Design, Build-up, and Commissioning of 350 kW Refrigeration Test Facility for Experimental Investigation of Large Cold Chain Equipment

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Mario Wenzel, Stefan Elbel, Pega Hrnjak
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Introduction

- The system has two circuits and can run as cascade (for lower temperature) and in parallel (for more capacity at higher temperature).
- The system was initially charged with R410A in the low stage (LS) and R134a in the high stage (HS).
- Test sections with visual access are installed to investigate e.g. oil flow in refrigerant pipes.
- Facility is equipped with additional instrumentation like mass flow meters to obtain accurate performance measurements at different ambient temperatures and load conditions.
- System was later charged with R410A in both circuits.
Experimental facility
Experimental facility

- Two compact screw compressors with:
  - Integrated oil separator
  - Variable frequency drive (VFD)
  - 3-stage capacity control (75 %, 50 % and 100 %)
  - Liquid injection for discharge gas cooling

Source: Bitzer user manual
Experimental facility

- Two air cooled condenser with controllable fans
- High stage evaporator and low stage evaporator (BPHX) with:
  - Two refrigerant circuits with two electronic expansion device; increases flexibility especially for big changes in capacity
  - One circuit for secondary fluid
To provide maximum flexibility for testing, the system was designed to operate in three different modes:

1. Cascade mode:
   To avoid high pressure ratios at low temperatures (down to -40 °C)

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Single stage</th>
<th>Two stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>R410A</td>
<td>10.8</td>
<td>3.3</td>
</tr>
<tr>
<td>R134a</td>
<td>15.0</td>
<td>3.9</td>
</tr>
<tr>
<td>R717</td>
<td>16.3</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Pressure ratios for single stage and two stage compression for different refrigerants (tc = 30 °C; t0 = 40 °C)
Operational mode

2. High stage mode only:
   To provide cooling capacity usually for medium temperature applications

3. Low stage mode only:
   Low stage can use desuperheater as condenser and therefore run as a single unit for small capacities or in parallel with high stage to provide cooling capacity
Compressors doesn't have a oil pump

» High pressure control by controlling condenser fans is important

West condenser

Condenser circuit

Desuperheater circuit

Controllable fans / group of fans

East condenser
Controls

- Electronic expansion valves for each refrigerant circuit
- Each liquid line is equipped with solenoid valve(s)
  » Pump-down possible
- Software control with two independent systems:
  » Emmerson “Einstein E2 controller” for control and safety functionality
  » In-house programmed PLC can only turn equipment ON or OFF and has safety functionality
Oil management

- Built-in oil separators which are directly flanged onto the compressor

Cross-section view of LS or HS screw compressor (4: check valve, 6: Vi-control, 7: differential pressure relief valve, 9: oil filter, 10: discharge temp. control device, 11: built-in motor) (Bitzer Kühlmaschinenbau GmbH)

<table>
<thead>
<tr>
<th>Section</th>
<th>Target velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge</td>
<td>10…18</td>
</tr>
<tr>
<td>Suction</td>
<td>4.5…20</td>
</tr>
<tr>
<td>Liquid</td>
<td>1…2.5</td>
</tr>
</tbody>
</table>
Running the high stage compressor with R134a allowed a simple performance comparison with the manufacturer’s data ($t_c = 35 \, ^\circ C$)
Experimental results  HS mode only (R410A)

- Cooling capacity of HS compressor with R410A at $t_0$: 14.6 °C, $t_c$: 40 °C
Experimental results cascade mode (R134a/R410A)

- Condensing temperature: 33 °C
- Evaporating temperature: -39 °C
Experience in operation

- System is designed to provide a wide range of cooling capacity.
- Commissioning process confirmed that at low compressor frequencies, oil can be trapped in the system; especially in the evaporators.
- Thus, evaporators with two (independent) refrigerant cycles have been selected.
Experience in operation

- After system was idle over winter time compressor started leaking on motor lid
- Replacing gaskets on HS compressor showed partly dried out gasket
- System should operated frequently to avoid gasket dry out
Summary

- Experimental two-stage refrigeration system in industrial scale has been designed from the ground up.
- To provide a wide range of cooling capacity, several options for capacity control are included in the design.
- Evaporators are designed for approximately 480 kW (high stage) and 210 kW (low stage).
- Presented data shows that the system is able to run in three different operation modes to provide cooling at medium temperatures and temperatures down to -39 °C.
Summary

- Test facility has been run in all three of the presented operation modes
- Measurements show good agreement between the catalog/calculated and measured data
Thank you for your attention