HEAT TRANSFER OF LOW GWP REFRIGERANTS

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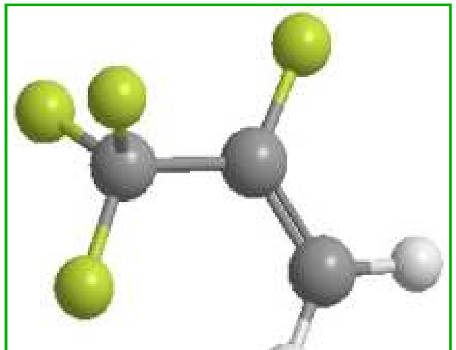
Honeywell

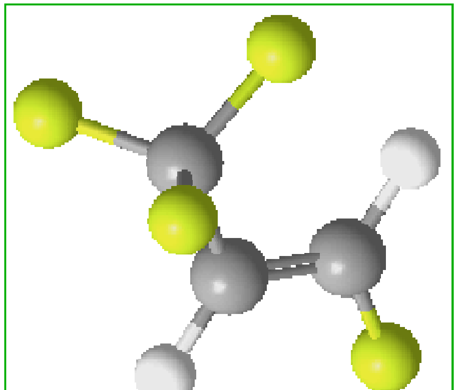
CONTENTS

Introduction

- Used data from NISTIRs 5144 (evaporation), 6095 (condensation) and 6333 (pressure drop) database of experimental data for micro-fin tubes
- Data includes both condensation and evaporation for single fluids (R22, R32, R134a,R125), azeotropic mixtures (R410A, R502, R507A) and zeotropic mixtures (R407C, R32/R125 and R32/R134a)
- Refprop 9.0 properties used for all calculations
- Various heat transfer and pressure drop correlations were evaluated
- Two very low GWP molecules have been developed HFO-1234yf and HFO-1234ze
- These molecules are components of our blends (L-41) to replace R410A which were tested in a 3 ton heat pump
- System data was used to analyze the relative heat transfer and pressure drop performance of the new refrigerants



HFO-1234yf



HFO-1234ze(E)

Evaporation Heat Transfer

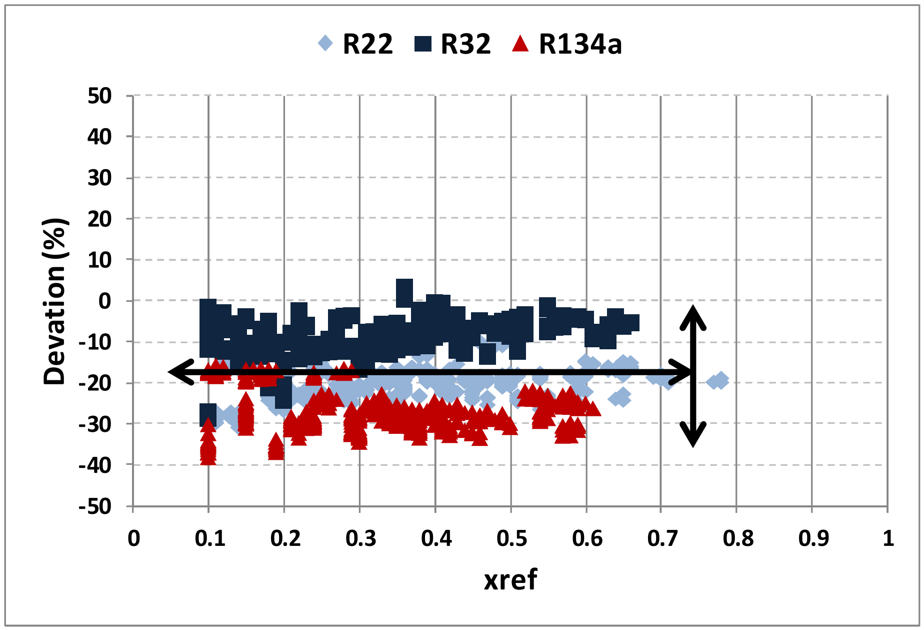
Different correlations were evaluated and two were selected

1. Thome et al. 1997- Annular flow in Microfin tubes
   - Approach based on new flow map (modified form of Steiner (1993) flow map)
   - Overall heat transfer coefficient has contributions from nucleate and covective
   - Asymptotic approach for convective and nucleate boiling (Cooper 1984)
   - Enhancement factor were included to account for microfin tubes

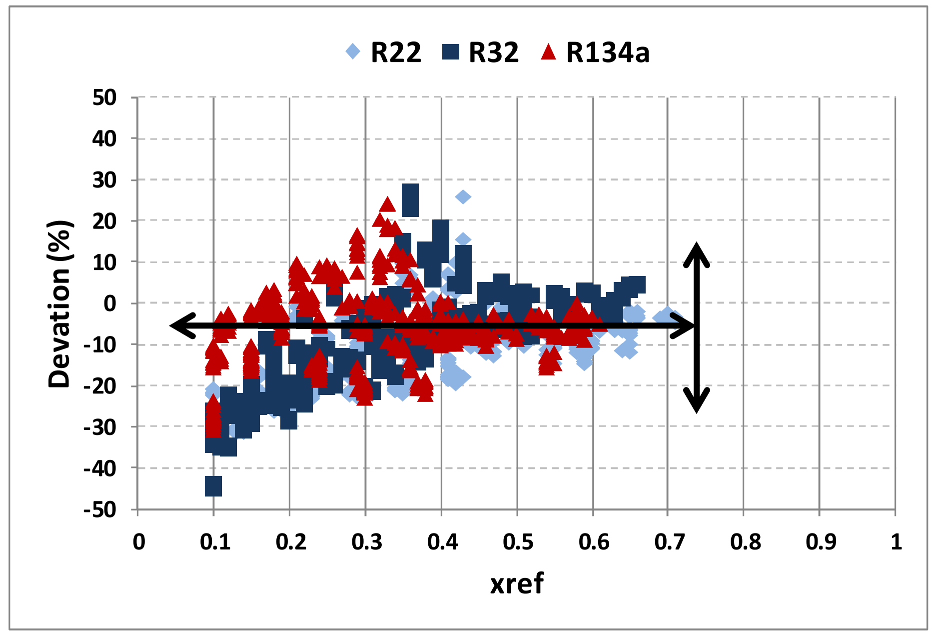
2. Cavallini et al. 1999 –Annular flow for Microfin tubes
   - Overall heat transfer sum of convective and nucleate boiling contributions
   - Nucleate boiling (Cooper 1984)- Suppression factor and enhancement factor
   - Area enhancement factor applied to smooth tube for convective coefficient
   - Accounted for surface tension effects and vapor shear

Evaporation Heat Transfer Coefficient-Pure Fluids

CAVALLINI



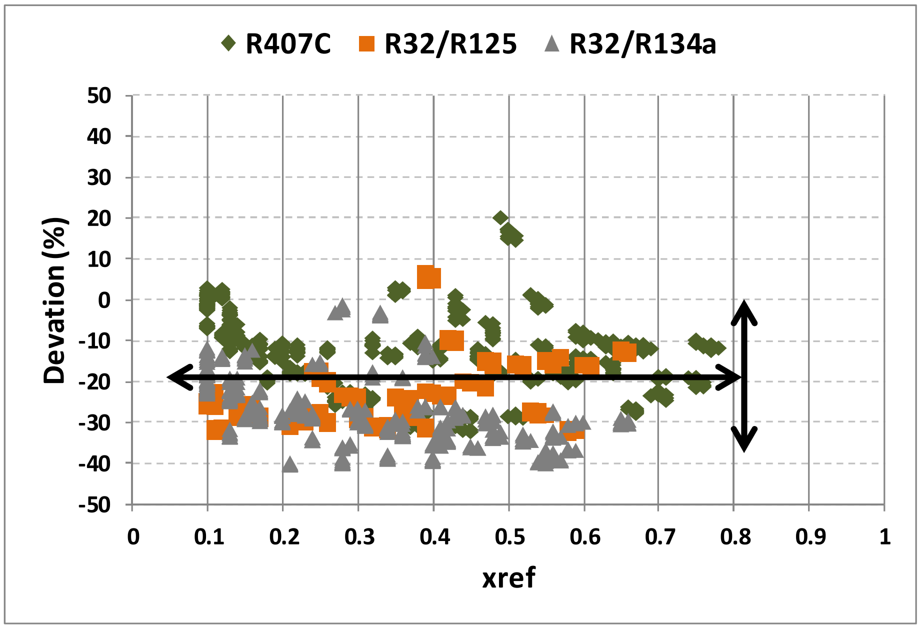
THOME



- Cavallini's correlation was found to be more consistent for this experimental data

Evaporation Heat Transfer Coefficient- Zeotropic Mixtures

CAVALLINI



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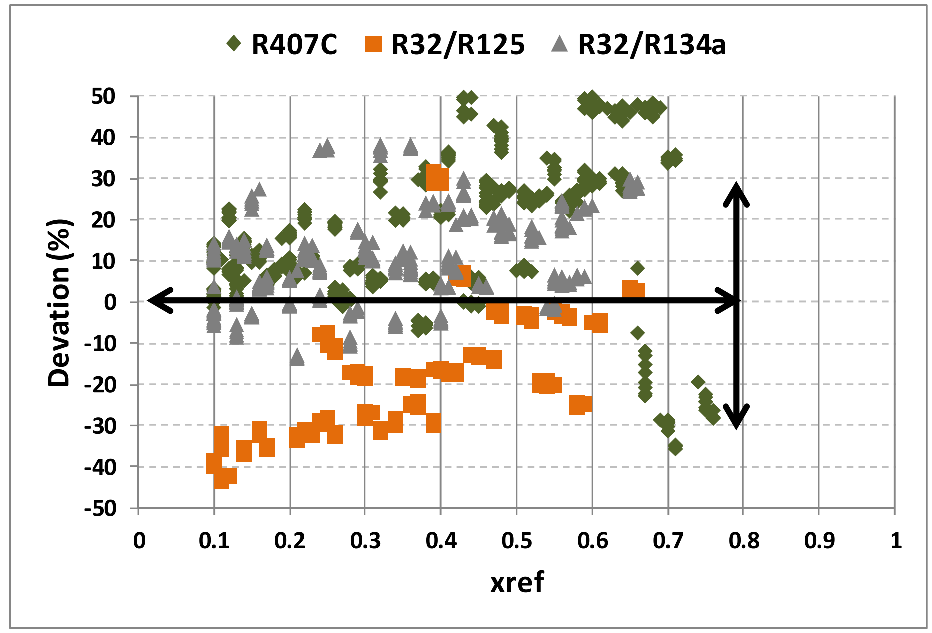


- Cavallini's correlation was found to be more consistent for this experimental data
- Cavallini's correlaton was used for further analysis

CONDENSATION HEAT TRANSFER

Different correlations were evaluated and three were selected

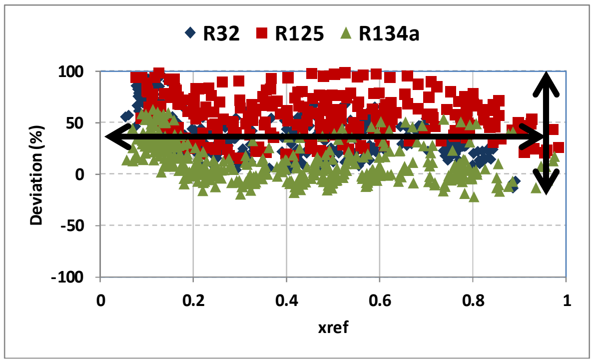
1. Cavallini et al. 1993,1995- Microfin and Cross grooved tubes
   - Correlation has form of forced convective equation
   - Area enhancement factors were used
   - Vapor shear and Surface tension effects were included

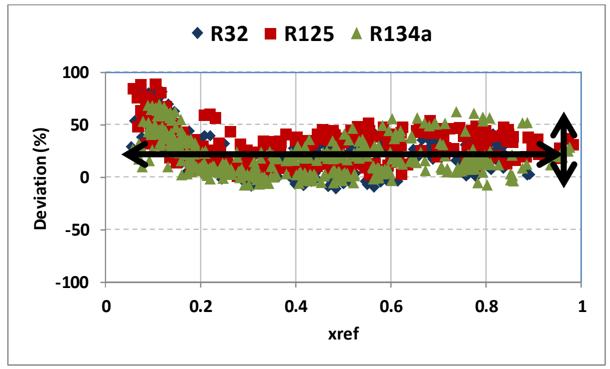
2. Koyama et al. 1998- Microfin tubes with pure fluids
   - Total heat transfer coefficient has contributions from forced convective condensation and natural convective condensation
   - Modified correlation for smooth tube by including area enlargement ratio
   - Did not account for surface tension effects

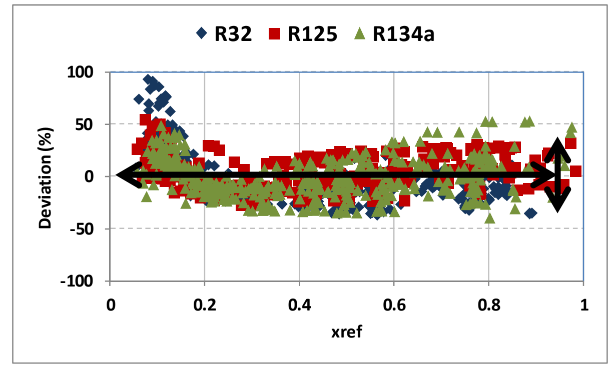
3. Cavallini et al. 2009- Microfins tubes pure fluids and near azeotropes
   - Total heat transfer coefficient contribution from annular and stratified wavy flows (asymptotic form exponent 3)
   - Surface tension effects were not considered
   - Validated against very large experimental database

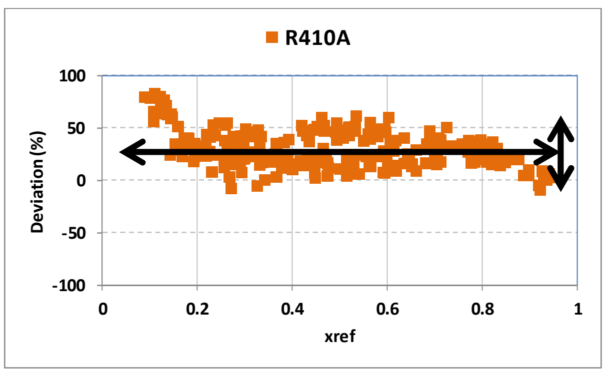
Condensation Heat Transfer Coefficient

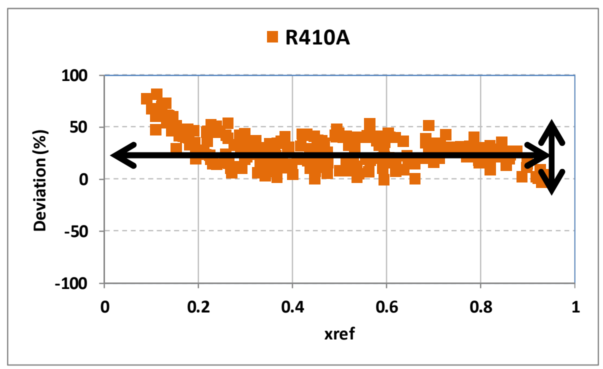
CAVALLINI-1993,1995 | **CAVALLINI-2009** | **KOYAMA**

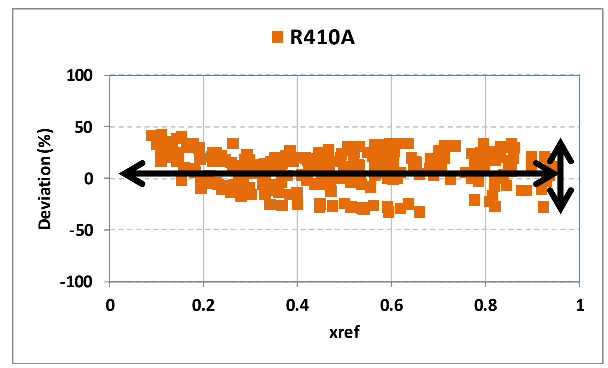






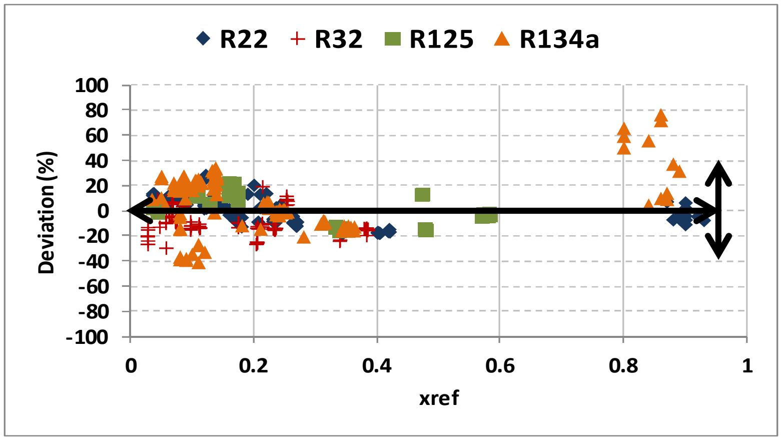
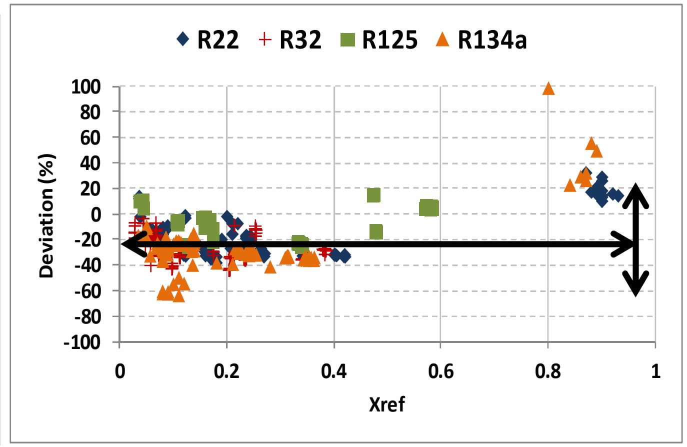
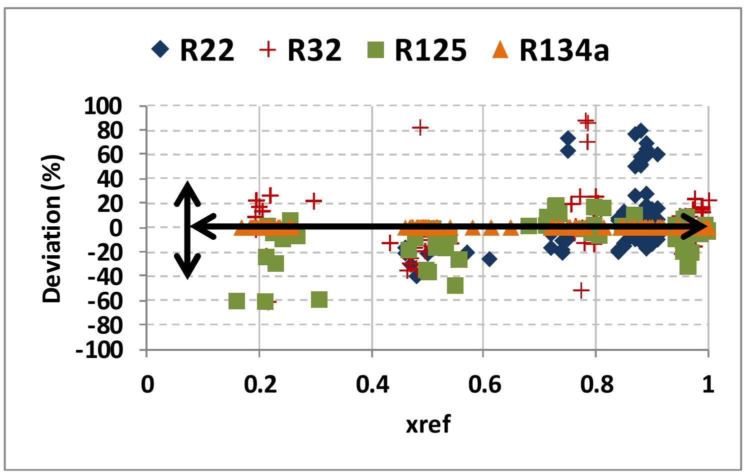
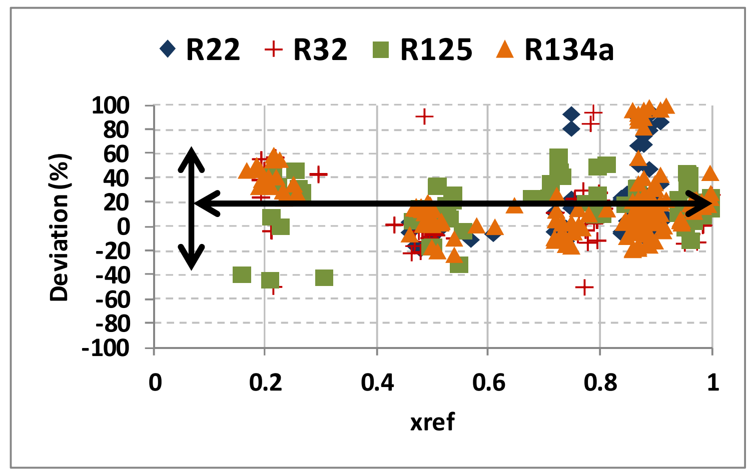






- Cavallini’s 2009 correlation was found to be more consistent than the earlier correlation
- Cavillini 2009 was chosen for further analysis since it was validated for a large experimental data set

Pressure Drop Evaluation-Pure Fluids

	CHOI	CAVALLINI
EVAPORATION		
CONDENSATION		

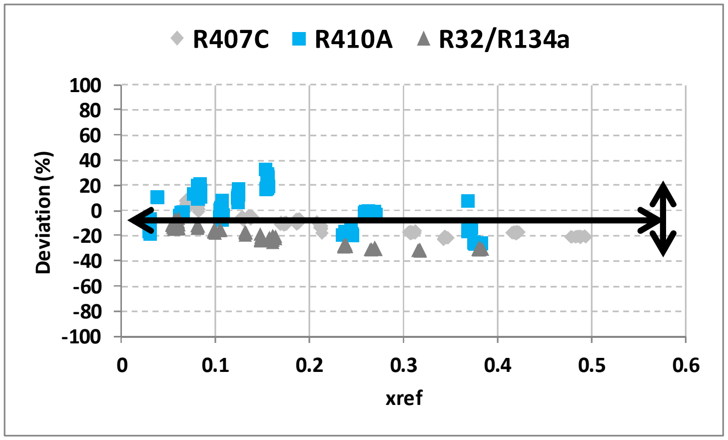
- Choi et al. 1999- Modified Pierre (1964) for evaporation and condensation
- Choi's correlation has a lower spread for condensation

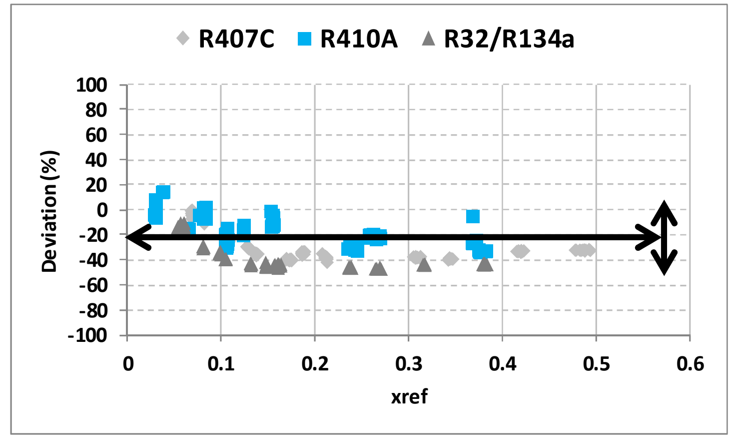
Pressure Drop Evaluation- Refrigerants Blends

CHOI

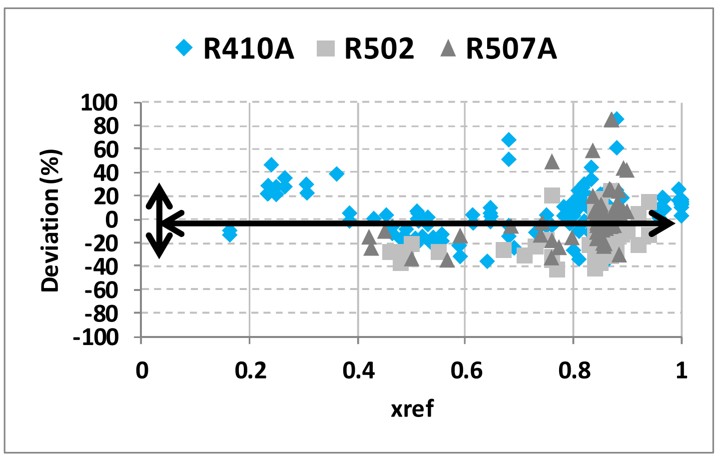
CAVALLINI

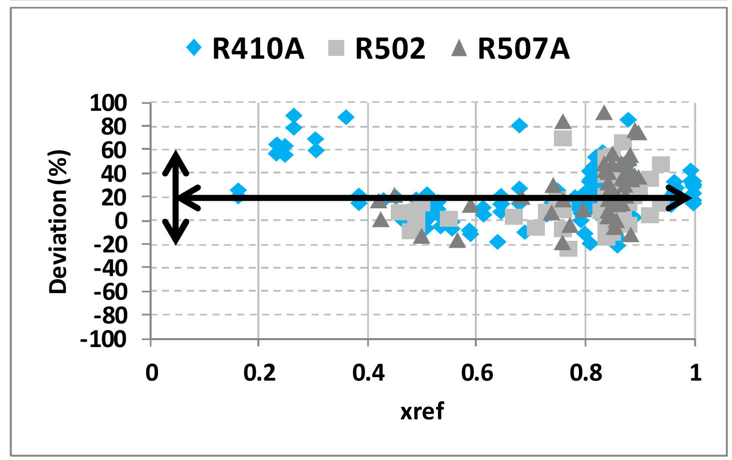
EVAPORATION





CONDENSATION





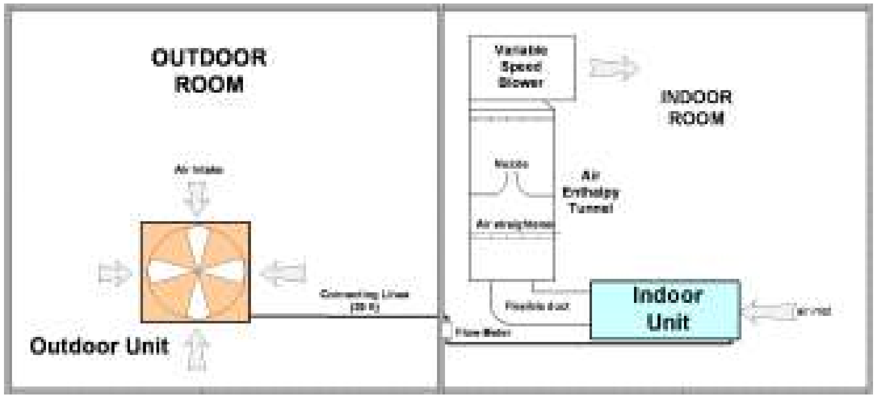
- Choi’s prediction for condensation show a lower spread
- Choi’s corrleation was selected for further analysis

LGWP R410A Replacements

Test System (R410A 13 SEER 3-Ton) and Operating Conditions

Tests Conditions according to AHRI Std 210

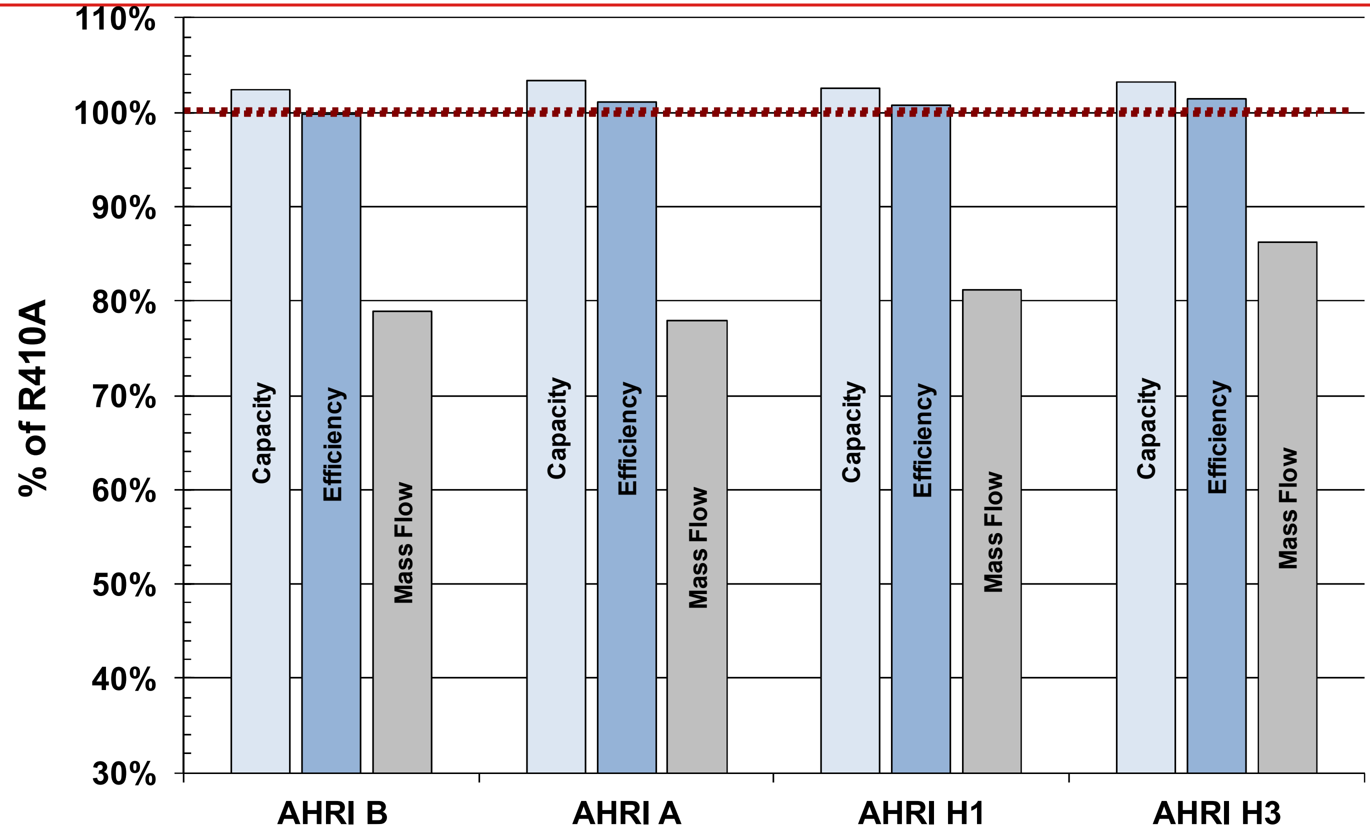
- All tests performed under near drop-in conditions (original equipment)
- An EEV was used for superheat control
- Charge optimization performed for AHRI test H1 condition



Test	Cooling Mode			
	Indoor Room		Outdoor Room	
	DB(F)	WB(F)	DB(F)	WB(F)
A	80	67	95	75
B	80	67	82	65
C	80	57	82	65
MOC	80	67	115	75

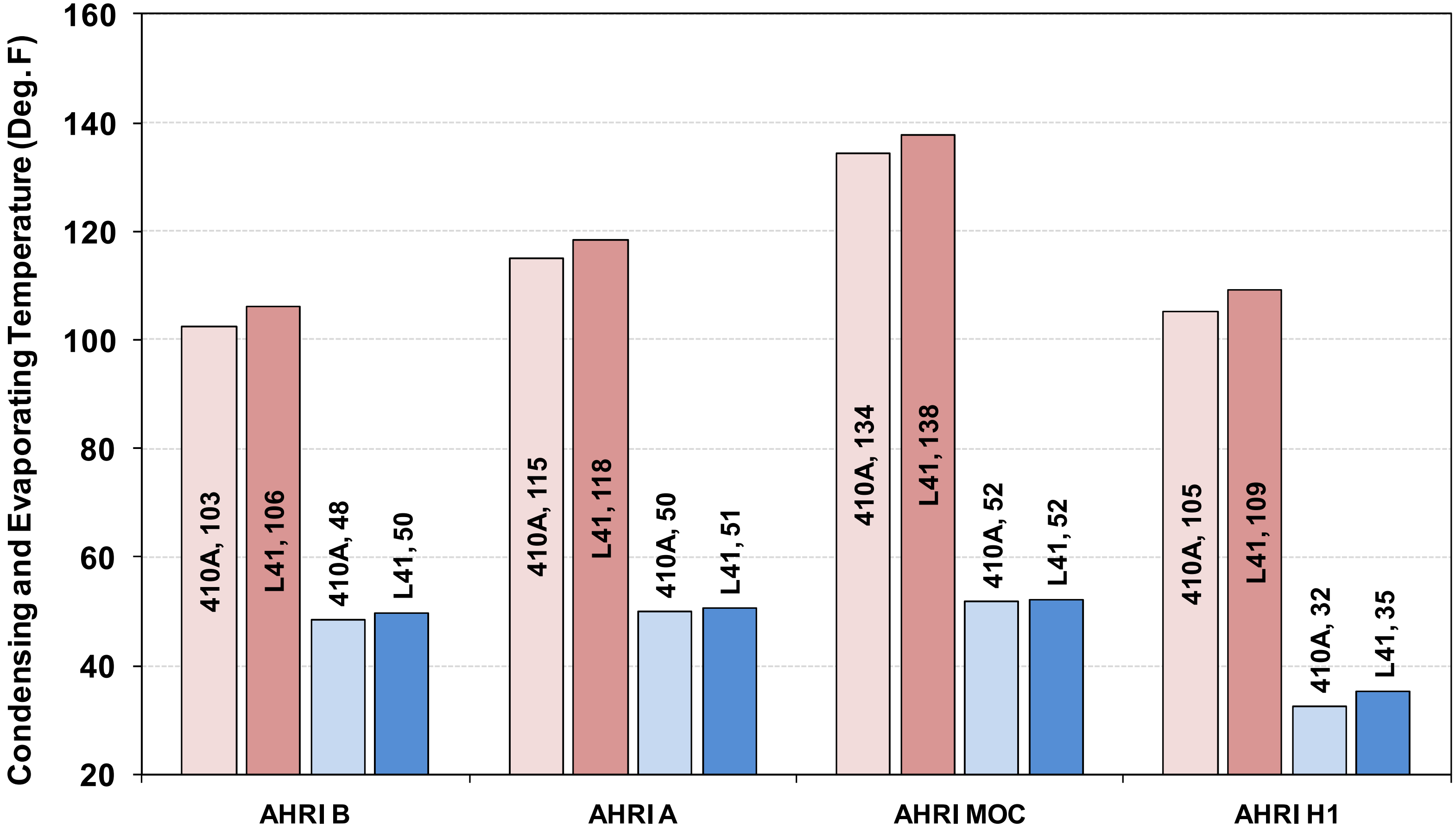
Test	Heating Mode			
	Indoor Room		Outdoor Room	
	DB(F)	WB(F)	DB(F)	WB(F)
H1	70	60	47	43
H2	70	60	35	33
H3	70	60	17	15

Experimental Results-L41



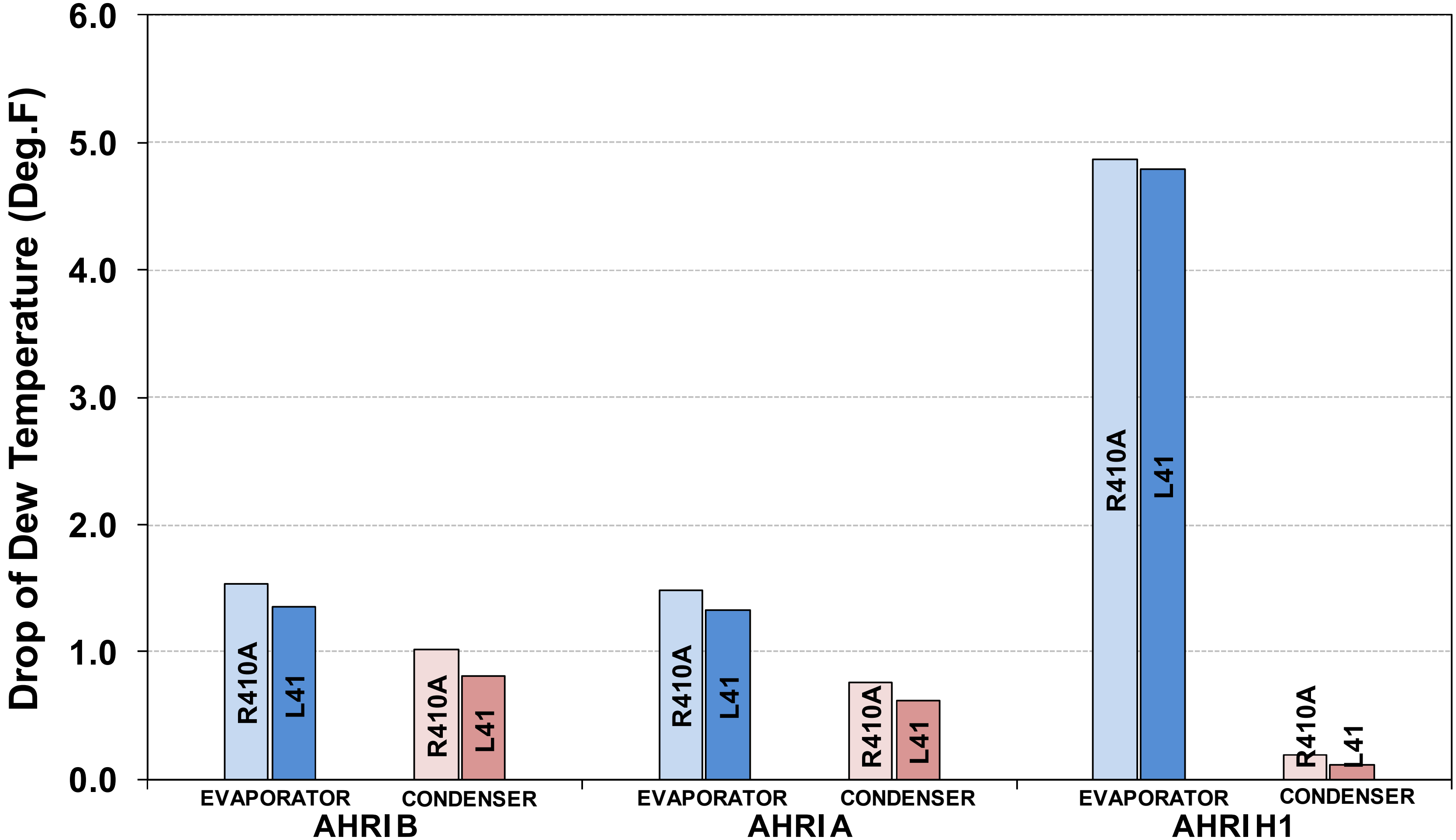
- Modified L-41: Reduced R-32 content to reduce discharge temperatures enabling use of current compressor technology in all climates.
- At AHRI MOC conditions discharge temperature is 24 F higher than R410A compared to 41F for R32
- Formulated to reduce flammability (BV < 4) and maintain GWP below R-32.
- A slightly larger displacement compressor (~10%) used to recover capacity but maintaining efficiency
- Lower mass velocities due to lower flow rates indicate further improvements in heat exchanger design may be possible

Evaporating and Condensing Temperatures



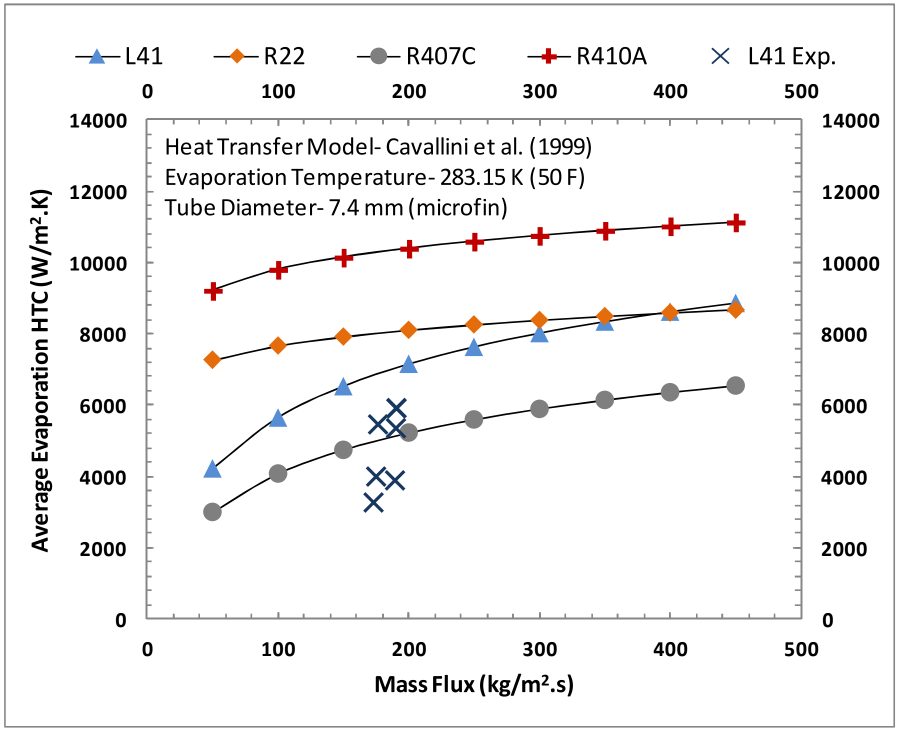
- Drop-in testing results show similar evaporating temperatures
- Condensing temperatures slightly higher indicating scope of improvement in heat exchanger design. However performance is not affected.
- This indicates good heat transfer properties since mass velocities ~ 75-80% of R410A

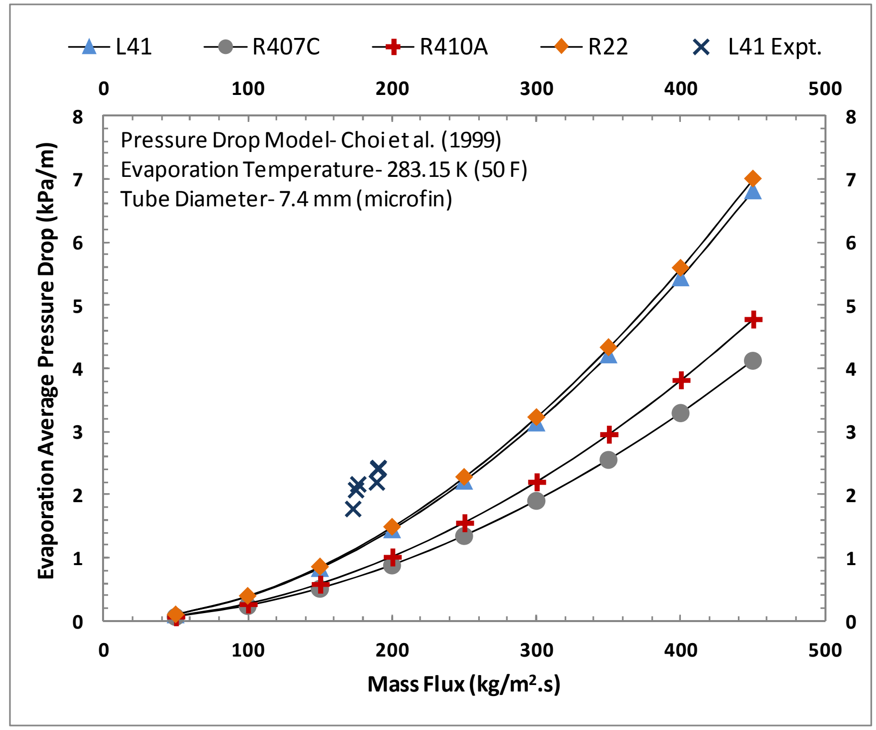
Pressure Drop in Heat Exchangers



- Drop of saturation temperature good measure of penalties in the system
- Lower drop of saturation temperature in heat exchangers. Further improvement in heat exchanger design to improve heat transfer is possible

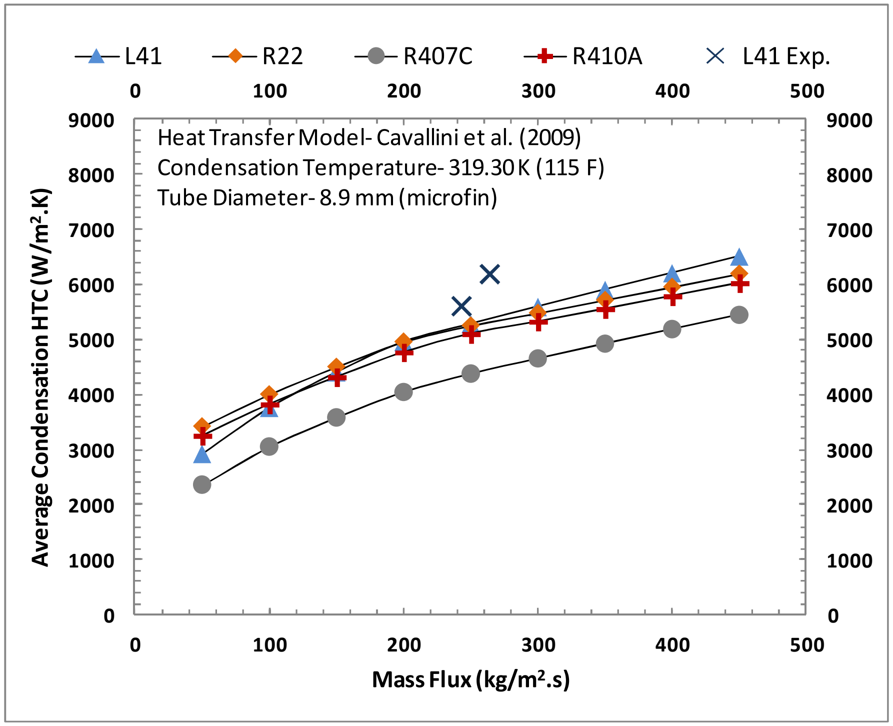
Evaporation Heat Transfer and Pressure Drop

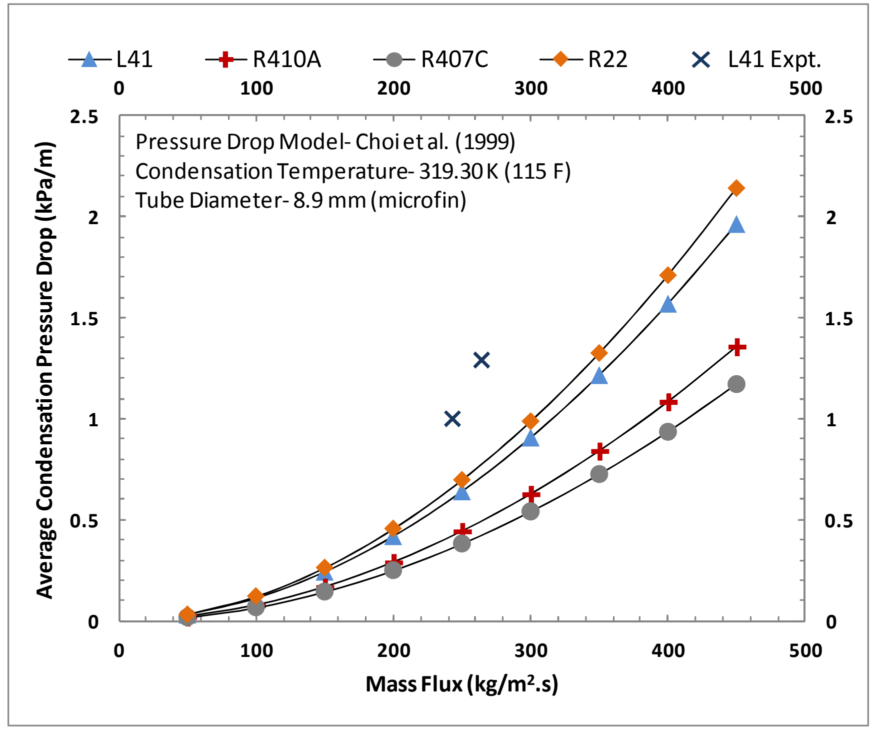




- Cavallini's correlation predicts heat transfer coefficients for L41 in between R22 and R407C
- Detailed system performance data was used to estimate the average heat transfer coefficient
  - Extracted total heat exchanger duty and used LMTD approach to calculate heat transfer coefficient
  - The uncertainty is heat transfer coefficient is estimated to be ± 30%
- Further research is necessary to understand the heat transfer characteristics of new fluids
- The pressure drop predictions seem reasonable since system pressure drop would be expected to be higher due to additional resistances

Condensation Heat Transfer and Pressure Drop





- Cavallini's correlation predicts heat transfer coefficients similar to R22 and R410A
- Further investigation of heat transfer coefficients is necessary
- The pressure drop data seems reasonable since system pressure drop would be expected to be higher due to additional resistances

CONCLUSIONS

- Under the test conditions studied, the new LGWP blends provide good system performance with minor system modification
- Improvements in heat exchanger design may further improve system performance with LGWP blends
- In these studies, the new blends seemed to have good heat transfer properties and presented a lower pressure drop in the heat exchangers
- Further research is necessary to understand the heat transfer and pressure drop properties of the new LGWP refrigerants

THANK YOU

QUESTIONS?