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Compressor Engineering
Refrigeration and Air Conditioning
High Performance Buildings

Experimental Study of a CO_2 Thermal Battery for Simultaneous Cooling and Heating Applications

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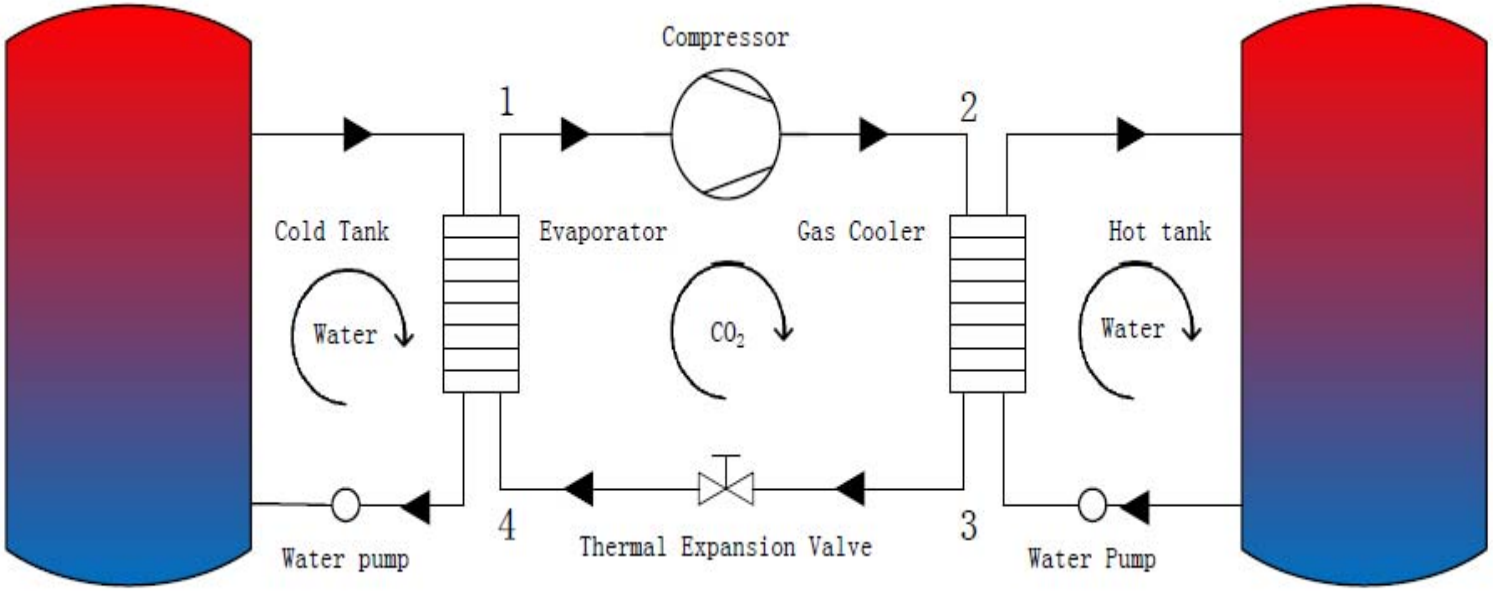
Motivation

- Global Energy shortage and environmental concerns
- Search for alternative refrigerant during phase-out of hydro fluorocarbon (HFC) & hydro chlorofluorocarbon (HCFC)
- Application of CO_2 heat pumps in simultaneous cooling and heating use in buildings

Objective

- Design and fabricate a CO_2 Thermal Battery
- Gather performance data from the system at various
  - Water flow rate
  - EXV opening
  - Refrigerant charge
  - Control strategy to obtain optimal system performance
- Investigate and analyze factors that influence the performance of CO_2 Thermal Battery

CO_2 Thermal Battery Design

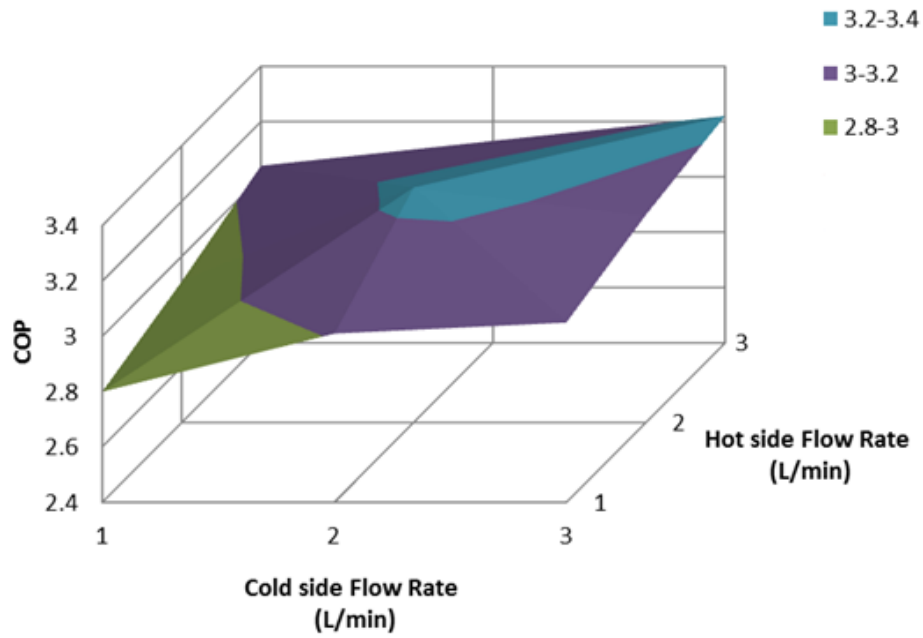


Actual Experimental Setup

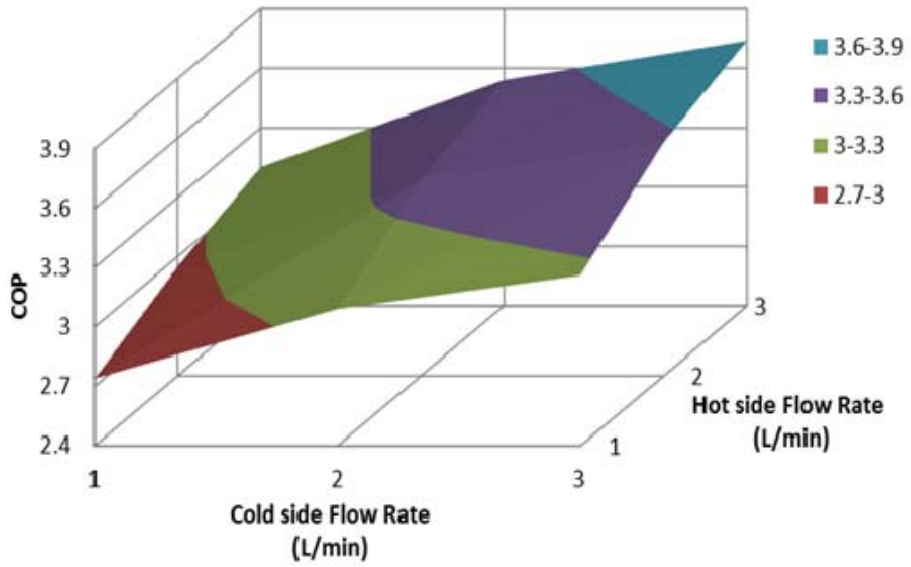
Test Parameters

1. Water Flow rate
   - 1L/min , 2L/min, 3L/min Hot and Cold side
2. ExV Opening
   - 1, 1 ¼, 1 ¾, 2 ½, 4, and 5 turns
3. Refrigerant Charge
   - At tank temperature:24 ºC
   - Flow rate at both heat exchangers: 1 L/min
   - ExV opening: 2 ½
   - Discharge pressure: From 90-72 Bar; Reduced @ 15 Bar/h
4. Optimum system performance
   - Large water flow rate to enhance heat exchange
   - Controlled water flow rate to enhance thermal profile

Results - Impact of water flow rate

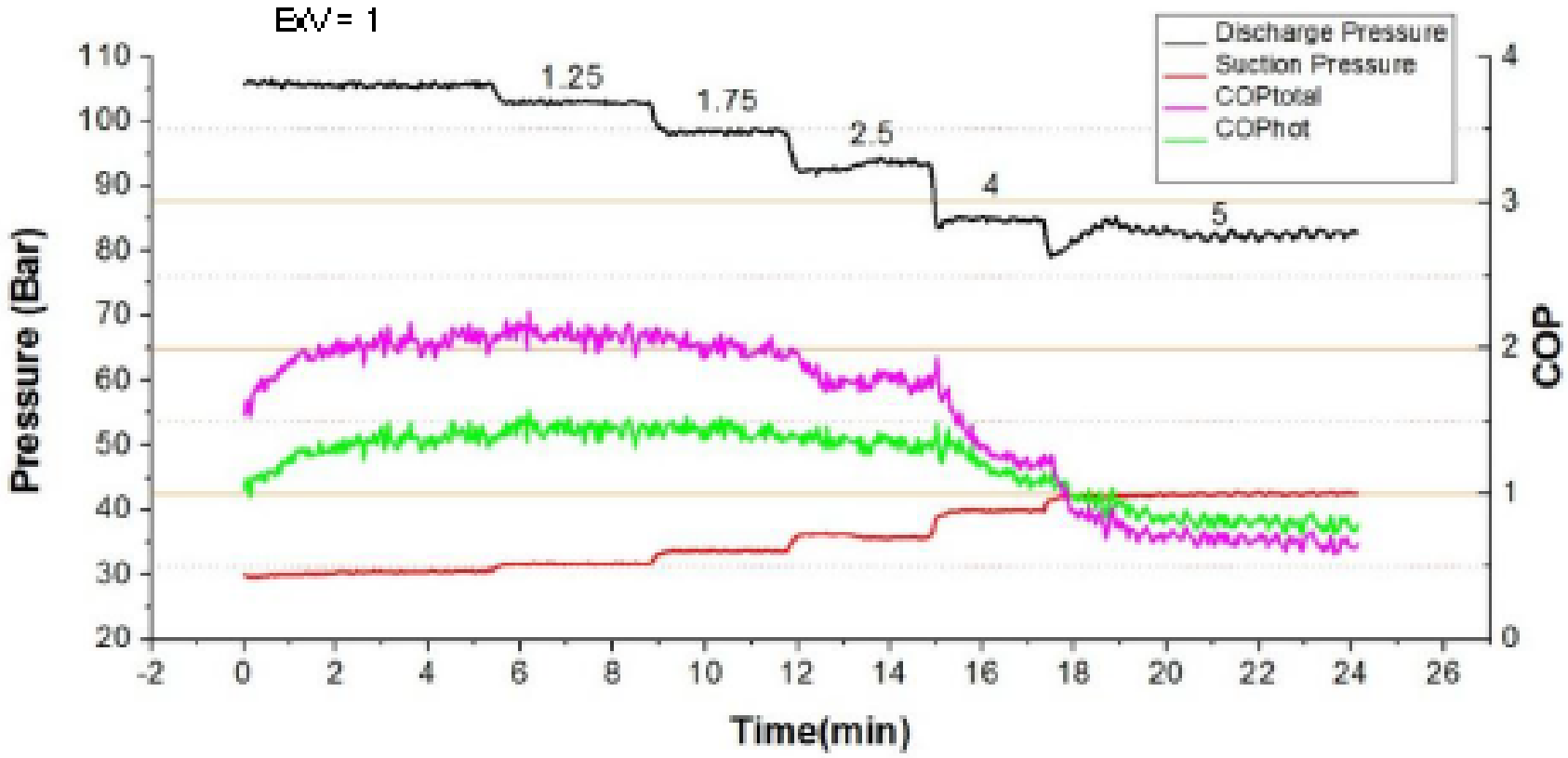


COP vs hot and cold water flow rates, ExV at 1 ¼ opening

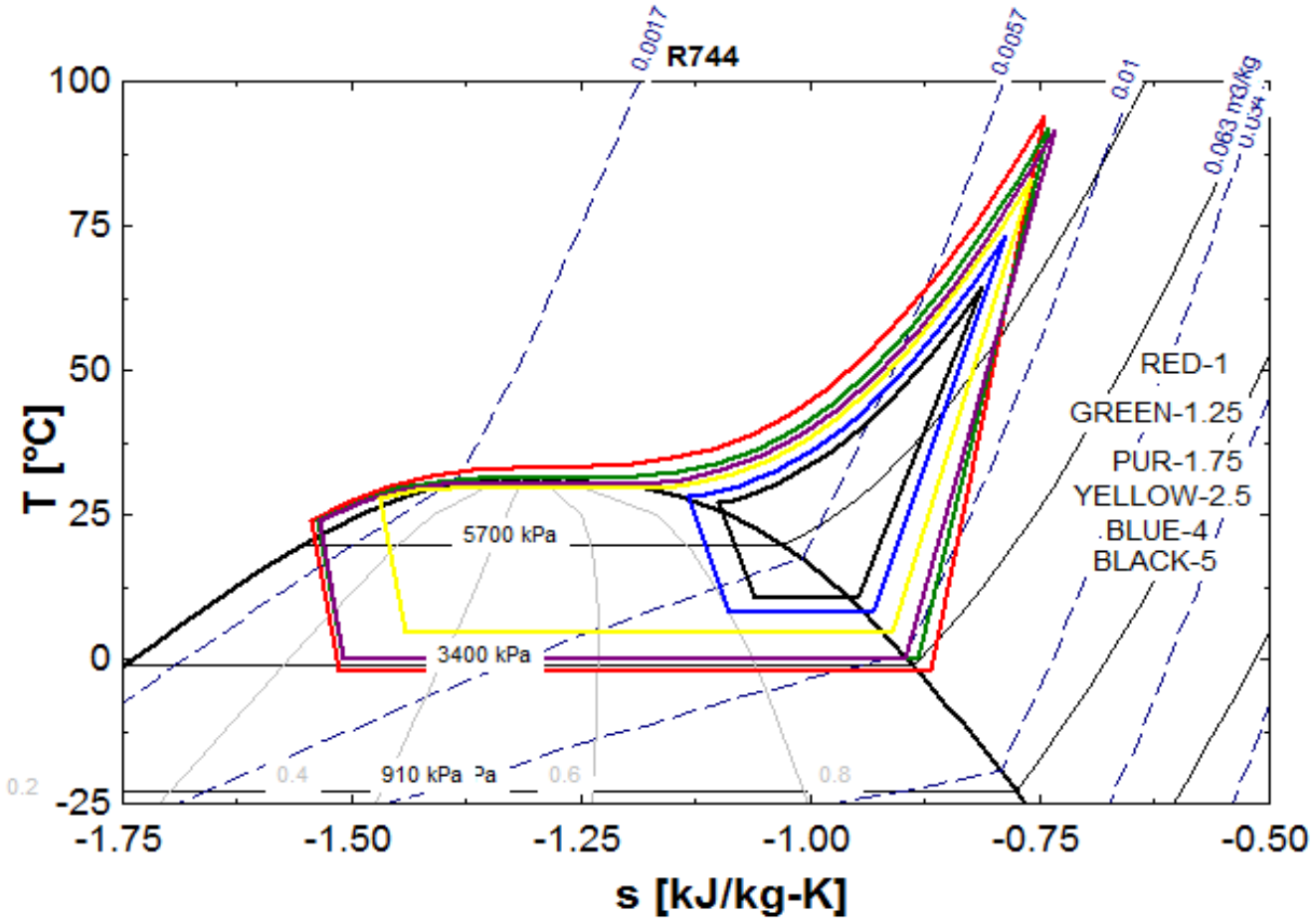


COP vs hot and cold water flow rates, ExV at 2 ½ opening

Results - Impact of ExV Opening

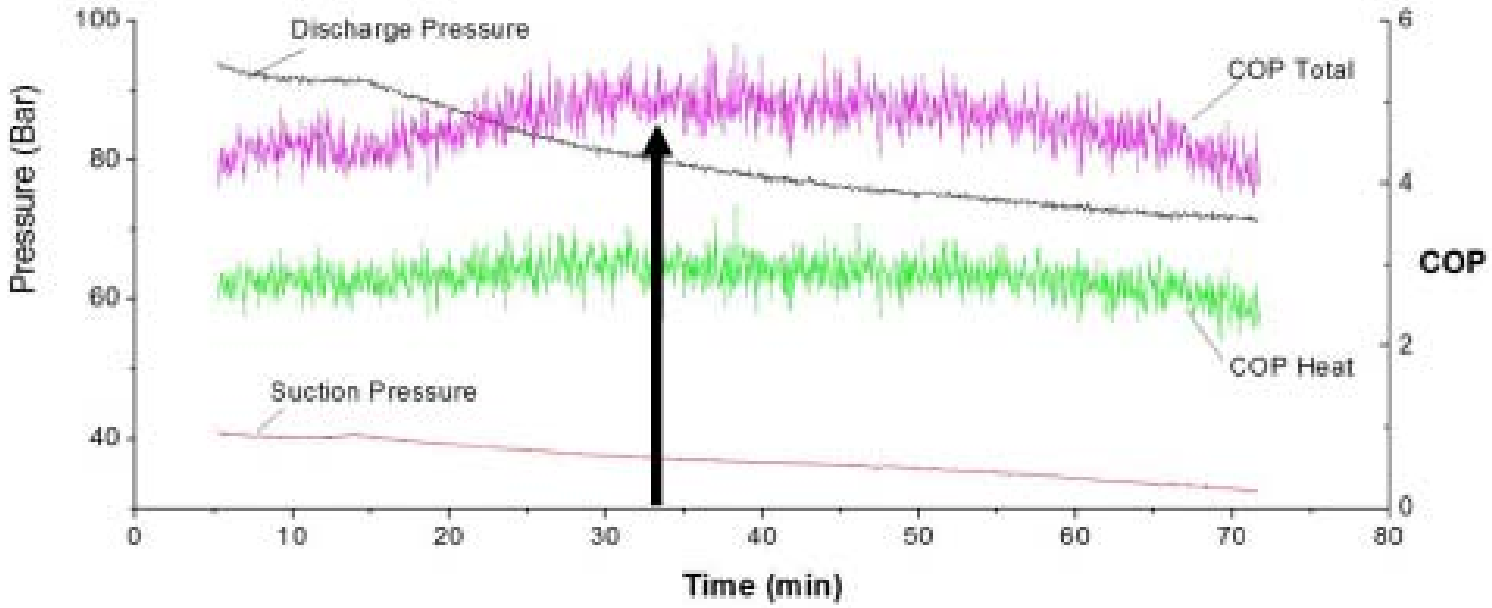


Results - Impact of ExV Opening



T-s Diagram of ExV stage opening at 23º C (73.4ºF) for hot and cold storage tank

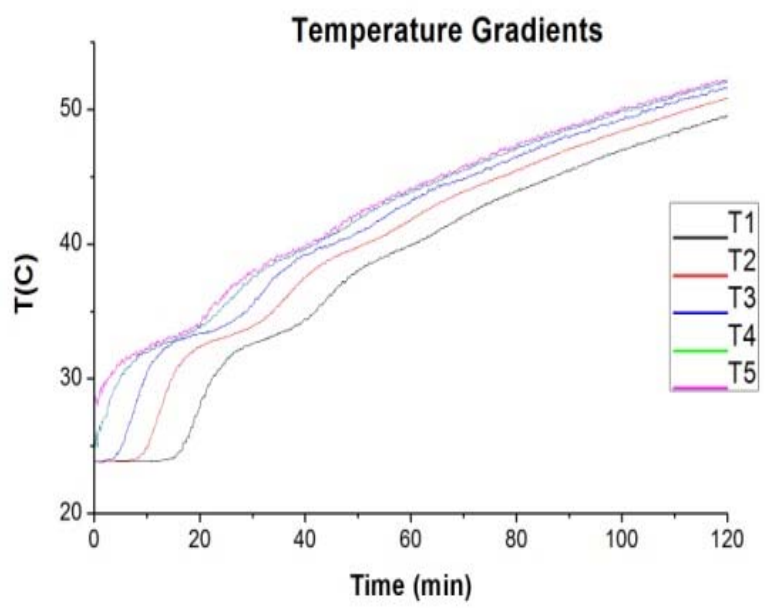
Results - Impact of Refrigerant Charge



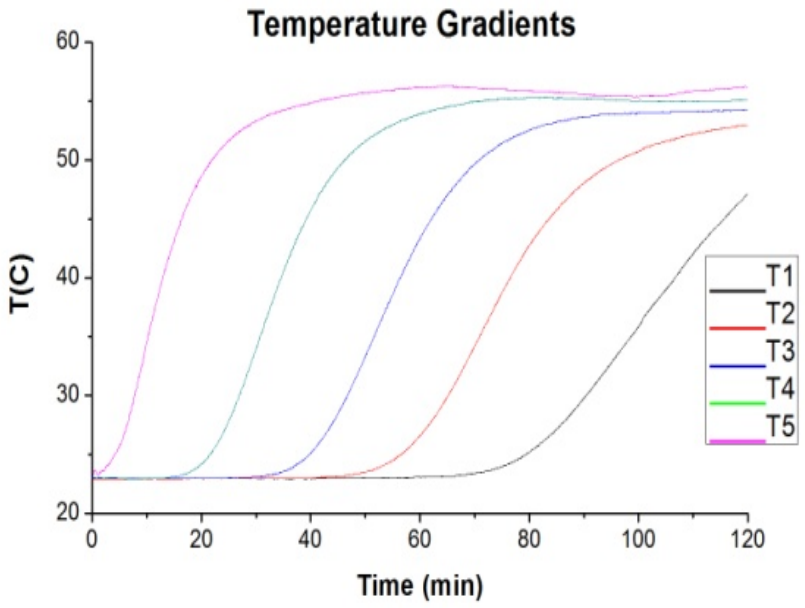
Optimum discharge pressure=82.5 bar

Results - Optimum System Performance

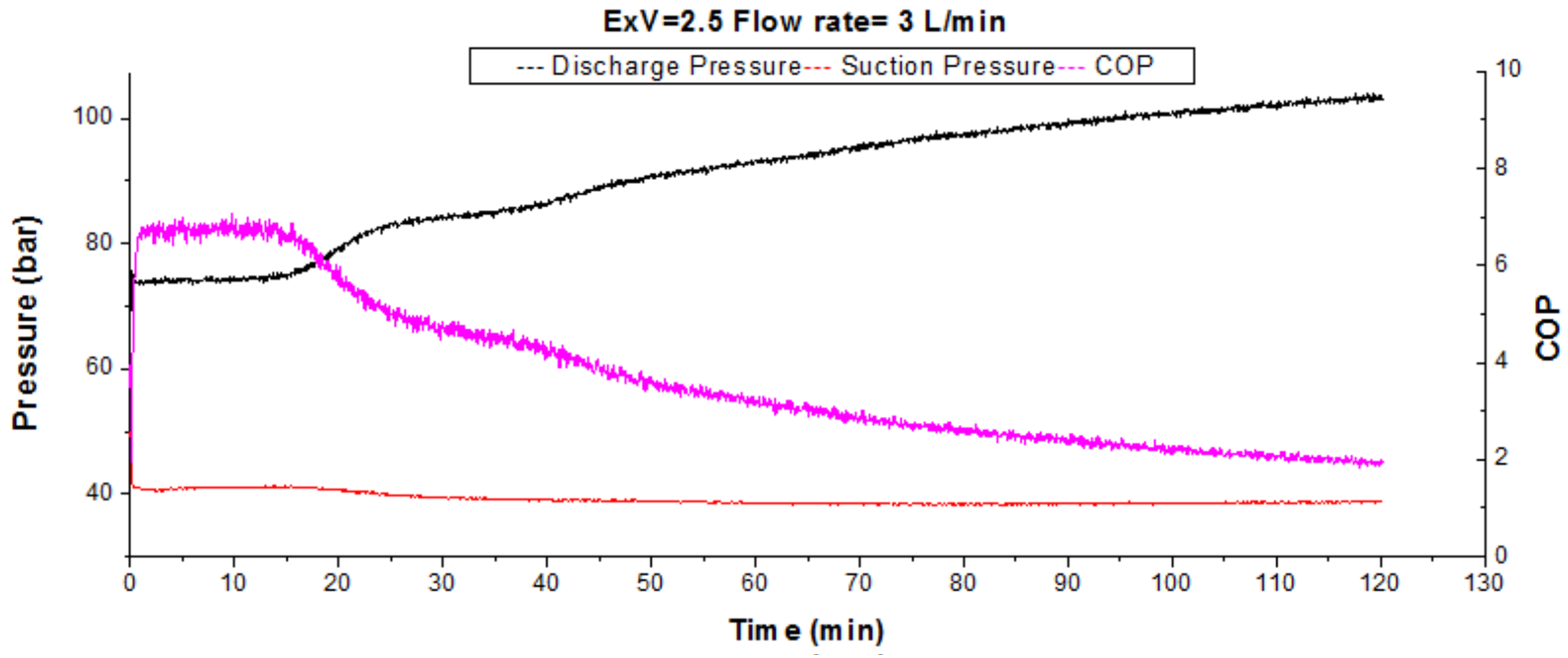
1. Maximizing water flow rate



2. Controlling water flow rate



Results - Optimum System Performance



Results - Optimum System Performance

	COP Total	Gas Cooler Capacity (W)	Time (min)
Case 1	3.88	1498.00	109
Case 2	4.00	1989.10	99

Case 2 can achieve 20% more average gas cooler capacity than Case 1. Case 2 takes 10 minutes less than case 1 to achieve the average 50 ºC hot water temperature.

Conclusion

- Increase of the water inlet temperature at gas cooler raises the discharge pressure significantly and drops both the heating and cooling COP
- Increase of the water temperature at evaporator raises the discharge pressure moderately
- Large water flow rate enhances the heat exchanger capacity and the total COP
- Small water flow rate seems better to maintain the thermal profile of the water tank

Conclusion

- Variable flow rate control strategy case proves to be 20% more efficient in terms of gas cooler capacity when compared to fixed flow rates
- COP tends to increase while closing the expansion valve at a constant water circulation rate of 3 L/min and at 50ºC gas cooler water inlet temperature
- Based on experimental results, a matched tank capacity is suggested between two storage tanks.

Acknowledgement

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Thank You!
Questions?