Exelon Generation Company, LLC
1400 Opus Place
Downers Grove, IL 60515-5701

www.exeloncorp.com

Exelon Nuclear

RS-01-084

April 18, 2001

United States Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555-0001

Braidwood Station, Units 1 and 2
Facility Operating License Nos. NPF-72 and NPF-77
NRC Docket Nos. STN 50-456 and STN 50-457

Byron Station, Units 1 and 2
Facility Operating License Nos. NPF-37 and NPF-66
NRC Docket Nos. STN 50-454 and STN 50-455

Subject: Annual Report of the Emergency Core Cooling System Evaluation Model Changes and Errors Required by 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors"

Reference: Letter from R. M. Krich (Commonwealth Edison Company) to U.S. NRC, "Request for a License Amendment to Permit Uprated Power Operations at Byron and Braidwood Stations," dated July 5, 2000

In accordance with 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactor," paragraph (a)(3)(ii), Exelon Generation Company (EGC), LLC, formerly the Commonwealth Edison Company (ComEd), is are submitting the annual report of the Emergency Core Cooling System (ECCS) Evaluation Model changes and errors for Byron Station, Units 1 and 2, and Braidwood Station, Units 1 and 2. This annual report is due to be submitted to the NRC by April 18, 2001.

Attachment 1, "Peak Cladding Temperature Rack-Up Sheets," provides updated information regarding the Peak Cladding Temperature (PCT) for the limiting Small Break and Large Break Loss of Coolant Accident (LOCA) analyses evaluations for the Byron and Braidwood Stations. Attachment 2, "Assessment Notes," contains a detailed description for each change or error reported. Attachment 3, "Assessment Notes Not Included in Peak Cladding Temperature Rack-Up Sheets," contains a brief description of other LOCA assessments not included in the PCT Rack-Up Sheets. All assessments in Attachment 3 resulted in benefits or no penalty to the calculated PCT. Note that we have conservatively chosen not to credit any PCT benefits, i.e., for each beneficial change, a delta PCT of zero degrees Fahrenheit was assigned.

For all the evaluation model changes and errors contained in this report, we have determined that the cummulative changes and errors are not "significant" as defined in 10 CFR 50.46, paragraph (a)(3)(i). Byron and Braidwood Stations continue to comply with the requirements of

A001

10 CFR 50.46 with the assessed PCT penalties. Based on these results, no near-term reanalysis is planned for the Byron Station or Braidwood Station, and a proposed schedule for providing such reanalysis is not required for the currently licensed power level (i.e., 3411 Megawatts thermal). Please note, however, that in the referenced letter, we submitted proposed changes to Facility Operating License Nos. NPF-72, NPF-77, NPF-37 and NPF-66, and Appendix A, Technical Specifications (TS), for Braidwood Station, Units 1 and 2, and Byron Station, Units 1 and 2, respectively. The proposed changes would revise the maximum power level specified in each unit's license and the TS definition of rated thermal power. A Large Break and Small Break LOCA analysis was performed to confirm compliance with 10 CFR 50.46 under uprated power conditions. This analysis will supercede the current analysis upon NRC approval of the license amendment request.

Please contact Mr. J. A. Bauer at (630) 663-7287 should you have any questions concerning this report.

Respectfully,

RM Krich

R. M. Krich
Director – Licensing
Mid-West Regional Operating Group

Attachment 1 – Peak Cladding Temperature Rack-Up Sheets
Attachment 2 – Assessment Notes
Attachment 3 – Assessment Notes Not Included in Peak Cladding Temperature Rack-Up Sheets

cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – Braidwood Station
NRC Senior Resident Inspector – Byron Station

Attachment 1

10 CFR 50.46
"Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors,"

Annual Report of the Emergency Core Cooling System Evaluation Model Changes and Errors

Assessments as of March 15, 2001

Peak Cladding Temperature Rack-Up Sheets

PLANT NAME:	Braidwood Station Unit 1
ECCS EVALUATION MODEL:	Small Break Loss of Coolant Accident (SBLOCA)
REPORT REVISION DATE:	03/15/01
CURRENT OPERATING CYCLE:	9

NOTE: The referenced notes are found in Attachment 2.

ANALYSIS OF RECORD (AOR)

Evaluation Model: NOTRUMP
Calculation: Westinghouse SEC-LIS-5314-C0, October 1997
Fuel: VANTAGE+ 17 x 17
Heat Flux Hot Channel Factor (FQ) = 2.60
Nuclear Enthalpy Rise Hot Channel Factor (FNΔH) = 1.70
Steam Generator Tube Plugging (SGTP) = 30%

Reference Peak Cladding Temperature (PCT)	PCT =	1695.0°F

MARGIN ALLOCATION

A. PRIOR LOSS OF COOLANT ACCIDENT (LOCA) MODEL ASSESSMENTS

None

B. CURRENT LOCA MODEL ASSESSMENTS

NOTRUMP - Mixture Level Tracking/Region Depletion Errors (Note 18)	ΔPCT =	13.0°F
Burst and Blockage/Time in Life (Notes 3 and 14)	ΔPCT =	0°F

NET PCT	**PCT =**	**1708.0°F**

PLANT NAME: Braidwood Station Unit 1
ECCS EVALUATION MODEL: Large Break Loss of Coolant Accident (LBLOCA)
REPORT REVISION DATE: 03/15/01
CURRENT OPERATING CYCLE: 9

AOR

Evaluation Model: BASH
Calculation: Westinghouse SEC-SAII-4747-C2, May 1996
Fuel: VANTAGE+ 17 x 17
FQ = 2.60 (Fq reduced to 2.5, Note 7)
FNΔH = 1.70
SGTP = 30%

Reference PCT	PCT =	1968.0°F

MARGIN ALLOCATION

A. PRIOR LOCA MODEL ASSESSMENTS

Translation of Fluid Conditions from SATAN to LOCTA (Note 8)	ΔPCT =	15.0°F
Reactor Coolant System (RCS) Crossover Leg Volume (Note 9)	ΔPCT =	3.0°F
Replacement Steam Generator (RSG) (SGTP 20%, Note 10)	ΔPCT =	21.0°F
Passive Heat Sink Increase (Note 11)	ΔPCT =	16.0°F
Reactor Coolant Fan Cooler (RCFC) Performance (Note 11)	ΔPCT =	1.0°F
LOCBART Fuel Rod Outside Diameter (FOD) Input Error (Note 13)	ΔPCT =	2.0°F
Initial Containment Pressure (Note 11)	ΔPCT =	-5.0°F
LBLOCA Burst Location Change (Note 12)	ΔPCT =	94.0°F
Removal of Translation of Fluid Conditions from SATAN to LOCTA (Note 8)	ΔPCT =	-15.0°F
Removal of Reactor Coolant System (RCS) Crossover Leg Volume (Notes 7 and 9)	ΔPCT =	-3.0°F
Accumulator Line/Pressurizer Surge Line Data (Note 1), LOCBART Space Grid Single Phase Heat Transfer Error (Note 5), LOCBART Zirc-Water Oxidation Error (Note 6), and Reanalysis of Limiting AOR (Note 7)	ΔPCT =	-32.0°F
Storage of lead shielding blankets in Containment (Note 15)	ΔPCT =	2.0°F
Decrease in RCFC start time (Note 15)	ΔPCT =	2.0°F
Increase in Containment Spray Flow rate (Note 15)	ΔPCT =	1.0°F

B. CURRENT LOCA MODEL ASSESSMENTS

LOCBART Vapor Film Flow Regime Heat Transfer Error (Note 17)	ΔPCT =	-15.0°F
LOCBART Cladding Emissivity Errors (Note 16)	ΔPCT =	-10.0°F

NET PCT	**PCT =**	**2045.0°F**

PLANT NAME: Braidwood Station Unit 2
ECCS EVALUATION MODEL: SBLOCA
REPORT REVISION DATE: 03/15/01
CURRENT OPERATING CYCLE: 9

AOR

Evaluation Model: NOTRUMP
Calculation: Westinghouse SEC-LIS-5396-C0, January 1999
Fuel: VANTAGE+ 17 x 17
FQ = 2.70
FNΔH = 1.75
SGTP = 30%

Reference PCT	PCT =	1806.0°F

MARGIN ALLOCATION

A. PRIOR LOCA MODEL ASSESSMENTS

Burst and Blockage/Time in Life (Note 3)	ΔPCT =	19.0°F

B. CURRENT LOCA MODEL ASSESSMENTS

NOTRUMP - Mixture Level Tracking/Region Depletion Errors (Note 18)	ΔPCT =	13.0°F
Trapped Nitrogen in Accumulator Lines (Note 19)	ΔPCT =	12.0°F
Burst and Blockage/Time in Life (Note 3)	ΔPCT =	-19.0°F
Burst and Blockage/Time in Life (Note 3)	ΔPCT =	40.0°F

NET PCT	**PCT =**	**1871.0°F**

PLANT NAME: Braidwood Station Unit 2
ECCS EVALUATION MODEL: LBLOCA
REPORT REVISION DATE: 03/15/01
CURRENT OPERATING CYCLE: 9

AOR

Evaluation Model: BASH
Calculation: Westinghouse SEC-SAII-4747-C2, May 1996
Fuel: VANTAGE+ 17 x 17
FQ = 2.60 (Fq reduced to 2.5, Note 7)
FNΔH = 1.70
SGTP = 30%

Reference PCT	PCT =	1968.0°F

MARGIN ALLOCATION

A. PRIOR LOCA MODEL ASSESSMENTS

Translation of Fluid Conditions from SATAN to LOCTA (Note 8)	ΔPCT =	15.0°F
RCS Crossover Leg Volume (Note 9)	ΔPCT =	3.0°F
Passive Heat Sink Increase (Note 11)	ΔPCT =	16.0°F
RCFC Performance (Note 11)	ΔPCT =	1.0°F
LOCBART FOD Input Error (Note 13)	ΔPCT =	2.0°F
Initial Containment Pressure (Note 11)	ΔPCT =	-5.0°F
LBLOCA Burst Location Change (Note 12)	ΔPCT =	94.0°F
Removal of Translation of Fluid Conditions from SATAN to LOCTA (Note 8)	ΔPCT =	-15.0°F
Removal of Reactor Coolant System (RCS) Crossover Leg Volume (Notes 7 and 9)	ΔPCT =	-3.0°F
Accumulator Line/Pressurizer Surge Line Data (Note 1), LOCBART Space Grid Single Phase Heat Transfer Error (Note 5), LOCBART Zirc-Water Oxidation Error (Note 6), and Reanalysis of Limiting AOR (Note 7)	ΔPCT =	-32.0°F
Storage of lead shielding blankets in Containment (Note 15)	ΔPCT =	2.0°F
Decrease in RCFC start time (Note 15)	ΔPCT =	2.0°F
Increase in Containment Spray Flow rate (Note 15)	ΔPCT =	1.0°F

B. CURRENT LOCA MODEL ASSESSMENTS

LOCBART Vapor Film Flow Regime Heat Transfer Error (Note 17)	ΔPCT =	-15.0°F
LOCBART Cladding Emissivity Errors (Note 16)	ΔPCT =	-10.0°F

NET PCT	**PCT =**	**2024.0°F**

PLANT NAME: Byron Station Unit 1
ECCS EVALUATION MODEL: SBLOCA
REPORT REVISION DATE: 03/15/01
CURRENT OPERATING CYCLE: 11

AOR

Evaluation Model: NOTRUMP
Calculation: Westinghouse SEC-LIS-5314-C0, October 1997
Fuel: VANTAGE+ 17 x 17
FQ = 2.60
FNΔH = 1.70
SGTP = 30%

Reference PCT	PCT =	1695.0°F

MARGIN ALLOCATION

A. PRIOR LOCA MODEL ASSESSMENTS

None

B. CURRENT LOCA MODEL ASSESSMENTS

NOTRUMP - Mixture Level Tracking/Region Depletion Errors (Note 18)	ΔPCT =	13.0°F
Burst and Blockage/Time in Life (Notes 3 and 14)	ΔPCT =	0°F

NET PCT	**PCT =**	**1708.0°F**

PLANT NAME:	Byron Station Unit 1
ECCS EVALUATION MODEL:	LBLOCA
REPORT REVISION DATE:	03/15/01
CURRENT OPERATING CYCLE:	11

AOR

Evaluation Model: BASH
Calculation: Westinghouse SEC-SAII-4747-C2, May 1996
Fuel: VANTAGE+ 17 x 17
FQ = 2.60 (Fq reduced to 2.5, Note 7)
FNΔH = 1.70
SGTP = 30%

Reference PCT	PCT =	1968.0°F

MARGIN ALLOCATION

A. PRIOR LOCA MODEL ASSESSMENTS

Removed Upper Internal Assembly Alignment Pins (Note 2)	ΔPCT =	5.0°F
Assembly Guide Pin Flakes (Note 4)	ΔPCT =	6.0°F
Translation of Fluid Conditions from SATAN to LOCTA (Note 8)	ΔPCT =	15.0°F
RCS Crossover Leg Volume (Note 9)	ΔPCT =	3.0°F
Replacement Steam Generator (RSG) (SGTP 20%, Note 10)	ΔPCT =	21.0°F
Passive Heat Sink Increase (Note 11)	ΔPCT =	16.0°F
RCFC Performance (Note 11)	ΔPCT =	1.0°F
LOCBART FOD Input Error (Note 13)	ΔPCT =	2.0°F
Initial Containment Pressure (Note 11)	ΔPCT =	-5.0°F
LBLOCA Burst Location Change (Note 12)	ΔPCT =	94.0°F
Removal of Translation of Fluid Conditions from SATAN to LOCTA (Note 8)	ΔPCT =	-15.0°F
Removal of Reactor Coolant System (RCS) Crossover Leg Volume (Notes 7 and 9)	ΔPCT =	-3.0°F
Accumulator Line/Pressurizer Surge Line Data (Note 1), LOCBART Spacer Grid Single Phase Heat Transfer Error (Note 5), LOCBART Zirc-Water Oxidation Error (Note 6), and Reanalysis of Limiting AOR (Note 7)	ΔPCT =	-32.0°F
Storage of lead shielding blankets in Containment (Note 15)	ΔPCT =	2.0°F
Decrease in RCFC start time (Note 15)	ΔPCT =	2.0°F
Increase in Containment Spray Flow rate (Note 15)	ΔPCT =	1.0°F

B. CURRENT LOCA MODEL ASSESSMENTS

LOCBART Vapor Film Flow Regime Heat Transfer Error (Note 17)	ΔPCT =	-15.0°F
LOCBART Cladding Emissivity Errors (Note 16)	ΔPCT =	-10.0°F
Assembly Guide Pin Flakes (Note 4)	ΔPCT =	-6.0°F

NET PCT	**PCT =**	**2050.0°F**

PLANT NAME:	Byron Station Unit 2
ECCS EVALUATION MODEL:	SBLOCA
REPORT REVISION DATE:	03/15/01
CURRENT OPERATING CYCLE:	9

AOR

Evaluation Model: NOTRUMP
Calculation: Westinghouse SEC-LIS-5396-C0, January 1999
Fuel: VANTAGE+ 17 x 17
FQ = 2.70
FNΔH = 1.75
SGTP = 30%

Reference PCT	PCT =	1806.0°F

MARGIN ALLOCATION

A. PRIOR LOCA MODEL ASSESSMENTS

Burst and Blockage/Time in Life (Note 3)	ΔPCT =	19.0°F

B. CURRENT LOCA MODEL ASSESSMENTS

NOTRUMP - Mixture Level Tracking/Region Depletion Errors (Note 18)	ΔPCT =	13.0°F
Trapped Nitrogen in Accumulator Lines (Note 19)	ΔPCT =	12.0°F
Burst and Blockage/Time in Life (Note 3)	ΔPCT =	-19.0°F
Burst and Blockage/Time in Life (Note 3)	ΔPCT =	40.0°F

NET PCT	**PCT =**	**1871.0°F**

PLANT NAME: Byron Station Unit 2
ECCS EVALUATION MODEL: LBLOCA
REPORT REVISION DATE: 03/15/01
CURRENT OPERATING CYCLE: 9

AOR

Evaluation Model: BASH
Calculation: Westinghouse SEC-SAII-4747-C2, May 1996
Fuel: VANTAGE+ 17 x 17
FQ = 2.60 (Fq reduced to 2.5, Note 7)
FNΔH = 1.70
SGTP = 30%

Reference PCT	PCT =	1968.0°F

MARGIN ALLOCATION

A. PRIOR LOCA MODEL ASSESSMENTS

Removed Upper Internal Assembly Alignment Pins (Note 2)	ΔPCT =	28.0°F
Translation of Fluid Conditions from SATAN to LOCTA (Note 8)	ΔPCT =	15.0°F
RCS Crossover Leg Volume (Note 9)	ΔPCT =	3.0°F
Passive Heat Sink Increase (Note 11)	ΔPCT =	16.0°F
RCFC Performance (Note 11)	ΔPCT =	1.0°F
LOCBART FOD Input Error (Note 13)	ΔPCT =	2.0°F
Initial Containment Pressure (Note 11)	ΔPCT =	-5.0°F
LBLOCA Burst Location Change (Note 12)	ΔPCT =	94.0°F
Removal of Translation of Fluid Conditions from SATAN to LOCTA (Note 8)	ΔPCT =	-15.0°F
Removal of Reactor Coolant System (RCS) Crossover Leg Volume (Notes 7 and 9)	ΔPCT =	-3.0°F
Accumulator Line/Pressurizer Surge Line Data (Note 1), LOCBART Space Grid Single Phase Heat Transfer Error (Note 5), LOCBART Zirc-Water Oxidation Error (Note 6), and Reanalysis of Limiting AOR (Note 7)	ΔPCT =	-32.0°F
Storage of lead shielding blankets in Containment (Note 15)	ΔPCT =	2.0°F
Decrease in RCFC start time (Note 15)	ΔPCT =	2.0°F
Increase in Containment Spray Flow rate (Note 15)	ΔPCT =	1.0°F

B. CURRENT LOCA MODEL ASSESSMENTS

LOCBART Vapor Film Flow Regime Heat Transfer Error (Note 17)	ΔPCT =	-15.0°F
LOCBART Cladding Emissivity Errors (Note 16)	ΔPCT =	-10.0°F

NET PCT	**PCT =**	**2052.0°F**

Attachment 2

10 CFR 50.46
"Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors,"

Annual Report of the Emergency Core Cooling System Evaluation Model Changes and Errors

Assessment Notes

1. Accumulator Line/Pressurizer Surge Line Data

Westinghouse identified an issue where the accumulator line piping schedule, installed at a nuclear plant, was different than the design value. This discovery led to a review of various geometric data related to the accumulator lines and pressurizer surge lines. Revised data was compared to the Loss of Coolant Accident (LOCA) analysis values to determine the effect on existing analysis results.

For the Small Break Loss of Coolant Accident (SBLOCA), the estimated effect of this issue on Peak Cladding Temperature (PCT) is 0°F, based on the following general characteristics of limiting small break transients. Only a small fraction of the available accumulator capacity is generally required to replenish vessel inventory to a level sufficient to terminate the cladding temperature excursion; and small variations in the rate of accumulator injection would be expected to have a minimal effect on PCT results. Furthermore, the pressurizer empties well before any core uncovery occurs, therefore, variations in the rate of pressurizer discharge would also be expected to have a minimal effect on PCT.

For the Large Break Loss of Coolant Accident (LBLOCA), the effect of this issue on PCT was determined on a plant-specific basis (see Note 7).

2. Removed Upper Internal Assembly Alignment Pins

This penalty addresses the removal of upper internal alignment pins at the Byron Station. Two pins have been removed from Byron Station Unit 1 and six pins have been removed from Byron Station Unit 2. Removal of the alignment pins resulted in a LBLOCA PCT penalty of +5.0°F for Byron Station Unit 1. Byron Station Unit 2 previously accounted for the removed pins by penalizing the Heat Flux Hot Channel Factor (i.e., FQ). Starting with Byron Station Unit 2 Cycle 6, a LBLOCA PCT penalty of +28.0°F was assessed in lieu of the FQ penalty. This will establish consistent treatment of the removed alignment pins for both units at Byron Station.

3. Burst and Blockage/Time in Life

Typically the SBLOCA analysis was performed using the PAD computer code assuming Beginning of Life (BOL) fuel performance data; and evaluated at other burnups using the SPIKE computer code. Presently this is explicitly modeled using a "time in life study." The burst and blockage model does not have any effect on the PCT if the PCT is less than 1700°F.

For the Byron Station Unit 2 and Braidwood Station Unit 2 analysis, the burst and blockage penalty is 40°F based on direct burnup studies. The previous burst and blockage penalty was 19°F based on the PCT of 1806 °F. Since the PCT increased by 25°F, (i.e., 12°F due to trapped nitrogen (i.e., Note 19) and 13°F due to the NOTRUMP Mixture Level Error (i.e., Note 18)), the burst and blockage penalty increased from 19°F to 40°F. For the Byron Station Unit 1 and Braidwood Station Unit 1 analysis, the burst and blockage PCT penalty was calculated to be 0°F.

4. Assembly Guide Pin Flakes

Bending of fuel assembly alignment pins to angles greater than 5 degrees may result in the generation of pin flakes or fragments. The flakes could potentially lodge themselves in an assembly and locally reduce assembly reactor coolant flow. The flakes could increase blockage of the hot rod subchannel during the reflood period and increase the PCT. This penalty of 6°F is only applicable to Byron Station Unit 1.

This PCT penalty was instituted based on the assumption that the pin flakes could potentially lodge and block the flow channels. To date, there is no evidence that pin flakes exist in the Byron Station Unit 1 Reactor Coolant System (RCS) and, therefore, this penalty was removed.

5. LOCBART Spacer Grid Single-Phase Heat Transfer Error

As discussed in Westinghouse Topical Report, WCAP-10484-P-A, "Spacer Grid Heat Transfer Effects During Reflood," dated March 1991, the Yao-Hochreiter-Leech correlation is used in the LOCBART computer code to calculate the single-phase heat transfer enhancement for axial elevations located downstream of spacer grids. The NRC Safety Evaluation for WCAP-10484-P-A, dated June 21, 1984, requires that a length-averaged value be used to specify the heat transfer coefficient for a given fluid cell, since use of a local value corresponding to the forward edge or the rear edge of the cell could be non-conservative. It was determined that the length-averaging in LOCBART was not being done correctly in all cases.

The effect of this error on existing results was determined on a plant-specific basis (see Note 7).

6. LOCBART Zirc-Water Oxidation Error

Westinghouse identified a logic error in the LOCBART computer code that caused the Baker-Just metal-water reaction calculations to be performed three times per timestep. Correcting the error was found to reduce the total cladding oxidation while increasing the heat deposition in the cladding.

The effect of this error on existing results was determined on a plant-specific basis (see Note 7).

7. Limiting Large Break (LB) LOCA Analysis of Record (AOR) Case Reanalyzed

The limiting LBLOCA Analysis of Record (AOR) case was reanalyzed. The reanalyzed case incorporated Note 1, "Accumulator Line/Pressurizer Surge Line Data," Note 5, "LOCBART Spacer Grid Single-Phase Heat Transfer Error," Note 6, "LOCBART Zirc-Water Oxidation Error," and Note 9, "RCS Crossover Leg Volume Error." The reanalyzed case reduced the total peaking factor (i.e., Fq) value assumed in the AOR from 2.6 to 2.5 for a fuel assembly burnup up to 4000 Megawatt-days/Metric tonne uranium (Mwd/Mtu); beyond 4000 Mwd/Mtu fuel assembly burnup, the Fq is 2.6.

Incorporation of the above changes resulted in a reduction in the PCT by 32°F. Additionally, the 3°F PCT penalty due to the RCS crossover leg volume error was removed since the error was correctly modeled in the reanalyzed case.

8. Translation of Fluid Conditions from SATAN to LOCTA

An error was discovered in the coding related to the translation of fluid conditions between the SATAN blowdown hydraulics computer code and the LOCTA computer code used for subchannel analysis of the fuel rods. In performing axial interpolations to translate the SATAN fluid conditions onto the mesh nodalization used by the LOCTA computer code, the length of the lower core channel fluid connection to the lower plenum node was incorrectly calculated. Calculations with the corrected model resulted in an increase of 15°F in the PCT for the LBLOCA. This penalty applies to both the Byron and Braidwood Station LBLOCA analyses.

Sensitivity studies to rebaseline the AOR using updated computer code versions/methodologies and minor input changes, described in Note 12, resulted in a PCT of 2062°F; a 94°F increase relative to the AOR. These results incorporate the SATAN/LOCTA error included in the letter

from R. M. Krich (Commonwealth Edison Company) to U.S. NRC, "Annual 10 CFR 50.46 Report," dated April 23, 1998. Therefore, this 15°F penalty is removed in this report.

9. Reactor Coolant System (RCS) Crossover Leg Volume Error

IMP is an electronic database containing a variety of plant geometry data whose primary purpose is to interactively support the LOCA Evaluation Model input preprocessors. Secondary purposes are to provide a convenient repository and ready reference for Nuclear Steam Supply System (NSSS) geometry information for a variety of functional groups that generally utilize the database simply for limited hand data extractions. Westinghouse discovered an error in a recent edition of the Byron and Braidwood Stations IMP Database associated with the RCS crossover leg volume. The IMP Database has been subsequently updated.

The impact of the error is a 3°F increase in PCT in the LBLOCA (see Note 7). The SBLOCA AOR bounds the increased crossover leg volume configuration and there is no adverse impact to SBLOCA PCT. This item applies to both Byron Station and Braidwood Station.

10. Replacement Steam Generator (RSG)

Westinghouse performed an evaluation to demonstrate the applicability of the current LBLOCA AOR to the Babcock & Wilcox International (BWI) RSGs. The evaluation consisted of evaluating the differences between the BWI and Westinghouse designed steam generators and the impact on the PCT. The evaluation resulted in a 21°F PCT penalty for the BWI RSGs. The evaluation for the RSG assumes a steam generator plugging level of up to 20%. This is applicable to Byron Station Unit 1 and Braidwood Station Unit 1.

11. Passive Heat Sink/Reactor Containment Fan Cooler (RCFC) Performance Data/Initial Containment Pressure Assumption

In the LBLOCA analysis, it is conservative to assume input data which minimizes the containment pressure during the transient, such as the assumption of the total amount of passive heat sinks, the performance of RCFCs, the assumption of initial containment pressure and containment spray flows.

a) Passive Heat Sink

The amount of passive heat sinks assumed in the AOR LOCA analysis is documented in the Updated Final Safety Analysis Report (UFSAR) Table 6.2-55, "Passive Heat Sink Data For Minimum Post LOCA Containment Pressure." Subsequent to the AOR, numerous modifications were done inside the containment. To perform the modifications, materials such as steel were installed inside the containment. Increased steel results in a decrease in the containment pressure during the LOCA and is potentially non-conservative.

Anytime modifications, (e.g., replacing the steam generators and addition of Safety Injection (SI) Tank Access Galleries, etc.), are done inside the containment, evaluations are performed to determine the impact of these modifications on the LOCA analysis. Westinghouse performed an evaluation to determine the impact on the PCT due to the addition of various passive heat sinks. The Westinghouse evaluation addressed the addition of steel due to RSGs, SI Tank Access Gallery, and an assumed miscellaneous containment metal mass corresponding to 20,000 sq. ft. at 0.2083 ft. thickness for future modifications. This evaluation determined a PCT penalty of 16°F for these additional passive heat sinks.

b) RCFC Performance Data

The RCFC performance data assumed in the AOR was determined to be incorrect. Corrected data was provided to Westinghouse to evaluate the impact on the LOCA analysis. The Westinghouse evaluation determined a PCT penalty of 1°F should be applied for the corrected data.

c) Initial Containment Pressure Assumption

The AOR assumed a conservative initial containment pressure of -1.0 psig. To partially offset the penalty due to items (a) and (b) above, the assumption for initial containment pressure was revised. The revised assumption for initial containment pressure is -0.5 psig. This revised assumption for the initial containment pressure resulted in a PCT benefit of 5°F. Note that the assumed initial containment pressure of -0.5 psig is bounded by the Technical Specification containment pressure limits.

12. PCT Assessment for the LBLOCA for the Byron and Braidwood Stations Due to Burst Location Change

The LBLOCA AOR for the Byron and Braidwood Stations is presented in Chapter 15, "Accident Analysis," of the UFSAR, and has a limiting case PCT of 1968°F. Westinghouse performed a series of sensitivity studies to rebaseline the AOR. One of the sensitivity cases using minor input changes indicated a PCT increase from 1968°F to 2062°F; a 94°F increase. Since the minor input changes and computer code version/methodology changes did not appear significant enough to account for the 94°F change, a non-conformance report was written, and an evaluation was undertaken to determine the cause of the PCT increase.

It was determined that the PCT increase was largely attributed to the change in the predicted location of the hot rod burst. Nodes immediately downstream of fuel assembly grids are typically non-limiting due to the enhanced cooling afforded by the grid. In the AOR, the hot rod burst occurred immediately downstream of a spacer grid; hence, the cladding temperature at the burst elevation remained relatively low. In the sensitivity case, the thermal-hydraulic results though not significantly changed, were sufficiently different to move the location of the rod burst by one node (i.e., 3 inches) and the cladding temperature at the burst node was not influenced by the presence of a grid.

The subsequently performed evaluation demonstrated that there is no valid reason to discredit the 3-inch shift in the hot rod burst location. Therefore, the plant-specific 94°F analytical PCT penalty will be assigned to the Byron Station and Braidwood Station cumulative PCT at this time.

This is not considered to be an error in the evaluation model nor an error in the application of the model, but merely a consequence of the discretization of the thermal-hydraulic process that is fundamental to the model. Westinghouse continues to consider the ramifications of the burst location behavior relative to the ability to obtain stable results and may introduce discretionary changes to the model in the future.

Application of the 94°F analytical PCT penalty allows removal of the 15°F PCT penalty for the SATAN/LOCTA Translation that was introduced in the 1997 10 CFR 50.46 Annual Report, submitted to the NRC by ComEd on April 23, 1997. This is because the SATAN/LOCTA computer code versions utilized in the sensitivity study incorporated the previous 15°F PCT penalty error.

13. LOCBART Input Fuel Rod Outside Diameter (FOD) Error

An input calculational error in the LBLOCA AOR for Byron and Braidwood Stations was discovered in the LOCBART computer code input corresponding to the fuel rod outside diameter. LOCBART is the rod heatup computer code of the BASH Evaluation Model. This constitutes an error in the application of the evaluation model as defined in 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors." A plant specific LOCBART sensitivity study was made which corrected the input FOD to its correct value, resulting in a 2°F PCT penalty.

14. SBLOCA Burst and Blockage/Time in Life (SPIKE Correlation Revision)

The SPIKE computer code and the associated methodology are used to estimate fuel rod burst PCT penalties for SBLOCA analyses. The SPIKE code has been revised to reflect more recent data that was generated using the SBLOCA Evaluation Model and methodology. The SPIKE computer code was updated and validated to reflect the new database information.

Small Break LOCA analyses which include burst and blockage effects based on direct burnup studies are not impacted by the revision to SPIKE. Since the Byron Station Unit 2 and Braidwood Station Unit 2 SBLOCA analysis includes burst and blockage effects based on direct burnup studies, no SPIKE case was run and there is no impact on PCT.

Burst and blockage effects do not adversely impact SBLOCA analyses with PCTs less than 1700 °F. For the Byron Station Unit 1 and Braidwood Station Unit 1 analysis, the burst and blockage PCT penalty was calculated to be 0°F.

15. RCFC Start Time, Increase in Containment Spray Flow Rate, Storage of Lead Shielding Blankets and Scaffolding Materials Inside Containment, and Steam Generator (SG) Blowdown Valve Leakage

In the LBLOCA AOR, the earliest start time of the RCFC was assumed to be 25 seconds. An evaluation was performed by Westinghouse to determine the impact of decreasing the start time from 25 to 15 seconds. The result was an increase in the PCT of 2°F.

In the LBLOCA AOR the containment spray flow rate was assumed to be 8900 gpm. An evaluation was performed by Westinghouse to determine the impact of increasing the containment spray flow rate from 8900 to 9255 gpm. The result was an increase in the PCT of 1°F.

The LBLOCA AOR does not assume any lead shielding blankets or scaffolding materials are stored inside containment. An evaluation was performed by Westinghouse to determine the impact of storing lead shielding blankets and scaffolding materials inside containment. The result was an increase in the PCT of 2 °F.

The LBLOCA AOR does not assume any SG blowdown valve leakage. An evaluation was performed by Westinghouse to determine the impact of 10 gpm/SG blowdown valve leakage. The result was that there is no impact on the PCT.

The SBLOCA AOR is not affected.

16. LOCBART Cladding Emissivity Errors

Section 2-17 of Reference 1, Section 3.2.5 of Reference 2, and Section 3-2 of Reference 3 describe expressions that are used to model radiation heat exchange between the rod, grid, and fluid during the reflood phase of the transient. It was discovered that the cladding surface emissivity values used with Equation 2-93 of Reference 1, Equation 3-47 of Reference 2, and Equation 3-8 of Reference 3 were substantially lower than the values that would be expected to exist during a large break LOCA reflood transient. A review of existing documentation was performed to determine the exact values that were intended to be used with the equations. Subsequently, a constant, representative value of 0.7 was used as the emissivity value in the LOCBART code based on the value used in the WCOBRA/TRAC code for a similar application (see Reference 4). These errors were determined to be Non-Discretionary Changes as defined in Section 4.1.2 of WCAP-13451, "Westinghouse Methodology for Implementation of 10 CFR 50.46 Reporting."

Representative plant calculations using the LOCBART code showed that these error corrections generally result in a small-to-moderate PCT benefit for plants with burst-node-limited PCTs occurring coincident with the onset-of-entrainment in reflood and a small PCT benefit or penalty for other plants. The generic PCT assessments for this issue were derived from the representative plant calculations as the bounding values for each of the two plant/transient categories (i.e., early-PCT, burst-node-limited plants and other plants) that were defined specifically for this purpose.

For Byron Station and Braidwood Station, a decrease of 10°F in the PCT is applied for this error.

References

1. WCAP-9561-P-A, "BART-A1: A Computer Code for the Best Estimate Analysis of Reflood Transients," M. Young, et al., March 1984.
2. WCAP-7437-L, "LOCTA-R2 Program: Loss of Coolant Transient Analysis," W.A. Bezella, et al., January 1970.
3. WCAP-10484-P-A, "Spacer Grid Heat Transfer Effects During Reflood," M. Young, et al., March 1991.
4. WCAP-12945-P-A Volume I (Revision 2) and Volumes II-V (Revision 1), "Westinghouse Code Qualification for Best Estimate Loss of Coolant Accident Analysis," S.M. Bajorek, et al., March 1998.

17. LOCBART Vapor Film Flow Regime Heat Transfer Error

As discussed in Reference 1, the Berenson model for film boiling is used in LOCBART to compute the cladding-to-fluid heat transfer coefficient for conduction across the vapor film in the vapor film flow regime, which occurs near the quench front and is assumed to consist of a conduction component and a radiation component. An error was discovered in LOCBART where the multiplier on this correlation was programmed incorrectly, resulting in a relatively minor under-prediction of the cladding-to-fluid heat transfer coefficient. This error correction was determined to be a Non-Discretionary Change as defined in Section 4.1.2 of WCAP-13451.

Representative plant calculations using the LOCBART code showed that this error correction generally results in a small-to-moderate PCT benefit for plants with burst-node-limited PCTs occurring coincident with the onset-of-entrainment in reflood and a small PCT benefit or penalty for other plants. The generic PCT assessments for this issue were derived from the representative plant calculations as the bounding values for each of the two plant/transient

categories (i.e., early-PCT, burst-node-limited plants and other plants) that were defined specifically for this purpose.

For Byron and Braidwood a decrease of 15°F in the PCT is applied for this error.

Reference

1. WCAP-9561-P-A, "BART-A1: A Computer Code for the Best Estimate Analysis of Reflood Transients," M.Y. Young, et al., March 1984.

18. NOTRUMP Mixture Level Tracking/Region Depletion Errors

Several closely related errors have been discovered regarding how NOTRUMP deals with the stack mixture level transition across a node boundary in a stack of fluid nodes. When the mixture level attempts to transition a node boundary in a stack of fluid nodes, it can occasionally have difficulty crossing the interface (i.e., level hang). When a mixture level hang occurs at a node boundary, this leads to situations where the flow for a given time step is reset and becomes inconsistent with the matrix solution of the momentum equation for an excessive period of time. This results in local mass/energy errors being generated. In addition, it was discovered that the code was not properly updating metal node temperatures as a result of the implementation of the nodal region depletion logic which can be incurred when a fluid node empties or fills. It is noted that several aspects of these errors, namely mixture level tracking and flow resets, are not directly tied to erroneous coding; rather, they are a direct result of modeling choices made and documented in the original code development/licensing. These errors affect all code versions up to and including NOTRUMP Version 37.0. These error corrections were determined to contain both Discretionary and Non-Discretionary Change aspects as defined in Sections 4.1.1 and 4.1.2 of WCAP-13451.

The nature of this error leads to a bounding 13°F increase of the calculated PCT for all standard Evaluation Model applications.

References

1. Westinghouse Letter NSBU-NRC-00-5972, "NRC Report for NOTRUMP Version 38.0 Changes," (Non-Proprietary), June 30, 2000.

19. Trapped Nitrogen in Accumulator Lines

To address the potential for gas accumulation in the Emergency Core Cooling System (ECCS) piping between the two check valves in the accumulator line (i.e., between valves SI8948 and SI8956) an evaluation was performed by Westinghouse. This evaluation resulted in an increase of 12°F in the PCT for the Byron Station Unit 2 and Braidwood Station Unit 2 SBLOCA. The PCT for the Byron Station Unit 1 and Braidwood Station Unit 1 SBLOCA and the LBLOCA were unaffected.

Attachment 3

10 CFR 50.46
"Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors,"

Annual Report of the Emergency Core Cooling System Evaluation Model Changes and Errors

Assessment Notes Not Included in Peak Cladding Temperature Rack-Up Sheets

The following is a brief description of other Loss of Coolant Accident (LOCA) assessments that reflect changes to the evaluation models, which are not included in the rack-up sheets. These assessments, in all cases, resulted in benefits or zero penalty to the calculated Peak Cladding Temperature (PCT). However, we have conservatively chosen not to credit these PCT benefits, i.e., for each change a delta PCT of zero degrees Fahrenheit is assigned. Evaluations of these changes are based upon conservative generic studies for Westinghouse designed Nuclear Steam Supply Systems (NSSSs) or engineering judgment. If a re-analysis or an evaluation is obtained from Westinghouse, the impact of these changes will be included and the effect of these changes will be reported as applicable.

Emergency Diesel Generator (EDG) Underfrequency Evaluation

The safety analyses are performed assuming the EDG operates at the steady state frequency. Recent EDG loading sequence tests and modeling indicate that the underfrequency reduction can be as much as 2 Hz (i.e., from 55 to 57 Hz) for a period of four seconds. The impact of the frequency swing during EDG loading sequences was evaluated and was determined to have an insignificant impact on the PCT.

EDG Frequency Evaluation

Currently, all safety analyses are performed assuming the EDG operates at the steady state frequency. However, the Technical Specifications allow EDG frequency to be within ± 1.2 Hz of the steady state frequency of 60 Hz. In the letter from R. M. Krich (Commonwealth Edison Company) to U.S. NRC, "Annual 10 CFR 50.46 Report," dated April 23, 1998, it was stated that Westinghouse would perform a formal assessment of any PCT impact associated with this EDG frequency band. After further evaluation and discussion, it was decided that the current assumption of EDG operation at steady state frequency is appropriate and that it is not necessary for Westinghouse to perform a formal PCT assessment. As stated in the 1998 Annual 10 CFR 50.46," Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors," Report, dated April 23, 1998, the impact on PCT has been determined to be small. There is sufficient inherent conservatism in the Westinghouse LOCA Emergency Core Cooling System (ECCS) Evaluation Models to bound uncertainty associated with EDG frequency uncertainty and the overall change to PCT is expected to be zero. Therefore, the utilization of steady state EDG frequency in the LOCA analysis is judged to be appropriate.

Fuel Rod Design and 10 CFR 50.46 Acceptance Criteria

Westinghouse representatives recently informed Exelon representatives that fuel rod corrosion and its associated feedback effect on rod internal pressure and the pressure stress limit have led to a potential violation of fuel rod design criteria and 10 CFR 50.46 acceptance criteria. Violation of the "no gap reopening" fuel rod criterion does not automatically result in a 10 CFR 50.46 acceptance criterion violation. This issue was first addressed in Westinghouse letter NSD-NRC-97-97-5404, dated October 28, 1997, to the NRC. This letter concluded that a substantial safety hazard as defined in 10 CFR 21, "Reporting of Defects and Noncompliance," does not exist, and that the same levels of safety as considered in the design basis evaluations were maintained.

Plant specific evaluations are performed every reload cycle using Westinghouse methodology to ensure that the reload design does not violate the 17% total localized

corrosion criterion of 10 CFR 50.46. Specifically, evaluations have been performed for Braidwood Station Unit 1 Cycle 9, Braidwood Station Unit 2 Cycle 8, Byron Station Unit 1 Cycle 10, and Byron Station Unit 2 Cycle 9. These evaluations have shown that the 17% total localized corrosion criterion of 10 CFR 50.46 is not violated.

LBLOCA Power Distribution

Appendix K to 10 CFR 50, "ECCS Evaluation Models," requires that the power distribution, which results in the most severe calculated consequences, be used in the ECCS Evaluation Model calculations. The current basis for all Westinghouse LBLOCA evaluations is the chopped cosine power distribution. Calculations were performed with BASH, which examined peak power locations and power distributions that were not considered in the original analysis. Under some circumstances, these evaluations lead to PCTs greater than those calculated with the cosine distribution. Previously, the Byron and Braidwood Stations included a conservative temporary PCT penalty of 100°F to bound the effects of other power shapes.

To address the power shape issue, Westinghouse has developed an alternate axial power shape methodology, ESHAPE (i.e., Explicit Shape Analysis for PCT Effects). The ESHAPE methodology is based on explicit analysis of a set of skewed axial power shapes. The NRC as part of the Westinghouse LBLOCA Evaluation Model has previously approved the explicit use of skewed power shapes. Westinghouse has performed evaluations for the Byron and Braidwood Stations using ESHAPE and has determined that the cosine power shape used in the Analysis of Record (AOR) remains limiting. Therefore, the PCT penalty of 100°F was removed.

LUCIFER2 Downcomer Azimuthal Flow Path Calculations

The LUCIFER2 computer code generates component databases that are used by the SATIMP, BASHER, and SPADES input processors to develop plant-specific input models for the LBLOCA and SBLOCA analyses. An error was discovered in LUCIFER2 whereby a reactor vessel diameter below the RCS hot/cold leg elevation was used for calculations that apply above the RCS hot/cold leg elevation, resulting in incorrect values for various downcomer azimuthal flow path parameters.

For the SBLOCA analysis, this error has no impact on the calculated PCT since the downcomer azimuthal flow paths defined in LUCIFER2 are not used.

For the LBLOCA analysis, this error only affects the SATAN6 computer code since the downcomer azimuthal flow paths defined in LUCIFER2 are not used in BASH computer code. Westinghouse calculations using the SATAN6 computer code showed that this error correction has no impact on PCT.

BASH Vapor Film Flow Regime Heat Transfer Error

As discussed in WCAP-9561-P-A, "BART-A1: A Computer Code for the Best Estimate Analysis of Reflood Transients," the Berenson model for film boiling is used in the BASH computer code to calculate the cladding-to-fluid heat transfer coefficient for conduction across the vapor film in the vapor film flow regime. An error was discovered in the BASH computer code, resulting in an underprediction of the cladding-to-fluid heat transfer coefficient (i.e., a lower heat transfer coefficient).

Westinghouse calculations using the BASH computer code showed that this error correction had a negligible effect on the core inlet flooding rate during reflood and as such has no impact on PCT.

BASH Broken Loop Accumulator Empty Time Logic Error

An error was discovered in the BASH computer code that resulted in immediate emptying of the faulted accumulator upon entry into the reflood phase of the transient.

For cases where the faulted accumulator empties prior to entry into the reflood phase of the transient, this error has no effect on PCT. For cases where the faulted accumulator empties during the reflood phase of the transient, this error would have a negligible effect on the containment pressure during the reflood phase and therefore would have a negligible effect on the core inlet flooding rate. There is no impact on PCT as a result of this error.

BASH Pumped Injection Spill Logic Error

An error was discovered in the BASH computer code that resulted in an underprediction of the spilling flow (i.e., a lower spilling flow) to containment for dry containment plants with accumulator/Safety Injection (SI) interaction that use the interactive COCO computer code.

Westinghouse calculations using the BASH computer code showed that this error would have a negligible effect on the containment pressure during the reflood phase and therefore would have a negligible effect on the core inlet flooding rate. There is no impact on PCT as a result of this error.

LOCBART Pellet Diameter Adjustment Error

To account for small differences in pellet average temperatures between the LOCA models and the fuel rod design models in the PAD computer code, part of the initialization process for the LOCTA-IV program fuel rod model (i.e., WCAP-8301, "LOCTA-IV Program: Loss-of-Coolant Transient Analysis," F.M. Bordelon et. al., June 1974) involves making small adjustments to the fuel pellet diameter such that the pellet average temperature at steady-state full-power operation matches the data from the PAD code. Note that WCAP-8301 was referenced by WCAP-8471 P-A, "Westinghouse ECCS Evaluation Model; Supplementary Information," dated April 1975. WCAP-8471 was approved by the NRC in a letter from D. B. Vssallo (NRC) to C. Eicheldinger (Westinghouse), dated May 30, 1975. To compensate for this adjustment to the pellet diameter, a factor is applied to the core power such that the ratio of core power to uranium dioxide (UO_2) mass remains constant. During review of the LOCBART code, which is based upon the LOCTA-IV model, it was discovered that a second compensating adjustment also existed, where a similar factor was being applied to the pellet density to achieve the same purpose. In order to avoid double-counting the pellet diameter adjustment effect, the code was corrected to use only the power adjustment in accordance with WCAP-8301. There is no impact on PCT as a result of this error.

SPADES Truncation Error

Various methods exist for entering input data into the SPADES computer code, which is used to generate the plant-specific input models for NOTRUMP. An error was discovered in the SPADES computer code whereby different methods of entering the input data could lead to minor differences in the resulting NOTRUMP input values due to differences in the truncation methods. There is no impact on PCT as a result of this error.

NOTRUMP Array Boundary Error

An error was discovered that could potentially affect the data stored within arrays of the NOTRUMP executable computer code. Areas of the NOTRUMP computer code and the user externals were coded such that references to data locations, beyond defined array boundaries, could possibly have been utilized. To correct this problem, array range checking is now being enabled during execution via the use of specific compiler options. With these compiler options activated, attempts to use data outside of defined array boundaries result in code termination with the offending source code line identified to the user. To activate these compiler options, the dimensions on several dummy argument one-dimensional arrays were changed to utilize appropriate coding conventions. NOTRUMP models that were considered to encompass the range of array storage requirements were chosen and executed with both the erroneous and corrected code versions. From the results, there was no impact to PCT.

NOTRUMP Volumetric/Mass Based Consistency Error

NOTRUMP contains user input options for either mass or volumetric flow in the momentum conservation equations. The latter is used in NOTRUMP for the AP600 Evaluation Model (EM) due to the low pressures experienced in the AP600 SBLOCA transient. When evaluating the use of certain AP600 model features for potential use in the standard 10 CFR 50, Appendix K EM, it was discovered that undesirable numerical oscillations were occurring when flow direction changes were predicted in certain flow links, causing the code to abort. The cause of the problem was determined to be an inconsistent method of updating certain mass and volumetric rate variables during portions of the SBLOCA transient. When reviewing the details of this error, it was discovered that other code locations were also affected by this error, which meant that both the standard NOTRUMP EM and the AP600 EM were affected. To correct the problem, several subroutines were modified to correctly update volumetric and mass-based flow calculations on a consistent basis.

Westinghouse Pressurized Water Reactor (PWR) plant calculations show that the nature of these changes leads to an estimated PCT impact of 0°F.

LOCBART Transient Termination

Recent analyses using the BASH computer code predicted downcomer boiling to occur before the cladding temperature and/or oxidation transients have been conclusively terminated. A method has been developed to extend the transient beyond the onset of downcomer boiling by correlating the boiling-induced reduction in downcomer driving head to a corresponding reduction in the core inlet flooding rate.

Westinghouse experience indicates that the PCT will occur prior to the onset of downcomer boiling for the majority of anticipated applications. If the PCT were to occur following the onset of downcomer boiling, the cladding temperature excursion will already have leveled off sufficiently that any increase in PCT that occurs following the onset of downcomer boiling would be expected to be insignificant. As such, this method of extending the transient beyond the onset of downcomer boiling will be implemented on a forward-fit basis.

NOTRUMP Inconel-690 Tube Properties

With the introduction of Alloy 690 tube material in the replacement Steam Generators (SGs), NOTRUMP tube material properties were updated to reflect the small differences between Alloy 600 (i.e., the material in the original SGs) and Alloy 690. The differences in material properties between Alloy 600 and Alloy 690 are expected to have a negligible effect on PCT, so this change will be implemented on a forward-fit basis.

Improved Code Input/Output (I/O) and Diagnostics, and General Code Maintenance

Various changes in code input and output format have been made to enhance usability and help preclude errors in analyses. This includes both input changes (e.g., more relevant input variables defined and more common input values used as defaults) and input diagnostics designed to preclude unreasonable values from being used, as well as various changes to code output which have no effect on calculational results. In addition, various blocks of coding were rewritten to eliminate inactive coding, optimize the active coding, and improve code commenting both for enhanced usability and to facilitate code debugging when necessary. The nature of these changes leads to an estimated PCT impact of 0°F.

BASH Isotherm Initialization Error

As discussed in Section 3-6 of Reference 1, the quench front progression in BART is computed using the isotherm migration method. An error was discovered in BASH whereby a variable was not being initialized for cases where a user entered the initial isotherm temperatures and elevations into the BASH input file instead of letting the code calculate the initial isotherms internally. This error existed in BASH Versions 18.0 and 19.0. This error correction was determined to be a Non-Discretionary Change as defined in Section 4.1.2 of WCAP-13451, Westinghouse Methodology for Implementation of 10 CFR 50.46 Reporting."

A survey of BASH-EM analyses under Westinghouse LBLOCA analysis cognizance found no usage of the erroneous option which is not accessed for standard production applications.

As a result, the correction of this error is treated as having a 0°F PCT effect for 10 CFR 50.46 reporting purposes.

Reference

1. WCAP-9561-P-A, "BART-A1: A Computer Code for the Best Estimate Analysis of Reflood Transients", M.Y. Young, et al., March 1984.

BASH Implementation of LOCBART Corrections

Since BART coding is used in both LOCBART and BASH, the following changes described elsewhere in this report have also been implemented into BASH for consistency.

- LOCBART Cladding Emissivity Errors
- LOCBART Vapor Film Flow Regime Heat Transfer Error
- LOCBART Dispersed Flow Regime Wall Emissivity Error

These changes were determined to be Non-Discretionary Changes as defined in Section 4.1.2 of WCAP-13451.

Representative plant calculations using the BASH code showed that these error corrections had a relatively minor effect on the core inlet flooding rate during reflood, which in turn would be expected to have a negligible effect on PCT.

As a result, these corrections are being treated as having a 0°F PCT effect for 10 CFR 50.46 reporting purposes.

Inadequately Dimensioned Core Reflux Flow Link Error in NOTRUMP

An error has been discovered which results in the termination of the NOTRUMP code when attempting to model more than 12 active core nodes. The problem results from an inadequately defined maximum number of core reflux flow links in the code externals. The nature of the error is such that code execution can not be performed when attempting to model more than 12 core nodes due to compiler options selected. This problem only exists in the NOTRUMP Version 37.0 code. This error correction was determined to be a Non-Discretionary Change as defined in Section 4.1.2 of WCAP-13451.

The nature of this error leads to no PCT impact for all EM applications due to the core modeling assumed in these models (i.e. <= 12 core nodes).

LOCBART Rod-to-Rod Radiation Error

An error was discovered in LOCBART whereby a variable was not being defined for the rod-to-rod radiation calculations. This error caused the radiation heat flux for the hot rod to be calculated incorrectly and caused the radiation heat flux for the adjacent rod to be zero. This error is present only in LOCBART Version 20.0. This error correction was determined to be a Non-Discretionary Change as defined in Section 4.1.2 of WCAP-13451.

Representative plant calculations using the LOCBART code showed that this error correction had a negligible effect on results. As a result, this correction is being treated as having a 0°F PCT effect for 10 CFR 50.46 reporting purposes.

LOCBART NUREG-0630 Coding Errors

The following errors were discovered in the LOCBART code related to the programming of the Reference 1 burst and blockage models for Zircaloy-4 cladding.

1. In Subroutine FBLOK, the assembly blockage corresponding to a burst temperature of 700°C (1292°F) and a temperature ramp rate of 25°C/s (45°F/s) was programmed as 13.6%, instead of the correct value of 13.8% from page 112 of Reference 1.

2. In Subroutine XPAND, the burst temperature corresponding to a burst strain of 48% (i.e., for a temperature ramp rate of 10°C/s or 18°F/s) or 45% (i.e., for a temperature ramp rate of 25°C/s or 45°F/s) was programmed as 1675°F, instead of the correct value of 1652°F (900°C) from pages 111 and 112 of Reference 1.

As discussed below, it was determined that correcting these errors would either have no effect on results or would be expected to result in a small PCT benefit, therefore, LOCBART updates will be deferred to a future code release. When corrected, these error corrections will represent Non-Discretionary Changes as defined in Section 4.1.2 of WCAP-13451.

The error in Subroutine FBLOK affects the calculation of assembly blockage for Zircaloy-4 cladding over the burst temperature range of 1247-1337°F, which is substantially lower than the burst temperatures that are encountered in typical licensing calculations. For a hypothetical case with a burst temperature in the affected range, the difference in assembly blockage is very small and would be expected to have a negligible effect on results.

The error in Subroutine XPAND affects the calculation of burst strain for Zircaloy-4 cladding over the burst temperature range of 1607-1697°F. It was determined that correcting the error would either have no effect on results or would result in a small reduction in burst strain, which would be expected to result in a small decrease in PCT with all other things being equal.

Based on the preceding information, these error corrections will be deferred to a future code release and are treated as having a 0°F PCT effect for 10 CFR 50.46 reporting purposes.

Reference

1. NUREG-0630, "Cladding Swelling and Rupture Models for LOCA Analysis," R. O. Meyer and D. A. Powers, April 1980.

NOTRUMP Core Heat Transfer Error

An error has been discovered in NOTRUMP which results in either a code abort or the usage of invalid steam table properties and/or heat transfer correlations in the core region under certain conditions. The problem results from the steam cooling core heat transfer correlation attempting to pass sub-cooled properties to steam property routines. Since the property routines do not perform input validity checking, this can result in

erroneous properties being returned/utilized by the correlation. This error can only occur when complete subcooling of the core cladding occurs in conjunction with core uncovery. This error affects all code versions up to and including NOTRUMP Version 37.0. This error correction was determined to be a Non-Discretionary Change as defined in Section 4.1.2 of WCAP-13451.

The nature of this error leads to no PCT impact for all standard EM applications due to the lack of this type of core uncovery process.

SATAN6 Momentum Flux Logic Error

An error was discovered in the SATAN6 momentum flux logic whereby the sonic velocity limit was being applied incorrectly. In some instances, this caused the break flow to hang near the end of the blowdown transient, instead of allowing the calculation to proceed normally to the end of blowdown. The erroneous logic was corrected to ensure proper application of the sonic velocity limit. This error correction was determined to be a Non-Discretionary Change as defined in Section 4.1.2 of WCAP-13451.

Representative plant calculations using the SATAN6 code showed that this error correction had a very minor effect on blowdown results for typical cases, which in turn would be expected to have a negligible effect on PCT. Even for a case with a more substantial effect on SATAN6 results, the effect on PCT was found to be small, due mainly to the fact that the core heatup near end-of-blowdown is essentially adiabatic.

As a result, this correction is being treated as having a 0°F PCT effect for 10 CFR 50.46 reporting purposes.

SATAN6 Reactor Coolant Pump Logic Error

An error was discovered in the SATAN6 reactor coolant pump logic where, during a time step in which the pump critical flow iteration failed to converge, the pump discharge mass flow rate was incorrectly reset to the value corresponding to the last iteration. This problem was resolved by removing the pump critical flow iteration from the code since the corresponding logic was found to be of little use for standard licensing applications. This change was determined to contain both Discretionary and Non-Discretionary aspects as defined in Sections 4.1.1 and 4.1.2, respectively, of WCAP-13451.

Representative plant calculations using the SATAN6 code showed that these changes had either no effect or a negligible effect on blowdown results, which would be expected to have either no effect or a negligible effect on PCT.

As a result, these changes are being reported as having a 0°F PCT effect for 10 CFR 50.46 reporting purposes.

Large Break LOCA Single Failure Assumption

A concern was raised by a licensee where a single failure in the Solid State Protection System, or Relay Protection System for older plants, could cause the loss of an entire train of safety injection pumps without causing the loss of the corresponding train of containment heat removal equipment. This situation is contrary to Section 3.6 of Reference 1, which defines the limiting single failure for LBLOCA analysis as the loss of

a single low pressure injection pump. To address this concern, the analysis guidance has been modified to direct the analyst to assume the
loss of an entire train of safety injection pumps, unless a less conservative single failure assumption can be justified. This was determined to represent a Non-Discretionary Change as defined in Section 4.1.2 of WCAP-13451.

Recent LBLOCA analyses have generally assumed the loss of an entire train of SI pumps as the limiting single failure, since the additional conservatism introduced by this simplification is typically small. A survey of BART-EM and BASH-EM analyses under Westinghouse LBLOCA analysis cognizance found no domestic applications in which the analyst assumed the loss of a low pressure injection pump as the limiting single failure.

As a result, this change is being treated as having a 0°F PCT effect for 10 CFR 50.46 reporting purposes.

Reference

1. WCAP-8471-P-A, "The Westinghouse ECCS Evaluation Model: Supplementary Information," F. M. Bordelon et. al., April 1975.

Simplified Isothermal Solution For LOCBART Subroutine Rate

As discussed in Reference 1, LOCBART was revised in 1999 to correct a logic error that caused the Baker-Just metal-water reaction calculations to be performed three times per time step. During the review of the corresponding code logic, it was determined that the complicated solution technique described in Section 3.3.2 of Reference 2 could be replaced with a simplified isothermal solution, with only a minimal effect on results. This replacement has been accomplished and was determined to represent a Discretionary Change that will be implemented on a forward-fit basis, in accordance with Section 4.1.1 of WCAP-13451.

Representative plant calculations using the LOCBART code confirmed that this change has a negligible effect on results that will be implemented on a forward-fit basis and is being treated as having a 0 °F PCT effect for 10 CFR 50.46 reporting purposes.

References

1. Westinghouse Letter NSBU-NRC-00-5970, "1999 Annual Notification of Changes to the Westinghouse Small Break LOCA and Large Break LOCA ECCS Evaluation Models, Pursuant to 10 CFR 50.46 (a)(3)(ii)," H. A. Sepp, May 12, 2000.
2. WCAP-8301, "LOCTA-IV Program: Loss-of-Coolant Transient Analysis," F. M. Bordelon et. al., June 1974.

PAD 4.0 Implementation

The Westinghouse Performance Analysis and Design (PAD) Model is used to generate fuel-related input data for use in LOCA licensing calculations. As documented in Reference 1, the Safety Evaluation for Version 4.0 of the PAD model was issued by the NRC on April 24, 2000. Use of PAD Version 4.0 is considered to represent a

Discretionary Change and will be implemented on a forward-fit basis, in accordance with Section 4.1.1 of WCAP-13451.

The implementation of PAD Version 4.0 with respect to 10 CFR 50 Appendix K LBLOCA and SBLOCA analyses will be handled on a forward-fit basis and is assigned a PCT estimate of 0°F for 10 CFR 50.46 reporting purposes.

References

1. WCAP-15063-P-A Revision 1, with Errata, "Westinghouse Improved Performance Analysis and Design Model (PAD 4.0)," J. P. Foster and S. Sidener, July 2000.

LOCBART Rod Internal Pressure Model Revisions

In the original LOCTA-IV model (Reference 1) the gas in the fuel rod plenum was assumed to remain at a constant, steady-state temperature throughout the entire transient. In order to more accurately track the rod internal pressure history during a LBLOCA, the use of this assumption in LOCBART has been replaced with the temperature-dependent model that was implemented previously in the SBLOCTA code as described in Reference 2. In addition, other minor changes were made to the LOCBART fuel rod internal pressure model, including an option to specify the volumes corresponding to the upper and lower annular blankets, and a simplified treatment of the crack and dish volumes. These changes were determined to represent a closely-related group of Discretionary Changes and will be implemented on a forward-fit basis in accordance with Section 4.1.1 of WCAP-13451.

These changes will be implemented on a forward-fit basis and are assigned an estimated PCT impact of 0°F for 10 CFR 50.46 reporting purposes.

References

1. WCAP-8301, "LOCTA-IV Program: Loss-of-Coolant Transient Analysis", F. M. Bordelon et al., June 1974.
2. Westinghouse Letter NTD-NRC-94-4253, "Revision to the Rod Internal Pressure Model in the Westinghouse SBLOCTA Code (Proprietary)", N. J. Liparulo, August 9, 1994.

LOCBART Dispersed Flow Regime Wall Emissivity Error

As discussed in Section 2-18 of Reference 1, the Sun, Gonzalez, and Tien model is used in LOCBART to predict radiant heat exchange between the fuel rod, vapor, and droplets in the dispersed flow regime. An error was discovered in LOCBART whereby the wall emissivity in the dispersed flow regime was substantially lower than the corresponding value identified in Section 2-18 of Reference 1. This error correction was determined to be a Non-Discretionary Change as defined in Section 4.1.2 of WCAP-13451.

Representative plant calculations using the LOCBART code showed that this error correction generally results in a small PCT benefit for plants with PCTs occurring early in reflood and a small-to-moderate PCT benefit for plants with PCTs occurring late in

reflood. The generic PCT assessments for this issue were derived from the representative plant calculations as the bounding values for each of the two plant/transient categories (i.e., early-reflood - PCT plants and late-reflood - PCT plants) that were defined specifically for this purpose.

For Byron Station and Braidwood Station, a 0°F PCT effect is assigned.

Reference

1. WCAP-9561-P-A, "BART-A1: A Computer Code for the Best Estimate Analysis of Reflood Transients," M.Y. Young, et al., March 1984.