R1234ze(E) AND R450A AS R134a ALTERNATIVES IN REFRIGERATION SYSTEMS: FROM FLUID PROPERTIES TO EXPERIMENTAL COMPARISON

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TPTPR2017

25 April 2017 | SEOUL, SOUTH KOREA

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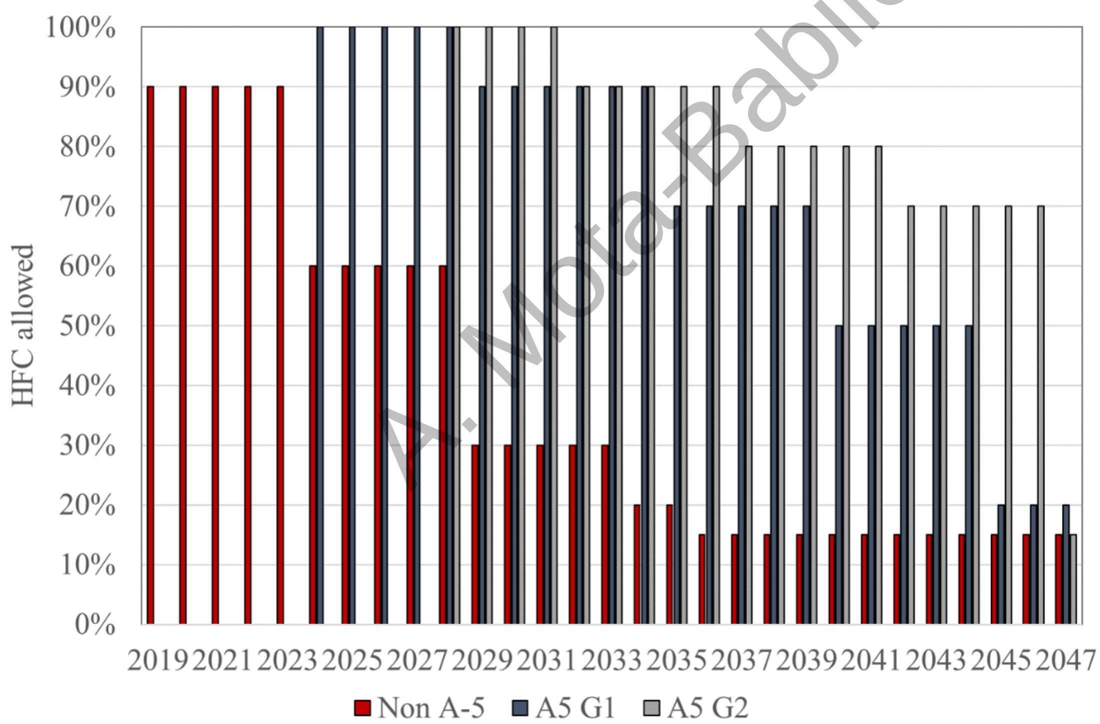
1. INTRODUCTION

2016 - Kigali's amendment of the Montreal Protocol

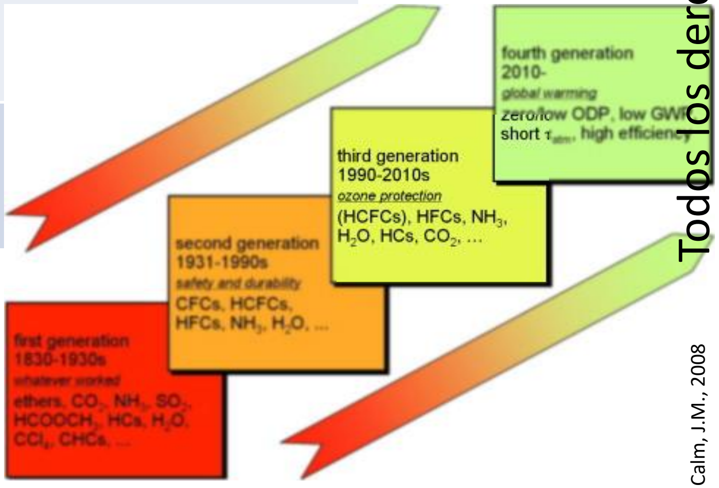
Elimination of HFCs could reduce global warming by 0.5 °C by 2100



1. INTRODUCTION

Most used HFCs

R134a	Commercial refrigeration (mid temp) Domestic refrigeration Mobile air conditioning Water chillers
R404A R507A	Commercial refrigeration (low and mid temp) Transport refrigeration Water chillers
R410A	Residential & light air conditioning Stationary air conditioner



Calm, J.M., 2008

1. INTRODUCTION

Most used HFCs

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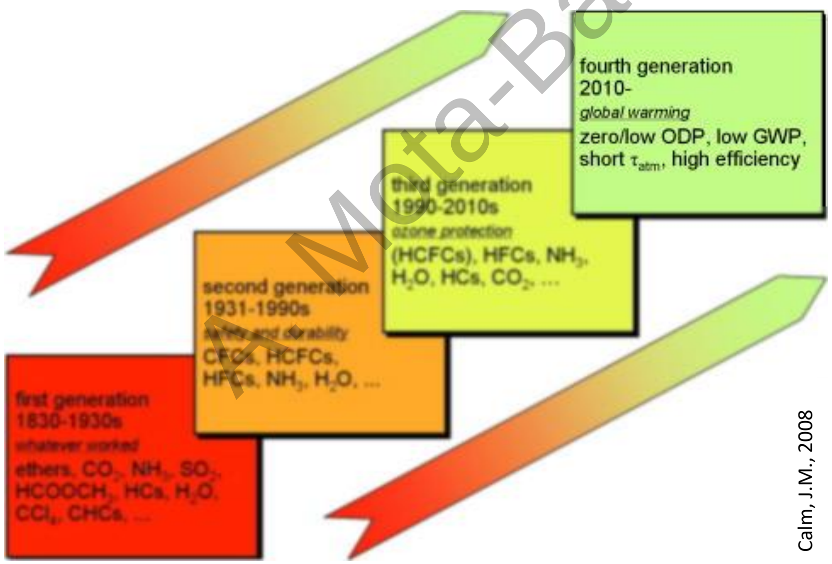

Calm, J.M., 2008

1. INTRODUCTION

Most used HFCs

R134a	Commercial refrigeration (mid temp) Domestic refrigeration Mobile air conditioning Water chillers

- Natural refrigerants
- Lower GWP HFCs
- HFOs
HFC/HFO mixtures

1. INTRODUCTION

Most used HFCs

R134a	Commercial refrigeration (mid temp) Domestic refrigeration Mobile air conditioning Water chillers

- Natural refrigerants
- Lower GWP HFCs
- HFOs
  HFC/HFO mixtures
  - Trade-off
    Drop-in solution

1. INTRODUCTION

Main HFOs to replace R134a

- R1234yf
- R1234ze(E)

- Very low GWP
- Compatibility
- Chemical stability

- Energy performance
- Knowledge
- Flammability (A2L)

- Price??

1. INTRODUCTION

HFC/HFO Mixtures to replace R134a

R1234yf

HFCs
R32, R134a...

R1234ze(E)

Compatibility

Chemical stability

Knowledge

Price??

1. INTRODUCTION

HFC/HFO Mixtures to replace R134a

R1234yf

HFCs
R32, R134a...

R1234ze(E)

Medium GWP

Compatibility

Chemical stability

Energy performance

Knowledge

Non – Flammable (A1)

Price??

1. INTRODUCTION

HFC/HFO Mixtures to replace R134a

R1234yf | R134a | R1234ze(E)

R1234yf → R513A

R1234ze(E) → R450A

- Medium GWP
- Energy performance
- Compatibility
- Knowledge
- Price??
- Chemical stability
- Non – Flammable (A1)

1. INTRODUCTION

Objective of the study

R1234yf

R134a

R1234ze(E)

R513A

R450A

Medium GWP

Compatibility

Chemical stability

Energy performance

Knowledge

Non – Flammable (A1)

Price??

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2. OVERVIEW OF FLUIDS

	R134a	R1234ze(E)	R450A
Composition	Pure fluid	Pure fluid	42% R134a / 58% R1234ze(E)
ANSI/ASHRAE Standard 34	A1	**A2L**	A1
GWP for IPCC Report of 2013 ($CO_{2\text{-eq}}$)	1300	**1**	547
Molecular weight (g mol^{-1})	102.03	114.04	108.69
Critical Temperature (K)	374.21	382.51	377.62
Critical Pressure (MPa)	4.06	3.63	3.82
Normal boiling point (K)	247.08	**254.18**	249.79
Glide at 0.1 MPa (K)	0	0	**0.61**
Liquid/Vapor density [a] (kg m^{-3})	1294.8 / 14.43	1240.1 / **11.71** ⇩	1259.64 / 13.18
Liquid/Vapor viscosity [a] (µPa s)	266.53 / 10.73	268.95 / **11.20** ⇧	264.23 / **11.16**
Liquid/Vapor c_p [a] (kJ kg^{-1} K^{-1})	1.34 / 0.90	1.32 / 0.88	1.33 / 0.89
Liquid/Vapor thermal conductivity [a] (mW m^{-1} K^{-1})	92.01 / 11.51	**83.06** / 11.58 ⇩	86.23 / 11.70

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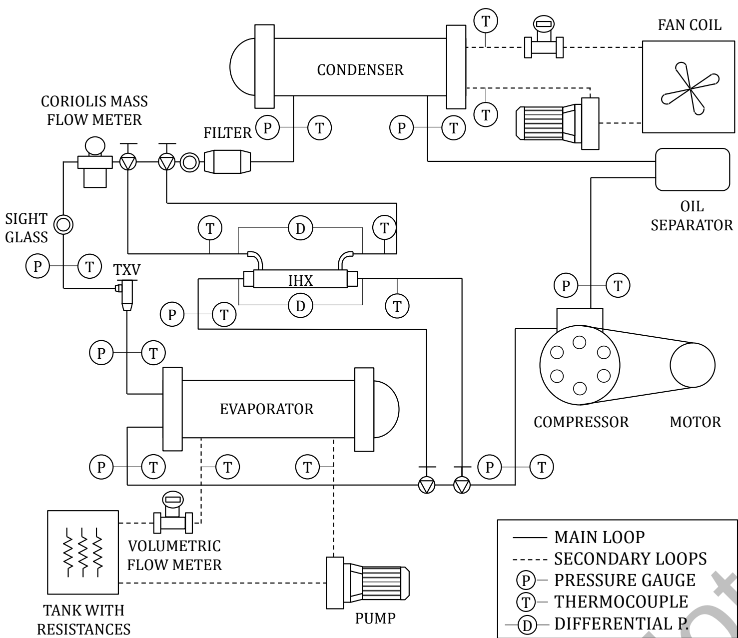
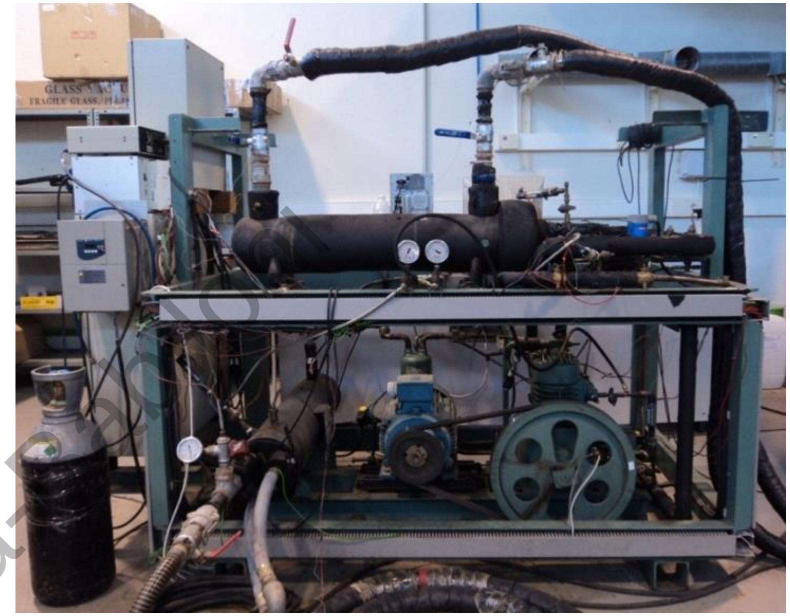
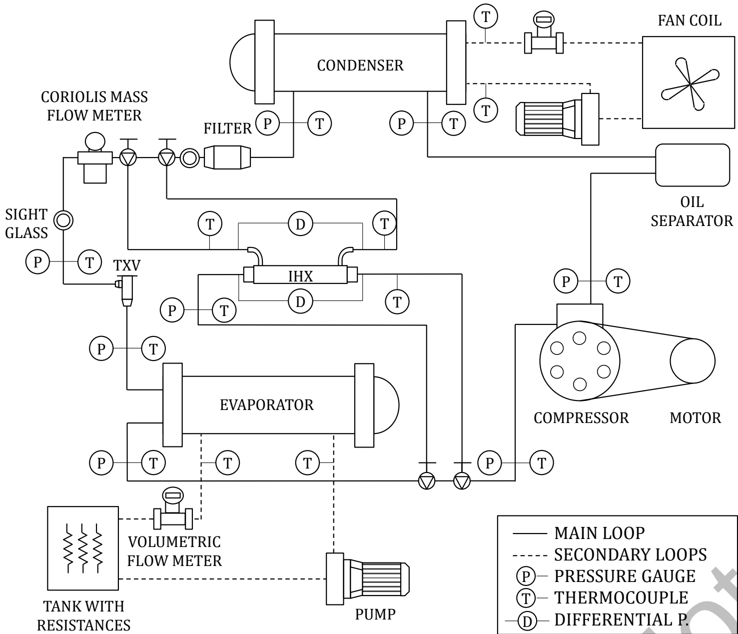
3. EXPERIMENTAL SETUP

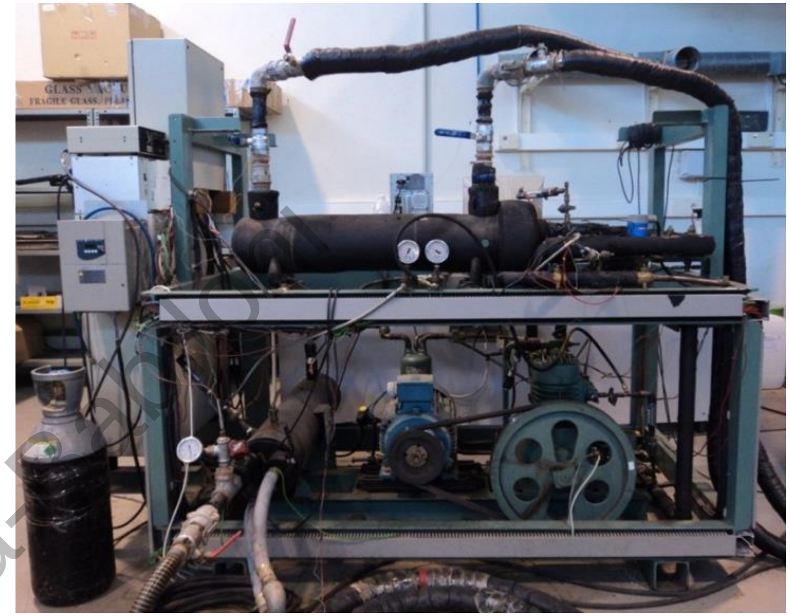




- Open type reciprocating compressor
- Shell and tube condenser and evaporator
- R134a thermostatic expansion valve
- Two secondary circuits using water and propylenglicol/water brine

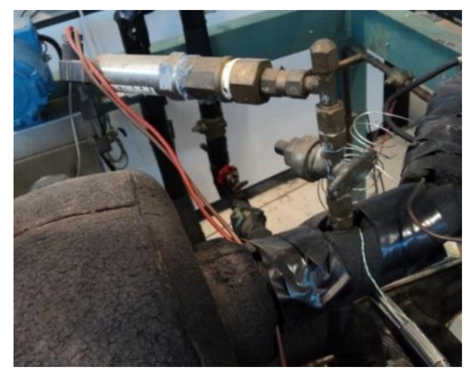
3. EXPERIMENTAL SETUP





REFPROP v9.1

- K-type thermocouples
- Piezoelectric pressure transducers
- Coriolis mass flow meter
- Digital wattmeter



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4. METHODOLOGY

THE TARGET OPERATING CONDITIONS ARE

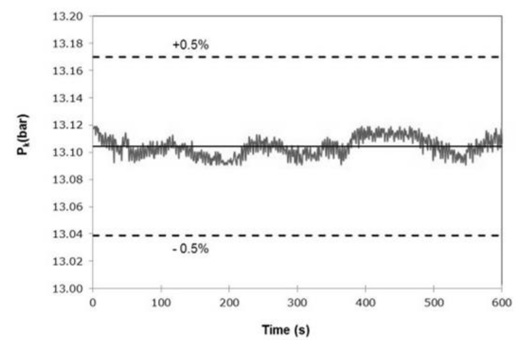
EVAPORATING TEMPERATURE (To): 260 K, 270 K, 280 K

CONDENSING TEMPERATURE: 300 K, 310 K, 320 K, 330 K

Evaporator superheating degree	7±1K
Condenser subcooling degree	2±1K

Steady-state conditions

- Tests recorded during 20 min
- Minimum of 5 min are averaged (600 measurements)



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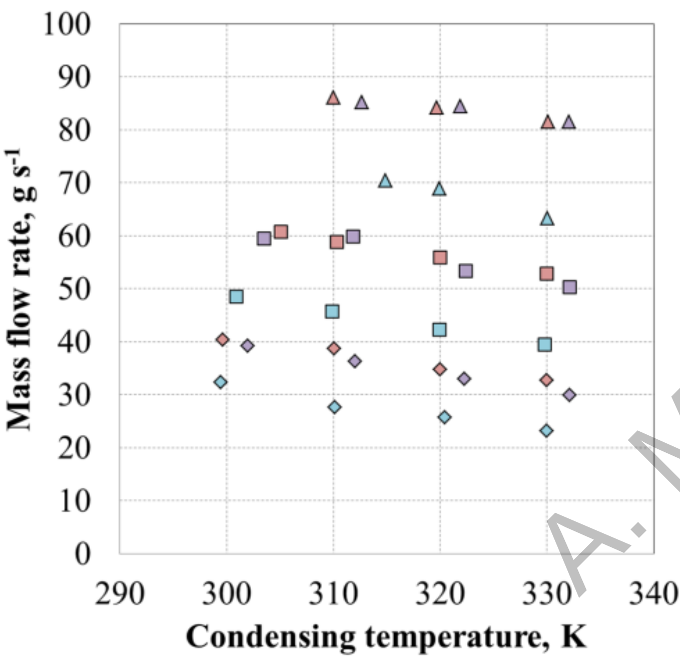
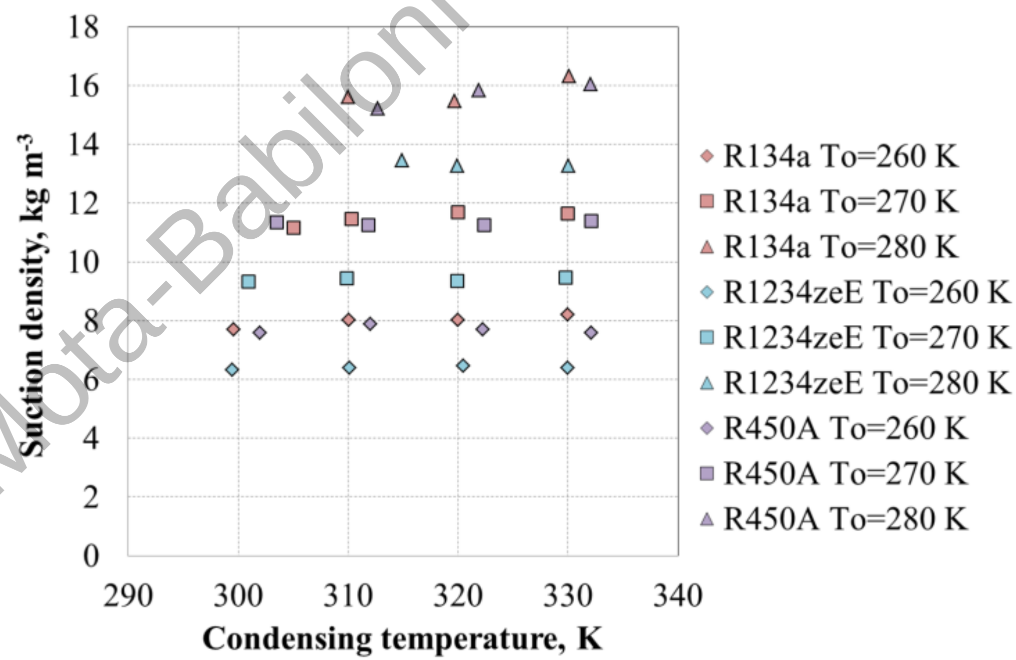
5. RESULTS AND DISCUSSION

MASS FLOW RATE

COMPRESSOR SUCTION DENSITY



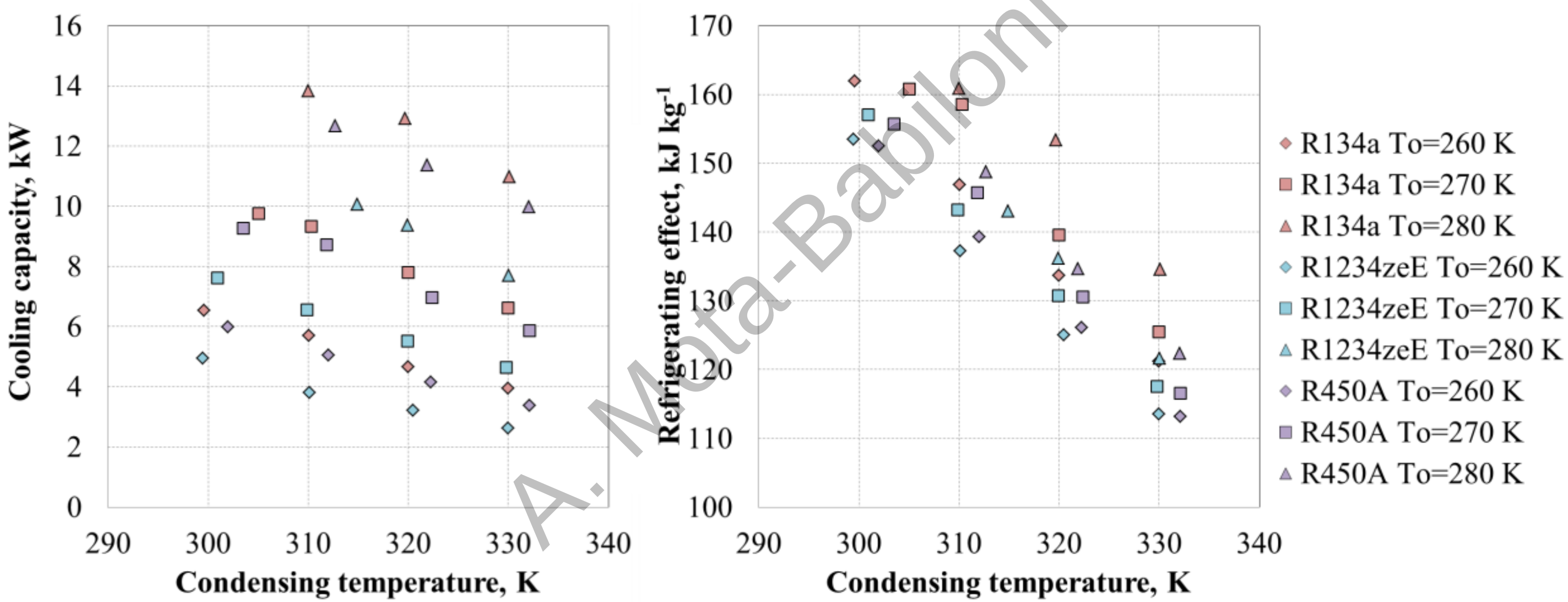


$$\dot{m}_{ref} = \rho_{suc} \eta_v V_G N / 60$$

5. RESULTS AND DISCUSSION

COOLING CAPACITY

REFRIGERATING EFFECT

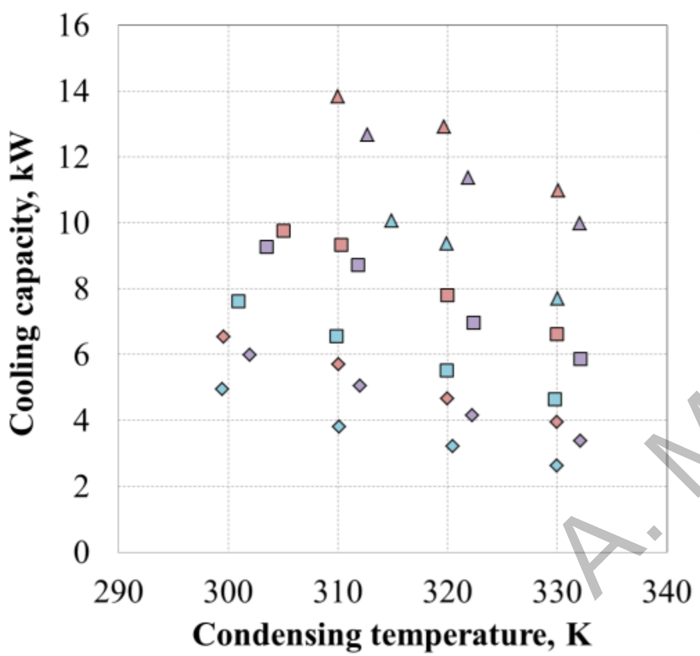


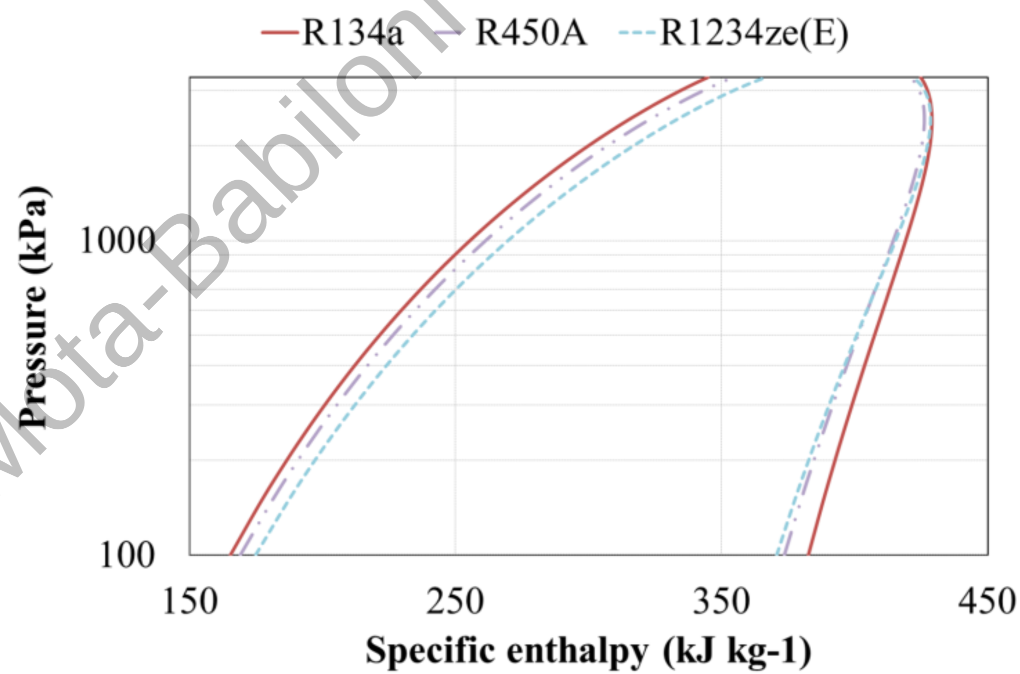
$$\dot{Q}_o = \dot{m}_{ref}\left(h_{out} - h_{in}\right)_o$$

5. RESULTS AND DISCUSSION

COOLING CAPACITY

LATENT HEAT OF VAPORIZATION

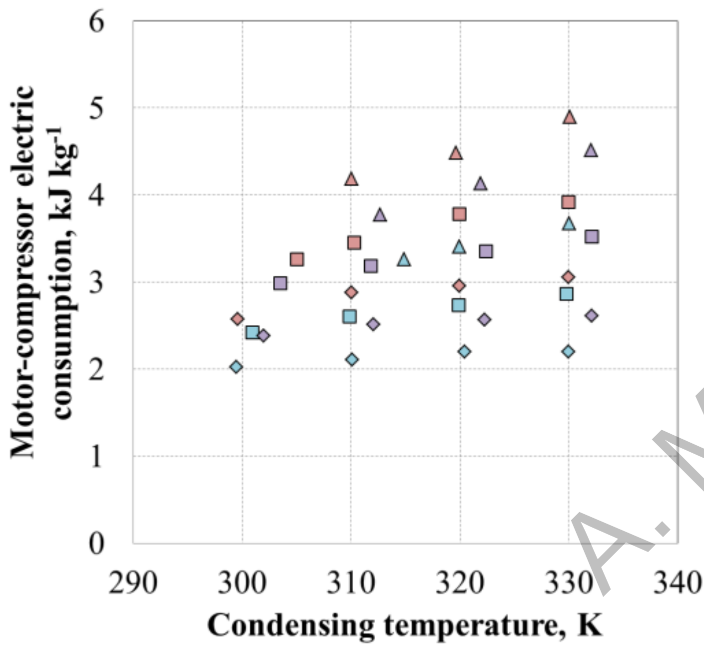


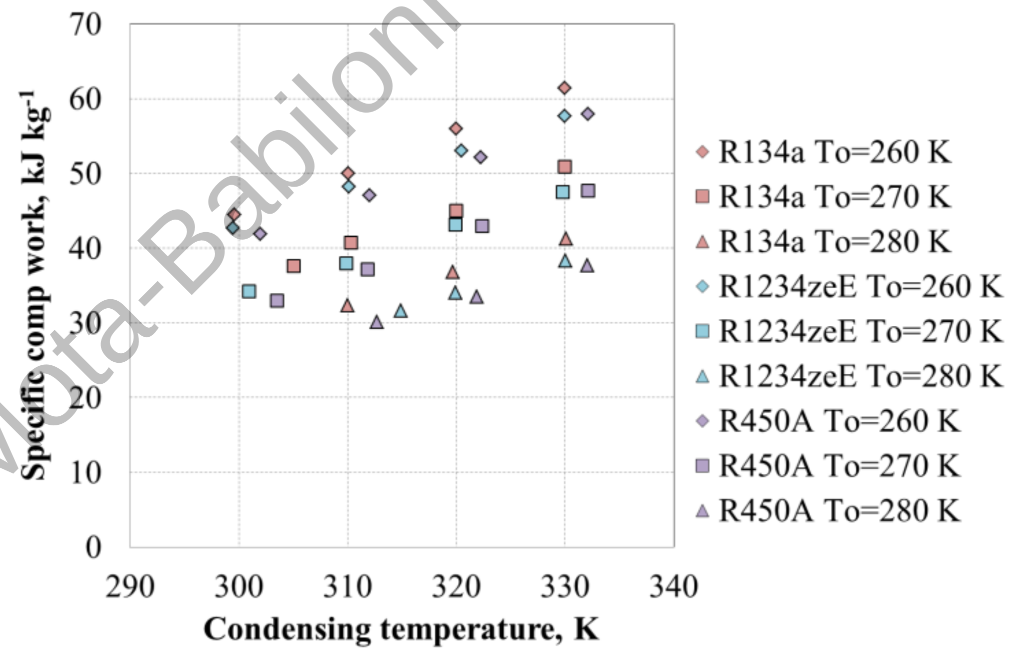


5. RESULTS AND DISCUSSION

POWER CONSUMPTION

SPECIFIC COMPRESSION WORK



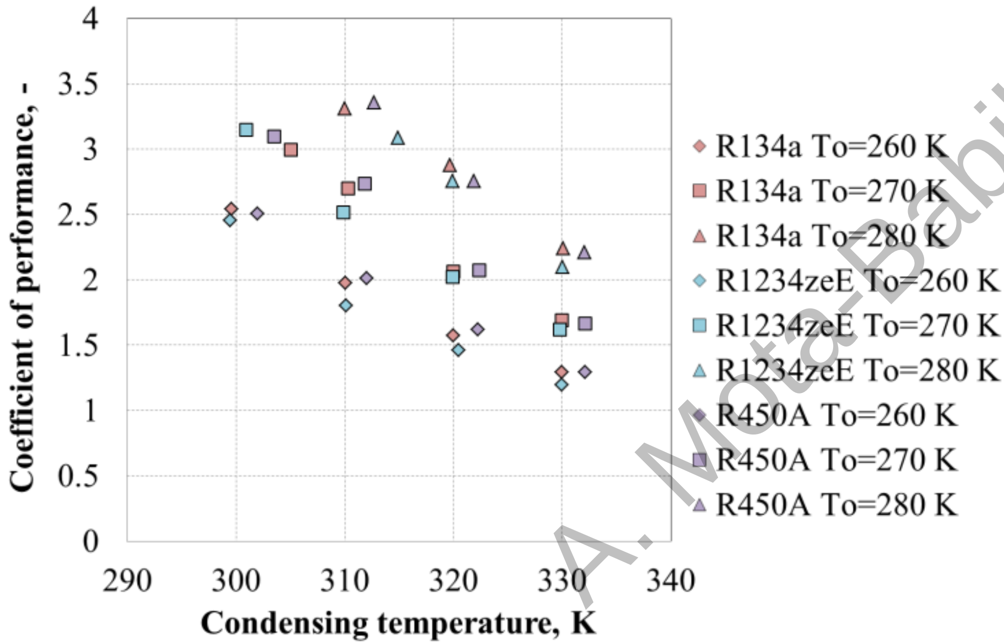


$$\dot{W}_c = \dot{m}_{ref}\left(h_{disc} - h_{suc}\right)\eta_{em}$$

5. RESULTS AND DISCUSSION

COEFFICIENT OF PERFORMANCE

THEO PRESSURE DROPS per m



Average in Discharge line, kPa

Tk / To	R134a	R450A	R1234zeE
310 / 260	3.0	2.7	2.3
330 / 270	1.8	1.5	1.4

Average in Suction line, kPa

Tk / To	R134a	R450A	R1234zeE
310 / 260	22.7	21.0	19.5
330 / 270	19.3	18.4	17.0

Compared to R134a → R450A comparable

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6. CONCLUSIONS

HFCs (as R134a) should be replaced

HFC/HFO mixtures could offer a trade-off solution

Experimental tests using R134a, R1234ze(E) and R450A

R1234ze(E) lower suction density → Great drop in coolign capacity

R1234ze(E) is not R134a drop-in replacement
New or redesign system

R450A and R134a comparable properties and performance

R450A could replace R134a in vapor compression systems
Drop-in or light retrofit

SPECIAL THANKS TO

The ÅForsk Foundation

Universitat Jaume I
ISTENER Research Group

KTH Royal Institute of Technology
Division of Applied Thermodynamics and Refrigeration

END OF PRESENTATION

THANK YOU FOR YOUR ATTENTION

Do you have any question?

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