HPWHsim: Under the Hood of a Heat Pump Water Heater Performance and Energy Simulator

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Session 6A

Behind the Scenes of Water Heater Numerical Simulations

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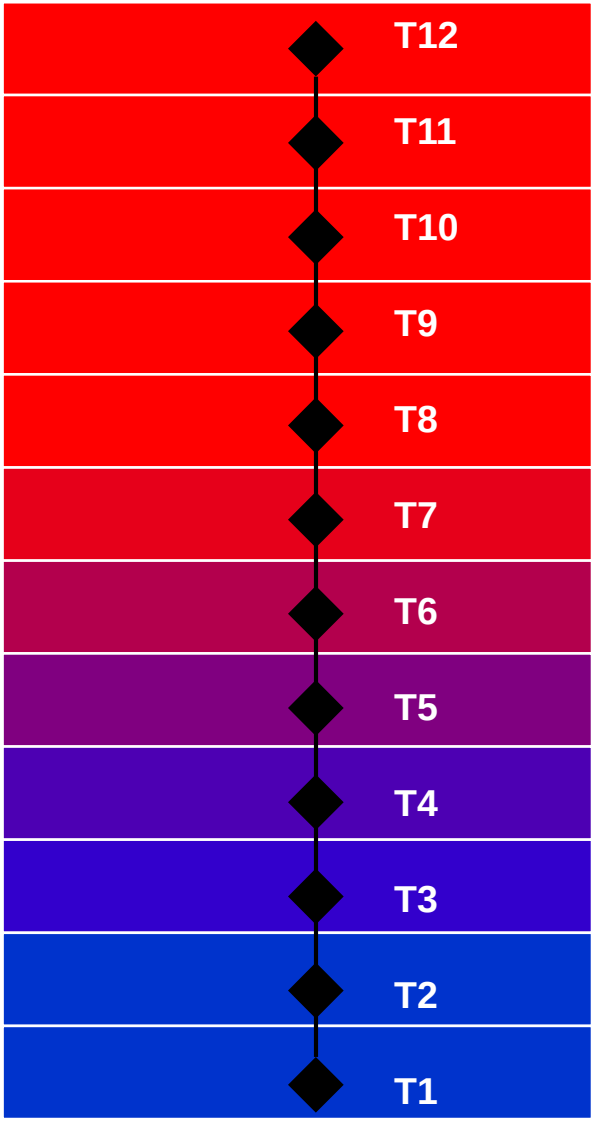
DESIGN

Purpose of HPWHsim

- Estimate the energy use implications of deploying existing Heat Pump Water Heater (HPWH) technology in a variety of scenarios. Used typically within a whole-house simulation.
- Currently used in CBECC-Res and SEEM
- Note that, with respect to equipment, this is a retrospective simulation.
  - We want a simulation that can, given HPWH products available on the market, estimate the energy use consequences under various installation conditions, and to do so as quickly as possible.

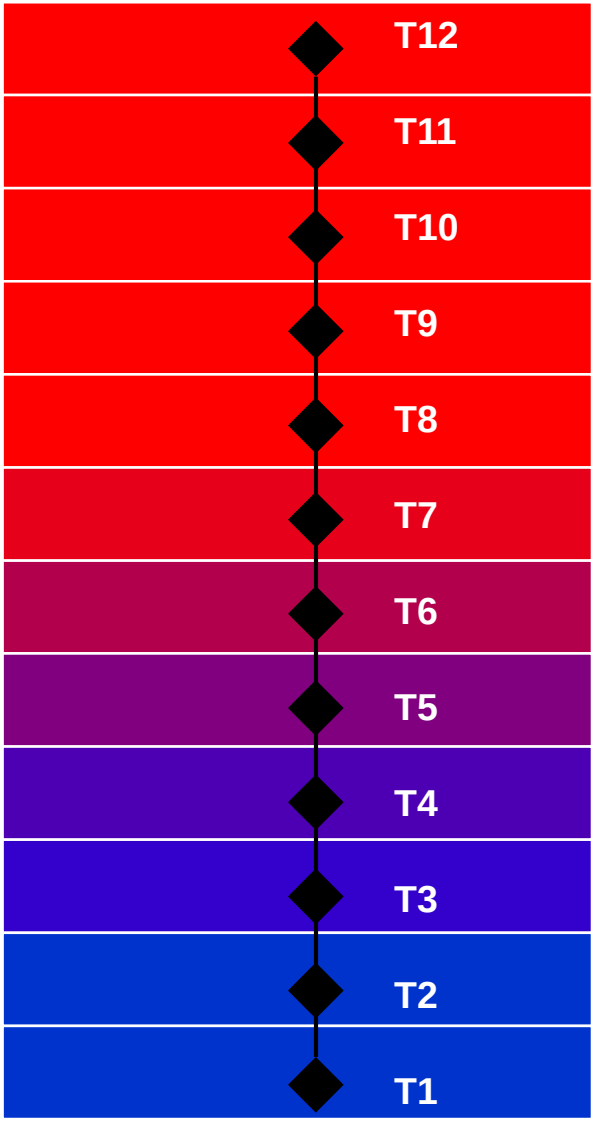
Basic Premise

- Chop the tank into nodes
- Define heat sources
- Track the following at the level of 1-minute
  - Water Draws
  - Node Temperatures
  - Heating component operation



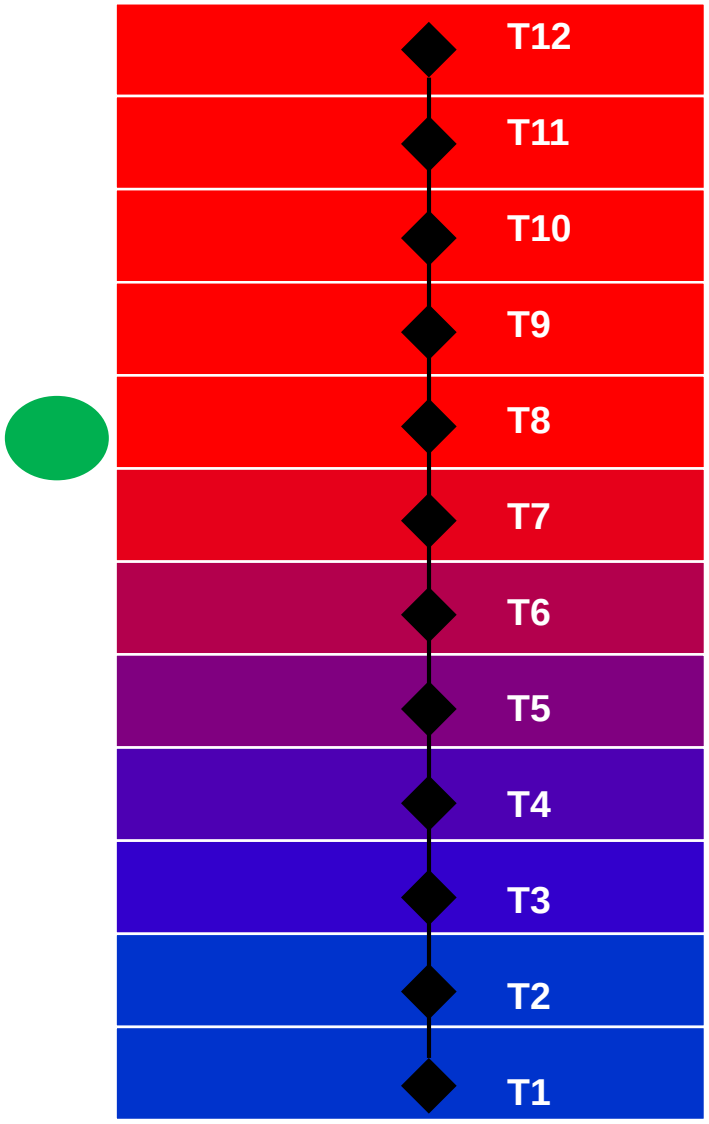
Primary Questions

1. When should we add heat to the tank?
2. How much heat should we add?
3. Where should we add it?



When Should we Add Heat?

Ideal case:
Here is an aquastat.
The heat pump activates when the aquastat drops below 100F.



When Should we Add Heat?

Reality:

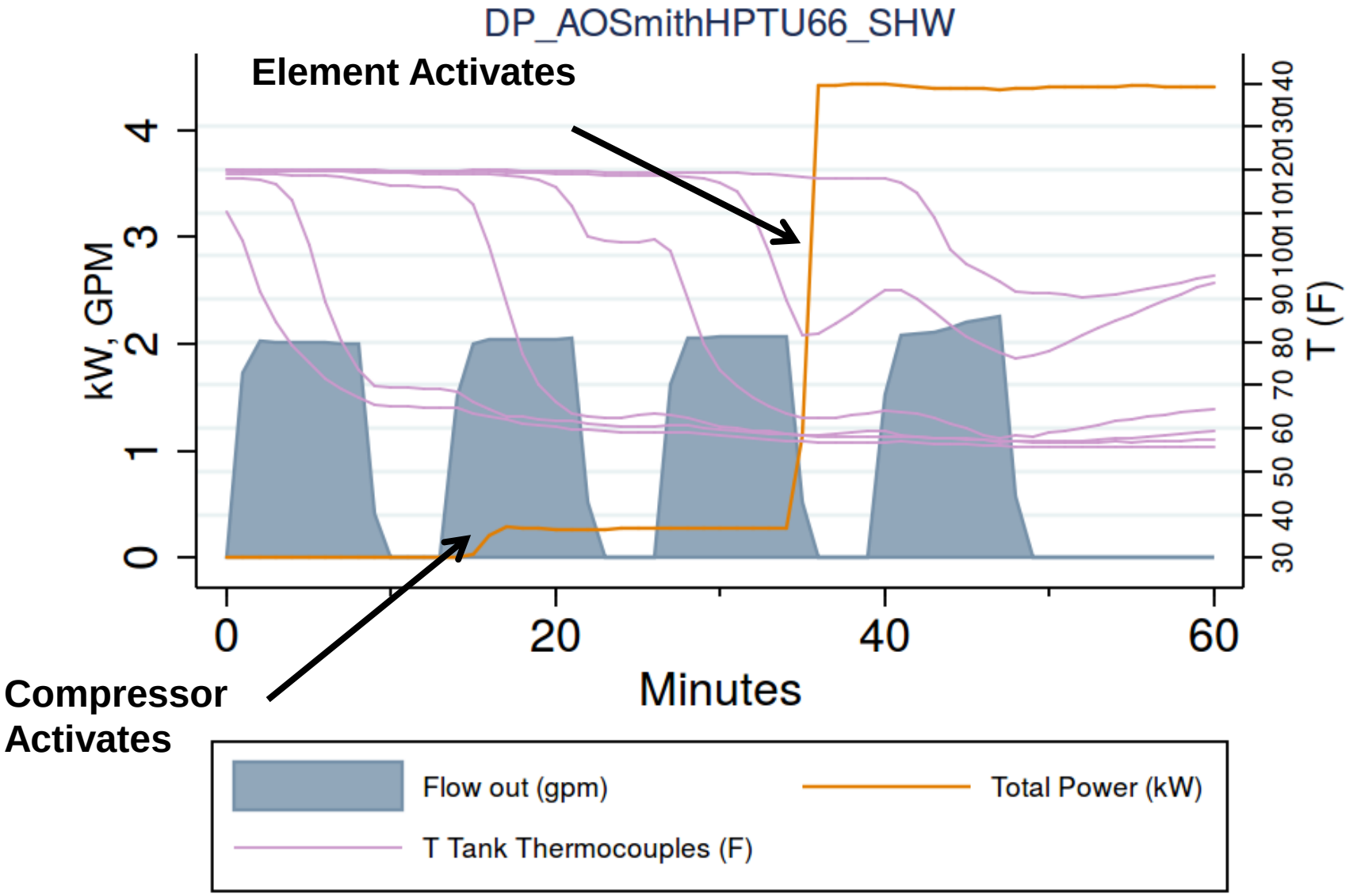
- Are thresholds based on a single aquastat?
- A linear combination of multiple aquastats?
- Do thresholds reference absolute temperatures (i.e. 100F)?
- Do thresholds reference relative temperatures (i.e. 20F below setpoint)?
- Does the logic reference aquastat readings or the rate of change of aquastat readings?
- Does the logic reference a combination of raw readings and rates of change of those readings?
- What is the hierarchy of heat sources?
- Does the lower element back up the upper element?
- Does it do so sometimes but not others?
- Can a resistive element run concurrently with the heat pump?
- If so, when is that allowed to happen?
- When can one heat source override another?

When Should we Add Heat?

Our Solution:

- Absolute or relative thresholds for simulated aquastat placements. Either a single node or an average of nodes.
  - For example, compressor logic in HPWHsim typically references the “bottom third” of the tank with a relative threshold, while upper resistive element logic may reference the “upper third” of the tank with an absolute threshold
- Heat sources are ordered by primacy, with each element having a dedicated backup that receives priority when its primary concludes a recovery.
  - For example, the compressor often serves as “backup” to the upper resistive element, in that once the upper resistive element finishes running then the HPWH switches to the compressor

When Should we Add Heat?



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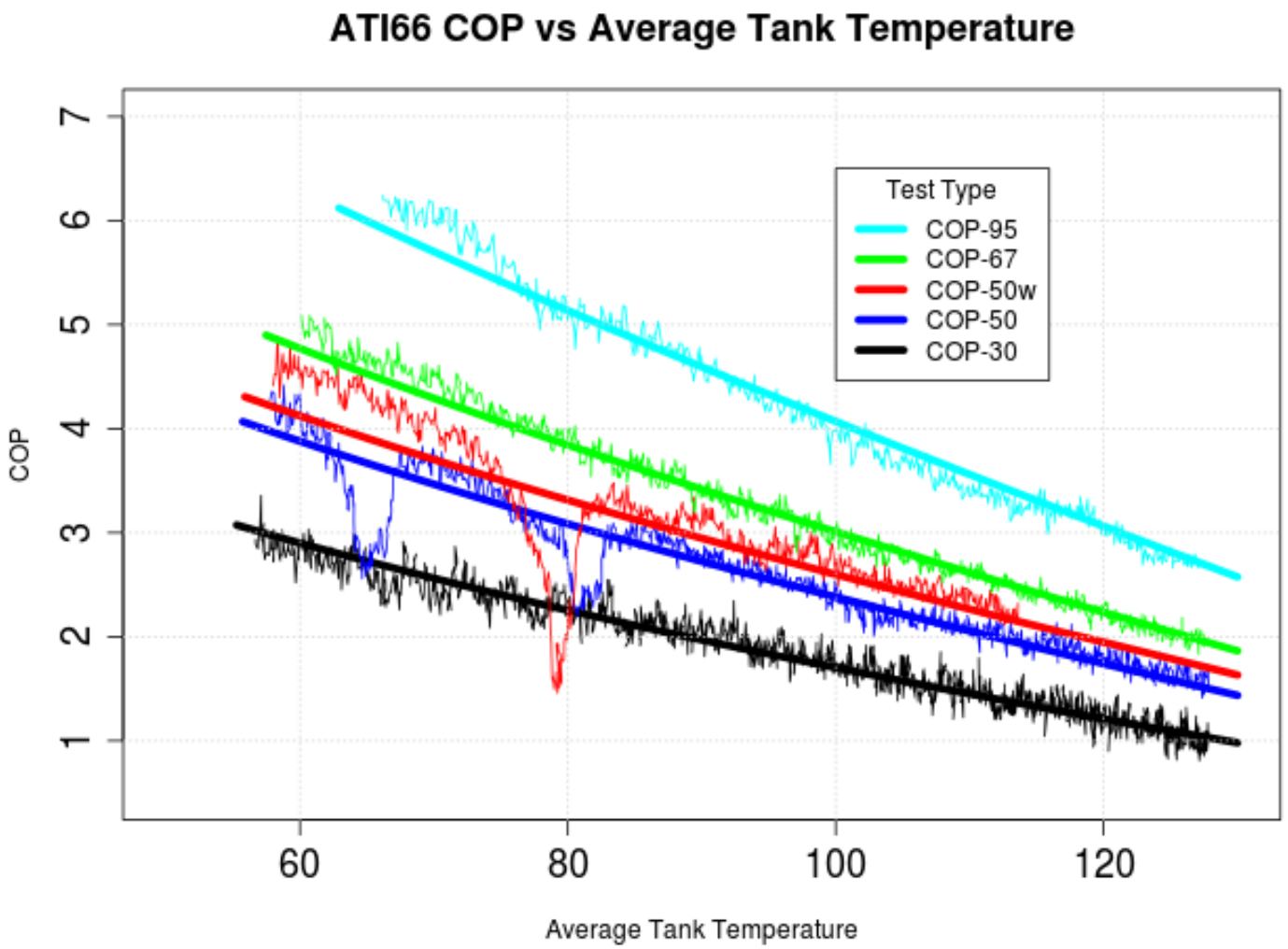

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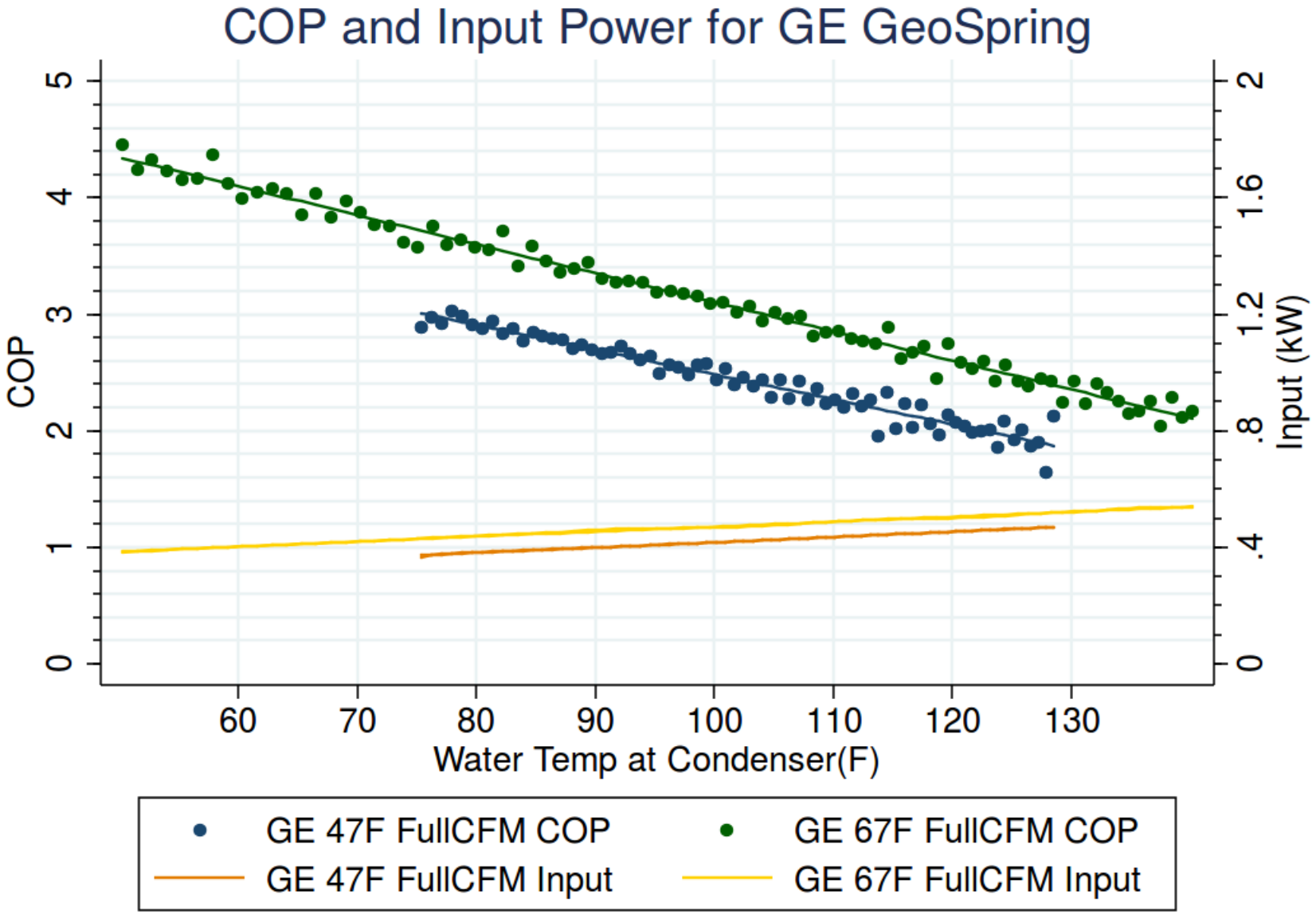

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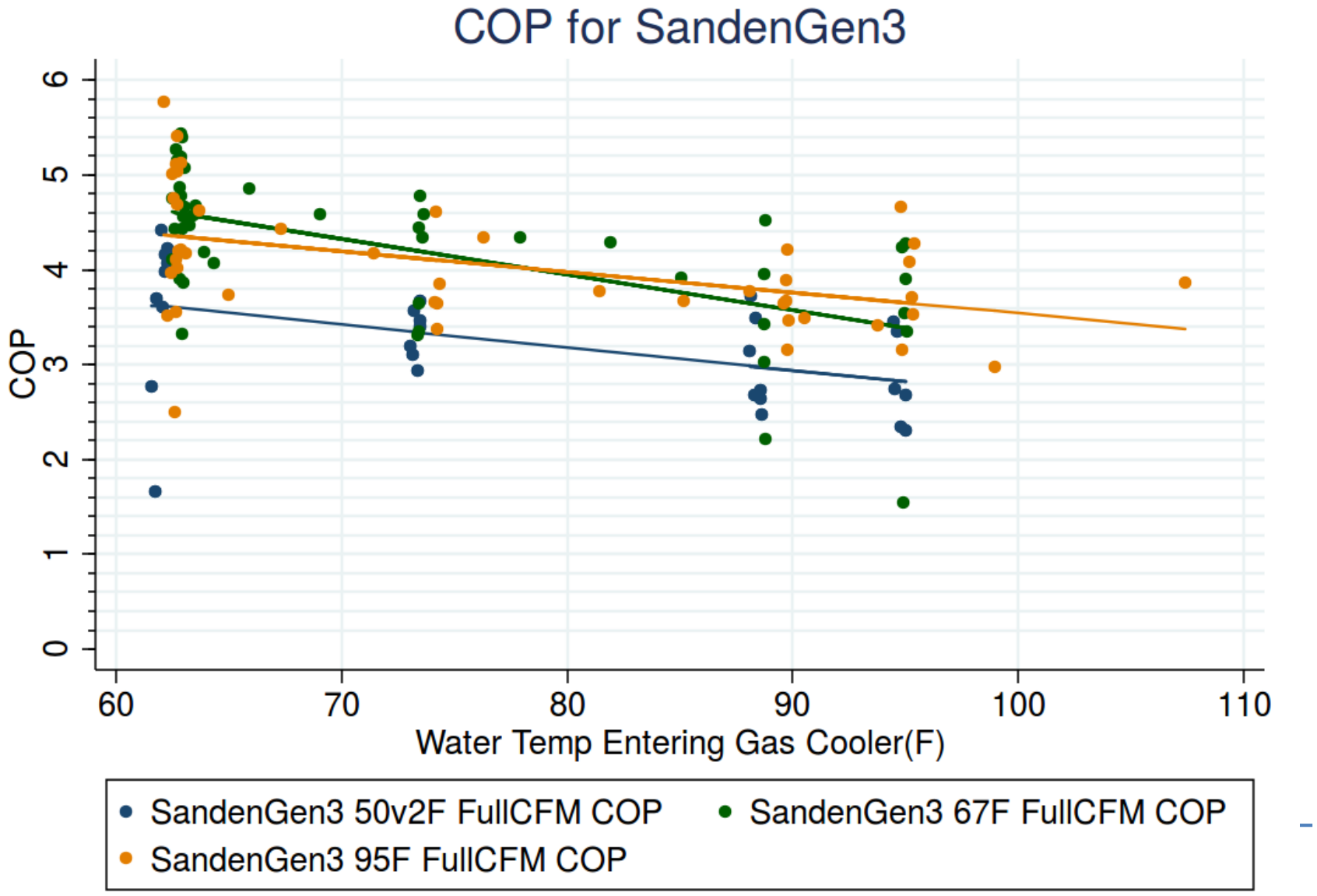
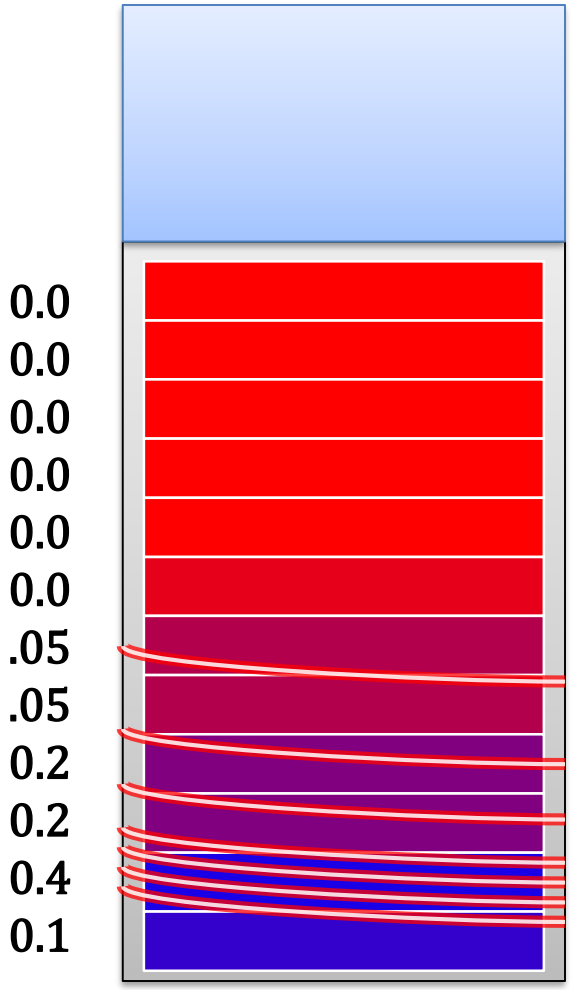


Where Should we Add Heat?

In General, We Define a Condenser Density

This is the fraction of the heat source that resides in each node of the tank. An example at left shows a possible "condensity" for a wrapped-tank condensing heat exchanger

For all heat sources, the "condensity" specifies their location with respect to the tank nodes. At the most basic level, heat is added to a node proportional to that node's condensity, and enforcing monotonicity of node temperatures



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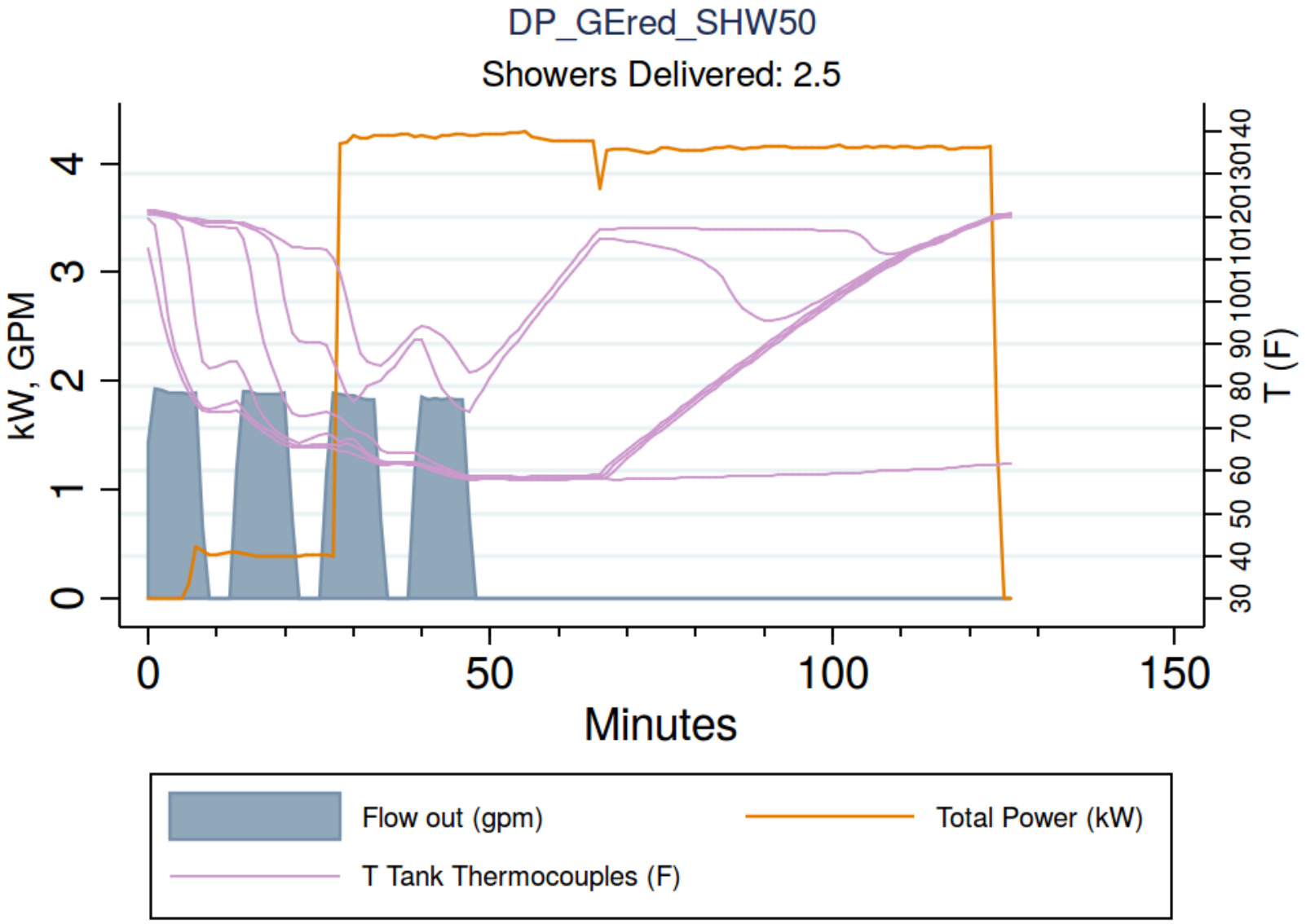

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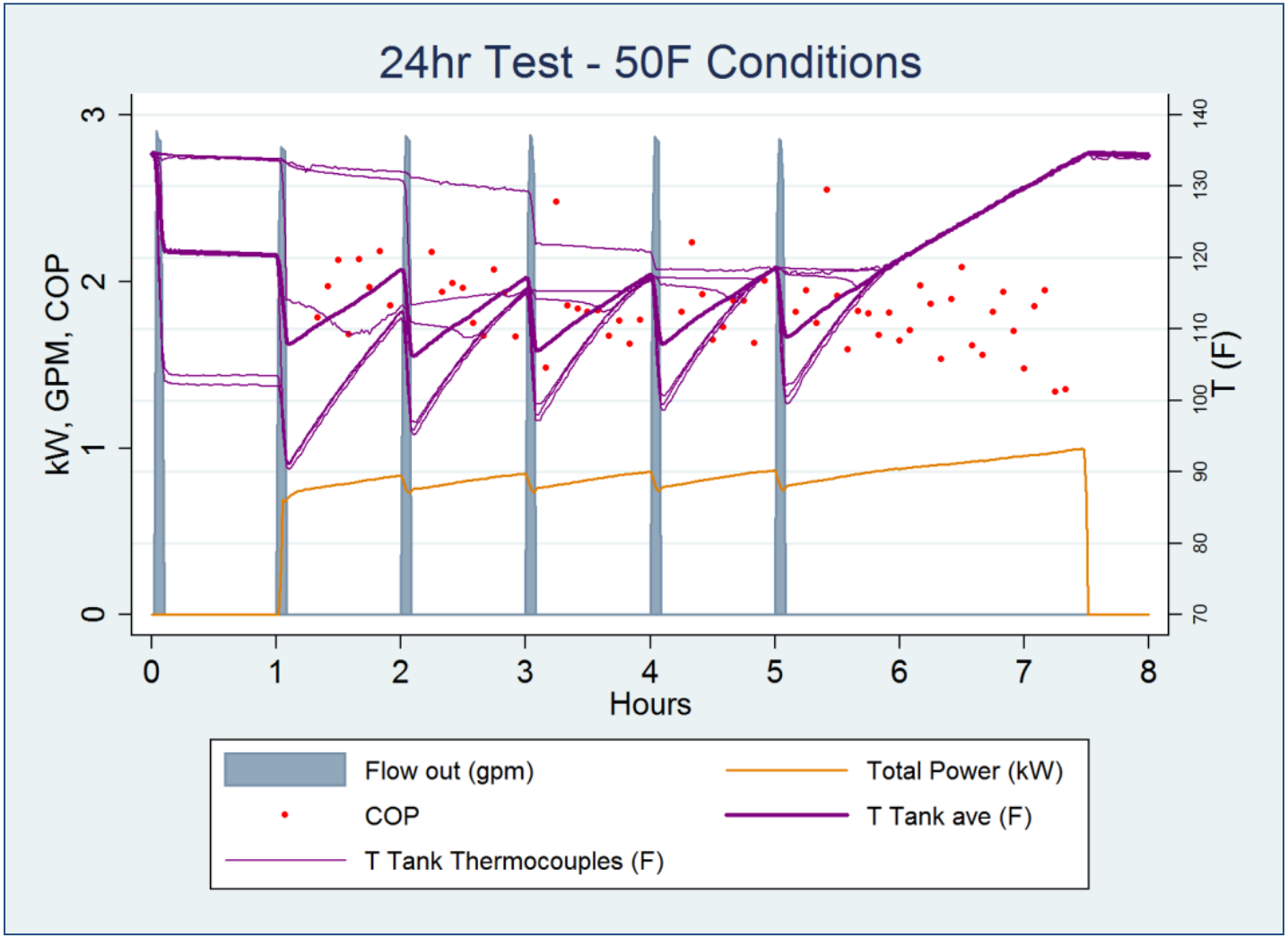

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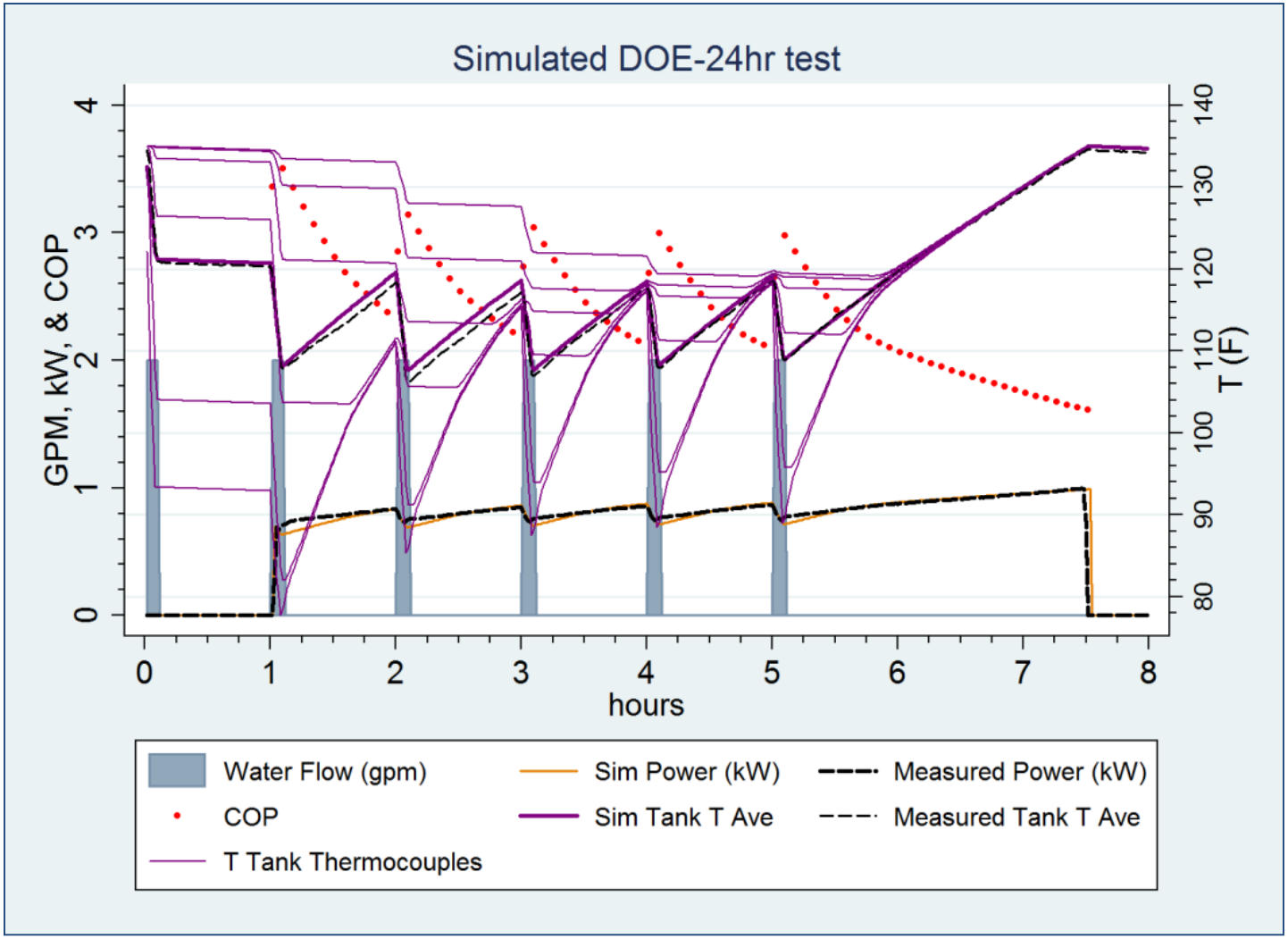

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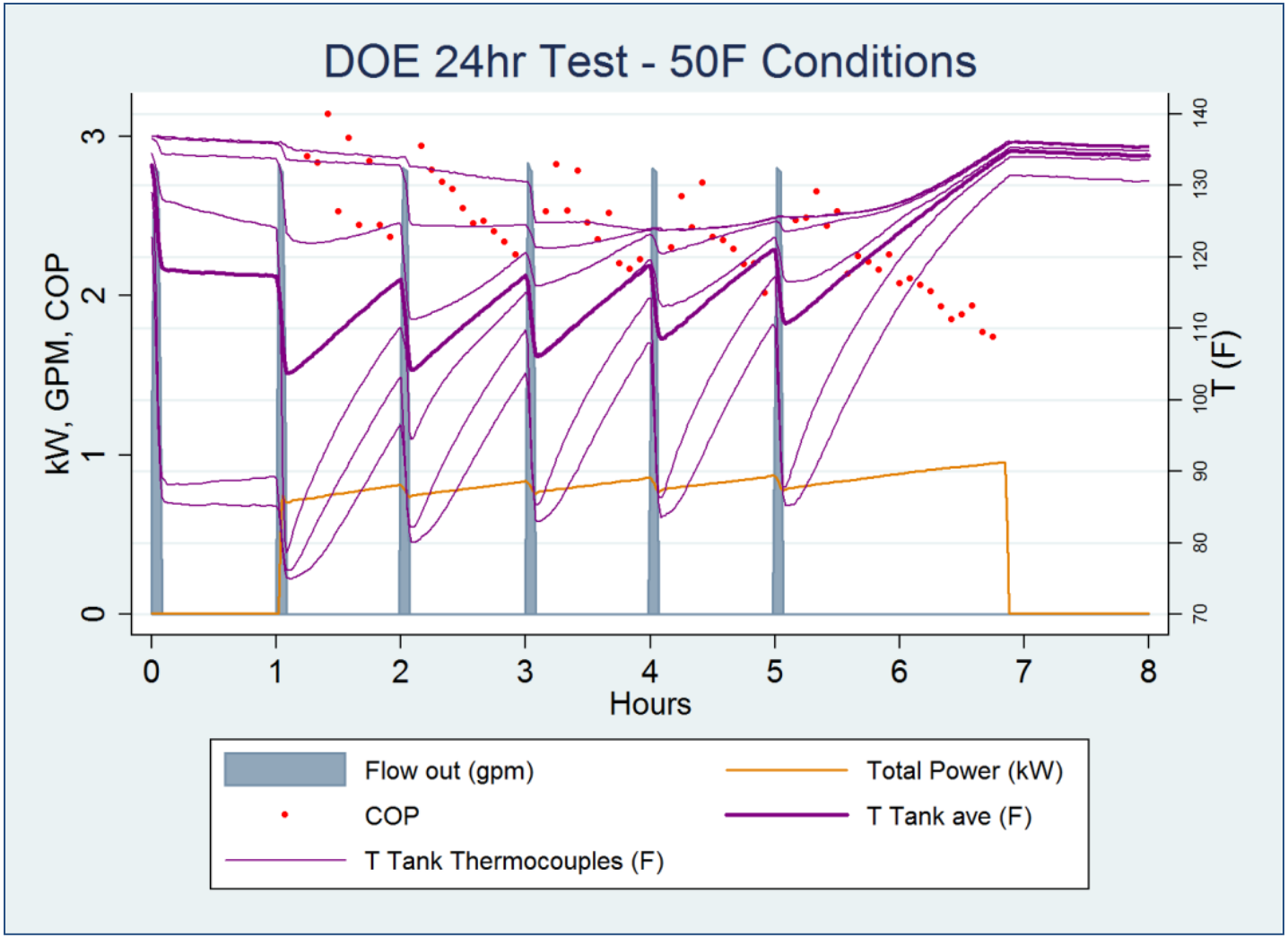

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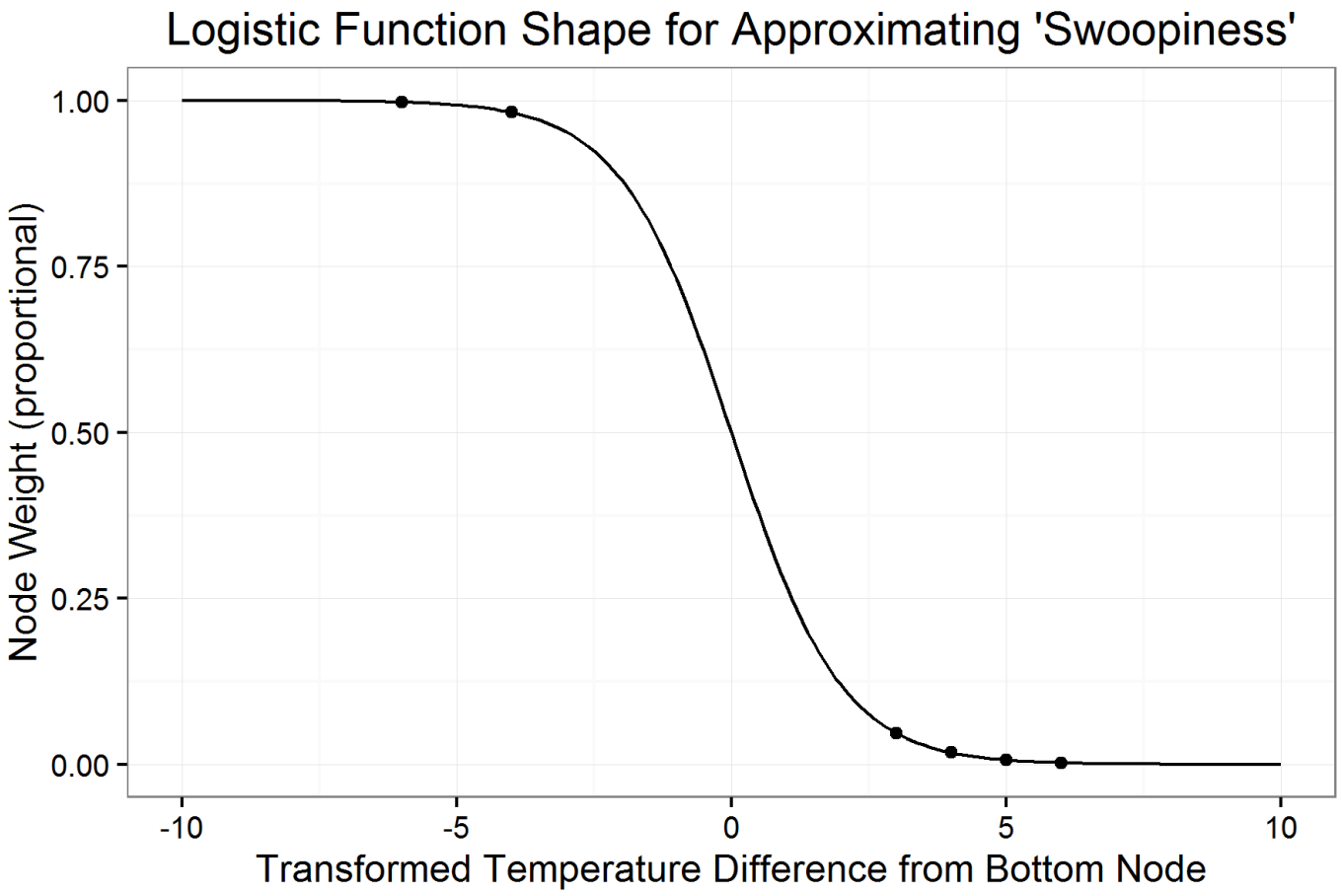

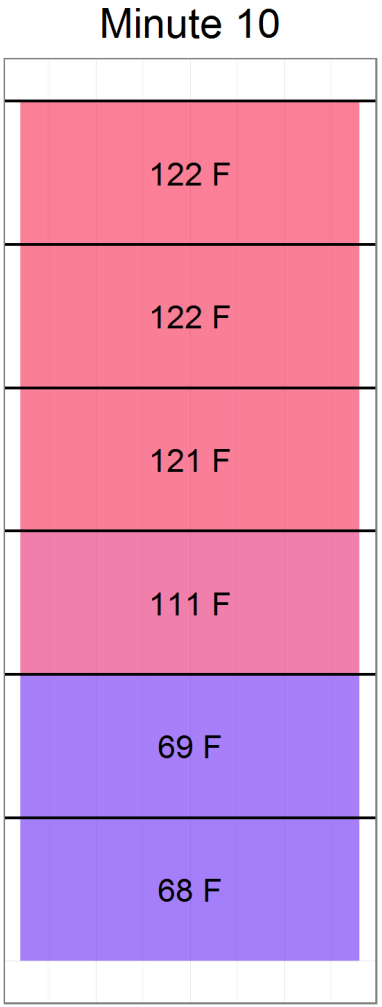

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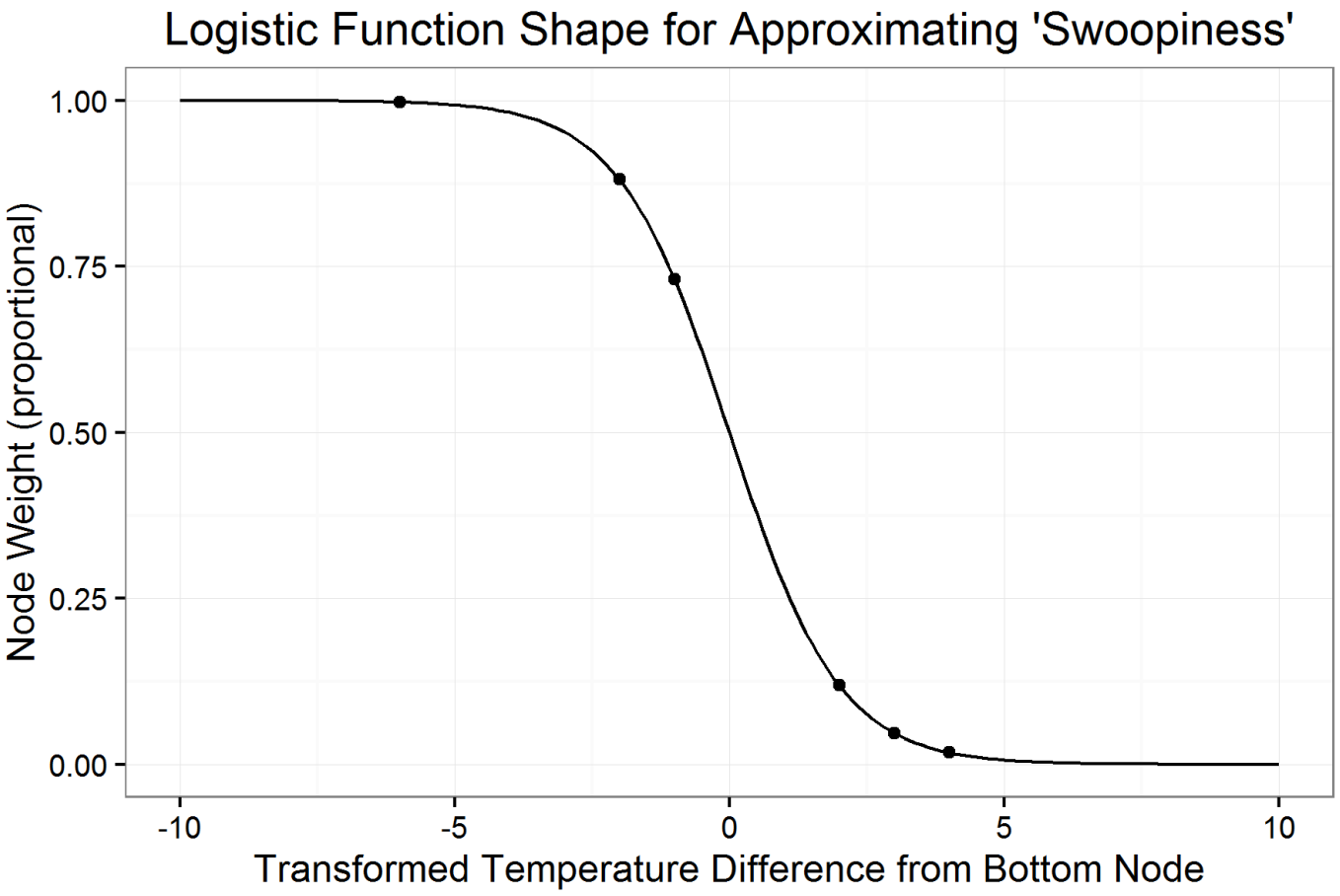

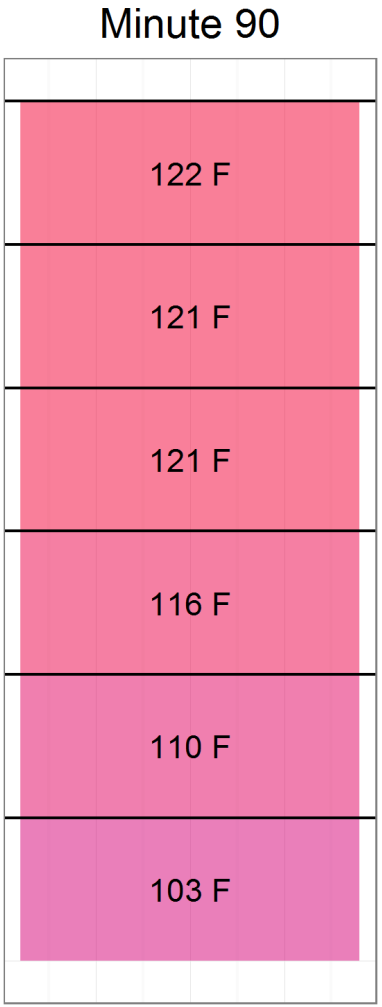

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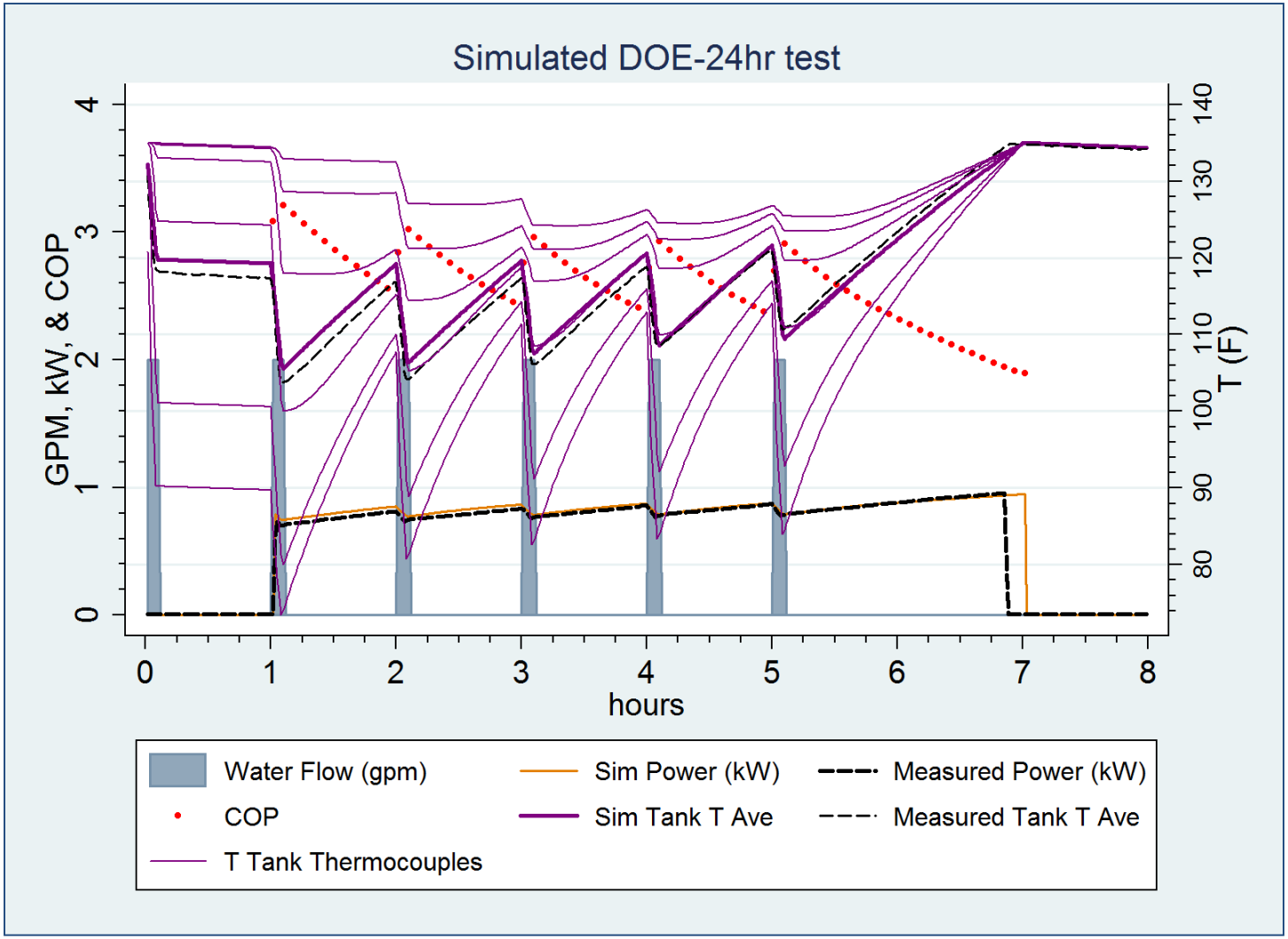

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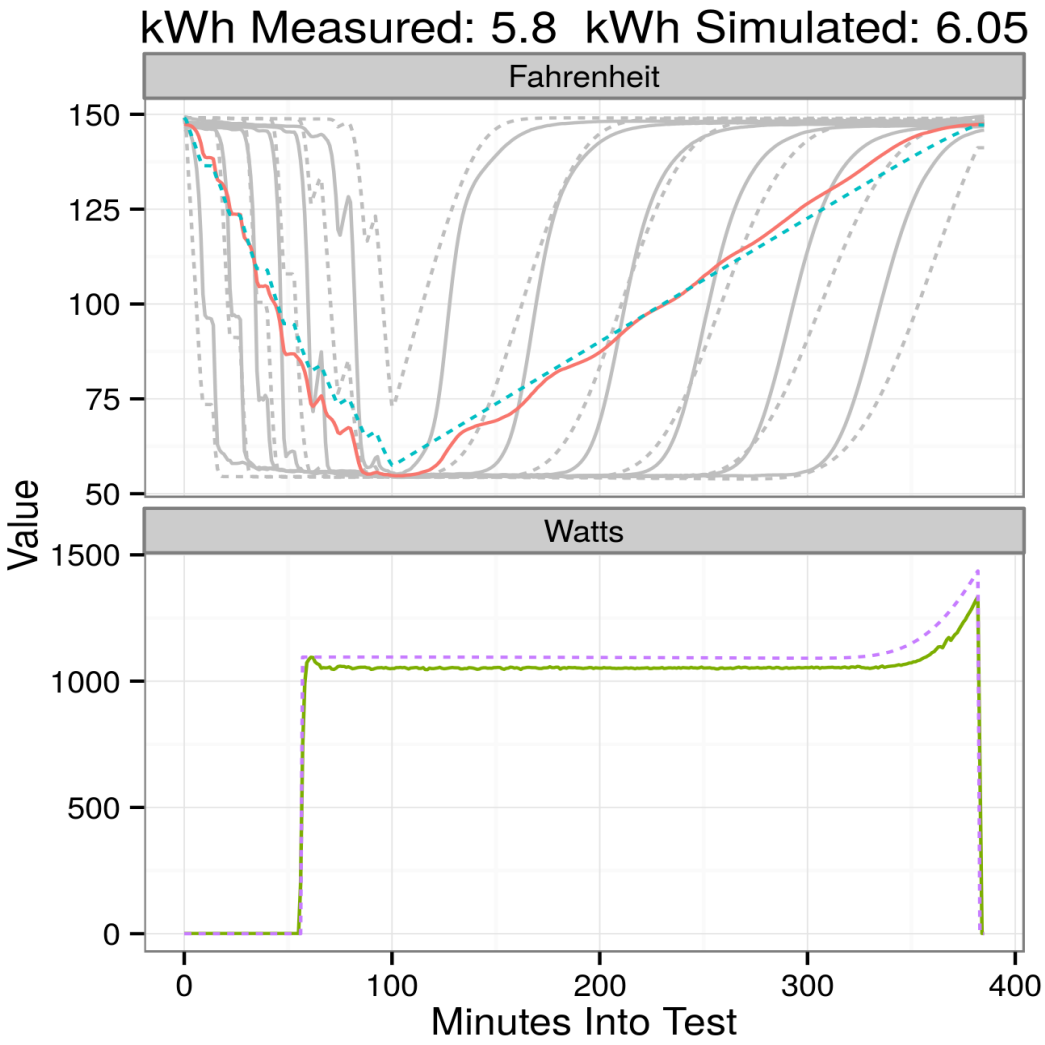

Sanden GAU/Gen3, with external, single-pass heat exchanger. 50F Shower Test modeled vs measured

Variable

- Measured Average Tank Temp
- Measured Input Power
- Simulated Average Tank Temp
- Simulated Input Power

Type

- Measured
- Simulated

Questions?