RELAP5/MOD3 TANK MODEL

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Problem – Surge Tank Vortex (Sucks)

- Review of ATR (Advanced Test Reactor) Surge Tank (ST) Indicated No Analysis Performed for Air Pull Thru to the Primary Coolant Pump (PCP) in case of an SBLOCA
- Failure of Pump Trip leads to loss of ST Inventory
- Would Air Pull Thru occur during Drain of the Surge Tank i.e. Would a Vortex form?
- Other Issues include:
- Advocates at ATR for the use of Civil Engineering Design Criteria (ASCE) on Drains and Sewers
- Or, Use a modification to RELAP5/MOD3 Off-take Model
- To Dissolve or Un-dissolve air in the Water

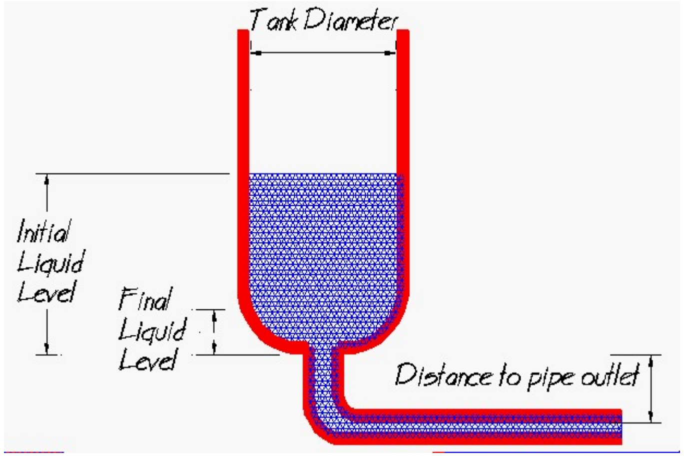
- Sewage Option -- Design Criteria from ASCE
  - Highly Conservative
  - Leads to Hardware Modifications for Surge Tank
  - Vortex Suppression Device or a Big Rubber Duck
  - Based on Tanks Open to the Atmosphere
  - Steady State Correlations
- Relap5/MOD3
  - Two-Phase Two Component with Air
  - Non-Equilibrium Temperatures for each phase
  - Off-Take Model Based on Tank Drain Analysis Data
  - Vapor Pull Thru or depression, can lead to Vortex
  - Originally referred to as Shrock Model, Lubin did a lot of the work

Additional Issues

- Lack of Dissolved NC Gas Model
  - Relap5 and Sewage Standards Bereft of
  - Why? Because every thing has been done in T/H
  - Dissolved NC Gas Models a “standard” in the Simulation Industry, effects noticed in RCP startup, Wet Layup
  - Sorely needed for “Complete Understanding” of propagtion in Reactor Systems
- NC Dissolved Gas “Hand Calcs”

  Make Conservative assumptions based on Henry’s Law

ATR Surge Tank



- Enclosed at Top
  - Air Covered
- Piping Length to Pump =
- Water in the recirculation system of ATR continually degassed 11.7 cm3/L N2
  - Water in ST does not recirculate, what is mass fraction of air in mixture, approximately 3.51x10-4 or ~ 10 cubic feet of volume out of 1000 cubic feet of water air mixture
- Other concerns: Distortions on Surfaces, incompressibility of water
- Sewage Proponent Concerns

In section 2, equations 1, 2, and 3. You refer to A as the cross area of the tank. If I double the cross area of the tank should be able to double the velocity that I can have without forming a vortex. If I extend this to the extreme, if I have an infinite diameter tank I can have an infinite volumetric flow rate without forming a vortex. I must be reading this wrong but it is causing me trouble and I was hoping you could help explain it to me.

The other question is in, section 2 on equation 3b. As I view the volumetric flow rates, as related to specific points in the simulation time, I see the rate of change in the second time frame you cover as having more impact than originally discussed. I'm curious how it came that this overall average is applied to the analysis. For example, we should be able to start the simulation at the point with a 3 cubic foot flow rate and go until it gets to 2 cubic feet flowrate. The equations should not care what happened in the previous 100 inches of tank head. Why is it that this volumetric flowrate average is applied instead of specific volumetric flow rates at the different periods of time?

Tank Drain Model

- Based on the Relap5 Off Take Model
- There is some confusion between air pull-through and vortex formation. In the experimental work of Smoglie it is pointed out that air (or vapor) pull-through occurs in two cases, pull-through with a vortex or pull-through without a vortex. The correlations in Smoglie4, approximately the same as that of Lubin, used in RELAP5/MOD3 take both cases into account.
- Air pull-through is examined using a modification to the RELAP5/MOD3 thermal hydraulics computer code with comparisons to Lubin and the criteria of Moody.
- Fred Moody, “Introduction to Unsteady ThermoFluid Mechanics,” 1990. INL Course Notes from Fred Moody.

Lubin Correlation

$$H_C = 0.69\left[\frac{W_{Liq}^2}{g\rho_{Liq}\left(\rho_{Liq}-\rho_{air}\right)}\right]^{1/5}$$

$H_C = critical\ height\ in\ feet\ for\ pull\ thru\ to\ occur$

$W_{Liq} = mass\ flow\ of\ liquid\ in\ Lbm/sec$

$\rho_{Liq}, \rho_{air} = Liquid\ and\ air\ densities\ in\ Lbm/ft^3$

$g = gravity\ acceleration\ constant$

Moody Correlation

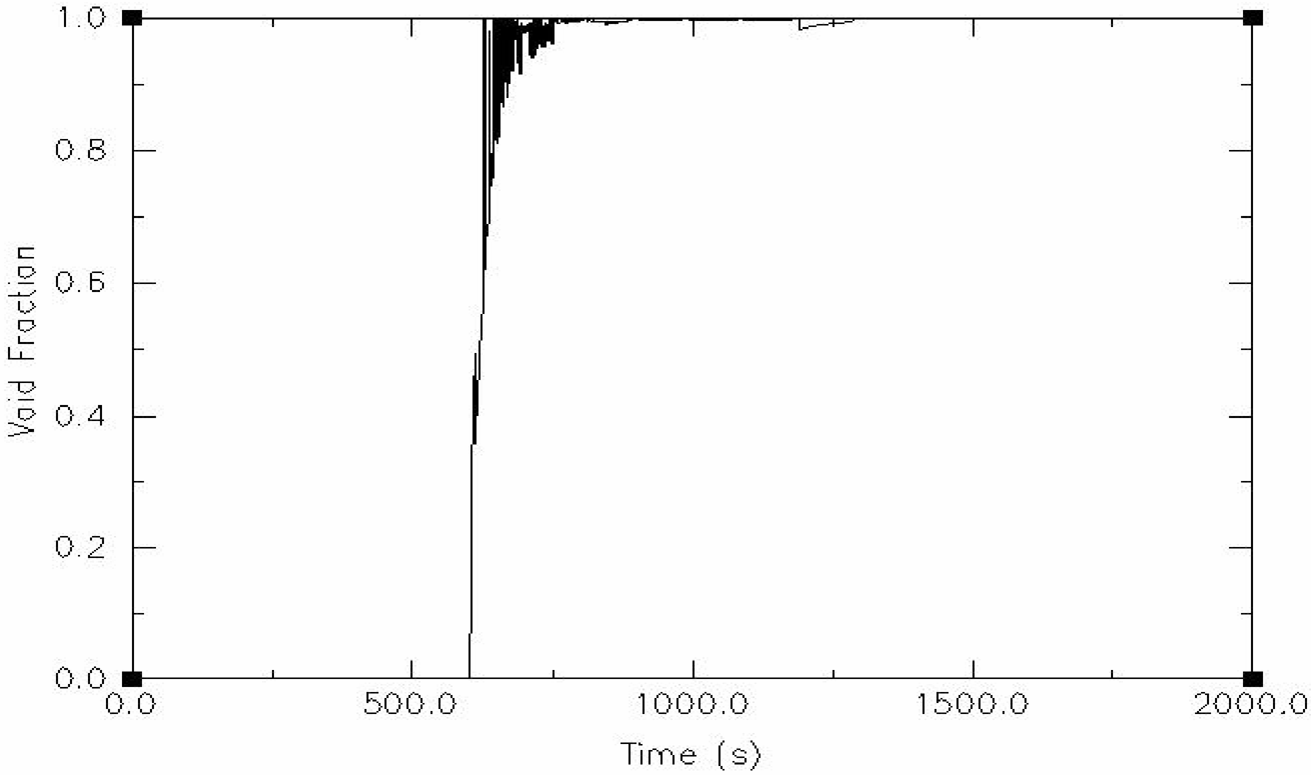
$$H_C = \left[\frac{20.0\, x W_{Liq}}{\pi D \rho_{Liq} \sqrt{g}} \right]^{2/3}$$

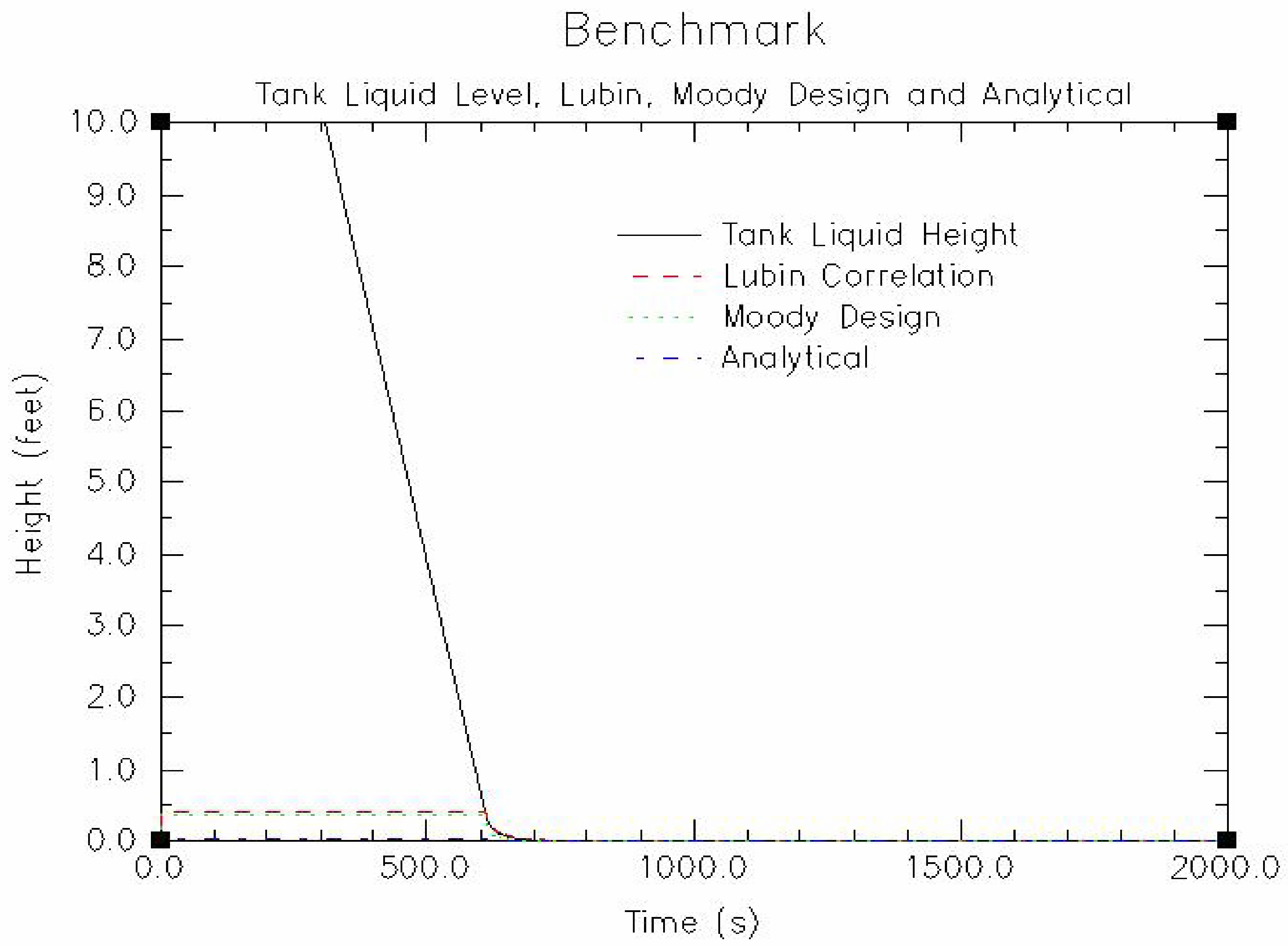
$$D = Tank\ Diameter$$

Lubin Correlation Implementation

- Subroutine hzflow in Relap5/Mod3
- Card 1 option change number 54.
- When critical height attained gas is taken out the bottom junction
- The code was validated by comparing the estimated critical height for vapor pull-through from a hand calculation based on Lubin's correlation to the code predicted results.
- Model of a tank open to the atmosphere at 14.7 psia and at a temperature of eighty degrees Fahrenheit.
- Moody Correlation with Control Variables

- Constant Mass Flow of 100 Lbm/sec at bottom of Tank
- Lubin correlation predicts a critical height of 0.4167 feet
- The Lubin correlation predicts a critical height of 0.416675 feet. The predicted height of pull-through from RELAP5/MOD3 is approximately 0.41683 feet.

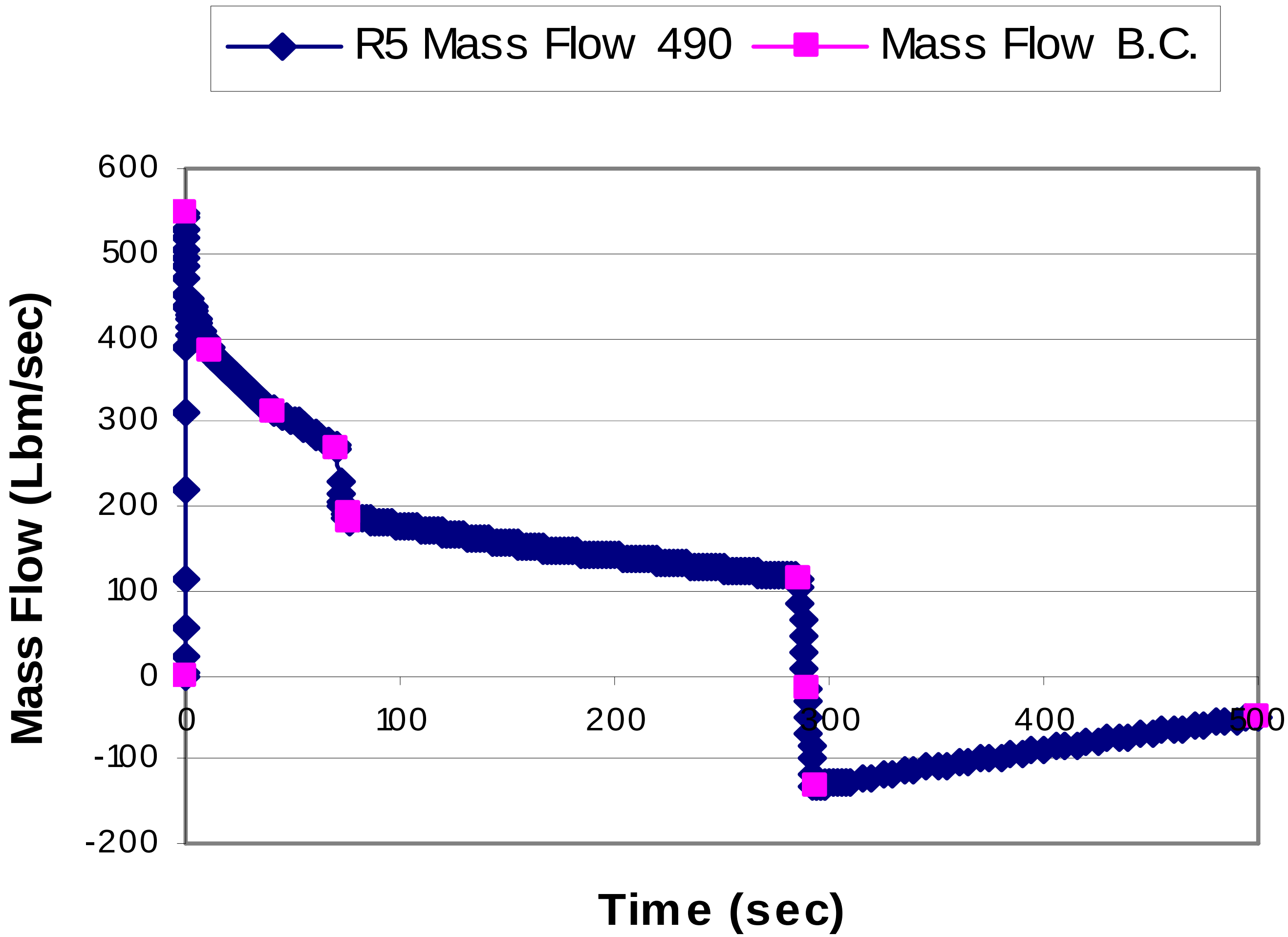




Benchmark
Tank Liquid Level, Lubin, Moody Design and Analytical
Tank Liquid Height
Lubin Correlation
Moody Design
Analytical
Height (feet)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
500.0
1000.0
1500.0
2000.0
Time (s)

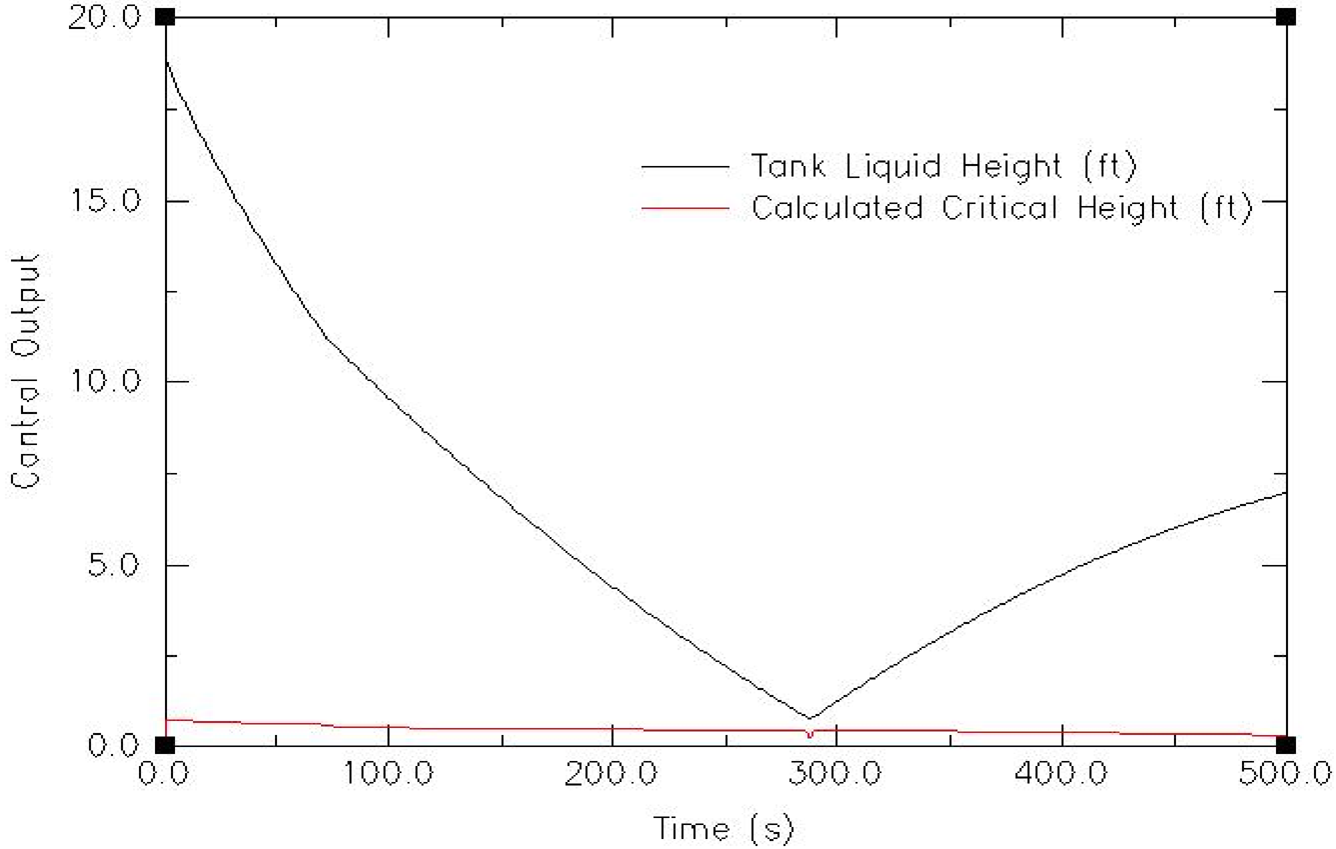
Transient Used for Calculation

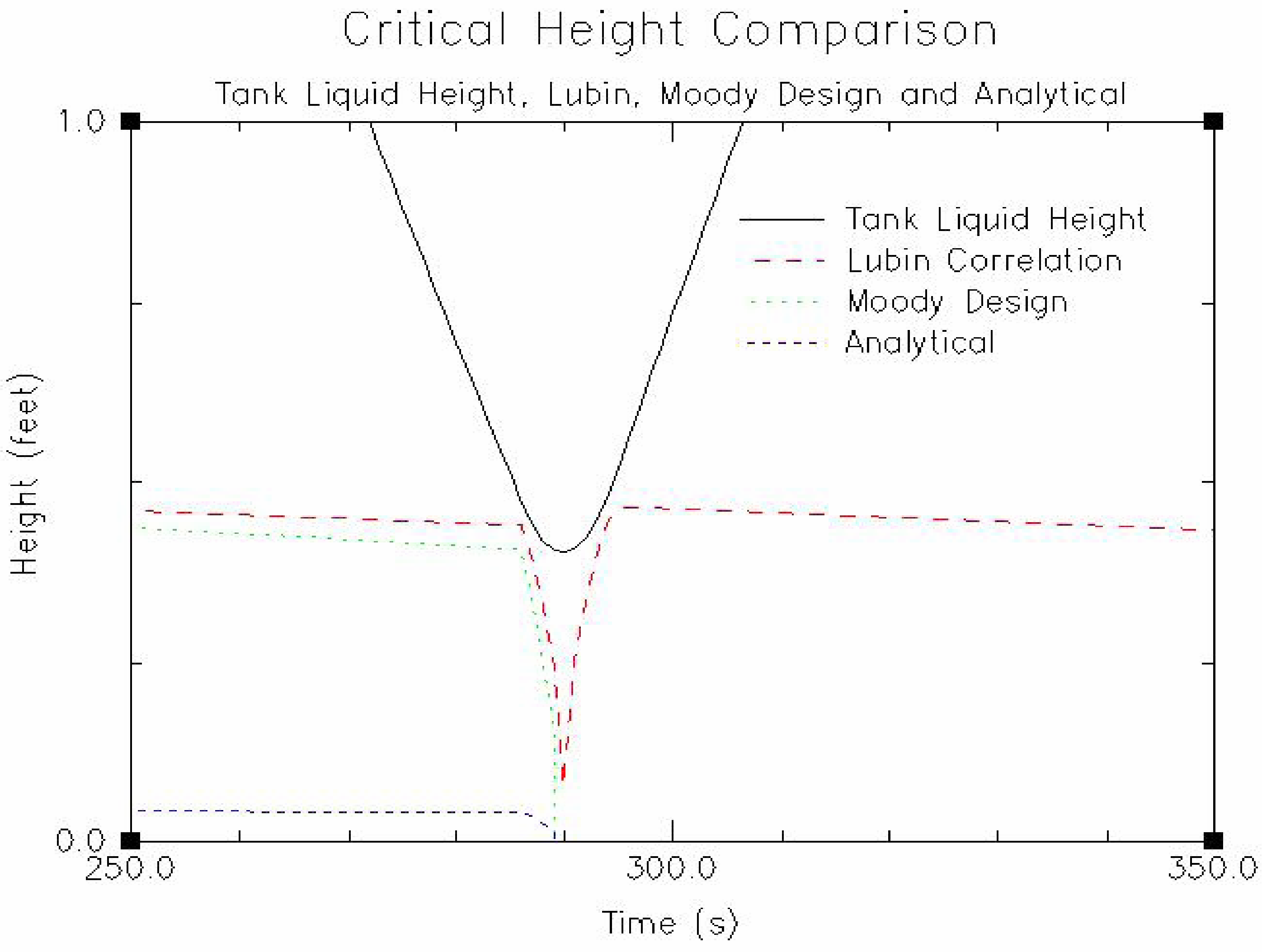
- **SBLOCA Case One PCP Fails to Trip**
- **S. T. Polkinghorne, “Analysis of ATR Small-Break LOCA with Engineered Safety Feature to Automatically Trip Primary Coolant Pumps,” EDF No. TRA-ATR-1487, July 1999.**
- **SBLOCA performed with MOD2**
- **Surge Tank Outflow from SBLOCA Used as BC**



Mass Flow Fit

Results


Tank Liquid Height (ft)
Calculated Critical Height (ft)
Control Output
Time (s)
20.0
15.0
10.0
5.0
0.0
0.0
100.0
200.0
300.0
400.0
500.0



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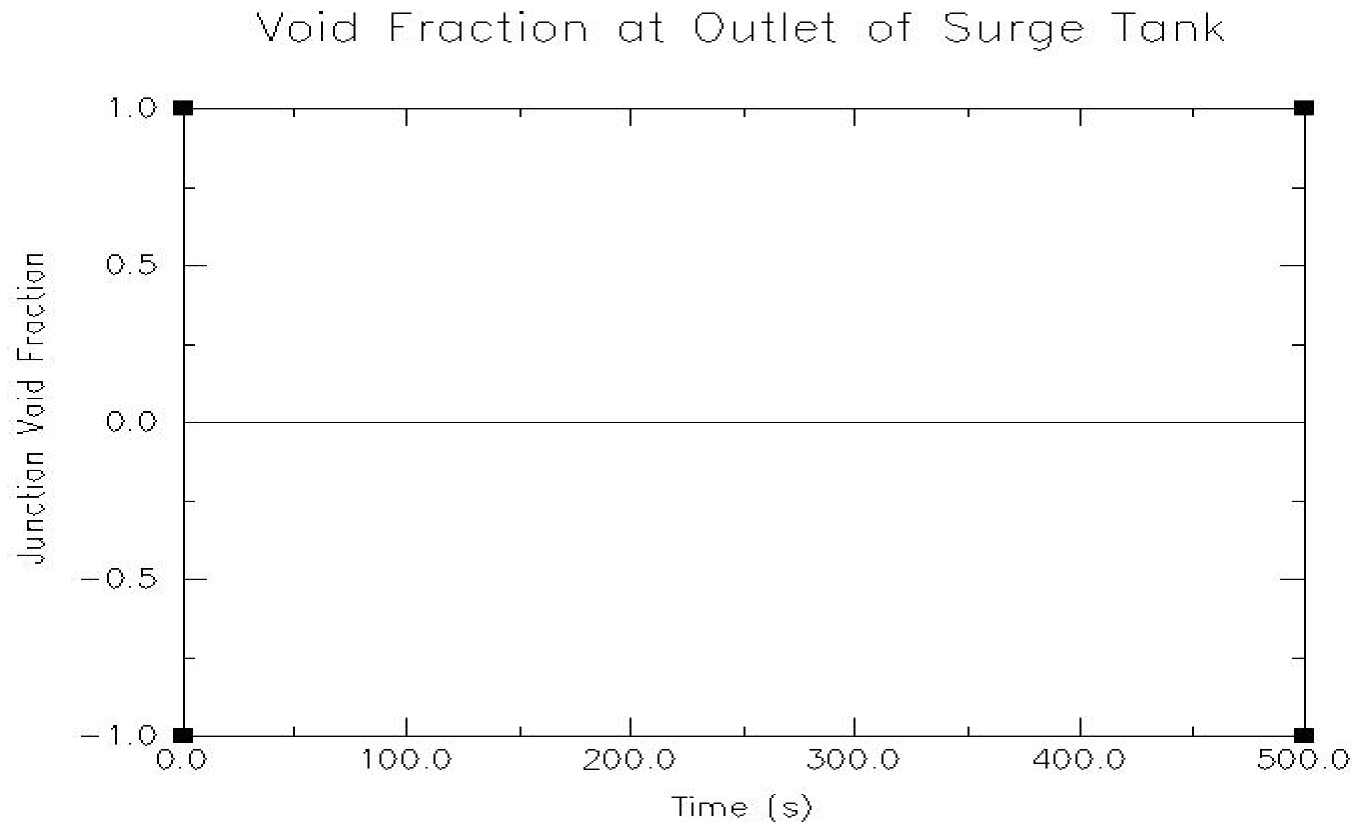
Discussion

- An additional discussion of the previous Figure is warranted.
- During the SBLOCA some system mass is lost out the break since the suction side of the pump pulls liquid out of the surge tank. This results in the tank level decrease.
- Eventually the EFIS is actuated due to low pressure and trips the primary pump. The liquid level in the tank recovers due to the primary pump trip and the actuation of the emergency pumps refilling the tank. This results in the tank liquid height reversal.
- The static correlations shown were programmed into RELAP5/MOD3 using control blocks so that a direct comparison to the RELAP5/MOD3 dynamic model could be made.

Did Any Gas Make It?



Conclusions

- Gas will not make it to pump
- Results appear to be in line with earlier analysis of scaled facility by Polkinghorne for ATR
- Additional safety margin with pipe lengths and pleana to pumps
- Msr. Cliff Davis Analysis of NC Gas into Rx showed it not to accumulate in Core with Mod3
- We won't talk about MOD2
- R5 needs a NC Gas in Liquid Solution Model

Acknowledgements

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