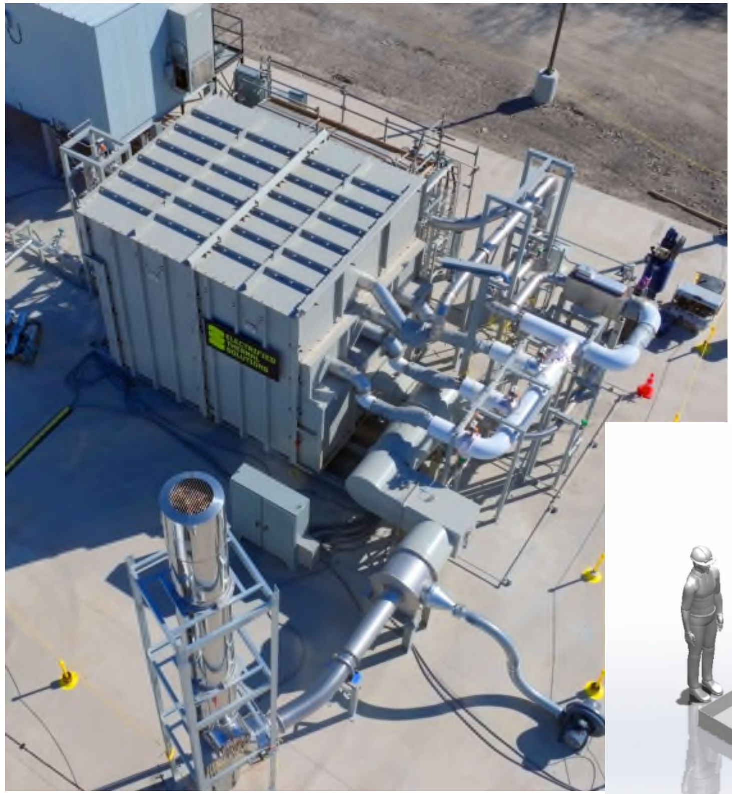
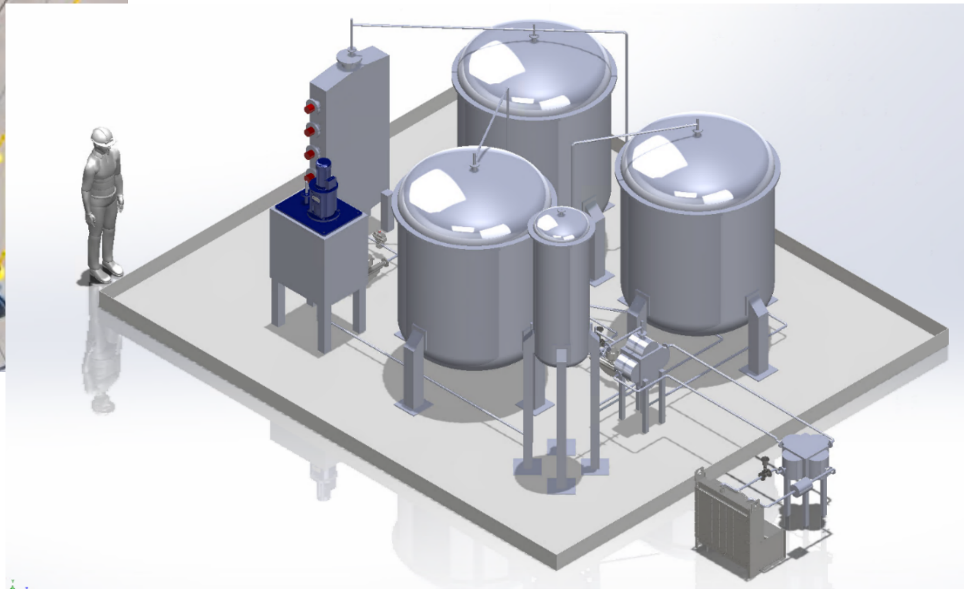
Two Novel Test Systems for Maintaining TES Output Temperature





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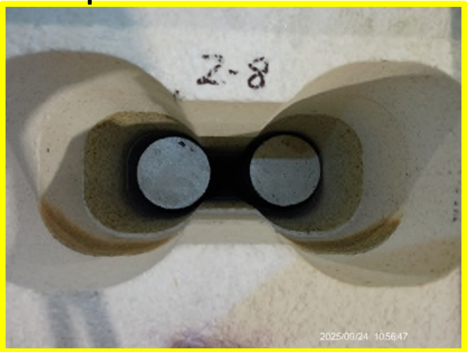
Joule Hive™ Thermal Battery (JHTB) - Commercial Demo

Commercial Demonstration Objectives

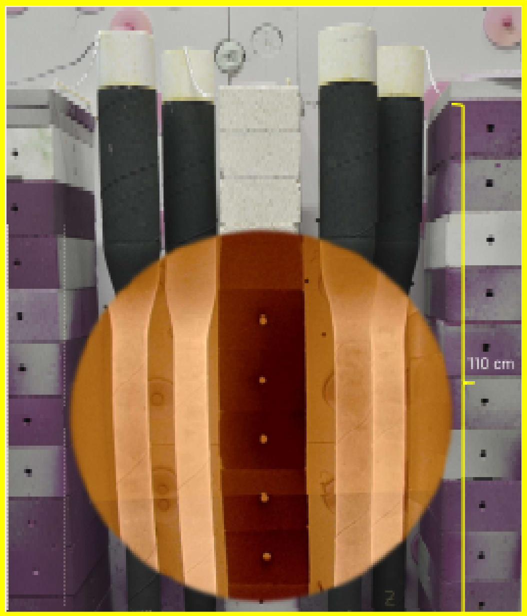
- **Show the operability** of the JHTB at commercial scale – 20 MWh(th)
- Outlet flows of **600°C, 900°C, and up to 1,500°C**
- **Low pressure** design near ambient conditions, 9.95kPa (40 "H2O) gauge
- Mass flow rate of 1.0 kg/sec
    - Flow splits need to **respond to the JHTB state of charge**
- Dynamic **mixing chamber**
    - Difference in outlet temperature distribution with variation less than 10% of the difference between inlet temperatures
- Internal temperatures up to 1,800 °C

The Joule Hive™ uses Electrified Bricks to Generate and Store Industrial Heat

Top view of e-brick

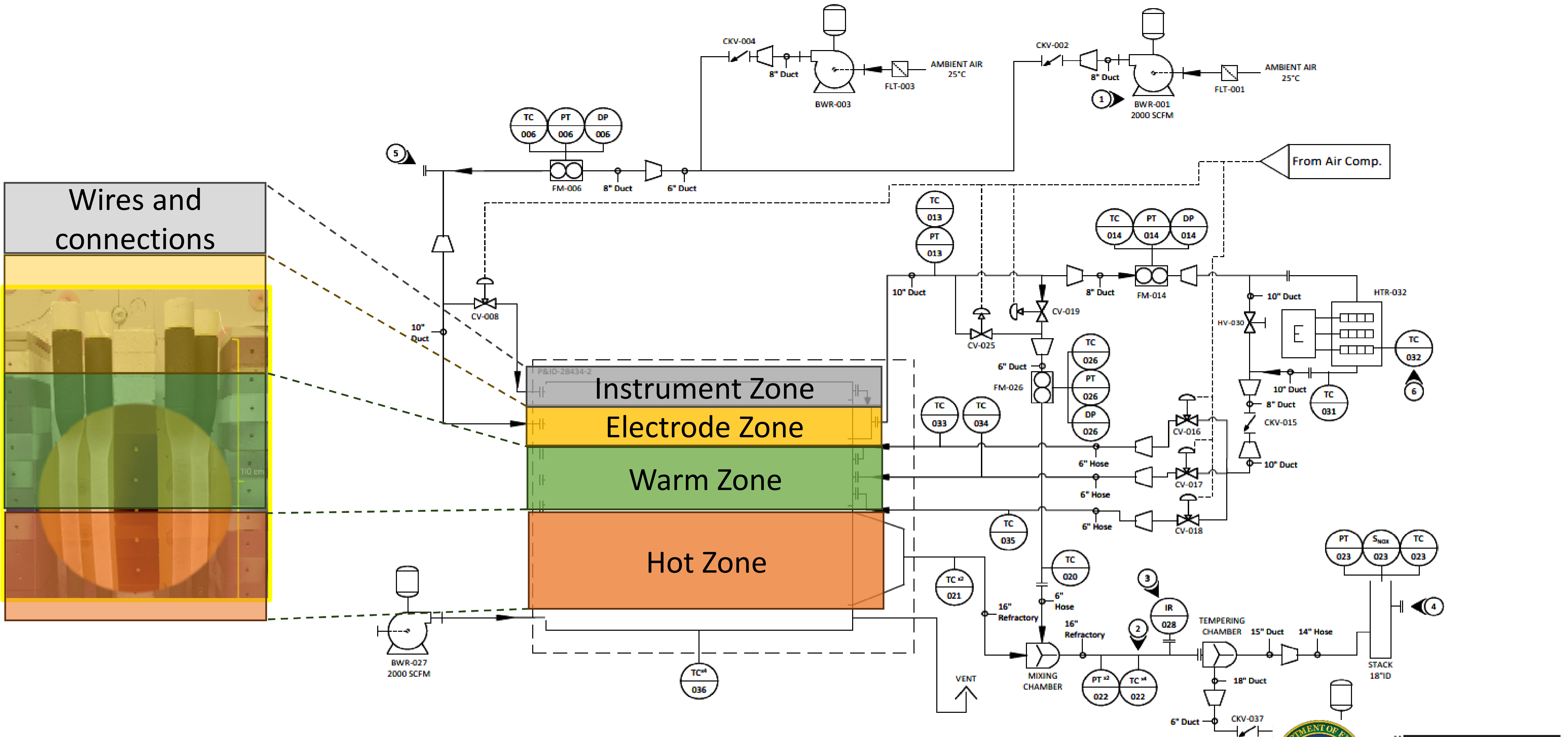


Side view of e-brick

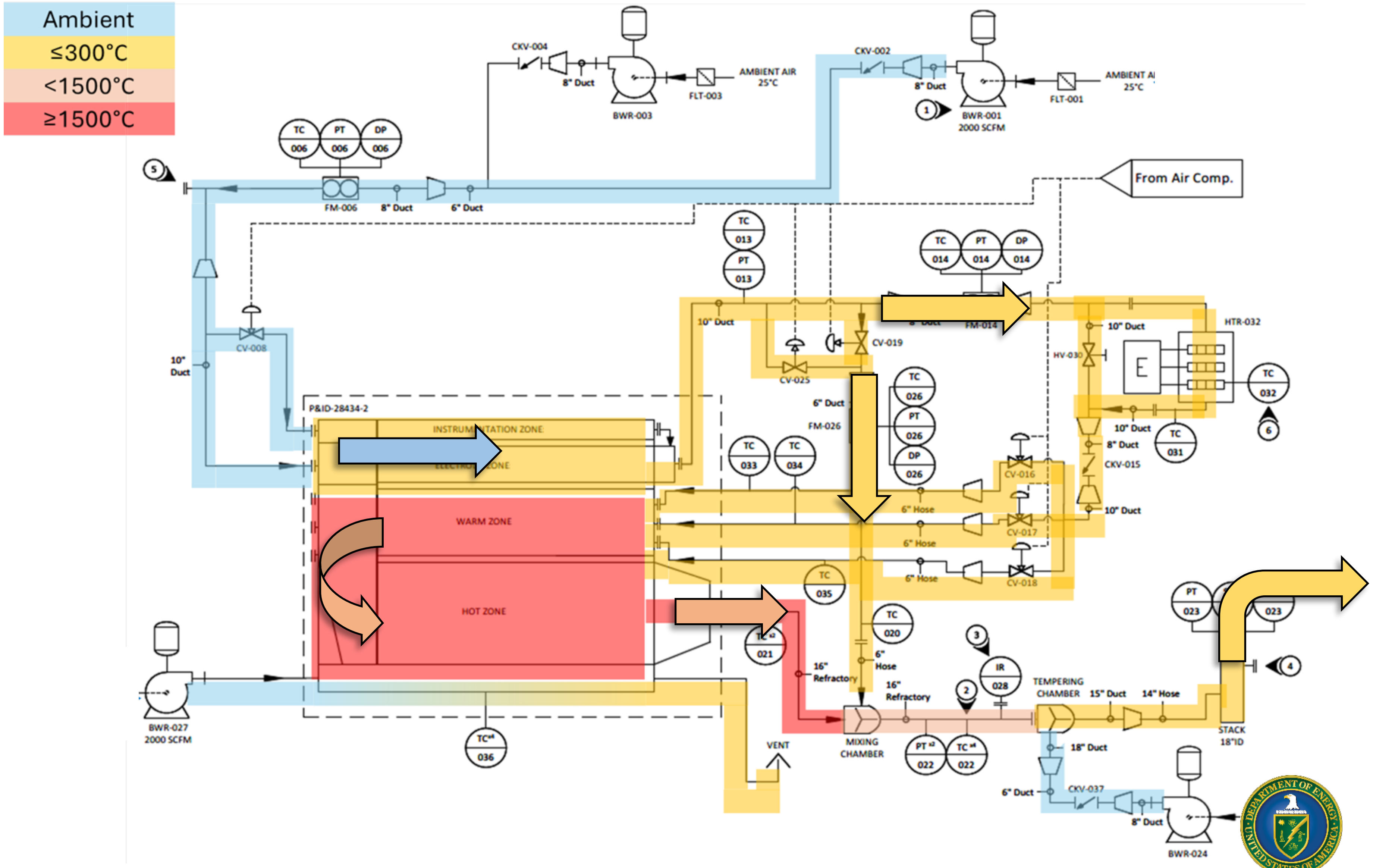


View of the front of the Hive during assembly

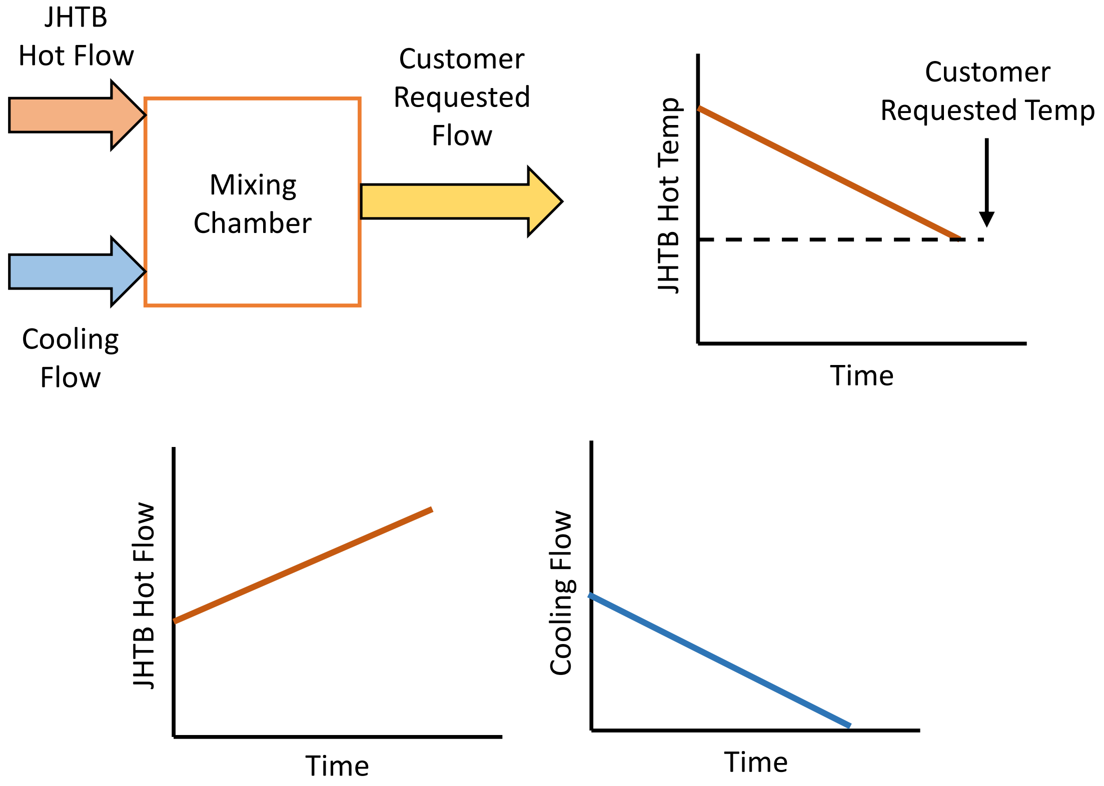
The Joule Hive™ is Split into Distinct Zones



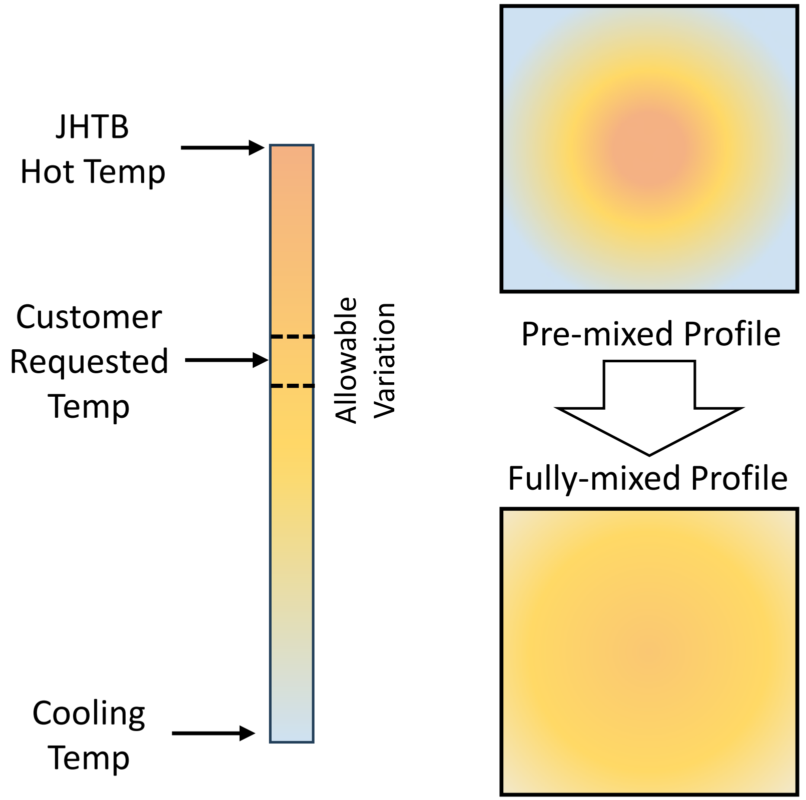
JHTB System Flow Path



Mixing for Consistent Temperature and Flow

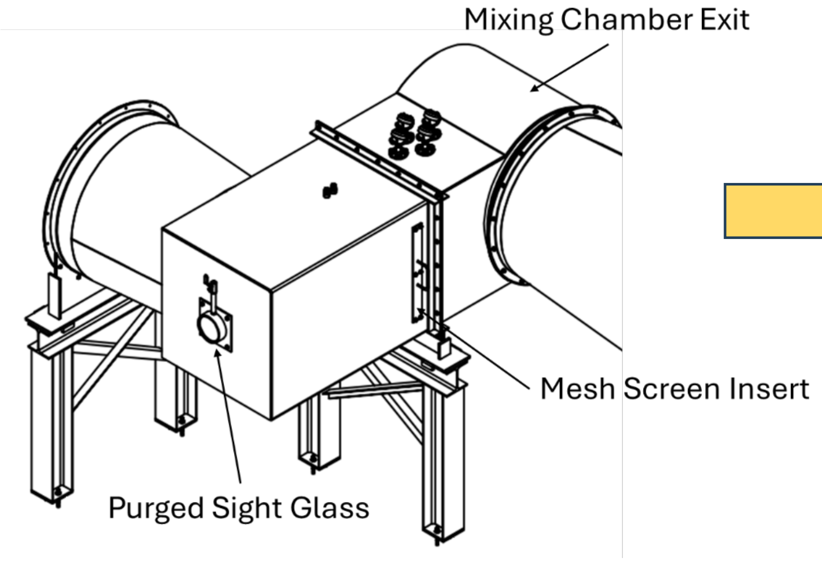


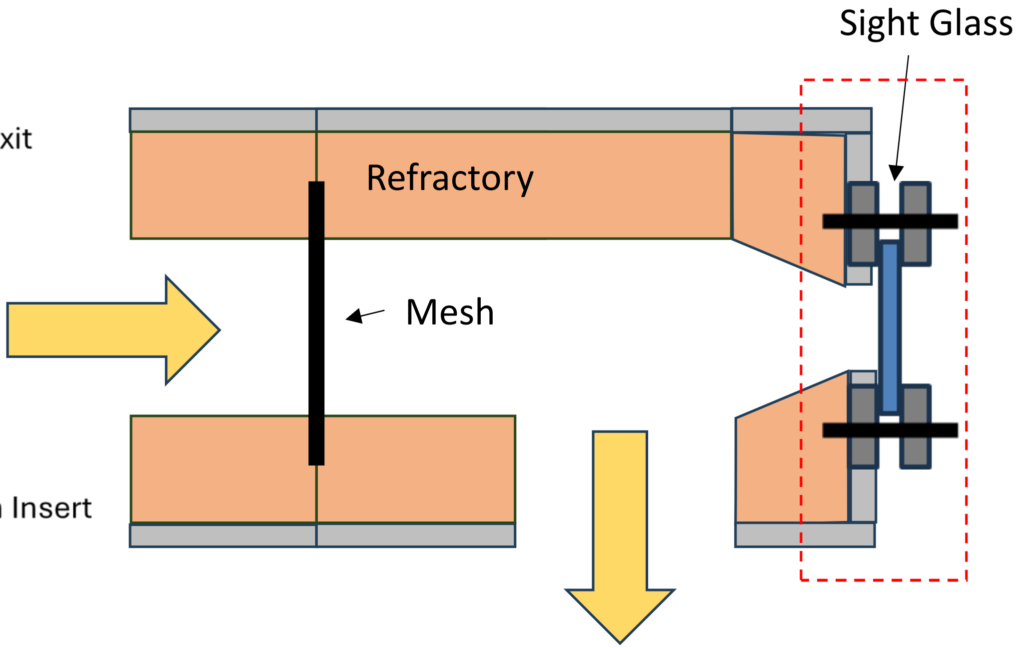
- Control valves vary flow as the JHTB outlet temperature changes
- SwRI-designed approach for consistent and uniform temperature and flow over full range

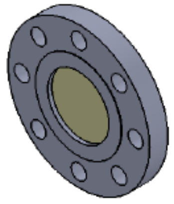


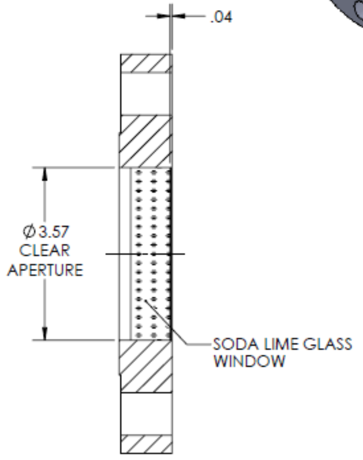
- Unmixed flow may continue for many lengths of the duct
- Mixing chamber creates a more uniform cross section with less than 10% variation

Method for Validating Temperature Uniformity





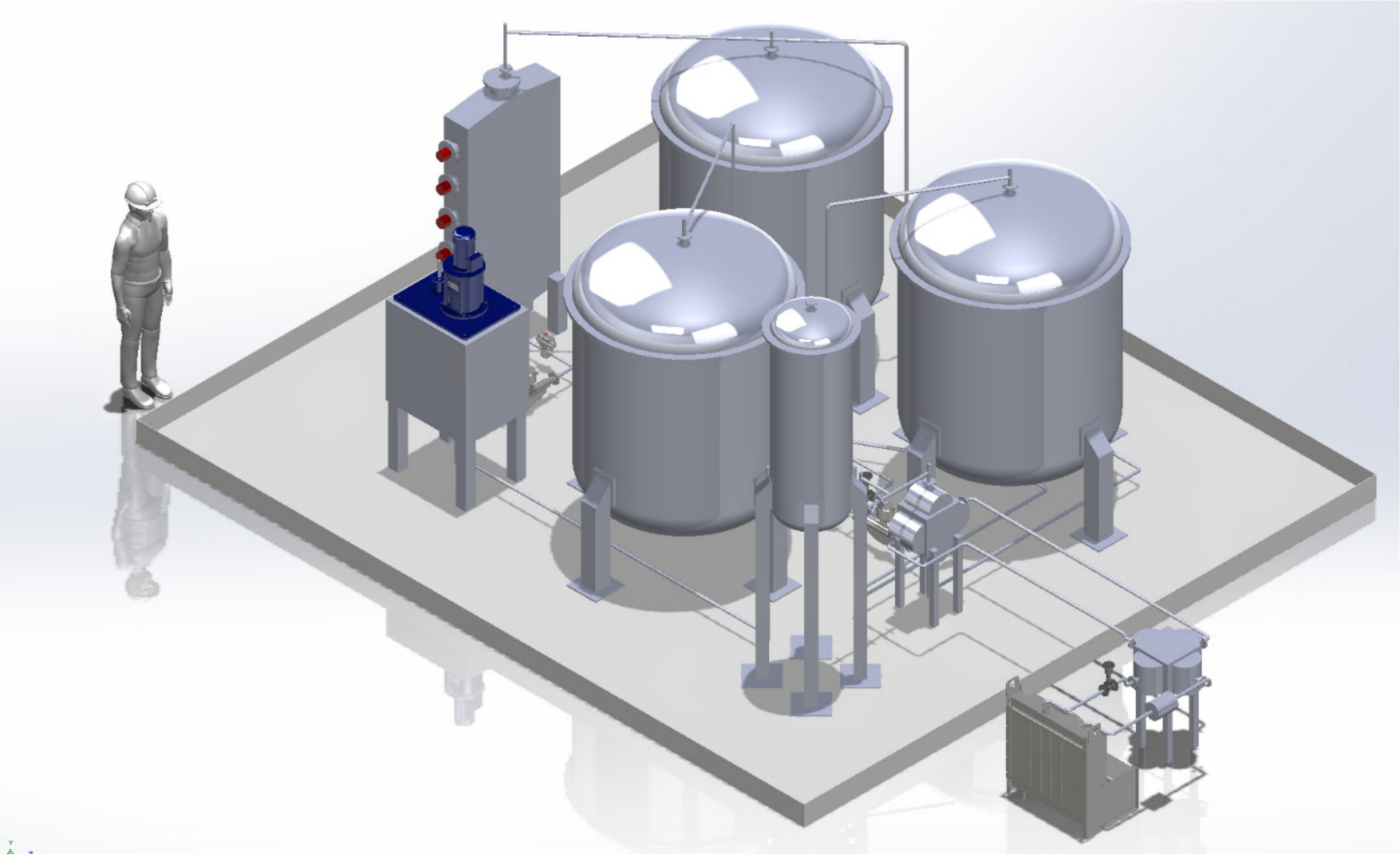




- Target mesh with sight glass for temperature distribution
  - Calibrated thermal camera and TCs
- Currently validating mixing
- Look for future updates on progress

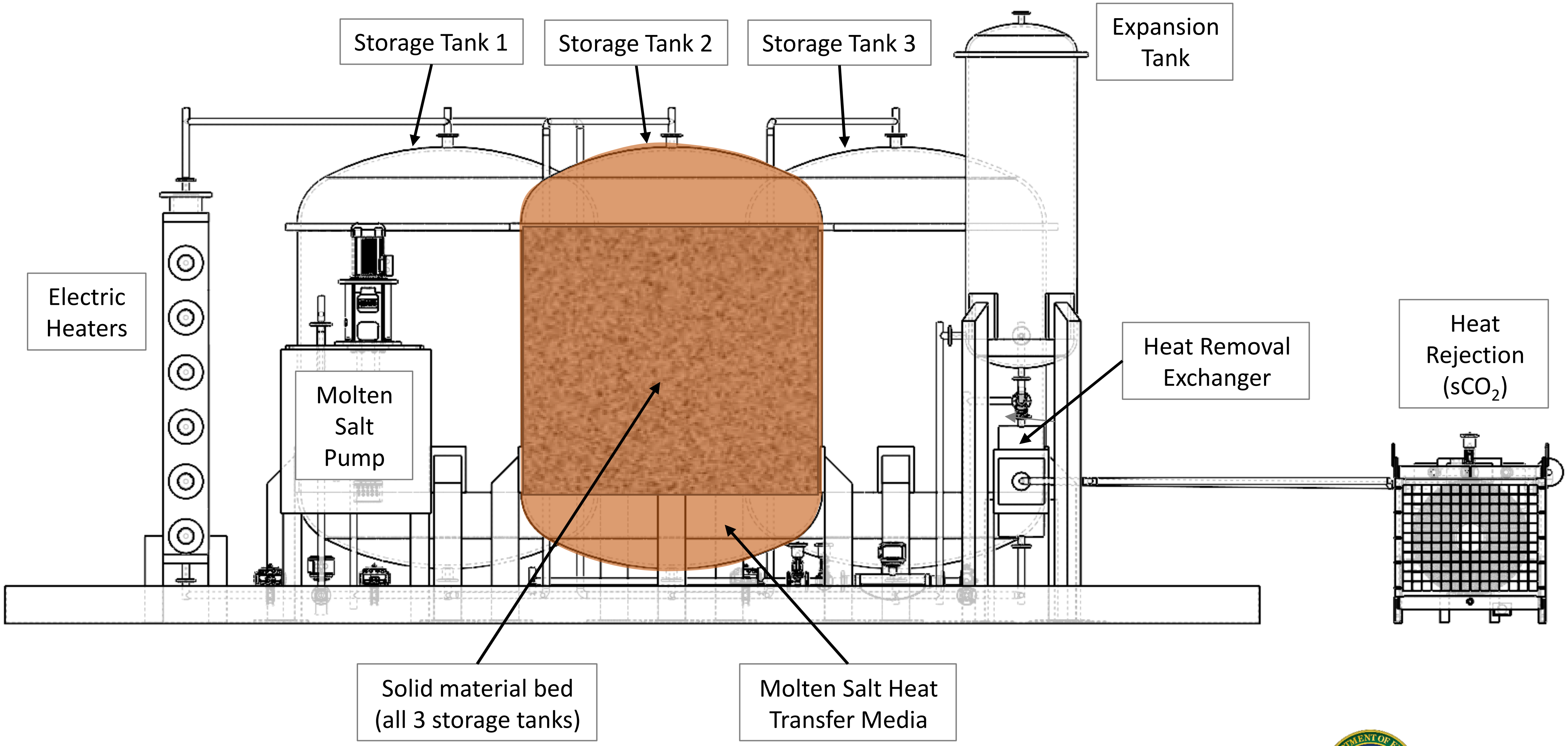
Dual Media Thermal Energy Storage (DMTES)

Parameter	Value
Storage temperature range	200°C to 400°C
Gross thermal capacity	1,000 kWh(th)
Actively Controlled Thermocline Usable Capacity	83.2%
Net thermal capacity	800 kWh(th)
Charge heat rate	100 kW(th)
Discharge heat rate	100 kW(th)
Heat transfer fluid	HiTec molten salt
Solid filler	Granite or Taconite pellets
Tank arrangement	3 Tanks in Series
Tank inner diameter	1.6 m
Combined thermocline height	3.75 m

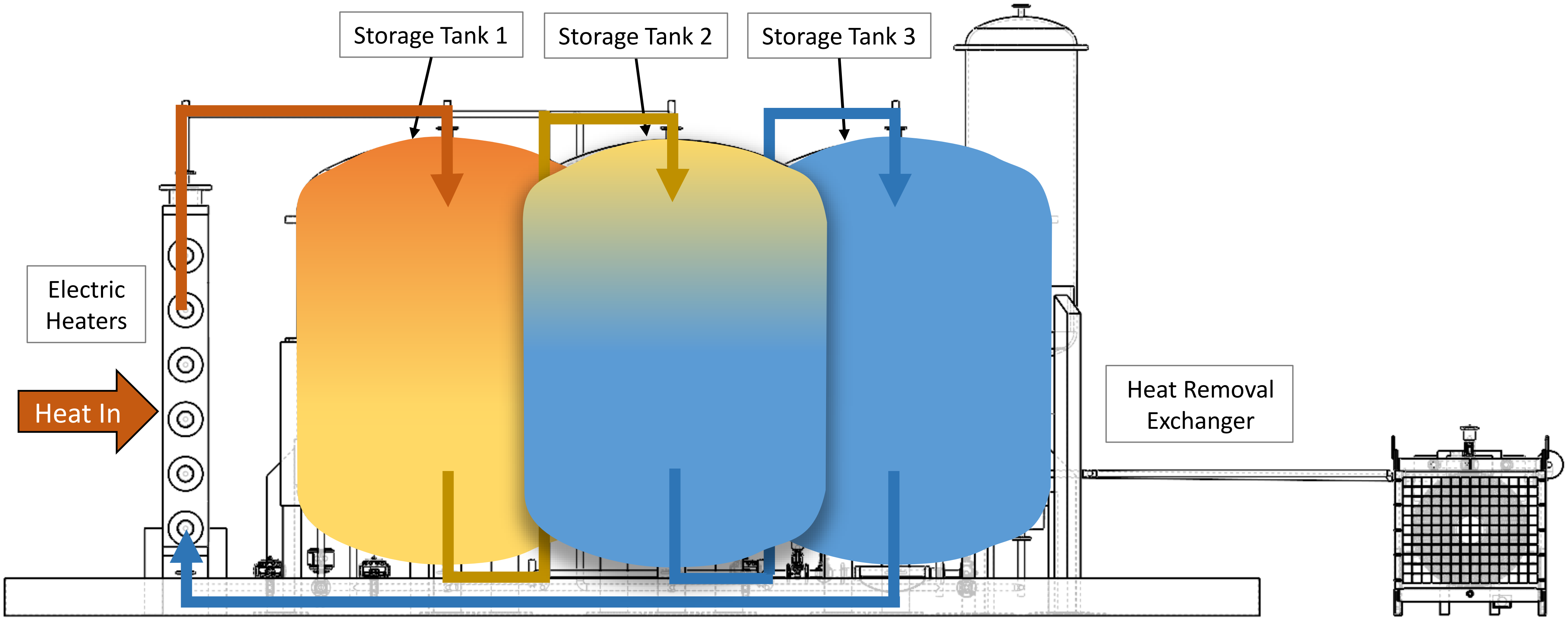


- Funded by the United States Department of Energy
- Storage developed based on patents by Terrafore Technologies

DMTES System Front View

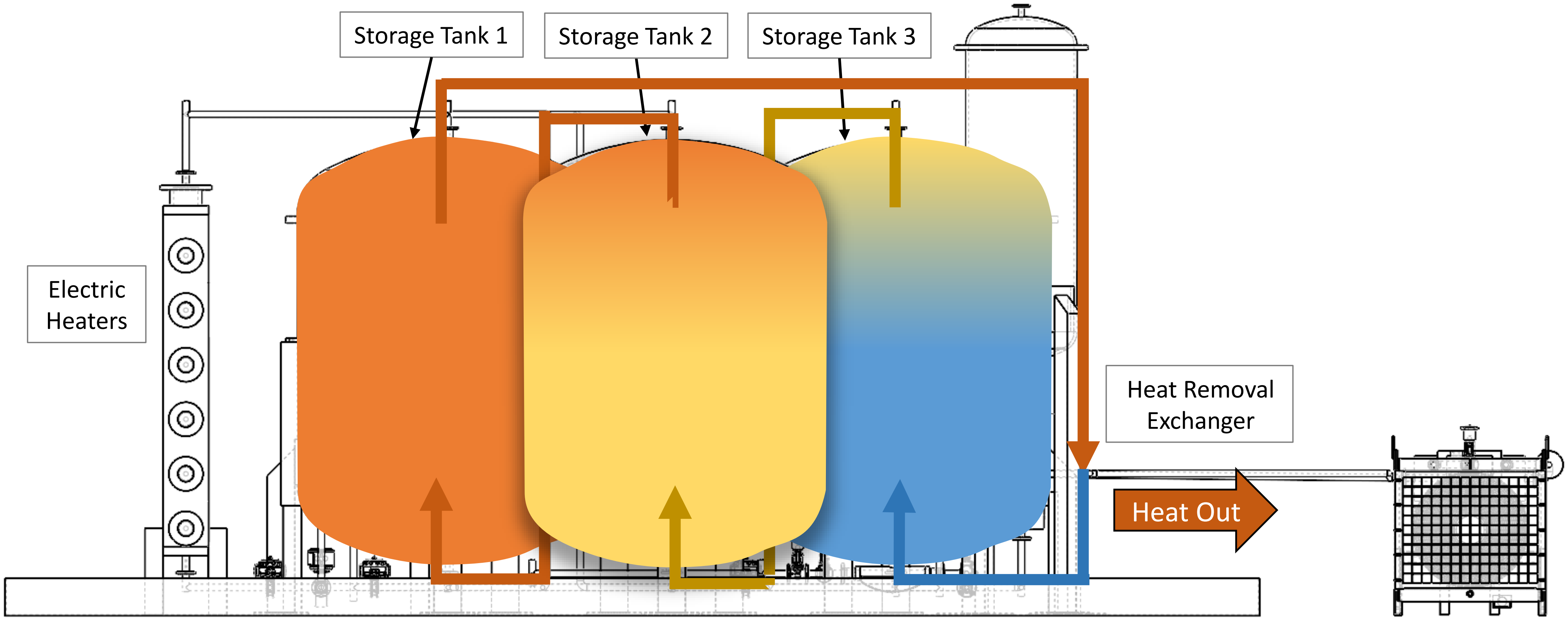


Baseline Example: Charging



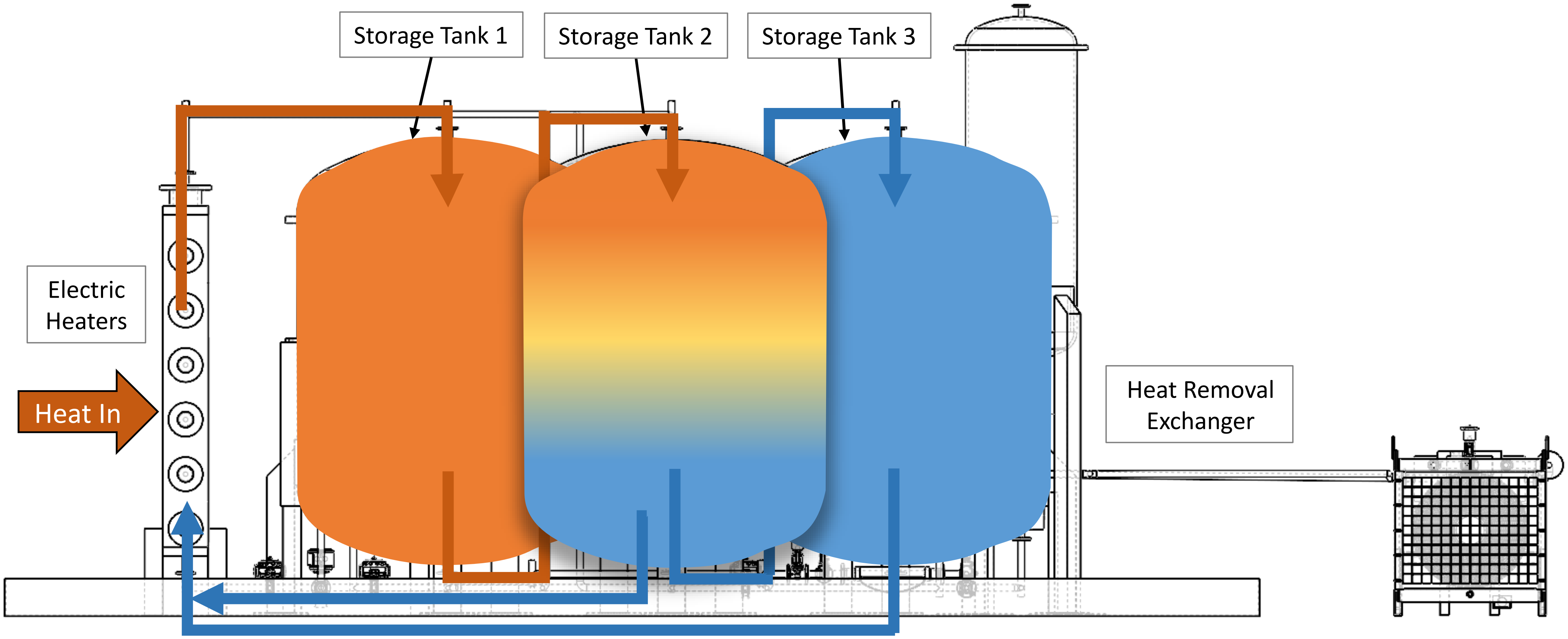
- Continuous flow between tanks in series with inlet on Tank 1 and outlet on Tank 3
- Depicted large gradient is intentional and limit thermocline capacity

Baseline Example: Discharging



- Continuous flow between tanks in series with inlet on Tank 3 and outlet on Tank 1

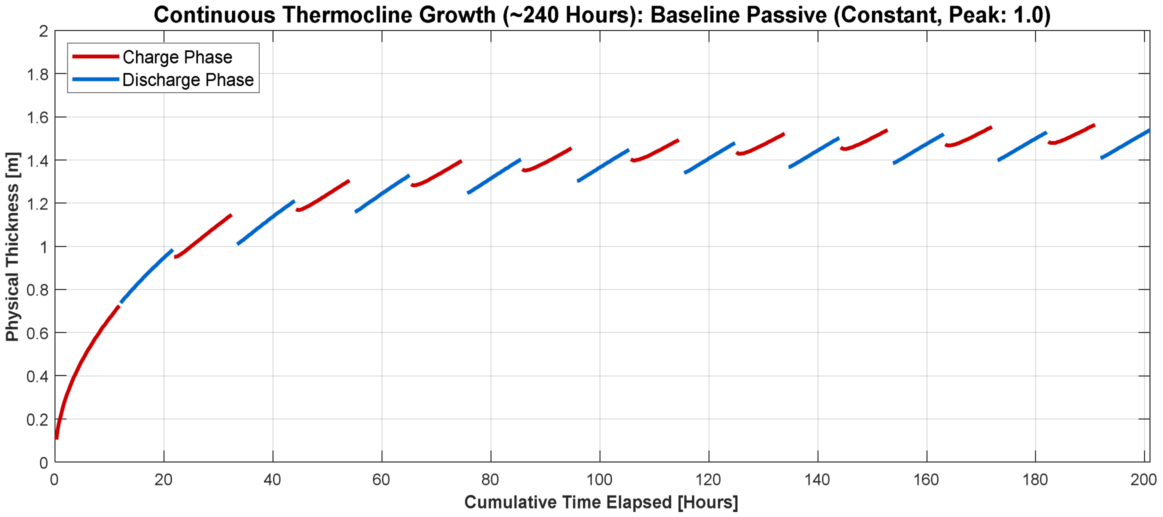
Active Control Example: Charging



- Split flow with controlled cold flow extraction at multiple tanks
  - Could include extraction along height of a tank, but does not here
- Active control for discharge is similar with multiple points for hot flow extraction

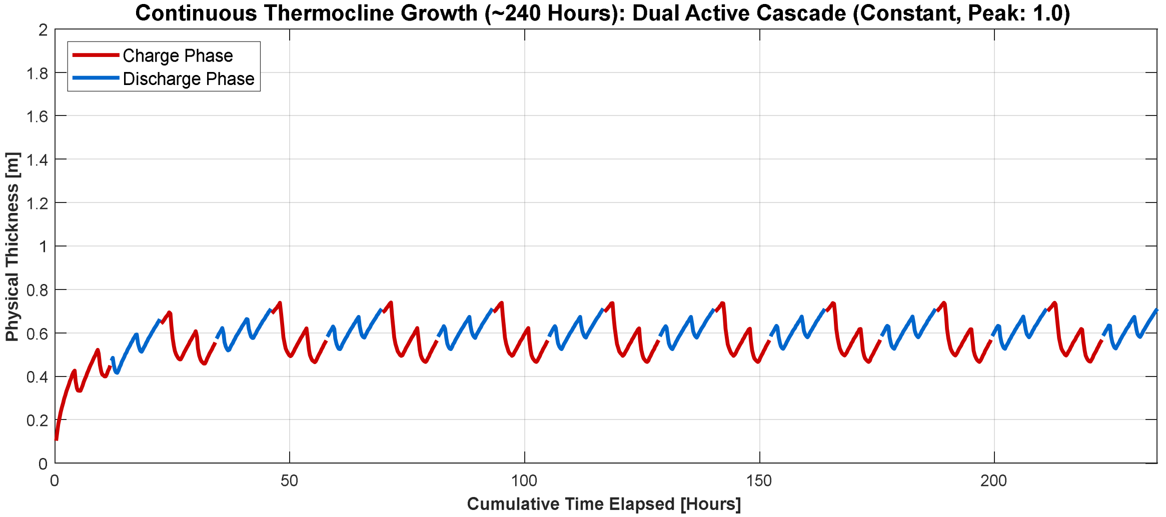
Thermocline Growth Baseline vs Active Management

Baseline



- Thermocline Width grows to ~1.5m
- Reaches limit cycle. Very little growth after 5th cycle

Dual- Active Managed Mode



- Thermocline Width maintained ~0.4m to ~0.5m in a 3.75m tank height
- Jagged line due to active fluid control at each tank exit during charge and discharge cycle

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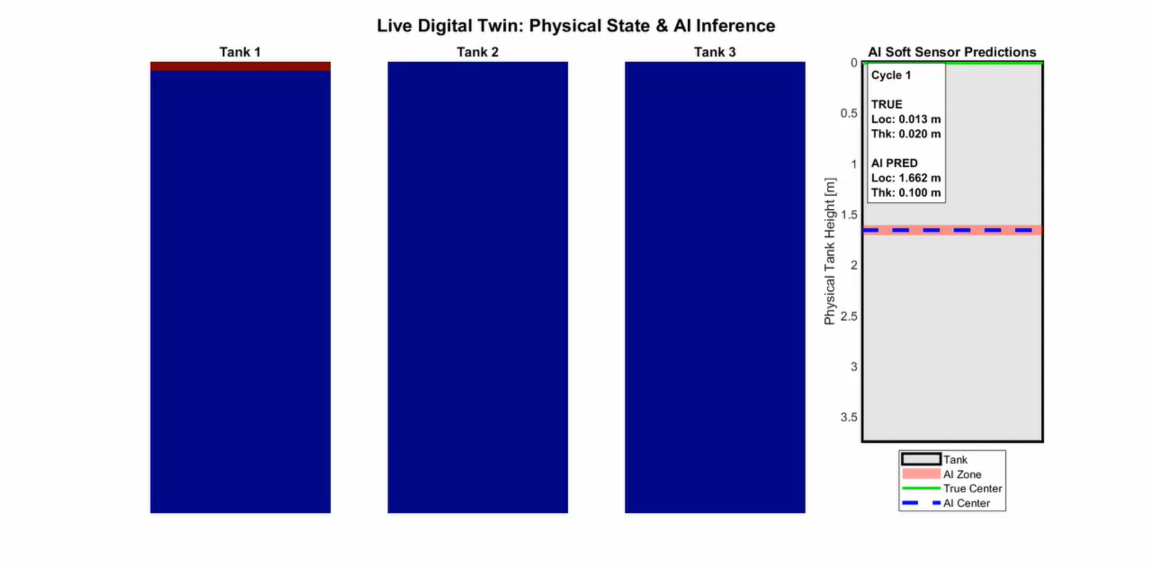
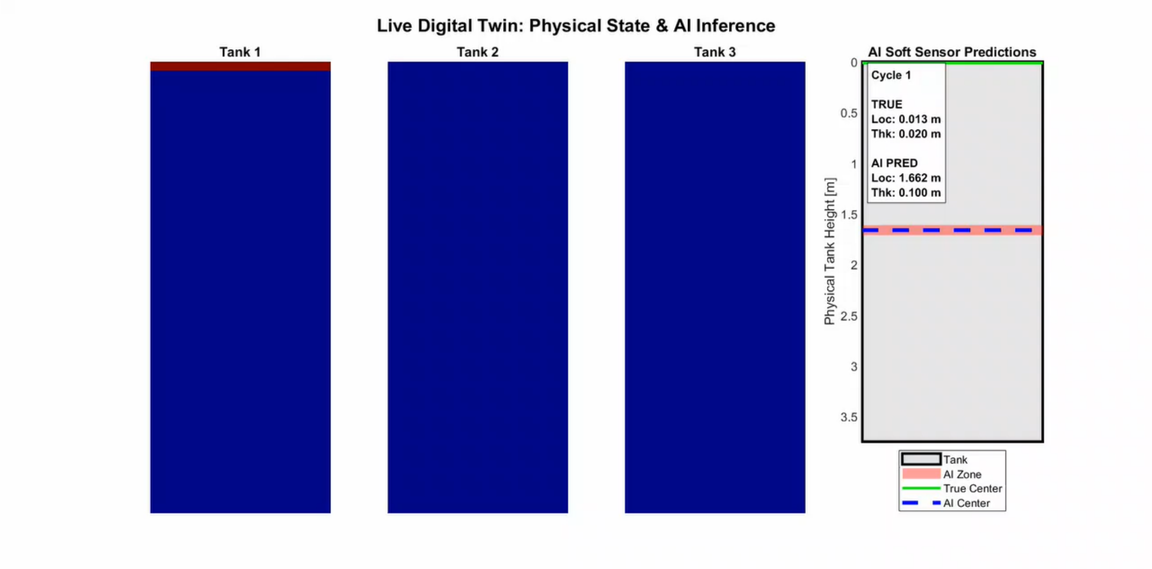
Animation: Thermocline Growth for continuous charge/ discharge cycles

Baseline



59% Usable Capacity

Dual-Active Mode



83% Usable Capacity

- A vertical thermocouple tree in each of the three tanks will sense thermocline height
- Physics informed neural network (PINN) trained to predict thermocline location
  - PINN could be used if thermocouple tree fails

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Questions?

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