5z-004

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

October 11, 1995

APPLICANT: GE Nuclear Energy (GE)

PROJECT: Simplified Boiling Water Reactor (SBWR)

SUBJECT: SUMMARY OF MEETING WITH GE TO DISCUSS CONTAINMENT TESTING ISSUES

A public meeting was held between the Nuclear Regulatory Commission (NRC) staff and GE representatives on August 21 and 22, 1995, at GE's offices in San Jose, California. The purpose of the meeting was for GE to discuss containment TRACG analysis, PANTHERS/PCC test results, and GIRAFFE test issues. The major topics discussed during the meeting were: (1) PANTHERS test data and analysis results, (2) GIRAFFE/Helium test data, (3) TRACG applications to SBWR containment analysis, (4) vacuum breaker single failure exemption request, and (5) scaling issues on GIRAFFE/Helium and PANDA tests. Attachment 1 is a list of attendees.

Since proprietary and non-proprietary handout slides were used for presentations and discussions during the meeting, GE has requested the staff to withhold the proprietary slides from the public disclosure in accordance with the provisions of 10 CFR 2.790 on August 22, 1995. Therefore, a copy of the proprietary slides is not attached with this meeting summary. However, a copy of non-proprietary slides is attached for this meeting summary (Attachment 2).

The following specific GE actions and NRC positions were identified during the meeting:

PANTHERS and Containment Application

1. GE agreed to provide NRC more legible PANTHERS drawing of temperature measurement locations in pool.

2. GE agreed to provide information on calculated flow regime/film thickness at bottom of condenser tubes.

3. GE will plot condenser heat removal rates as a function of driving temperature difference.

4. GE will provide pressure drop in inlet header for pure steam tests.

5. GE will evaluate energy balance for transient tests with respect to changes in sensible energy storage.

6. GE agreed to review and clarify conclusion stating PANTHERS/PCC performance models SBWR/PCC performance.

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GIRAFFE/Helium

1. GE agrees to modify test objective #3 to remove goal of reinforcing use of data from previous testing.

2. GE will provide clarifications to data presentations:

   - Water vapor weight column in gas sampling measurements

   - Uncertainty in noncondensible concentration measurements

   - Normalization of total sample concentrations to 100 percent

   - Precise definitions of delta-ps in PCC and LOCA vent lines

   - Provide spread in helium concentrations (partial pressures) related to band of temperatures in PCC tubes

3. GE will evaluate GIRAFFE and PANTHERS data for consistent trends with helium concentration.

4. GE agreed to look at thermodynamic conditions in GIRAFFE wetwell to confirm application of microheaters is not overcontrolling the test

TRACG

1. GE will evaluate how to treat discrepancy in calculated PCC pool temperature in the context of best estimate model application.

2. GE will address the range of the data base for single tubes vs. PANTHERS and the correlations used in TRACG.

3. GE will explain trends in predicted pressure drop for PANTHERS tests at low inlet pressure.

4. GE will implement improved correlations based on technical consensus and previous data:

   - Kuhn (UCB) correlation for condensation heat transfer
   - Forster-Zuber pool boiling correlation on pool side

5. GE will define what constitutes acceptable validation of TRACG and address the issue of whether confidence in TRACG is eroded as a result of change in correlations.

6. GE will evaluate which analysis will be repeated as a result of changing the correlations.

7. GE will identify methodology to be used for TRACG based containment analysis to NRC/ACRS.

8. GE will develop plan on how to address disconnect on description of TRACG model application to containment and reach agreement with NRC in the next week conference call.

NRC Positions

1. Passive Autocatalytic Recombiner (PAR): This is a new technology. Therefore, GE should verify the applicability of the PAR system under umbrella of the SBWR test program.

2. Hydrogen treatment: The functionality of the Passive Containment Cooling system (PCCS) must be demonstrated for all possible ranges of hydrogen concentration in accordance with 10 CFR 50.44 (2-5 percent hydrogen) as well as 10 CFR 50.4 (100 percent hydrogen).

3. Requirement for opening of vacuum breaker in GIRAFFE/Helium test: NRC will consider data (i.e. steady state conditions were reached in PCC) and arguments that substantiate GE's position that the relevant phenomena have been covered by the tests performed.

4. Microheater power in GIRAFFE/Helium tests: GE should provide data (thermal gradients, etc.) to justify that the tests were not overcontrolled to maintain suppression chamber pressure.

5. NRC will issue a position paper on vacuum breaker single failure exemption for SBWR application.

6. NRC will resolve issue of whether review of Application Methodology is within current scope (GE contends it is). This should be part of proposed GE/NRC dialog (Reference content/scope of Qualification & Application LTR submittals scheduled for 1996).

At the end of the meeting, GE informed the staff that a decision on whether to restart the design review will be deferred to December 1995. GE agreed to document the schedule, including timing and rationale for SSAR review restart.

Original signed by
Son Q. Ninh, Project Manager
Standardization Project Directorate
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Docket No. 52-004

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NAME	SNinh/sg		JKudrick*		JNWilson					
DATE	10/11/95		10/03/95		10/11/95					

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As stated

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EJordan, T-4 D18
JMoore, O-15 B18
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NRC/GE
MEETING ATTENDEES
AUGUST 21 AND 22, 1995

NAME	ORGANIZATION
S. Ninh	NRC/NRR/PDST
J. Kudrick	NRC/DSSA/SCSB
A. Drozd	NRC/DSSA/SCSB
P. Boehnert	NRC/ACRS
V. Schrock	ACRS Consultant
K. Vijaijan	DOE
E. Condon	DOE
T. Mulford	EPRI
R. Srinivasan	EPRI
T. Fernandez	EPRI Consultant
J. Quinn	GE-NE
B. Shiralkar	GE-NE
R. Buchholz	GE-NE
J. Leatherman	GE-NE
A. Illich	GE-NE
H. Upton	GE-NE
J. Fitch	GE-NE
J. Duncan	GE-NE
R. Gamble	GE-NE
S. Khorana	GE-NE
M. Parker	GE-NE
M. Herzog	GE-NE
J. Torbeck	GE-NE
P. Billig	GE-NE
K. Kobayashi	JAPC/GE

Attachment 1

GE Nuclear Energy

SBWR GE/NRC/DOE/EPRI - Containment Meeting

PANTHERS /PCC Test Results

Containment TRACG Analysis

GIRAFFE Test Issues

August 21 & 22, 1995

Attachment 2

Participants

Name	*Agency*	*Phone*
A. Drozd	NRC	301-415-
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K. Vijaijan	DOE	
T. Mulford	EPRI	415-855-
T. Fernandez	EPRI	415-855-
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R. Buchholz	GE	408-925-4584

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R. E. Gamble	GE	408-925-3352
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G. A. Wingate	GE	408-925-1073

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K. T. Schaefer	GE	408-925-2443
P. Novak	GE	408-925-
N. Barkley	GE	408-925-
F. Hatch	GE	408-925-

Arrangements

Meeting location (August 21 & 22, 1995):

GE Nuclear Energy

175 Curtner Avenue

San Jose, California

Building J

Room J1010

Contacts:

John Leatherman	408-925-2023
Kurt Schaefer	408-925-2443

Agenda

Monday morning, August 21, 1995, Room J1010

8:30 *Introductions*

8:45 *Discussion on of any deviations in the PANTHERS/PCC test matrix PFB(JRF/BSS/JET)*

9:15 *Tests review:PFB(JRF/BSS/JET)*

- *Instrumentation: location, calibration and failures (if any)*
- *Data processing and storage*
- *Presentation of results:*
    - * *applicability of SBWR transient analysis*
    - * *helium test results: results and discussion*

11:45 *Lunch (GE Cafeteria)*

Agenda

Monday afternoon, August 21, 1995, Room J1010

12:45	Discussion of planned objectives and achieved goals with respect to TRACG qualification and the SBWR certification process JRF(BSS/JET)
	* comparison with 1-tube correlation
	* TRACG calculations and comparisons
4:00	Review/collect Open Items from first day JDD
5:00	End of first day of the meeting

Agenda

Tuesday morning, August 22, 1995, Room J1010

8:30 *Comments/clarifications of first day of meeting JDD*

8:45 *Continuation of discussion of PANTHERS/PCC results PFB(JRF/BSS/JET)*

10:00 *GIRAFFE audit/inspection follow-up discussion MH(PN/NB/JET)*

- *VB cycling*
- *Effect of microheaters*
- *Results of the lighter than air tests and in particular, the air samples from the four tests, and whether the VB actuated*

11:45 *Lunch (GE Cafeteria)*

Agenda

Tuesday afternoon, August 22, 1995, Room J1010

12:45 Status of the SBWR vacuum breaker issue HAU(JLT)

1:30 Discussion of scaling: REG(BSS)

- * GIRAFFE (core power, heat losses, PCC sizing)
- * PANDA (general)

3:00 Break

3:30 Review of open issues from the two days of meetings JDD

5:00 End of meeting

GE Nuclear Energy

NRC Meeting on Containment Analysis

PANTHERS Goals with respect to TRACG Qualification

B. S. Shiralkar

August 21, 1995

PANTHERS Test Objectives

- *Demonstrate that prototype PCC heat exchanger meets design requirements for heat rejection*
- *Provide qualification database for TRACG for quasi-steady heat rejection performance of a prototype heat exchanger*
  - *PCC flow/pressure drop (PC1)*
  - *Condensation heat transfer on primary side including effects of noncondensibles (PC2)*
  - *Secondary side heat transfer (PC3)*
  - *Parallel tube effects (PC4)*
  - *Parallel module effects (PC5)*
- *Determine and quantify differences between lighter-than-steam and heavier-than-steam noncondensibles*

Test Objectives Met

TRACG Qualification Objectives

- *PCC pressure drop*
  - *TRACG predictions slightly high (conservative)*
- *PCC Heat Transfer*
  - *TRACG predictions conservative on total heat transfer by ~15%*
  - *Evaluating improved correlations*

    Kuhn (UCB) correlation for condensing side

    Forster-Zuber pool boiling for pool side
- *Noncondensible buildup with vent closed*
  - *Higher concentration in tubes for nitrogen (conservative)*
  - *Lower concentration in tubes for helium (nonconservative)*
- *Parallel tube and module effects*
  - *Not significant with air*
  - *Present with helium (vent closed)*

Nitrogen data predicted conservatively *Helium data needs to be bounded*

GE Nuclear Energy

PANTHERS-PCC Test Program

Paul F. Billig
SBWR Test Operations and Analysis

Presentation to NRC on
August 21, 1995

filename: nrc8-21

Outline

- **Morning Topics - PANTHERS/PCC Testing**
  - Test Matrix
  - Instrumentation
  - Data Processing and Storage
  - Test Results
    - Steady-State Tests
    - Transient Tests
      - Water Level
      - Non-condensable Gas Buildup
  - Applicability of PANTHERS/PCC to SBWR
- **Afternoon Topics - PANTHERS/PCC Analyses**
  - TRACG Calculations and Comparisons
  - Discussion

Test Matrix

- Presented in TAPD (NEDO-32391, Rev. B), Tables A.3-2a-d and A.3-25, and T/H Data Report (SIET 00393RP95, Rev. 0)
- All thermal-hydraulic tests completed (Table A.3-2a-d)
  - 97 steady-state tests
  - 11 transient tests
- Some structural tests deferred (Table A.3-25)
  - LOCA cycles completed - 10 cycles
  - Pneumatic tests deferred
    - Ansaldo to review structural results and decide if tests necessary - may be bound by large number of performance tests
    - Ansaldo redesign of header covers to prevent leakage
  - Remaining tests may be necessary for final component qualification but not SBWR certification

Instrumentation

- Types and location of all instruments described in Test Plan & Procedures (SIET 00098PP91, Rev. 1) and Test Specification for IC & PCC Instrument Installation (SIET 00157ST92, Rev. 1)
- Types and location of thermal-hydraulic instruments repeated in T/H Data Report
  - Appendix A: Instrument List
  - Appendix B: Modified Instruments
- Calibrations performed by SIET
  - Laboratory certified to calibrate instruments
  - Conform to standards traceable to Italian equivalent of U.S. National Bureau of Standards
  - Calibration records available on site

Instrumentation (continued)

- **Instrumentation Failures**
  - Given in Apparent Test Results for each test
  - Most problems related to some structural instruments
  - One tube inner wall thermal-couple never worked (DTWB011)
  - No failure of critical instruments (see TP&P, Section 13.3 for list)

Data Processing and Storage

- **Data Tape Format described in T/H Data Report, Appendix E**
  - Files include both directly acquired signals and derived quantities
  - Instrument name included for direct signals
  - Measurement name for derived quantities defined in Appendix E
  - Additional files give constants for derived quantities, instrument zeroes and historical data
  - All files are in ASCII format
- **Data Storage**
  - All data stored on 4 mm 120 Mbyte tapes
  - Original tapes are at SIET
  - Copy sent to NRC with T/H Data Report
  - Data also stored on GE VAX computer in San Jose

Test Results (Steady-state tests)

- *Tabulated in T/H Data Report (Tables 7.1 - 7.6)*
- *Shown in Data Analysis Report (Figures 3.1 - 3.15)*
- *Saturated Steam Tests*
  - *Heat removal vs. inlet pressure is linear*
  - *Intercept (no condensation) corresponds to saturated conditions in pool*
- *Superheated Steam Tests*
  - *Results similar to saturated tests*
  - *Except at high flow, steam desuperheats in riser and upper header*

Test Results (Steady-state tests, continued)

- Saturated Steam/air Tests
  - Provides broad database to characterize PCC at various steam/air mixtures
  - Tests at same gas fractions and various inlet pressures
  - Smooth transition to complete condensation at high pressures
    - Heat rejection rate tends to asymptote at higher pressures
    - Limit = energy to condense steam and subcool to pool temperature
    - Heat transfer declines in lower tube region
  - Increase in air concentration => decrease in condensation
- Superheated Steam/air Tests
  - Results similar to saturated tests
  - More than 50% of superheat lost in riser

Test Results (Transient tests)

- Shown in T/H Data Report (Figures 7.2 - 7.16) and Data Analysis Report (Figures 3.16 - 3.37)
- Water Level
  - Demonstrates change in condenser performance versus pool water level
  - Performance improves as level lowers to top of tubes
    - Less head => cooler pool
  - Performance decreases as tubes uncover
    - Less heat transfer surface => higher pressure needed to maintain condensation
    - Beyond design basis conditions
      - SBWR water sufficient to keep tubes covered at least 72 hours
      - Demonstrates margin in system design

Test Results (Transient tests, continued)

- Non-condensable Gas Buildup (Air, Helium, & Air/Helium)
  - Steam start with vent closed and specified steam flow
    - condensation induced flow
  - Pressure rises as gas accumulates in PCC and vent line
- Air Injection Tests
  - Gas builds up in vent line, lower header, and lower tube region
  - Temperatures in lower regions approach pool temperatures
  - Eventually all condensation occurs in top of tubes

Test Results (Transient tests, continued)

- **Helium Injection Tests**
  - Performance differs from air tests
    - Helium remains in PCC unlike air tests
    - Buoyancy prevents accumulation in lower regions
  - Temperatures in various regions indicate wide dispersal of helium
    - Greater condensation occurs in lower than upper tube regions
    - Nonsymmetric temperature distribution within headers and between headers
  - Significantly less gas needed to degrade condenser performance
    - No large accumulation in vent line and lower headers
    - Higher accumulation within tubes

Test Results (Transient tests, continued)

- Air/helium Injection Tests
  - Performance more similar to helium tests
    - Gases remain in PCC
  - Temperatures in various regions indicate wide dispersal of helium
    - Nonsymmetric temperature distribution within headers and between headers
  - Condensation in tubes vary
    - Some tubes show little condensation near end of transient
    - One tube shows condensation along complete tube
    - One tube shows less condensation at bottom of tube
  - Little gas needed to degrade condenser performance
    - Similar to helium tests
    - Some accumulation in vent line and headers

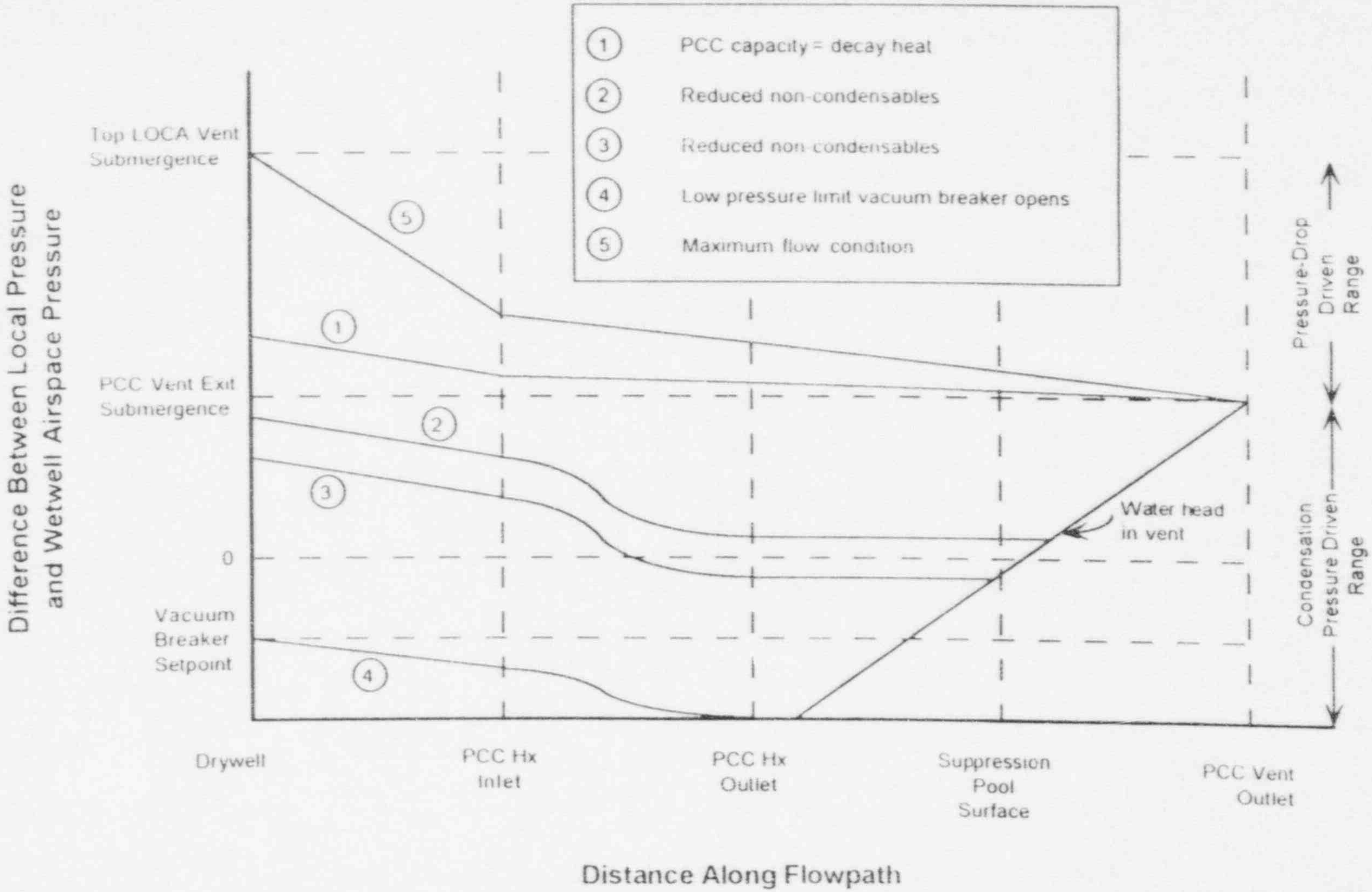
Test Results - Conclusions

- PANTHERS/PCC achieved thermal-hydraulic test objectives
  - PCC condenses steam at design conditions
  - PCC able to vent non-condensable gases
  - PCC performance is well behaved
- Large database available for TRACG code qualification
  - Steady-state tests at broad range of steam and air flows
  - Transient performance at various pool water levels
  - Transient performance with gas buildup
- Lighter-than-steam gas behaves differently than heavier-than-steam gas
  - Buoyancy overcomes downward flow under condensation induced flow conditions
  - Tests measure differences in condenser thermal-hydraulic performance

Applicability of PANTHERS/PCC to SBWR

- TAPD, Sec. A.3.1.1.4 and Fig. A.3-3 describe PCC operational modes and applicability of PANTHERS-PCC data
- Two main operating modes of PCC
  - Pressure Drop Driven Mode
    - PCC capacity $\leq$ core decay heat
    - PCC flow is forced by DW/WW dP
  - Condensation Pressure Driven Mode
    - PCC capacity $\geq$ core decay heat
    - Flow induced DW to PCC dP due to condensation
- PCC tests capture both modes

Fig. A.3-3: PCC Operational Modes



Applicability to SBWR (continued)

- Both PCC operational modes represented by PANTHERS
- Pressure Drop Driven Mode
  - Steady-state steam/air mixture tests model this behavior
  - Test T23 captures high pressure drop through system similar to early blowdown when main vents are open
  - Test T9 captures range of conditions with flow through PCC but not main vent
  - Test T2 demonstrates conditions near crossover to condensation mode
- Condensation Pressure Driven Mode
  - Steam only and gas injection tests model this behavior
  - Spectacle flange on vent pipe simulates pipe submergence in S/P
  - Steam only tests (T41, T43) show operation with all N/C gases purged
  - Injection tests of air (T51), helium (T76), and air/helium (T78) demonstrate performance with gases trapped in Hx

Applicability to SBWR - Conclusions

- Conditions tested in PANTHERS/PCC are representative of conditions predicted in SBWR containment analysis for PCC operation (e.g., inlet flows, mass fractions, temperatures, and pressures)
- Tests capture both pressure drop driven and condensation pressure driven modes
- Steady-state tests cover range of steam/air fractions for SBWR
- Transient tests demonstrate condensation pressure driven flows both with and without the presence of non-condensable gases in the PCC
- SBWR integrated systems tests (PANDA and GIRAFFE) complete the qualification database by demonstrating system performance

Applicability to SBWR - Conclusions

- PANTHERS/PCC performance models SBWR PCC performance
- Tests capture both pressure drop driven and condensation pressure driven modes
- Steady-state tests cover range of steam/air fractions for SBWR
- Transient tests demonstrate condensation pressure driven flows both with and without the presence of non-condensable gases in the PCC
- SBWR integrated systems tests (PANDA and GIRAFFE) complete the qualification database by demonstrating system performance

PANTHERS-PCC Post-Test Analysis

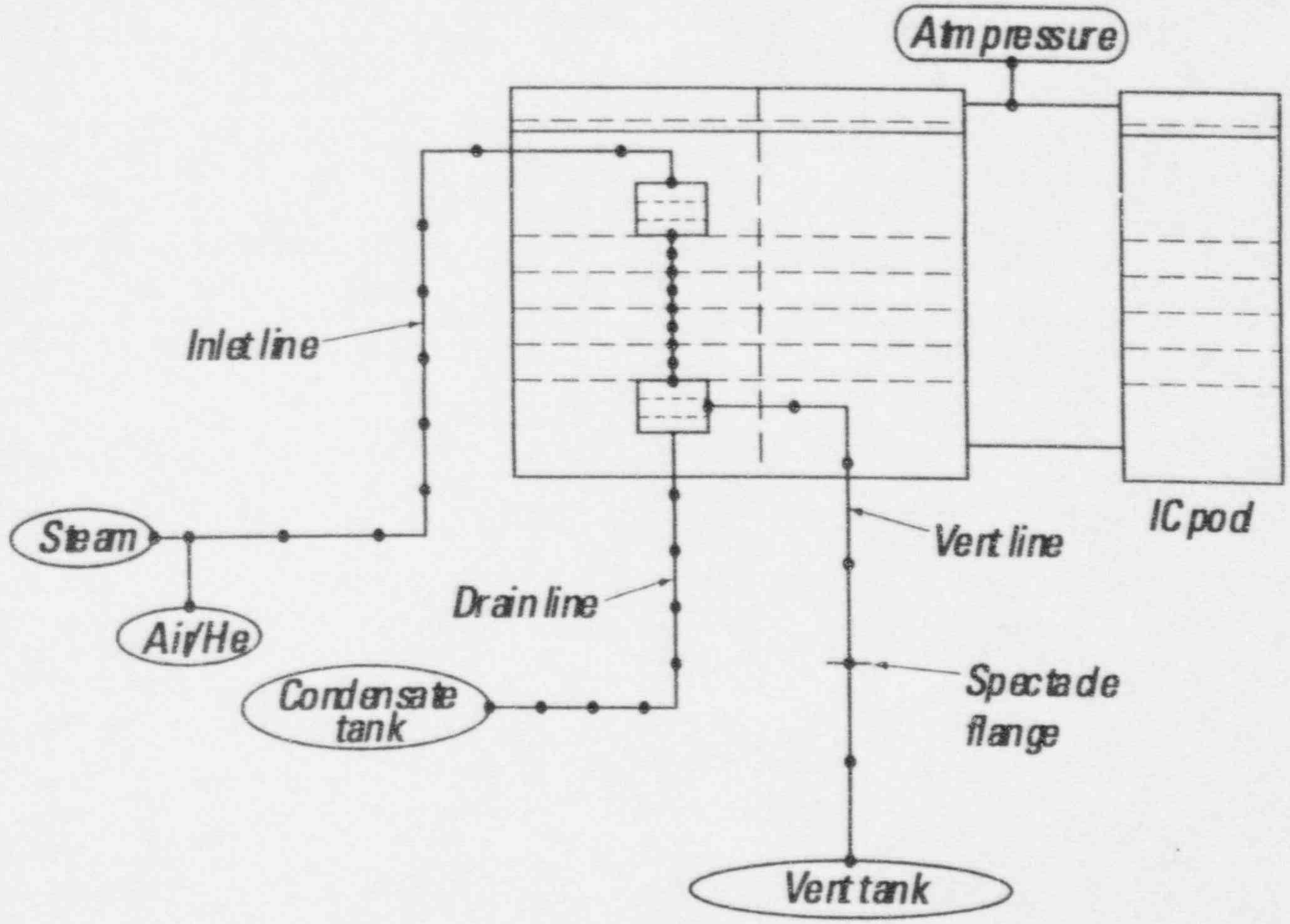
By Jim Fitch

NRC /GE Meeting
San Jose, Ca.
August 21, 1995

Objectives of post-test evaluation

- *Evaluate applicability of TRACG correlations for calculation of PCC performance*
  - *tube side*
  - *pool side*
- *Evaluate applicability of "lumped-tube" input model of PCC for use in containment system analysis.*
  - *parallel module effects*
  - *parallel tube effects*
- *Evaluate capability of code/input model to distinguish distributional effects of gases which are lighter and heavier than steam*

TRACG model of PANTHERS PCC

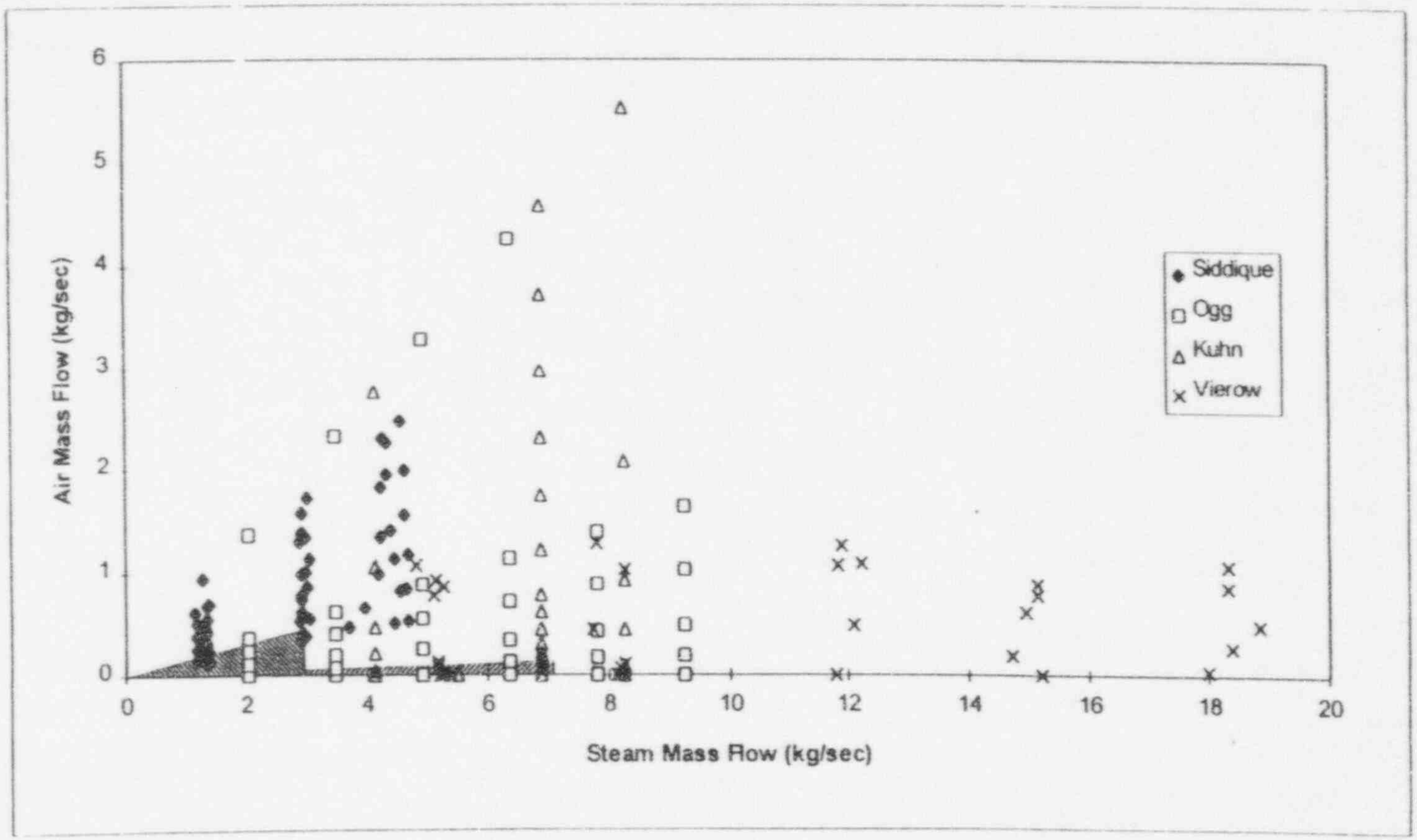


Correlations used by TRACG

- *Correlations are built into the code*
- *Condensation heat transfer on tube side is calculated using the "Tsukuba" correlation. Function of:*
    - *condensate film Re number*
    - *vapor stream Re number*
    - *noncondensable gas mass fraction*
- *Nucleate boiling heat transfer on pool side is calculated using the Chen correlation*
- *Correlations are applied on a local (not integral) basis*
- *There are no plans to develop special "multi-tube" correlations for SBWR containment analyses*

Correlations used by TRACG

- ***University condensation heat transfer data vs SBWR PCC operating range***



Tests for post-test evaluation

- *"Checks" indicate results for today's meeting*

Test Number	Test Type	Data Comparison
41 ✓	SS - pure steam	inlet pressure
43 ✓	SS - pure steam	inlet pressure
49 ✓	SS - pure steam	inlet pressure
9 ✓	SS - steam/air	heat rejection rate, Δp
15 ✓	SS - steam/air	heat rejection rate, Δp
18 ✓	SS - steam/air	heat rejection rate, Δp
23 ✓	SS - steam/air	heat rejection rate, Δp
2	SS - steam/air	heat rejection rate, Δp
17	SS - steam/air	heat rejection rate, Δp
19	SS - steam/air	heat rejection rate, Δp
22	SS - steam/air	heat rejection rate, Δp
35	SS - steam/air	heat rejection rate, Δp
51 ✓	TR - nc buildup	inlet pressure vs air inventory
76 ✓	TR - nc buildup	inlet pressure vs helium inventory
78 ✓	TR - nc buildup	inlet pressure vs air/helium inventory
55	TR - water level	inlet pressure vs water level

Steady-state pure-steam tests

- *TRACG underpredicts heat rejection rate at a given inlet pressure by 35-40%*
- *Use of a standard pool boiling correlation on the pool side and the Kuhn correlation on the tube side reduces the underprediction to 15-20%*
- *The applicability of the pool boiling and Kuhn correlations is supported by the PANTHERS wall temperature data*
- *The remaining discrepancy between test and calculation may be associated with the lower pool temperature in the tests vs the calculations (100 °C vs 104 °C)*

Steady-state steam/air tests

TEST CONDITIONS

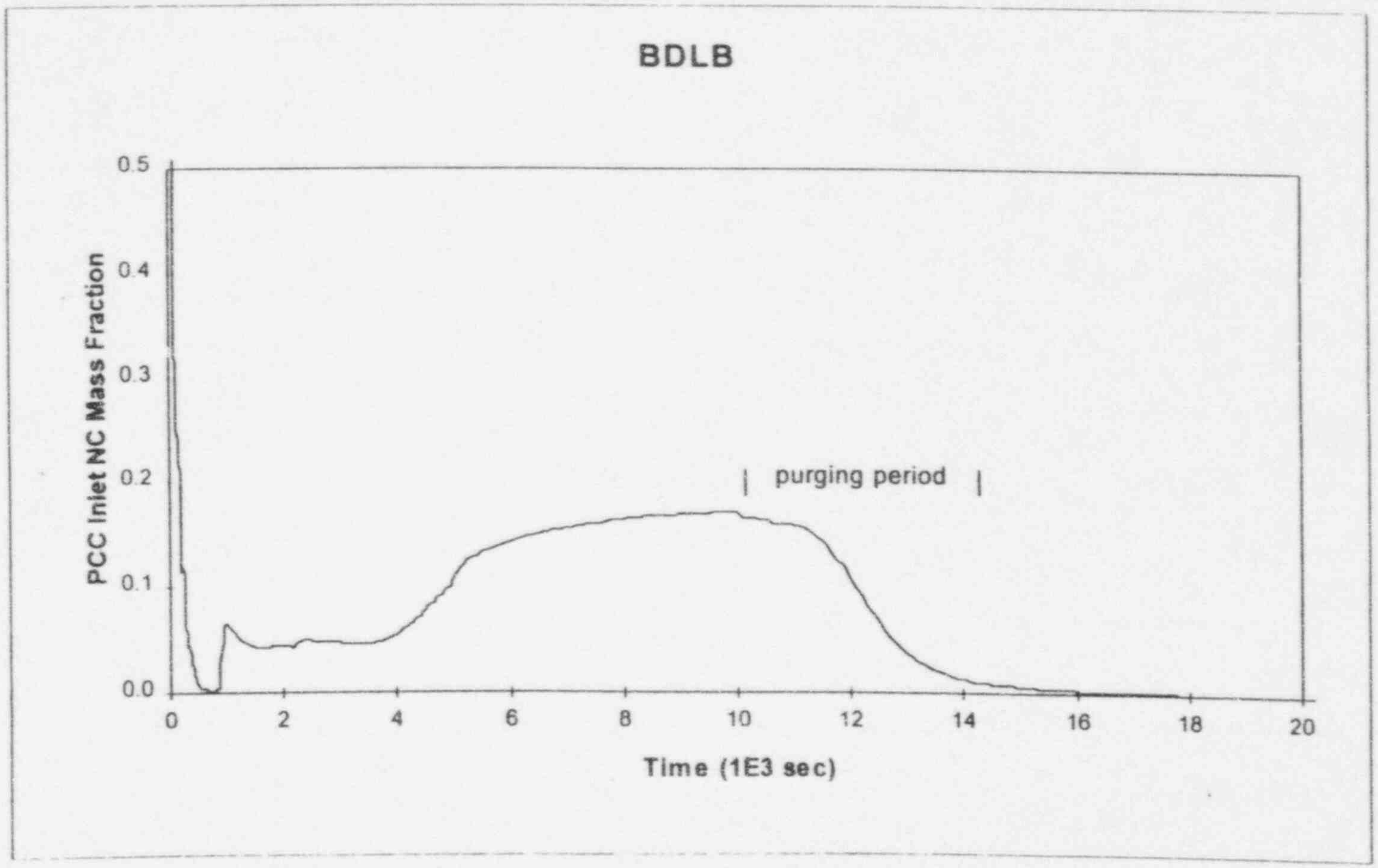
Test No.	Steam Flow (kg/sec)	Air Flow (kg/sec)	Air Mass Fraction	Inlet Pressure (kPa)	Inlet Temperature (°C)
9	4.96 - 5.00	0.076-0.077	0.015	296 - 782	142 - 174
15	5.00 - 5.10	0.165-0.167	0.032	300 - 790	140 - 176
18	4.99 - 5.02	0.40	0.073-0.074	284 - 641	135 - 165
23	4.97 - 5.03	0.85 - 0.87	0.146-0.148	298-584	135 - 160

Steady-state steam/air tests

- *Heat rejection rate for given air flow, steam flow, and inlet pressure is generally underpredicted by 15-20%*
- *Pressure loss is overpredicted by a comparable amount*
- *Heat rejection rate and pressure loss are related because less heat rejection means higher flow rate in the vent*
- *Data trends with varying inlet pressure at fixed inlet flows are well represented*
- *Results are less sensitive to pool-side h than pure steam because of large degradation on tube-side h*
- *It is expected that the comparisons would be improved by use of Forster-Zuber and Kuhn in place of the present correlations.*

Application to SBWR transient analysis

- ***PCC inlet conditions vary slowly with time***



Application to SBWR transient analysis

- *Consider the length of time it takes to "fill" the condenser vs the time scale of a significant change in the inlet conditions.*
- *For BDLB PCCS purge requires about one hour whereas condenser fill time is on the order of 6 seconds.*
- *Condenser adjusts to changing inlet conditions on a much shorter time scale than that over which the conditions are changing.*
- *Conclusion: development and validation of correlations based on steady-state data is adequate for application to SBWR transient performance.*
- *Integral systems tests will provide final confirmation.*

Transient tests

- *Vent closed at spectacle flange*
- *Steady-state established for pure steam at 5 kg/sec (like Test 41_1)*
- *Noncondensable gas injected until inlet pressure reached 790 kPa*
- *Test 51: Air injected at a nominal flow rate of 4.3 g/sec for about 2 hrs (Final inventory = 28.6 kg)*
- *Test 76: He injected at a nominal flow rate of 0.7 g/sec for about 40 min (Final inventory = 1.45 kg)*
- *Test 78: Air/He in a 4:1 mass ratio injected at a nominal flow rate of 5.5 g/sec for about 20 min (Final inventory = 5.8 kg)*
- *Test and analysis results plotted as inlet pressure vs accumulated noncondensable inventory*

Transient tests

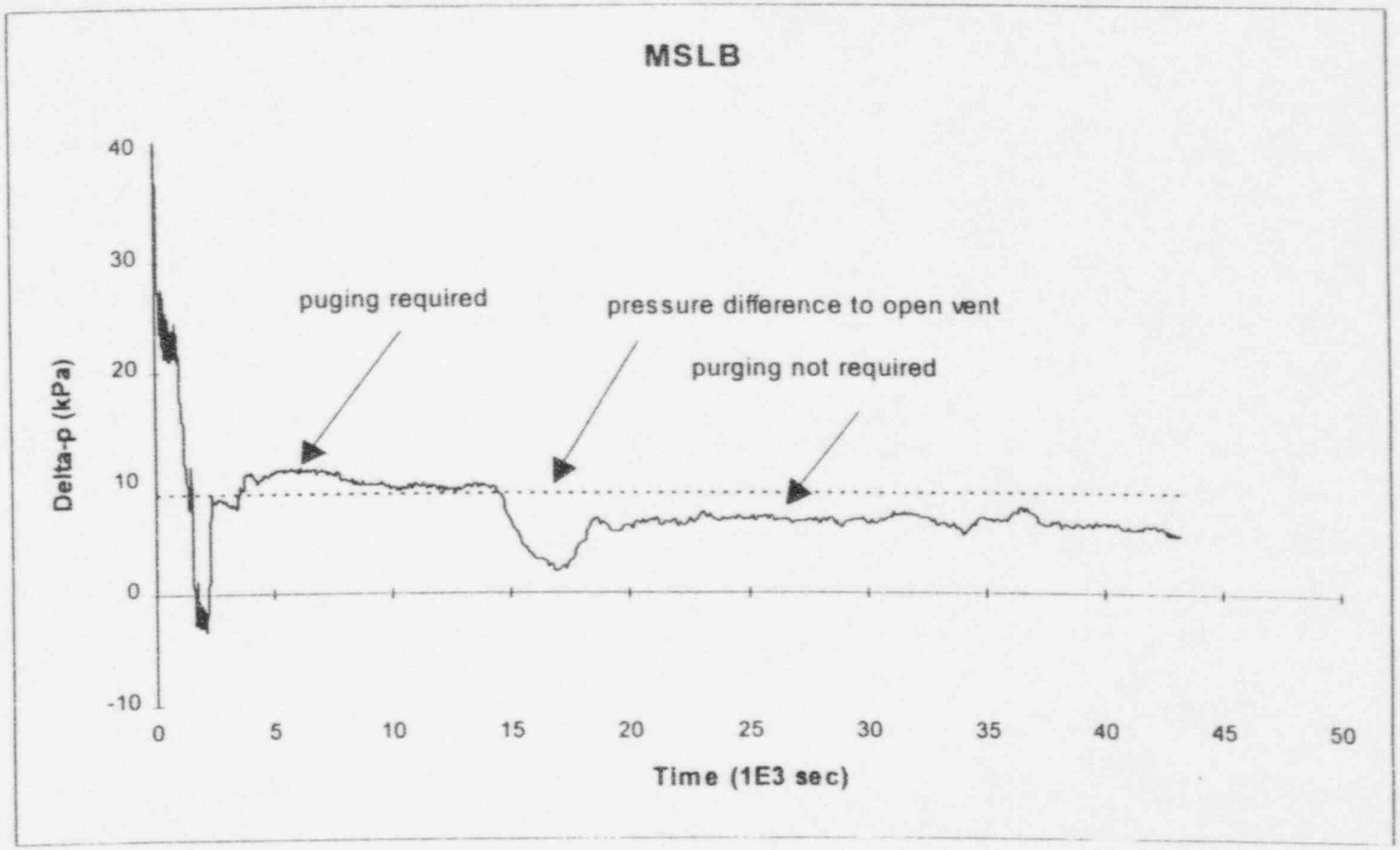
- *Results of comparisons between TRACG and PANTHERS for air and helium injection can be explained.*
- *Air tends to settle at the bottom (lower portion of tubes, lower headers, drain line above water level, and vent line above flange)*
- *PANTHERS facility collects more air in the vent pipe because of heat loss which is not included in the TRACG model.*
- *Helium tends to move upward throughout the condenser.*
- *TRACG cannot predict the upward movement of the helium, at lest not with a one-tube model.*

Containment behavior for light gas

- Conditions tested at PANTHERS are only applicable to performance with vent closed.
- In SBWR application, any degradation in performance will force the vent to open.
- Gas purging via open vent will dominate over distributional effects within condenser.
- PANTHERS/TRACG comparison indicates TRACG cannot predict details of light-gas distribution in a "dead-end" condenser with a one-tube model.
- GIRAFFE tests will confirm there is no adverse effect of a light gas on integrated system performance.
- Bounding calculations can be used to evaluate the 100% M-W reaction case.

Containment behavior for light gas

- ***PCC vent opens whenever performance is degraded***



JRF 31
8/21/95

Summary and conclusions

- **Significant progress in post-test analyses of PANTHERS PCC data**
  - 3/3 steady-state pure steam tests analyzed
  - 4/9 steady -state steam/air tests analyzed
  - 3/4 transient tests analyzed
- **Calculations are conservative for pure steam and steam/air tests**
  - Heat rejection rate underpredicted by 35-40% for pure steam and 15-20% for steam/air tests
  - Data trends captured
- **Need for modified correlations indicated**
  - Forster-Zuber (pool boiling) on pool side
  - Kuhn (UCB) on tube side
- **Need to supplement TRACG with bounding calculation for evaluation of 100% M-W reaction case**

Meeting Goals

- Scaling supports certification test data use
- Insulation decision re:Panda correct
- Panthers PCC TAPD objective met
- Giraffe Audit/SIT test #/scope satisfactory
  - No VB cycling acceptable
  - Microheater effect; noncondensible meas.
- VB single failure criteria concerns of NRC understood-approach to resolution agreed

Meeting Goals

JAN 95 GE AUDIT.

- Panda QA items from ~~11/94~~ resolved
- Test Data representative of SBWR; useable in Certification/TRACG qualification
- TRACG Containment Analysis Roadmap

GIRAFFE Helium Tests

- Test Facility Description
- Test Objectives
- Test Initial Conditions
- Test Procedures
- Presentation Goals
- Vacuum Breaker cycling, Effect of Microheaters
- Test Results

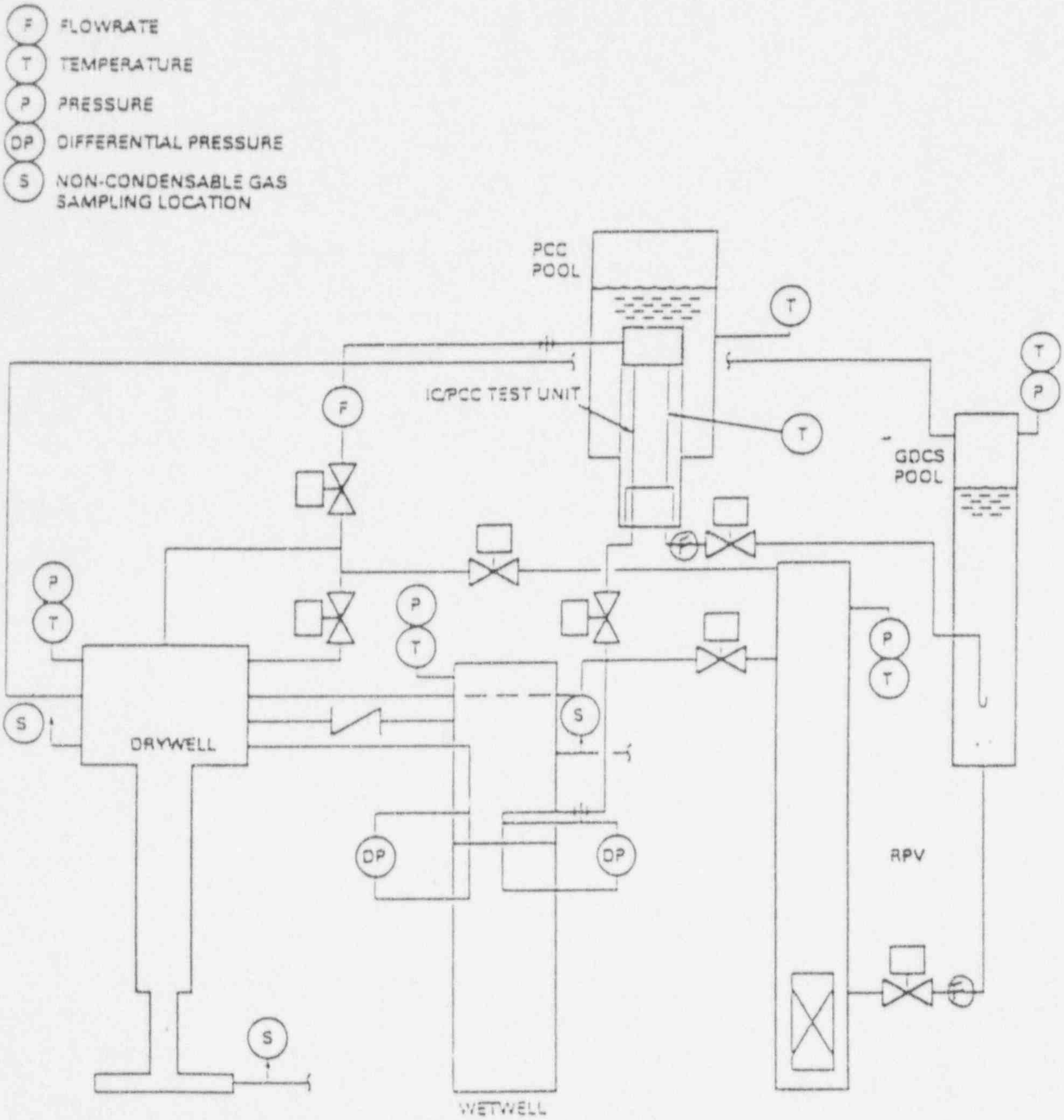
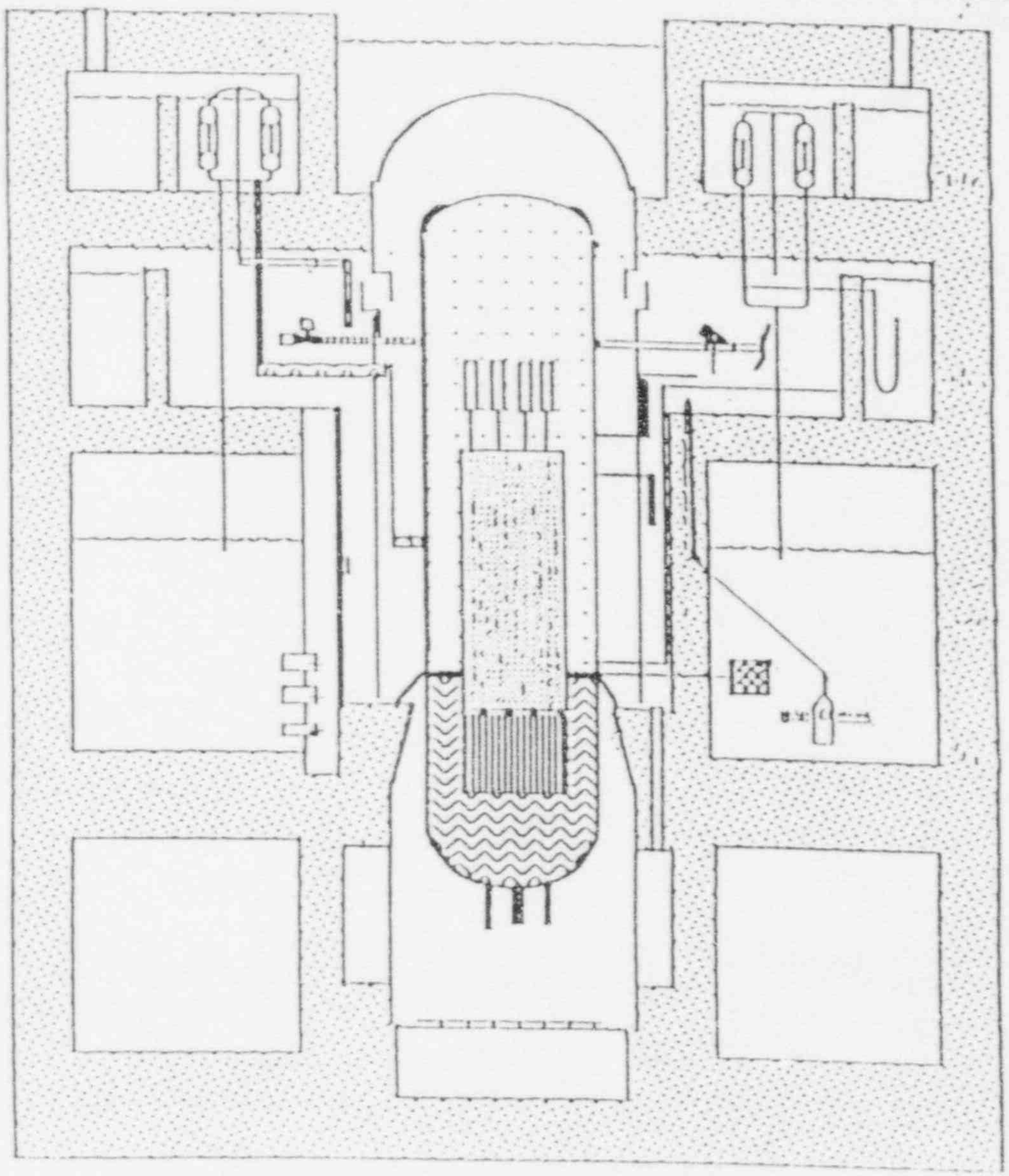


FIGURE 3-1. GIRAFFE Test Facility Schematic

SBWR Containment



GIRAFFE Helium Test Objectives

- Demonstrate PCCS operation in the presence of noncondensible gases that are lighter than and heavier than steam, including demonstrating the process of purging noncondensibles from the PCC condenser
- Provide a database for TRACG qualification
- Provide a tie-back test to repeat a previous GIRAFFE test, including appropriate QA documentation to reinforce the validity of the previous testing

HELIUM Test H-1

- Purpose: To provide a base case with 4% nitrogen in the Drywell, calculated for SBWR SSAR conditions one hour after a Main steam line break
- Initial conditions based on SBWR TRACG results :
  - RPV pressure set equal to steam dome pressure
  - Drywell, wetwell and GDCS vapor temperatures set equal to liquid temperature, and total pressures set equal to average pressure for each vessel
  - RPV heater power is set equal to scaled SBWR decay power at one hour plus RPV stored energy and heat losses and D/W heat losses

HELIUM Test H-2

- Purpose: To investigate the effect of Helium on PCCS performance
- Helium replaces the volume of nitrogen in the drywell
- All other initial conditions are the same as test H-1

Test H-3 ~~100%~~ Metal Water Reaction at one hour post LOCA

- Purpose: To investigate the effects of the maximum expected concentration of Helium on PCCS performance.
- Initial Conditions: Except for the addition of Helium in the Drywell, all other initial conditions are the same as for Test H-1.
- Mixture of Steam, Helium and Nitrogen in the Drywell to represent a 20% SBWR metal water reaction at one hour after a Main Steam line break
- Helium equivalent to 23% of Drywell volume is injected into the D/W

Test H-4 ~~100%~~ MW Reaction at one hour post LOCA

- Purpose: To investigate the effect on PCCS performance when the 23% volume of Helium is injected over a one hour time period into the drywell
- Initial Conditions: Same as for Test H-1
- Total mass of Helium injected = H-3 initial mass of Helium in drywell
- Helium injection rate = 0.00027 kg/sec.

  (total of 1 kg helium will be injected)

Tie-back Test T-1

- Purpose: Repeat a Post Phase 2 Test to reinforce the validity of the previous testing
- Facility configuration: PCCS tube length 1.8m, D/W microheaters used, RPV heater power based on 2000mw SBWR
- Initial Conditions: Based on SBWR conditions at one hour after MSLB (28% Nitrogen in D/W)
- Drywell to wetwell vacuum breaker is located in annular drywell region approximately at middle of wetwell airspace (In the present SBWR design, V/B is located at wetwell roof.)
- GDCS injection at one hour post loca (In present SBWR design GDCS injection is already completed due to increased nozzle size.)

Test T-2

- Purpose: Widen the range of initial nitrogen concentration in the Drywell to demonstrate that peak D/W pressure is not sensitive to the initial nitrogen mass in the D/W
- Inital D/W nitrogen concentration : midway between that for Tests H-1 and T-1. (Total D/W Pressure=266 KPa)
- Total nitrogen concentration in the system: same as H-1, therefore the Wetwell initial nitrogen concentration is less than H-1. (Total W/W Pressure=257 KPa)

Table 9-1. GIRAFFE He Integral Systems Tests Initial Conditions

Parameter	Value	Tolerance
RPV Pressure (KPa)	295	± 6KPa
Initial Heater Power (Kw)	66+heat loss compensation	± 1Kw
RPV Water Level (m)*	12.0	± 0.150m
Drywell Pressure (KPa)	294	± 4KPa
Wetwell Pressure (KPa)	285	± 4KPa
Wetwell Nitrogen Pressure (KPa)	240	± 4KPa
GDCS Gas Space Pressure (KPa)	294	± 4KPa
GDCS Nitrogen Pressure (KPa)	274	± 4KPa
Suppression Pool Temperature (K)	352	± 2K
PCC Pool Temperature (K)	373	± 2K
GDCS Pool Temperature (K)	333	± 2K
GDCS Pool Level* (m)	**	
Suppression Pool Level* (m)	3.25	± 0.075m
PCC Pool Collapsed Water Level* (m)	23.2	± 0.075m
PCC Vent Line Submergence (m)	0.95	± 0.075m

* Referenced to the Top of Active Fuel (TAF).

** GDCS pool level should be positioned in hydrostatic equilibrium with the RPV level (including an appropriate adjustment for temperature difference).

Table 9-2. GIRAFFE He Integral Systems Test Matrix

GIRAFFE Test No.	Helium Injection Rate (Kg/sec)	Drywell Initial Partial Pressures (KPa) (±2KPa)		
		Nitrogen	Steam	Helium
H1	0	13	281	0
H2	0	0	281	13
H3	0	13	214	67
H4	0.00027	13	281	0

Table 9-3. GIRAFFE He Tie-back Test Initial Conditions

Parameter	Value	Tolerance
RPV Pressure (KPa)	189	± 6KPa
RPV Collapsed Water Level (m)*	9.1	± 0.150m
Initial Heater Power (Kw)	96	± 1Kw
Drywell Total Pressure (KPa)	188	± 4KPa
Drywell Nitrogen Partial Pressure (KPa)	53	± 4KPa
Drywell Steam Partial Pressure (KPa)	135	± 4KPa
Wetwell Pressure (KPa)	174	± 4KPa
Wetwell Nitrogen Pressure (KPa)	164	± 4KPa
GDCS Pool Gas Space Total Pressure (KPa)	188	± 4KPa
GDCS Pool Gas Space Nitrogen Partial Pressure (KPa)	151	± 4KPa
Suppression Pool Temperature (K)	326	± 2K
PCC Pool Temperature (K)	373	± 2K
GDCS Pool Temperature (K)	350	± 2K
GDCS Pool Level* (m)	14.1	± 0.075m
Suppression Pool Level* (m)	3.5	± 0.075m
PCC Pool Collapsed Water Level* (m)	23.2	± 0.075m
PCC Vent Line Submergence (m)	0.90	± 0.075m

* Referenced to the TAF.

Table 9-4. GIRAFFE He Test T2 Initial Conditions

Parameter	Value	Tolerance
RPV Pressure (KPa)	257	± 6KPa
RPV Water Level (m)*	12.0	± 0.150m
Initial Heater Power (Kw)	66 +Heat loss comp.	± 1Kw
Drywell Total Pressure (KPa)	266	± 4KPa
Drywell Nitrogen Partial Pressure (KPa)	38	± 4KPa
Drywell Steam Partial Pressure (KPa)	228	± 4KPa
Wetwell Pressure (KPa)	257	± 4KPa
Wetwell Nitrogen Pressure (KPa)	212	± 4KPa
GDCS Pool Gas Space Total Pressure (KPa)	266	± 4KPa
GDCS Pool Gas Space Nitrogen Partial Pressure (KPa)	246	± 4KPa
Suppression Pool Temperature (K)	352	± 2K
PCC Pool Temperature (K)	373	± 2K
GDCS Pool Temperature (K)	333	± 2K
GDCS Pool Level* (m)	**	± 0.075m
Suppression Pool Level* (m)	3.25	± 0.075m
PCC Pool Collapsed Water Level* (m)	23.2	± 0.075m
PCC Vent Line Submergence (m)	0.95	± 0.075m

* Referenced to the TAF.

** GDCS pool level should be positioned in hydrostatic equilibrium with the RPV level (including the appropriate adjustment for temperature difference).

Test Initialization Procedures

- Pressurize D/W to 200 KPa using house steam.
- Feed hot water to RPVand use bundle heater to pressurize.
- Pressurize PCC condenser to 200 KPa.
- Feed hot water to GDCS Pool and pressurize with nitrogen.
- Feed hot water to PCC pool.
- Connect RPV, D/W and PCC Condenser.Adjust pressures using house steam.
- Initialize Suppression Chamber. Use house steam to increase water temperature.
- Set Decay heat simulation using one loop controller.

Test Procedures (continued)

- Final initialization of each vessel. Adjust water levels and pressures in S/C, GDCS pool and RPV. Adjust D/W steam pressure and then add the noncondensible gas.
- Just prior to Test Start: Close PCC drain to RPV, Close PCCS house steam supply, Open D/W to PCCS steam supply and PCCS drainage to GDCS, connect PCCS to S/C.
- Test Start.
- Operator monitors S/C and D/W pressures, opens Vacuum breaker when S/C pressure is 3240 Pa higher than D/W and closes when pressure difference is less than 2060 Pa.
- S/C microheater adjustment during test.

Presentation Goals

- Achieve consensus with the NRC on the following open technical items from the GIRAFFE Helium test audit/inspection:

  V/B Cycling is not required to satisfy the test objective on demonstrating the PCC condenser purge/vent process.

  S/C microheater adjustments during the tests, do not adversely effect the test results.

- Present Test Results, including gas sampling results.

PCC Condenser Purge/Vent Process

- During each of the helium tests, purging of noncondensible gases from the PCC condenser occurred.The LOCA vent remained covered during all tests.
- Direct gas sampling results show that for each test approximately 50% of the noncondensible gases were vented by the PCCS to the S/C.
- For Tests H3&4, 50% of the initial helium volume is equal to 30 times the PCC condenser volume.
- The helium tests confirm that even for large quantities of noncondensible gases, the PCCS can purge the noncondensibles within less than one hour.

Vacuum Breaker Cycling

- V/B only opened during Test H1, the 4% nitrogen case.
- For Test H1, the nitrogen in the PCC tubes was mainly at the bottom of the tubes. As a result, the PCC heat removal was very high and within approximately one hour it exceeded the input decay heat. The drywell pressure dropped, and then the V/B opened two times when the S/C pressure exceeded the D/W pressure by 3240 Pa. In each case, the V/B only opened for several seconds. Therefore, only a small amount of noncondensibles flowed back to the D/W and then flowed into the PCC increasing the amount of noncondensible at the bottom of the tubes.

V/B Cycling did not occur for all other tests

- For Test H2, with 4% helium: Helium was approximately uniformly distributed along the tube lengths. This resulted in a PCC heat removal rate less than that for H1.Therefore, the PCC heat removal did not exceed the decay heat input during the first hour of the test. The D/W pressure did decrease, but it did not drop below the S/C pressure.
- For Tests H3&4: The helium behaved similar to Test H2.
- For Test T2, with 14% nitrogen: The nitrogen behaved similar to Test H1, but due to the higher concentration of nitrogen, it took longer to vent the nitrogen from the D/W. Therefore, the D/W pressure did not drop below the S/C pressure.

Suppression Chamber Microheater Power Adjustments During Tests

- During heat loss tests the microheater power settings determined so that heat losses are completely compensated by microheater power.
- Once the gas venting becomes intermittent, the gas space plenum temperatures are monitored. These temperatures are maintained at a constant value, by controlling the microheater power.
- After gas venting is completed, the S/C pressure should not increase further. The gas plenum pressure is monitored and is maintained by controlling the microheater power.

Direct Measurement of Noncondensible Gas Concentrations

- Samples are collected at three locations: upper & lower D/W and at the S/C.
- Samples are collected at one hour intervals.
- Samples are measured using a gas chromatograph to determine the concentrations of each gas.
- The accuracy of the measurement is +/- 3%.

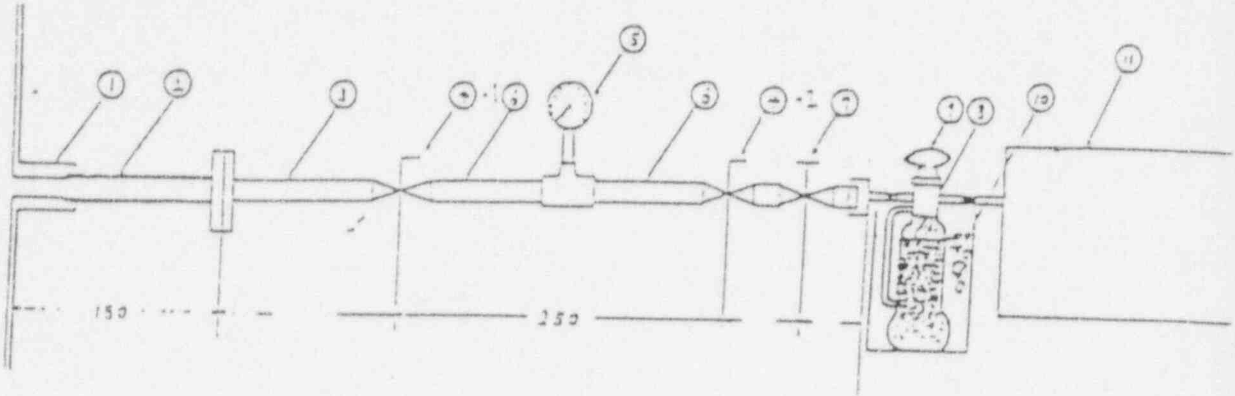


Fig-2.1 Equipment and instruments for water sampling
(sample volume ≤ 3 ℓ)

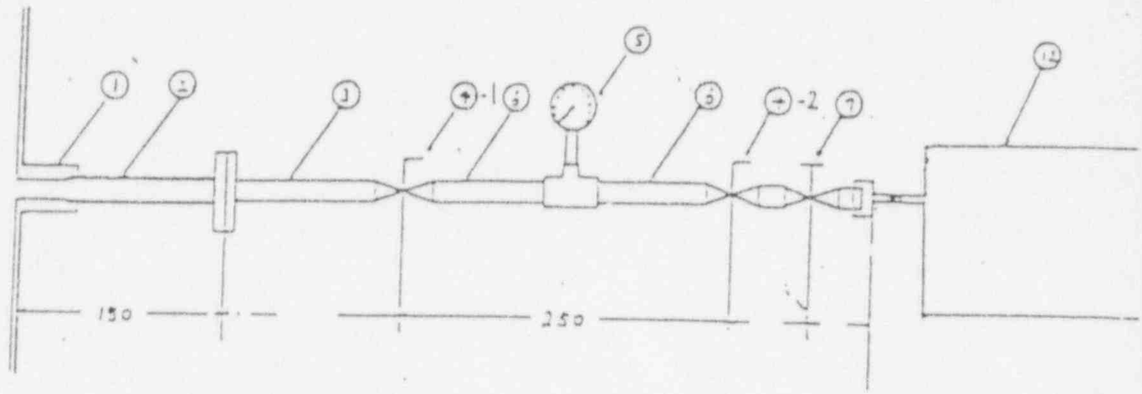


Fig-2.2 Equipment and instruments for non-condensable gas sampling
(sample volume ≤ 1 ℓ)

NO.	Tite	Quality	Remarks
1	Bass	SUS 304	OD:35ϕ, ID:15.7ϕ
2	pipe	SUS 304	1/2B.SCH:40
3	pipe	SUS 304	3/8B.SCH:40
4-1,-2	stop valve	SUS	Ball Valve
5	pressure gage	SUS	AMU3/8PT.10Kg/cm^2
6	pipe	SUS 304	3/8B.SCH:40
7	Needle valve	SUS	
8	absorption Battle	Glass	Filling up $CaCl_2$ and poly-wool
9	Cock	Glass	
10	Cooling Bath	SUS	Filling up $CaCl_2$ and Dry-Ice
11	gas sampling Bag 1	PVF	maximum 2 litters
12	gas sampling Bag 2	PVF	maximum 2 litters

Report on Result of Measurement Analysis

Report No. KKS 0706-0 3136

June 7, 1995

To: GE Nuclear Energy

KOKAN KEISOKU
Measurement certification business concerned with concentration
Registration No.
Kanagawa Prefecture No. 90
1-1, Minamiwatarida-cho,
Kawasaki-ku, Kawasaki-shi (210)
Tel: 044-277-8008, Fax: 044-277-8179

The result of your requested measurement analysis will be reported as follows:-

1. Subject : Measurement analysis of noncondensable gases and steam
2. Site of Measurement: TOSHIBA CORPORATION, HAMAKAWASAKI FACTORY
   NUCLEAR ENGINEERING LABORATORY
   4-1, Ukisima-cho, Kawasaki-ku, Kawasaki-shi 210, Japan
3. Date of measurement: May 30. 1995
4. Name of Test : H1-3 (TS init. cond. 95.6% steam 4.4% N_2)
5. Results of measurement analysis P_T = 294 kPa

5.1. LDW (LOWER DRYWELL)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	0.1	4.4	95.5	2.23 (in 2.86l)
2	1	0.1	17.5	82.4	1.11 (in 1.67l)
3	2	0.1	22.0	77.9	0.92 (in 1.47l)
4	3	<0.1	30.3	69.7	0.79 (in 1.41l)
5	4	<0.1	28.4	71.6	0.83 (in 1.44l)
6	5	<0.1	34.7	65.3	0.63 (in 1.18l)
7	6	<0.1	32.2	67.8	0.69 (in 1.26l)
8	7	<0.1	28.7	71.3	0.87 (in 1.52l)
9	8	<0.1	33.8	66.2	0.64 (in 1.20l)

HI-3

(TS initial condition 95.6% stm, 4.4% N_2)

5.2. UDW (UPPER DRYWELL)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	<0.1	1.4	98.6	9.97 (in 12.61)
2	1	0.2	<0.1	99.8	14.91 (in 18.61)
3	2	0.1	0.1	99.8	8.38 (in 10.41)
4	3	0.1	0.1	99.8	3.89 (in 4.851)
5	4	<0.1	0.1	99.8	1.31 (in 1.631)
6	5	0.2	0.2	99.8	1.43 (in 1.751)
7	6	0.1	0.1	99.7	1.54 (in 1.921)
8	7	0.2	0.2	99.6	1.62 (in 2.031)
9	8	0.1	<0.1	99.8	1.95 (in 2.421)

(TS initial condition 15.8% stm, 84.2% N_2)
P_T = 285 kPa

5.3. SC (SUPPRESSION CHAMBER)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	<0.1	86.8	13.2	0.11 (in 1.031)
2	1	<0.1	85.7	14.3	0.12 (in 1.041)
3	2	<0.1	85.8	14.2	0.12 (in 1.051)
4	3	<0.1	86.1	13.9	0.12 (in 1.071)
5	4	<0.1	86.9	13.1	0.11 (in 1.041)
6	5	<0.1	87.5	12.5	0.10 (in 0.981)
7	6	<0.1	87.4	12.6	0.10 (in 0.991)
8	7	<0.1	85.5	14.5	0.12 (in 1.031)
9	8	<0.1	86.7	13.3	0.11 (in 1.031)

Report on Result of Measurement Analysis

Report No. KKS 0706-0 3140

June 9, 1995

To: GE Nuclear Energy

KOKAN KEISOKU
Measurement certification business concerned with concentration
Registration No.
Kanagawa Prefecture No. 90
1-1, Minamiwatarida-cho,
Kawasaki-ku, Kawasaki-shi (210)
Tel:044-277-8008, Fax:044-277-8179

The result of your requested measurement analysis will be reported as follows:-

1. Subject : Measurement analysis of noncondensable gases and steam
2. Site of Measurement: TOSHIBA CORPORATION, HAMAKAWASAKI FACTORY
   NUCLEAR ENGINEERING LABORATORY
   4-1, Ukisima-cho, Kawasaki-ku, Kawasaki-shi 210, Japan
3. Date of measurement: June 2, 1995
4. Name of Test : H2 (Test spec initial condition 95.6% stm 4.4% He)
5. Results of measurement analysis $P_T = 294$ kPa

5.1. LDW (LOWER DRYWELL)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	1.3	<0.1	98.7	2.66 (in 3.361)
2	1	9.3	0.1	90.6	1.96 (in 2.691)
3	2	9.2	0.1	90.7	1.61 (in 2.211)
4	3	10.8	0.1	89.1	1.56 (in 2.181)
5	4	10.1	0.1	89.8	1.82 (in 2.521)
6	5	9.7	0.1	90.2	1.44 (in 1.991)
7	6	9.3	0.1	90.6	1.69 (in 2.321)
8	7	8.8	0.1	91.1	1.70 (in 2.321)
9	8	7.8	<0.1	92.2	1.84 (in 2.481)

H-2

(Test spec initial condition 95.6% stm, 4.4% He)

5.2. UDW (UPPER DRYWELL)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	1.5	<0.1	98.5	1.73 (in 2.191)
2	1	0.1	<0.1	99.9	1.91 (in 2.381)
3	2	0.1	<0.1	99.9	1.65 (in 2.061)
4	3	0.2	<0.1	99.8	1.41 (in 1.761)
5	4	0.2	<0.1	99.8	1.49 (in 1.861)
6	5	0.2	<0.1	99.8	1.58 (in 1.971)
7	6	0.2	<0.1	99.8	1.78 (in 2.221)
8	7	0.2	<0.1	99.8	1.50 (in 1.871)
9	8	0.2	<0.1	99.8	1.38 (in 1.721)

5.3. SC (SUPPRESSION CHAMBER)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	1.4	84.8	13.8	0.13 (in 1.181)
2	1	2.8	84.5	12.7	0.10 (in 0.981)
3	2	2.8	83.7	13.5	0.12 (in 1.101)
4	3	2.8	83.4	13.8	0.12 (in 1.081)
5	4	2.8	83.2	14.0	0.12 (in 1.071)
6	5	2.8	83.5	13.7	0.12 (in 1.091)
7	6	2.8	83.7	13.5	0.12 (in 1.111)
8	7	2.8	83.5	13.7	0.12 (in 1.091)
9	8	2.8	84.4	12.8	0.11 (in 1.071)

(Test spec initial condition 84.2% N_2, 15.8% stm)

P_T = 285 KPa

Report on Result of Measurement Analysis

Report No. KKS 0706-0 3165

June 22, 1995

To: GE Nuclear Energy

KOKAN KEISOKU

Measurement certification business concerned with concentration

Registration No.

Kanagawa Prefecture No. 90

1-1, Minamiwatarida-cho,

Kawasaki-ku, Kawasaki-shi (210)

Tel:044-277-8008, Fax:044-277-8179

The result of your requested measurement analysis will be reported as follows:-

1. Subject : Measurement analysis of noncondensable gases and steam
2. Site of Measurement: TOSHIBA CORPORATION, HAMAKAWASAKI FACTORY
   NUCLEAR ENGINEERING LABORATORY
   4-1, Ukisima-cho, Kawasaki-ku, Kawasaki-shi 210, Japan
3. Date of measurement: June 16, 1995
4. Name of Test : H3 (Test spec initial condition: 72.8% stm, 22.8% He, 4.4% N2) P_T = 294 kPa
5. Results of measurement analysis

5.1. LDW (LOWER DRYWELL)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	18.1	2.4	79.5	0.70 (in 1.101)
2	1	38.6	5.0	56.4	0.55 (in 1.211)
3	2	47.2	5.9	46.9	0.38 (in 1.011)
4	3	39.6	4.8	55.6	0.63 (in 1.411)
5	4	40.3	5.0	54.7	0.56 (in 1.281)
6	5	40.2	5.0	54.8	0.62 (in 1.411)
7	6	34.5	4.9	60.6	0.60 (in 1.231)
8	7	26.8	3.7	69.5	0.66 (in 1.181)
9	8	26.6	3.5	69.9	0.67 (in 1.191)

H-3

(TS init cond: 72.8% stm, 22.8% He, 4.4% N_2)

5.2. UDW (UPPER DRYWELL)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	6.6	0.7	92.7	3.96 (in 5.321)
2	1	0.5	<0.1	99.5	3.40 (in 4.251)
3	2	0.3	<0.1	99.7	2.64 (in 3.291)
4	3	0.2	<0.1	99.8	2.75 (in 3.431)
5	4	0.3	<0.1	99.7	3.12 (in 3.891)
6	5	0.3	<0.1	99.7	3.35 (in 4.181)
7	6	0.4	<0.1	99.6	4.15 (in 5.181)
8	7	0.3	<0.1	99.7	4.99 (in 6.231)
9	8	0.3	<0.1	99.7	4.20 (in 5.241)

5.3. SC (SUPPRESSION CHAMBER)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	3.2	82.1	14.7	0.13 (in 1.101)
2	1	11.2	75.6	13.2	0.14 (in 1.321)
3	2	12.0	77.6	10.4	0.10 (in 1.201)
4	3	12.0	76.6	11.4	0.11 (in 1.201)
5	4	12.0	75.3	12.7	0.13 (in 1.271)
6	5	12.3	76.1	11.6	0.12 (in 1.281)
7	6	12.3	75.2	12.5	0.13 (in 1.301)
8	7	12.6	74.9	12.5	0.13 (in 1.291)
9	8	12.8	75.1	12.1	0.13 (in 1.341)

(Test Spec initial condition: 15.8% stm
84.2% N_2)
$P_T = 285$ KPa

H4

Report on Result of Measurement Analysis

Report No. KKS 0707-0 3181
July 5, 1995

To: GE Nuclear Energy

KOKAN KEISOKU
Measurement certification business
concerned with concentration
Registration No.
Kanagawa Prefecture No. 90
1-1, Minamiwatarida-cho,
Kawasaki-ku, Kawasaki-shi (210)
Tel:044-277-8008, Fax:044-277-8179

The result of your requested measurement analysis will be reported as follows:-

1. Subject : Measurement analysis of noncondensable gases and steam
2. Site of Measurement: TOSHIBA CORPORATION, HAMAKAWASAKI FACTORY
NUCLEAR ENGINEERING LABORATORY
4-1, Ukisima-cho, Kawasaki-ku, Kawasaki-shi 210, Japan
3. Date of measurement: June 27, 1995
4. Name of Test : H4 (Test Spec initial condition: 95.6% stm 4.4% N_2) $P_T = 294 kPa$
5. Results of measurement analysis

5.1. LDW (LOWER DRYWELL)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	0.3	8.3	91.4	2.14 (in 3.17l)
2	1	6.2	24.5	69.3	1.06 (in 1.90l)
3	2	10.8	25.6	63.6	1.10 (in 2.15l)
4	3	11.6	26.5	61.9	0.87 (in 1.75l)
5	4	11.2	24.4	64.4	0.93 (in 1.80l)
6	5	11.5	24.8	63.7	0.93 (in 1.82l)
7	6	12.3	26.3	61.4	0.98 (in 1.99l)
8	7	12.2	26.2	61.6	0.88 (in 1.78l)
9	8	11.2	24.2	64.6	1.00 (in 1.93l)

H4

(CTS initial condition: 95.6% stm, 4.4% N_2)

5.2. UDW (UPPER DRYWELL)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	1.9	1.1	97.0	8.29 (in 10.6l)
2	1	2.6	<0.1	97.4	10.44 (in 13.3l)
3	2	0.3	<0.1	99.7	8.76 (in 10.9l)
4	3	0.2	<0.1	99.8	2.26 (in 2.82l)
5	4	0.1	0.1	99.8	2.38 (in 2.97l)
6	5	0.2	0.1	99.7	2.15 (in 2.68l)
7	6	0.1	0.1	99.8	2.06 (in 2.59l)
8	7	0.1	0.1	99.8	1.98 (in 2.47l)
9	8	0.1	0.1	99.8	2.20 (in 2.74l)

5.3. SC (SUPPRESSION CHAMBER)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	(-0.5)	<0.1	79.1	20.9	0.18 (in 1.07l)
2	0	0.3	85.0	14.7	0.12 (in 1.02l)
3	1	13.7	74.8	11.5	0.13 (in 1.41l)
4	2	14.9	73.1	12.0	0.14 (in 1.46l)
5	3	14.9	72.5	12.6	0.14 (in 1.38l)
6	4	15.0	73.2	11.8	0.13 (in 1.38l)
7	5	14.8	72.6	12.6	0.14 (in 1.36l)
8	6	15.0	72.9	12.1	0.13 (in 1.34l)
9	7	15.1	73.3	11.6	0.13 (in 1.40l)
10	8	15.1	73.5	11.4	0.12 (in 1.30l)

(Test Spec Initial Condition: 15.8% stm, 84.2% N_2)

P_T = 285 KPa

Report on Result of Measurement Analysis

Report No. KKS 0707-0 3182

July 5, 1995

To: GE Nuclear Energy

KOKAN KEISOKU

Measurement certification business concerned with concentration

Registration No.

Kanagawa Prefecture No. 90

1-1, Minamiwatarida-cho,

Kawasaki-ku, Kawasaki-shi (210)

Tel: 044-277-8008, Fax: 044-277-3179

The result of your requested measurement analysis will be reported as follows:-

1. Subject : Measurement analysis of noncondensable gases and steam
2. Site of Measurement: TOSHIBA CORPORATION, HAMAKAWASAKI FACTORY NUCLEAR ENGINEERING LABORATORY 4-1, Ukisima-cho, Kawasaki-ku, Kawasaki-shi 210, Japan
3. Date of measurement: June 29, 1995
4. Name of Test : T2 (Test Spec initial conditions: 85.7% stm, 14.3% N_2) P_T = 266 KPa
5. Results of measurement analysis

5.1. LDW (LOWER DRYWELL)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	<0.1	14.4	85.6	1.04 (in 1.511)
2	1	<0.1	31.2	68.8	0.72 (in 1.301)
3	2	<0.1	39.1	60.9	0.57 (in 1.161)
4	3	<0.1	39.3	60.7	0.54 (in 1.111)
5	4	<0.1	46.3	53.7	0.44 (in 1.021)
6	5	<0.1	48.3	51.7	0.43 (in 1.041)
7	6	<0.1	45.7	54.3	0.54 (in 1.241)
8	7	<0.1	49.6	50.4	0.43 (in 1.061)
9	8	<0.1	48.4	51.6	0.43 (in 1.041)

T2

(Test Spec initial conditions: 85.7% stm, 14.3% N_2)

5.2. UDW (UPPER DRYWELL)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	0	<0.1	3.1	96.9	4.91 (in 6.30l)
2	1	<0.1	0.2	99.8	6.25 (in 7.80l)
3	2	<0.1	0.2	99.8	3.58 (in 4.46l)
4	3	<0.1	0.2	99.8	4.42 (in 5.51l)
5	4	<0.1	0.2	99.8	3.78 (in 4.71l)
6	5	<0.1	0.2	99.8	5.99 (in 7.47l)
7	6	<0.1	0.1	99.9	3.49 (in 4.35l)
8	7	<0.1	0.2	99.8	5.89 (in 7.34l)
9	8	<0.1	0.2	99.8	6.77 (in 8.44l)

5.3. SC (SUPPRESSION CHAMBER)

Sample No.	Passage Hours (h)	Helium (%)	Nitrogen (%)	Steam (%)	Water vapor weight (g)
1	(-0.5)	<0.1	74.5	25.5	0.20 (in 0.97l)
2	0	<0.1	84.6	15.4	0.11 (in 0.89l)
3	1	<0.1	84.1	15.9	0.11 (in 0.86l)
4	2	<0.1	84.8	15.2	0.12 (in 0.98l)
5	3	<0.1	85.6	14.4	0.11 (in 0.95l)
6	4	<0.1	85.1	14.9	0.11 (in 0.92l)
7	5	<0.1	85.3	14.7	0.11 (in 0.93l)
8	6	<0.1	85.5	14.5	0.11 (in 0.95l)
9	7	<0.1	85.2	14.8	0.11 (in 0.92l)
10	8	<0.1	84.6	15.4	0.10 (in 0.80l)

(Test Spec initial conditions: 17.5% stm, 82.5% N_2)

P_T = 257 KPa

H-1 TEST DATA

H-2 TEST DATA

TOSHIBA

H-3 TEST DATA

TOSHIBA

H-4 TEST DATA

TOSHIBA

T-1 TEST DATA

TOSHIBA

T-2 TEST DATA

TOSHIBA

PANDA PCC/IC HEADER INSULATION EVALUATION

J. E. TORBECK

22 AUGUST 1995

PANDA PCC/IC HEADER INSULATION EVALUATION

SCALING EVALUATIONS -- COVERED BY BOB GAMBLE

ANALYSIS OF EFFECT OF HEADER INSULATION

- STEADY STATE TRACG CALCULATIONS
- TRANSIENT TRACG CALCS FOR TEST M3

ADDITIONAL STEADY STATE TESTS

- EFFECT OF REDUCED PCC POOL LEVEL
- INVESTIGATION OF TEST RESULTS REPEATABILITY

ANALYSIS OF EFFECT OF HEADER INSULATION

STEADY STATE TRACG CALCULATIONS

- HEAT REMOVAL FROM UNINSULATED HEADERS IS APPROXIMATELY 15% OF THE TOTAL PCC HEAT REMOVAL
- HEAT REMOVAL FROM INSULATED HEADERS IS APPROXIMATELY 8% OF TOTAL
- INSULATION CHANGES TOTAL HEAT REMOVAL BY 3 TO 8% DEPENDING ON AIR CONTENT

TRANSIENT TRACG CALCS FOR TEST M3

- DRYWELL AND WETWELL GLOBAL PRESSURE RESPONSE IS ESSENTIALLY UNCHANGED
- VACUUM BREAKER OPENING IS EFFECTED

INSULATION HAS SMALL EFFECT ON TOTAL PCC HEAT REMOVAL AND INTEGRAL SYSTEM RESPONSE

CONCLUSION

DECISION TO PROCEED WITHOUT HEADER INSULATION FOR PANDA TRANSIENT TESTS IS SUPPORTED BY:

- SCALING EVALUATIONS
- TRACG ANALYSIS
- ADDITIONAL STEADY STATE TESTS

GE Nuclear Energy

SBWR Vacuum Breaker Single Failure-Open "Exemption" Request

Presented at the GE/NRC SBWR Testing/TRACG Mtg.

By

H. A. Upton on 8/22/95

Historical Background

- BWR S/P Steam Bypass Leakage Requirements:
  - Traditionally covered by SRP Sec. 6.2.1.1.C
    - Based on early Mk I, II, and III pressure suppression testing
    - Leak rates established for earlier plants not appropriate for passive plants
  - Industry position on passive BWRs found in URD Chapter 5, Sec. 7.2.26
    - Based on achieving very tight, essentially zero leakage barrier to bypass leakage during blowdown
    - 1 cm^2 ($A/\sqrt{K}$) established as bases for evaluation of wetwell design pressure (May 1992)

Historical Background (Contd.)

- To reliably meet 1 cm^2 requirement SBWR needed
  - A new leak tight /reliable vacuum breaker design
  - A welded steel barrier between wetwell and drywell
  - Absolute minimum number of wetwell penetrations
- Vacuum breaker design, development and test program was undertaken in July 1992
- Vacuum breaker prototype built, testing complete and final test report written by 12/94
- March 1994 NRC issued SECY-94-084 redefining check valves as active components subject to single failure

SBWR Vacuum Breaker

- Simple poppet type check valve with one moving part
- Double barrier seal to ensure leak tightness
  - Seal design provides single seat failure protection
- Inlet and Outlet screens to protect seals from LOCA debris
- Anti-Chatter ring to prevent excessive seat wear
- Designed to meet PRA failure rate of 3×10^{-4} failures/demand
- Design leak area = $0.02\ cm^2$ (2% of allowable WW leak rate)
- Passive operation - normally in the closed position
- Direct valve disk position monitoring with MCR alarms

VB Loads Reduced by Design

- SBWR WW designed leak tight
  - with welded steel liner
  - Limited number of sealed penetrations
- Only 3-20 inch diameter vacuum breakers are installed (compared to 8-20 inch VB for ABWR)
  - only 2 required to operate following DBA
- Vacuum breakers located away from hydrodynamic loads
  - high on the diaphragm floor and protected (similar to ABWR)
- Valves are predicted to lift < 20 times following a DBA and only after blowdown
- Vacuum breaker DBA loads and stresses are far below valve capability

Overview of Test Results

- Prototype vacuum breaker has been built, tested and environmentally qualified
- Leak Tightness - As built leak tightness demonstrated to be bubble tight (~ 0.0002 cm² ($A/\sqrt{K}$) with hard seat alone)
- Performance Testing - Lifted at required DP, performed smoothly, opening and closing with minimum amount of chatter. Valve stroke had to be increased to increase capacity.
- DBA Leak Tightness - Valve aged by radiation, high temp., and vibration the equivalent of 60 yr. life. Valve was shocked periodically with cold water. Valve leakage remained zero.
- Reliability Testing - VB cycled 3000 times without a failure even with ingestion of sandblasting grit. PRA reliability goal met. VB maximum allowable leak rate never exceeded.

Planned Surveillance Test Program

- SBWR vacuum breakers will be subject to operational testing and surveillance
- DW to WW bypass leakage testing:
  - Surveillance interval: Every refueling outage
  - Procedure: Isolate S/P from DW, pressurize to 2.7 psi above WW, record WW pressure/temperature/level for ~ 30 min. Final value must be less than TS acceptance criteria .
- Local leak rate test:
  - Surveillance interval: If DW to WW bypass leakage testing failed
  - Procedure: Remove VB outlet screens, seal exhaust port with specially design flanges, pressurize sealed chamber with N2 or air to ~ 2 psid and monitor pressure decay
- Inservice Inspection: (See attached Table)

Planned Inservice Inspection

SURVEILLANCE	FREQUENCY
7.1 Opening Setpoint: The opening setpoint will be verified by manually lifting the disc and measuring the opening force.	Once every 2 years
7.2 Free Movement and Dash Pot Surveillance: The disc will be dropped from the full open position and the closing time shall be monitored and compared to an acceptance criteria.	Once every 2 years
7.3 ISI by ASME XI for Class MC Components: Visual examination of accessible surface areas and seals.	Once every 2 years
7.4 Elastomers: The seal elastomers will be changed periodically.	Once every 6 years
7.5 Visual Examination: The vacuum breaker body, exhaust ports, inlet and outlet screens, disc and seal will be visually examined for external damage or debris.	Once every 2 years
7.6 Instrumentation Surveillance: The proximity sensors will be changed periodically to prevent a failure during reactor operation. A failure of any of the sensors is detected in the MCR through an alarm at any time during operation.	Once every 10 years or as or as required

Conclusion

- *GE successfully designed, built and tested a new vacuum breaker to stringent SBWR requirements*
- *SBWR VB installed in protected locations*
- *Operational testing and surveillance requirements will insure valve operability*
- *Most probable VB failure mode is failure to open - accounted for in SBWR design*
- *Vacuum breaker testing demonstrated proper functioning despite all credible conditions meeting single failure exemption requirements of ANSI/ANS 58.9*
- *Vacuum breaker testing was conducted with close NRC scrutiny*

Conclusion

- *SBWR vacuum breaker testing and final report was completed and submitted to NRC 12/94*
- *"SBWR Drywell to Wetwell Vacuum Breaker Valve White Paper" and Single Failure Exemption Request submitted 2/95*
- *Large sunk investment by GE and NRC in vacuum breaker development and review*
- *GE needs to disposition prototype vacuum breaker*
- *Request closure on 2/95 single failure-open "exemption" request*

GE Position: SBWR VB should be exempt from single failure-open requirement

GE Nuclear Energy

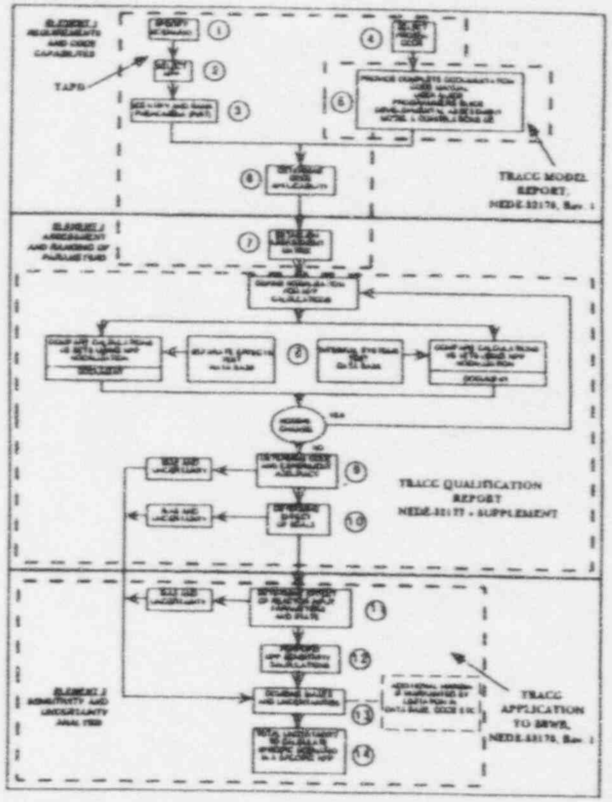
NRC Meeting on Containment Analysis

Containment Analysis Roadmap

B. S. Shiralkar

August 21, 1995

TRACG Documentation Road Map



Documentation Summary

- *TAPD Rev. C (August 95)*
  - *PIRT, data needed for assessment, test and analysis program*
- *TRACG Model LTR - NED 32176 Rev.1 (Dec. 95)*
  - *TRACG models, basis and range of application (reactor vessel and containment)*
- *TRACG Qualification - NED 32177 (Feb. 93) + Supplement (April 96)*
  - *includes PANTHERS, PANDA, GIRAFFE post test analysis*
  - *Discussion of applicability to SBWR*
  - *Quantitative comparisons of predictions vs. data*
- *TRACG Model Application to SBWR - NED 32178 (April 96)*
  - *Design application methodology*

TRACG Application for DBA Analysis (contd.)

- *SSAR calculation basis*
  - *102% of rated power*
  - *Loss of a/c power*
  - *Initial pool temperature at maximum value (43.3 C)*
  - *Drywell to wetwell effective leakage area of 1 cm^2*

PANDA Scaling - PCC Header Insulation

By Robert Gamble

NRC Meeting

San Jose, CA

Aug. 22, 1995

PCC Header Heat Loss - System Considerations

- Total PANDA PCC heat removal increased by approximately 10%
  - Only important when Decay heat is within 10% of PCC maximum capacity since PCC will self regulate to balance steam generated from decay heat
- Scaling measurement is Qpcc/Qdecht
  - Parameter can vary from ~0 (PCC full of n-c's) to 3 in SBWR during time frame of PANDA test. It will vary over similar range in PANDA.
- Fill time constant will vary by same percentage (~10%)
  - Not a significant amount for nominal value of 29 seconds

PCC Heat Transfer

- **PCC heat transfer given by**

$$\dot{Q} = \frac{A}{R}(T_{PCC} - T_{pool})$$

A is the header surface area and R is the total "resistance" to heat transfer given by

$$R = R_{inner} + R_{wall} + R_{outer}$$

where

$$R_{inner} = \frac{1}{h_{inner}}$$

$$R_{wall} = \frac{D_i \ln(D_o/D_i)}{2k_{wall}}$$

$$R_{outer} = \frac{1}{h_{outer}}$$

PCC Header Heat Loss - Bottom-up Effects

- Key parameters effecting PCC behavior are: blanketing, shear enhancement and degradation due to n-c's
- The time constant for blanketing (filling) has been addressed above. No bottom-up mechanism has been identified that would indicate a significant distortion in blanketing from the increased header heat removal.
- The shear enhancement and n-c concentration parameters vary over a wide range of conditions over the length of the tubes and the various system conditions in the SBWR
  - Ranges will be similar in PANDA

PCC Header Heat Loss - Conclusion

- Scaling effect of uninsulated header considered from system, component and bottom-up perspective

Scaling does not indicate any significant distortions from uninsulated header

GIRAFFE/He Scaling

By Robert Gamble

NRC Meeting
San Jose, CA
Aug. 22, 1995

GIRAFFE Scaling - Ideal Scaling

- Desired scaling for methodology used on SBWR is
  - $\tau_R = H_R = 1$
  - $Q_R = V_R = A_R = W_R = R$

$$z_R = \frac{z_{SBWR}}{z_{GIRAFFE}}$$

Z is some parameter

- Nominal R for GIRAFFE is 1:400
- Two distortions in GIRAFFE results in compromises
  - Large heat losses in Lower DryWell (LDW) (18% of scaled decay heat)
  - PCC heat removal scaled less than nominal system scale (1:690)
- Also,
  - Drywell aspect ratio very large in GIRAFFE

GIRAFFE Scaling - Drywell Heat Losses

- Drywell heat losses are compensated by additional steam generation in the RPV
- The result is that from a top down perspective the energy entering and exiting the GIRAFFE DW is balanced similar to the SBWR and the net heat flow to the PCC is scaled properly (~1:400)
- Condensation of steam at bottom of LDW results in downward gas velocity
- Therefore the drywell mixing in GIRAFFE may not be representative of SBWR
- Probably not representative anyway because of tall thin facility

GIRAFFE Scaling - Drywell Heat Losses (Cont'd)

- **Does not significantly effect PCC conditions**
  - Non-representative amount of n-c's may be trapped in LDW but sufficient n-c's are present to fill PCC many times (~30)
  - Therefore PCC will have many throughputs of n-c's as they are moved over to the WW as is expected in SBWR
- **PCC bottom-up parameters are n-c fraction, Free stream Re, Condensation layer thickness (Re film)**
  - These will vary over similar ranges in SBWR and GIRAFFE as discussed later
- **Therefore Drywell n-c distribution not crucial to test objective of demonstrating PCC performance in presence of lighter and heavier than air n-c's**

GIRAFFE Scaling - PCC Sizing

- *Two possible options to accommodate small PCC are:*
  - *Use PCC heat removal as nominal Q scale (1:690)*
  - *Use volume scale as nominal Q scale (1:400)*
- *The latter was selected for GIRAFFE/He*
- *This has the following results*
  - *DW fill time constant (pressurization rate) is maintained at 1:1*
  - *Several PCC parameters are distorted*

GIRAFFE Scaling - PCC Sizing (Cont'd)

- **The top down parameter of interest in the PCC is Qpcc/Qdecht**
  - **The GIRAFFE range is similar to the expected SBWR range**
    - Ranges from 0 to ~3 in SBWR
    - Ranges from 0 to 1.8 in GIRAFFE
  - **PCC generally regulates to a value of ~1**
- **The bottom-up parameters of interest are: blanketing, shear enhancement and degradation due to n-c's**
  - **The key parameters reflecting these phenomena are: the film Re, the free stream Re, and the non-condensible mass fraction, Yn-c**
  - **The ranges for these parameters are similar in SBWR and GIRAFFE**

Variation in PCC Bottom-Up Parameters (SBWR)

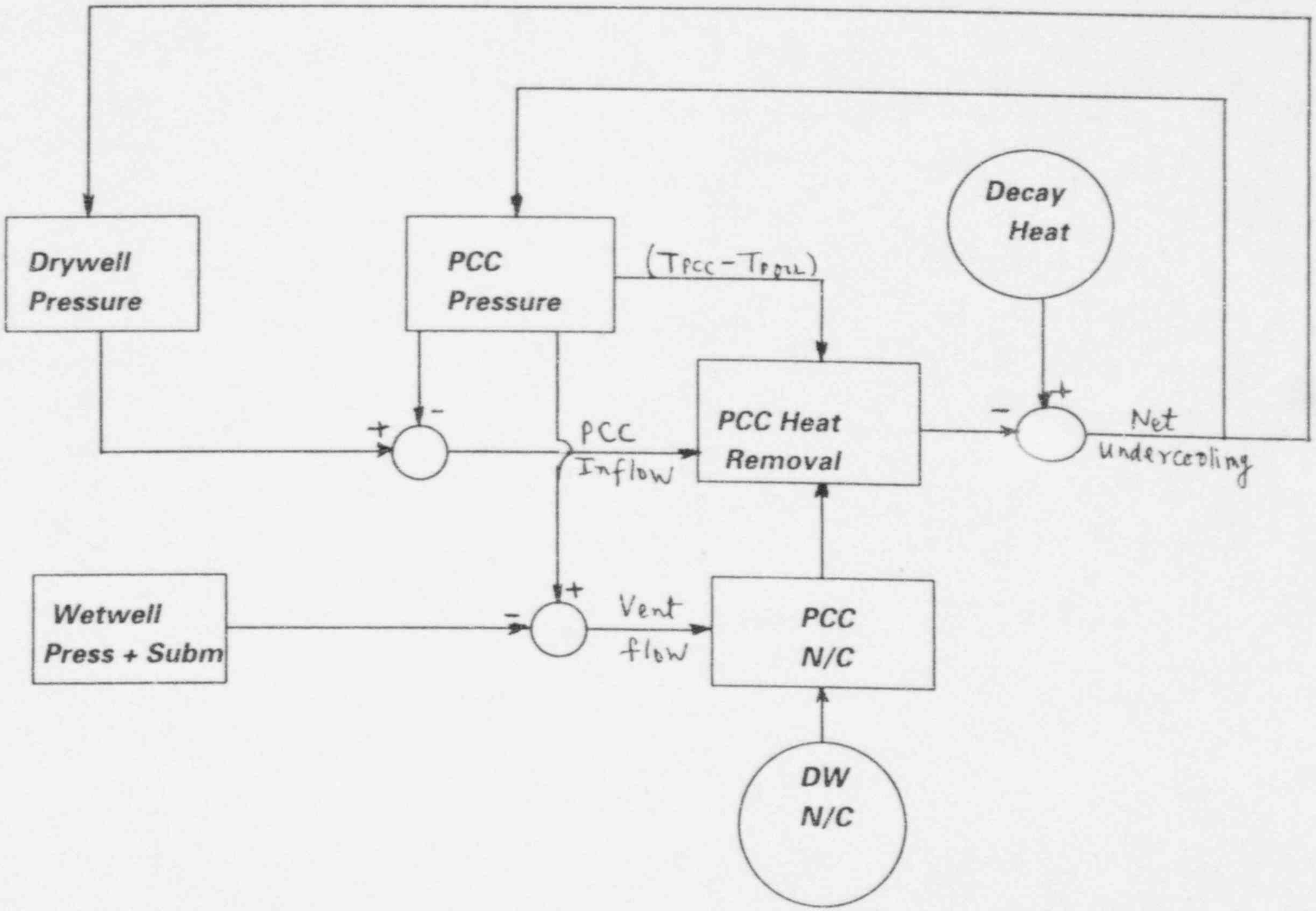
- *Film Re varies from small value at entrance to large number at exit*
  - *from ~0 to 1500*
- *Free stream Re varies from large number at entrance to small number when all steam is condensed (with small amount of n-c's)*
  - *from Order 30k to 0*
- *Yn-c varies based on inlet conditions*

Variation in parameters due to PCC sizing is much smaller than variation due to axial variation in conditions

GIRAFFE Scaling - Conclusions

- Two distortions in the GIRAFFE/He facility were considered: higher than desired heat losses in the Lower Drywell and a smaller than desired PCC size
- The GIRAFFE/He test objectives of demonstrating PCC performance in presence of lighter and heavier than air n-c's is not adversely effected by these distortions

Why SBWR Containment Response is Insensitive to Noncondensible Distribution



- *Feedbacks on N/C holdup and drywell pressure stabilize response*