Analysis Techniques

1. Gain familiarity with the problem.
   - Generate events table.
   - Tell the story – explain the system response.
   - Identify significant difference with data, or trends that you do not understand.

2. Explore differences from data or unexplained trends using a Cause and Effect Diagram.

3. Quantify effects
   - Sensitivity Analysis
   - Direct Comparison
   - Derived Data
   - Big or Small
   - Identify Key Analysis Parameters

Strengths & Limitations of C&E Diagram Method

The Cause and Effect Diagram method has a few advantages and disadvantages:

+ The C&E diagram provides a structured approach to analysis. It can help guide/hone analytical thinking.
+ The C&E diagram can be directly tied to terms equations solved by TRACE.
+ Can help you examine things you might have overlooked (although it doesn't prevent you form overlooking items).
+ The C&E diagram can help guide discussions with other engineers when you seek input in an analysis.
- The C&E diagram cannot account for physics or code behaviors that you are unaware of.
- The C&E diagram requires more effort than ad hoc analysis (where you just jump in and start exploring).

MIT Pressurizer Model issues

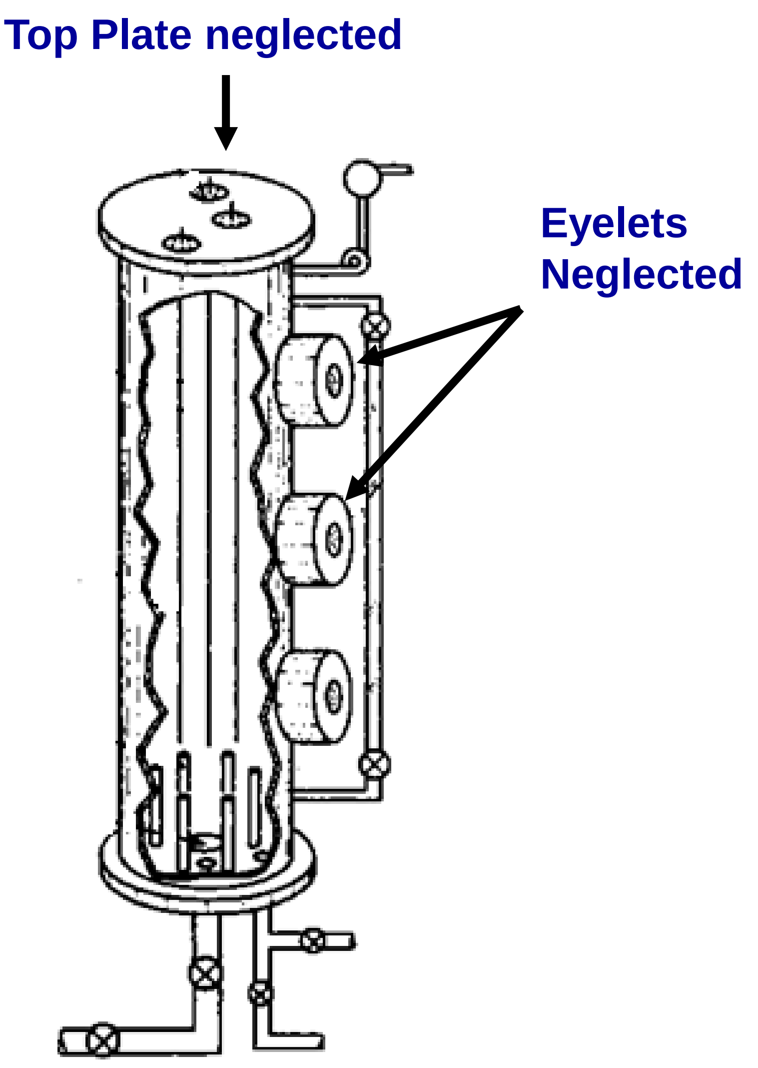
Here are some of the problem issues in the MIT pressurizer model:

1. The liquid velocity on the fill did not match data and was low. This affected mass flow into the system.
2. The pipe junction areas were too small for the pipe. This also affected the mass flow into the system.
3. The pipe included noncondensable gas. Thus the temperature did not increase as it would with saturated steam. This impacted condensation rates.
4. The level tracking flag was not set. This impacts interfacial condensation (causing too much condensation as liquid crosses cell boundaries). Leads to discontinuous jumps in solution.
5. Some of the metal in the walls is not accounted for in the base model.
6. There appears to a subtle initial conditions problem (the average wall temperature is too high). Initial temperature is about 0.5 K too high.

Metal in the Wall not Accounted for

The largest factor impacting condensation is the wall stored energy. Our exploration of the MIT pressurizer data showed that heat transfer due to heating the walls is an order of magnitude greater than heat loss to the environment during liquid inflow.

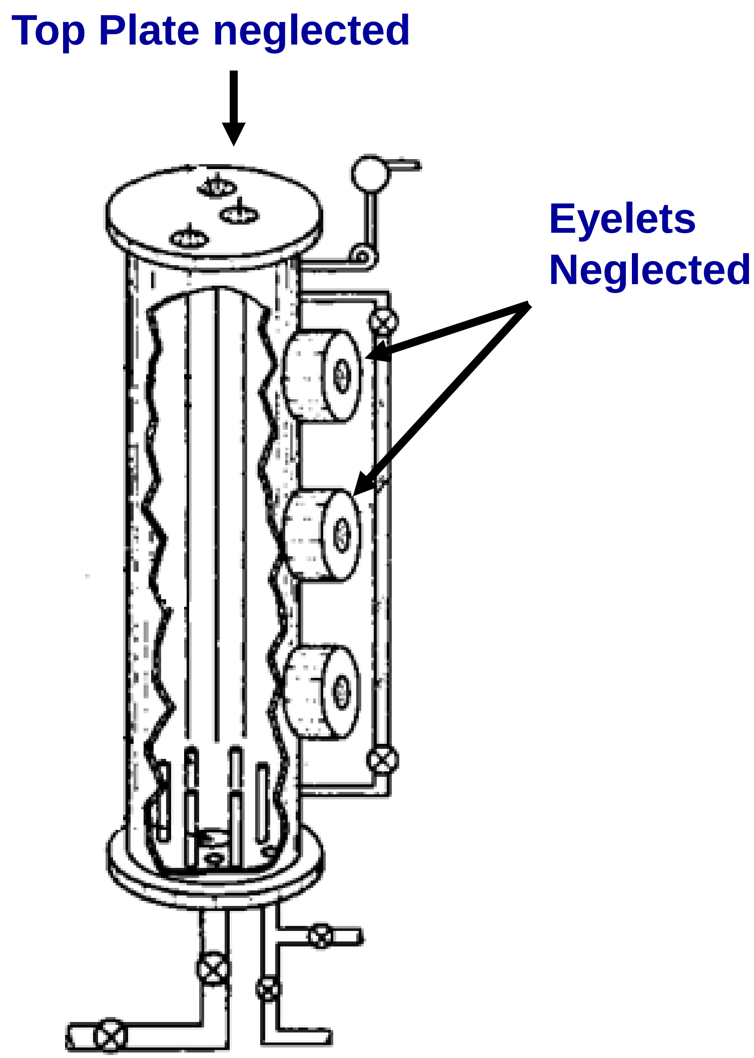
Thus neglecting metal in the vapor space walls can have a noticeable impact.



Metal in the Wall not Accounted for

As a rough estimate and a simple sensitivity, the wall thickness in the final model was adjusted from 8.33e-3 m to 9.33e-3 m (increase of 12%).

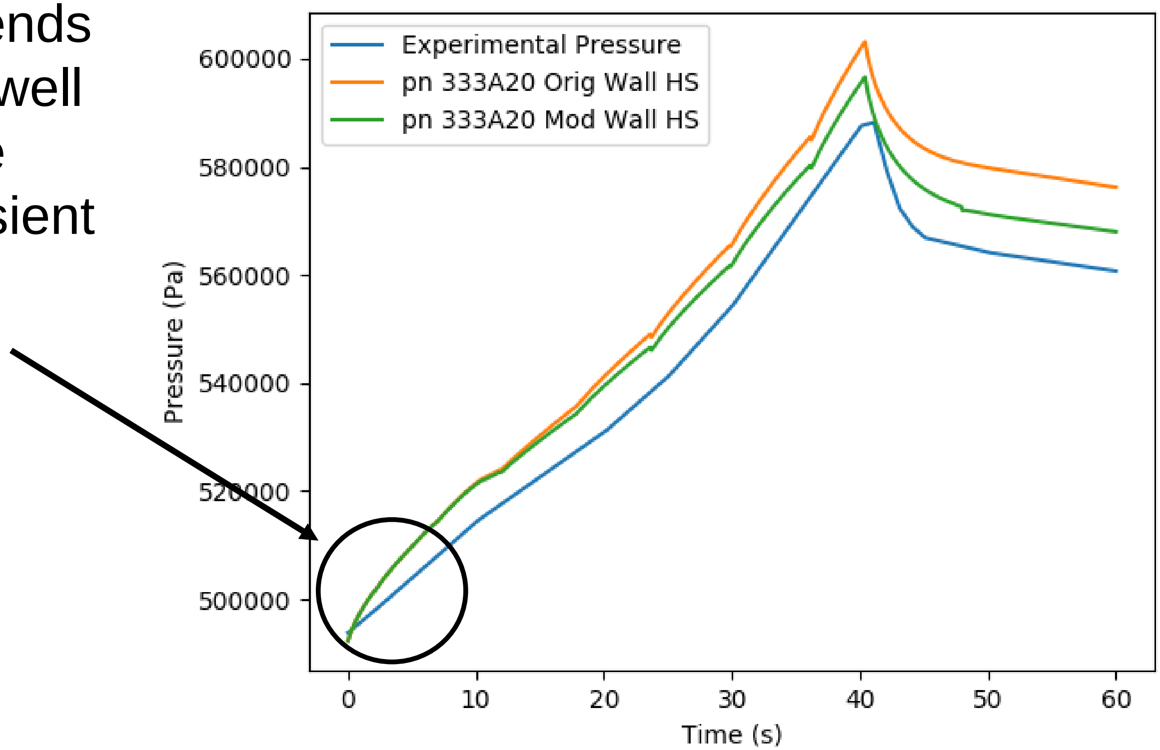
A more accurate estimate and distribution of mass could be calculated from available geometric data, but this seemed reasonable for a quick sensitivity.



Metal in the Wall not Accounted for

The following shows the impact of adjusting the metal in the wall by 12%. The result is improved, although the error is still significant.

Note that the trends match the data well except for at the start of the transient where an offset occurs.



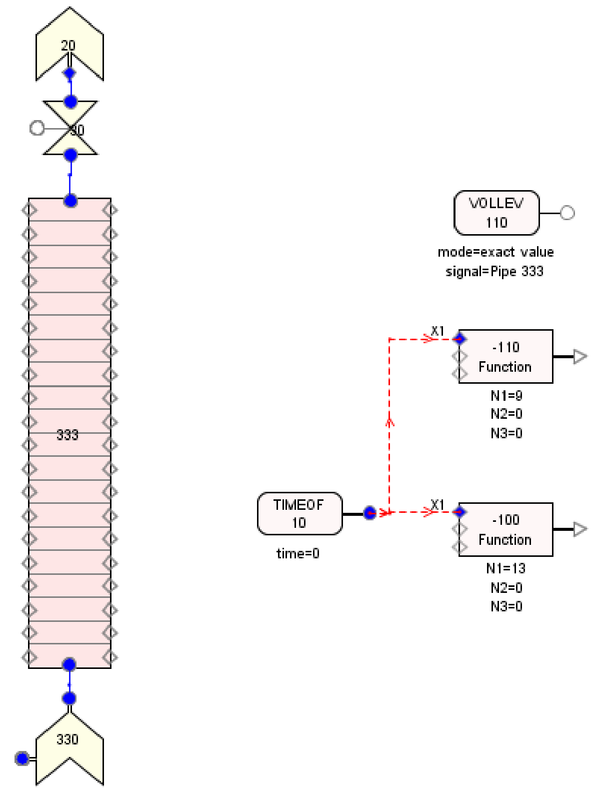
Initial Wall Temperature

In the base model, the initial wall temperature was set to saturation temperature. In our analysis while preparing this exercise, the initial thought was that maybe this was connected to not using steady state to set initial conditions (initial wall temperature – did that show up in your C&E diagram?)

Initial Wall Temperature

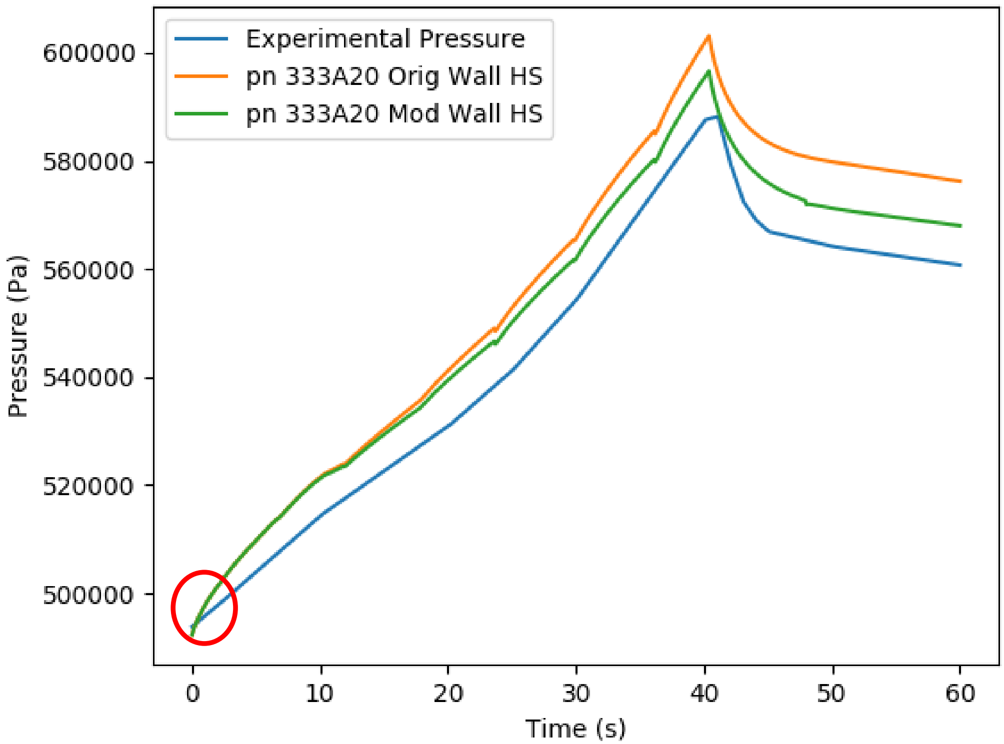
To test this theory the model was modified to run in steady state mode before the transient. A break set to the initial pressure was added at the top for the steady state and removed for the transient.

The result was a pressure response that looked nearly identical to the previous result.



Initial Wall Temperature

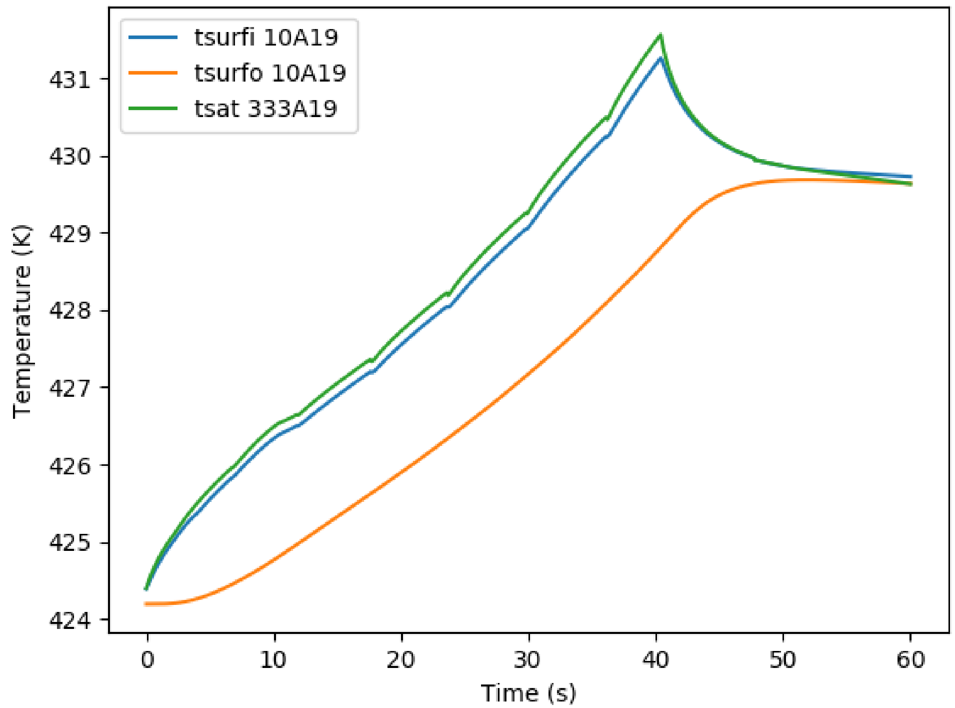
It was noted that initially the pressure response in the simulation is somewhat steeper (i.e., the experiment shows less condensation initially than the simulation).



Initial Wall Temperature

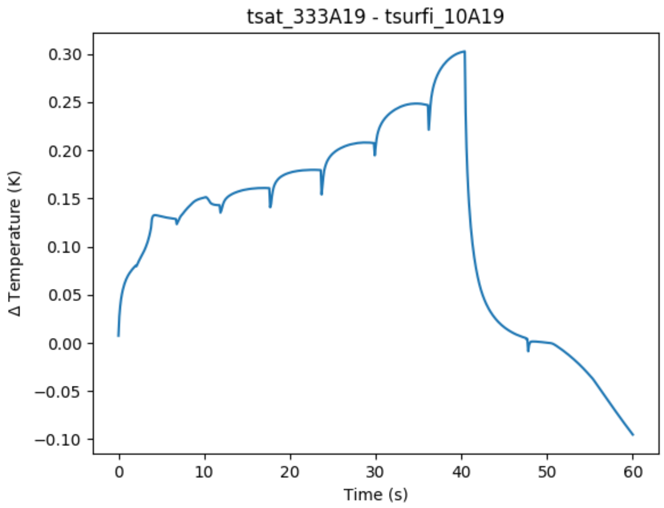
To explain the simulation response, the inner and outer wall temperature and the saturation temperature were plotted. The wall is initially close to the saturation temperature.

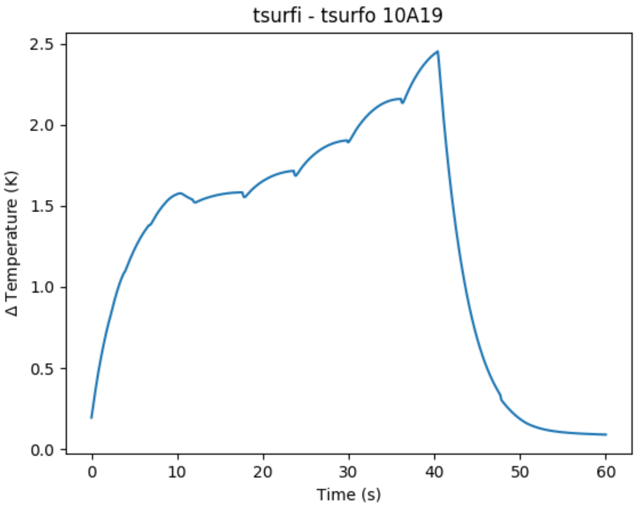
As the steam temperature increases, it takes a little time for the vapor and wall temperature to separate and for the difference in inner and outer wall temp. to reach a maximum.



Initial Wall Temperature

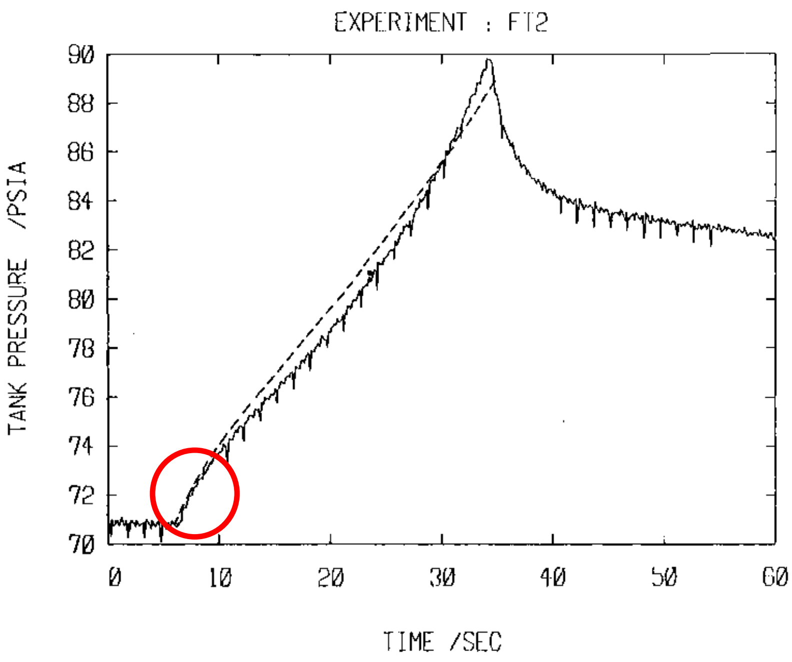
This shows the difference between the inner wall temperature and the saturation temperature, and the inner and outer wall temperatures. Again, this illustrates that it takes a few seconds for the vapor and average wall temperatures to separate. Thus it takes a few seconds for condensation to ramp up.





Initial Wall Temperature

The initial steep increase of pressure due to ramping of condensation seems to make physical sense. Why does this steep initial increase of pressure not show up in the test ST4 data? Lets look at two other MIT pressurizer tests. Both show the steeper pressure increase initially.



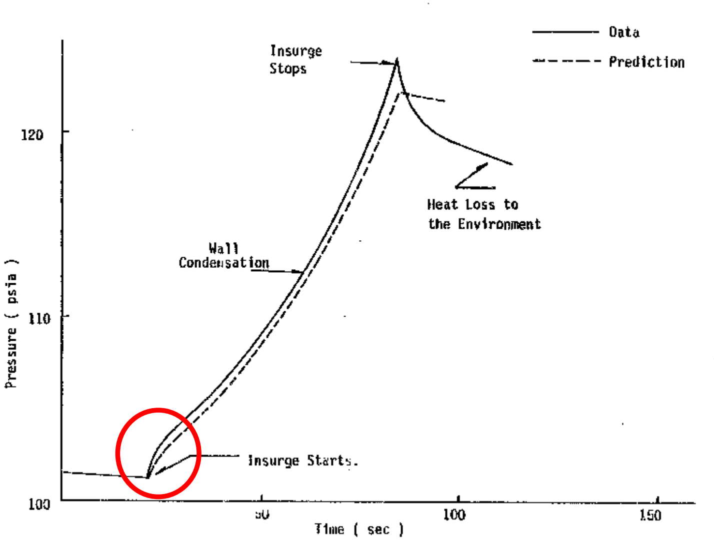
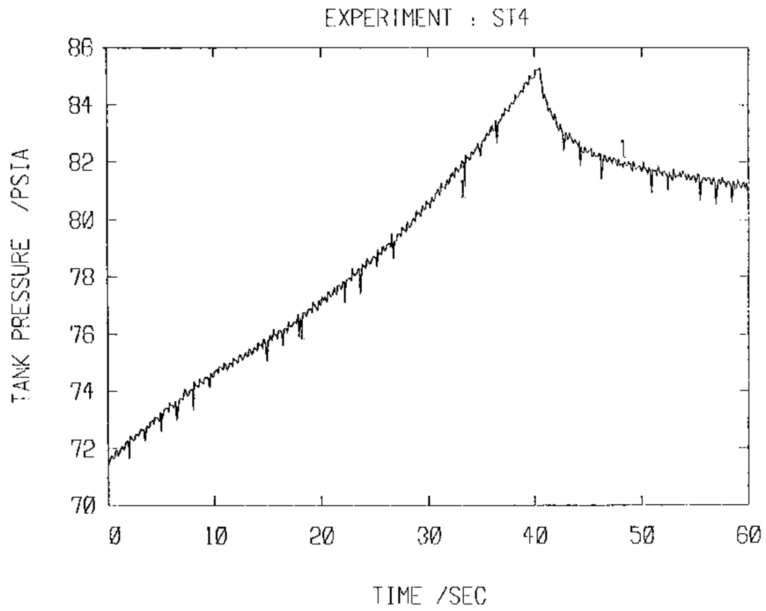


Figure 5.1 Prediction of the Pressure of Partially Full Tank Insurge Experiment.

Initial Wall Temperature

Note that test ST4 does not show a steady state period at the start of the transient. The conjecture is that a couple of seconds of the initial inflow are missing from the test data. Thus the data truncates the initial steep increase in pressure.

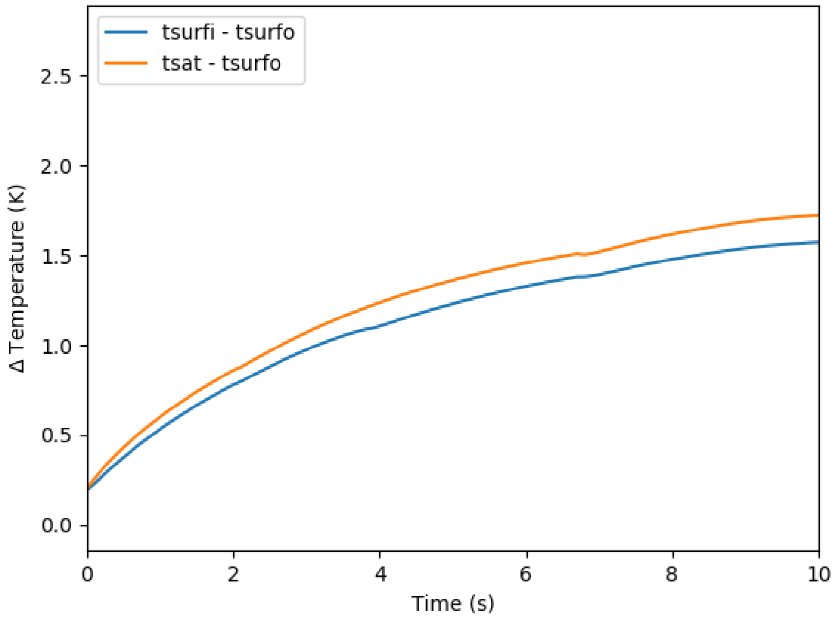
One way to test this against the model is to set the average wall temperature to the temperature expected a few seconds after the transient starts.



Initial Wall Temperature

Below is the difference in inner and outer wall temperatures for the first 10 seconds of the ST4 experiment run from a steady state case. At about 3 seconds, the average wall temperature is about 0.5 K below the saturation temperature.

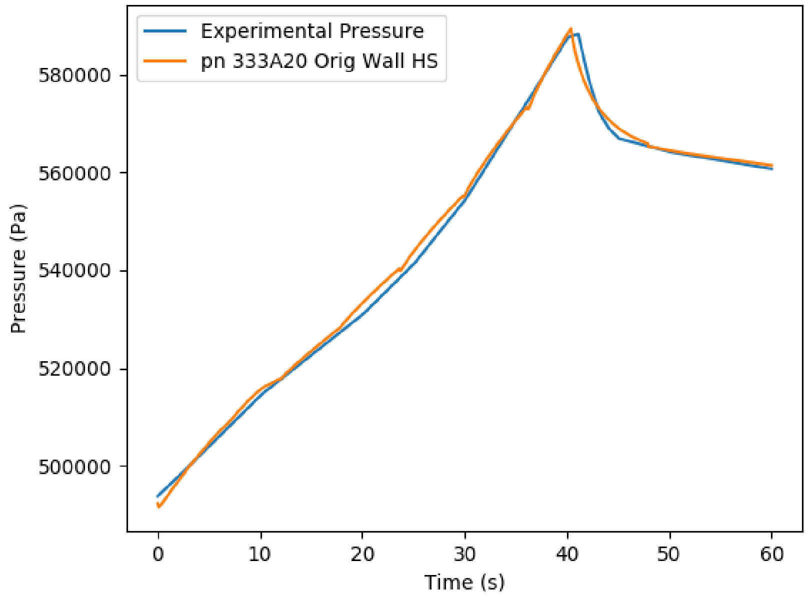
To test this conjecture, the wall temperature was adjusted from the saturation temperature of 424.4 K to 423.9 K.



Initial Wall Temperature

The following is the result after setting the average wall temperature 0.5 K below the saturation temperature. The agreement with data is very good.

This supports the idea that test ST4 is missing a few seconds of liquid insurge in the recorded data.



Initial Wall Temperature

One method that has been used in the past to improve results for the MIT test ST4 is to increase heat transfer to the environment to about 1100 kW/m^2. Note that the initial response still does not match.

Also the tail end response where heat loss to the environment is dominant differs in slope (i.e., too much condensation).