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Project No. 694

BAW-10192

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U.S. Nuclear Regulatory Commission
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Subject: **PWR Owners Group Topical Report BAW-10192 Rev. 1, "B&W ECCS Evaluation Model," Transmittal of Additional Information (PA-ASC-0256)**

Enclosures:

1. BAW-10192 Pre-submittal Presentation
2. Directory Table identifying location of new content

The purpose of this letter is for the Pressurized Water Reactor Owners Group (PWROG) to provide the enclosed information to assist in the review of the subject Topical Report. Enclosed is the presentation discussed during the pre-submittal conference call for BAW-10192 and a table that identifies the topics that have been revised in this revision to BAW-10192 and their location within the report.

Please provide this material to the NRC reviewer to assist in his review.

Correspondence related to this transmittal should be addressed to:

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If you have any questions, please do not hesitate to contact Dennis Buschbaum at (817)-475-6989 or Mr. R. J. Schomaker of AREVA NP of the PWR Owners Group at (434) 832-2917.

Sincerely,

RJ Schomaker

Robert J. Schomaker approved for

Dennis Buschbaum, Chairman
PWR Owners Group

cc: Holly Cruz, NRC
Stacey Rosenberg, NRC
PWROG Management Committee
Steering Committee
Analysis Subcommittee
PWROG Project Management Office
R.J. Schomaker, AREVA

Table Summarizing the Key Changes from Revision 0 to Revision 2 of BAW-10192

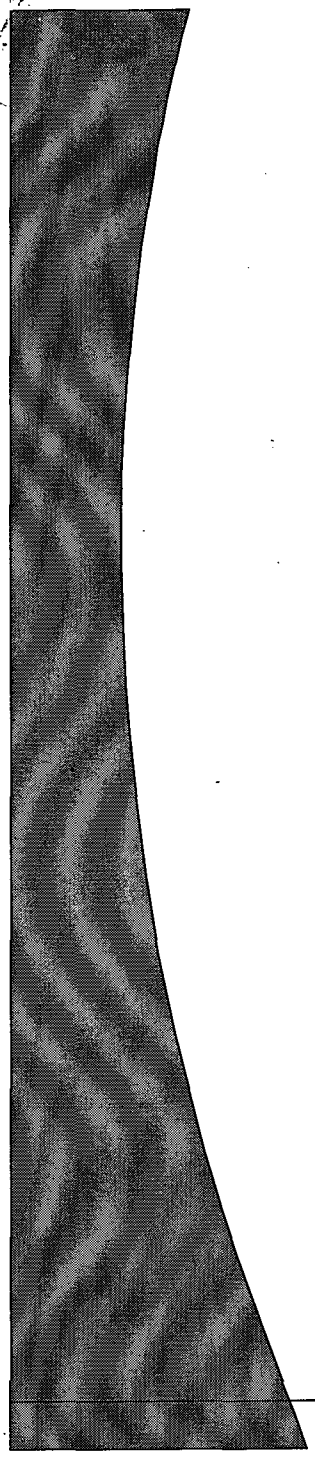
Volume 1: LBLOCA

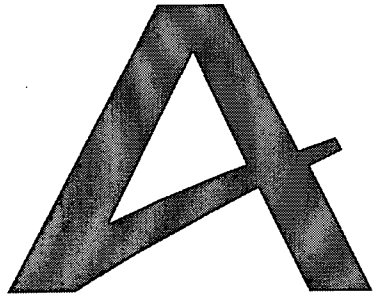
Item	Description	Page
1	Update revision and/or date	i, v, 4-1, 4-2
2	Update the company name	i, iii, 1-1, 3-1
3	Update page number	vii, viii, x, xi
4	Editorial and miscellaneous updates and typographical correction	2-1, 2-2, 4-1, 4-4, 4-8, 4-9, 4-11, 4-12, 4-13, 4-15, 4-16, 4-18, 4-19, 4-20, 4-21, 4-31, 4-32, 4-33, 4-41, 4-42, 4-43, 4-44,4-47, 4-48, 4-49, 4-52, 4-58, 4-59, 4-60, 6-1, 9-1, 9-7, 9-8, 9-9, A-1, A-5, A-7, A-8, A-10, A-26, A-34, A-35, A-37, A-41, A-61, A-62, A-64, A-76, A-79
5	Tie to the RAI from Rev 00	4-10, 4-13, 4-25, 4-34, 4-37, 4-38, 4-39, 4-40, 4-41, 4-44, 4-45, 4-48, 4-49, A-6, A-11, A-12, A-17, A-19, A-25, A-30, A-33
6	Update References	10-1 through 10-3
7	Add new source reference – M5 (BAW-10172P-A) and additional information on M5 cladding	1-1, 4-16, 4-18, 4-19, 4-20, 4-21, 9-9, 9-13, 10-3
8	Add new source reference – GDTACO (BAW-10184P-A)	4-11, 9-7, 9-9, 10-2
9	Add new source reference – RELAP5 (BAW-10164P-A)	4-11, 4-28
10	Add new source reference – Stain steel replacement rod (BAW-2149-A)	4-21, 10-3
11	Additional detail on the steam generator/steam generator tube plugging	1-3, 4-6, 9-10
12	Additional information on break sizes that demonstrate early DNB for SBLOCA	4-3, 4-41
13	Additional detail on mixed-core modeling	4-27
14	Additional detail on analyzed power level plus uncertainty	4-9, 4-14, 4-44, 9-8, 9-9, 9-11
15	Additional Information on energy disposition factor/ power flattening	4-13, 4-14, 4-15, 9-13
16	Additional Information on supplemental pin methodology (hot pin and Gadolinia pin)	4-7, 4-13
17	Additional detail on reactivity coefficient	4-12
18	Additional detail on RCS pump modeling	4-26, 4-27, 9-8
19	Additional detail on local cladding oxidation	2-1, 5-1
20	Additional detail on coolable geometry	2-2, 7-1, 7-2
21	Additional detail on long-term cooling	2-2, 8-1, 8-2, 8-3
22	Additional detail on Actinide DH	4-12, 9-9, 9-11
23	Additional information on CHF correlation vs. fuel type	4-28, 4-29, 9-5
24	Additional Information on initial CFT inventory	9-8

Table Summarizing the Key Changes from Revision 0 to Revision 2 of BAW-10192

Volume 2: SBLOCA

Item	Description	Page
1	Update revision and/or date	i, v
2	Update the company name	i, iii, 1-1, 3-1
3	Update page number	vii, viii, ix
4	Editorial and miscellaneous updates and typographical correction	2-1, 4-2, 4-3, 4-5, 4-6, 4-8, 4-13, 4-21, 4-23, 4-28, 6-2, 9-1, 9-3, 9-4, 9-5, 9-6, 9-7, A-1, A-16, A-31, A-43
5	Tie to the RAI	4-3, 4-5, 4-25
6	Update References	10-1 through 10-2
7	Add new source reference – M5 (BAW-10172P-A) and additional information on M5 cladding	1-1, 4-24, 9-8
8	Add new source reference – GDTACO (BAW-10184P-A)	4-4, 9-5, 9-8, 10-2
9	Add new source reference – RELAP5 (BAW-10164P-A)	4-18, 4-22, 10-2
10	Additional detail on void-dependent cross flow model	4-18, A-16
11	Additional detail on the steam generator/ steam generator tube plugging	1-3, 4-8, 4-10, 9-9
12	Additional information on SBLOCA analyses with Gadolinia fuel	4-6
13	Additional information on break sizes that demonstrate early DNB for SBLOCA	4-1, 4-26
14	Additional information on using supplemental pins for TIL SBLOCA analyses	4-25
15	Additional information on mixed-core modeling	4-17, 4-18
16	Additional detail on analyzed power level plus uncertainty	4-3, 4-7, 9-8
17	Additional detail on RCS pump modeling	4-20, 4-21, 9-7
18	Additional detail on local cladding oxidation	2-1, 5-1
19	Additional detail on coolable geometry	2-2, 7-1, 7-2
20	Additional detail on long-term cooling	2-2, 8-1
21	Additional detail on Actinide	4-5, 9-8
22	Additional detail on Power flattening	4-6
23	Additional information on CHF correlation vs. fuel type	4-22, 9-5
24	Additional Information on initial CFT inventory	9-7





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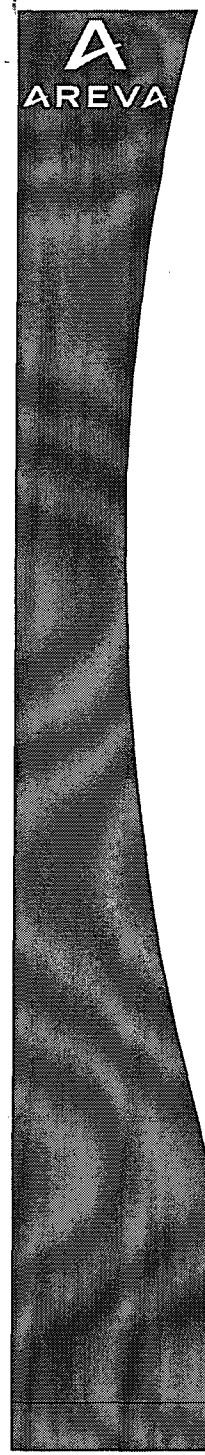


BWNT LOCA Evaluation Model
BAW-10192 Revision 2

J. A. Klingenfus

Advisory Engineer

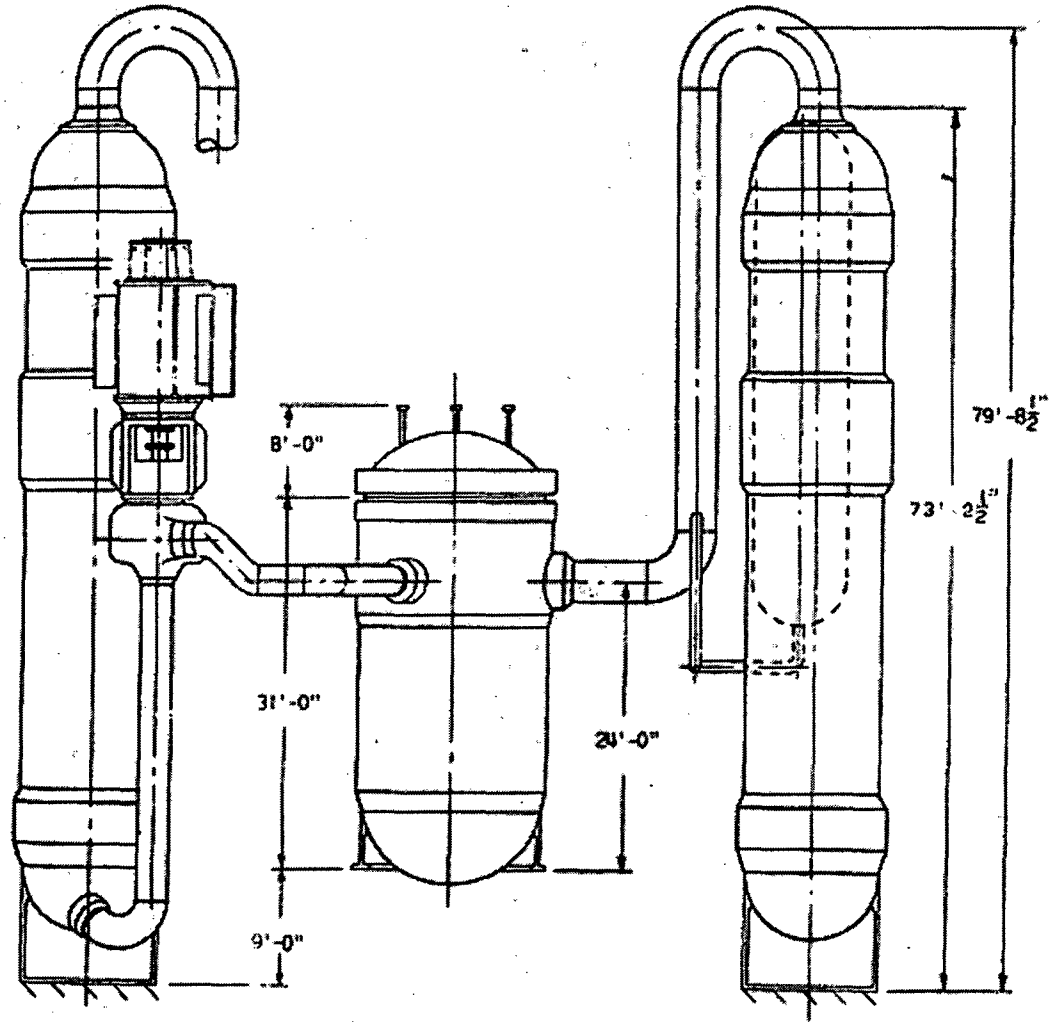
June 11, 2009

Overview

- Purpose
  - Updates to BAW-10192 Revision 0 (BWNT LOCA EM), the LOCA Evaluation Model for B&W-designed plants
    - 177 Fuel Assembly Lowered-Loop Plants
    - 177 Fuel Assembly Raised-Loop Plants
    - 205 Fuel Assembly Raised-Loop Plants (none in service)
- Background
  - B&W Plant Layouts
  - ECCS Description
- Evaluation Model (EM) Description and History
- BAW-10192 Revision 2 Changes
  - New NRC approved code revisions
  - PSC Generated EM Changes Reported to NRC
  - Additional Details on EM Methods

Background: B&W NSSS Designs

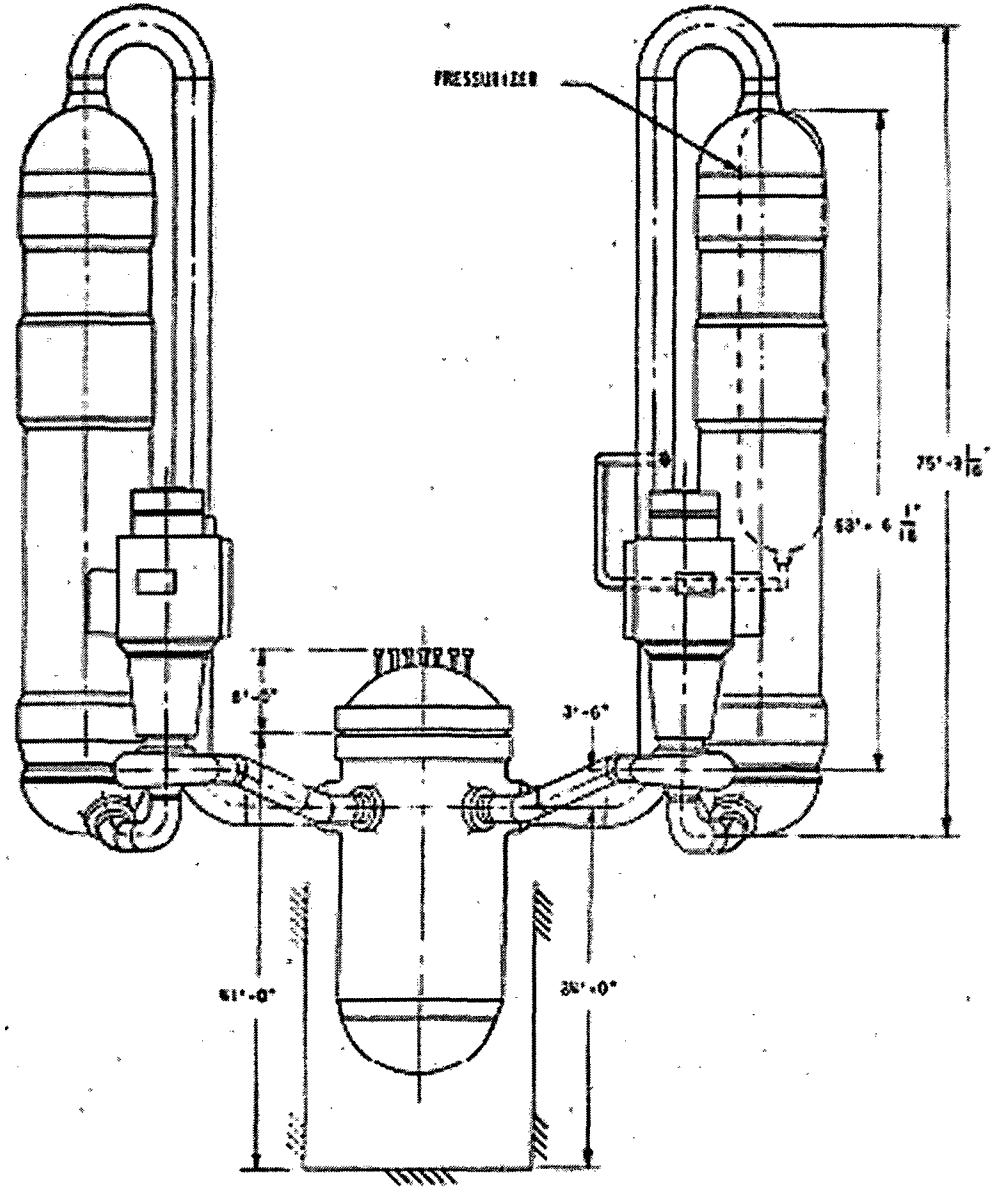
B&W 177FA Lowered Loop
ANO-1
CR-3
ONS-1, 2, 3
TMI-1



Background: B&W NSSS Designs

B&W 177FA Raised Loop

DB-1



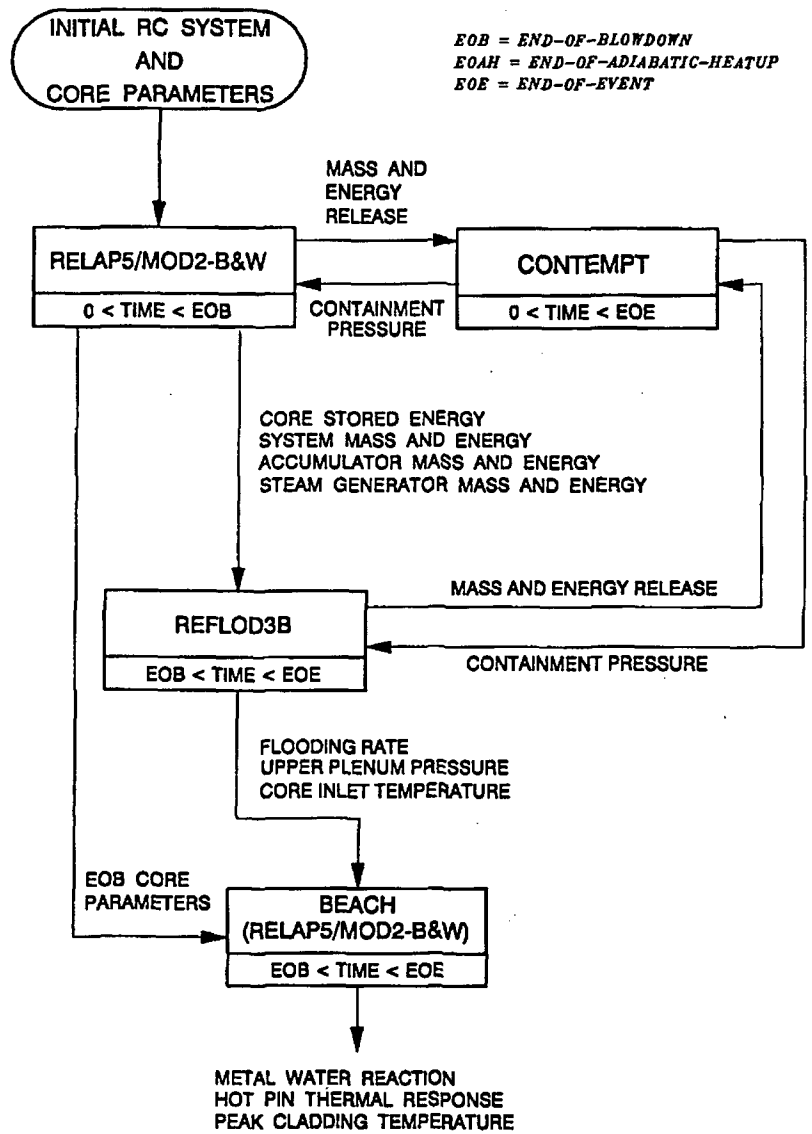
Background: B&W Plant ECCS

- **High Pressure Injection**
  - Inject into cold leg pump discharge piping
  - Flow at pressures above code safeties for 177 FA LL Plants
  - 177 FA Raised Loop Plant has medium head injection
- **Core Flood Tanks (CFTs)**
  - 177 FA plants have two 1410 ft^3 tanks filled with roughly 1000 ft^3 of liquid and a nominal 600 psig nitrogen overpressure (Similar to W & CE accumulators/SITs)
  - Directly inject to RV downcomer slightly above the RV inlet/exit nozzle belt centerline
- **Low Pressure Injection**
  - Direct injection to RV downcomer
  - Uses same nozzles as CFTs

BWNT LOCA Evaluation Model

- 10 CFR 50 Appendix K deterministic calculational framework for evaluating a LOCA for the B&W plant designs
- Used to demonstrate acceptable performance of a plant's ECCS following a LOCA as indicated by compliance to 10 CFR 50.46 criteria with maximum allowed peaking based on the limits of normal operation
- EM analyses specifically assure compliance with first three 50.46 criteria
- EM provides guidance on how plant specific considerations are used to evaluate the fourth and fifth criteria (coolable geometry and long-term core cooling)
- EM has three volumes
  - 1 – LBLOCA
  - 2 – SBLOCA
  - 3 – Licensing Addendum with RAI responses, TER, and SER

FIGURE 4-1. LARGE BREAK ANALYSIS CODE INTERFACE.



EM Description (Inputs)

- Core power level
- RCS flow
- RCS average temperature
- Core peaking
- Fuel initial temperatures from SS fuel code
- Fuel pin initial geometry from SS fuel code

EM Description (Codes)

- **Blowdown System – RELAP5/MOD2-B&W**
  - System analysis with containment pressure boundary conditions, hot pin, hot channel, average channel fuel pin temperatures, CFT flows, LOCA M&E into containment
- **Refill and Reflood System – REFLOD3B**
  - Uses stored energy and initial conditions from end of blowdown with a containment pressure boundary conditions.
  - Calculates time of core recovery, core inlet liquid temperature, core flooding rate, core exit pressure for use in BEACH.
- **Refill and Reflood Core Thermal Analysis – BEACH**
  - Only RELAP5/MOD2-B&W core model with 2-D fine mesh rezoning option activated with separated hot and average channels.
  - Uses RELAP5 EOB conditions with REFLOD3B boundary conditions

EM Description (Codes Cont'd)

- **Containment Pressure – CONTEMPT – Minimum containment pressure response from blowdown and reflood system analyses.**
  - **Uses initial conditions and inputs to minimize the containment pressure.**
  - **The blowdown containment pressure is calculated based on several iterations between the blowdown system (RELAP5/MOD2-B&W) and CONTEMPT.**
  - **The reflood containment pressure is calculated based on EOB conditions and several iterations between the reflood system (REFLOD3B) and CONTEMPT.**

EM Description

- Direct Output
  - PCT
  - Local Oxidation
  - Core flow blockage
  - Time of core quench (onset of LTC)
- Indirect Output
  - Whole core hydrogen generation
  - Coolable core geometry based on swelling and rupture flow blockage

History of BWNT LOCA

- Developed in early 1990s
- Similar to the NRC-approved RSG LOCA (BAW-10168), a deterministic EM for W and CE plants
- Revision 0 was submitted in 1994 and approved in 1997
- Currently used by all B&W plants to perform LOCA analyses
- Revision 1 was submitted for NRC review in 2000.
  - This LBLOCA revision was developed to replace the REFLOD3B system reflood analysis with RELAP5/MOD2-B&W to fully integrate the LBLOCA PCT analysis into one run with a containment pressure boundary condition.
  - It was subsequently withdrawn after the NRC reviewers indicated they would not review this as an EM revision but a totally new EM.

BAW-10192 Rev 2 Changes from Rev 0 Include

- Updates to NRC-approved source references (e.g. RELAP5/MOD2-B&W, BEACH, M5 Cladding Material)
- Modifications to Rev. 0 text to reflect preliminary safety concern (PSC) resolutions to comply with the Appendix K requirements. These were associated with 10 CFR 21 reports sent to the NRC.
- Expanded discussions on
  - mixed-core applications,
  - Appendix K power uncertainty,
  - analyses for off-nominal operation,
  - extensions of the EM methods to gadolinia fuel,
  - minor changes made under 10 CFR 50 reports, etc.
- Expanded discussions on the types of plant specific evaluations that are performed to comply with coolable geometry and long-term cooling (e.g. GSI-191) criteria

EM Codes/Source Ref Updates (RELAP5/MOD2-B&W)

- Revision 0 of the BWNT LOCA EM referred to Revision 3 of RELAP5/MOD2-B&W (BAW-10164). Multiple revisions of this topical have been approved since Rev 0 of the EM was approved.
  - Rev 2 and 3 of BAW-10164 (submitted 9/18/92) was approved (3/14/95) after the EM was submitted. No SER limitations imposed that limited the EM.
  - Rev 4 of BAW-10164 was submitted (9/30/97) and approved with the M5 topical BAW-10227 (12/14/99 and 2/4/00) for analyzing M5 cladding models and methodology
  - Addendum to Rev 4 of BAW-10164 submitted (2/29/00) and approved (4/9/02)
    - Hot pin capability
    - Changes to the HC and AC fuel temperature uncertainty models
    - SBLOCA core void-dependent cross-flow model
  - Rev 5 of BAW-10164 was submitted and withdrawn because it went with the withdrawn Rev 1 of BWNT LOCA EM
  - Rev 6 of BAW-10164 was submitted (3/31/06) and approved (6/25/07)
    - BHTP CHF correlation for use with BHTP fuel LOCA analyses

EM Codes/Source Ref Updates (BEACH)

- Revision 0 of the BWNT LOCA EM referred to Revision 4 of BEACH (BAW-10166). Multiple revisions of this topical have been approved since Rev 0 of the EM was approved.
  - Rev 4 of BAW-10164 (submitted 9/18/92) was approved (1/31/94) after the EM was submitted. Any SER limitations imposed were addressed by EM analyses or checks.
  - Rev 5 of BAW-10164 was submitted (12/10/01) and approved (11/7/03)
    - Justification for increase in the initial cladding temperature at the beginning of reflood
    - Increase in the containment pressure range
    - Decrease of the minimum flooding rate

EM Codes/Source Ref Updates (M5 Cladding)

- Revision 0 of the BWNT LOCA EM included fuel pin cladding models for zircaloy cladding.
- On 9/30/97 AREVA submitted, BAW-10227 Rev 0, Evaluation of Advanced Cladding and Structural Material (M5) in PWR Reactor Fuel.
  - The NRC approved the use of the models and methods for analyzing M5 cladding as discussed in this topical on 12/14/99 as augmented by an addendum on 2/4/00.
  - Revision 1 was submitted (1/19/01) and approved (6/18/03) to extend the methods up to a burnup to 62 GWd/MTU for M5 cladding based on the approval of BAW-10186P-A Rev 1, Extended Burnup Evaluation.

PSC Generated EM Changes Reported to NRC

- Various changes in the method of analysis were imposed because of new information obtained from sensitivity studies performed after Rev 0 of the EM was originally developed and sent to the NRC.
  - CFT initial pressure and liquid inventory used in LOCA analyses
  - Clarification of the moderator temperature coefficient used in partial power LOCA analyses
  - LBLOCA RCP two-phase pump head degradation models
  - SBLOCA RCP two-phase pump head degradation models

PSC Changes: CFT Initial Conditions

- Revision 0 of the EM described the use of nominal initial pressures and liquid inventory (levels) for any system or component in the LOCA analyses
- Subsequent large and small LOCA sensitivity studies performed after the EM was originally submitted revealed significant PCT variations related to the CFT initial pressure and level. (Preliminary Safety Concern: PSC 5-94)
- All current large and small LOCA analyses consider the minimum to maximum initial CFT pressure and liquid inventory as allowed technical specifications to set the limiting initial conditions to produce a conservative PCT that bounds any initial condition for the CFT.
- Reported to the utilities in annual 50.46 reports for 1994 and 1995
- Reported to the NRC in
  - PSC 5-94 30 day 50.46 report to NRC, letter JHT-95-12 January 27, 1995
  - PSC 5-94 final report to NRC, letter JHT-95-89 August 25, 1995

PSC Change: MTC for Partial Power LOCA Analyses

- LOCA sensitivity studies are performed at partial power levels to generate an allowable MTC curve versus power level in which the partial power PCT is bounded by the most limiting full power PCT analysis.
- There was a preliminary safety concern written in 1994 (PSC 4-94) and later dismissed when the plant MTC versus power level was shown to be more negative than the bounding MTC curve needed to preserve the full power PCT analysis.
- The MTC limit is checked on a cycle specific against the MTC limit curve each reload to ensure the full power PCT remains bounding.

PSC Change: RCP Two-Phase Pump Degradation Modeling

- **LBLOCA**
  - **LBLOCA sensitivity studies are used to determine if the limiting results are produced by a minimum, maximum, or "nominal" two phase void-dependent multiplier on the head difference curves (PSC 1-99).**
  - **Reported to utilities in annual 50.46 reports for 1998 and 1999**
  - **Reported to NRC in:**
    - **PSC 1-99 30 day report to NRC, letter OG-1740, February 4, 1999. (Accession Number ML003681781)**
    - **PSC 1-99 interim report to NRC, letter OG-1746, March 5, 1999.**
    - **PSC 1-99 final report to NRC, letter OG-1781, February 1, 2000. (Accession Number ML003681781)**

PSC Change: RCP Two-Phase Pump Degradation Modeling

- **SBLOCA**
  - SBLOCA sensitivity studies and comparisons to applicable test data were used to determine if the minimum, maximum, or "nominal" two phase void-dependent multiplier on the RCP head difference curves was conservative for pumps-on analyses (PSC 2-00).
  - These analyses justify operator action time to trip RCPs following a SBLOCA. An NRC SER approves the method of analysis and curve selected for use for all existing B&W plant types.
  - Reported to utilities in annual 50.46 reports for 2000 and 2001
  - Reported to the NRC in:
    - PSC 2-00 initial report to NRC (> 2200 F for 2 min RCP trip), letter FTI-00-2433, September 26, 2000
    - PSC 2-00 interim report to NRC, letter FTI-00-3085, December 22, 2000.
    - PSC 2-00 final report to NRC, letter FANP-01-988, April 22, 2001. (Accession Number ML01950222)

Additional Details

- **Core Power Uncertainty**
  - **Rev 0: Imposed 2% uncertainty increase**
  - **Rev 2: Allows for 2% or reduced uncertainties associated with Caldon or other systems that improve heat balances**
- **Energy Deposition Factor**
  - **Rev 0 provides steady-state and transient values (0.973 and 0.96).**
  - **Rev 2: Current analyses use specific analyses to determine appropriate deposition factors that are equal to or more conservative that the values in the Rev 0 topical.**
- **Actinide Contribution to Decay Heat**
  - **Rev 0: The 1979 ANS standard was identified with no details.**
  - **Rev 2: The actinide energy contribution will be appropriate for the time in life that produces the highest calculated fuel pin temperatures during the LOCA.**

Additional Details (Cont'd)

- **Gadolinia Fuel**
  - **Rev 0: Gadolinia fuel was not specifically described.**
  - **Rev 2: Describes use of NRC approved GDTACO code for the fuel pin initial temperatures and properties. Gadolinia analyses are performed using supplemental hot pins at reduced LHR limits.**
- **Mixed Core Analyses**
  - **Rev 0: No discussion was included.**
  - **Rev 2: Describes LOCA applications with fuel designs that are hydraulically dissimilar.**
- **SBLOCA Time-in-Life Analyses**
  - **Rev 0: Convoluted, multiple case set described in Sect 4.3.4**
  - **Rev 2: Hot pins with different internal pin pressures are used to evaluate PCT changes associated with swelling and rupture timing changes consistent with Section 4.3.4 discussion.**

Additional Details (Cont'd)

- SBLOCA vs LBLOCA Break Sizes
  - Rev 0: DNB and a break size of 0.75 ft^2 was described.
  - Rev 2: Clarify that the transition between SBLOCA and LBLOCA is defined by the break size that does not cause the cladding to experience DNB during the first few seconds of the LOCA imposed from full power 4 RCP operation. The break size can be different based on the fuel design used. Generally the transition occurs between 0.5 to 0.75 ft^2.
- Core Power Peaking
  - The text was modified to describe the radial and axial peaking methods described in the RAI responses and consideration of how LOCA LHR limits are extended to 0 and 12 ft.
- EOC T_{ave} Reductions
  - LOCA analyses with a reduced RCS T_{ave} define what negative MTC is needed to preserve the PCT for normal T_{ave} applications.

Additional Details (Cont'd)

- **Replacement Rods**
  - **Rev 0: No discussion.**
  - **Rev 2: The effect of stainless steel or low enriched UO_2 rods are considered in the LOCA analyses with the associated peaking as considered in the NRC approved BAW-2149 topical report.**
- **Steam Generator Tube Plugging**
  - **Rev 0: No discussion.**
  - **Rev 2: Analyses will consider the effects the steam generator tube plugging.**
- **SBLOCA Analyses with Offsite Power Available**
  - **Rev 0: No offsite power available analyses were performed.**
  - **Rev 2: Offsite power available analyses are performed with the operators manually tripping the RCPs on indication of loss of subcooling margin within the plant specific timing determined by analyses (generally 1 or 2 minutes).**

Updates to EM Text for Criteria 4 and 5

- **Coolable Geometry**
  - Clarification that compliance with 10CFR50.46(b)(4) is not explicitly provided by EM LOCA analyses
    - Seismic loads and LOCA hydraulic loads mechanical evaluation determine the fuel geometry at the onset of the accident
    - Cladding swelling and rupture flow blockage from the accident
  - Demonstrate that total flow blockage will not exceed 90% at any point in the transient
- **Long-Term Core Cooling**
  - Supplemental analyses support compliance
  - Emergency and Abnormal Operating Procedures play a large role (ECCS control, sump switch over, managing pump NPSH, etc.)
  - Assurance that ECCS will perform their required safety function
    - Boric acid concentration control (no excessive dilution or precipitation)
    - GSI 1-91 effects

Summary

- Revision 2 of BWNT LOCA updates material that has been approved by the NRC or adds additional details of the methods used to address LOCA for cycle specific fuel reloads or off-nominal conditions
  - NRC-approved source references (e.g. RELAP5/MOD2-B&W, BEACH, M5 Cladding)
  - New methods previously reported to the NRC to meet Appendix K requirements and changes to ensure conservative treatment of certain inputs that have a significant effect on PCT predictions
  - Expanded detail of off-nominal methods of analysis
  - Expanded discussions on coolable geometry and long-term cooling considerations