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January 12, 2001
NRC:01:004

Document Control Desk
ATTN: Chief, Planning, Program and Management Support Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Viewgraphs for January 16, 2001 Meeting Between SPC and the NRC – EXEM BWR-2000 LOCA Methodology

Two proprietary copies and two nonproprietary copies of the viewgraphs to be presented at the January 16, 2001 meeting between SPC and the NRC are provided with this letter. The subject of the meeting is the recently submitted topical report on BWR LOCA methodology. (NOTE: One proprietary copy and one nonproprietary copy have been sent directly to Mr. N. Kalyanam.)

Siemens Power Corporation considers some of the information contained in the enclosure to this letter to be proprietary. As required by 10 CFR 2.790(b), an affidavit is enclosed to support the withholding of this information from public disclosure.

Very truly yours,

James. F. Mallay, Director
Regulatory Affairs

/arn

Enclosures

cc: N. Kalyanam (w/Enclosures)
Project No. 702

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AFFIDAVIT

STATE OF WASHINGTON)
) ss.
COUNTY OF BENTON)

1. My name is Jerry S. Holm. I am Manager, Product Licensing, for Siemens Power Corporation ("SPC"), and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by SPC to determine whether certain SPC information is proprietary. I am familiar with the policies established by SPC to ensure the proper application of these criteria.

3. I am familiar with the SPC information included in the presentation material transmitted with the letter NRC:01:004, dated January 12, 2001, from James F. Mallay to the Document Control Desk. These viewgraphs are referred to herein as "Documents." Information contained in these Documents has been classified by SPC as proprietary in accordance with the policies established by SPC for the control and protection of proprietary and confidential information.

4. These Documents contain information of a proprietary and confidential nature and is of the type customarily held in confidence by SPC and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in these Documents as proprietary and confidential.

5. These Documents have been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in the Documents be withheld from public disclosure.

6. The following criteria are customarily applied by SPC to determine whether information should be classified as proprietary:

(a) The information reveals details of SPC's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for SPC.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for SPC in product optimization or marketability.

(e) The information is vital to a competitive advantage held by SPC, would be helpful to competitors to SPC, and would likely cause substantial harm to the competitive position of SPC.

7. In accordance with SPC's policies governing the protection and control of information, proprietary information contained in these Documents has been made available, on a limited basis, to others outside SPC only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. SPC policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

Gerald S Holm
____

SUBSCRIBED before me this 11th

day of January, 2001.

Amy R. Nixon
____

Amy R. Nixon
NOTARY PUBLIC, STATE OF WASHINGTON
MY COMMISSION EXPIRES: 12/06/03

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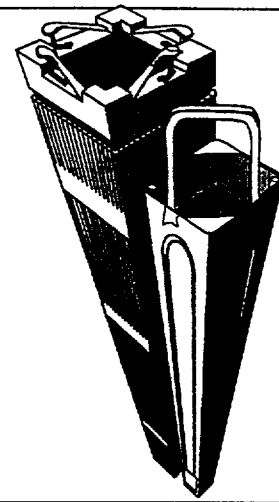
EXEM BWR-2000 ECCS Evaluation Model



Presented by: Jerry Holm
Gene Jensen
Scott Franz
Chuck Hendrix

U. S. Nuclear Regulatory Commission
January 16, 2001

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EXEM BWR-2000 ECCS Evaluation Model
Agenda

- Introduction (Jerry Holm)
- Current Approved Methodology (Gene Jensen)
- Code Changes (Scott Franz)
- Application Changes (Chuck Hendrix)
- Sample Problems / Sensitivity Studies (Chuck Hendrix)
- Verification (Scott Franz and Chuck Hendrix)
- Conclusion

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EXEM BWR-2000 ECCS Evaluation Model

Introduction

- Improved PCT Margins
- Replace FLEX with RELAX
- EPRI Pump model.
- Benchmarking to Satisfy 1997 Inspection Report
- Approval Requested by September 30, 2001

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Current Approved Methodology

- Evolution of BWR Evaluation Models
- 4 Principal Models and Additional Minor Upgrades
  - BWR Fuel Heatup Model, {XN-235(A)} HUXY Code
  - NJP BWR Evaluation Model, {XN-75-55(A) Rev. 2 and Supplements 1 & 2} (RELAP-EM, HUXY)
  - Jet Pump EXEM/BWR Evaluation Model, {XN-NF-80-19(P)(A) Volumes 2, 2A, 2B, & 2C} (RELAX, FLEX, HUXY)
  - Revised EXEM/BWR Evaluation Model, {ANF-91-048(P)(A)} (Same Codes)
- Evolution described and detailed roadmap with references for each evaluation model feature is presented in Section 2 of EMF-2361(P)

Current Approved Methodology (Cont.)

- Currently Approved EXEM/BWR Evaluation Model
  - Model consists of four basic codes:
    - RODEX2 code, fuel rod thermal-mechanical code
    - RELAX code, reactor system transient analysis code (blowdown)
    - FLEX code, reactor system transient analysis code (refill & reflood)
    - HUXY code, single fuel assembly transient heatup code

Current Approved Methodology (Cont.)

- RODEX2 Code
  - Calculates burnup dependent fuel rod initial conditions for LOCA analysis
  - Provides conservative initial stored energy
  - Provides burnup dependent fuel and cladding dimensions
  - Calculates fission gas release for LOCA initial conditions

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Current Approved Methodology (Cont.)

- RELAX Code
  - Derived from RELAP4 code (Mod 3)
  - Three equation model, homogeneous equilibrium assumptions
  - Calculates transient response of primary system to LOCA blowdown
    - RCS pressure
    - RCS coolant flow rates
    - RCS component coolant inventories
    - Transient core power
    - Transient heat transfer and fluid conditions
  - RELAX performs system blowdown calculation for entire primary coolant system
  - RELAX also performs detailed blowdown calculation for single hot assembly

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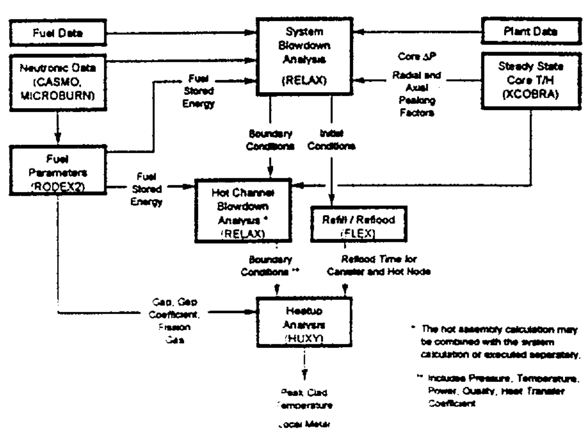
Current Approved Methodology (Cont.)

- FLEX Code
  - System transient code developed to calculate jet pump BWR refill behavior and time of core reflood
  - Obtains initial conditions from RELAX at end of blowdown (time of rated LPCS)
  - Calculates the transient flow and accumulation of ECCS in the RCS lower plenum
  - Principal output is the time of core reflood when fluid mixture has filled the lower plenum and entrained liquid has reached the plane of interest (POI)
  - Secondary output is time when mixture level in bypass region reaches the POI

Current Approved Methodology (Cont.)

- HUXY Code
  - Fuel assembly heatup code which models a horizontal POI in the maximum power assembly for entire LOCA transient
  - Calculates the transient heat transfer, metal-water reaction and fuel rod temperatures for all fuel rods in the hot assembly at the POI
  - Obtains initial conditions from RODEX2 results
  - During blowdown HUXY calculates heat transfer using heat transfer coefficients and fluid conditions from RELAX hot assembly results
  - During refill HUXY calculates radiation heat transfer among rods and structure supplemented by spray cooling heat transfer coefficients
  - At time of reflood, the Appendix K reflood heat transfer coefficient is applied to all rods at the POI

Current Approved Methodology (Cont.)



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Code Changes

- Replacement of FLEX with RELAX
- Reflood Criteria
- Ishii / Ohkawa-Lahey Drift Flux Correlation
- ANFB CHF correlation
- EPRI Pump Model
- Over Condensation Model

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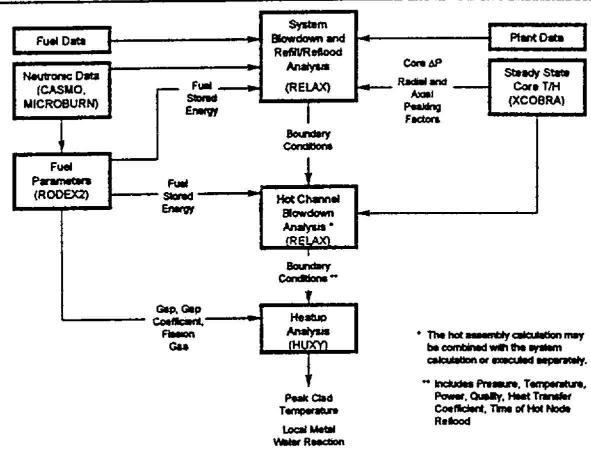
Code Changes (Cont.)

- Replacement of FLEX with RELAX
  - FLEX was originally developed to determine the time of reflood. This was done to resolve computational limitations concerning hardware and software using RELAX
  - Improved numerical techniques installed in the 1991 version of RELAX coupled with faster computers has significantly reduced the need for FLEX
  - The removal of FLEX provides:
    - Reduced opportunity for errors in input decks. Removes possible discontinuities which may occur
    - Is more efficient for calculations
    - Reduces the number of codes for maintenance and benchmarking
  - The time of reflood is now determined using RELAX

Code Changes (Cont.)



Code Changes (Cont.)
Reflood Criteria

- The FLEX mechanism for the determination of reflood has been implemented into RELAX as follows.
- The following parameters are used to determine if a reflood has occurred

- When these criteria have been met, the condition for the start of reflood will be accepted.

Code Changes (Cont.)

Ishii / Ohkawa-Lahey

- 1991 version of RELAX contains both the Ishii and Ohkawa-Lahey drift flux correlations
- It is desireable to remove the Ishii correlation due to a singularity which exists in the formulation
- Removal of the Ishii drift flux correlation removed a discontinuity in the RELAX code when switching between the two correlations
- The Ohkawa-Lahey drift flux correlation is now used throughout the entire computational space of a boiler calculation
- The Ohkawa-Lahey drift flux correlation reduces to the Kutateladze CCFL condition; therefore, it is also used for the CCFL calculation

Code Changes (Cont.)

Ishii / Ohkawa-Lahey

Code Changes (Cont.)
ANFB CHF Correlation

- SPC will use the latest CHF correlation approved for our fuel designs (ANFB, SPCB). The following is an example of the installation of the ANFB CHF Correlation
- Used to maintain consistency between steady state licensing methodology and LOCA methodology
- Applied within the data range envelope in which ANFB was developed as described below. A previous SER restricts the use of ANFB for transient LOCA analysis.

Code Changes (Cont.)
ANFB CHF Correlation

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Code Changes (Cont.)

EPRI Two-Phase Degradation Pump Model

- RELAX upgraded from the Semi-Scale Two-Phase Degradation model. This was done for the SPC PWR Appendix K methodology in compliance to a request by the NRC.
- Application to BWR analysis provides continuity between the PWR and BWR methodology
- New model provides more realistic results for full scale plant analysis

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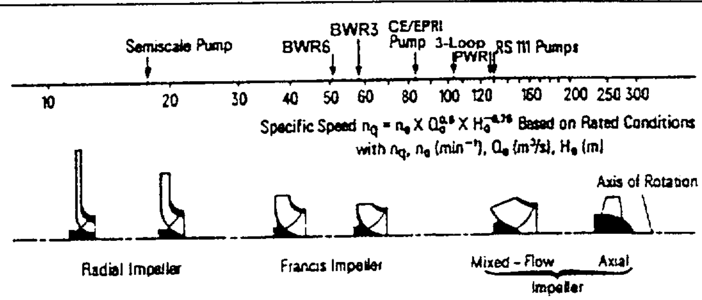
Code Changes (Cont.)

EPRI Two-Phase Degradation Pump Model



- The impact of this model for Large Break LOCA is small.
- The impact for Small Break LOCA decreases the PCT. This change typically results in Large Break cases being the limiting case which is what is expected.

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Code Changes (Cont.)
Over Condensation Model

- One-Dimensional Homogeneous Equilibrium codes over predict the amount of condensation in volumes where large amounts of subcooled liquid are injected. This results in a non-realistic pressure suppression in that volume.
- The Enthalpy Injection model has been added to RELAX to manage this aspect of a one-dimensional homogeneous equilibrium model
- Aspects of the Enthalpy Injection Model

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Code Changes (Cont.)
Over Condensation Model

- Aspects of the Enthalpy Injection Model (cont.)

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Code Changes
Summary

- Replacement of FLEX with RELAX
- Reflood Criteria
- Ishii / Ohkawa-Lahey Drift Flux Correlation
- ANFB CHF correlation
- EPRI Pump Model
- Over Condensation Model

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Modeling Application Changes

- Four Modeling Modifications are Required for EXEM BWR-2000
  - Increased jet pump noding and modified jet pump exit description
  - Phase separation model in the bypass
  - Core nodalization
  - Upper plenum nodalization

Modeling Application Changes (Cont.)

- Modification Summary
  - Model modifications apply to the RELAX system model
  - Current applications - RELAX system analysis is terminated at the time of end of blowdown (EOB)
  - EXEM BWR-2000 - RELAX analysis is extended to the time of core hot node reflood
  - Modifications improve RELAX analysis of the reflood phase of a LOCA
  - No impact on the conservative prediction of thermal-hydraulic phenomena in the blowdown phase

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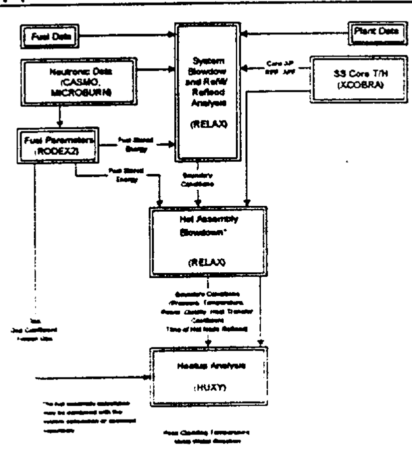
Modeling Application Changes (Cont.)



Modeling Application Changes (Cont.)

Modeling Application Changes (Cont.)
Jet Pump Modeling

- Increased jet pump nodalization and modified jet pump exit description

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Modeling Application Changes (Cont.)

Jet Pump Modeling

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Modeling Application Changes (Cont.)

Core Bypass Region Modeling

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Modeling Application Changes (Cont.)

Core Bypass Region Modeling

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Modeling Application Changes (Cont.)

Core Nodalization for LOCA Analysis

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Modeling Application Changes (Cont.)

Core Nodalization for LOCA Analysis

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Modeling Application Changes (Cont.)

Core Nodalization for LOCA Analysis

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Modeling Application Changes (Cont.)

Core Nodalization for LOCA Analysis

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Modeling Application Changes (Cont.)

Core Nodalization for LOCA Analysis

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Modeling Application Changes (Cont.)

Upper Plenum Nodalization for LOCA Analysis

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Model Application and Sensitivities

- BWR LOCA/ECCS Analysis Example Problems
- EXEM BWR-2000 Methodology Sensitivity Studies

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Model Applications and Sensitivities (Cont.)
Example Problem Summary

- Representative calculations from a typical BWR/3 break spectrum analysis
- BWR/3 systems are the most challenging for LOCA analysis because of low ECCS capacity

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Model Applications and Sensitivities (Cont.)
Example Problem Summary

- Break Spectrum Parameters
  - Break size/location
    - Recirculation pump suction line
    - Recirculation pump discharge line
  - Break type
    - Double-ended guillotine
    - Split
- ECCS Single Failure (BWR/3)
  - SF-LPCI (2 LPCS)
  - SF-DG (2 LPCI and 1 LPCS)
  - SF-HPCI (4 LPCI and 2 LPCS)
- Axial Power Profile
  - Top peaked
  - Center peaked

Model Applications and Sensitivities (Cont.)
Example Problem Summary

Model Applications and Sensitivities (Cont.)
Example Problem Summary

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Example Problem
Upper Plenum Pressure

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Example Problem (Cont.)
Total Break Flow

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Example Problem (Cont.)

LPCS Flow

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Example Problem (Cont.)

Lower Plenum Liquid Mass

Example Problem (Cont.)

Average Core Liquid Mass

Example Problem (Cont.)

Guide Tube Liquid Mass

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Example Problem (Cont.)

Bypass Liquid Mass

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Example Problem (Cont.)

HUXY Analysis

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Model Applications and Sensitivities (Cont.)

EXEM BWR-2000 Methodology Sensitivity Studies

- Confirm that EXEM BWR-2000 analysis is not excessively sensitive to RELAX nodalization or input
  - Average core nodalization
  - Upper plenum nodalization
  - Hot channel nodalization
  - Time steps
- EXEM BWR-2000 shows insignificant sensitivity to the above parameters

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Verification

- Verification of the new models has been done using two facilities:
  - TLTA
    - The Two Loop Testing Facility benchmark has been rerun through blowdown
  - FIST
    - Three cases have been explored. Two large break cases and one small break

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Verification (cont.)
TLTA

- SPC has used the TLTA benchmark to assess the blowdown behavior of RELAX. However, the EXEM BWR-2000 EM has several changes made to the RELAX code, as well as model changes. The latest TLTA benchmark input deck has been modified with the following items.
  - Seven evenly spaced core nodes
  - [ ]
  - EPRI two-phase pump degradation model applied.
- The benchmark was run to assess the impact of these changes along with the application of the EXEM BWR-2000 version of RELAX.

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Verification (cont.)
TLTA

Lower Plenum Mass

Verification (cont.)
TLTA

Verification (cont.)
TLTA

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Verification (cont.)
TLTA

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Verification (cont.)
FIST

- Large Break 6DB1-B
  - Test 6DB1-B is a BWR/6 DBA simulation, with HPCS, LPCS and LPCI available.
  - Scaled 1.878 ft^2 suction line and 0.348 ft^2 drive line breaks.
  - An average central orifice region bundle is modeled with a power of 5.045 MW.
  - The transient begins with a coincident double-ended recirculation line break and power trip.

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Verification (cont.)
FIST (Large Break DB1-B)

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Verification (cont.)
FIST (Large Break DB1-B)

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Verification (cont.)

FIST (Large Break DB1-B)

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Verification (cont.)

FIST (Large Break DB1-B)

Verification (cont.)

FIST (Large Break DB1-B)

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Verification (cont.)

FIST (Large Break DB1-B)

Verification (cont.)
FIST (Large Break DB1-B)

Verification (cont.)
FIST

- Large Break 4DBA1
  - 4DBA1 is a BWR/4 design basis accident simulation with a 1.065 in^2 (scaled from 4.14 ft^2) suction line and 0.1645 in^2 (scaled from 0.064 ft^2) drive line breaks
  - The test simulates a failure of a single diesel generator, resulting in the loss of one LPCI pump. One HPCI, one LPCS, and two LPCI are assumed available. The HPCI is connected to the upper plenum and the LPCIs are connected to the intact drive line. In an actual BWR/4 plant, the HPCI injects through the feedwater line. Because the upper plenum is a homogeneous volume in RELAX, SPC methodology connects the feedwater line to the middle downcomer and the HPCI to the upper downcomer.
  - The FIST ECCS pumps all are tripped on at 30 seconds, as opposed to the BWR/6 DBA tests where Level 2 trips with a delay are used. Also, the HPCI is tripped off at a pressure of 115 psia, consistent with an actual BWR/4 (turbine-driven pumps).

Verification (cont.)
FIST (Large Break 4DBA1)

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Verification (cont.)
FIST (Large Break 4DBA1)

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Verification (cont.)
FIST (Large Break 4DBA1)

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Verification (cont.)
FIST (Large Break 4DBA1)

Verification (cont.)
FIST (Large Break 4DBA1)

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Verification (cont.)
FIST (Large Break 4DBA1)

Verification (cont.)
FIST (Large Break 4DBA1)

Verification (cont.)
FIST

- Small Break 6SB2C
  - This test simulated a BWR/6 recirculation suction line break of 0.05 ft^2 (0.01227 in^2 actual).
  - The system is configured as in the large-break test with HPCS being injected into the upper plenum and LPCI into the bypass.
  - The event is initiated by the "break" on the suction side of recirculation pump number 2 and coincident power scram, trip of the recirculation pumps, and feedwater flow.
  - The pressure controller maintained the system pressure essentially constant until the MSIV was closed following the Level 1 trip.
  - This test simulated three LPCI systems available.

Verification (cont.)
FIST (Small Break 6SB2C)

Verification (cont.)
FIST (Small Break 6SB2C)

Verification (cont.)
FIST (Small Break 6SB2C)

Verification (cont.)
FIST (Small Break 6SB2C)

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Verification (cont.)

FIST (Small Break 6SB2C)

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Verification (cont.)

FIST (Small Break 6SB2C)

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Verification (cont.)
FIST (Small Break 6SB2C)

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Verification (cont.)
FIST (Small Break 6SB2C)

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Verification (cont.)
FIST

- Conclusion
  - The hydraulics and mass inventories were conservatively predicted.
  - Large-break (DBA) PCTs are conservatively calculated using best-estimate methods.
  - SBLOCA PCTs are bound when the conservatism included in the EM methodology is applied. This result is acceptable because small break events are not limiting in BWRs and the test evaluated simulated an extremely small break in which core uncovery and the resulting heat-up is minor such that the conservatism (Appendix K coefficients) are not allowed to raise fuel temperature to values of concern.
  - It is concluded that the SPC methodology using the RELAX code to simulate the blowdown and refill/reflood periods of a LOCA and the HUXY code for the heat-up period will produce conservative PCTs.

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EXEM BWR-2000
Conclusion / Summary

- The EXEM BWR-2000 methodology is simplified from the current methodology by the removal of FLEX and replacing it with RELAX
- Changes made to the methodology significantly improve results for small breaks while large breaks are less impacted
- The overall EXEM BWR-2000 methodology is more robust