-assemble

**Improved defrost performance**
- Reduce hot gas consumption
- Reduce downtime of evaporator when defrosting
- Low liquid storage

**Broad application range**
- Fully compatible to ICF 15-4, ICF 20-4, and ICF 20-6
- Several ICF variants available to fit specific system design and needs
- Wide application range spanning evaporators up to 200kW (58 TR) evaporator capacity

**Easy system design**
Support optimal system design with the Coolselector®2 application tool
Estimating savings – simplified method:

\[
Savings \bigg[ \frac{kWh}{\text{defrost}} \bigg] \approx \frac{Q_{e,\text{dim}} [kW]}{COP} \cdot \tau_{\text{defrost}} [h]
\]

\[COP \approx 2.5 \text{ at } T_e = -25^\circ C \text{ and } T_c = 30^\circ C\]

<table>
<thead>
<tr>
<th>Location</th>
<th>Measured Savings [kWh/defrost]</th>
<th>Estimated savings [kWh/defrost]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bring</td>
<td>20.0</td>
<td>22.0</td>
</tr>
<tr>
<td>DTI</td>
<td>5.0</td>
<td>5.1</td>
</tr>
<tr>
<td>Reitan</td>
<td>12.6</td>
<td>10.7</td>
</tr>
</tbody>
</table>

- Example calculation, Bring:

\[
Savings \approx \frac{66 kW}{2.5} \cdot \frac{50 \text{ min}}{60 \text{ min/h}} = 22.0 \frac{kWh}{\text{defrost}}
\]
Controls
Conclusions

The industrial refrigeration industry has been using ammonia for more than 100 years. Experience shows that ammonia has been and still is the one of the most effective refrigerants due its unique properties.

Today’s challenges:

- Ammonia is still the preferred refrigerant for industrial applications, however safety is a topic that has to be treated professionally.
- Low charge ammonia systems is an obvious solution for mitigating the risk. “low charge” is the name of the game for new ammonia systems, in particular in the US market.
- High efficiency solutions need to be implemented where it can reduce the total cost of ownership.
- Reliable solutions is an must.
Questions