On the Use of CO_2 as a Heat Distribution Fluid for Sustainable Ammonia Heat Pump Solutions

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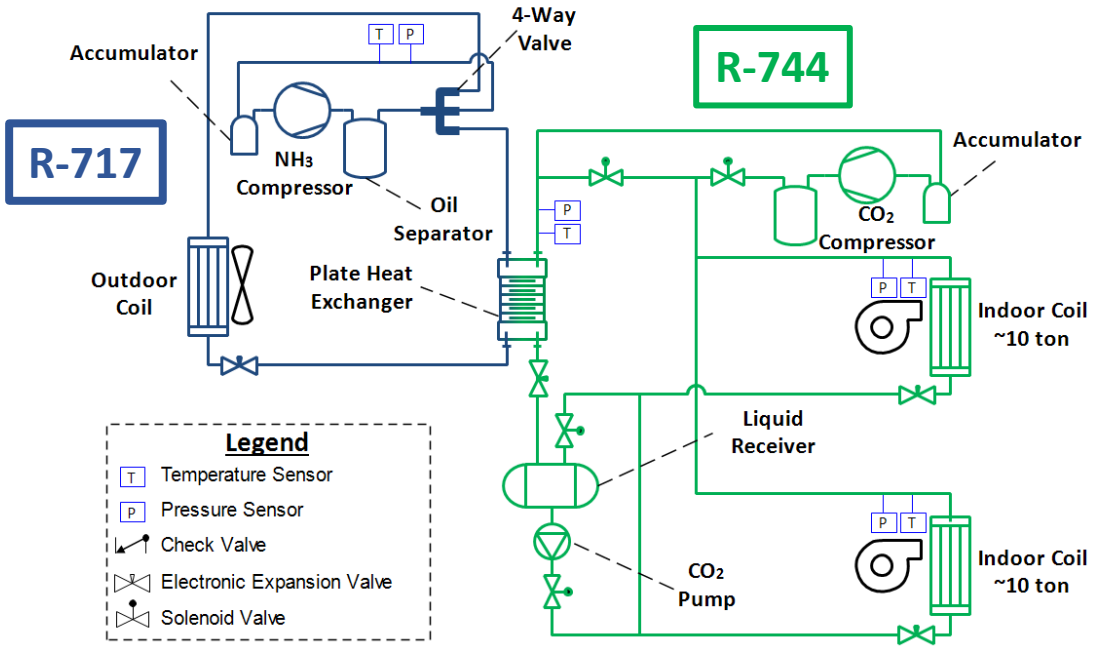
Today's Presentation: Pumping SC CO_2

- Background and motivation
- Test setup
- Results
- Discussion
- Summary

Background and Motivation

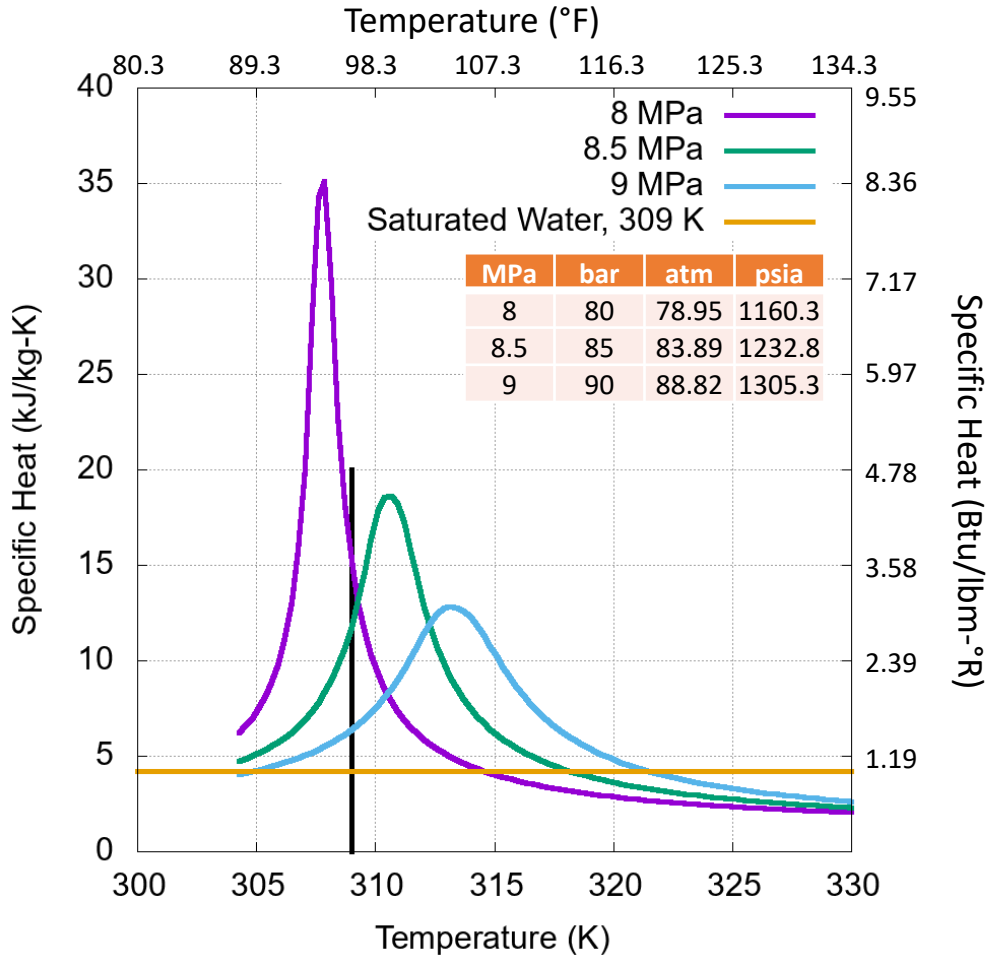
- Main project: develop, test, and field site evaluation of a low GWP *heat pump*.[1]
- R-717 (NH_3) must be isolated outdoors.
- R-744 (CO_2) is efficient in cooling but has challenges in heating.
  - Supercritical fluid.
  - Low lift, lower efficiency.



[1]Electric Power Research Institute, "Environmentally Friendly Advanced Refrigerant Options in Commercial HVAC Applications," Electric Power Research Institute, Palo Alto, 2022.

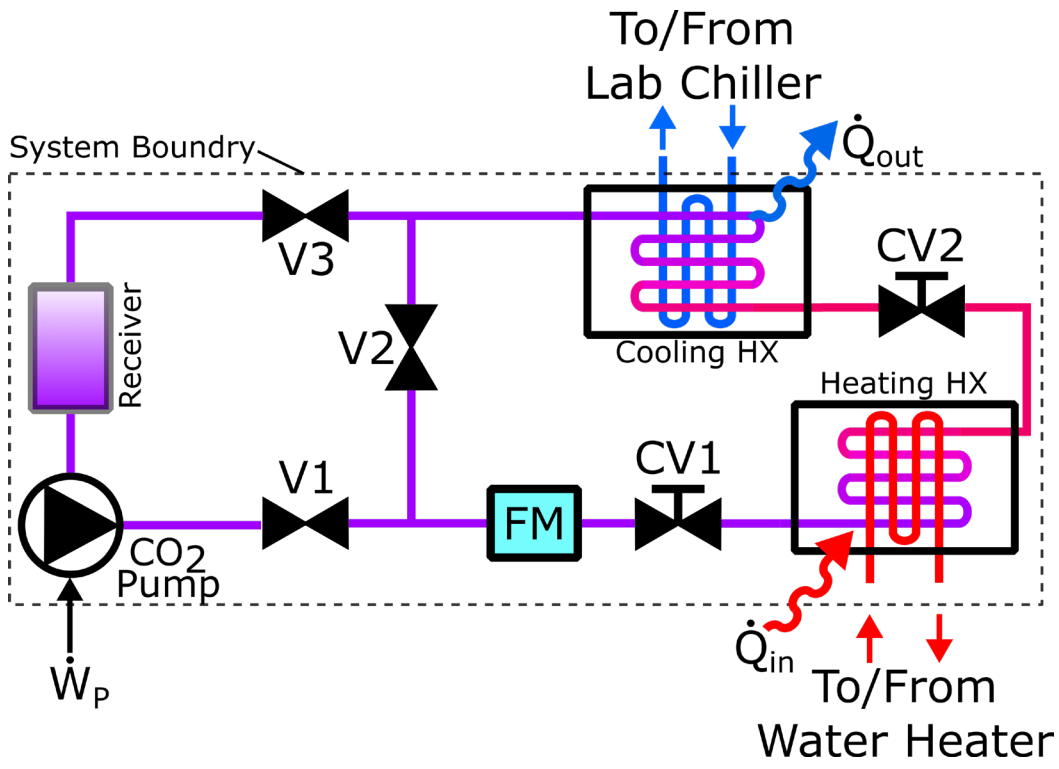
Background and Motivation

- Question: Could we use a CO_2 *pump* to circulate SC CO_2 for heating mode?
  - SC CO_2 is relatively dense fluid.
- Advantages:
  - High heat capacity.
  - Simplifies design.
- Disadvantages:
  - Performance unknown.



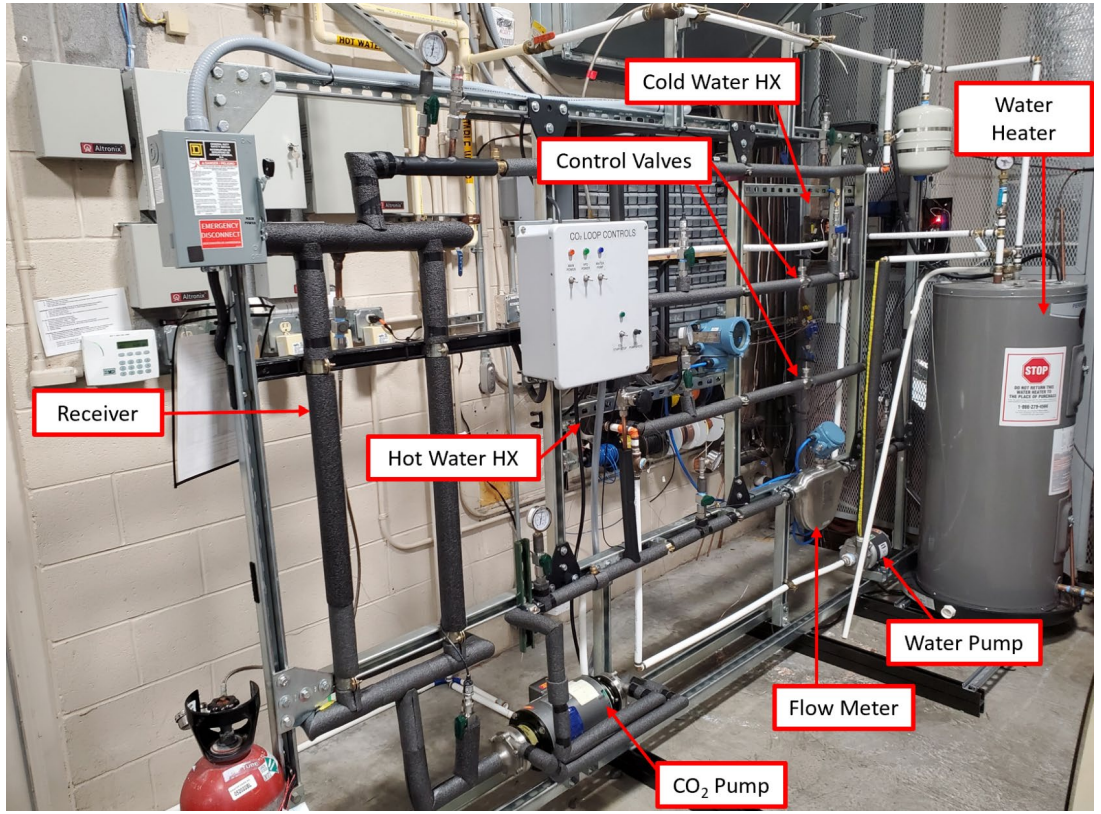
SC CO_2 Pumping Test Setup

- Mimic heating mode of heat pump.
- CO_2 pump is rated to handle high pressures.
- Needle valves and heat exchangers act together for heat transfer and pressure drop.



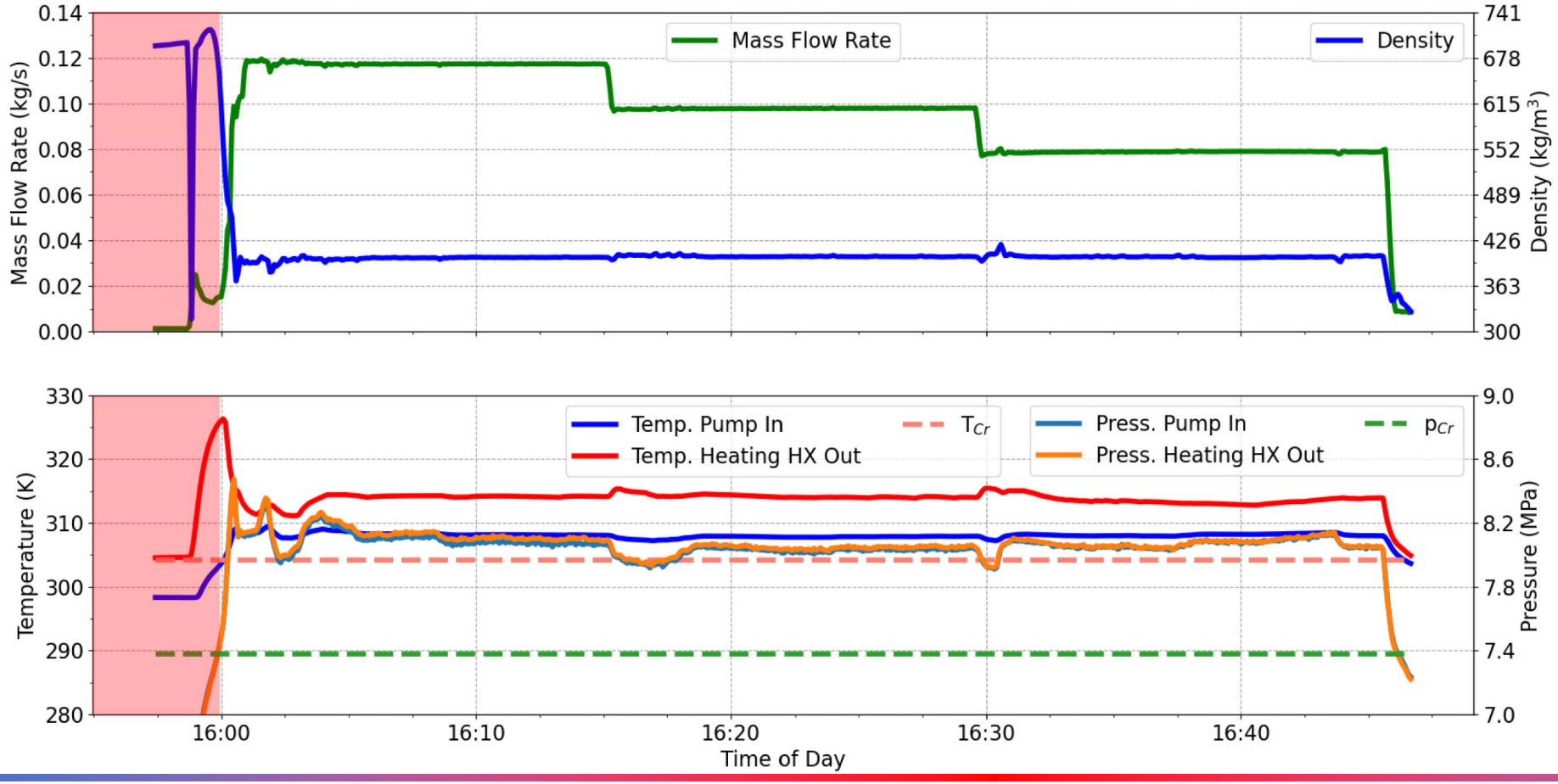
SC CO_2 Pumping Test Setup

- CuFe tubing (5/8” and 1-1/8”).
- Receiver made from CuFe tubing.
- System charged a with CO_2 cylinder *with* dip tube.
- **Test Plan**:
  - Vary temperature (and pressure).
  - Speed of pump.
  - Needle valve position (pressure drop).



Results: Test Example

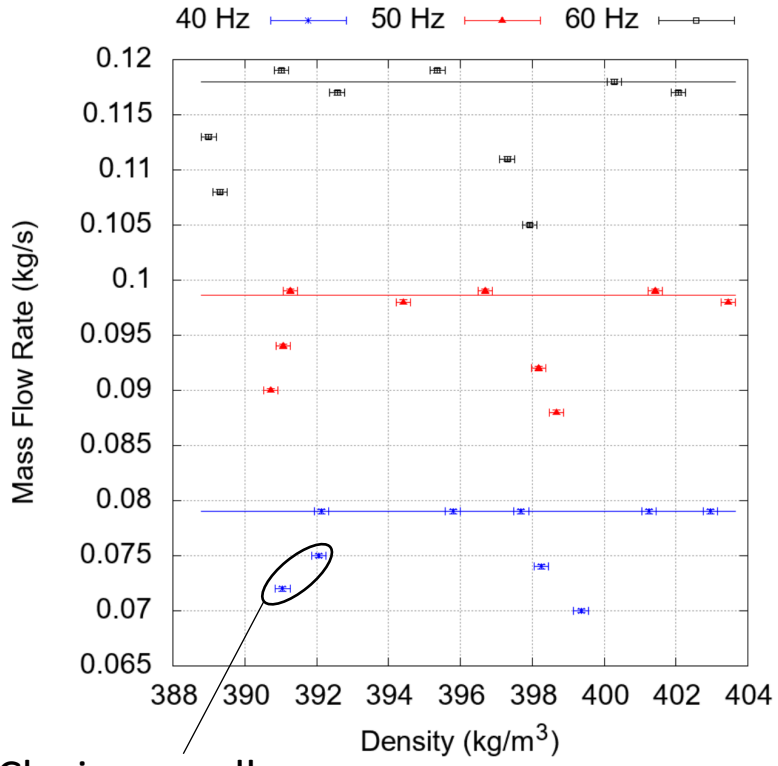
Subcritical



Temperature		
K	°C	°F
280	6.9	44.3
290	16.9	62.3
300	26.9	80.3
304	**30.9**	**87.5**
310	36.9	98.3
320	46.9	116.3
330	56.9	134.3

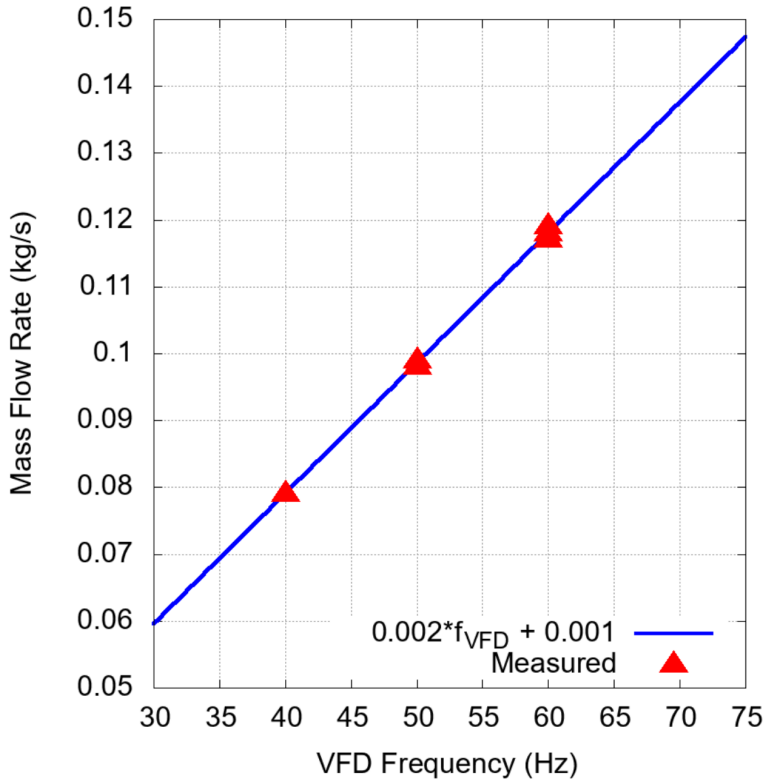
Pressure (gauge)			
MPa	bar	atm	psi
7.0	70.0	69.1	1015.3
7.3	**72.9**	**71.9**	**1057.1**
7.4	74.0	73.0	1073.3
7.8	78.0	77.0	1131.3
8.2	82.0	80.9	1189.3
8.6	86.0	84.9	1247.3
9.0	90.0	88.8	1305.3

Results: Flow Rates



Closing needle valves.

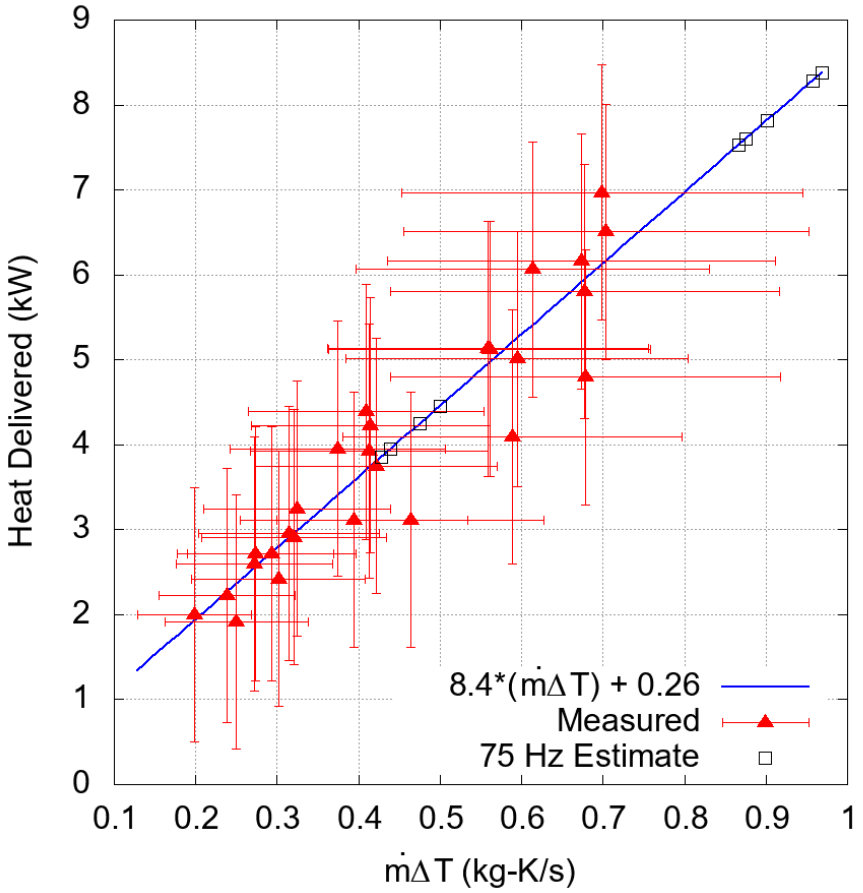
(a)



(b)

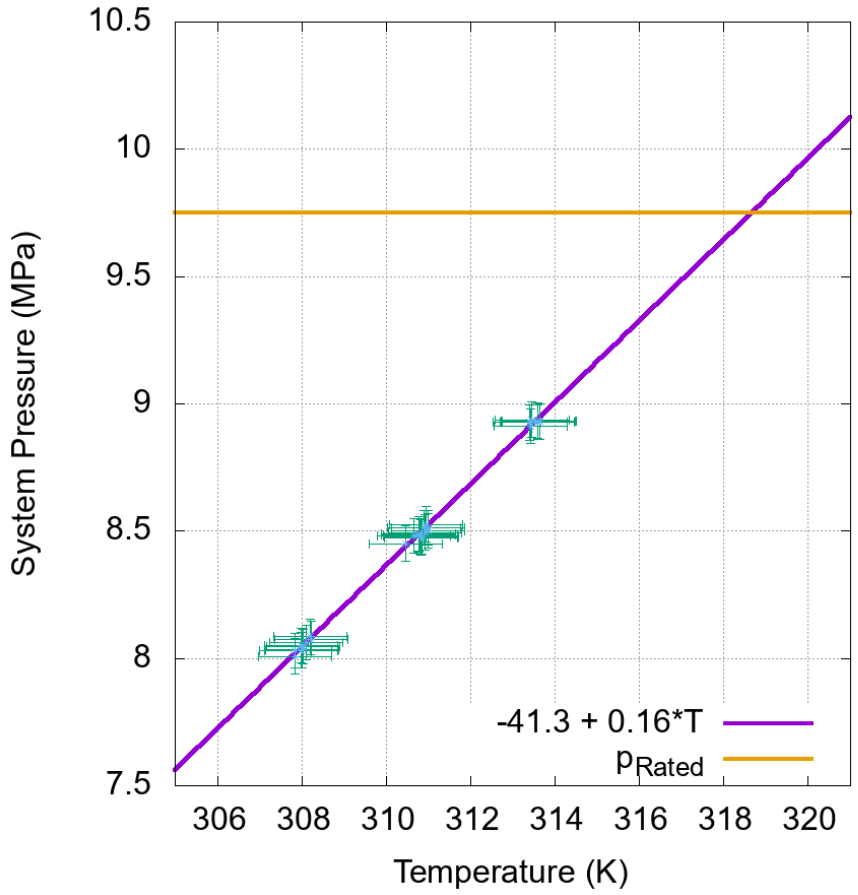
- Slight changes (~2%) in density don't affect mass flow rate.
- Mass flow rate linear over range tested.
- Pump rating: 12.1 to 20.8 L/min for 19.8 to 13.7 m of head at 60 Hz.
  - At 60 Hz, SC CO_2 ~18 L/min at undetermined head.
- Takeaway: ability to pump SC CO2!

Results: Heat Transferred



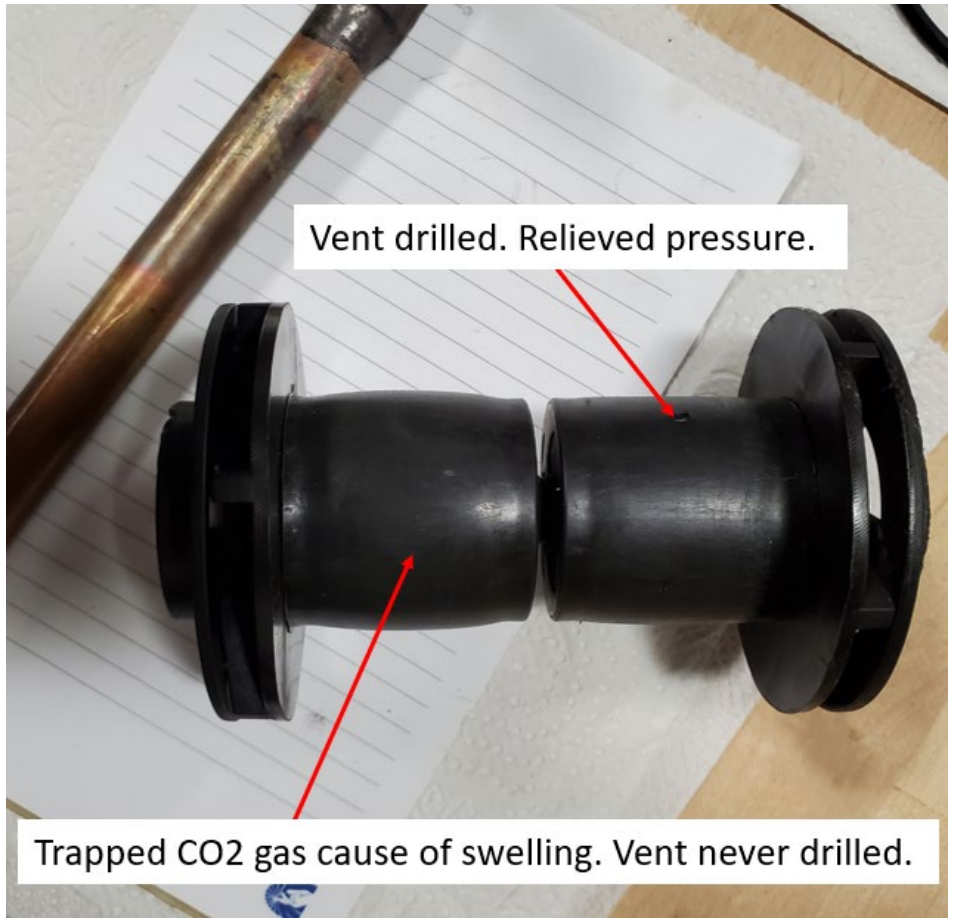
- Moving about 7 kW at 150 to 200 W.
  - 6.5 kW for CO_2 compressor.
  - Need between 35.2 and 70.3 kW for the heat pump.
- Large error bars
  - Uncertainty in temperature propagated through.

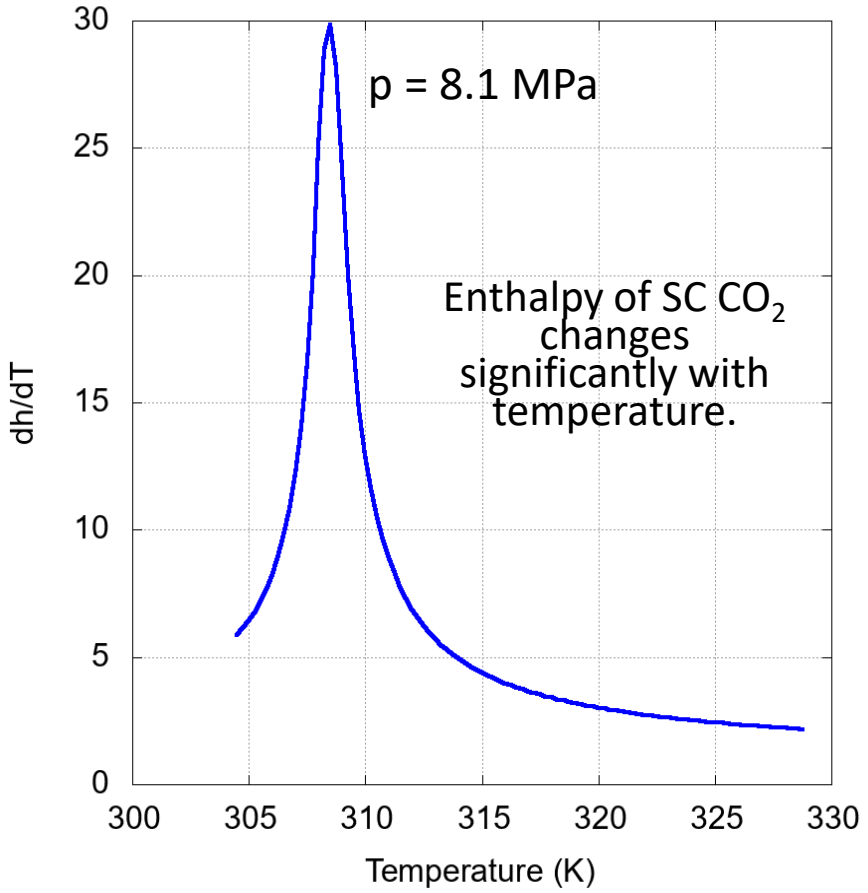
Discussion: Opportunities



- Increase temperature of delivered SC CO_2
  - System pressure determined by pump inlet temperature (outlet of cooling HX).
- Decrease mass charge of CO_2 to increase temperature at same pressure.
  - Optimal charge likely exists.
- Overspeed VFD
  - 75 Hz for example.

Discussion: Experience





Summary and Acknowledgments

- *Pumping* of SC CO_2 was demonstrated.
- Opportunities were identified for improved performance (increased heat transfer).
- Pitfalls were encountered/identified to be avoided in future work.

- This project was funded by CEC's EPIC Program, EPC-19-014, and SCE, SDG&E, and Southern Company.
- Thank you to our team members at Optimized Thermal Systems and Mayekawa.

Appendix

Major Components

Component	Manufacturer	Part Number	Notes
CO_2 Pump	Hy-Save	820-DS-050-VSD-B	12 MPa Max
Brazed Plate Heat Exchanger	SWEP	B4TMx30	14 MPa Max
Coriolis Flow Meter	Emerson	CMFS025MB67N2BAEKZZ	10.3 MPa Max
Needle Valves	Swagelok	SS-18RS8	> 20 MPa
Digital Pressure Sensor	ProSense	SPT25-10-2000A	0-13.8 MPa F.S.
Cu-Fe Tubing	Mueller Streamline	N/A	13 MPa rating