Comparison of Oil Retention in R134a and CO_2 Climate Control Systems

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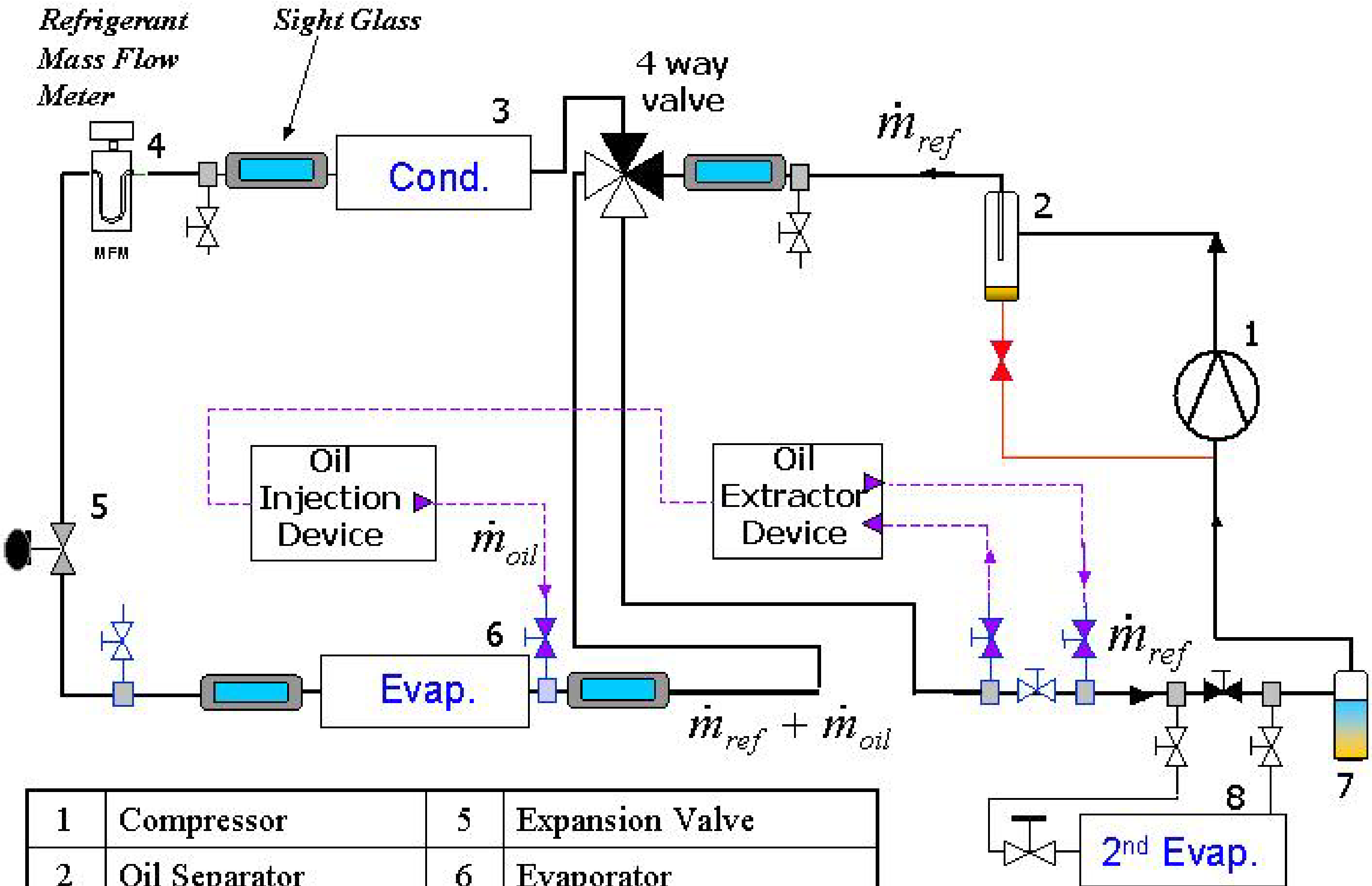
Objective:

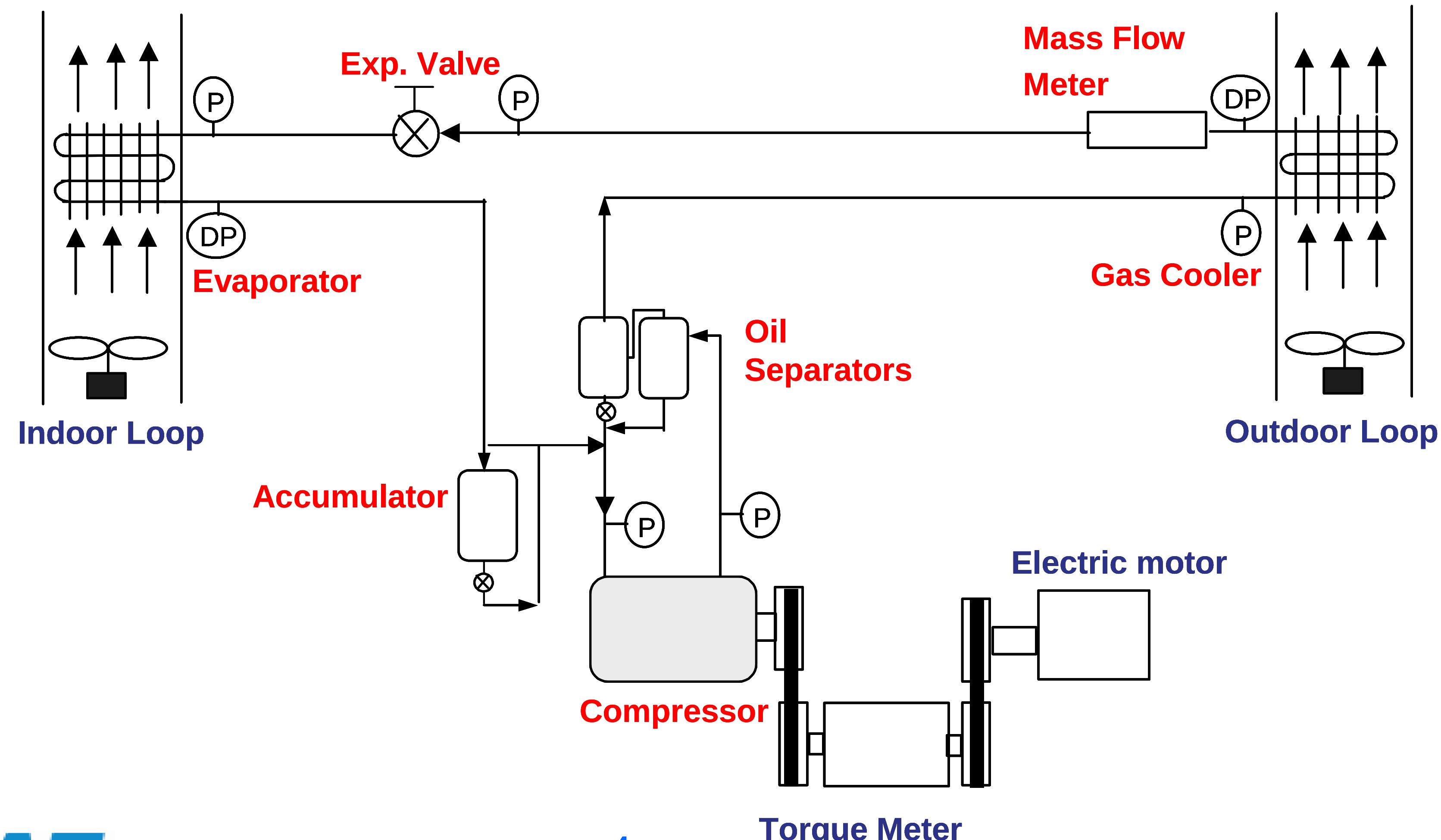
- Introduction
- Research Overview
- Experimental Results
- Comparison Oil Retention Characteristics
- Conclusions

Experimental Test Facility for R134a



1	Compressor	5	Expansion Valve
2	Oil Separator	6	Evaporator
3	Condenser	7	Accumulator
4	Mass Flow Meter	8	Flush Evaporator

Experimental Test Facility for CO_2



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Experimental Conditions

Refrigerants : R134A, R22, R410A, CO_2 (Lee, 2003)

Lubricants : Mineral, POE and PAG Oil

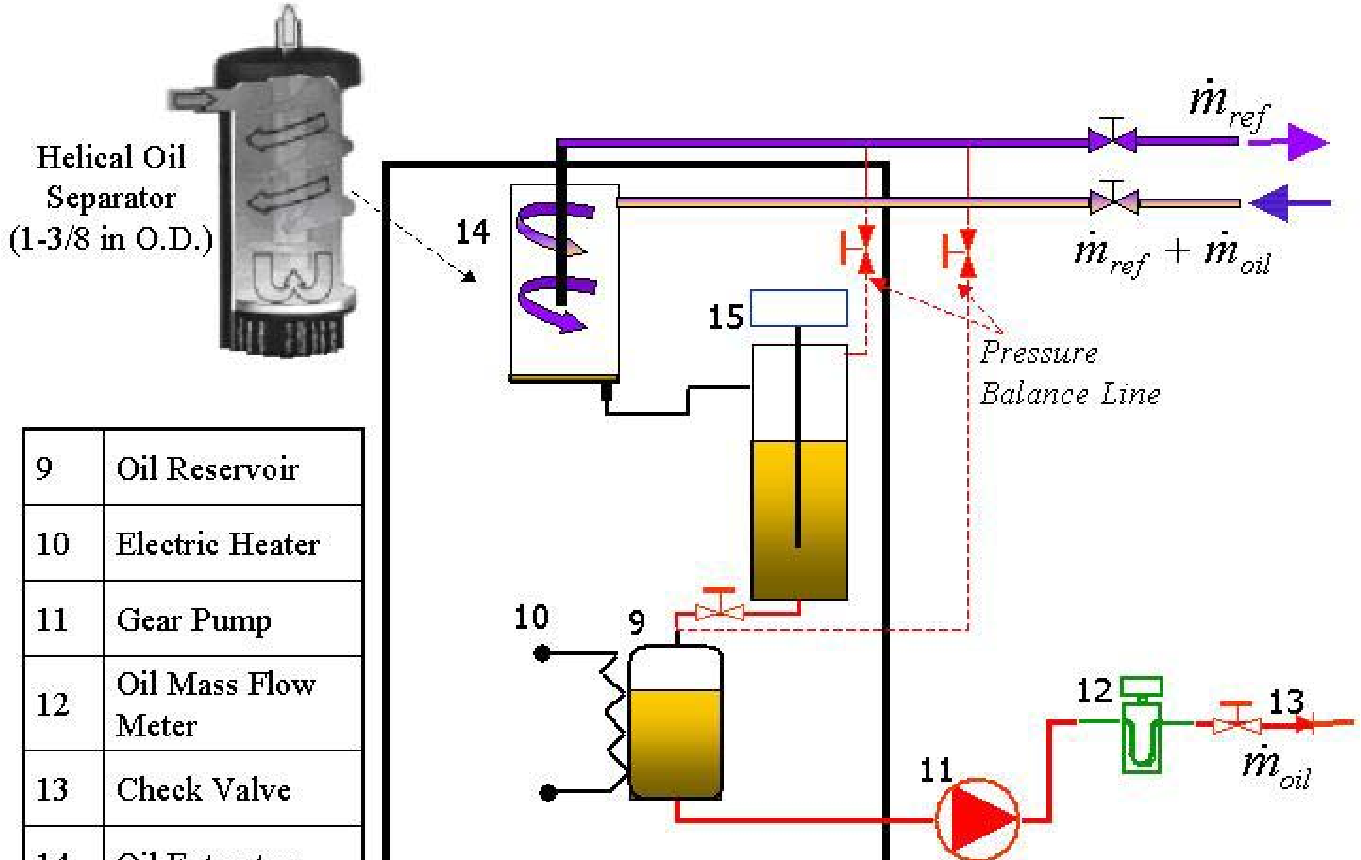
Refrigerant mass flow rate:

- 14 to 45 g/s (steady state)

- Oil Circulation Ratio (OCR): 1 to 6 wt.%

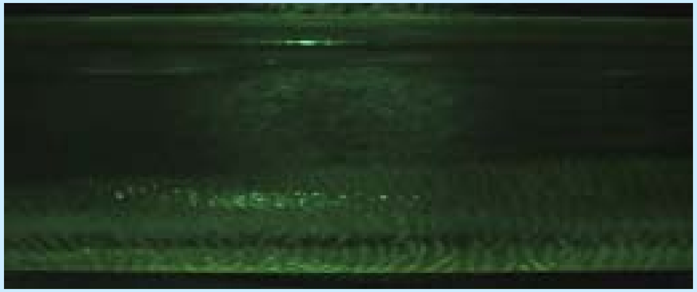
$$\mathrm{OCR[wt.\%]} = \frac{\dot{m}_{oil}}{\dot{m}_{oil} + \dot{m}_{ref}} \times 100$$

Oil Injection-Extraction Device



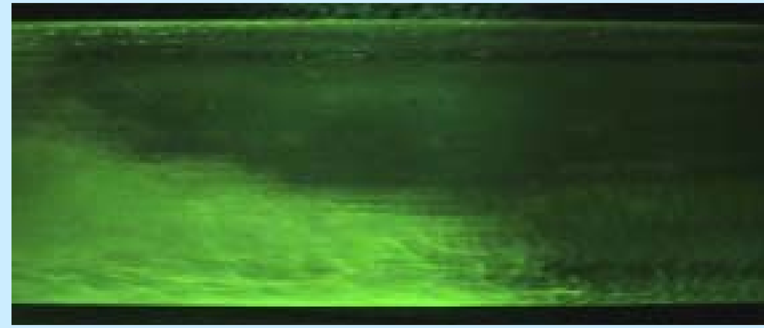
9	Oil Reservoir
10	Electric Heater
11	Gear Pump
12	Oil Mass Flow Meter
13	Check Valve
14	Oil Extractor
15	Oil Level Sensor

R134a/POE Horizontal Suction line Flow Visualization



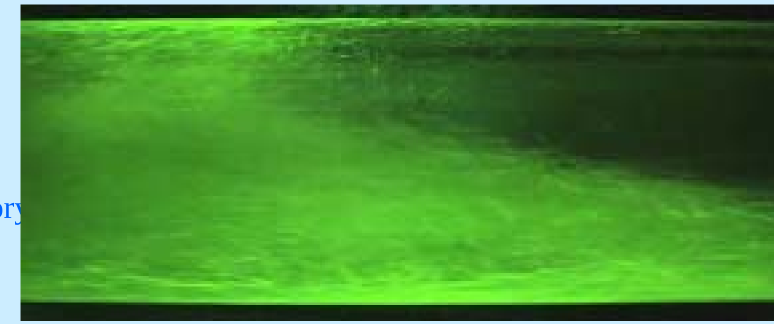
•OCR < 0.5 wt.%

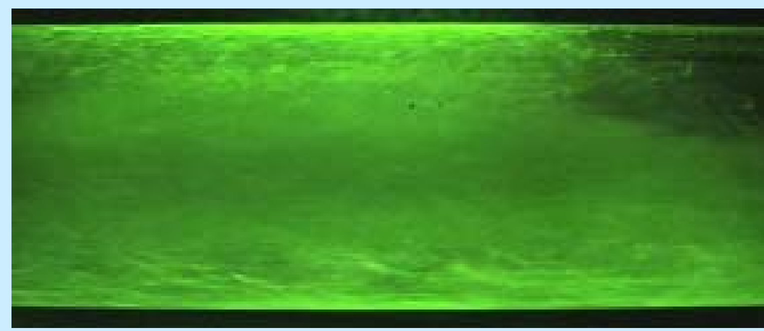
•Test Code: 1LS (without any injection)



•OCR = 0.5 → 6.5 wt.%

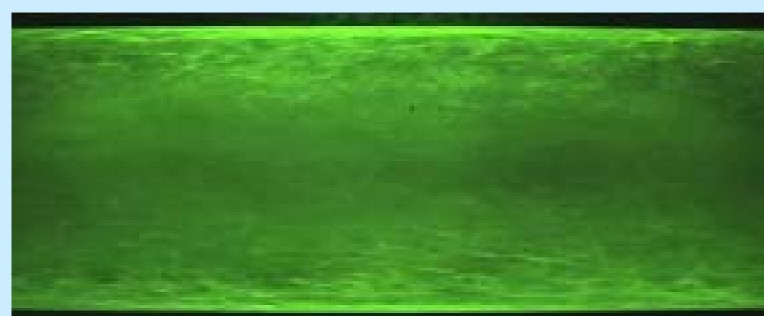
•Test Code: 1LS transitory



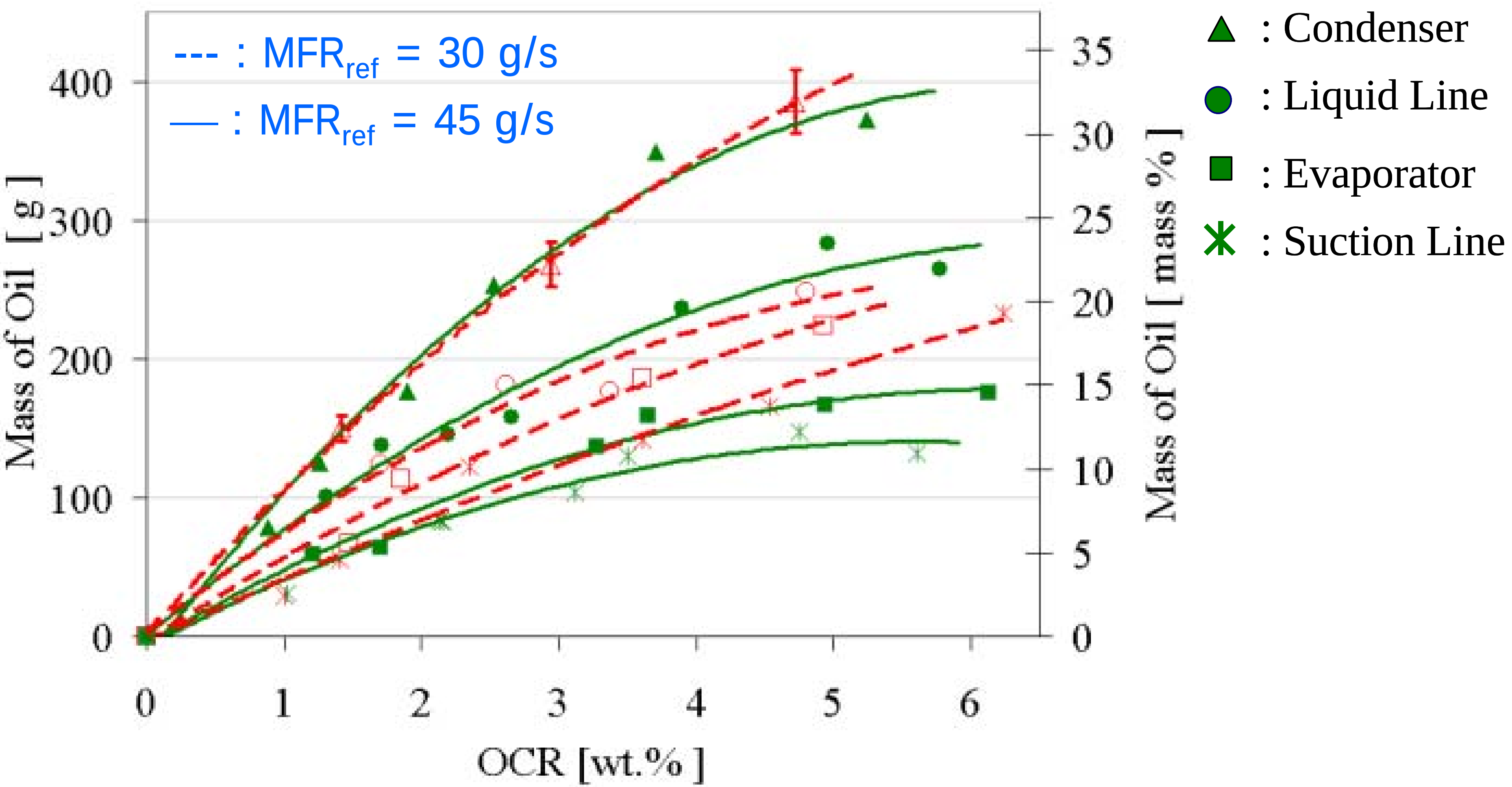


•OCR = 6.5 wt.%

•Test Code: 1LS with oil injection

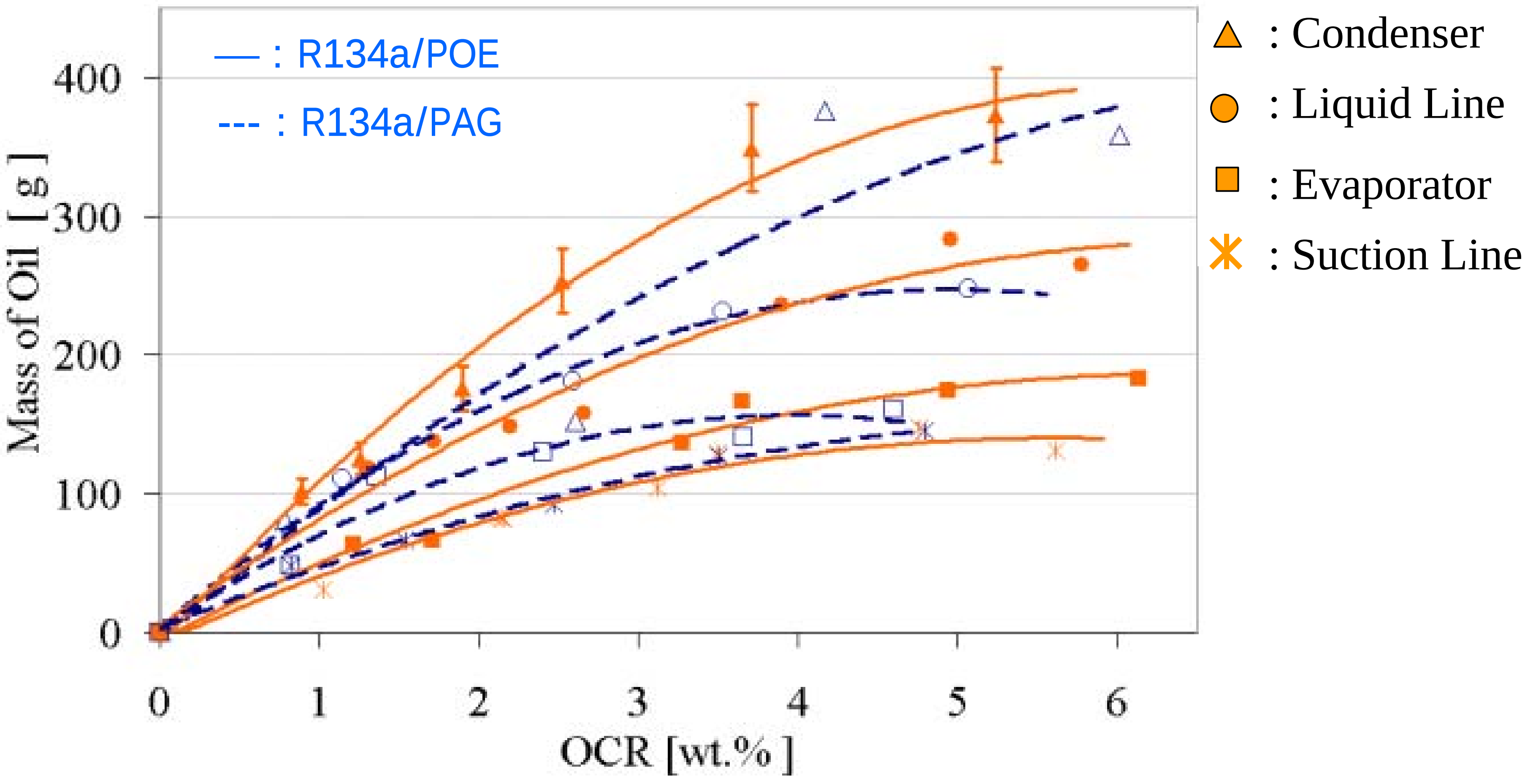


Cumulative Oil Retention for R134a/POE

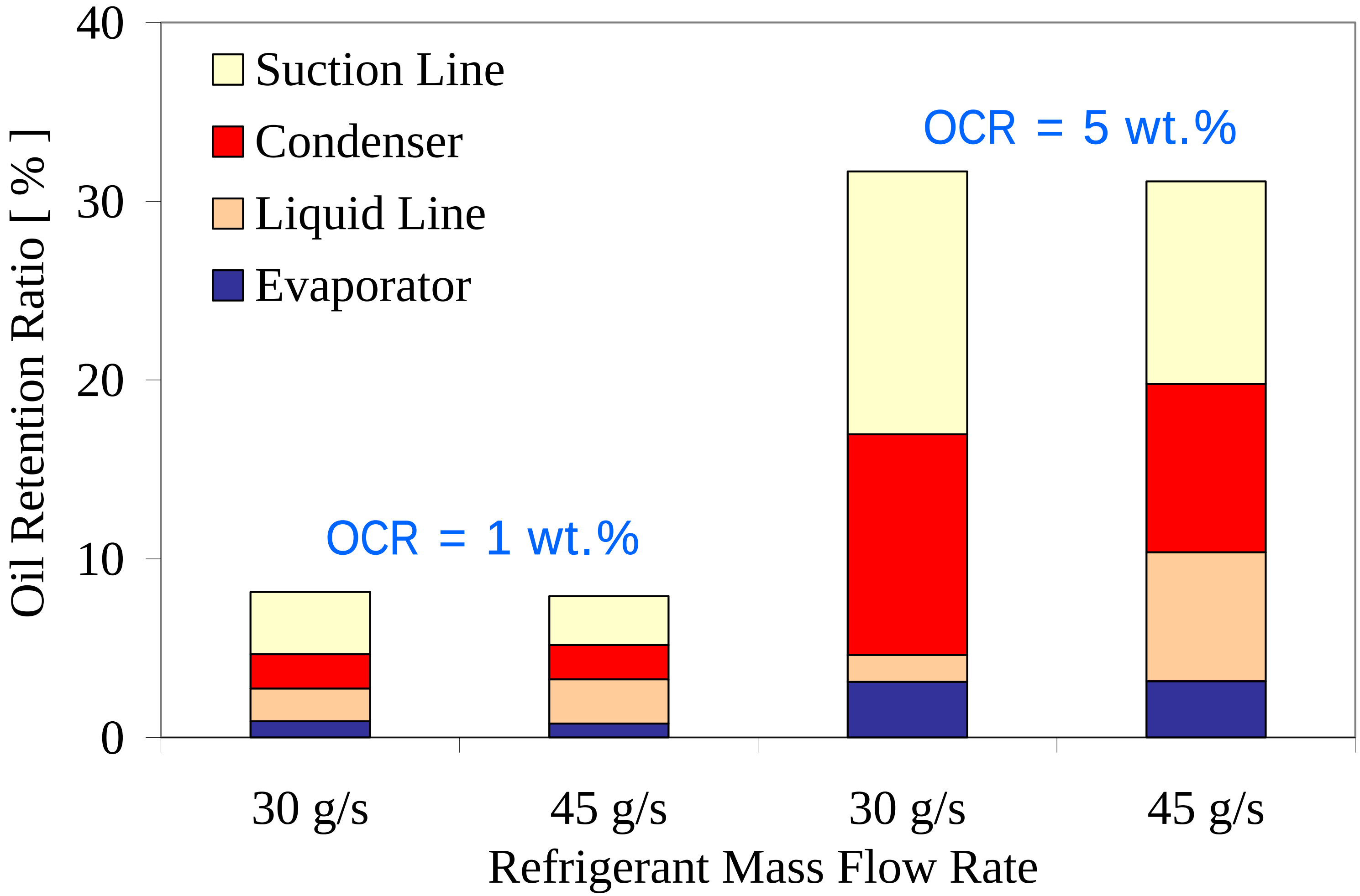


Cumulative Oil Retention for R134a/POE and R134a/PAG

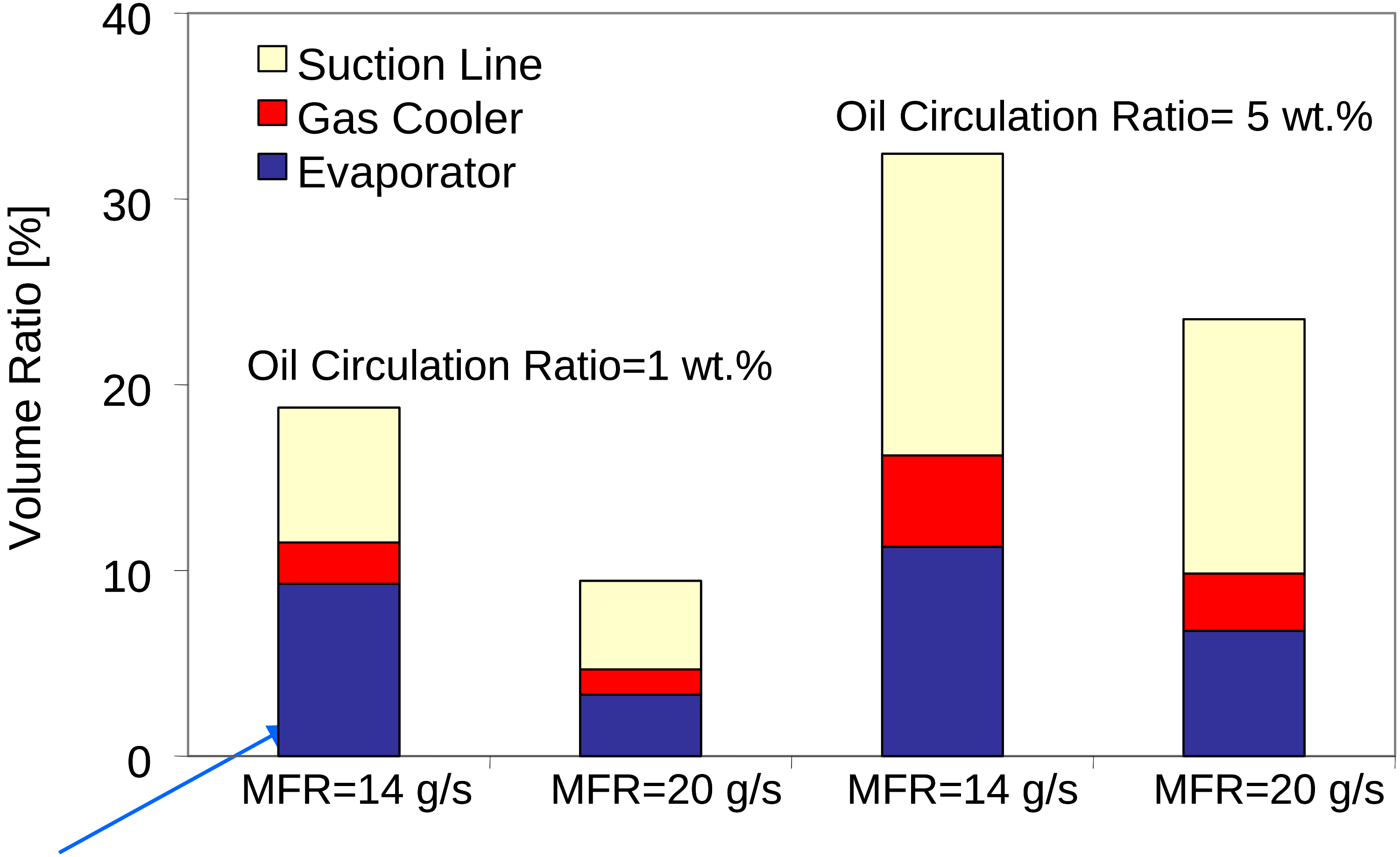
Ref. Mass Flow rate = 45 g/s



Oil Distribution for R134a/POE

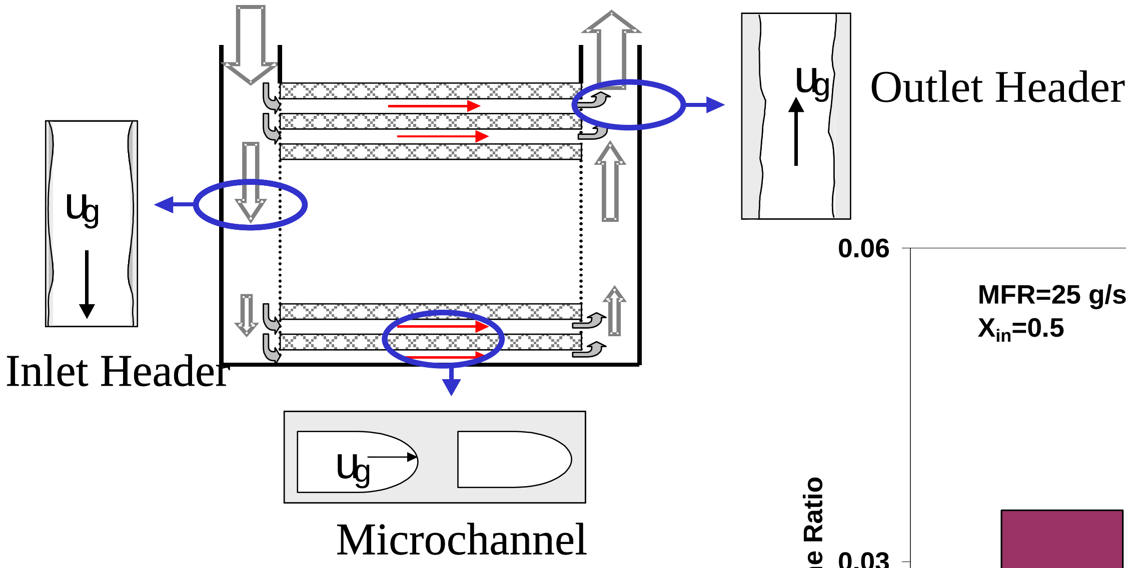


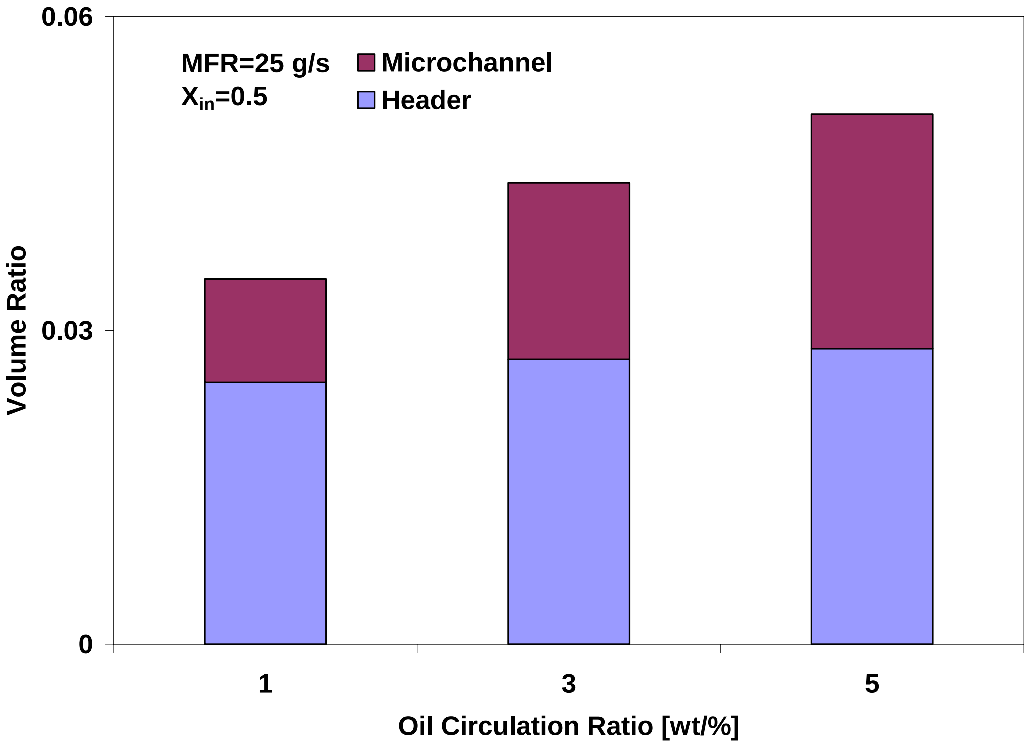
Oil Distribution for CO_2 / PAG (Lee, 2003)



*most of the oil is retained in the headers of the microchannel heat exchanger

Outlet Header Microchannel Evaporator CO_2/PAG (Lee, 2003)





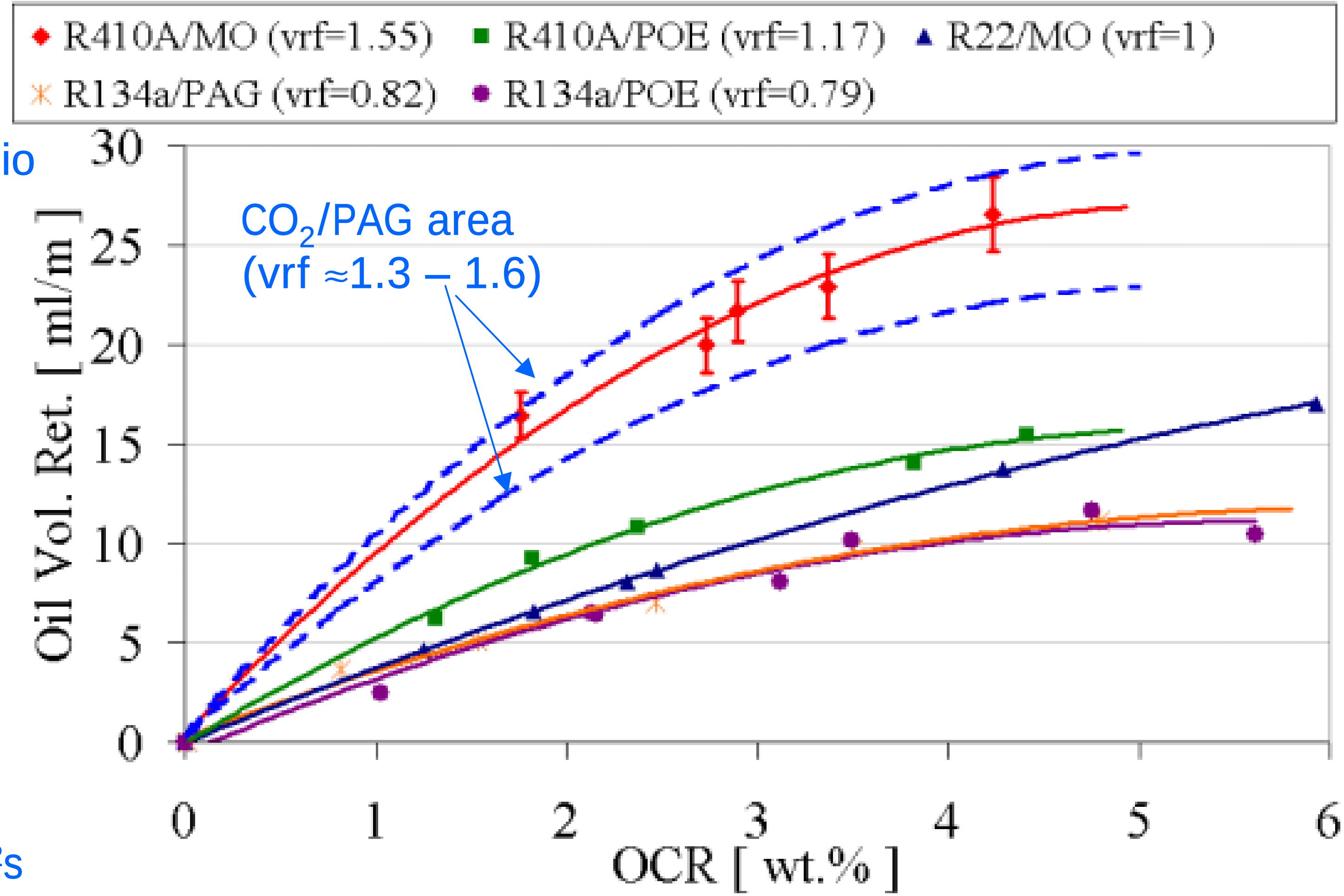
Effect of Change of Mixture Viscosity on Oil Retention Volume

Kinetic Viscosity Ratio

$$\tilde{v} = \frac{v_{liquid,film}}{v_{ref,vapor}}$$

Viscosity Ratio Factor (vrf)

$$\text{vrf} = \frac{\tilde{v}_{oil-ref}}{\tilde{v}_{MO-R22}}$$



$Re_{vapor} \cong 24 \times 10^4$

$m_{flux} \cong 160$ kg/m²s

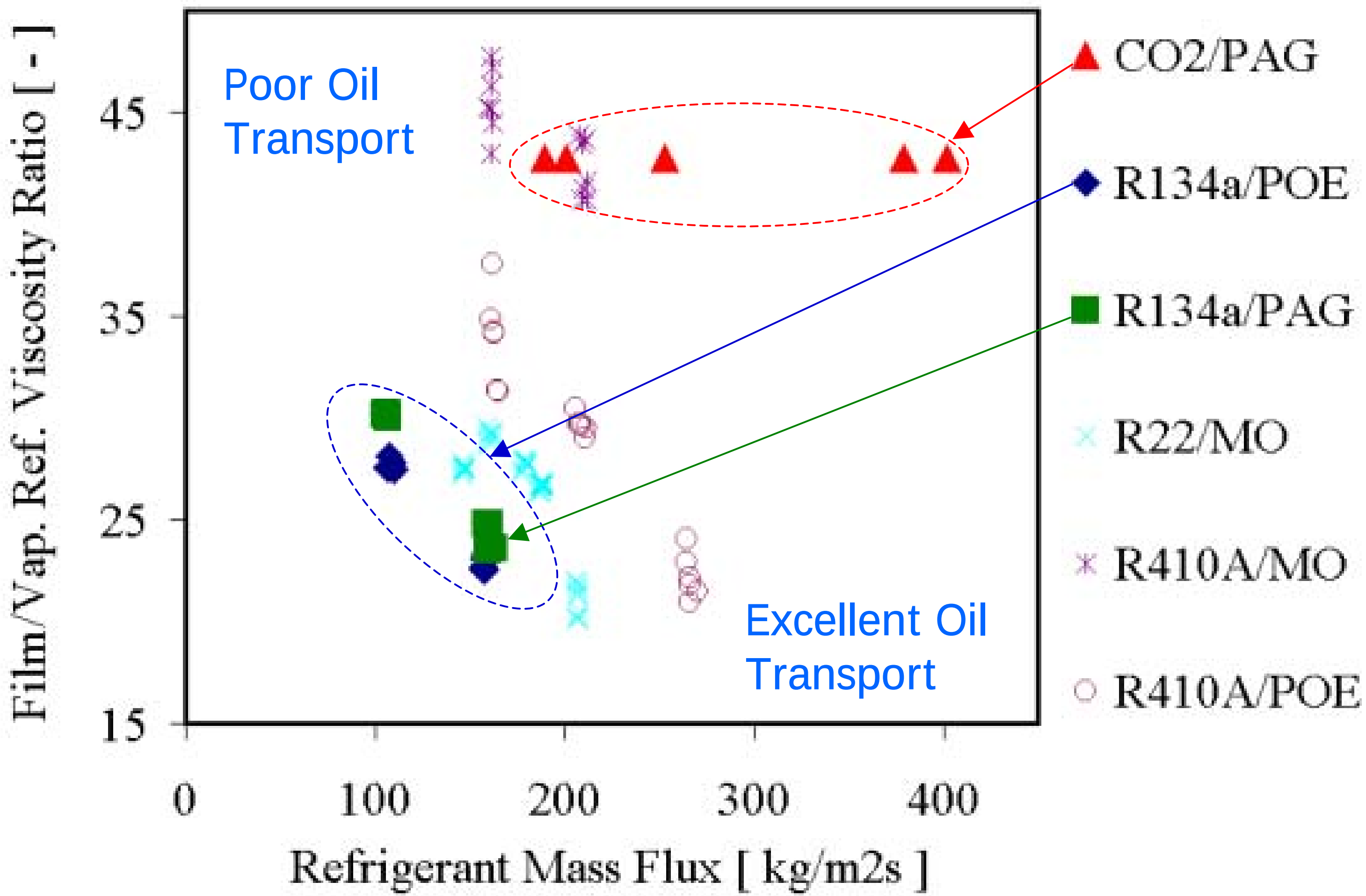
Oil Retention Data Comparison

- For R134a/POE systems, if the OCR increases from 0 to 5 wt.% the oil retention increases
  - Up to 13 ml/m in the suction line
  - Up to 2.1 ml/m in the evaporator
  - Up to 1.4 ml/ m in the liquid line

The Reynolds number in the suction line varied between $17{,}000 < Re_g < 26{,}000$ for R134a systems

- CO_2/PAG systems have lower oil retention in the microchannel since the increased mass flux promotes the oil transport. However, the oil is retained in the headers (←oil traps).
- For CO_2/PAG mixture the maximum oil retention in the suction line was 10 ml/m and the Reynolds number ranged from $12{,}000 < Re_g < 35{,}000$ during the experiments

Schematic Map for Oil Transport in the Suction Line of Air Conditioning Systems



Characteristic Parameters for Oil Retention

$$OR = f\left(OCR, g, \rho_{ref}, \vec{\mathrm{v}}_{ref}, \mu_{ref}, D, \sigma_{film}, \mu_{film}, \rho_{film}, \bar{\varepsilon}_{pipe}, x\right)$$

G

Gravity

Re

Solubility

Pressure,

Temperature,

ref-oil mixture

Pipe relative surface roughness

Quality and miscibility oil-ref pair

Dimensionless Numbers for Oil Retention

Refrigerant Reynolds Number: $$Re_g = \frac{\rho_g v_g D}{\mu_g} = \frac{G_g \cdot D}{\mu_g}$$

Oil Circulation Ratio: $$OCR = \frac{\dot{m}_{oil}}{\dot{m}_{oil} + \dot{m}_{ref}}$$

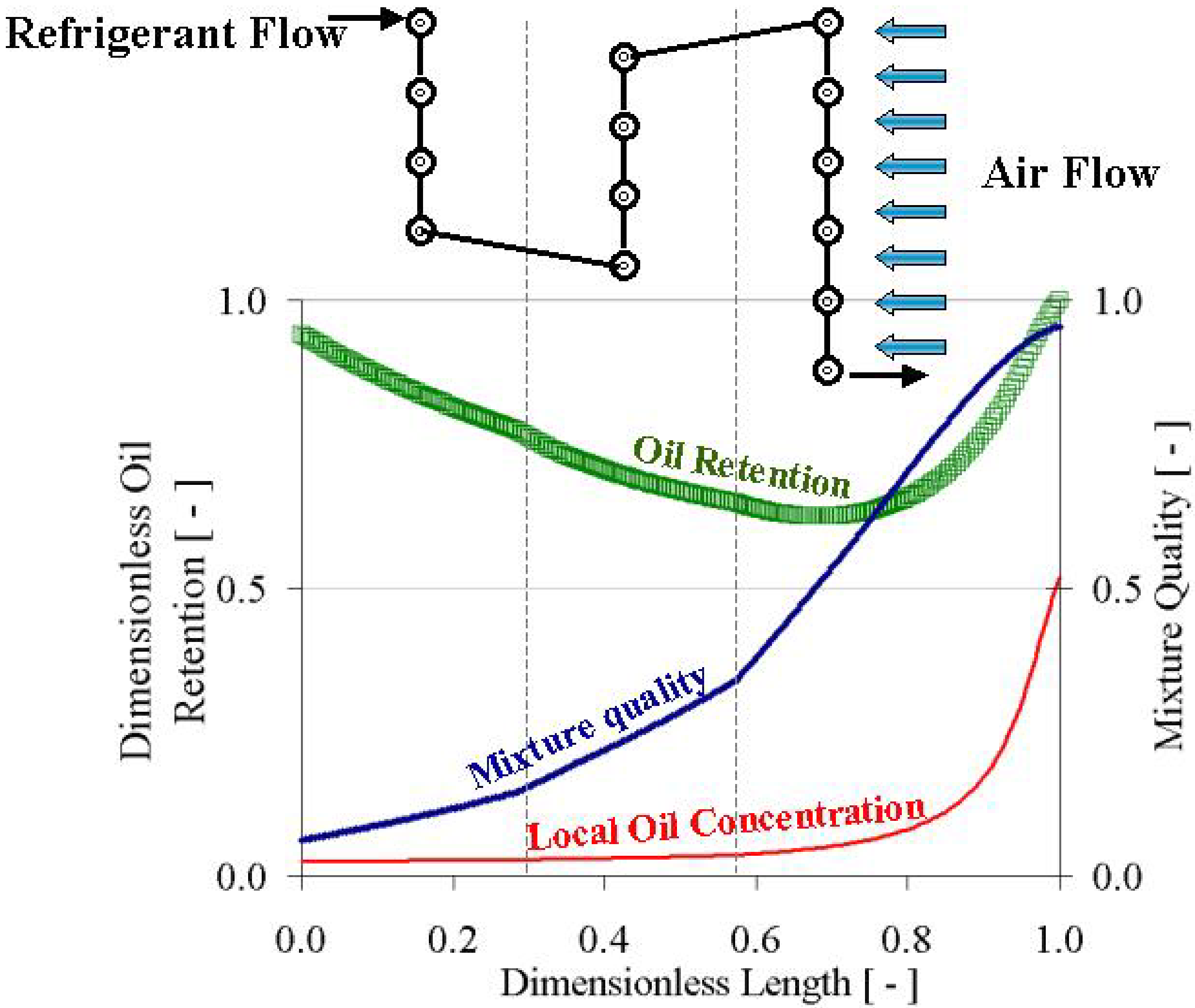
Mixture Viscosity Ratio: $$\tilde{\nu} = \frac{\nu_{liquid,film}}{\nu_{ref,vapor}}$$

Mixture Weber Number: $$We_m = \frac{G_m{}^2 D}{\rho_m \cdot \sigma_m}$$

Oil Retention in the Fin and Tube Evaporator for R134a/PAG

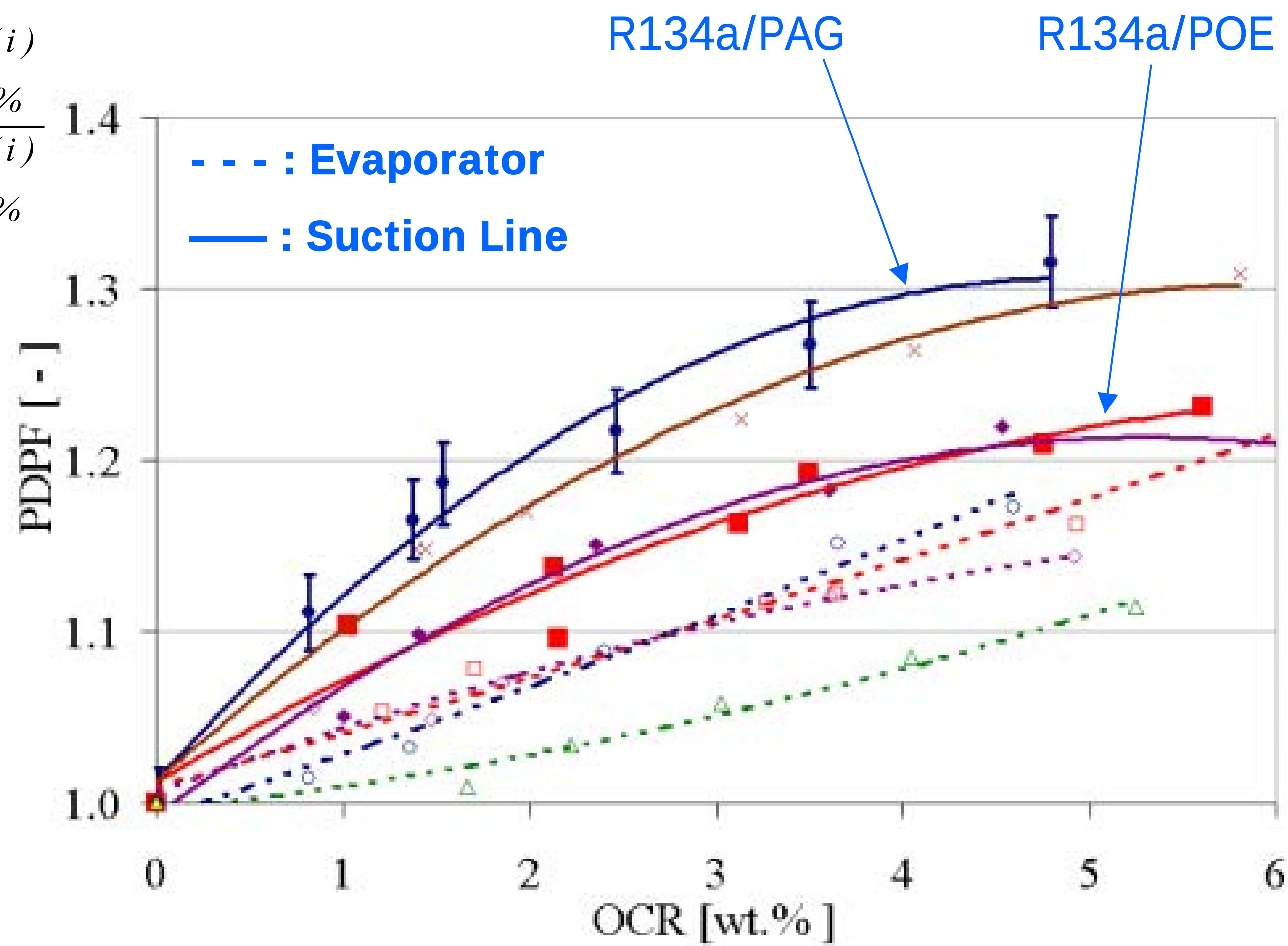
Fin-and Tube Evaporator

MFRref = 45 g/s
OCR = 2.4 wt.%
Pin = 0.465 MPa
Xin = 0.06
No. of Seg. = 224

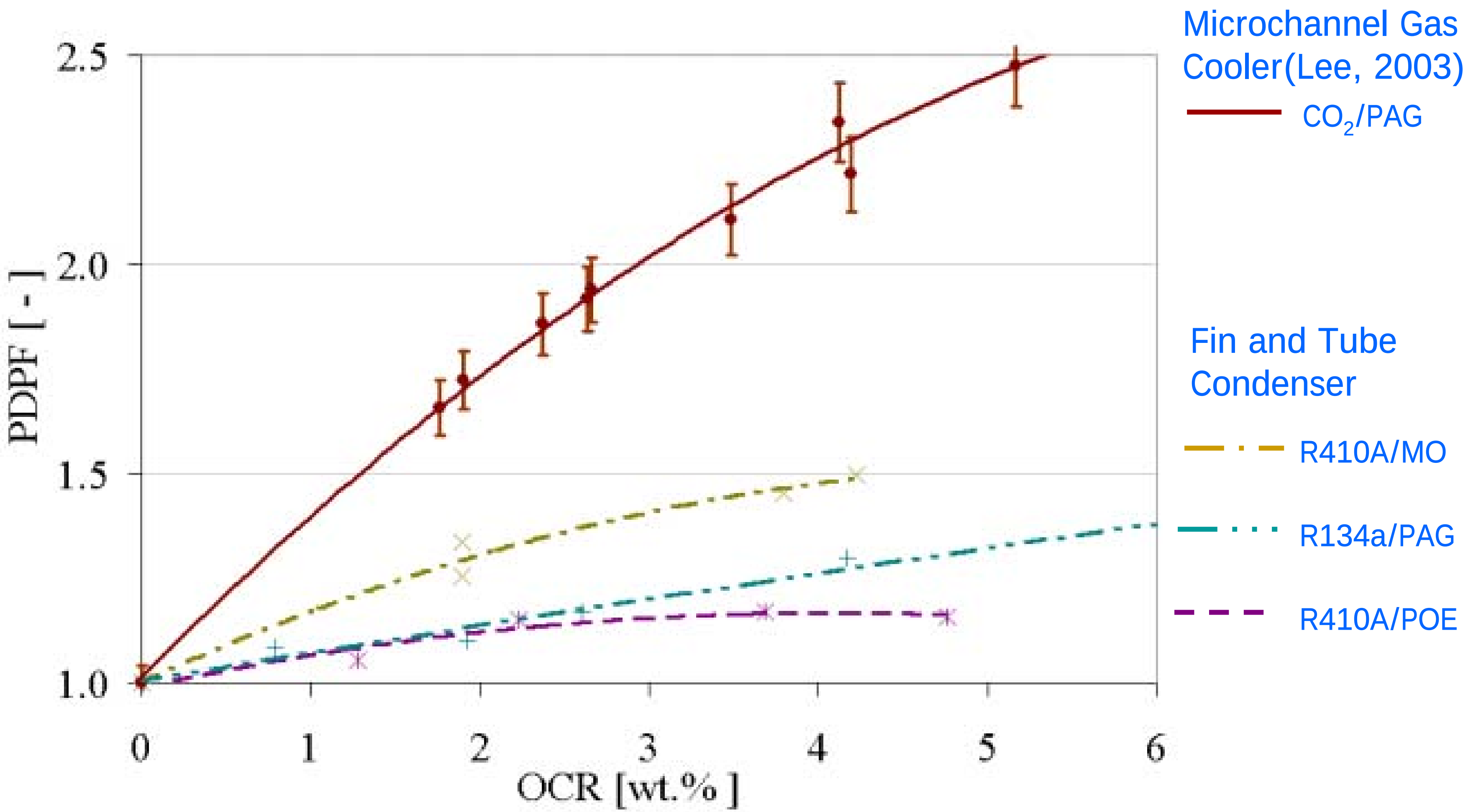


R134a Pressure Drop Penalty Factor in the Evaporator and Suction Line

$$\mathbf{PDPF}\,[-] = \frac{\Delta P\Big|_{OCR=x\,wt.\%}^{component(i)}}{\Delta P\Big|_{OCR=\mathbf{0}\,wt.\%}^{component(i)}}$$



CO_2 and R134a Pressure Drop Penalty Factor in the Condenser/Gas Cooler



Conclusion

- Oil Retention (OR) increases when:
  - OCR ↑ (OCR = main independent variable!)
  - Liquid Film Viscosity ↑
  - Refrigerant Mass flux G ↓
- The oil retention volume ratio for R134a system is slightly less than that of CO_2 system, especially at low OCRs.
- R134a/POE and R134a/PAG mixtures have similar oil retention characteristics
- A very soluble refrigerant-oil mixture (such as R134a/PAG) promotes the oil transport even thought the viscosity of the pure oil is considerable.

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Conclusion (cont)

- **CO_2/PAG Systems using micro channel HX suffered of**
  - **High oil retention in the evaporator and gas cooler**
  - **High Pressure drop penalty factor due to the oil retained**
- **When the OCR increased from 0 to 5 wt.% then the PDPF increases of about**
  - 30% for R134a and 20% for CO_2 in the suction Line
  - 20% in the evaporator (R134a)
    - more than double that in CO_2 evaporator (microchannel HX)
  - 50% in the condenser (R134a)
    - 2.5 times in the gascooler (CO_2 microchannel HX)