Hybrid thermally driven ionic liquid heat pump water heater and dehumidifier for commercial applications

Rohit Bhagwat[1], Michael Schmid[2], Paul Glanville[3], and Saeed Moghaddam[1]

[1]University of Florida

[2]Micro Nano Technologies

[3]GTI Energy

Introduction

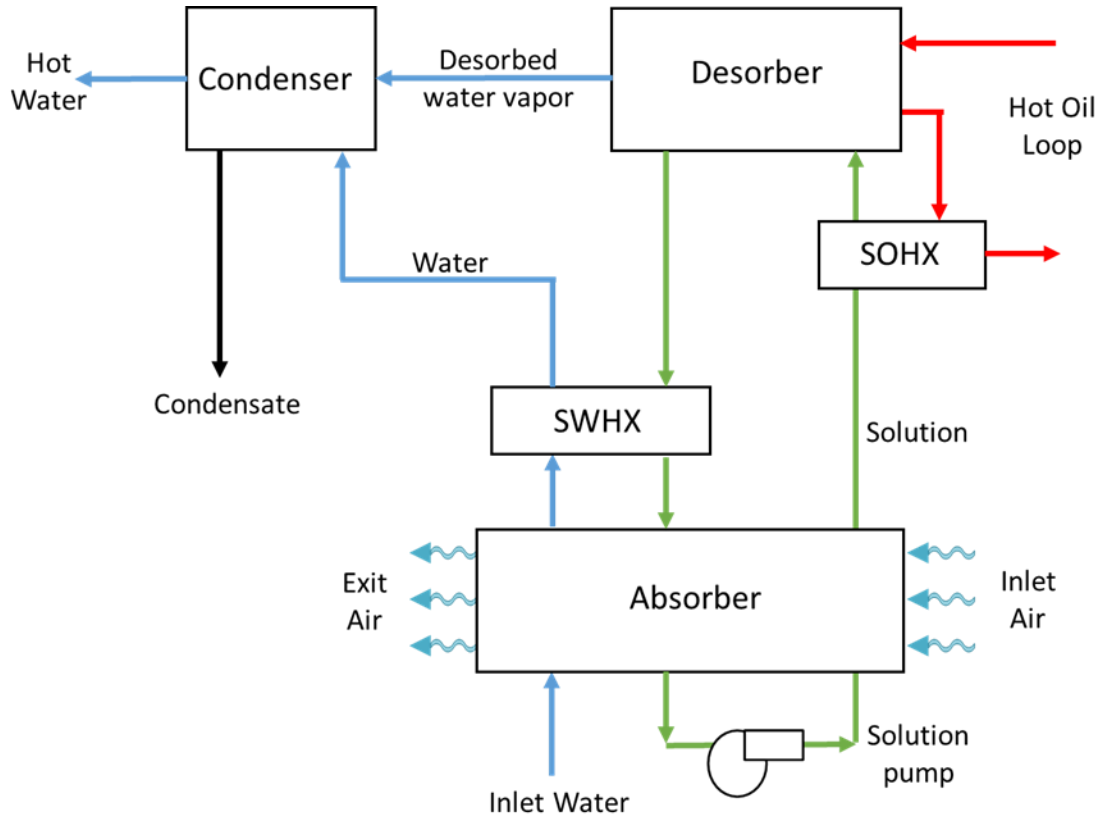
- Food and Beverage Industry
  - Wide range of processes
    - Heating
    - Baking
    - Drying
    - Freezing
    - Pasteurization
    - Cleaning/Sanitation
  - Demand
    - Dehumidification
    - Hot Water

Outline/Agenda

- Semi-Open Absorption Heat Pump Water Heater (HPWH)
- Research Focus
- Experimental Test Suite
- Experimental Results
- Conclusion

Semi-Open Absorption HPWH

- Introduced 2017
  - Chugh & Gluesenkamp
- Tested @ ORNL
  - 2017 - original configuration
  - 2019 - updated absorber
- Cycle characteristics
  - Single effect
  - Ionic liquid desiccant
  - Heat driven
  - Open absorber



Semi-Open Absorption HPWH

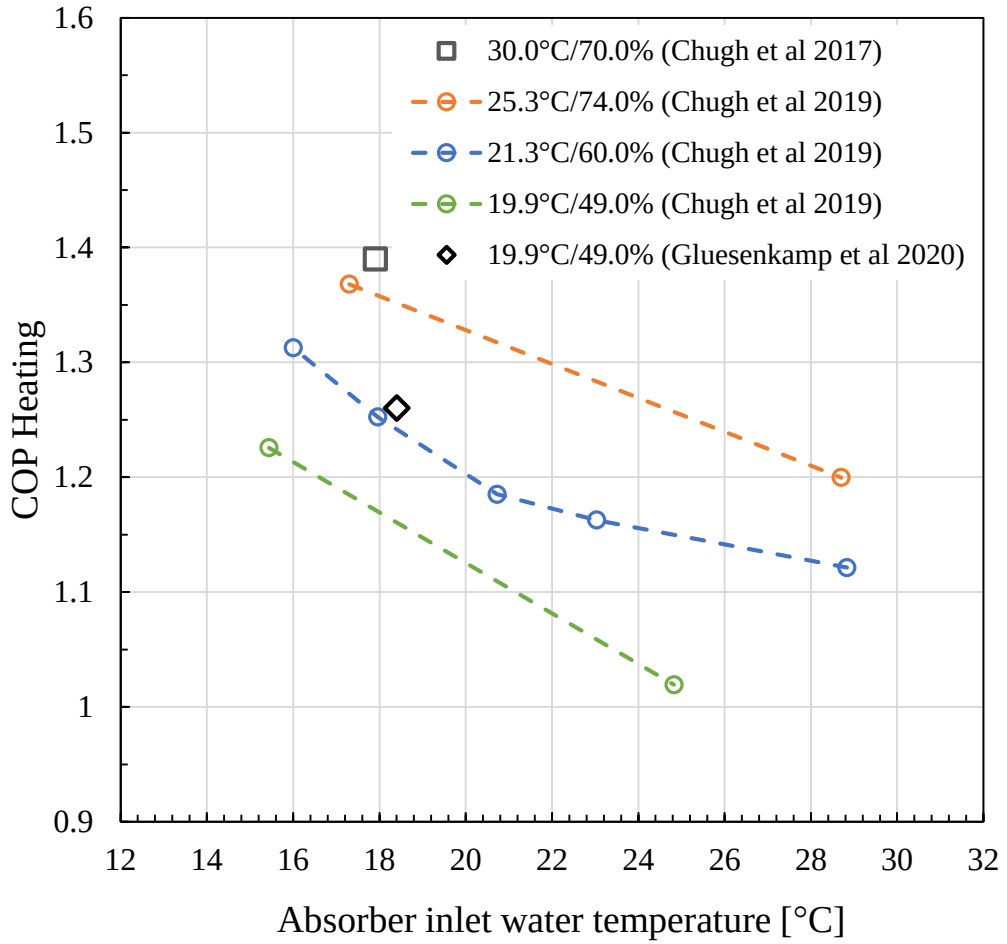
- Desorber/Condenser
  - Single Panel (0.15 m^2)
  - Stainless Steel
- Absorber
  - 3 Generations
  - Multiple Plate
- Water Flow Rate
  - ~ 0.34 lpm UEF
  - ~ 0.46 lpm

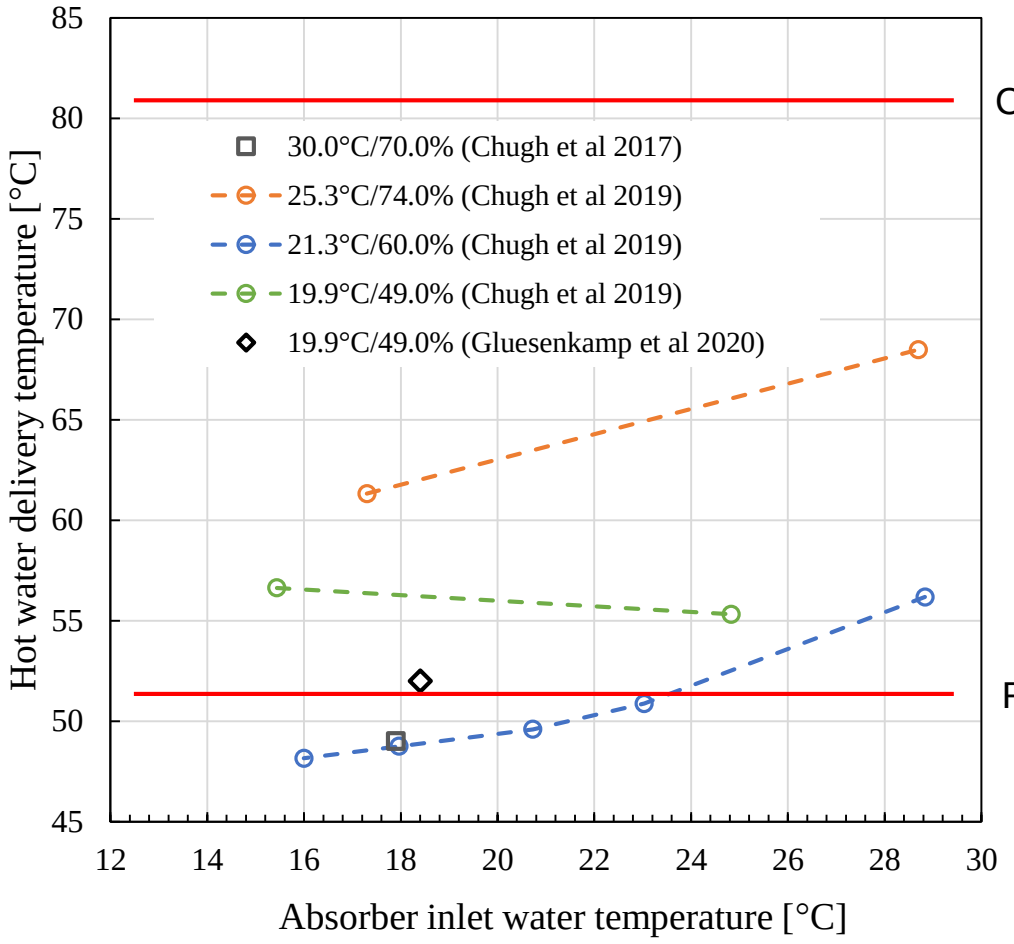
Absorber	Gen 1 (Chugh 2017)	Gen2 (Chugh 2019)	Gen 3 (Glues. 2020)
Number of panels	4	7	13
Active surface area (m^2)	0.42	0.92	1.89
Active plate volume (m^3)	0.0084	0.008	0.01191
Active surface area/volume ratio (m^{-1})	50	115	158.59
Plate material	Metal & 3D printed polymer	Polycarbonate	Polycarbonate
Solution side fin height	1.5 mm	1mm	0.6 mm

Applications

- Efficient heat driven water heater
  - > efficiency than existing gas WH
- Dual application environments
  - Commercial kitchens
    - Hot/humid exhaust
    - High use of 82 °C water
    - Lower HVAC cooling demand as well (dehumidification)
  - Food processes
    - Hot/humid exhaust
    - High use of 82 °C water
    - Lower HVAC cooling demand as well (dehumidification)

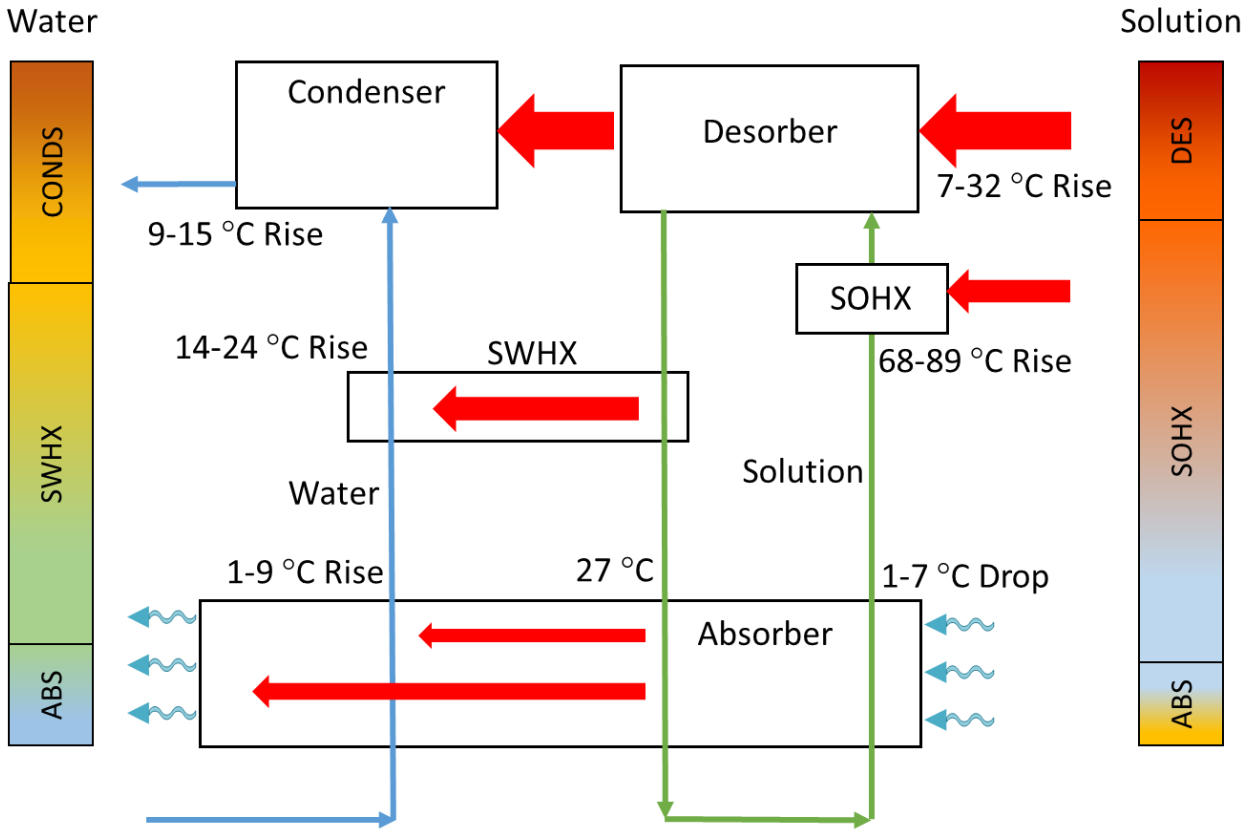
Semi-Open Absorption HPWH





HPWH – Research Focus

- Performance envelope
- Improve cycle heat recovery
  - Condenser
    - Surface Modifications
  - Cycle configurations
- Water delivery temperature
  - Residential
  - Commercial

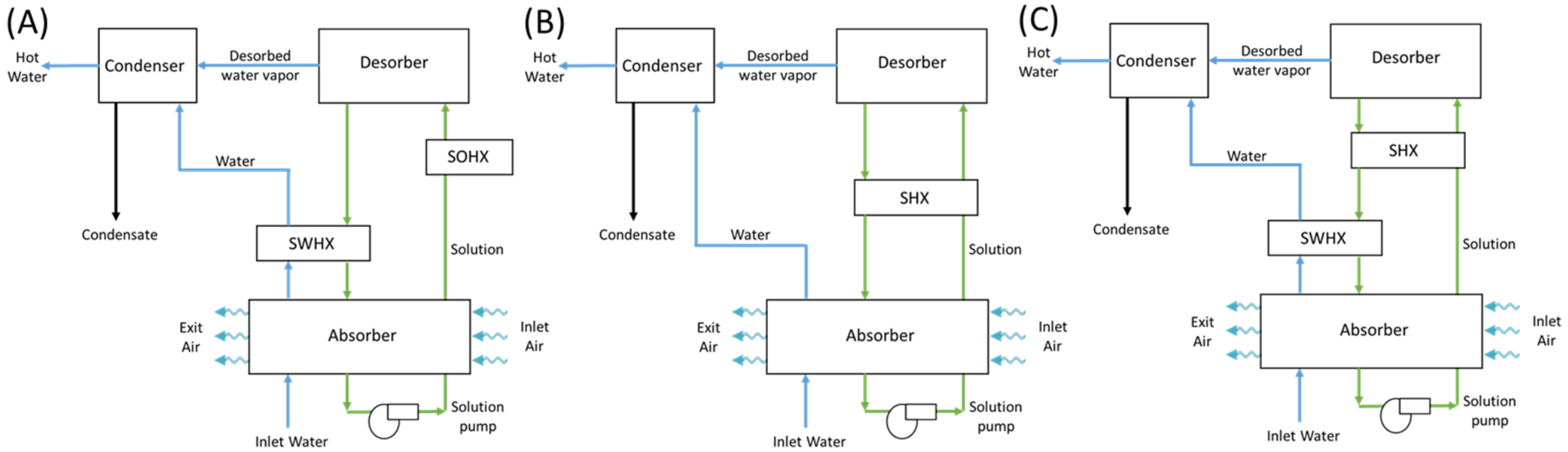


Condenser Modifications

- Desorber drain
  - Vent w/liquid trap
  - Prevent steam from exiting
- Legacy capacity
  - Chugh 2019 – max 1.4 kW
    - 20.3 °C air inlet dew pt.
  - Gluesenkamp 2020 – 825 W
    - 9 °C air inlet dew pt.
- Current capacity
  - Max 2.6 kW
    - 20.3 °C air inlet dew pt.
  - ~10% increase at low dew pt.

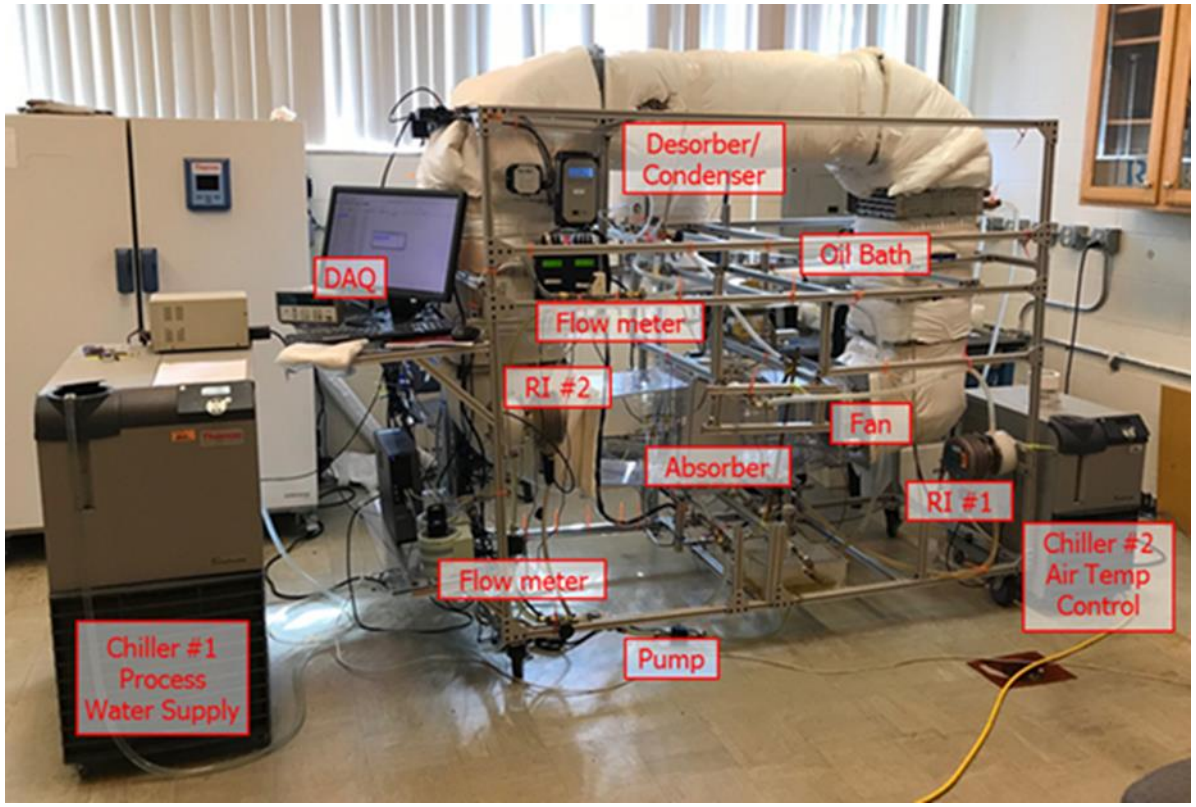
Vent Trap

Absorption HPWH Configurations

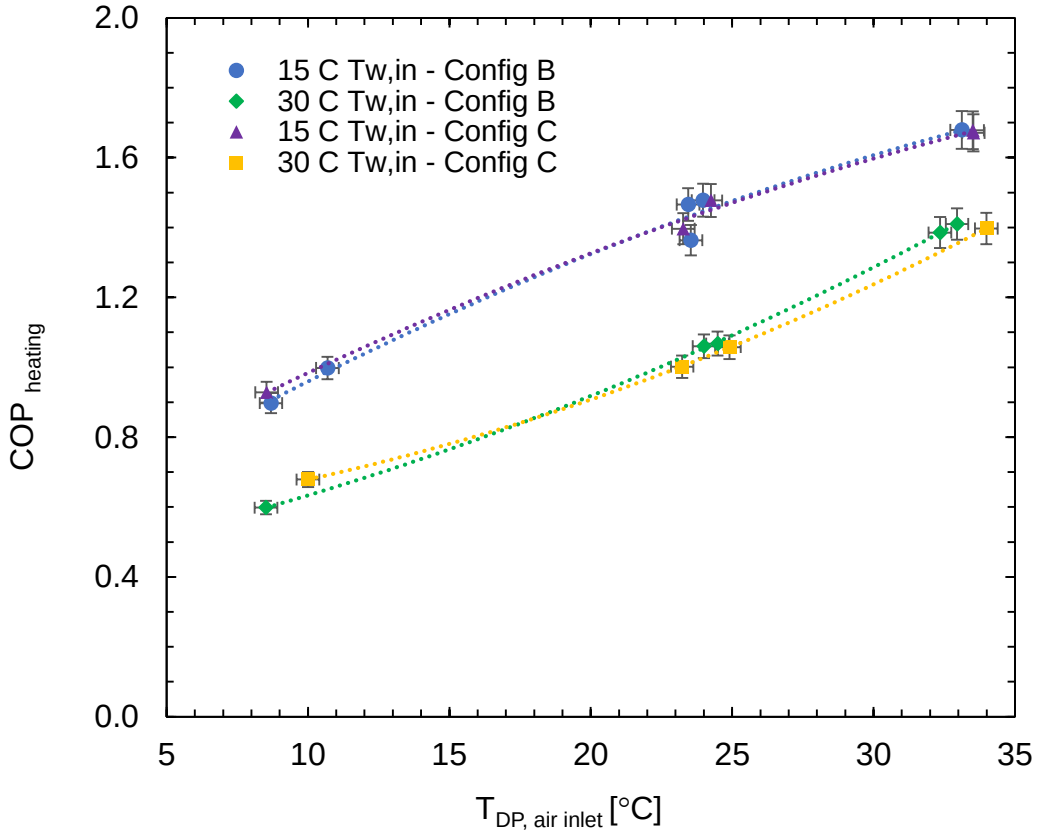


Test Suite/Conditions

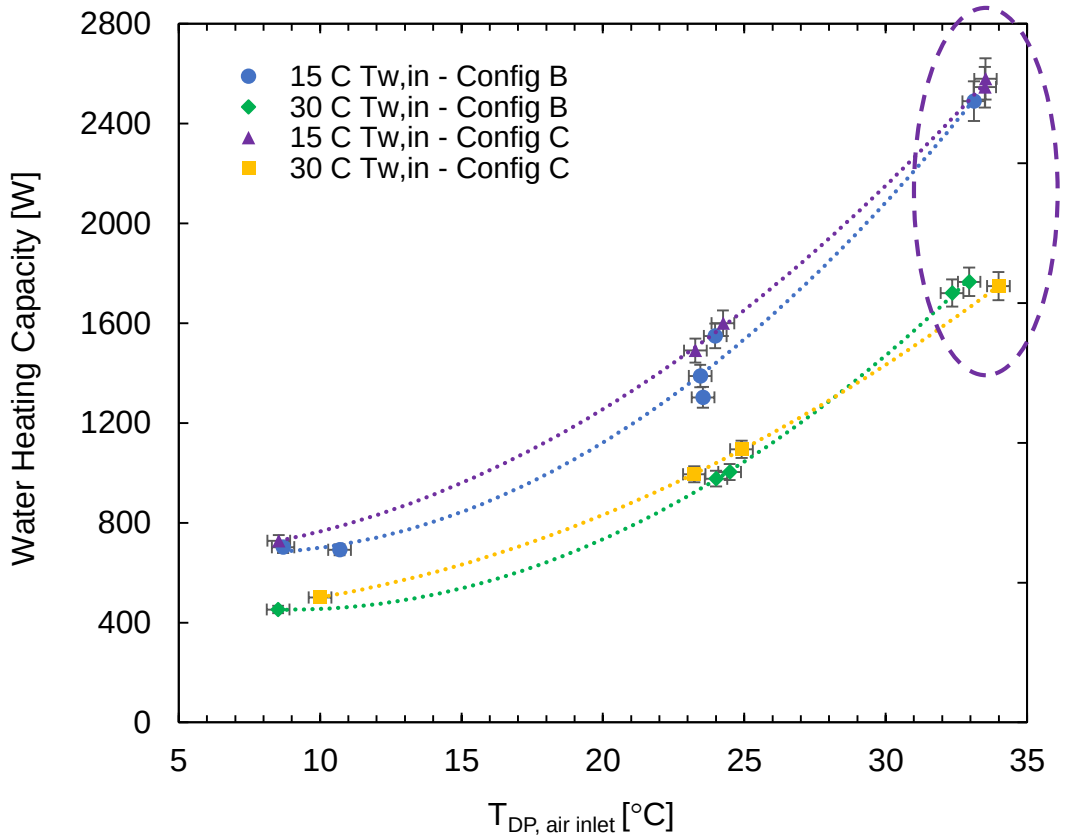
- Consistent
  - Air flow rate (155 cfm)
  - Solution flow rate (0.3 lpm)
  - Heat input (150 °C)
  - Water delivery temp
- Varied
  - Cycle configuration (B & C)
  - Inlet air conditions
  - Inlet water conditions



Experimental Results – Water Heating

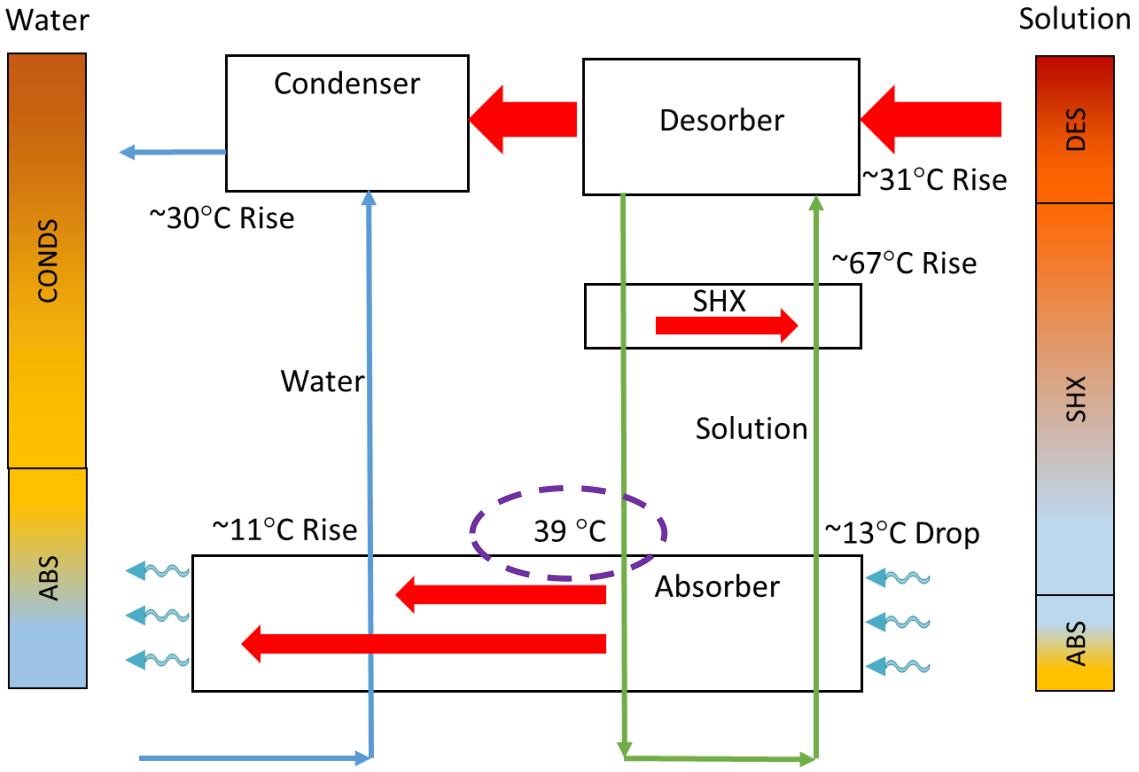


Efficiency

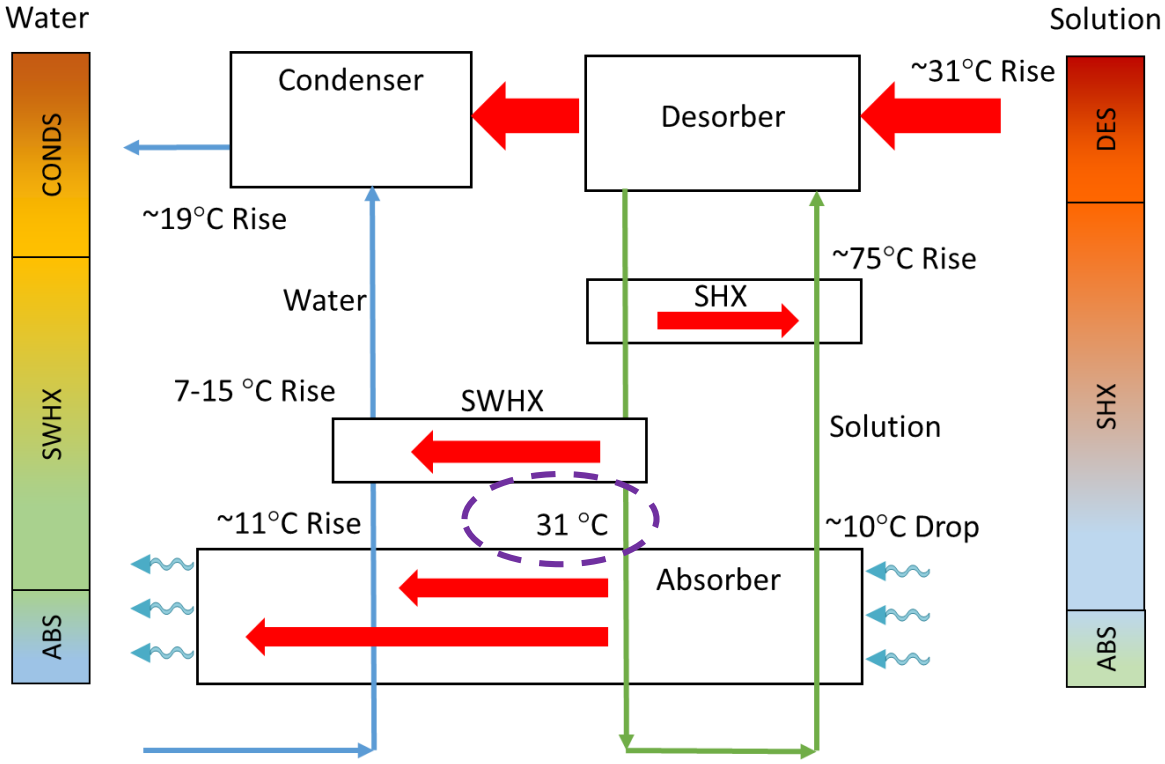


Capacity

Experimental Results – 52 °C Water Delivery

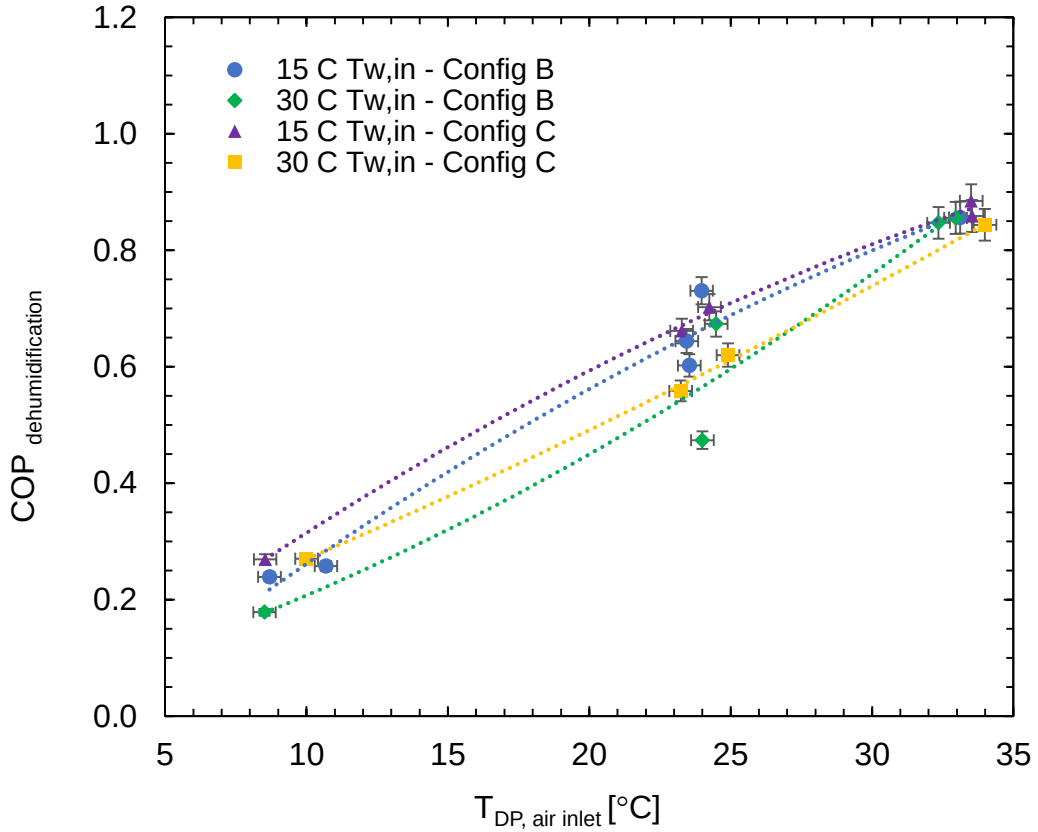


Configuration B

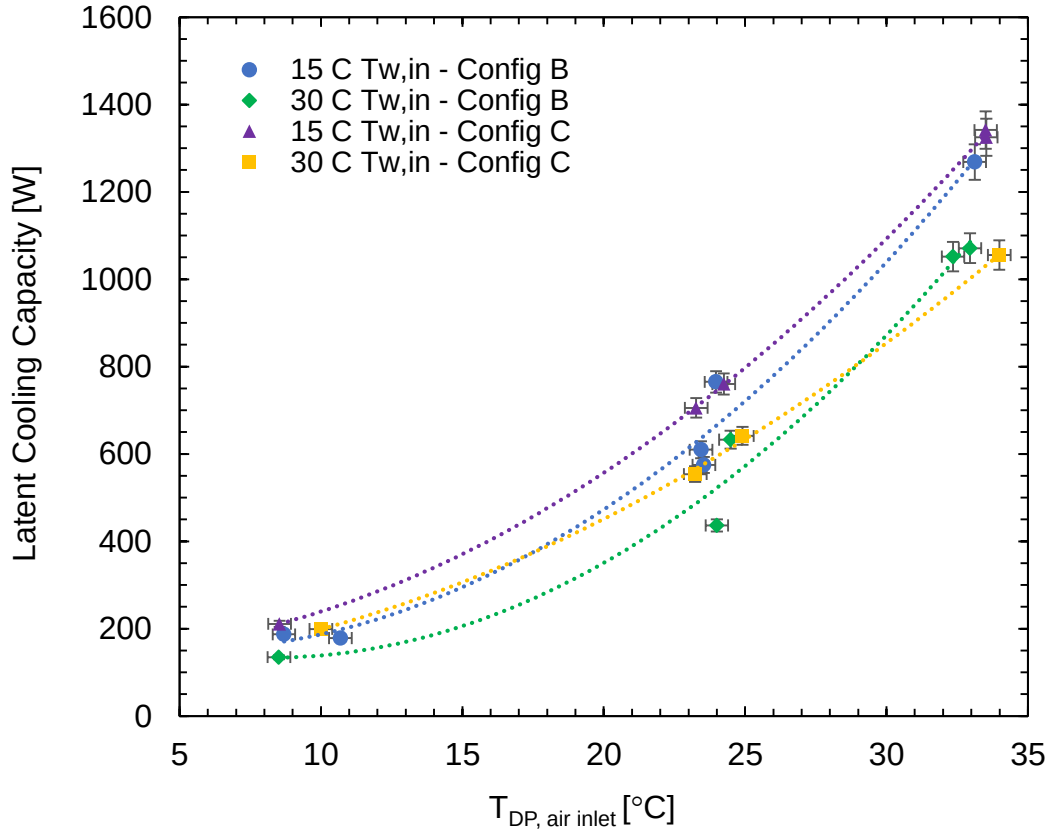


Configuration C

Experimental Results - Dehumidification

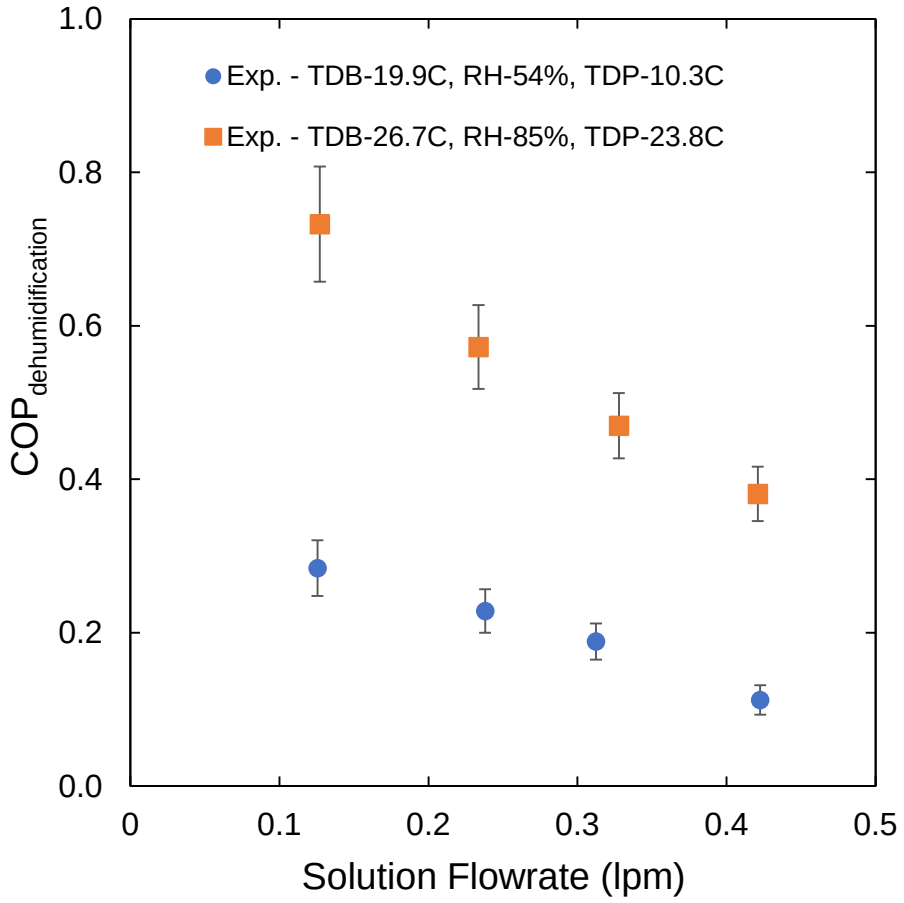


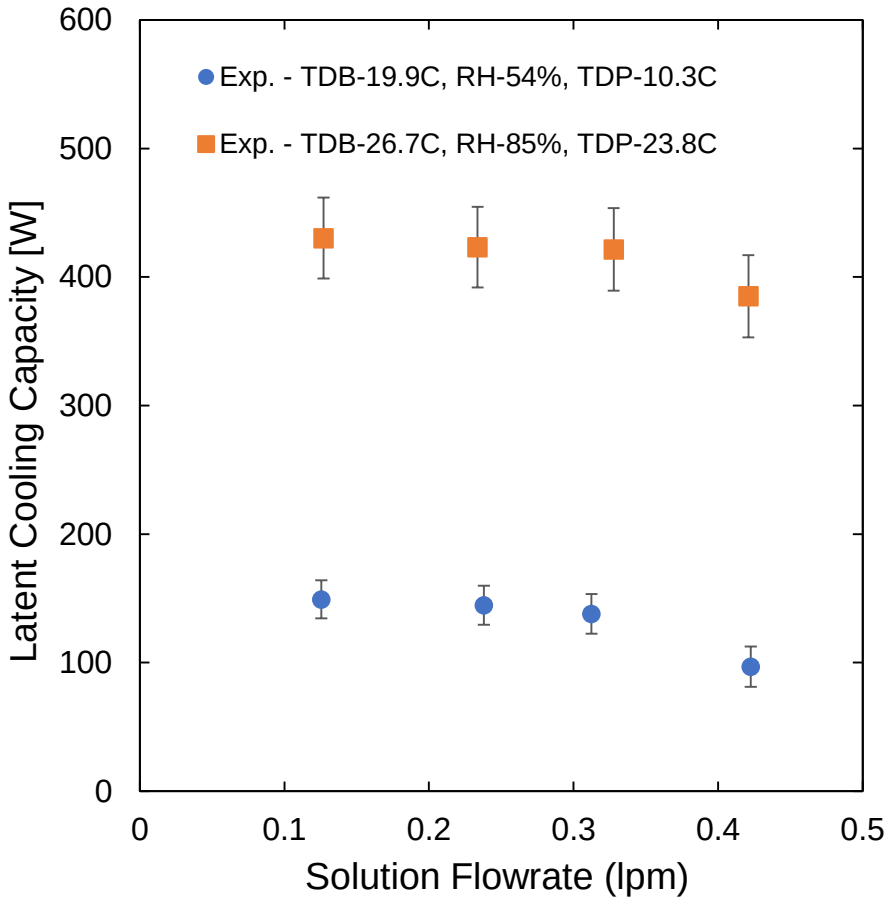
Efficiency



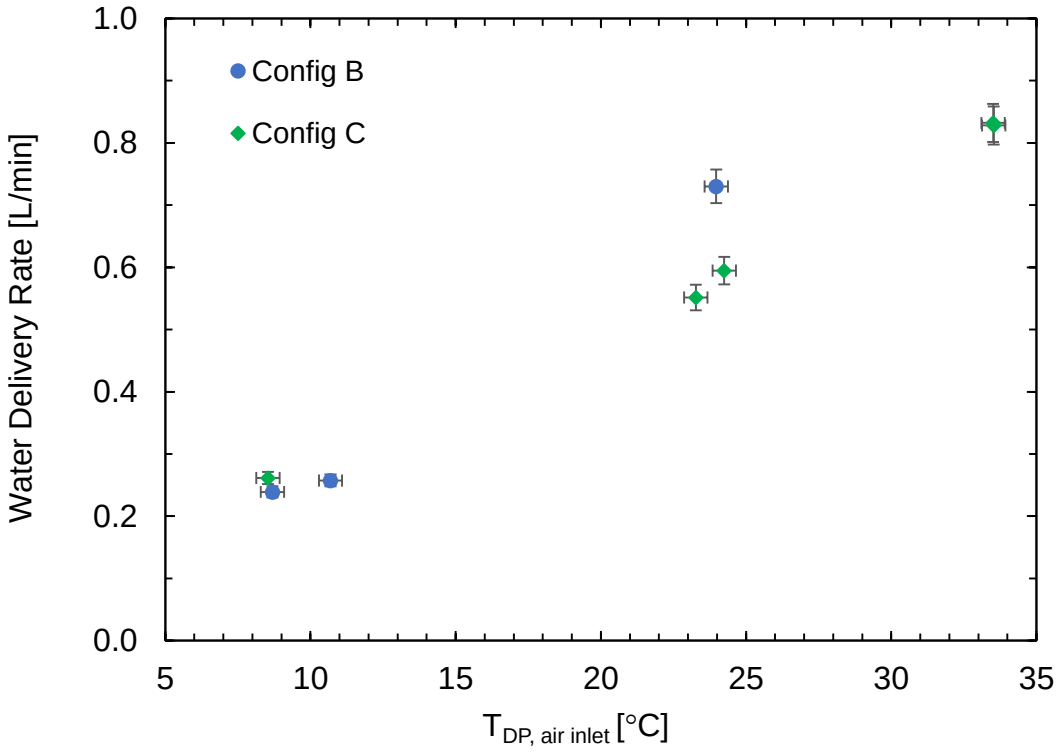
Capacity

Experimental Results – Solution flowrate

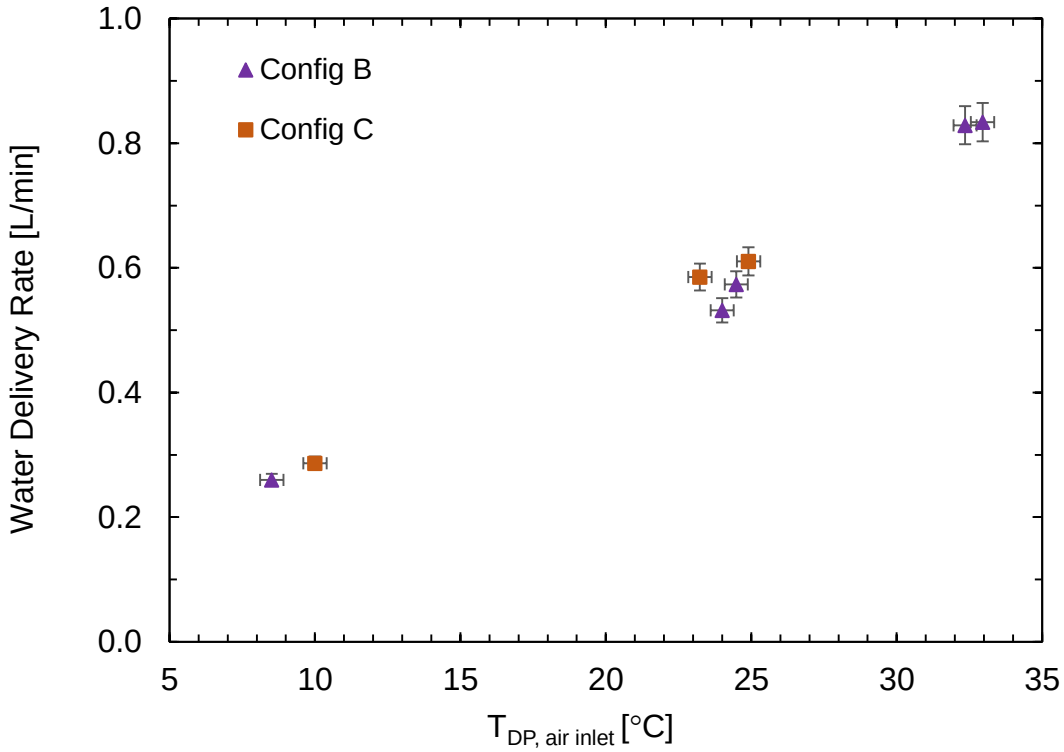




Experimental Results – Water flow rate



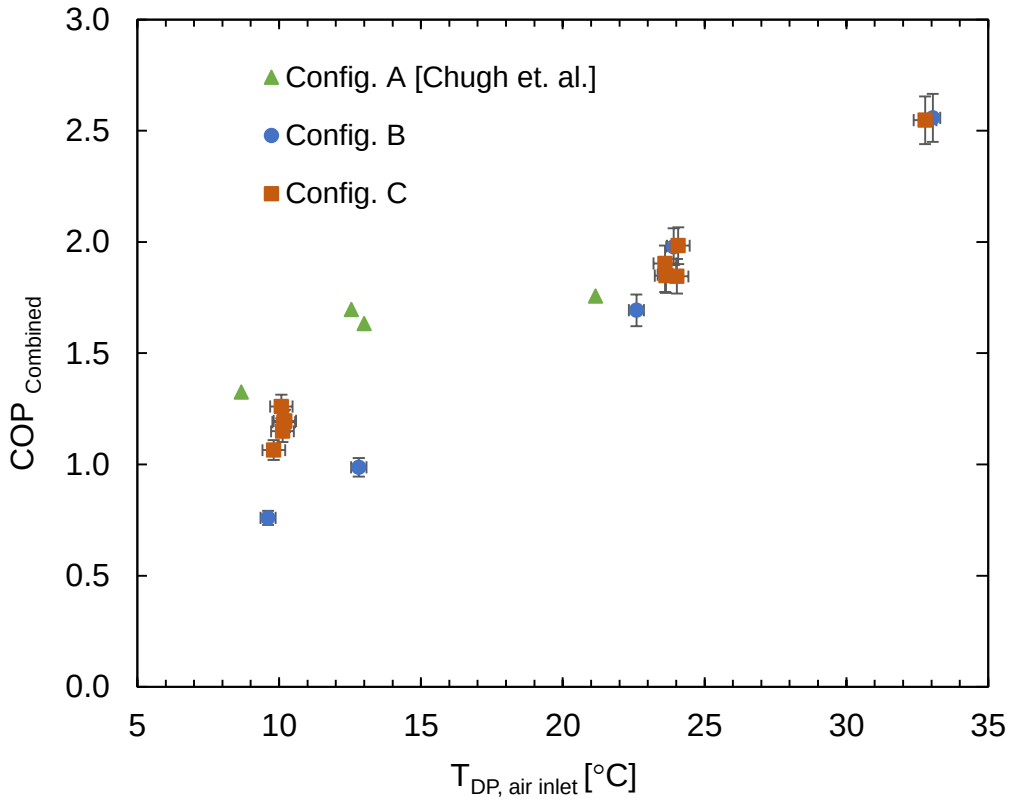
15 °C Water Inlet Temp



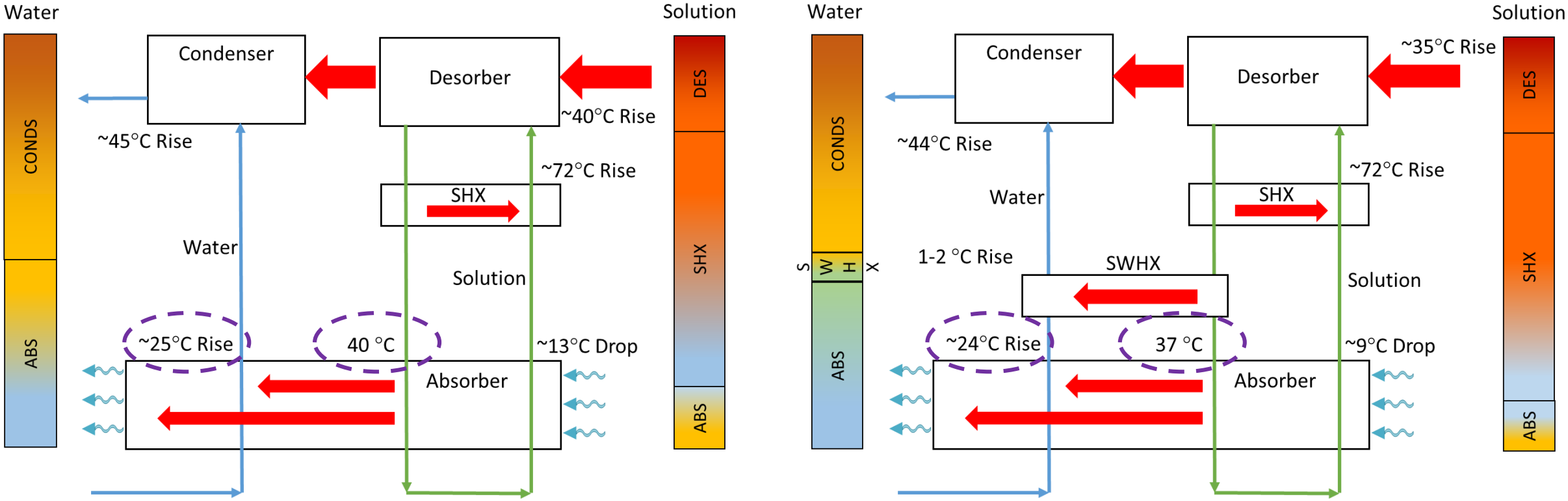
30 °C Water Inlet Temp

Experimental Results – Perf. Comparison

- Performance
  - Increases with dewpt
  - Configuration C
    - SWHX impact @ high dew pt.
  - Up to 2.6 kW @ humid conditions



Experimental Results – 82 °C Water Delivery

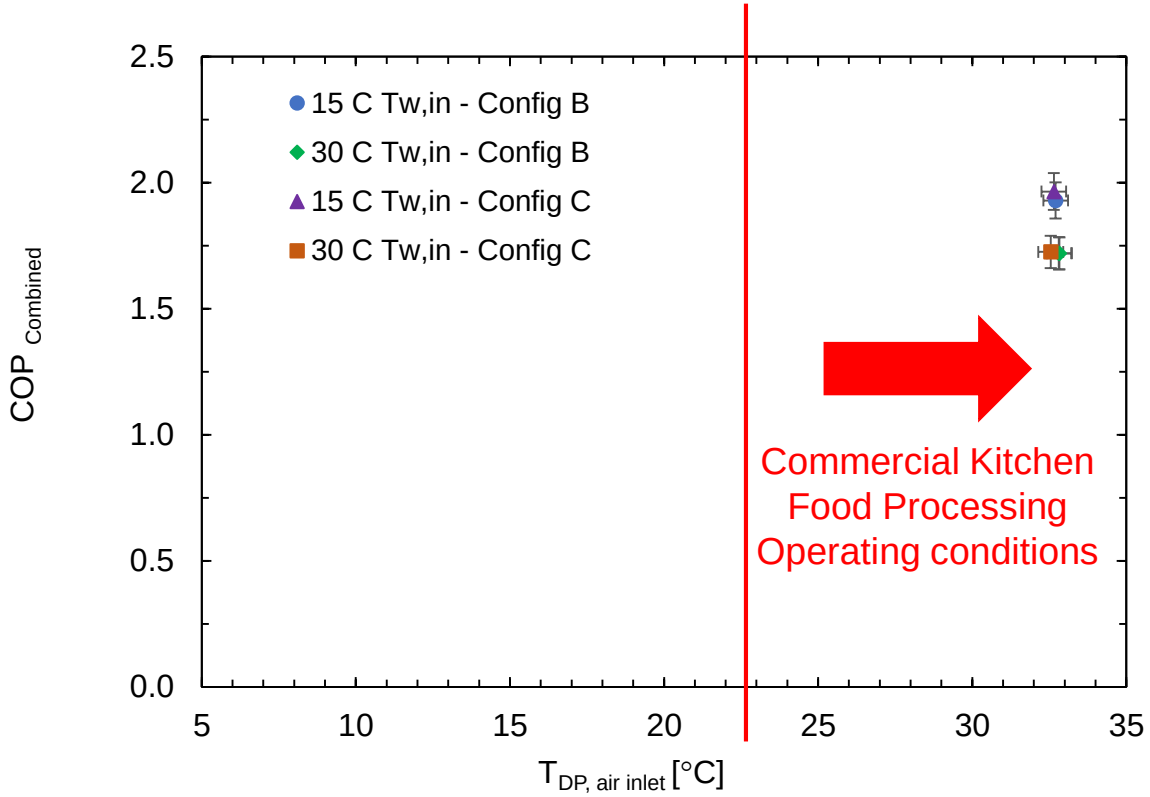


Configuration B

Configuration C

Experimental Results – 82 °C Water Delivery

- Water delivery temp
  - Residential
    - 51.7 °C – all conditions
    - 0.2 – 0.86 lpm
  - Commercial
    - 82 °C
    - 0.25 lpm
- Performance
  - Higher conds temp
  - 25% reduction in COP



Conclusion

- Increased the system capacity and COP through condenser modification
- Examined different system configurations and their impact on system capacity, COP, and water outlet temperature
- Demonstrated a maximum water delivery temperature of 82 °C, suitable for commercial applications.

Acknowledgements

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Questions

Rohit Bhagwat

Michael Schmid

Paul Glanville

Saeed Moghaddam

mschmid@mntusa.com