Herrick Laboratories PURDUE UNIVERSITY

2016 Purdue Conferences
Compressor Engineering
Refrigeration and Air Conditioning
High Performance Buildings

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

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July 11 -14, 2016

PURDUE UNIVERSITY

Center for High Performance Buildings at Purdue

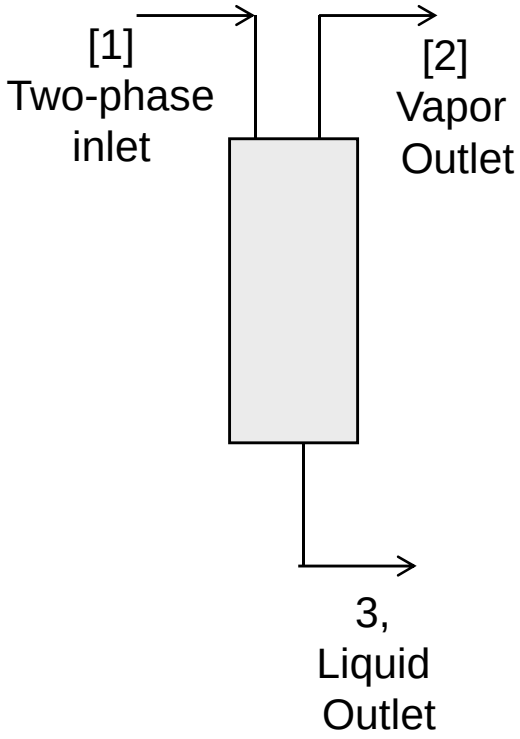
Presentation Outline

- 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

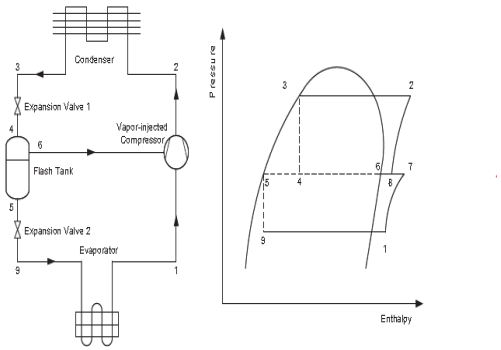
Objective:

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

BACKGROUND

Making use of two-phase separators

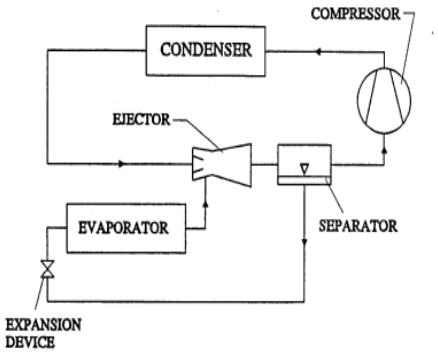
Flash Tank Economizer Cycle



(Wang, 2008)

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

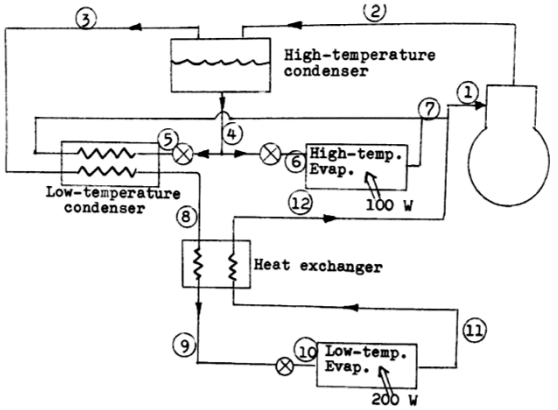
Ejector Cycle



(Domanski, 1995)

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

Mixed Refrigerant System (2 evaporators)



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

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 $5 < x_i < 15$ %

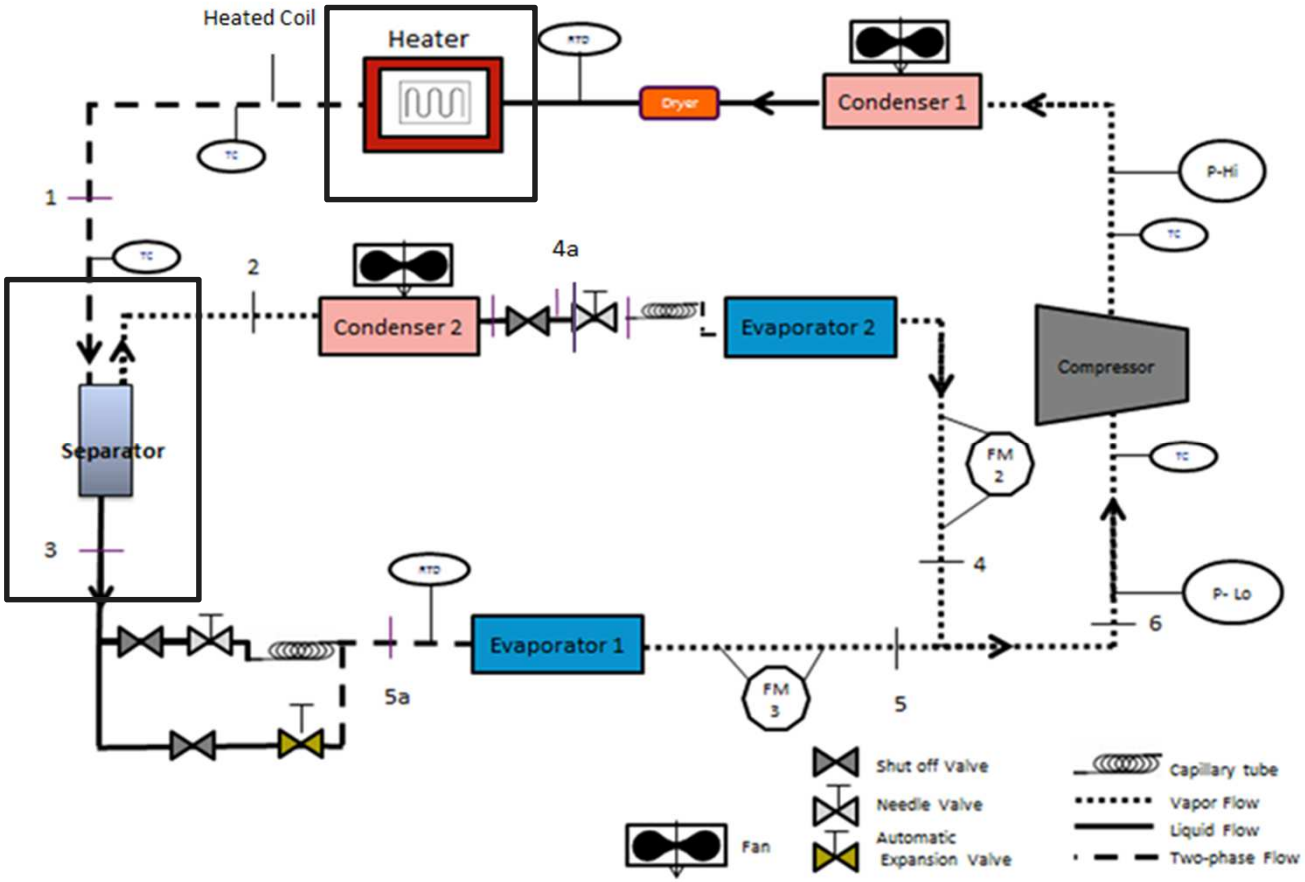
Geometry	Sep 1in[mm]	Sep 2in[mm]
Inlet branch	0.34(8.7)	0.47(12)
Body Diameter	0.72(18.3)	0.94(23.8)
Overall Height	15.748(400)	15.748(400)

- Tuo & Hrnjak (2012)
  - Expanded on separation enhancers
  - Angling and dual inlet significantly improve separation

- **Flows are 10 – 20 times higher than small refrigeration appliances**

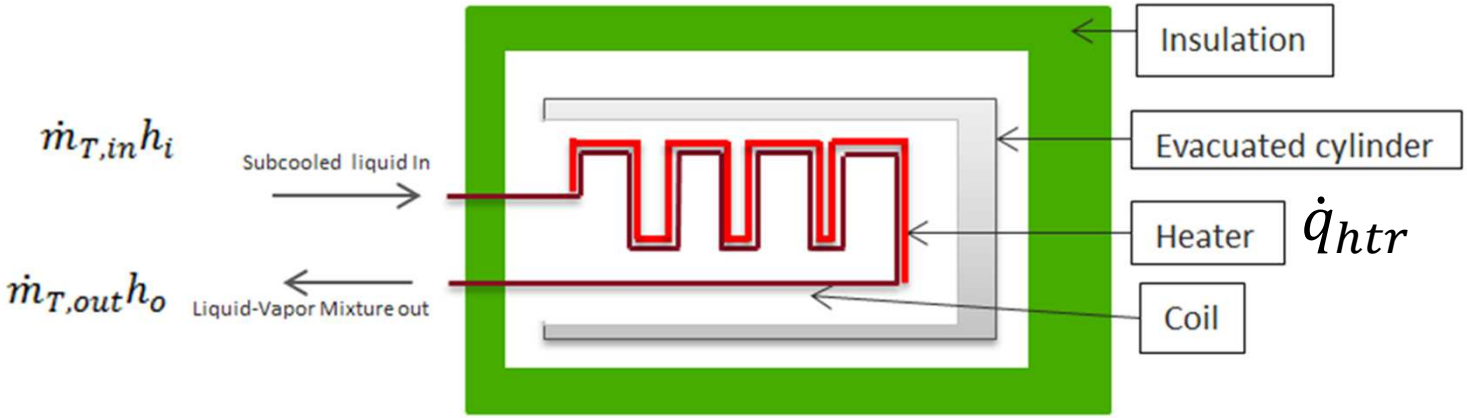
METHODS

Two-Phase Separator Test Facility



METHODS

Two-Phase Control



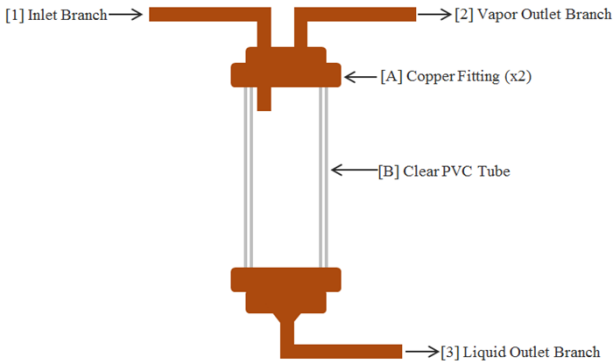
$$\dot{q}_{htr} = \dot{m}_T(\boldsymbol{h_o} - h_i)$$

$$x_i = \frac{\boldsymbol{h_o} - h_f}{h_v - h_f}$$

METHODS

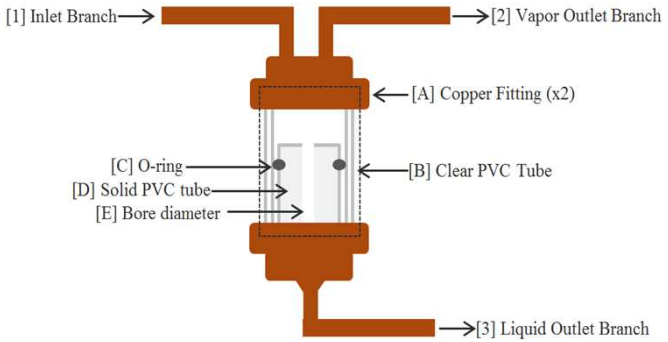
Separator Geometry

Separator 1



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

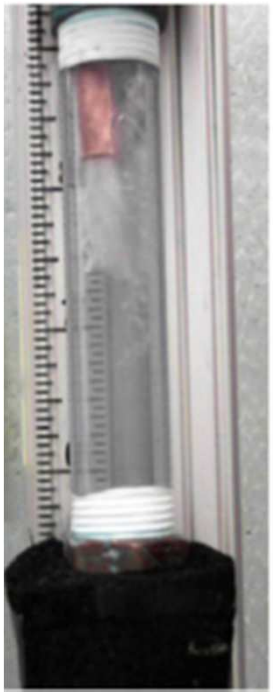
Separator 2

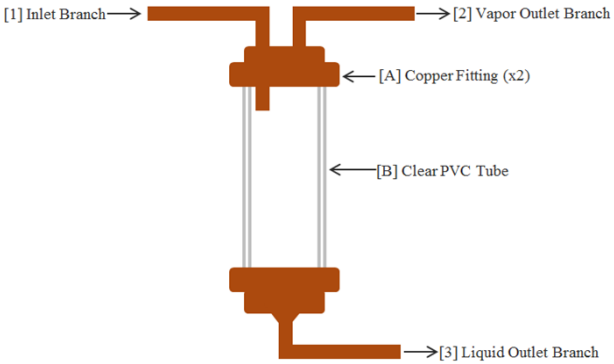


Geometry	in[mm]
Inlet,Oulet(liq,vap)	0.232(0.200)
Body Diameter	0.742(18.847)
Overall Height	1.750(44.450)
Inlet to bottom	0.656(16.67)

RESULTS

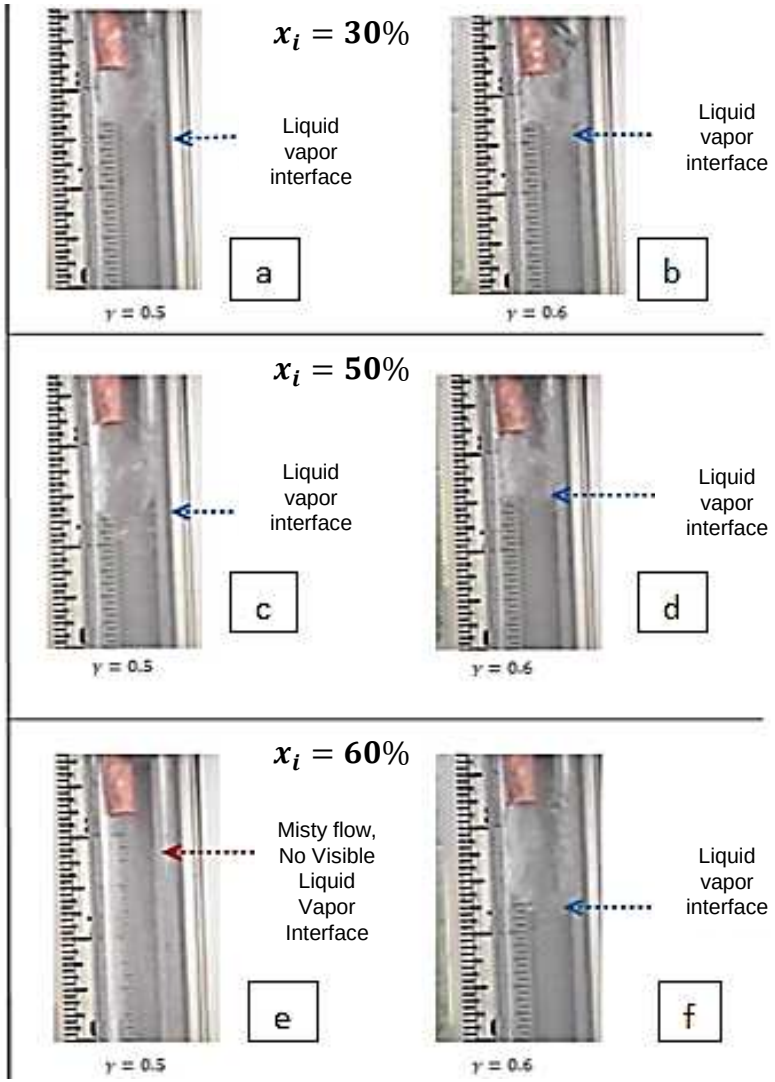
Separator 1





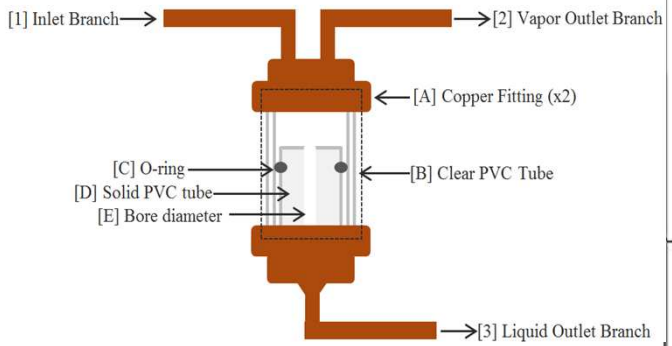
$$P = 115\ Psia\ [800kPa]$$

$$\dot{m}_T = 12\ lbm/hr [5.44\ \frac{kg}{hr}]$$



RESULTS

Separator 2



$$P = 115\ Psia\ [800kPa]$$

$$\dot{m}_T = 6\ lbm/hr[2.7\ \frac{kg}{hr}]$$

$x_i = 30\%$

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 & FUTURE WORK

Conclusion

- Liquid-Vapor separation is effective for both geometries so long as x_i and γ are balanced.
- Major Observations:

1) $x_1 > \gamma$: No clear liquid-vapor interface was ; 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 $\dot{x_i} > \gamma$.

Questions

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