EXPERIMENTAL STUDY OF TWO-PHASE SEPARATORS FOR VAPOR COMPRESSION SYSTEMS IN HOUSEHOLD APPLIANCES

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July 11 -14, 2016
Presentation Outline

- Introduction
- Background
- Methods
- Results
- Conclusion & Future Work
INTRODUCTION

Project Motivation

- Regulatory and financial incentives drive industry to meet increasing demand at higher system efficiencies.

Why Two-phase separators?

- Simple, passive component
- Offers system efficiency improvements

Objective:

- Evaluate the design of separators suitable for the operational ranges of household refrigeration.
BACKGROUND

Making use of two-phase separators

Flash Tank
Economizer Cycle

Ejector Cycle

Mixed Refrigerant System (2 evaporators)

- Heating Capacity and COP improvements: 34% and 6% (He et al. 2006)

- Increase suction pressure at compressor inlet
- Reduction of compressor work
- Chaudry, Zhuo, and Junge (2015) reached 15% efficiency for an AC ejector system.

- Tested with R-12 and R-114, 50% mixture (Stoecker, 1978)
- Energy savings of 12% in two-evaporator refrigerator

(Wang, 2008)

(Domanski, 1995)
Recent Experimental Findings

- Milosevic (2010)
  Flash gas bypass for R134a automotive A/C
  - Findings:
    - Geometry 1 effectively separated $10 < \dot{m} < 30$ g/s and $5 < x_i < 20\%$
    - Geometry 2 effectively separated up to $10 < \dot{m} < 45$ g/s and $5 < x_i < 15\%$

- Tuo & Hrnjak (2012)
  - Expanded on separation enhancers
  - Angling and dual inlet significantly improve separation
    - Flows are 10 – 20 times higher than small refrigeration appliances

<table>
<thead>
<tr>
<th>Geometry</th>
<th>Sep 1in[mm]</th>
<th>Sep 2in[mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet branch</td>
<td>0.34(8.7)</td>
<td>0.47(12)</td>
</tr>
<tr>
<td>Body Diameter</td>
<td>0.72(18.3)</td>
<td>0.94(23.8)</td>
</tr>
<tr>
<td>Overall Height</td>
<td>15.748(400)</td>
<td>15.748(400)</td>
</tr>
</tbody>
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METHODS

Two-Phase Separator Test Facility
METHODS

Two-Phase Control

\[ \dot{q}_{htr} = \dot{m}_T (h_o - h_i) \]

\[ x_i = \frac{h_o - h_f}{h_v - h_f} \]
**METHODS**

**Separator Geometry**

### Separator 1

- **Geometry**: Inlet, Outlet (liq, vap)
  - **in[mm]**: 0.232 (0.200)
- **Body Diameter**: 0.423 (10.733)
- **Overall Height**: 4.125 (104.775)
- **Inlet to bottom**: 1.500 (38.100)

### Separator 2

- **Geometry**: Inlet, Outlet (liq, vap)
  - **in[mm]**: 0.232 (0.200)
- **Body Diameter**: 0.742 (18.847)
- **Overall Height**: 1.750 (44.450)
- **Inlet to bottom**: 0.656 (16.67)
RESULTS

Separator 1

\[ P = 115 \text{ Psia} \ [800 \text{kPa}] \]
\[ m_T = 12 \text{ lbm/hr} \ [5.44 \frac{\text{kg}}{\text{hr}}] \]
Separator 2

\[ P = 115 \text{ Psia} \ [800\text{ kPa}] \]
\[ \dot{m}_T = 6 \text{ lbm/hr} \[2.7 \text{ kg/hr}\] \]

- \( x_i = 30\% \) Full Liquid column, Liquid Vapor interface is above visible range of separator
- \( x_i = 50\% \) Full Liquid column, Liquid Vapor interface is above visible range of separator
- \( x_i = 60\% \) Full Liquid column, Liquid Vapor interface is above visible range of separator
Conclusion

- Liquid-Vapor separation is effective for both geometries so long as $x_i$ and $\gamma$ are balanced.
- Major Observations:
  1) $x_1 > \gamma$ : No clear liquid-vapor interface was found; no liquid buildup was found within the separator.
  2) $x_1 < \gamma$ : The liquid-vapor interface was visible and a liquid buildup was observed within the separator vessel.

Future work

- System Level Testing
- Further investigate vapor branch quality when $x_i > \gamma$. 