ASHRAE 1721-RP: Oil Return and Retention in Unitary Split System Gas Lines with HFC and HFO Refrigerants

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Agenda

- Project Background
- Test Setup
- Modifications
- Oil Injection
- Oil Retention Measurement Method
- Project Schedule
Motivation

- The rising applications of variable speed and tandem compressors coupled with emerging refrigerant-oil combinations have brought about the importance of additional design parameters to help determine not only the line size but to also give values for oil retention for interconnecting gas lines of systems running vapor compression cycle.

Objectives

- Gain a better understanding with regard to oil retention of interconnecting gas lines used in air-conditioning systems.
- Develop a user-friendly modeling tool and engineering design guidelines for sizing refrigerant piping in unitary split systems.
- Collect data for a wide range of tests that considers existing and new refrigerant-lubricant combination, different orientation and geometry of refrigerant lines, varying refrigerant flow rates and with different concentrations of oil.

Task Overview

Task 1: Literature Review
- Papers related to studies carried out in past have been reviewed and reported
- Various oil measurement techniques have been studied and reported

Task 2: Development of Test Matrix
- Preliminary test matrix has been prepared and reported which considers
- PMS has agreed to initiate testing with R134a with POE
- Further oils will be selected for the remaining refrigerants based on the results obtained from R134a and POE

Task 3: Design and Construction of Experimental Setup
- Construction of the test setup is completed
- Results of shakedown test with only refrigerant will be presented in the current meeting

Task 4: Collect R134a/POE Baseline Data
- Baseline data will be collected in the upcoming quarter
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Test Setup
Test Setup

[Diagram of a HVAC system with labels for various components such as Oil Separators, Condensers, Chiller, Receiver, Refrigerant, Oil Pump, Water Pump, Vertical Test Sections, Horizontal Test Sections, Development Length.]
Test Setup

Agenda

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## Test Matrix

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Refrigerant</th>
<th>Oil</th>
<th>Viscosity [cSt]</th>
<th>Nominal Line Diameter [mm]</th>
<th>Oil Circulation Rate [%]</th>
<th>Mass Flow Rate</th>
<th>Test Section Saturation Temperature [°C]</th>
<th>Test Section Inlet Temperature [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Baseline)</td>
<td>R134a</td>
<td>POE</td>
<td>32cSt</td>
<td>19.05</td>
<td>0.5, 3, 5</td>
<td>1/3, 1, 2 and 3x of Jacob's Limit</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>R410A</td>
<td>POE</td>
<td>68cSt</td>
<td>19.05</td>
<td>0.5, 3, 5</td>
<td>1/3, 1, 2 and 3x of Jacob's Limit</td>
<td>40</td>
<td>64</td>
</tr>
<tr>
<td>2</td>
<td>R410A</td>
<td>POE</td>
<td>100cSt</td>
<td>19.05</td>
<td>0.5, 3, 5</td>
<td>1/3, 1, 2 and 3x of Jacob's Limit</td>
<td>40</td>
<td>64</td>
</tr>
<tr>
<td>2</td>
<td>R410A</td>
<td>POE</td>
<td>170cSt</td>
<td>19.05</td>
<td>0.5, 3, 5</td>
<td>1/3, 1, 2 and 3x of Jacob's Limit</td>
<td>40</td>
<td>64</td>
</tr>
</tbody>
</table>

### Refrigerant Only: Suction Line

#### Suction Line Test (Previous)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Refrigerant - Lubricant</th>
<th>Nominal Line Diameter [mm]</th>
<th>Ref. Mass Flow Rate [kg/hr]</th>
<th>Oil Circulation Rate [kg/hr]</th>
<th>Test Section Saturation Temperature [°C]</th>
<th>Test Section Inlet Temperature [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Baseline)</td>
<td>R134a - POE 32</td>
<td>19.05</td>
<td>11</td>
<td>0.055</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>1 (Baseline)</td>
<td>R134a - POE 32</td>
<td>19.05</td>
<td>33</td>
<td>0.33</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>1 (Baseline)</td>
<td>R134a - POE 32</td>
<td>19.05</td>
<td>66</td>
<td>0.55</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>1 (Baseline)</td>
<td>R134a - POE 32</td>
<td>19.05</td>
<td>100</td>
<td>0.165</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>1 (Baseline)</td>
<td>R134a - POE 32</td>
<td>19.05</td>
<td>33</td>
<td>0.99</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>1 (Baseline)</td>
<td>R134a - POE 32</td>
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<td>1 (Baseline)</td>
<td>R134a - POE 32</td>
<td>19.05</td>
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<td>1.98</td>
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<td>20</td>
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<td>10</td>
<td>20</td>
</tr>
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<td>1 (Baseline)</td>
<td>R134a - POE 32</td>
<td>19.05</td>
<td>100</td>
<td>0.5</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>1 (Baseline)</td>
<td>R134a - POE 32</td>
<td>19.05</td>
<td>3</td>
<td>10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>1 (Baseline)</td>
<td>R134a - POE 32</td>
<td>19.05</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td></td>
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</tbody>
</table>
### Suction Line Test (Current)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Refrigerant - Lubricant</th>
<th>Nominal Line Diameter [mm]</th>
<th>Nominal Line Diameter [mm]</th>
<th>Ref. Mass Flow Rate [kg/hr]</th>
<th>Oil Circulation Rate [kg/hr]</th>
<th>Test Section Saturation Temperature [°C]</th>
<th>Test Section Inlet Temperature [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Baseline)</td>
<td>R134a - POE 32</td>
<td>19.05</td>
<td></td>
<td>0.055</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.33</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.55</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td>0.165</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.99</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>66</td>
<td></td>
<td></td>
<td></td>
<td>0.33</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.98</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td>3.3</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

- Added bypass valve on the refrigeration loop

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### Refrigerant Only: Suction Line

**Test Date: 13 Jun. 2019**  
**Refrigerant: R134a**  
**Test: Suction Line**

#### Refrigerant Mass Flow Rate [kg/hr]

- **Reference Signal**
- **Moving Average of 20 points**
- **Setpoint**

- **66 kg/hr**
- **33 kg/hr**
- **11 kg/hr**

#### Refrigerant Temp at Test Section Inlet

- **Refrigerant Sat Temp**
- **Setpoint**

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23 June 2019  
RP:1721 Oil Retention in gas lines
Pulsation – Refrigerant Pump

![Graph showing refrigerant mass flow rate and temperature over time.]

- Test Date: 09 Jan 2019
- Refrigerant: R134a
- Test: Suction Line

- Raw Signal
- Moving Average of 20 Points
- Setpoint
- 100 kg/hr
- 66 kg/hr
- 33 kg/hr
- 11 kg/hr

Pulsation – Diaphragm Pump (100 kg/h)

![Graph showing refrigerant mass flow rate and pressure over time.]

- Test Date: 09 Jan 2019
- Refrigerant: R134a
- Test: Suction Line

- Raw Signal
- Moving Average of 20 Points
- Setpoint
- 100 kg/hr

- Ref. Pump Discharge Pressure
- Ref. Suction Pressure
- Test Section Pressure

- Time [hr]
- Pressure [kPa]
Pulsation – Gear Pump (100 kg/h)

Pulsation – Diaphragm Pump (66 kg/h)
Pulsation – Gear Pump (66 kg/h)

Test Date: 12 Jun. 2019  Refrigerant: R134a  Test: Suction Line

Pulsation – Diaphragm Pump (33 kg/hr)

Test Date: 09 Jan. 2019  Refrigerant: R134a  Test: Suction Line
Pulsation – Gear Pump (33 kg/hr)

Liquid Refrigerant in Oil Separator

**Problem**
- Liquid Refrigerant getting condensed in the oil separator especially for the discharge line test

**Solution**
- Insulate the vapor line between the vertical test section and the oil separators
- Add a heater in the oil collector and maintain a temperature 10K > Sat. Temperature of the system to ensure all the refrigerant is evaporated
- If needed, connect the oil collector to the condenser inlet with a check valve
Liquid Refrigerant in Oil Separator

Solution

• Insulated the vapor line between the vertical test section and the oil separators
• Added a PID controlled heater along with thermocouples in the oil collector
• We maintain a temperature 10K > Sat. Temperature of the system to ensure all the refrigerant is evaporated
• Added PID controlled heater along with thermocouple in oil collector as well
• Added pressure equalization line between the oil separator shell and the oil collector for the oil to flow under gravity

Agenda

• Project Background
• Test Setup
• Modifications
• Oil Injection
• Oil Retention Measurement Method
• Project Schedule
Oil Injection

Oil Return Issue – 33 kg/hr
## Oil Return Issue – 33 kg/hr

![Graph showing oil return issue](image)

## Oil Return Solution

<table>
<thead>
<tr>
<th>Test Section</th>
<th>Refrigerant Mass Flow Rate [kg/h]</th>
<th>Test Section Inside Diameter [mm]</th>
<th>Mass Flux [kg/s-m²]</th>
<th>Jacob’s Limit</th>
<th>Nominal Pipe Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>33</td>
<td>16.9</td>
<td>40.8</td>
<td>1</td>
<td>3/4”</td>
</tr>
<tr>
<td>Vertical</td>
<td>33</td>
<td>10.9</td>
<td>97.8</td>
<td>2.4x</td>
<td>1/2”</td>
</tr>
<tr>
<td>Horizontal</td>
<td>11</td>
<td>16.9</td>
<td>13.6</td>
<td>0.3x</td>
<td>3/4”</td>
</tr>
<tr>
<td>Vertical</td>
<td>11</td>
<td>6.3</td>
<td>98.0</td>
<td>2.4x</td>
<td>5/16”</td>
</tr>
</tbody>
</table>

RP:1721 Oil Retention in gas lines
Oil Return Issue

Oil Injection Result: Test ID 33
Oil Injection Result: Test ID 33
Oil Injection Result : Test ID 34

Test Date : 18 Jun 2019  Refrigerant : R134a  Test : Suction Line

- Refrigerant Mass Flow Rate [Nm³/hr]
- Temperature [°C]
- Oil Mass Flow Rate [l/hr]
- Oil Pump Operating Percentage
- Pressure [kPa]

- Raw Signal
- Moving Average of 20 points
- Setpoint
- Refrigerant Temp at Test Section Inlet
- Refrigerant Sat Temp
- Oil Pump Suction Pressure
- Oil Pump Discharge Pressure
Oil Injection Result : Test ID 35

Test Date : 20-Jun-2019  Refrigerant : R134a  Test: Suction Line

- Raw Signal
- Moving Average of 20 points
- Setpoint

Oil Retention in gas lines

Oil Injection Result : Test ID 35

Test Date : 20-Jun-2019  Refrigerant : R134a  Test: Suction Line

- Oil Mass Flow Rate
- Oil Pump Operating Percentage

Pressure [kPa]

RP:1721 Oil Retention in gas lines
## Oil Injection Result

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Description</th>
<th>TestID 33</th>
<th>TestID 34</th>
<th>TestID 35</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Refrigerant</td>
<td>R134a</td>
<td>R134a</td>
<td>R134a</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Oil</td>
<td>POE-32</td>
<td>POE-32</td>
<td>POE-32</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Test Mode</td>
<td>Suction</td>
<td>Suction</td>
<td>Suction</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Horizontal Pipe Dia</td>
<td>16.9</td>
<td>16.9</td>
<td>16.9</td>
<td>mm</td>
</tr>
<tr>
<td>5</td>
<td>Vertical Pipe Dia</td>
<td>10.9</td>
<td>6.3</td>
<td>10.9</td>
<td>mm</td>
</tr>
<tr>
<td>6</td>
<td>Ref Flow Rate</td>
<td>21.1</td>
<td>8.76</td>
<td>30.31</td>
<td>kg/h</td>
</tr>
<tr>
<td>7</td>
<td>Oil Flow Rate</td>
<td>0.89</td>
<td>0.36</td>
<td>0.16</td>
<td>kg/h</td>
</tr>
<tr>
<td>8</td>
<td>Ref Mass Flux - Horizontal</td>
<td>26.07</td>
<td>10.83</td>
<td>37.46</td>
<td>kg/m²·s</td>
</tr>
<tr>
<td>9</td>
<td>Ref Mass Flux - Vertical</td>
<td>62.53</td>
<td>78.09</td>
<td>89.86</td>
<td>kg/m²·s</td>
</tr>
<tr>
<td>10</td>
<td>OCR</td>
<td>4.23</td>
<td>4.08</td>
<td>0.54</td>
<td>%</td>
</tr>
<tr>
<td>11</td>
<td>Oil Retention - Horizontal</td>
<td>10.49</td>
<td>11.63</td>
<td>4.27</td>
<td>g/m</td>
</tr>
</tbody>
</table>

23 June 2019

Ankit Sethi & Pega Hrnjak (2014) Oil retention and pressure drop of R1234yf and R134a with POE ISO 32 in suction lines, HVAC&R Research, 20:6, 703-720
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Oil Retention Measurement
Agenda

- Project Background
- Test Setup
- Test Matrix
- Shakedown Test Results (Oil Free)
- Oil Retention Measurement Method
- Project Schedule

Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1: Literature Review</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 2: Development of Test Matrix</td>
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</tr>
<tr>
<td>Task 3: Design and Construction of Experimental Setup</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Task 4: Collect R134a/POE Baseline Data</td>
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<td></td>
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</tr>
<tr>
<td>Task 5: Collection of R410A data with first Lubricant</td>
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<tr>
<td>Task 6: Collect data with remaining Refrigerant-Oil Combinations</td>
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<td>Task 7: Development of Model</td>
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<tr>
<td>Quarterly Progress Report</td>
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<tr>
<td>Final Report</td>
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</table>
Thank You.