Preventing Battery Cooling Failures with Blockage Detection and Rectification

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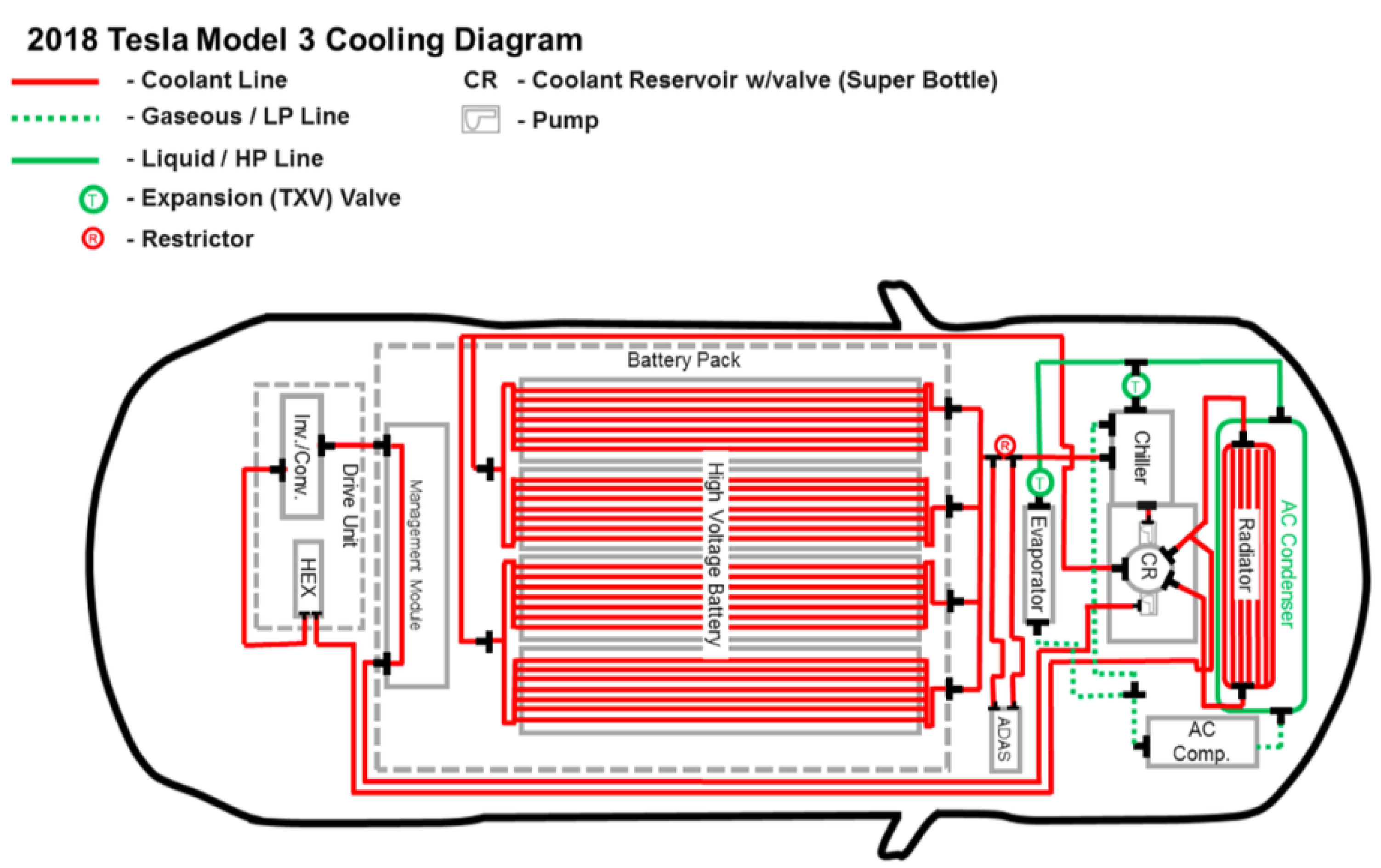
Background

- High-capacity batteries such as lithium-ion batteries produce large amounts of heat during usage.
- Excessive heat generation in lithium-ion batteries can result in thermal runaway, causing permanent system damage.
- Liquid cooling systems are useful in preventing critical temperatures in battery powered systems [1].
- Flow restrictions in liquid cooling loops can reduce coolant flow, leading to critical system temperatures.
- Digital Twin (DT) technology provides an option for real-time thermal and electrical tracking and decision making in physical systems.

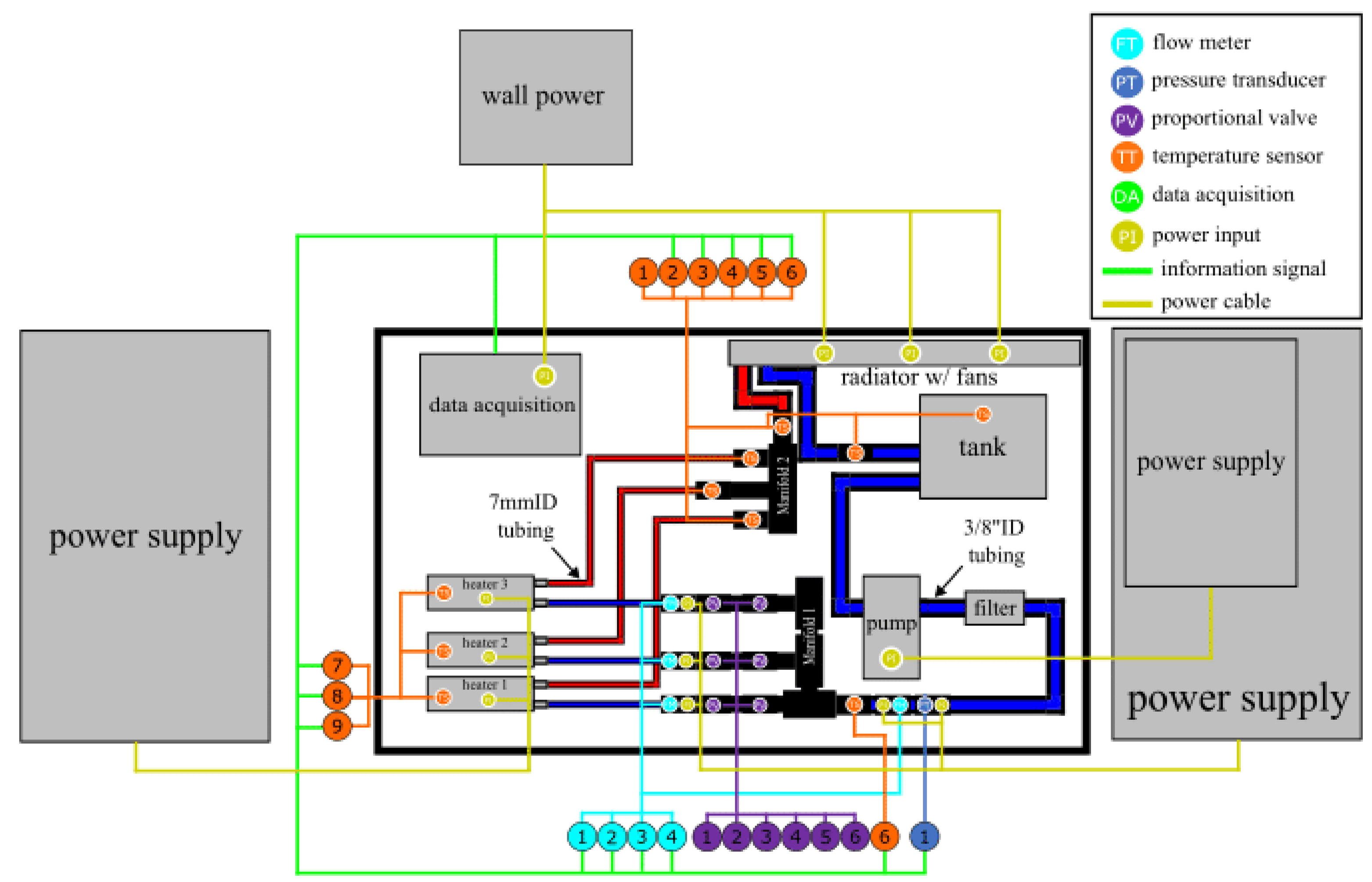


Tesla Model 3 Liquid Cooling System (LCS) [1]

Key Points

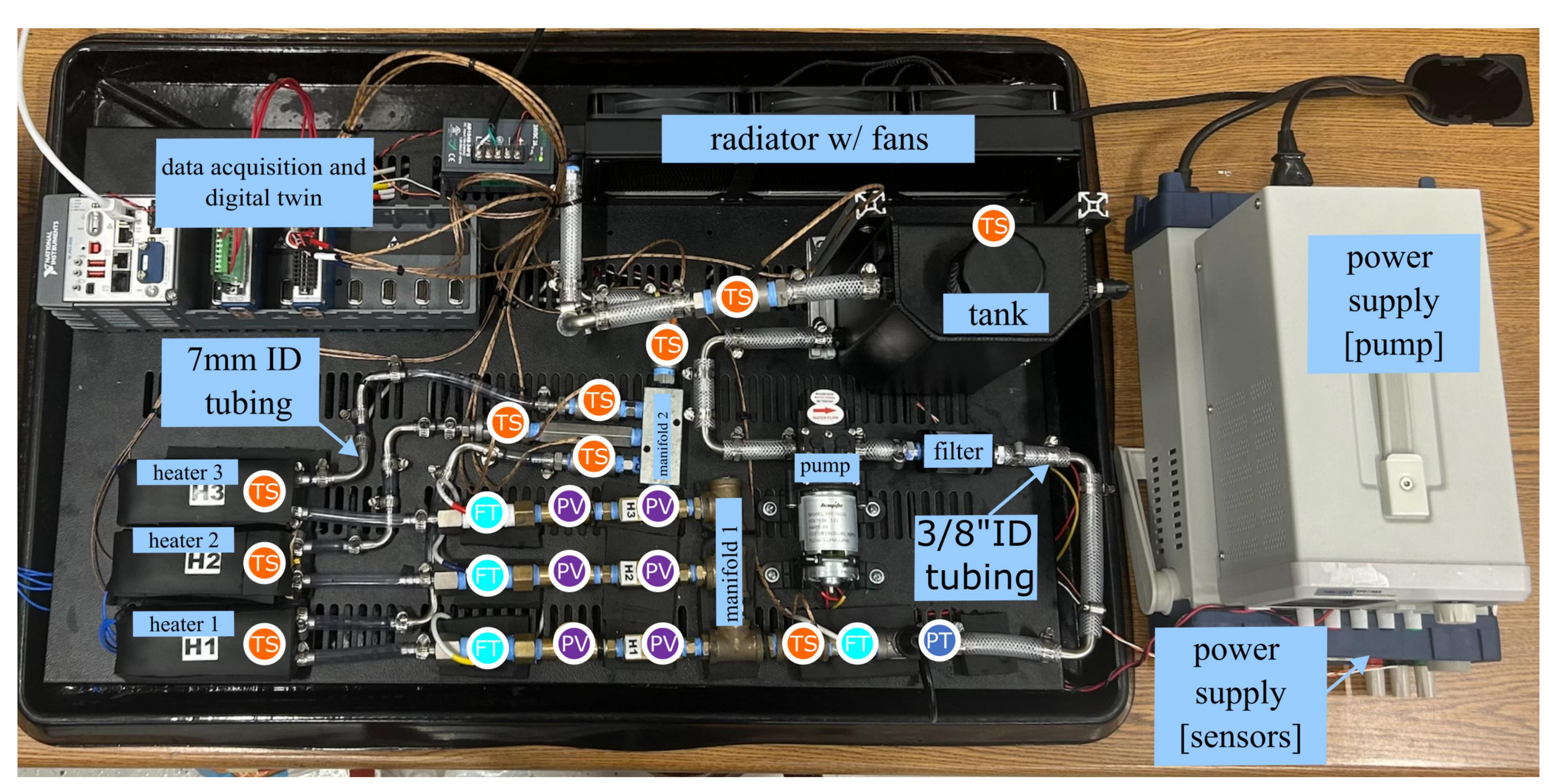
- Digital Twins (DT) can simulate battery cooling fluid flow.
- DT contains thermal model that allows for simulating the generation, propagation, and dissipation of the battery's heat.
- DT also contains electrical component that allows for simulation thermal response due to changes in power usage.
- Using thermal and electrical component together, DT is able to detect and address flow restrictions in cooling systems before critical temperatures are reached.

Design



Theoretical physical twin design diagram

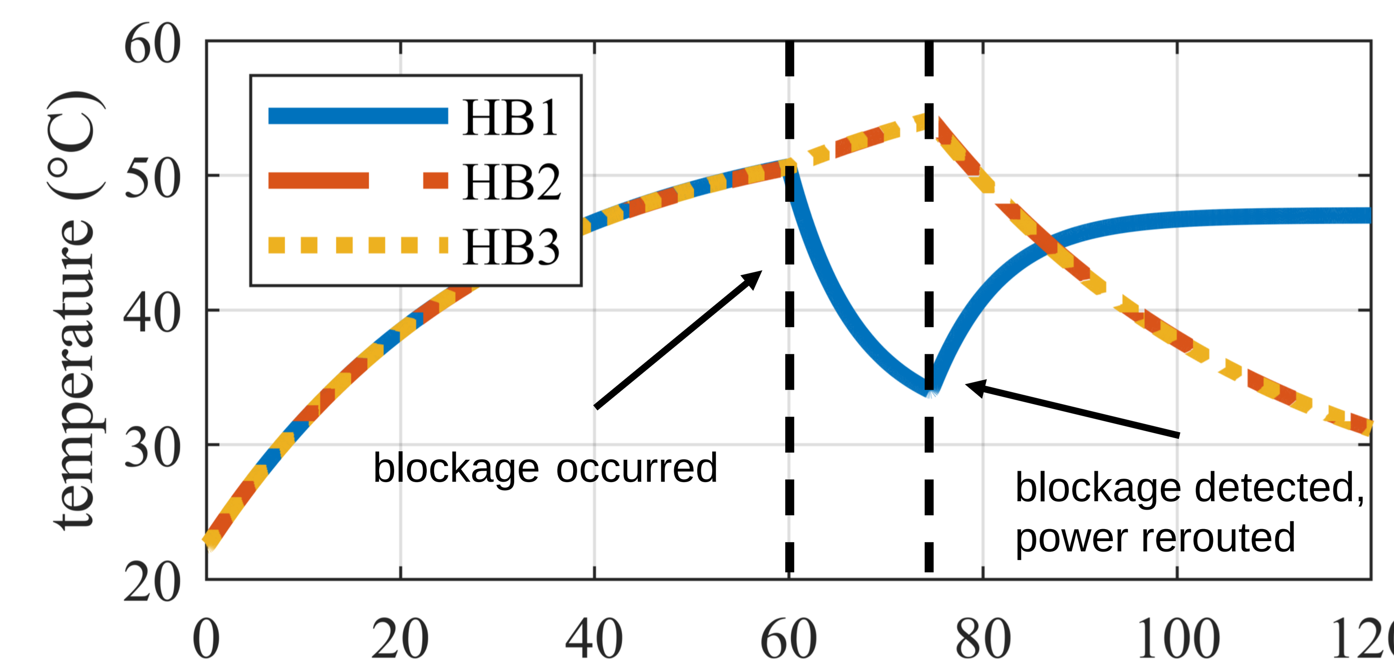
- Thermal model with electrical information input used to emulate proposed physical twin configuration.
- Physical twin emulator sends data to data analysis and decision-making model.
- Model conducts thermal simulations using Newton's law of cooling: $q = h_c \cdot A \cdot dT$, and Fourier's law of conduction: $q = -k \cdot \nabla T$.
- Physical twin emulator is designed based on constructed physical twin testbed.

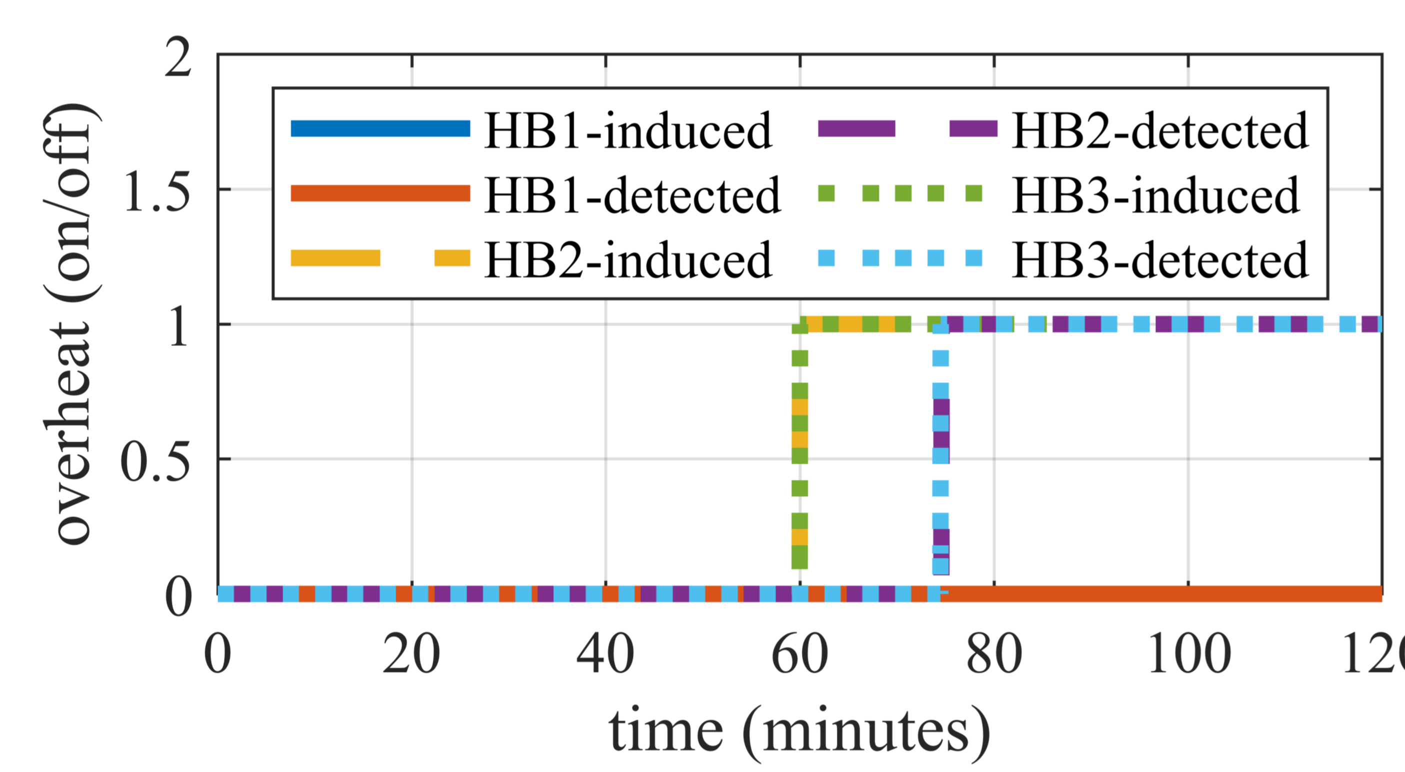


Physical twin testbed

Results

- Simulated testing was performed on a model containing three heating modules to simulate power electronic heat generation, a radiator for heat dissipation, and general piping components.
- A sudden blockage producing 95% fluid flow reduction was simulated in 2/3 of the heaters in the emulator at 60 minutes into the simulation.





Data results from simulated DT testing

- Blockage was detected approximately 17 minutes post-induction.
- Decision-making processes rerouted power flow to unaffected modules to preserve system integrity.
- System remains over 40°C below critical temperatures.
- System demonstrates capacity to react to multiple concurrent sudden blockages.

[1] Melançon, S. (2022, April 2). *Ev battery cooling: Challenges and solutions*. Laserax. https://www.laserax.com/blog/ev-battery-cooling

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