FPL

10 CFR 50.4
L-2006-241
October 17, 2006

Attn: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Turkey Point Unit 3
Docket No. 50-250
Significance Determination Regarding a Loss of Power to an Operating Residual Heat Removal Pump - Additional Information Regarding Gothic Analysis

References:
1) NRC Letter, Mr. C. A. Casto to Mr. J. A. Stall, Turkey Point Nuclear Plant – NRC Integrated Inspection Report 05000250/2006015; EA-06-200, Preliminary White Finding, dated August 24, 2006
2) FPL letter L-2006-239 to the NRC dated October 13, 2006, Additional Information Pertaining to Regulatory Conference on Turkey Point Preliminary White Finding Held October 10, 2006
3) FPL letter L-2006-240 to the NRC dated October 17, 2006, Presentation Material Pertaining to Regulatory Conference on Turkey Point Preliminary White Finding Held October 10, 2006

In Reference 1 the NRC documented a preliminary white finding related to a loss of power to an operating residual heat removal (RHR) pump that occurred at Turkey Point Unit 3 in March 2006. Florida Power and Light Company (FPL) representatives met with the NRC staff at a regulatory conference held on October 10, 2006 to present the NRC with additional information related to the finding. At the conference, the NRC staff requested additional information which was provided by Reference 2. The material presented at the conference was provided by Reference 3.

On October 16, 2006, FPL was requested to provide additional information regarding the GOTHIC thermal-hydraulic analysis performed in response to the loss of RHR event. This request was made through the NRC Senior Resident Inspector to the FPL Turkey Point Licensing Manager. Attached to this letter is the response to the information request regarding the thermal-hydraulic analysis.

If there are any questions regarding this request, please contact James Connolly at 305-246-6632.

Very truly yours,

Michael O Burce FOR

Terry O. Jones
Vice President
Turkey Point Nuclear Plant

cc: Regional Administrator, Region II, USNRC.
Senior Resident Inspector, USNRC, Turkey Point

A001

FLORIDA POWER AND LIGHT COMPANY

RESPONSE TO NRC INFORMATION REQUEST FROM REVIEW OF TURKEY POINT DECAY HEAT REMOVAL DATED OCTOBER 4, 2006 GOTHIC ANALYSIS PERFORMED FOR UNIT 3 LOSS OF RESIDUAL HEAT REMOVAL FLOW EVENT

REVISION 0

October 17, 2006

Prepared by: _____ Date: 17 OCT 06

Reviewed by: _____ Date: 17 OCT 06

Reviewed by: _____ Date: 17 Oct 06

RESPONSE TO NRC INFORMATION REQUEST FOR NEXT REVISION OF SIGNIFICANCE DETERMINATION PROCESS RISK-INFORMED INSPECTION NOTEBOOK

PURPOSE

Reference 1 transmitted specific requests for GOTHIC modeling and analysis information regarding the Turkey Point (PTN) Unit 3 loss of residual heat removal event of March 08, 2006. The following provides the responses to these questions for transmittal to NRC.

The information requested is only for clarification of already existing analyses developed for Turkey Point Unit 3. No modifications were made to the design of Safety Related items which are necessary to assure the integrity of the reactor coolant pressure boundary, the capability to shutdown and maintain the reactor in a safely shutdown condition, or the capability to prevent or mitigate the consequences of accidents that could result in offsite exposures comparable to 10CFR100 levels. Consistent with previous PSA-related insights to risk-informed applications, this evaluation is classified as Quality Related.

These responses were based on input from Numerical Applications Inc. and Westinghouse Electric Co.

NRC Request Paragraph 1.0:

Please identify the decay heat curve used in the analysis and the core power level. The nodalization diagram does not show the level of nodal detail in the vessel; particularly the core, upper plenum, and hot legs. Are the core, upper plenum, and hot leg regions represented each with a single cell or are these regions axially segmented to properly tract the large void gradients in these regions? Does GOTHIC have a level tracking model? What flow regimes are encountered in the hot legs during these events? How is countercurrent flow modeling in GOTHIC and what limits are placed on this flow behavior? Please explain.

FPL Response:

The decay heat curve used for this analysis was a best estimate based on Reference 2 assuming actual cycle power history and event initiation at 64 hours after shutdown from a 50% power level held for 24 hours.

The GOTHIC nodalization used in this model primarily consists of single cell components. The vessel model is subdivided to show the lower plenum, core region and upper plenum. This nodalization was selected because the event being analyzed occurs several days after reactor shutdown with the system already vented and depressurized. As such, the transient with no Safety Injection progresses as a boiloff/slow mixing event. Since both the vessel and pressurizer are vented, any flow through the hot legs which does occur is a result of the density differences between the top of the core and the liquid which is pushed up into the steam generator U-tubes. Therefore, fluid velocities are very small, and large void gradients do not develop. For analysis cases 2 and 3 with Safety Injection, voiding does not occur. The flow path nodalization utilized for this analysis does include junctions connected at the top and bottom halves of the hot legs to both the vessel and the steam generator steam generator volumes. This modeling approach enables the density differences to drive countercurrent flow through the system.

GOTHIC calculates the liquid and vapor fraction in each volume. The level in each volume is determined by the product of the liquid volume fraction and the volume height. This collapsed liquid level can be selected for display for any volume.

NRC Request Paragraph 2.0:

For each of the cases show the void fraction vs time in the following components:

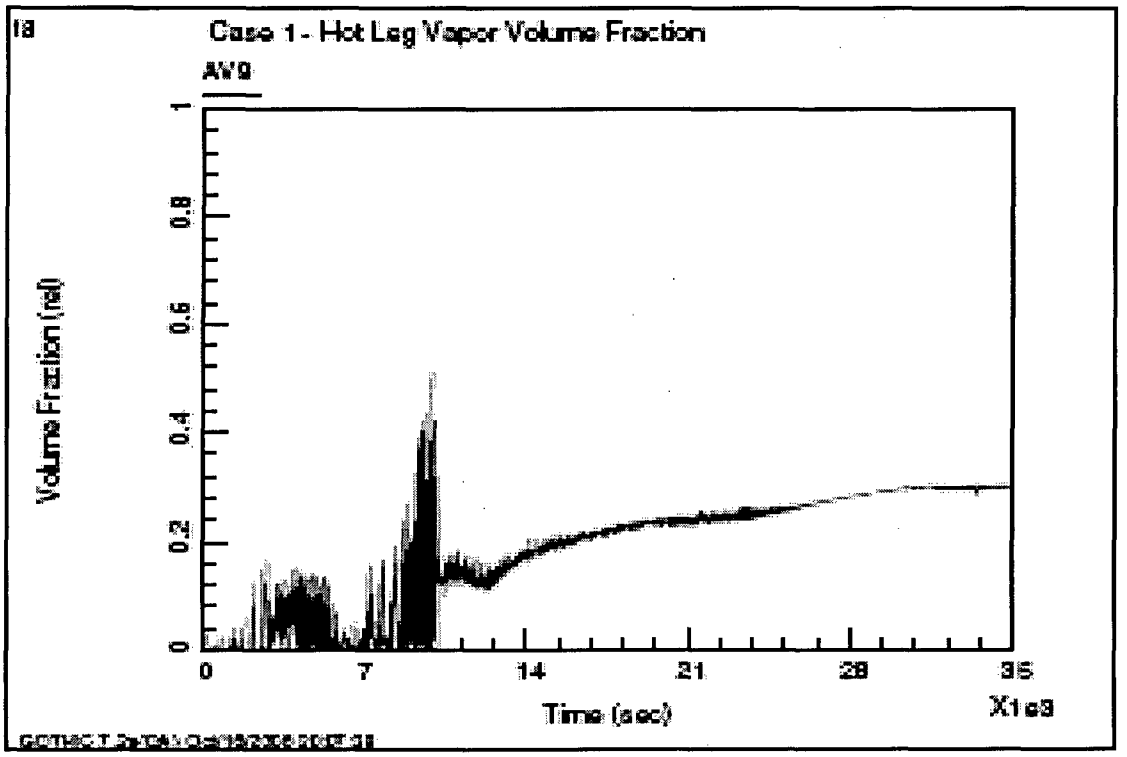
- *core (show the axial void distributions in the core vs time).*
- *hot legs*
- *upper plenum adjacent the hot legs*

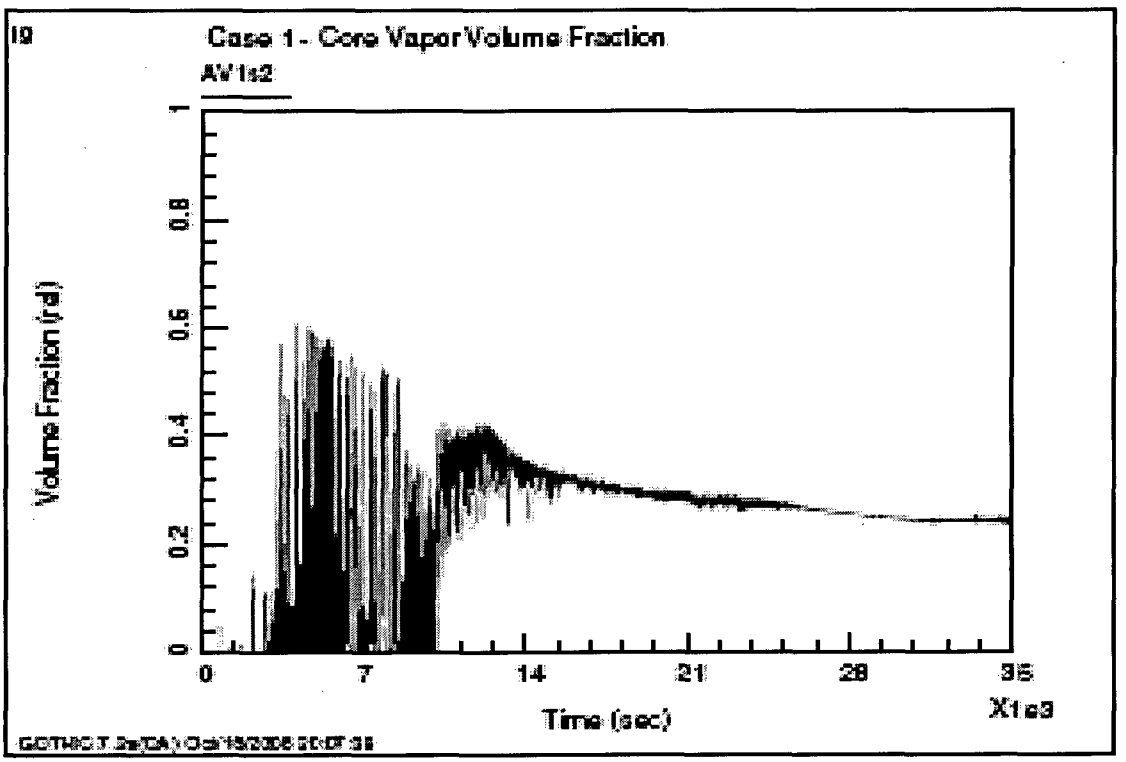
Are the Figures labeled hot leg level and vessel level, liquid levels or two-phase levels? If not please provide the two-phase level plots in the upper plenum and hot legs vs time. Does the nodalization/code allow a void gradient to develop along the hot legs from the upper plenum to the location of the RHR line? How is countercurrent flow and entrainment in the hot legs model/simulated? Please explain.

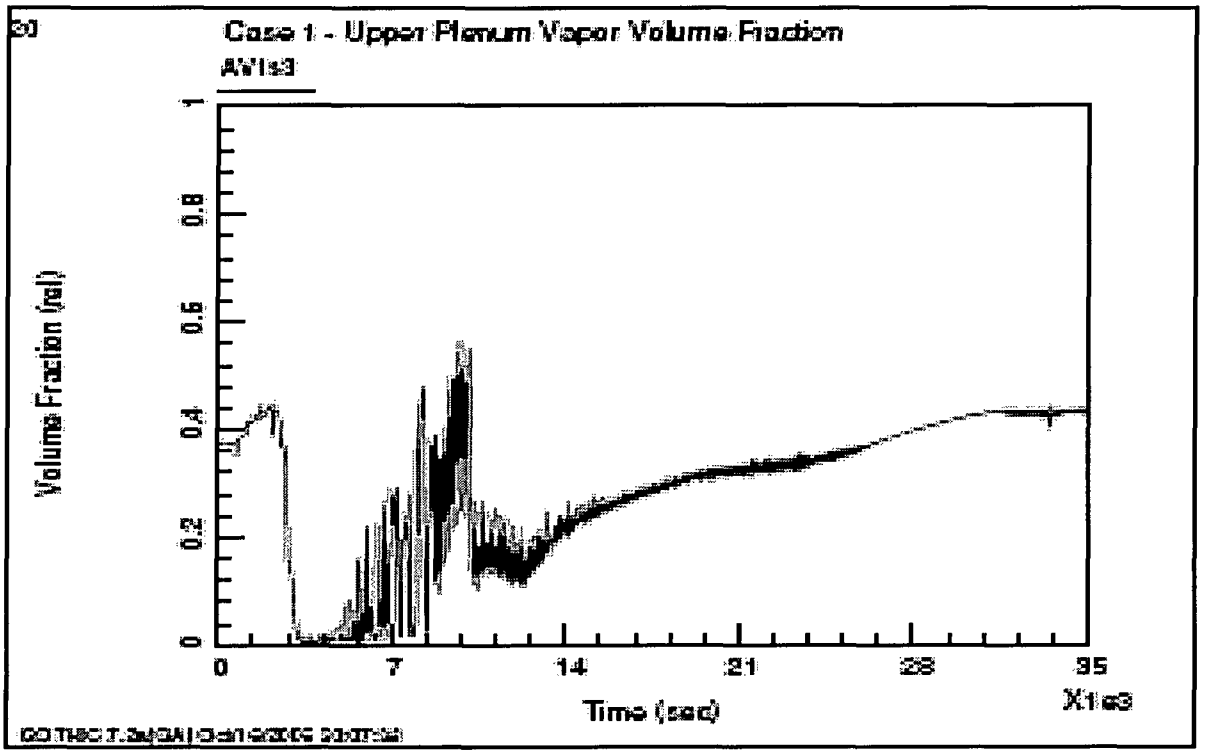
FPL Response:

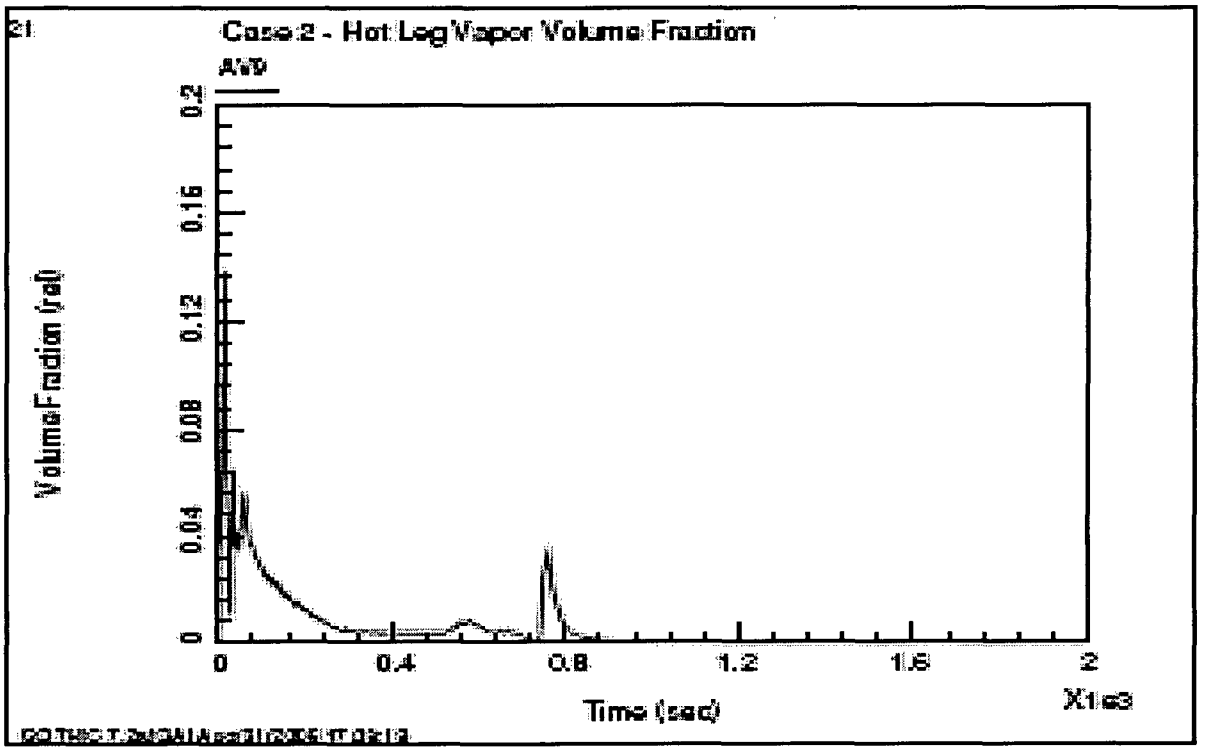
The requested figures are provided on the following pages for all three cases analyzed. Note that the vapor void fraction includes both steam as well as air. Therefore, since the vessel is drained to the elevation of the flange at the beginning of the event, the initial void fraction in the upper plenum is approximately 40%. However, there is no mechanism to draw air from the vessel or U-tubes into the hot legs. The liquid levels calculated by GOTHIC represent collapsed liquid levels. 'Two-phase' or 'mixture level' plots are not available, however such plots would not be meaningful since the hot legs are not being emptied during the first nine hours of Case 1. In fact, due to the heating and pressurization of the RCS, the collapsed liquid level on the primary side of the steam generators, which is initially set at the elevation of the tube sheet, rises into the lower region of the U-tubes to enable heat transfer to the secondary. For the figures depicting the results of cases 2 and 3, note that the time frames cover not more than the first hour since any voiding occurs only during this time frame. For discussion of steam entrainment into the RHR pump suction, refer to the response to NRC Request Paragraph 4.0.

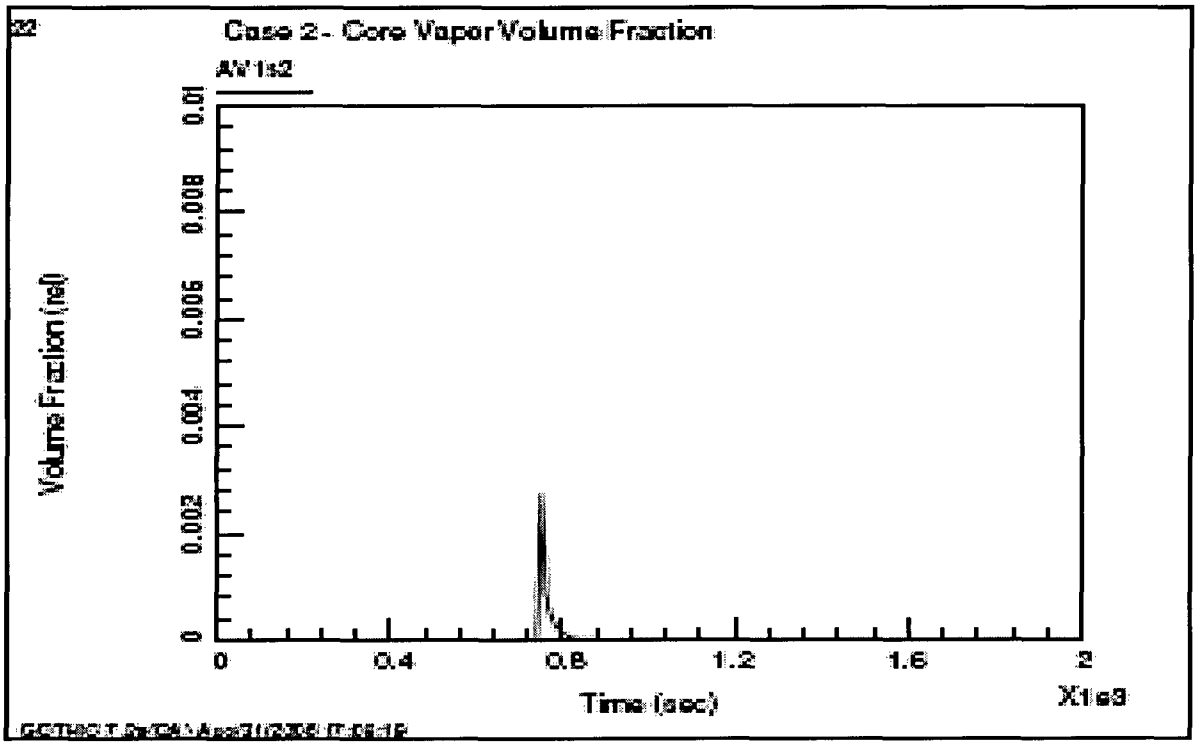
As described in the response to NRC Request Paragraph 1.0, countercurrent flow occurs due to the parallel flow paths employed. Entrainment is function of inter-facial drag, which is accounted for within flow paths by GOTHIC.

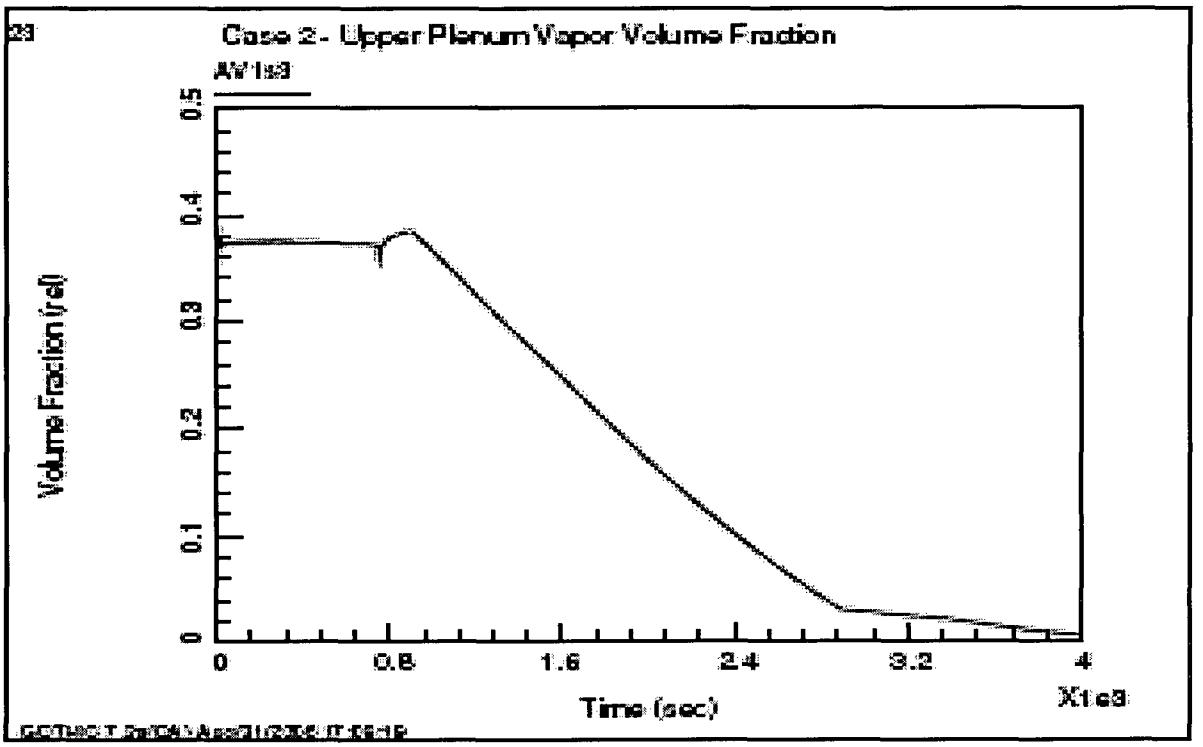

18
Case 1 - Hot Leg Vapor Volume Fraction
AV9
Volume Fraction (rel)
0
0.2
0.4
0.6
0.8
1
0
7
14
21
28
35
Time (sec)
X1e3

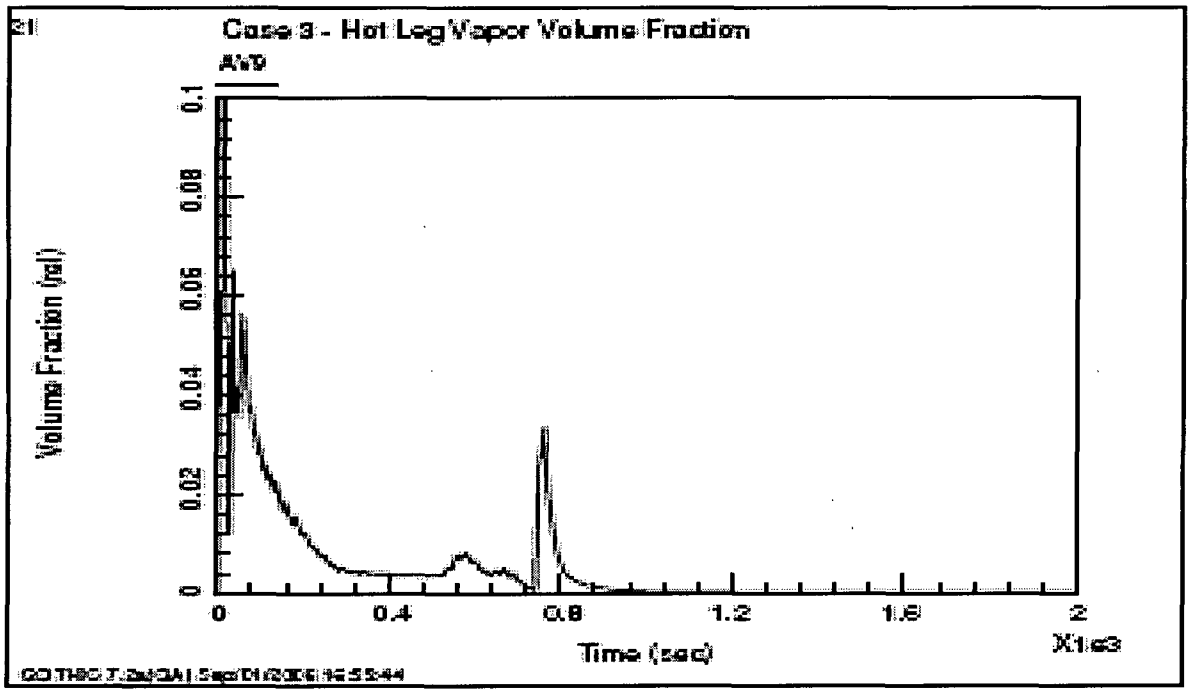

19
Case 1 - Core Vapor Volume Fraction
AV1s2
Volume Fraction (rel)
0
0.2
0.4
0.6
0.8
1
0
7
14
21
28
35
Time (sec)
X1e3

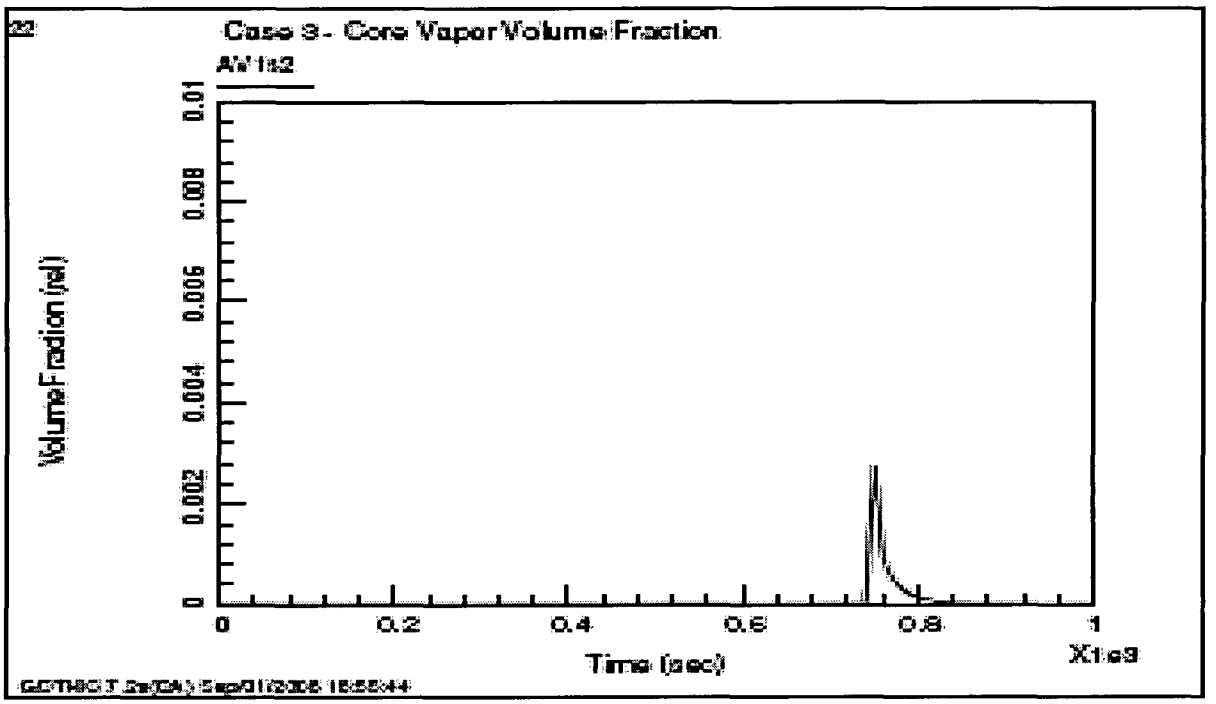

20
Case 1 - Upper Plenum Vapor Volume Fraction
AVI:3
Volume Fraction (rel)
0
0.2
0.4
0.6
0.8
1
0
7
14
21
28
35
Time (sec)
X1e3

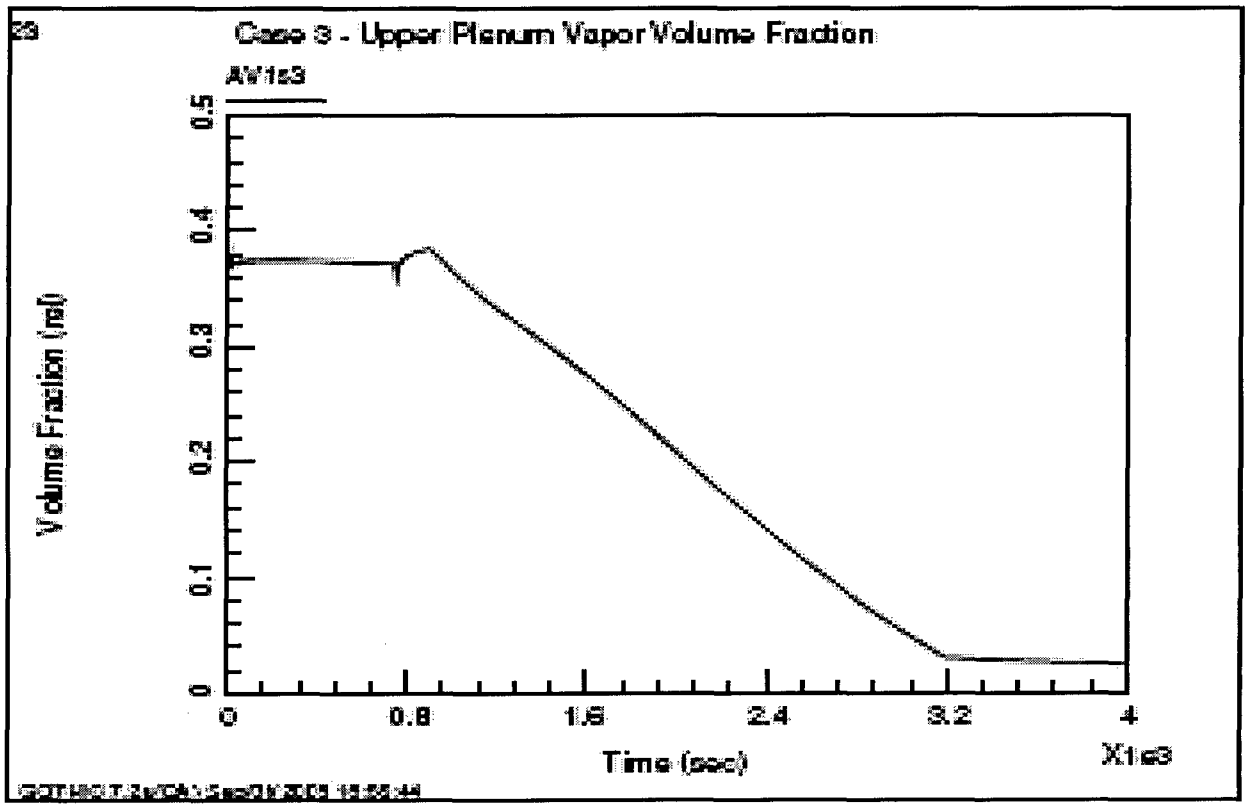

21
Case 2 - Hot Leg Vapor Volume Fraction
AVI9
Volume Fraction (rel)
0
0.04
0.08
0.12
0.16
0.2
0
0.4
0.8
1.2
1.6
2
Time (sec)
X1e3


22
Case 2 - Core Vapor Volume Fraction
AV1s2
Volume Fraction (rel)
0
0.002
0.004
0.006
0.008
0.01
0
0.4
0.8
1.2
1.6
2
Time (sec)
X1e3


23
Case 2 - Upper Plenum Vapor Volume Fraction
AV1s3
Volume Fraction (rel)
0
0.1
0.2
0.3
0.4
0.5
0
0.8
1.6
2.4
3.2
4
Time (sec)
X1e3


21
Case 3 - Hot Leg Vapor Volume Fraction
AV9
Volume Fraction (rel)
0
0.02
0.04
0.06
0.08
0.1
0
0.4
0.8
1.2
1.6
2
Time (sec)
X1:e3


22
Case 3 - Core Vapor Volume Fraction
AV 1:2
Volume Fraction (rel)
0
0.002
0.004
0.006
0.008
0.01
0
0.2
0.4
0.6
0.8
1
Time (sec)
X1:e3


Case 3 - Upper Plenum Vapor Volume Fraction
AV1e3
Volume Fraction (nd)
0
0.1
0.2
0.3
0.4
0.5
0
0.8
1.6
2.4
3.2
4
Time (sec)
X1e3

NRC Request Paragraph 3.0:

Please explain how heat transfer in the steam generator develops. Does the steam compress the non-condensables into the upper portions of the active tubes or is the steam mixed with the non-condensables? How is heat transfer modeled between the primary and secondary? Are the heat transfer and film coefficients level/region dependent? Explain how condensation is calculated in the steam generators, particularly when the two-phase level change on both sides. Is heat transfer from the non-condensable region modeled? Please explain.

FPL Response:

Steam will mix with the non-condensable gasses in the vapor portion of the tubes, and the vapor region will be compressed as liquid is forced into the tubes. This compression of the gases has a significant role in Case 2 after the Safety Injection pump is started, which restores the liquid level in the tubes sufficiently to allow natural circulation to occur. Standard GOTHIC heat transfer options were applied. The selected heat transfer option on the primary side of the steam generators was limited to convection into the continuous liquid phase. On the secondary side, a GOTHIC heat transfer model was selected which applies condensation to dry portions of surfaces and convection to wet portions of surfaces as applicable. This same option will also use boiling heat transfer if the surface temperature is greater than saturation. In this event, the steam generator inventory is sufficiently high that drying of the surfaces would not be expected to occur, which would preclude condensation heat transfer from taking place.

NRC Request Paragraph 4.0:

What is the void fraction in the hot legs at the time RHR is placed in service? What void fraction will cause cavitation of the RHR pumps? Please show that the conditions in the hot legs will not preclude operation of RHR at the actuation times and that the GOTHIC code properly models the void distributions expected in the upper plenum and hot legs.

FPL Response 4:

Reference 3 documents the results of investigations of vortexing considerations for RHR suction lines in the hot legs of Westinghouse PWRs. That report discusses individual plant tests and scale model tests to determine the minimum hot leg level for RHR operation. The required level is based on the more limiting of that level at which air is ingested on a continuous basis but not more than 2% by volume of intake flow rate or the level at which air is ingested in sporadic gulps which do not exceed 5% by volume of intake flow. For the Turkey Point hot leg and RHR suction geometry, the required hot leg level is 25.9 feet at maximum RHR flow (approximately 3.3 inches above hot leg mid-loop). During the transient, the collapsed liquid level is maintained above this required hot leg level thus vortexing is avoided.

Investigation of the NPSH requirements for the Turkey Point RHR pumps at 3700 gpm indicates that the elevation head is sufficient to provide the required NPSH without credit for RCS pressure (assuming that RCS pressure is equal to saturation pressure). Note that the RHR pumps are located approximately 28 feet below the hot leg mid-loop elevation.

Hot leg void fractions are presented in the response to NRC Request Paragraph 2.0 above. RHR can be assumed to be placed into service at any time during the time lines presented in the analysis.

NRC Request Paragraph 5.0:

Please describe and present the benchmarking and validation effort for GOTHIC to demonstrate that the code can successfully predict key phenomena including the prediction of two-phase level swell, axial void distributions in the core, upper plenum, and hot leg regions during periods of voiding characteristic of this event. Please describe the separate effects and integral tests used to validate GOTHIC.

FPL Response:

Extensive benchmarking of the standard GOTHIC models for heat transfer, two-phase flow, and non-condensable gas behavior has been performed and is documented in EPRI Report NAI-8907-09, GOTHIC Containment Analysis Package Qualification Report. Attachment 1 to this response presents a summary of this qualification effort. Note that NRC has approved the use of GOTHIC for Containment analyses and has also approved the use of GOTHIC by Dominion to perform Mass and Energy Release calculations (SER dated August 30, 2006).

Westinghouse developed generic plant models that include RHR system models, RCPs, thermal conductors, and steam generators models. A series of functional tests were performed with each of the new plant models to verify that they were capable of modeling the phenomena of interest during transients at shutdown. The results from the functional tests were reasonable and demonstrated that the generic plant models were able to adequately modeled the important shutdown phenomena.

Model validation testing was performed to qualify the capability of the GOTHIC code and the generic plant model noding structure for modeling the important phenomena during shutdown events. Both standalone and system models for the FLECHT SEASET test facility were constructed. Results from these models (generated using GOTHIC Version 6.1P) were compared with FLECHT SEASET test data covering several major modes of operation, including single-phase natural circulation, two-phase natural circulation and reflux condensation with helium gas injection. The model results compared well with test data in the single-phase and two-phase natural circulation cooling modes. The model exhibited the expected overall behavior under reflux condensation conditions as well. The results of these data comparisons provided validation for the GOTHIC FLECHT SEASET model under single-phase and two-phase natural circulation conditions and form a basis for the full scale shutdown analysis plant models operating in those cooling modes. To calculate the proper two-phase flow in natural circulation, the code must provide a reasonable calculation of the void distribution in the upper plenum, hot legs and SG tubes.

Note that GOTHIC has been used extensively for analysis of Pressurized Water Reactor shutdown operations as documented in References 4, 5 and 6.

NRC Request Paragraph 6.0:

What sensitivity studies were performed to justify the model and the adequacy of the simulations? What time steps were used in the analyses? Please discuss the sensitivity of the results to the manner in which the void fraction is determined (flow regimes and drag modeling of void in two-phase regions)? Please explain.

FPL Response 6:

The impact of changes to model parameters such as noding and heat transfer options was not evaluated. GOTHIC automatically calculates a time step size to be used at each time step that falls within the range selected by the user. GOTHIC determines the time step size based on solution stability (e.g., flow and phase change Courant limits, avoiding large variations in calculated parameters, oscillations in gravity-driven systems, etc.). A minimum time step of 0.0001 was applied in all cases.

REFERENCES

1. NRC to Turkey Point Licensing information request of October 16, 2006, Subject: "Review of Turkey Point Decay Heat Removal Dated October 4, 2006 GOTHIC Analysis".

2. "Residual Decay Energy for Light-Water Reactors for Long-Term Cooling", Branch Technical Position ASB 9-2, Standard Review Plan, NUREG-0800, Rev.2, July 1981.

3. WCAP-11916, Rev. 0, "Loss of RHRS Cooling While the RCS is Partially Filled," Westinghouse Electric Corp., July, 1988.

4. WCAP-14089, Rev. 1, "Analyses to Develop a Basis for Surge Line Flooding Response to Support Shutdown Operations", Westinghouse Electric Corp., 1994.

5. WCAP-14988, Rev. 0, "Use of GOTHIC Computer Code for Analyses to Support Shutdown Operations", Westinghouse Electric Co., April, 1998.

6. WCAP-15145, Rev. 0, "Development and Testing of Generic Plant Models with the GOTHIC Computer Code for Analyses to Support Shutdown Operations", Westinghouse Electric Co., February, 1999.

Attachment 1 (page 1 of 13)
GOTHIC Validation Test Matrix

22 GOTHIC VALIDATION TEST MATRIX

The majority of code validation that has been performed for GOTHIC is documented in the preceding sections of this qualification report. Additional validation information comes from the individual action reports that are completed each time a change is made or a new model is added to GOTHIC. The action reports include any testing that was performed to validate the new model. Some, but not all, of the validation tests included in action reports are also documented in the qualification report. A third source of validation documentation is contained in reports published by GOTHIC users.

The validation matrix which follows provides a summary of GOTHIC validation tests from the three sources listed above. The matrix is in spreadsheet form, with phenomena of interest as column headings and validation tests as rows. Tests identified as GSP # are GOTHIC standard problems that were developed to test GOTHIC capabilities. Only quantitative comparisons with analytical or experimental results are included in the validation matrix. Tests that provide only qualitative results, some of which are documented in previous sections of the qualification report, are not included in the validation matrix.

The listed phenomena were identified by a review of the GOTHIC Technical Manual. Some very basic phenomena such as mass, energy and momentum conservation and equations of state are not listed because they are fundamental to all of the other modeled phenomena and therefore implicitly included.

The validation tests can be classified as analytic, separate effects or combined effects. The analytic tests compare the code results to generally accepted analytic solutions to the governing physical laws or to a correlation fit to experimental data. The separate effects tests have primary focus on a single phenomenon with other phenomena possibly playing minor roles. The combined effects tests measure selected system parameters in tests where multiple phenomena play significant roles, possibly at different times in a transient test. Some of the validation tests also represent comparisons with multiple test runs in an experimental program designed to study various aspects of a particular problem. The heavy line across the lower part of the matrix divides the combined effects tests from the separate and analytic tests.

The matrix cells identify the significant phenomena for each test. An 'x' in a particular row indicates that test provides validation for the phenomenon identified by the corresponding column label. There is also a number located above each column heading on the first page of the matrix to identify the total number of tests that apply to that particular phenomenon. Note that some of the tests represent comparison with two or more experiments but that only one test is credited in the validation tally. For those phenomena marked with a zero in the top row, none of the tests currently identified in the matrix provide significant validation for the phenomenon. The validation tally is also shaded to indicate the testing coverage. No shading for phenomena with no relevant testing, light shading for 1 test, medium shading for 2 to 4 tests and dark shading for 5 or more relevant tests.

Attachment 1 (page 2 of 13)
GOTHIC Validation Test Matrix

	Test	Drop Entrainment	Drop Deposition	Drop Settling	Drop Breakup	Drop Evaporation	Drop Condensation	Drop Agglomeration	Mist Generation	Mist Depletion	Pressure Wave Propagation	Surface Wave Propagation	Impact Loads	Drag Loads	Pressure Drop/ Single Phase	Pressure Drop/ Bubbly Flow	Pressure Drop/ Film Drop Flow	Pressure Drop/ Stratified Flow	Pressure Drop/ Slug Flow	Stratified Flow Transition to Slug
1	Drop Entrainment	x	x																	
2	Drop Settling Velocity			x																
3	Jet and Drop Breakup				x															
4	Drop Heat and Mass Transfer					x														
5	GSP 27 - Heat Transfer Options																			
6	GSP 14 - CSNI Numerical Benchmark																			
7	Horizontal Cylinder in A Rectangular Cavity																			
8	GSP 25 - Thermal Conduction In Solids																			
9	Conductor Surface-to-Surface Radiation																			
10	Thermal Diffusion in Vapor and Liquid																			
11	GSP 37 - UofW Flat Plate Condensation																			
12	Mist/Diffusion Layer Model for Wall Heat and Mass Transfer								x	x										
13	Grout Mold Evaporation Experiments																			
14	GSP 1 - Natural Circulation														x					
15	Vertical and Horizontal Openings														x					

Attachment 1 (page 3 of 13)
GOTHIC Validation Test Matrix

	Test	DropEntrainment	DropDeposition	DropSettling	DropBreakup	DropEvaporation	DropCondensation	DropAgglomeration	Mist Generation	Mist Depletion	Pressure Wave Propagation	Surface Wave Propagation	Impact Loads	Drag Loads	Pressure Drop/ Single Phase	Pressure Drop/ Bubbly Flow	Pressure Drop/ Film Drop Flow	Pressure Drop/ Stratified Flow	Pressure Drop/ Slug Flow	Stratified Flow Transition to Slug
16	Thermally Driven Cavity																			
17	GSP 2 - Hydrogen Injection Into Air																			
18	GSP 3 - Air Compression																			
19	Turbulence Generated by A Square Grid																			
20	Flow in A Rectangular Duct																			
21	Plane Jet																			
22	GSP 23 - Choked Flow																			
23	Stratified Flow																			x
24	Hydrogen Burn Tests																			
25	Flame Facility Experiments																			
26	Nevada Test Site Experiments																			
27	GSP 6 - Pump Performance														x					
28	GSP 7 - Single Heat Exchanger																			
29	GSP 8 - Double Heat Exchanger																			
30	GSP 23 - Heat Exchanger Options																			

Attachment 1 (page 4 of 13)
GOTHIC Validation Test Matrix

	Test	Drop Entrainment	Drop Deposition	Drop Settling	Drop Breakup	Drop Evaporation	Drop Condensation	Drop Agglomeration	Mist Generation	Mist Depletion	Pressure Wave Propagation	Surface Wave Propagation	Impact Loads	Drag Loads	Pressure Drop/ Single Phase	Pressure Drop/ Bubbly Flow	Pressure Drop/ Film Drop Flow	Pressure Drop/ Stratified Flow	Pressure Drop/ Slug Flow	Stratified Flow Transition to Slug
31	AAF CAC Tests																			
32	Bruce Air Cooler Test																			
33	Saime Air Cooler																			
34	GSP 24 - Fan Heating																			
35	GSP 25 - Vacuum Breaker																			
36	Dousing Tests														x				x	
37	Isotope Decay																			
38	AECL Recombiner																			
39	Condensation Experiments																			
40	Pipe Pressure Drop															x	x			
41	Ice Formation on Coole Plate																			
42	Ice Melting with Condensation																			
43	BNW Ice Condenser Test																			

Attachment 1 (page 5 of 13)
GOTHIC Validation Test Matrix

	Test	DropEntrainment	DropDeposition	DropSettling	DropBreakup	DropEvaporation	DropCondensation	DropAglomeration	Mist Generation	Mist Depletion	Pressure Wave Propagation	Surface Wave Propagation	Impact Loads	Drag Loads	Pressure Drop/ Single Phase	Pressure Drop/ Bubbly Flow	Pressure Drop/ Film Drop Flow	Pressure Drop/ Stratified Flow	Pressure Drop/ Slug Flow	Stratified Flow Transition to Slug
44	Solitary Wave Velocity											x								
45	Water Aerosol Leakage (WALE) Experiments	x	x	x	x	x														
46	Light Water Reactor Aerosol Containment (LACE) Tests																			
47	FLECHT SEASET Natural Circulation Tests														x	x	x	x		
48	CVTR Simulated DBA Tests		x	x		x	x		x	x										
49	Marviken Full Scale Containment Tests	x	x	x		x		x							x	x	x		x	
50	Battelle-Frankfurt Containment Tests	x	x	x		x		x	x	x					x		x			
51	HEDL Hydrogen Mixing Tests								x	x										
52	HDR Full Scale Containment Tests		x	x		x		x	x	x					x		x			
53	Nuclear Power Engineering Corporation (NUPEC) Tests		x	x		x	x													
54	PRV Tests		x	x		x									x				x	
55	TOSQAN								x											
56	MISTRA								x											
55	Edwards Pipe Blowdown Experiments										x									

Attachment 1 (page 6 of 13)
GOTHIC Validation Test Matrix

	Test	Buoyancy Induced Stratification	Flashing	Boiling Heat Transfer	Natural Convection	Forced Convection	Mixed Convection	Thermal Conduction in Solids	Thermal Diffusion in Vapor	Thermal Diffusion in Liquid	Thermal Radiation	Condensation on Walls	Pool Boiling	Pool Surface Evaporation	Pool Surface Condensation	Heat and Mass Transfer in Superheated Steam	Bubble Condensation	Forced Circulation	Natural Circulation	Gas Mixing
		4	5	1	17	10	7	10	4	1	1	12	1	4	1	1	2	2	4	7
1	Drop Entrainment																			
2	Drop Settling Velocity																			
3	Jet and Drop Breakup		x																	
4	Drop Heat and Mass Transfer																			
5	GSP 27 - Heat Transfer Options				x							x								
6	GSP 14 - OSNI Numerical Benchmark							x												
7	Horizontal Cylinder in A Rectangular Cavity				x															
8	GSP 25 - Thermal Conduction in Solids							x												
9	Conductor Surface-to-Surface Radiation										x									
10	Thermal Diffusion in Vapor and Liquid								x	x										
11	GSP 37 - UofW Flat Plate Condensation				x	x	x					x								
12	Mist/Diffusion Layer Model for Wall Heat and Mass Transfer				x	x	x					x								
13	Grout Mold Evaporation Experiments				x	x	x							x						
14	GSP 1 - Natural Circulation																		x	
15	Vertical and Horizontal Openings				x														x	

Attachment 1 (page 7 of 13)
GOTHIC Validation Test Matrix

	Test	Buoyancy Induced Stratification	Flashing	Boiling Heat Transfer	Natural Convection	Forced Convection	Mixed Convection	Thermal Conduction in Solids	Thermal Diffusion in Vapor	Thermal Diffusion in Liquid	Thermal Radiation	Condensation on Walls	Pool boiling	Pool Surface Evaporation	Pool Surface Condensation	Heat and Mass Transfer in Superheated Steam	Bubble Condensation	Forced Circulation	Natural Circulation	Gas Mixing
		4	5	1	17	10	7	10	4	1	1	12	1	4	1	1	2	2	4	7
16	Thermally Driven Cavity				x														x	
17	GSP 2 - Hydrogen Injection Into Air																			x
18	GSP 3 - Air Compression																			
19	Turbulence Generated by A Square Grid																			
20	Flow In A Rectangular Duct					x														
21	Plane Jet																			
22	GSP 28 - Choked Flow																			
23	Stratified Flow																			
24	Hydrogen Burn Tests																			
25	Flame Facility Experiments																			
26	Nevada Test Site Experiments																			
27	GSP 6 - Pump Performance																	x		
28	GSP 7 - Single Heat Exchanger																			
29	GSP 8 - Double Heat Exchanger																			
30	GSP 23 - Heat Exchanger Options																			

Attachment 1 (page 8 of 13)
GOTHIC Validation Test Matrix

	Test	Buoyancy Induced Stratification	Flashing	Boiling Heat Transfer	Natural Convection	Forced Convection	Mixed Convection	Thermal Conduction in Solids	Thermal Diffusion in Vapor	Thermal Diffusion in Liquid	Thermal Radiation	Condensation on Walls	Pool Boiling	Pool Surface Evaporation	Pool Surface Condensation	Heat and Mass Transfer in Superheated Steam	Bubble Condensation	Forced Circulation	Natural Circulation	Gas Mixing
		4	5	1	17	10	7	10	4	1	1	12	1	4	1	1	2	2	4	7
31	AAF CAC Tests																			
32	Bruce Air Cooler Test																			
33	Salme Air Cooler																			
34	GSP 24 - Fan Heating																			
35	GSP 25 - Vacuum Breaker																			
36	Dousing Tests																			
37	Isotope Decay																			
38	AECL Recombiner																			
39	Condensation Experiments											x								
40	Pipe Pressure Drop																			
41	Ice Formation on Cooler Plate																			
42	Ice Melting with Condensation																			
43	BNW Ice Condenser Test																			

Attachment 1 (page 9 of 13)
GOTHIC Validation Test Matrix

	Test	Buoyancy Induced Stratification	Flashing	Boiling Heat Transfer	Natural Convection	Forced Convection	Mixed Convection	Thermal Conduction in Solids	Thermal Diffusion in Vapor	Thermal Diffusion in Liquid	Thermal Radiation	Condensation on Walls	Pool Boiling	Pool Surface Evaporation	Pool Surface Condensation	Heat and Mass Transfer in Superheated Steam	Bubble Condensation	Forced Circulation	Natural Circulation	Gas Mixing
		4	5	1	17	10	7	10	4	1	1	12	1	4	1	1	2	2	4	7
44	Solitary Wave Velocity																			
45	Water Aerosol Leakage (WALE) Experiments		x																	
46	Light Water Reactor Aerosol Containment (LACE) Tests		x		x			x				x		x	x					
47	FLECHT SEASET Natural Circulation Tests			x	x	x		x					x				x	x	x	
48	CVTR Simulated DBA Tests				x	x	x	x	x			x				x				x
49	Marviken Full Scale Containment Tests	x	x		x	x		x				x		x			x			x
50	Battelle-Frankfurt Containment Tests	x			x	x	x	x	x			x								x
51	HEDL Hydrogen Mixing Tests	x			x	x	x	x	x			x								x
52	HDR Full Scale Containment Tests				x	x	x	x						x						x
53	Nuclear Power Engineering Corporation (NUPEC) Tests	x			x			x				x								x
54	PRV Tests																			
55	TOSQAN				x							x								
56	MISTRA				x							x								
55	Edwards Pipe Blowdown Experiments		x																	

Attachment 1 (page 10 of 13)
GOTHIC Validation Test Matrix

	Test	Vapor Compression	Vapor Decompression	Liquid Compression	Liquid Decompression	Vapor Entrainment in Liquid	Jet Mixing	Mass Diffusion in Vapor	Turbulence	Buoyant Plume Behavior	Critical Flow	Leakage Flow	Pool Swell/Air Injection	Vent Clearing	Hydrogen Burn	Pipe/Component Pressure Drop	Isotope Transport	Isotope Decay	Pump Performance	Heat Exchanger Performance
		10	8	0	3	0	4	3	9	3	4	0	1	1	3	2	1	0	2	3
1	Drop Entrainment																			
2	Drop Settling Velocity																			
3	Jet and Drop Breakup																			
4	Drop Heat and Mass Transfer																			
5	GSP 27 - Heat Transfer Options																			
6	GSP 14 - CSNI Numerical Benchmark		x																	
7	Horizontal Cylinder In A Rectangular Cavity																			
8	GSP 26 - Thermal Conduction In Solids																			
9	Conductor Surface-to-Surface Radiation																			
10	Thermal Diffusion In Vapor and Liquid																			
11	GSP 37 - UofW Flat Plate Condensation																			
12	Mist/Diffusion Layer Model for Wall Heat and Mass Transfer																			
13	Grout Mold Evaporation Experiments																			
14	GSP 1 - Natural Circulation																			
15	Vertical and Horizontal Openings																			

Attachment 1 (page 11 of 13)
GOTHIC Validation Test Matrix

	Test	Vapor Compression	Vapor Decompression	Liquid Compression	Liquid Decompression	Vapor Entrainment in Liquid	Jet Mixing	Mass Diffusion in Vapor	Turbulence	Buoyant Plume Behavior	Critical Flow	Leakage Flow	Pool Swell/Air Injection	Vent Clearing	Hydrogen Burn	Pipe/Component Pressure Drop	Isotope Transport	Isotope Decay	Pump Performance	Heat Exchanger Performance
		10	8	0	2	0	4	3	9	3	4	0	1	1	3	2	1	0	2	3
16	Thermally Driven Cavity								x											
17	GSP 2 - Hydrogen Injection Into Air	x																		
18	GSP 3 - Air Compression	x																		
19	Turbulence Generated by A Square Grid								x											
20	Flow In A Rectangular Duct								x											
21	Plane Jet								x											
22	GSP 23 - Choked Flow										x									
23	Stalled Flow																			
24	Hydrogen Burn Tests														x					
25	Flame Facility Experiments								x						x					
26	Nevada Test Site Experiments	x							x						x					
27	GSP 6 - Pump Performance																		x	
28	GSP 7 - Single Heat Exchanger																			x
29	GSP 8 - Double Heat Exchanger																			x
30	GSP 23 - Heat Exchanger Options																			x

Attachment 1 (page 12 of 13)
GOTHIC Validation Test Matrix

	Test	Vapor Compression	Vapor Decompression	Liquid Compression	Liquid Decompression	Vapor Entrainment in Liquid	Jet Mixing	Mass Diffusion in Vapor	Turbulence	Buoyant Plume Behavior	Critical Flow	Leakage Flow	Pool Swell/Air Injection	Vent Clearing	Hydrogen Burn	Pipe/Component Pressure Drop	Isotope Transport	Isotope Decay	Pump Performance	Heat Exchanger Performance
31	AAF CAC Tests																			
32	Bruce Air Cooler Test																			
33	Saime Air Cooler																			
34	GSP 24 - Fan Heating																			
35	GSP 25 - Vacuum Breaker																			
36	Dousing Tests															x				
37	Isotope Decay																x			
38	AECL Recombiner																			
39	Condensation Experiments																			
40	Pipe Pressure Drop																			
41	Ice Formation on Coole Plate																			
42	Ice Melting with Condensation																			
43	BNW Ice Condenser Test																			

Attachment 1 (page 13 of 13)
GOTHIC Validation Test Matrix

	Test	Vapor Compression	Vapor Decompression	Liquid Compression	Liquid Decompression	Vapor Entrainment in Liquid	Jet Mixing	Mass Diffusion in Vapor	Turbulence	Buoyant Plume Behavior	Critical Flow	Leakage Flow	Pool Swell/Air Injection	Vent Clearing	Hydrogen Burn	Pipe/Component Pressure Drop	Isotope Transport	Isotope Decay	Pump Performance	Heat Exchanger Performance
		10	8	0	3	0	4	3	9	3	4	0	1	1	3	2	1	0	2	3
44	Solitary Wave Velocity																			
45	Water Aerosol Leakage (WALE) Experiments																			
46	Light Water Reactor Aerosol Containment (LACE) Tests	x	x		x						x									
47	FLECHT SEASET Natural Circulation Tests		x		x														x	
48	CVTR Simulated DBA Tests	x	x				x	x	x											
49	Marviken Full Scale Containment Tests	x	x										x	x		x				
50	Battelle-Frankfurt Containment Tests	x	x					x	x	x										
51	HEDL Hydrogen Mixing Tests						x	x	x	x										
52	HDR Full Scale Containment Tests	x	x																	
53	Nuclear Power Engineering Corporation (NUPEC) Tests	x	x							x										
54	PRV Tests	x									x									
55	TOSQAN						x													
56	MISTRA						x													
55	Edwards Pipe Blowdown Experiments				x						x									