Conserving Natural Resource Use in Buildings

Performance Testing and Comparison of Liquid Overfeed and Cascade CO_2 Systems with R404A Primary – TEST

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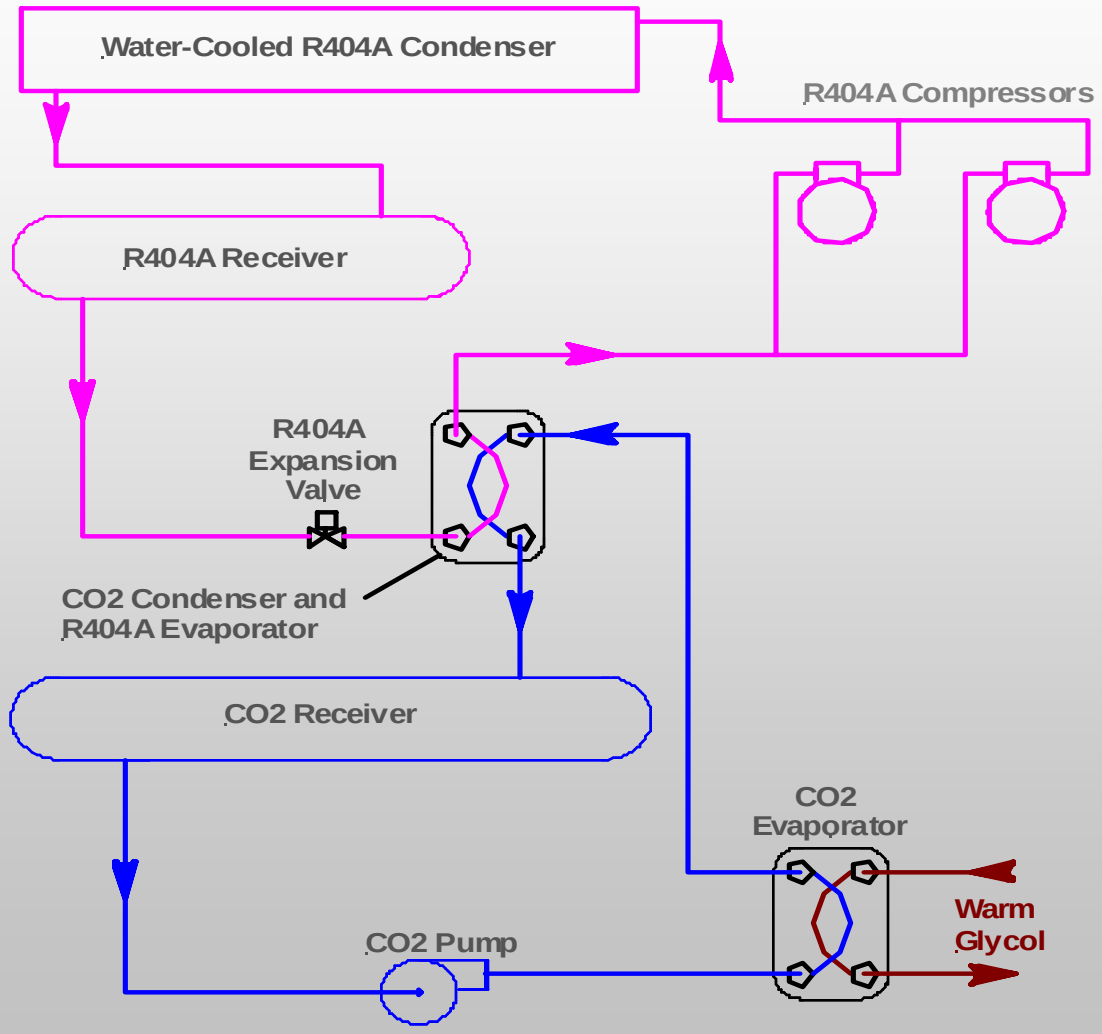
Overview

- Laboratory testing to compare energy use of two types of secondary CO_2 systems.
- **1) Liquid Overfeed:** Liquid CO_2 pumped through evaporator and condensed back to liquid.
- **2) Cascade:** Direct expansion of CO_2 to superheated state and compressed to intermediate condensing temperature.

Liquid Overfeed System



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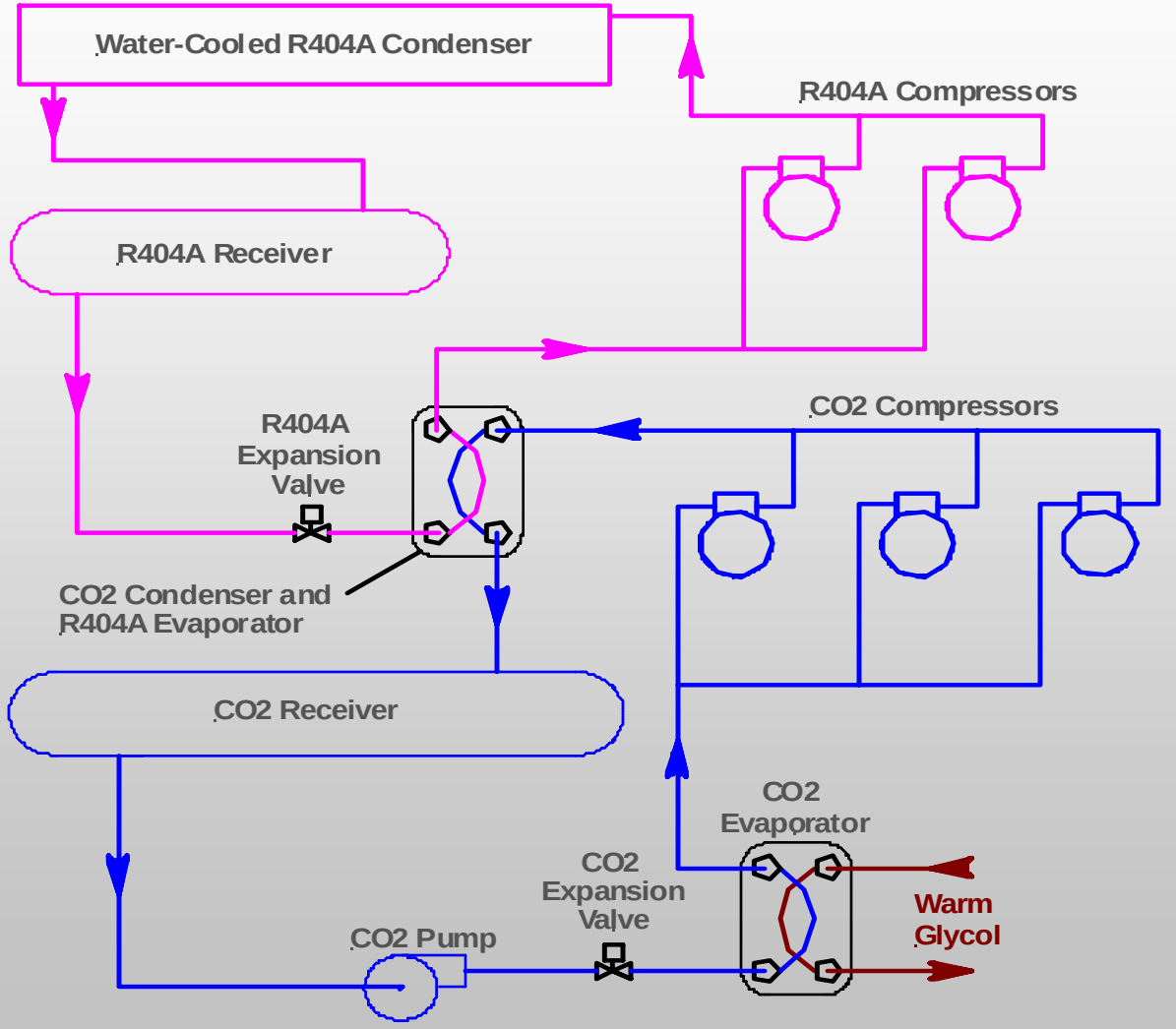
Cascade System



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Equipment

- R404A Compressors: 4-cylinder semi hermetic reciprocating type with suction stop unloaders on one bank of cylinders
- CO_2 compressors: 2-cylinder semi-hermetic reciprocating type
- CO_2 liquid pump: Hermetically sealed pump with motor in housing (no shaft seal)
- Heat exchangers: Brazed plate type
- Flow measurements: Coriolis effect mass flow meters

Test Conditions

Run Type	Condensing Temp °C (R404A Primary)	Evaporating Temp °C (CO_2 Secondary)
Pumped Liquid	49	-32 -4
	41	-32 -4
	21	-32 -4
	10	-32 -4
Cascade	49 41 30 21 10	-32

Procedures

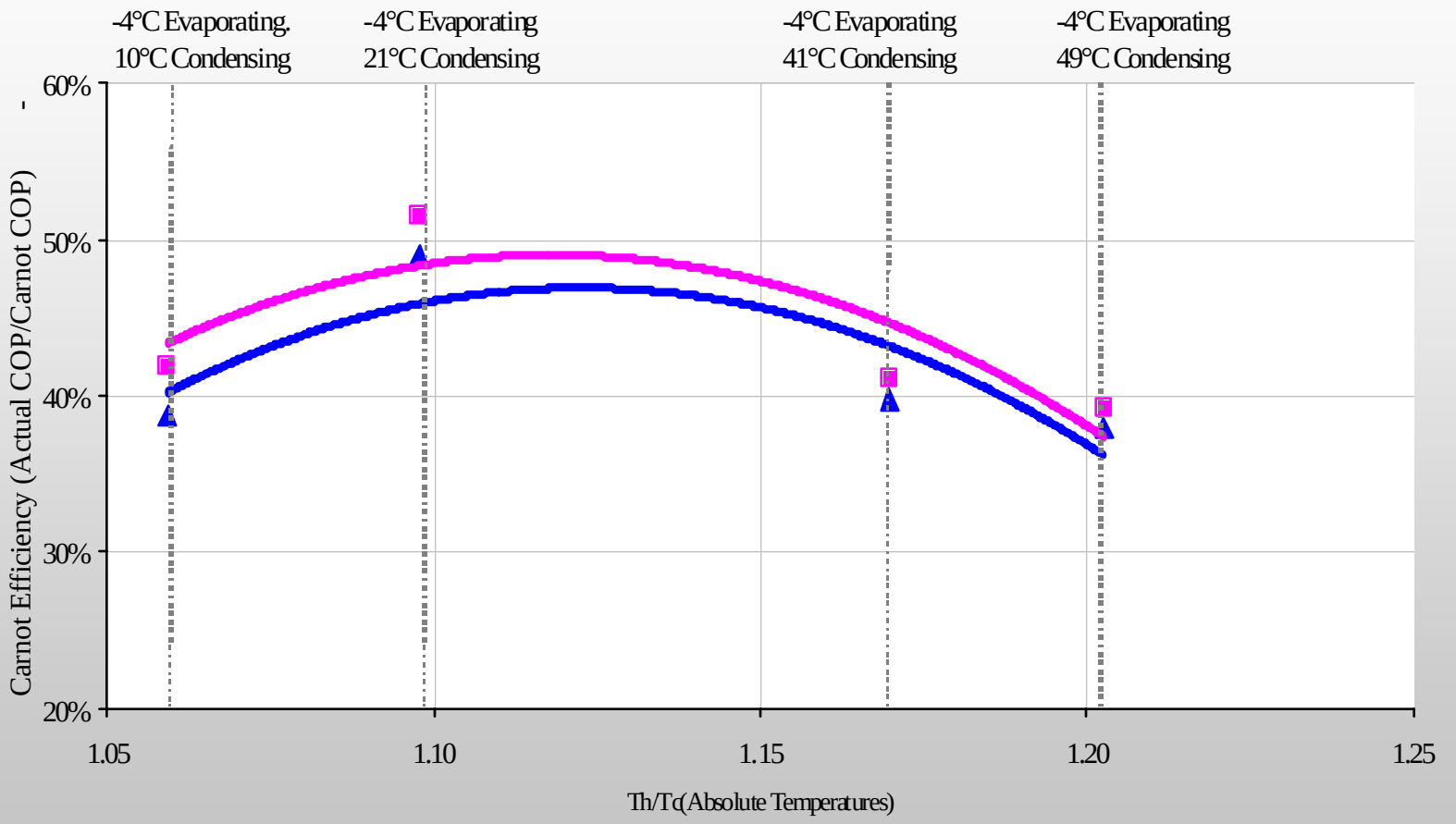
- Tests conducted at Ingersoll-Rand Climate Control's Research and Development facility in Bridgeton, MO, USA
- R404A primary condenser water flow adjusted to obtain required condensing temperature
- Liquid Overfeed:
  - R404A evaporating temperature set to obtain required CO_2 temperature.
  - Approximately 1:1 overfeed ratio
- Cascade
  - CO_2 evaporating temperature set by adjusting heat load
  - CO_2 condensing temperature approximately –7°C.
  - CO_2 superheat approximately 30°K (due to relatively warm glycol on hot side of CO_2 evaporator).

Photos of Test Setup

Results

- Data corrected for:
  - Excessive pressure drop through pressure regulating valves
  - Relatively large size and power use of liquid pump used in test system.
  - 1°C higher allowable CO_2 evaporating temperature in Liquid Overfeed system
  - Relatively small size of CO_2 condenser/R404A evaporator in test system

Results, -4°C
CO_2 Evaporating Temperature



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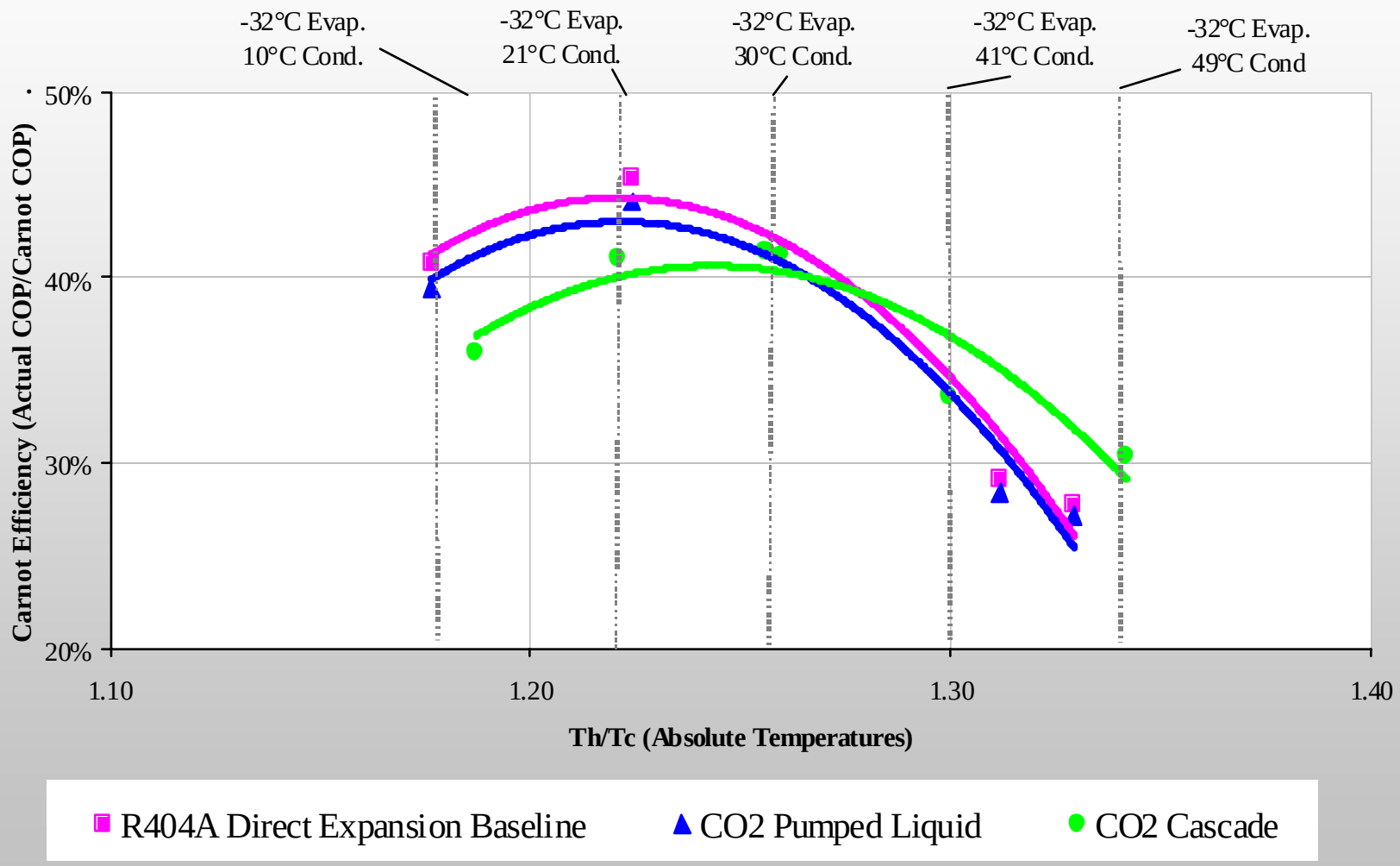
Results, -32°C
CO_2 Evaporating Temperature



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Conclusions

- Carnot efficiency of Liquid Overfeed approximately same as R404A baseline.
- Carnot efficiency of Cascade approximately 5% higher at 49°C condensing, but 5% lower at 10°C condensing.
- Results not unexpected. Typically see 2-stage systems such as cascade having higher energy efficiency at high temperature ratios.

Thank You

Contact Information

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