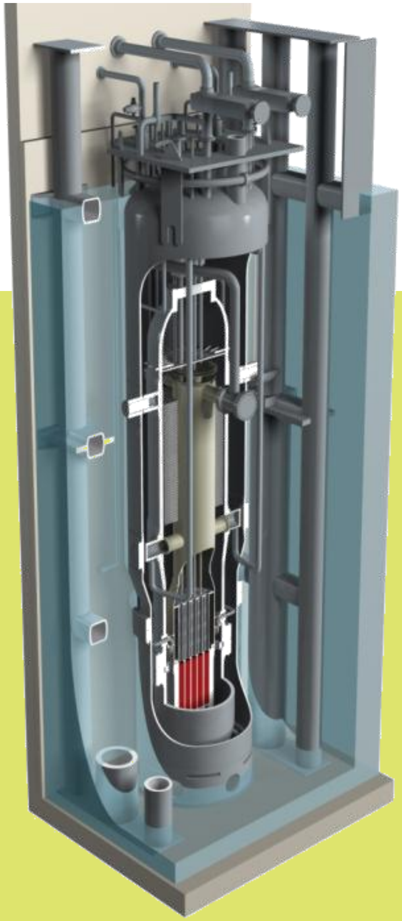

RELAP5 Applications & Improvements At NuScale

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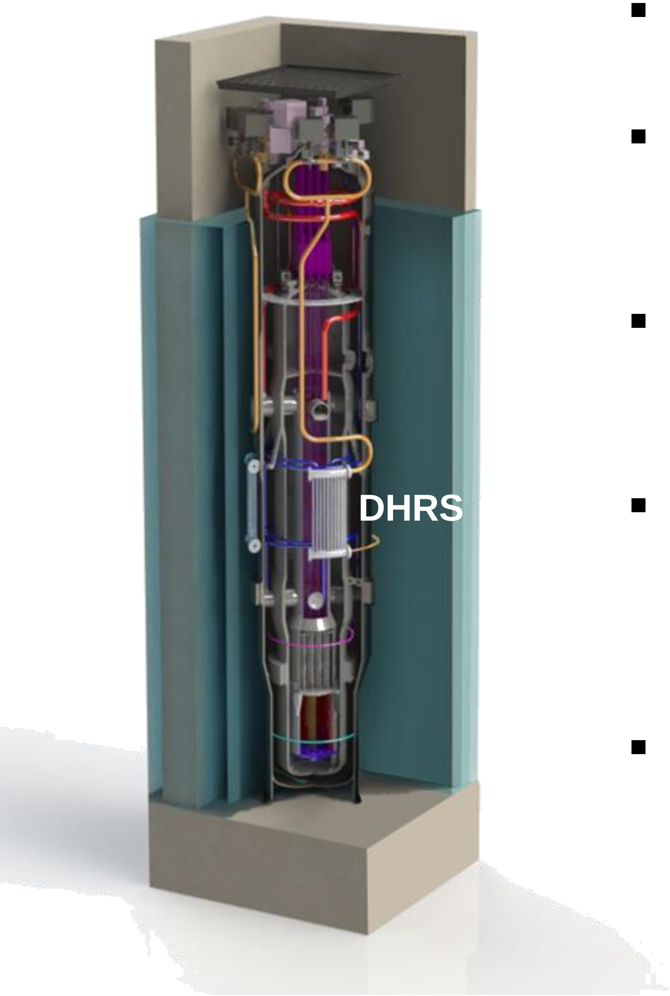
NuScale Power™

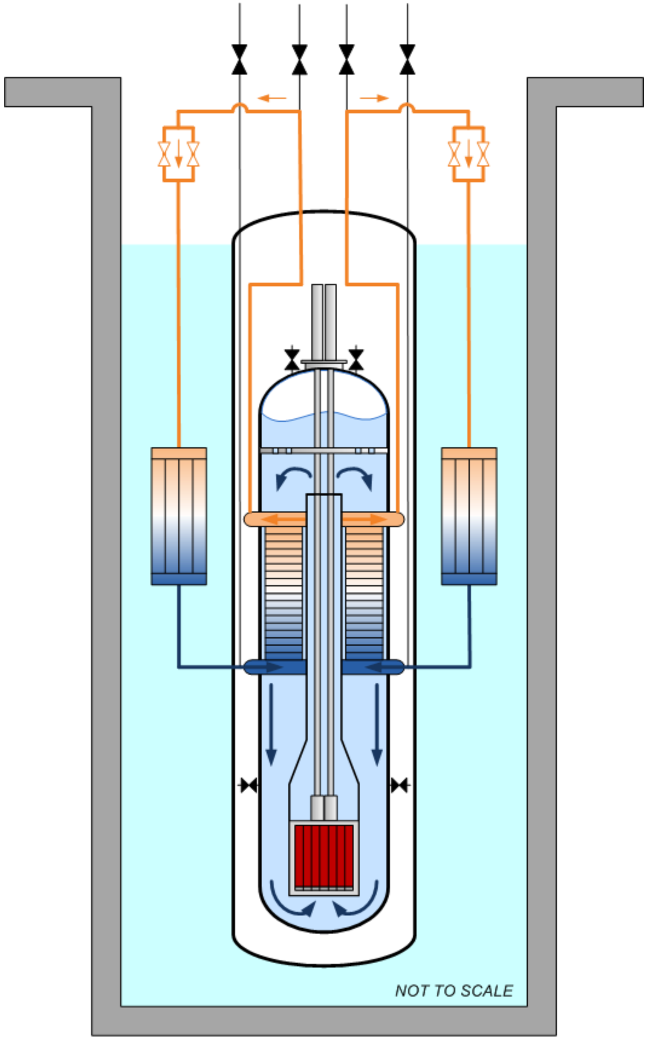
Key Safety Elements of the NuScale Design

- No need for AC or DC power for safe shutdown and stable cooling for an indefinite period
- Passive safety features
- Small core size / low fission product inventory
- Very low normalized core damage frequency
- Additional fission product barriers
- Small releases that are significantly delayed (total integrated release very small)
- Site boundary at EPZ
- No need for offsite evacuation
- Enhanced seismic performance
- Deeply embedded spent fuel pool with 4 x water volume per MWt of 1000 MWe plant

Decay Heat Removal System – *Using Steam Generator*

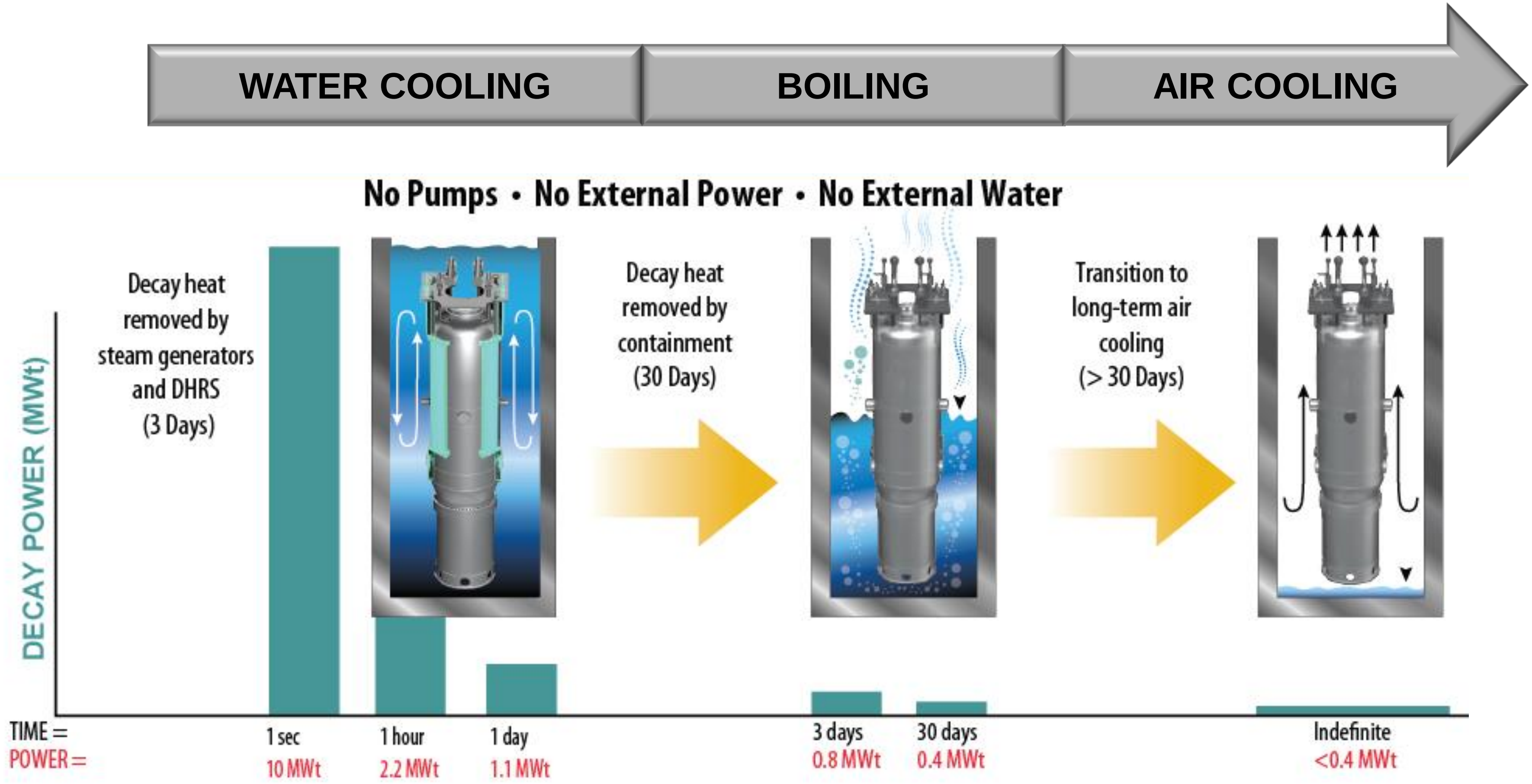


- Main steam and main feedwater isolated
- Decay Heat Removal Isolation Valves (DHRIVs) opened
- Steam from steam generator is condensed in the DHRS tubes.
- Decay heat passively removed via the DHR heat exchangers to the Reactor Pool
- DHRS provides 3-10 days of decay heat removal



NUSCALE POWER™

Innovative Advancements to Reactor Safety
*Nuclear fuel cooled indefinitely without AC or DC power**



- ***30 days is a minimum based on very conservative estimates.***

****Alternate 1E power system design eliminates the need for 1E qualified batteries to perform ESFAS protective functions – Patent Pending***

Who am I?

- MU, WVU, NCSU and U of Idaho
- Physics, Math, Engineering Mechanics and Nuclear
- T/H, CFD, Rx Physics, Analysis And Code Development
- INL ~ 20 Years, (W) T/H, Consultant
- Hobbies are Bball, Power Lifting, Math, GrandKids

NuScale Power™

Outline

- Talk about R5 Applications
- Options in the Code that help
- Subroutine Katokj – Drift Flux Co, Vgj
- Bubbling Steam through Liquid
- Four Foot GE Level Swell
- Always use Collapsed Level for Conservatism

R5 Applications

- We will be using it for SBLOCA and Non-Loca (Chapter 15) Transient Analysis
- Appendix K Evaluation Models via Conservative Method
- Reg Guide 1.203
- Non-Loca Chapter 15 (NUREG-0800) or the SRP
- INL and NuScale have developed and tested the requisite Appendix K Models
- Moody Choked Flow, Baker-Just, etc.
- CHF Models in preparation (see talk from last year) which discuss the implementation from Stern Tests
- CHF Pipe Component

Options

- Mass Error
- Difference between State and Mixture Density Multiplied by the Volume
- What helps?
- Options 54, 61 coupled together can reduce the mass error by significant amounts
- Option 61 can depressurize for blow downs too quickly, so please run sensitivity studies with Cd

Nonproprietary

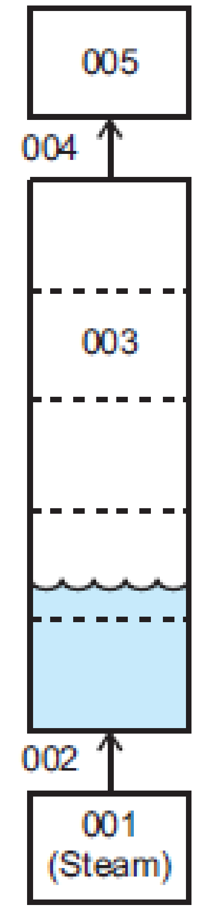
NuScale Power™

Katokj

- Drift Flux for Interfacial Drag
- Katokj - calculates Vgj and c0 using Kataoka-Ishii correlation (medium-high vapor flux) and churn-turbulent bubbly flow correlation at low
- Kataoka, I. and Ishii, M., 1987, "Drift Flux Model for Large Diameter Pipe and New Correlation for Pool Void Fraction", Int. J. Heat & Mass Transfer, Vol 30, No. 9, pp. 1927-1939.
- Code incorrectly using churn-turbulent for all regions, also fixed some numbers.

Bubbling Steam through Liquid

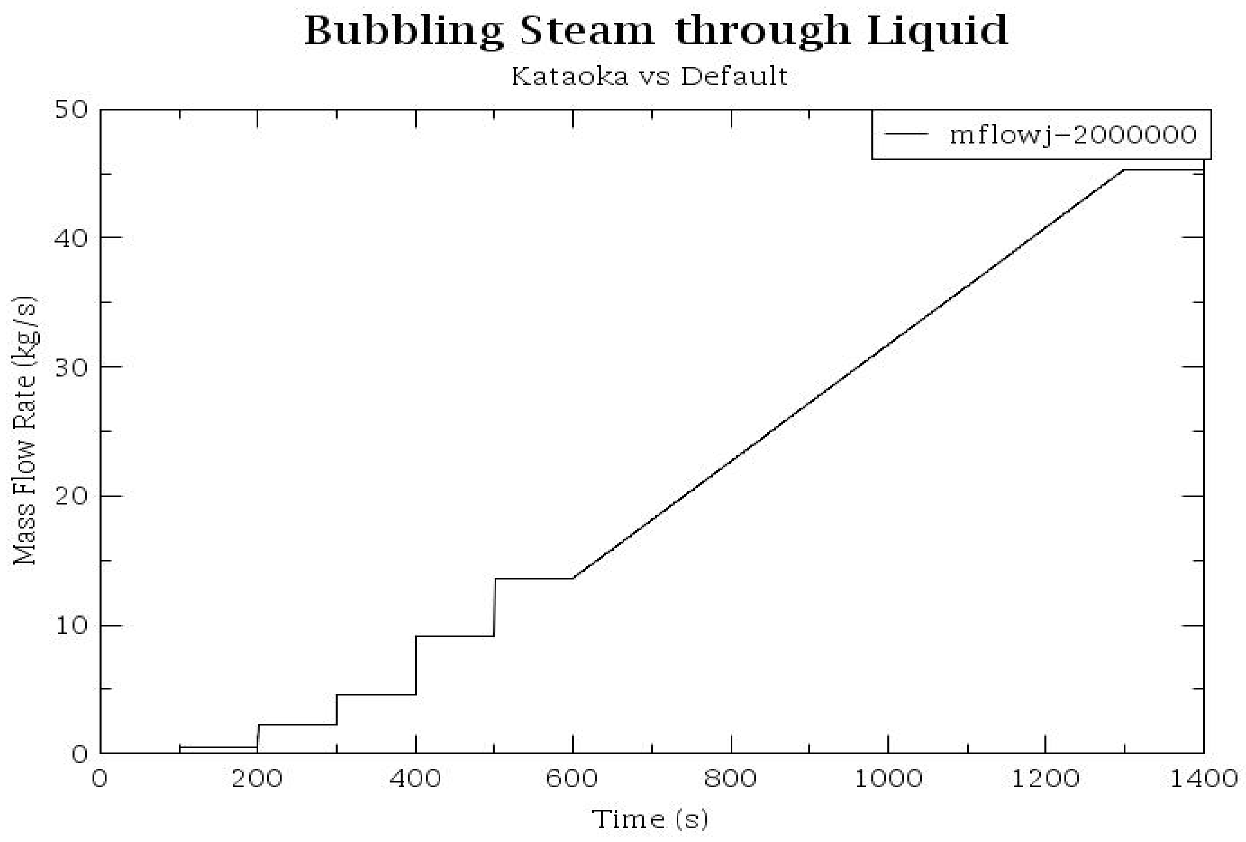
- Verification
- Designed for liquid entrainment and two-phase level swell for increasing steam flow rate
- This is a thought problem where Saturated Steam is bubbled up thru saturated water in steps of increasing mass flow. Quasi steady conditions are allowed to be established
- The flow rate is then increased linearly to allow the liquid to be entrained out the top of the column
- Pipe has 5 volumes – each 3 feet long and a flow area of 3 square feet. Bottom of pipe is saturated liquid at 1000 psia with a liquid level in the 2nd pipe volume. The remainder of the pipe is saturated steam. A TDJ injects saturated steam at 1000 psia in the bottom volume and the top volume is also connected to a TDV with saturated steam.

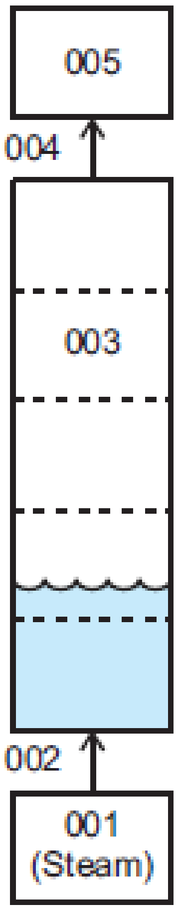


NUSCALE POWER™

Mass Flow Injected

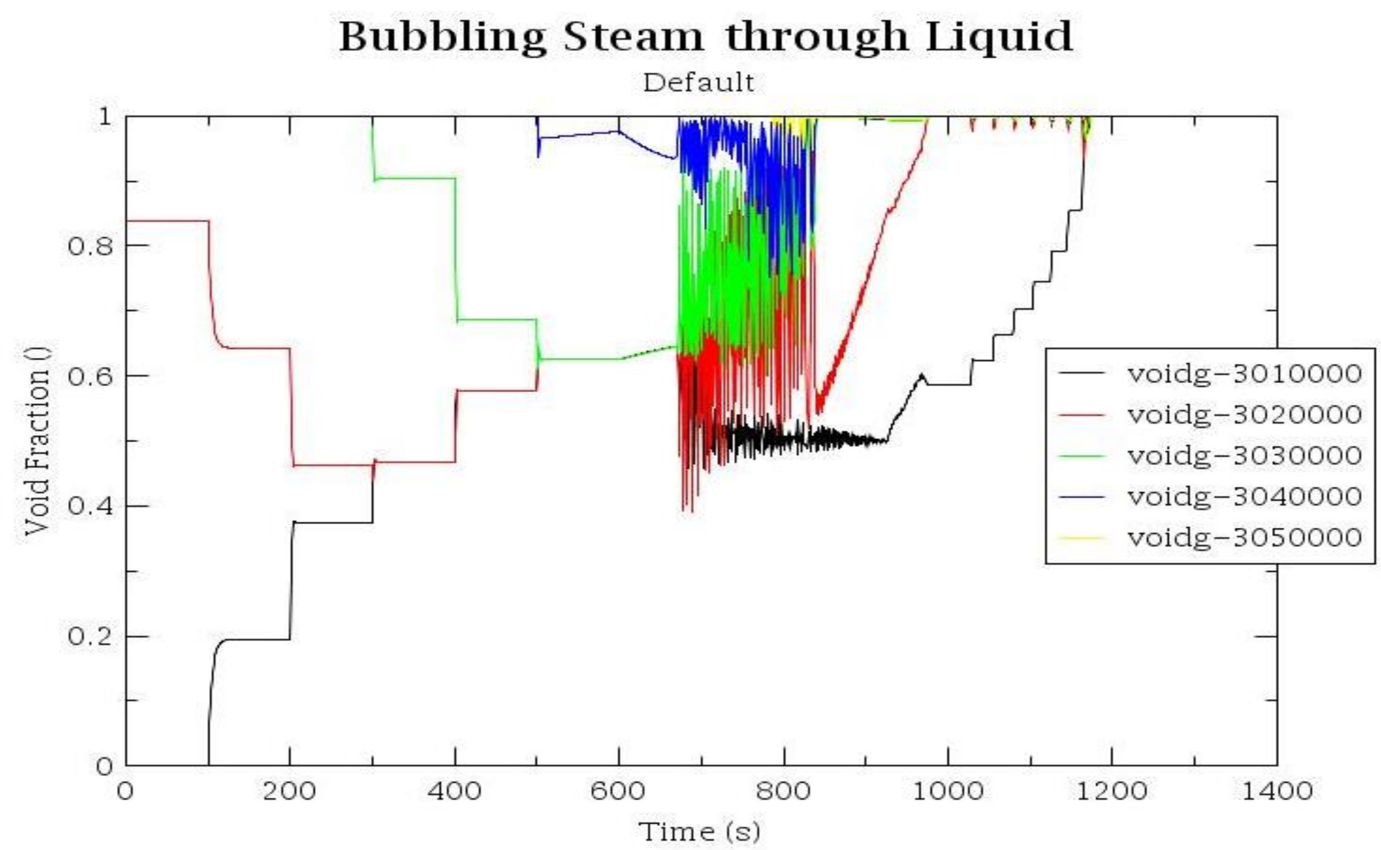
Mass flow rate is increased every 100 s in a step wise fashion which stabilizes after each increase. Then the flow is linearly ramped.

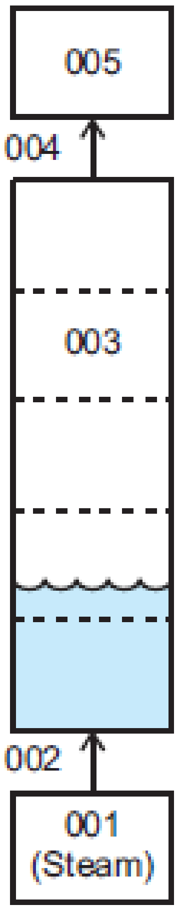




Void Fractions - Default

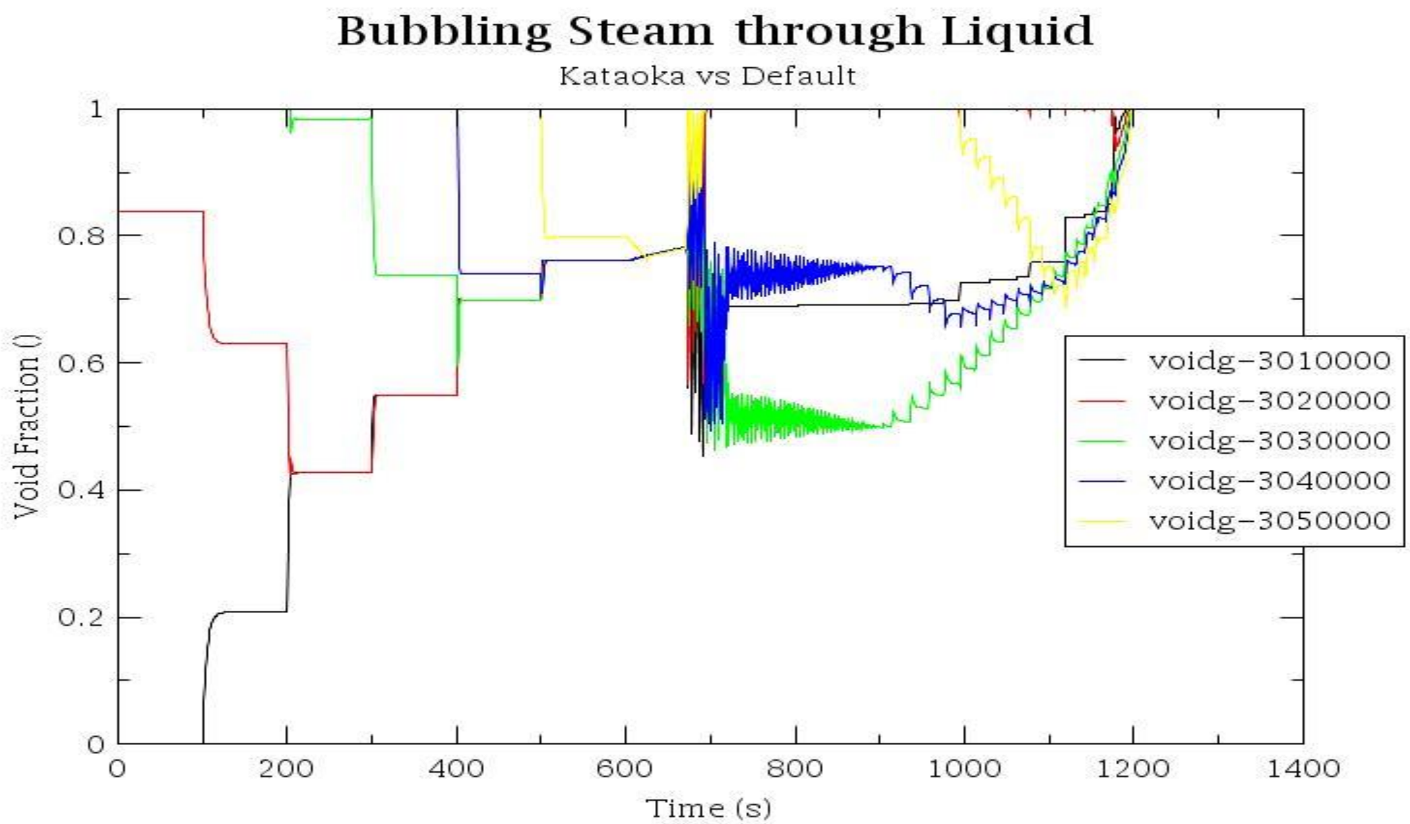
After 600 seconds get slug and annular flow regime transitions, numerical oscillations. Water fills 2nd and 3rd volumes.

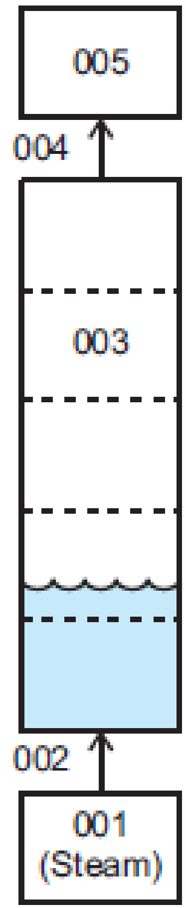




Void Fractions - Kataoka-Ishii

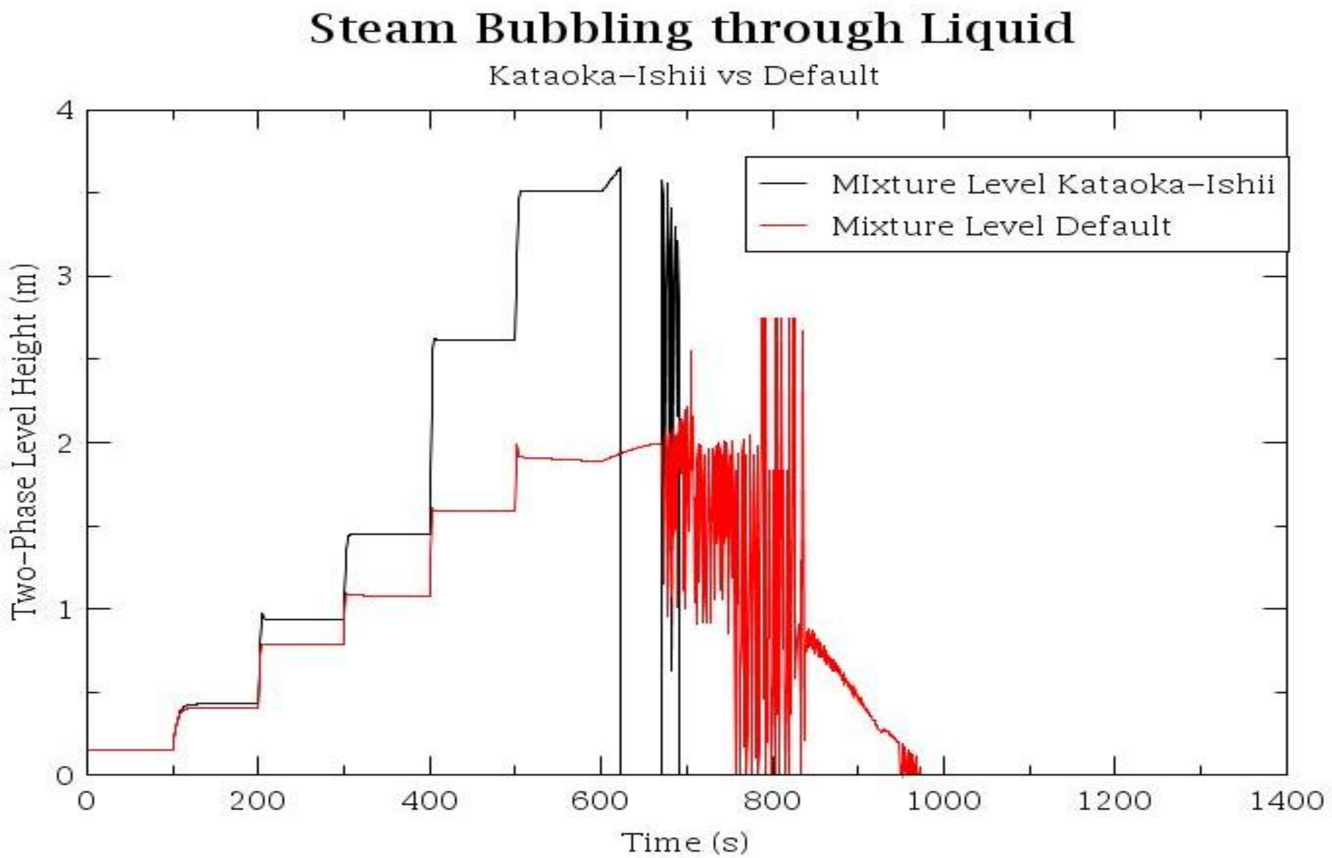
After 600 seconds we don't get as many slug and annular flow regime transitions, or numerical oscillations. Water fills 2nd and 3rd volumes at lower rate.

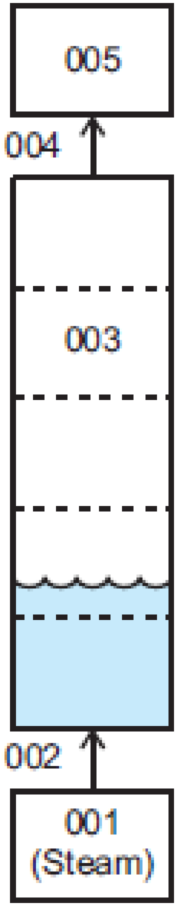




Mixture Level Kataoka Ishii vs Default

A little after 600 seconds the void goes up linearly, we lose two-phase level, a little before 700 seconds we do not have enough flow to entrain the water out, the water falls back down. See previous slide.

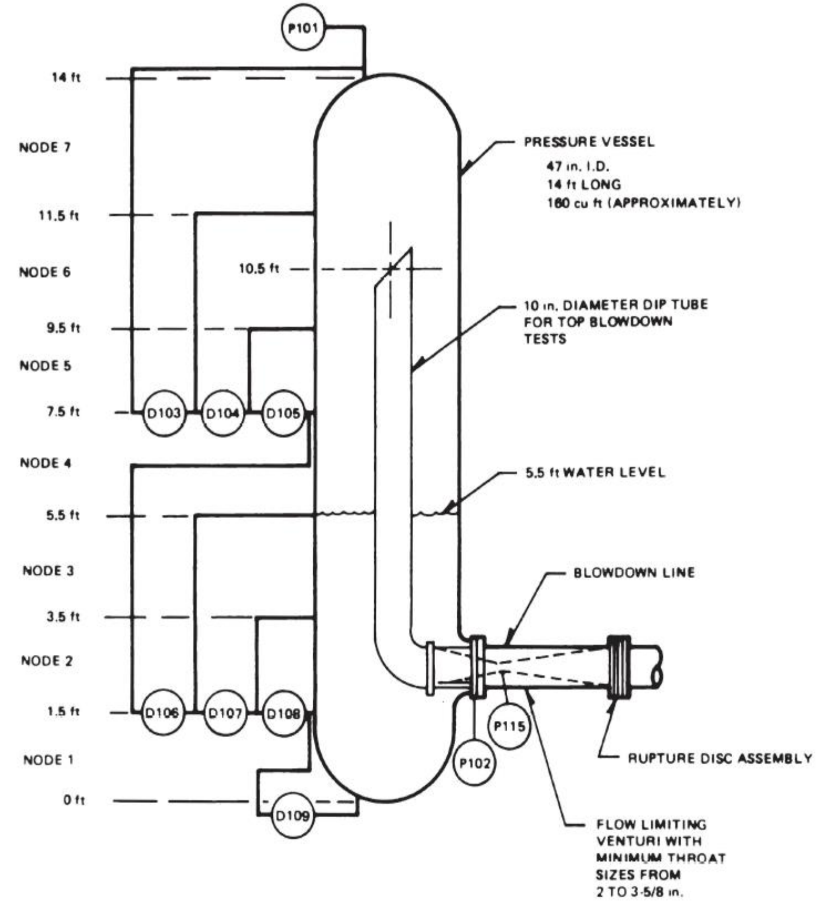




GE Level Swell Four Foot Test

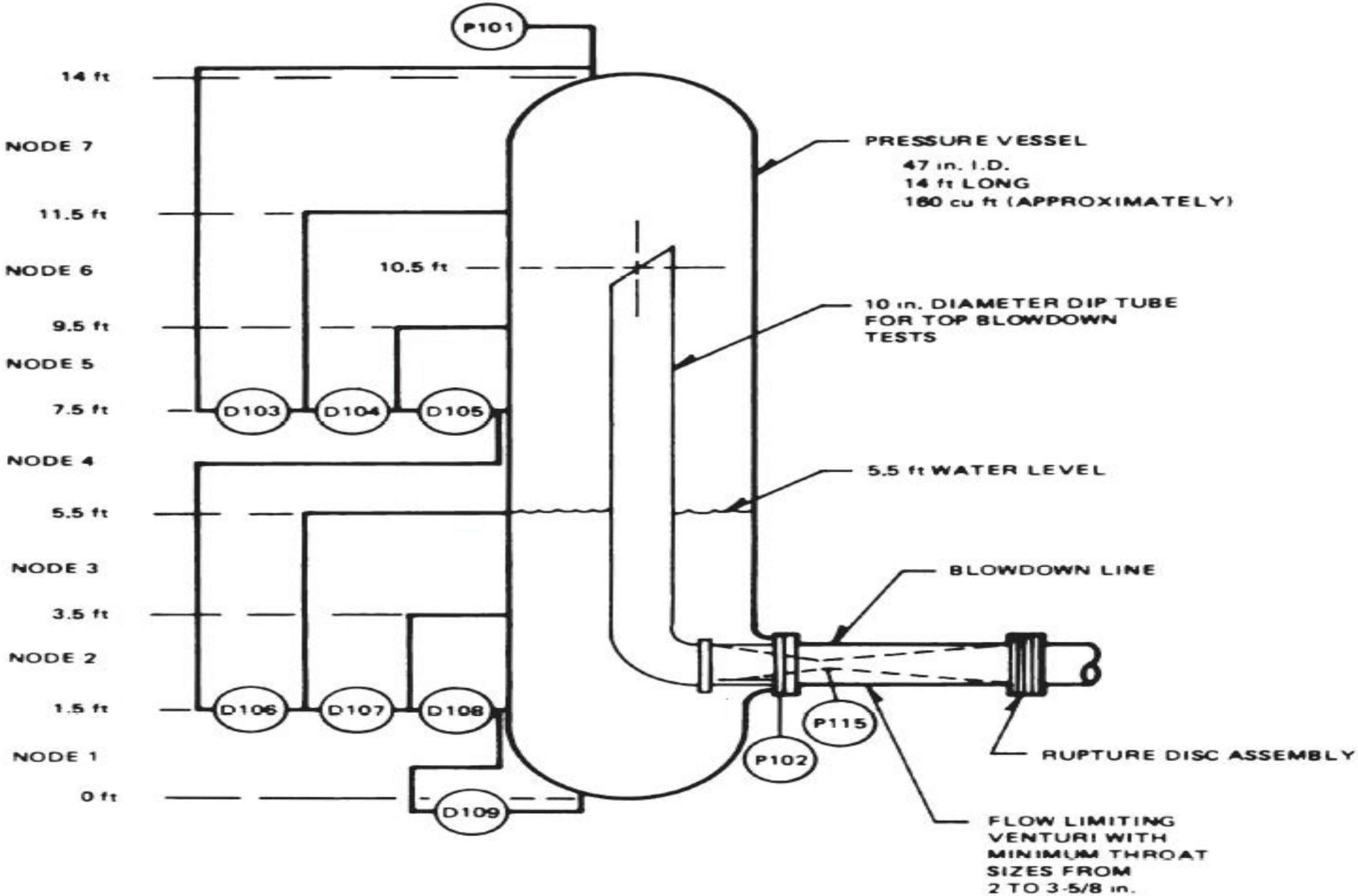
Validation

GE conducted a series of separate-effects blow down tests during the 1970s to study transient swell phenomena in two-phase water mixtures. Test number 5801-15 was performed in a four-foot d Large Blow down Vessel.

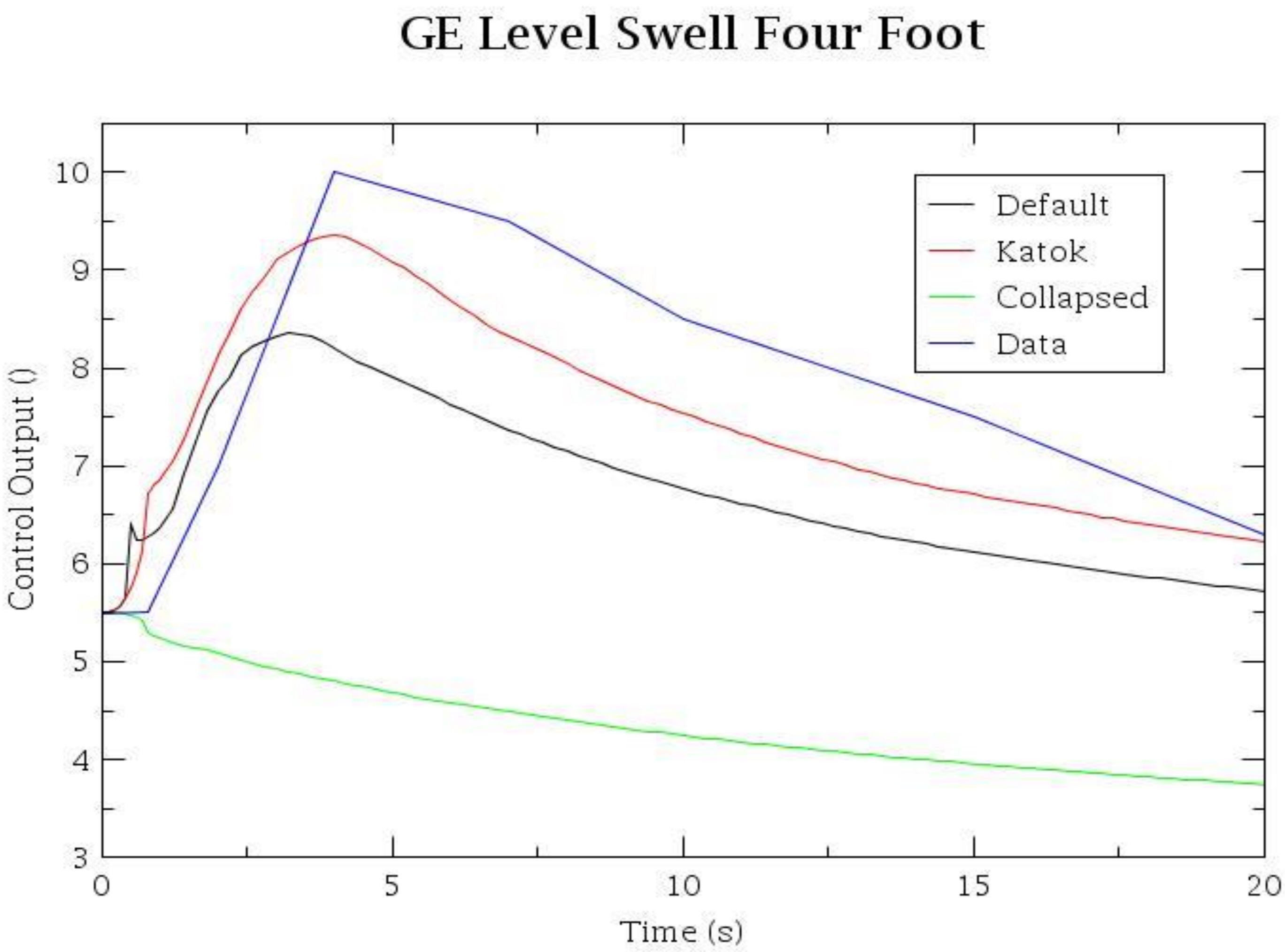


The initial conditions for all top-break, large-tank GE level swell tests were a system filled to a level of 5.5 ft (1.68 m) with demineralized water at a pressure of 1060 psia (7.28MPa) and a fluid temperature corresponding to the saturation temperature at this pressure, 561.9K (551.7^{o}F). Before initiating the various blowdowns, the system was allowed to 'soak' for thirty minutes to equalize the temperature in the fluid and structural material. The blowdowns were initiated by a rupture disk assembly connected to the downstream.

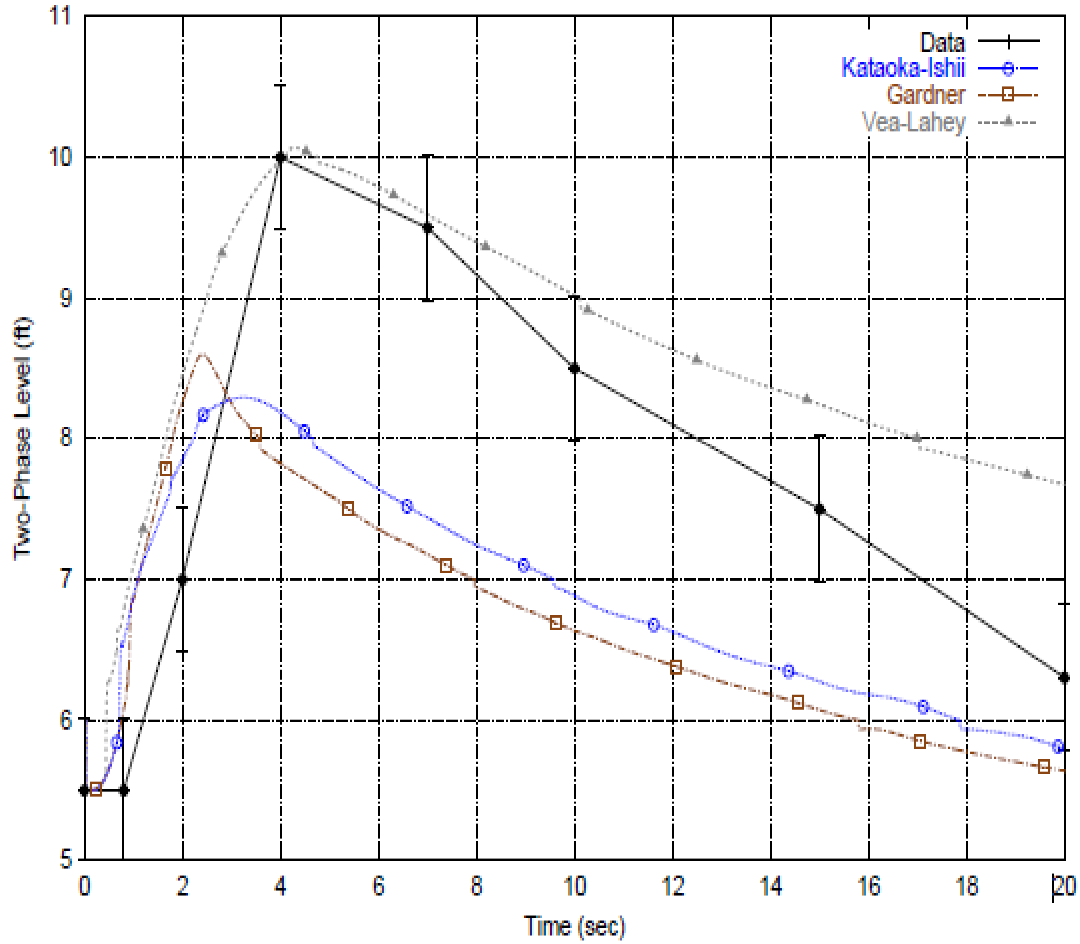
GE Level Swell Four Foot Test



Level with Kataoka Ishsii



Level without corrected Kataoka Ishsii



Nonproprietary

Summary

- Correction and Modification of Kataoka-Ishii Correlation gives improved results for Mixture Level
- Thought Problems are Illustrative
- Experiments are tougher
- The correlations can affect the numerics – Surprise
- Noteworthy that the default model appears not to have been benchmarked against level experiments at the time
- As always, Additional sensitivity studies need to be performed
- Use Collapsed Liquid Level for Conservatism
- Questions?

GE Level Swell 4 Foot

BWR Refill-Reflood Program—
Model Qualification Task Plan

NP-1527
Research Project 1377-1
NUREG/CR-1899
GEAP-24898

Interim Report, October 1981

Prepared by

GENERAL ELECTRIC COMPANY
175 Curtner Avenue
San Jose, California 95125

Principal Investigators
J. A. Findlay
G. L. Sozzi

GE Level Swell 4 Foot

Two-phase mixture density in the measurement nodes was obtained from the measurements of the axial differential pressure, i.e., hydrostatic head of the fluid. This technique has been used previously for measuring two-phase density during blowdown tests. The density and known volume of the measurement node determines the fluid mass inventory. The average nodal void fraction is determined from the nodal density and thermodynamic properties of the liquid and vapor phases at the system pressure,

$$\overline{\alpha}_i = (\overline{\rho}_i - \rho_f)/(\rho_g - \rho_f)$$

where

$\overline{\alpha}_i$ = Average void fraction in i th node

$\overline{\rho}_i$ = Average mixture density in i th node

ρ_f, ρ_g = Liquid and vapor densities based on pressure in node.

The two-phase mixture level is bracketed by the partially filled measurement node containing the level. The two-phase level can be determined within the node by a linear extrapolation of the two-phase void profile below the level. The level is

GE Level Swell 4 Foot

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The two-phase mixture level is bracketed by the partially filled measurement node containing the level. The two-phase level can be determined within the node by a linear extrapolation of the two-phase void profile below the level. The level is

GE Level Swell 4 Foot

$$Z_z\phi = \frac{L_i\,(\bar{\rho}_i - \rho_g)}{(\bar{\rho}_{i-1} - \rho_g)}$$

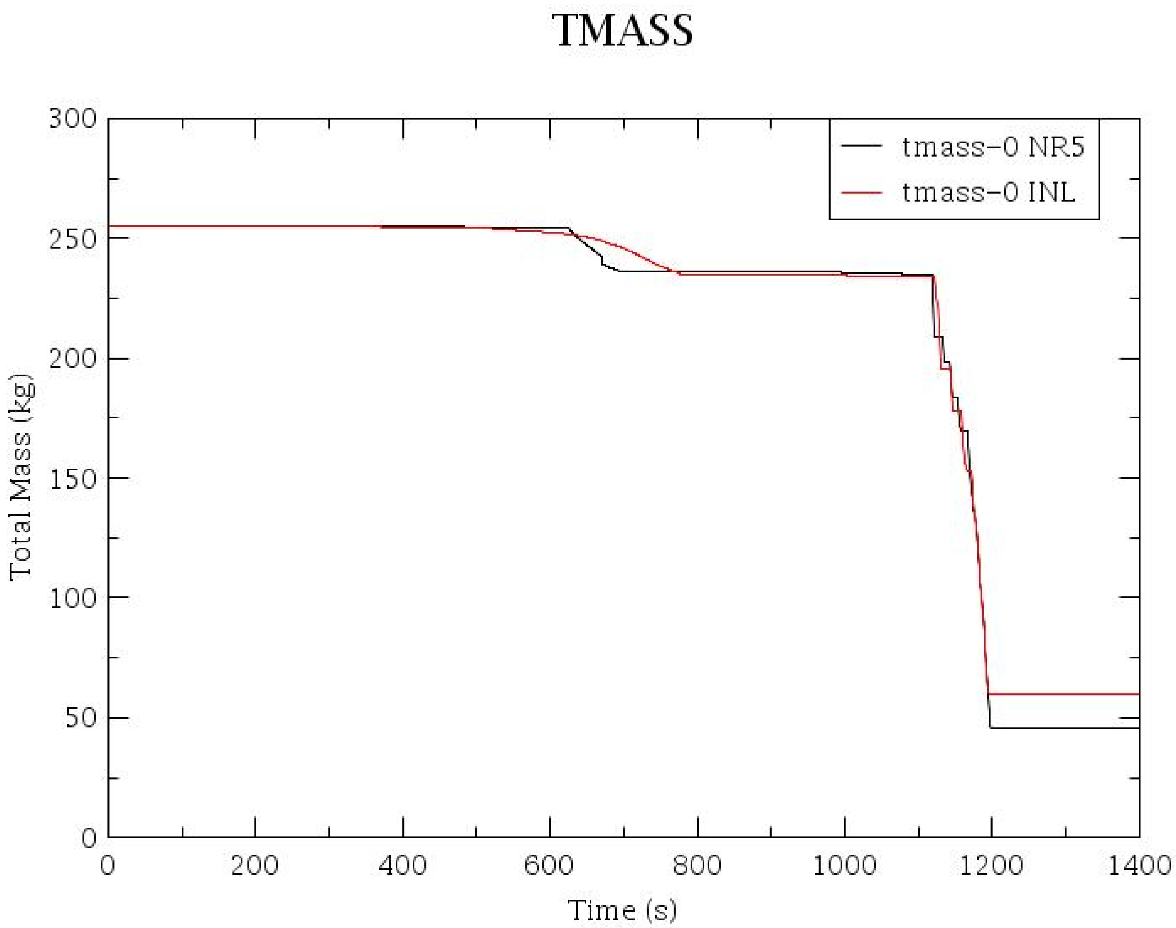
where

$\bar{\rho}_i$ = Average nodal density in partially filled node i,

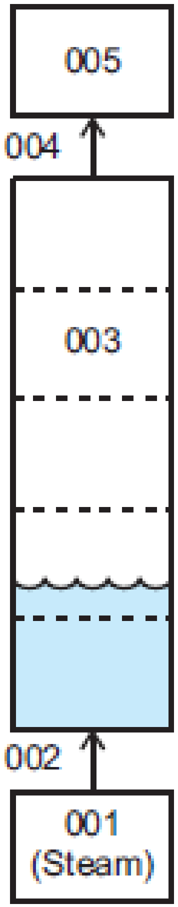
$\bar{\rho}_{i-1}$ = Average nodal density in completely filled lower node (i-1)

L_i = Height of i th node.

Tmass



TMASS
300
250
200
150
100
50
0
0
200
400
600
800
1000
1200
1400
Time (s)
Total Mass (kg)
tmass-0 NR5
tmass-0 INL



005
004
003
002
001
(Steam)

- ## ORNL Benchmarks for NRELAP5

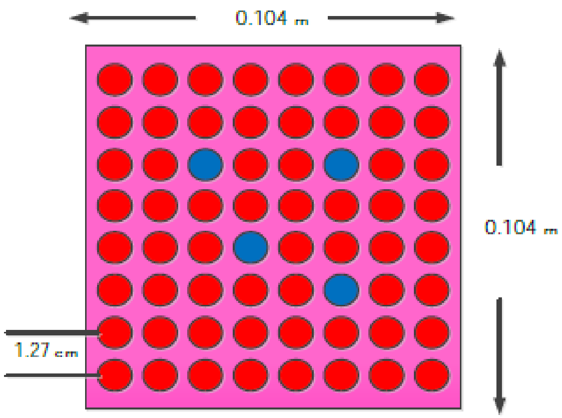
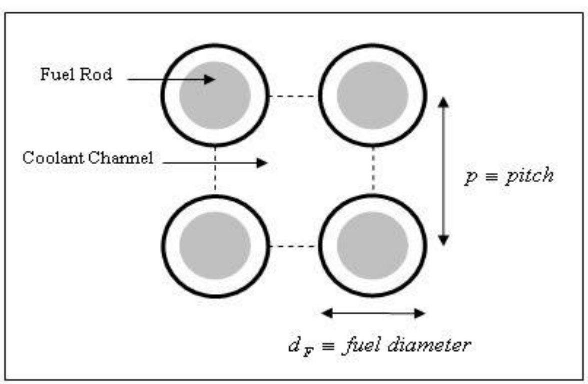
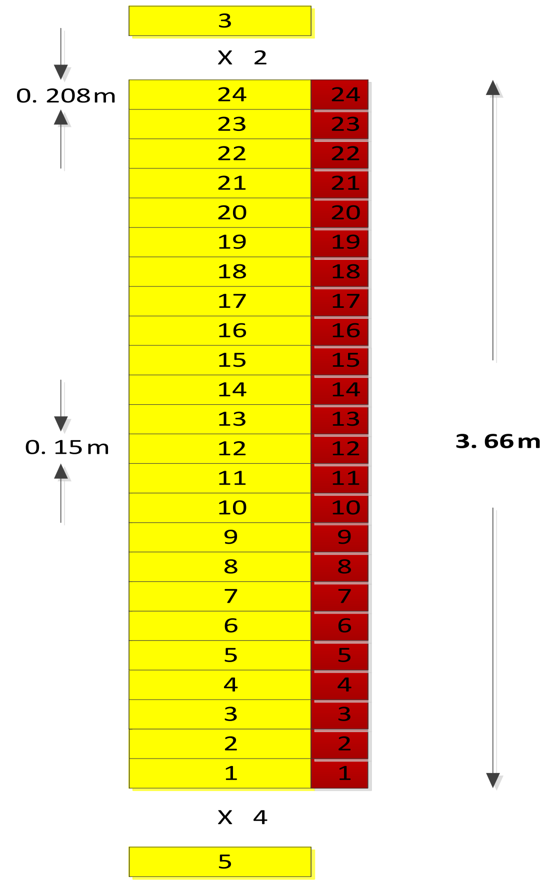


Fig. 1. ORNL bundle geometry

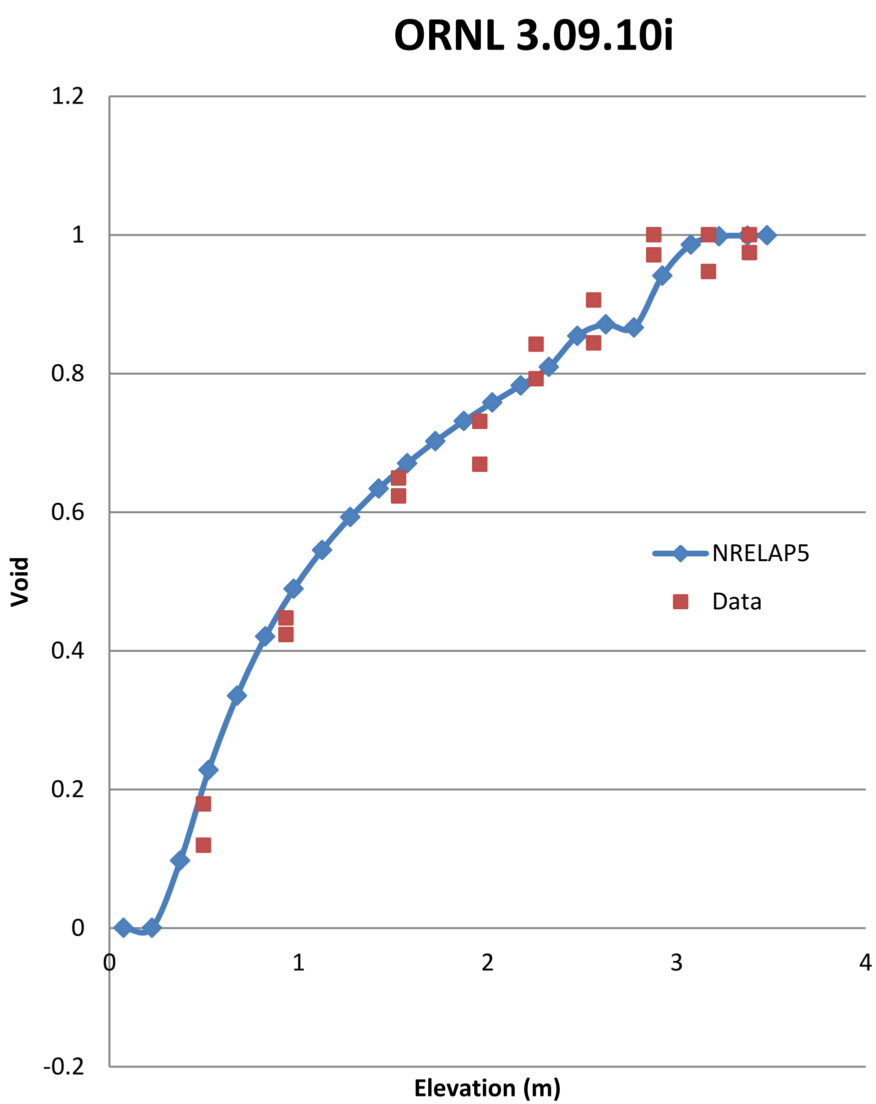
3.09.10 Test	Pressure (MPa)	Inlet Temperature (K)	Mass Flow (Kg/s)	Power (kW)
I	4.50	473.0	0.18396	487.359

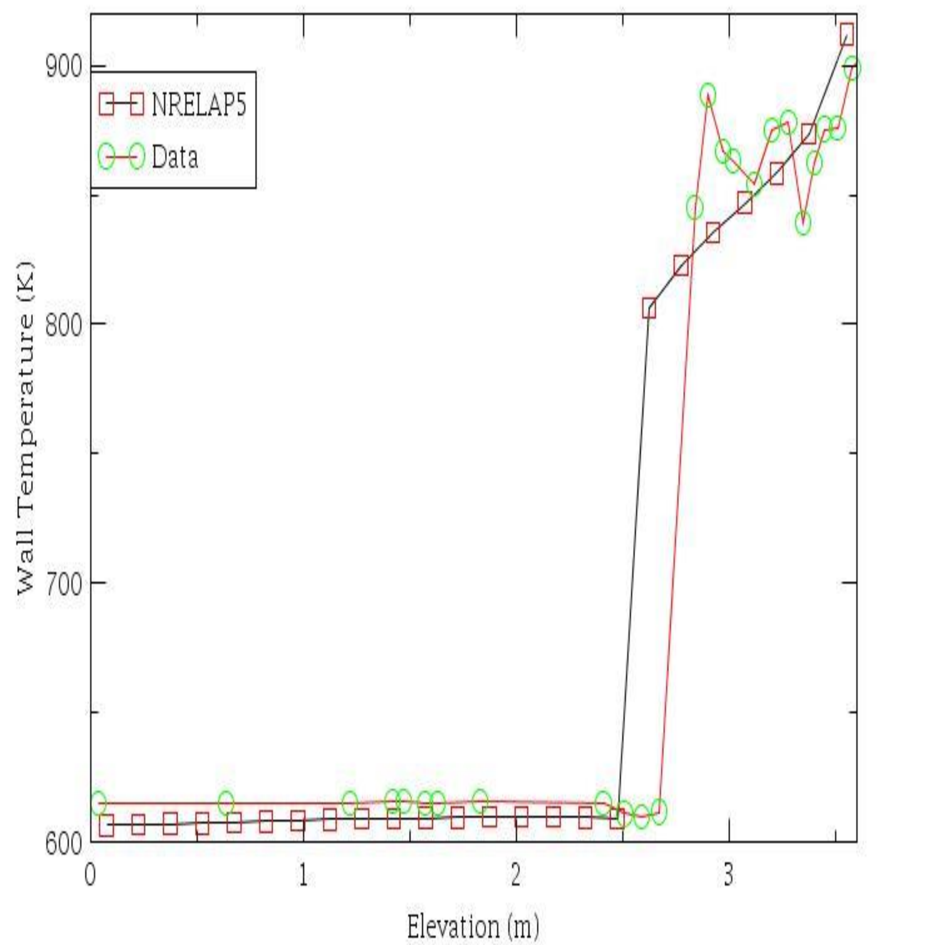




NRELAP5 ORNL 3.09.10I model

Results for ORNL





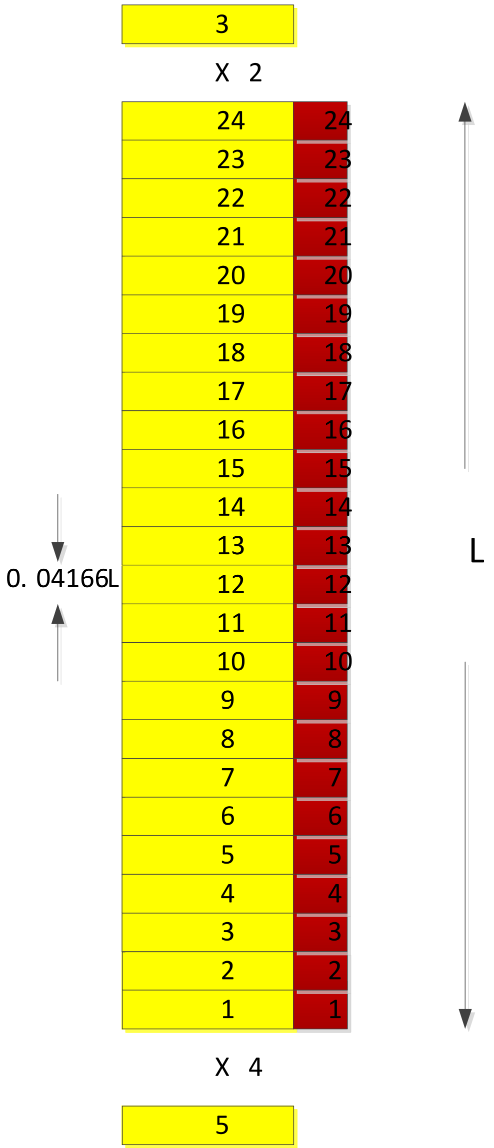
PROCEDURES for TESTS

- The test procedure was to ramp the power slowly to avoid the burnout of heater elements.
- Over longer periods of transient time to steady state, the same procedure was followed during the simulation.
- A time step of 0.05-0.1 seconds was used during 3000.0-4000.0 seconds of transient to steady state using the semi-implicit integration scheme.

Initial and boundary conditions

Test	Pressure Ratio In/Out X	Inlet Temp Ratio	Mass Flow Ratio	Power Ratio
379	1.31/1.26	0.775	0.988	0.736
372	1.27/1.26	0.774	0.15	0.225
389	1.25/1.23	0.75	0.342	0.0004

STERN Lab Test Model



The following Table shows the normalized values for the inlet pressure, temperature, and mass flow and the bundle power with respect to the maximums (M) obtained during the testing. It also shows the bundle power and CHF ratios, along with the NRELAP5 (N5) error predictions.

Case	374	379	389	252	150	375	140	435
Pi/M	.13	.13	.13	1.0	.63	.13	.62	.25
Ti/M	.59	.59	.53	.94	.89	.59	.89	.64
W/M	.34	.59	.34	.45	.25	.44	.25	.27
Pwr/M	.43	.74	.45	.32	.32	.49	.30	.36
CHF/M	.44	.74	.46	.32	.33	.50	.32	.36
N5 % Errror	13.	13.	12.	5.	7.	12.	18.	33.

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