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W3F1-2008-0006

March 4, 2008

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

SUBJECT: RAI Response to Supplement to ECCS Performance Analysis Submittal In Support of Next Generation Fuel in Waterford 3 - 1999 EM Optional Steam Cooling Model Justification
Waterford Steam Electric Station, Unit 3
Docket No. 50-382
License No. NPF-38

REFERENCES:
1. Entergy letter to the NRC "Emergency Core Cooling System Performance Analysis," dated August 9, 2007 (W3F1-2007-0038)
2. Entergy letter to the NRC "Supplement to the ECCS Performance Analysis Submittal In Support of Next Generation Fuel in Waterford 3 - 1999 EM Optional Steam Cooling Model Justification," dated October 4, 2007 (W3F1-2007-0045)
3. NRC letter to Entergy dated February 7, 2008, Request for Additional Information

Dear Sir or Madam:

By letter (Reference 1), Entergy Operations, Inc. (Entergy) provided a Waterford Steam Electric Station, Unit 3 (Waterford 3) revised Emergency Core Cooling System (ECCS) Performance Analysis that supports the implementation of CE 16x16 Next Generation Fuel (NGF) described in WCAP-16500. On October 4, 2007, an addendum to the Emergency Core Cooling System (ECCS) Performance Analysis (Reference 2) was also provided to address a limitation and condition in the final NRC Safety Evaluation (SE) for the Westinghouse topical report (TR) CENPD-132, Supplement 4-P-A, Addendum 1-P, "Calculative Methods for the CE Nuclear Power Large Break LOCA Evaluation Model – Improvement to 1999 Large Break LOCA EM Steam Cooling Model for Less Than 1 in/sec Core Reflood."

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Since Reference 2 was submitted for NRC staff review, Entergy has held conference calls with NRC Staff members on January 17 and 24, 2008 to discuss the RAI questions. A total of ten (10) RAI questions were proposed by NRC staff members via letter dated February 7, 2008 (Reference 3). Entergy's response to the RAI is included in Attachment 1.

This letter contains no commitments. If you have any questions or require additional information, please contact Ron Williams at 504-739-6255.

Sincerely,

RJM/RLW

Attachment: 1. RAI Response to Supplement to ECCS Performance Analysis Submittal In Support of Next Generation Fuel in Waterford 3 -1999 EM Optional Steam Cooling Model Justification

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Attachment 1

W3F1-2008-0006

RAI Response to Supplement to ECCS Performance Analysis Submittal In Support of Next Generation Fuel in Waterford 3 -1999 EM Optional Steam Cooling Model Justification

RAI Response to Supplement to ECCS Performance Analysis Submittal In Support of Next Generation Fuel in Waterford 3 -1999 EM Optional Steam Cooling Model Justification

Reference 1 - CENPD-132-P-A Supplement 4-P-A Addendum 1-P-A, "Calculative Methods for the CE Nuclear Power Large Break LOCA Evaluation Model, Improvement to 1999 Large Break LOCA EM Steam Cooling Model for Less Than 1 in/sec Core Reflood," August 2007

2 - Entergy letter to the NRC "Emergency Core Cooling System Performance Analysis," dated August 9, 2007 (W3F1-2007-0038)

3 - Entergy letter to the NRC "Supplement to the ECCS Performance Analysis Submittal In Support of Next Generation Fuel in Waterford 3 - 1999 EM Optional Steam Cooling Model Justification," dated October 4, 2007 (W3F1-2007-0045)

RAI 1 - *Figure 3.3-7 does not show quench. Please show the results of the calculation through quench for figure 3.3-7 and also the peak local oxidation plot until quench in Figure 3.3-2.*

Entergy Response:

Figure 3.3-7 (in Reference 3), which is the rupture node cladding temperature calculation, does not show quench because the implementation of the requirements of Appendix K in the 1999 EM conservatively requires that for core reflood rates less than 1 in/sec, the hot rod reflood heat transfer is based on steam cooling methodology with no return to nucleate boiling. The LOCA cooling rates calculated by the 1999 EM, under these Appendix K restrictions, are conservatively less than best estimate modeling. Nevertheless, the 1999 EM transient calculations for Waterford 3 were extended far enough in time to determine the peak local oxidation percentage with the numerical precision reported. Furthermore, the calculated cladding temperature on the rupture node in Figure 3.3-7 at the end of the transient is roughly 1300 °F, which is below the level for significant oxidation that would increase the peak value reported.

To confirm this with additional numerical information, the limiting case for local oxidation percentage from the supplementary submittal was rerun for an additional time period. The results for the rupture node cladding temperature and local oxidation are given in the following table:

Time (seconds after break)	Rupture Node Cladding Temperature (°F)	Increase in Rupture Node Oxidation Percentage from the Value Reported at 500 seconds of 16.9%
500	1308	0.0
550	1208	0.00106
600	1138	0.00132
650	1117	0.00148
700	1090	0.00157
750	1075	0.00164

As the results in the table show, the increase in rupture node oxidation for the time period after 500 seconds, as the rupture node temperature decreases from 1308 °F to 1075 °F, is less than 0.002%. This shows that the reported peak oxidation percentage would not be different to the level of numerical precision used to report the result if the calculation were carried to a later end time.

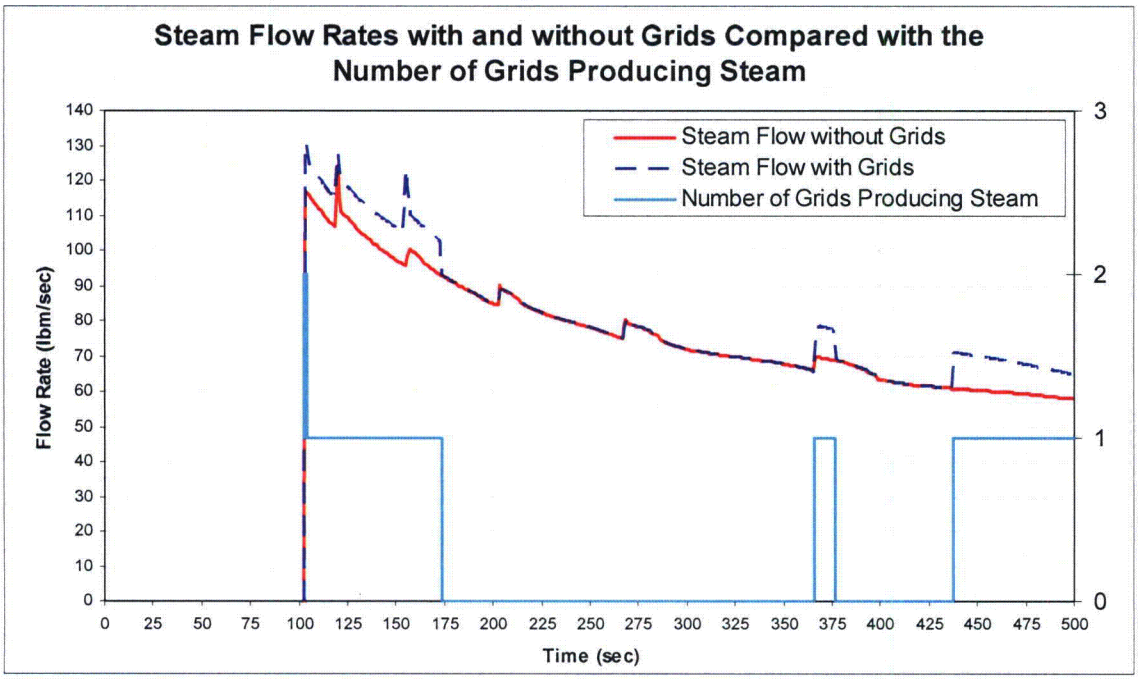
RAI 2 - *Please explain why once the spacer grids quench, the steam flow does not return to the lower steam flow consistent with the steam flow without grids dashed line in Figure 3.3-4.*

Entergy Response:

As shown in Figure 3.3-3 (in Reference 3), Spacer Grid 7 has not yet been covered by the core two-phase mixture level, and is therefore still contributing to the steam flow rate plotted in the upper curve of Figure 3.3-4 at the end of the transient.

Other examples of the performance of the model when all the grids are quenched were provided in response to a previous RAI during the review of the model. See Reference 1, Section E, Figures 2b-1 and 2b-2, for example. These figures show that when the spacer grids are covered by the core two-phase mixture level, then the steam flow rate with and without grids are the same. Figure 2b-2 is included below:

Figure 2b-2



This figure overlays the number of grids producing steam on top of the steam flow rates. Throughout much of the transient, there is no additional steam being produced by the grids. Most of the benefit to the PLO [Peak Local Oxidation] (Figure 2b-5) comes from grid 7 producing steam in the last 60 seconds of the transient. A description of what is happening when the grids start and stop producing steam can be found in Figure 2b-3.

RAI 3 - *How does this model compare with FLECHT reflood data (in particular, steam flow and heat transfer coefficient) for the tests when the reflood rate is near 1 inch per second and the pressure is lowest?*

Entergy Response:

The response to this question was addressed satisfactorily during a January 24, 2008 conference call between the NRC staff reviewer, Waterford 3 Project Manager, Westinghouse personnel and Entergy. Per the NRC Waterford 3 Project Manager's direction, the response to this question is not being provided.

RAI 4 - *Do axial regions above the rupture node to the top of the core remain at intermediate temperatures that are lower than the peak cladding temperature (PCT) sufficiently long to cause the oxidation to also approach 17 percent? Please provide the clad temperatures above the rupture node out to quench along with the oxidation percentage.*

Entergy Response:

No, axial elevations above the rupture node do not remain at intermediate temperatures long enough to accumulate significant oxidation. The rupture node with double sided oxidation at its high temperature levels is the limiting location for local oxidation percentage for the Waterford 3 plant configuration and is more than double the amount of oxidation compared to the nodes above it. Using the limiting case for local oxidation percentage from the response to RAI No. 1 as a basis, the following table provides additional information for these non-limiting elevations at two points in time and for four nodes above the rupture node:

Time (seconds after break)	**Cladding Temperature (°F)**	**Local Oxidation Percentage (%)**
One Node Above Rupture Node		
500	1725	8.01
750	1407	8.08
Two Nodes Above Rupture Node		
500	1790	6.45
750	1496	6.64
Three Nodes Above Rupture Node		
500	1775	3.65
750	1561	4.10
Four Nodes Above Rupture Node		
500	1677	1.92
750	1544	2.39

As the results in the table above indicate, the nodes above the rupture node remain at intermediate temperatures longer due to the steam cooling heat transfer requirements, but the oxidation percentages and the rates of oxide accumulation are considerably lower, and do not challenge the limiting conditions for peak local oxidation.

RAI 5 - *Is thermal radiation to the grids modeled from the surrounding rods above and below the grid spacers? If not please explain why it is neglected.*

Entergy Response:

The response to this question was addressed satisfactorily during a January 24, 2008 conference call between the NRC staff reviewer, Waterford 3 Project Manager, Westinghouse personnel and Entergy. Per the NRC Waterford 3 Project Manager's direction, the response to this question is not being provided.

RAI 6 - *Does Figure 3.3-4 include flow redistribution after rupture? Please explain.*

Entergy Response:

The response to this question was addressed satisfactorily during a January 24, 2008 conference call between the NRC staff reviewer, Waterford 3 Project Manager, Westinghouse personnel and Entergy. Per the NRC Waterford 3 Project Manager's direction, the response to this question is not being provided.

RAI 7 - *Is there any heat transferred to the entrained drops above the quench front? How is this heat transfer modeled? Please explain.*

Entergy Response:

The response to this question was addressed satisfactorily during a January 24, 2008 conference call between the NRC staff reviewer, Waterford 3 Project Manager, Westinghouse personnel and Entergy. Per the NRC Waterford 3 Project Manager's direction, the response to this question is not being provided.

RAI 8 - *Is Baker-Just applied at all temperatures? Does Baker-Just reaction rate constant capture the data over the full range of temperatures down to and including quench? Please explain.*

Entergy Response:

The 1999 EM is an NRC-approved evaluation model and complies with the requirements of Appendix K, which requires the application of the Baker-Just oxidation correlation. In the 1999 EM, the Baker-Just oxidation correlation is applied over the full range of temperatures calculated during the hot rod heatup analysis as required by Appendix K. The Baker-Just correlation is known to be overly conservative at high temperatures (greater than 1600 °F) compared to best estimate correlations. As demonstrated by the data provided above, for temperatures down to and including quench, the increment of oxidation calculated is very much smaller (by several orders of magnitude) than the oxidation accumulated at higher temperatures. Even if the Baker-Just reaction rate constants fail to conservatively capture the data at low temperatures, the contribution to the calculated transient oxidation at twice the rate

would not be significant compared to the overly conservative calculations at higher temperatures.

Additional NRC Questions from another NRC Staff Reviewer:

Section 4.0 of the supplementary large break LOCA analysis in the October 4, 2007, letter stated that the analysis of record (AOR) results included in the August 9, 2007, letter are unchanged by the supplementary LBLOCA results using the NRC-approved version of the optional steam cooling model. In support of the above, please address the following issues.

RAI 9 - *Table 3.1.1 listed the key results of a large break loss-of-coolant accident (LBLOCA) analysis for the limiting local oxidation case using the NRC-approved optional steam cooling model. Please list the results similar to those in Table 3.1.1 for the same limiting case analyzed by the earlier version of the optional steam cooling model, and demonstrate that the AOR results calculated by the earlier version of the model are not or slightly different from the results in Table 3.1.1.*

Entergy Response:

Actually Table 3.1-1 in the October 4, 2007 (Reference 3) letter provided key results for the case without using the optional steam cooling model. It is Table 3.2-1, Peak Local Oxidation Case Run with the Optional Steam Cooling Model, in the Reference 3 letter that shows the key results for the limiting local oxidation case using the NRC-approved optional steam cooling model. The following table provides the requested comparison between the Analysis of Record (AOR) results for this case from the August 9, 2007 (Reference 2) letter and the final results given in Table 3.2-1 of the Reference 3 letter. To the level of numeric precision used to report these results, there is no impact on the key results between the two versions of the optional steam cooling model. This is the same result for the limiting local cladding oxidation case as reported for the peak cladding temperature case in Section 3.4 of the Reference 3 letter.

Peak Local Oxidation Case Comparison Between the AOR and the Final Optional Steam Cooling Model		
CASE	**AOR**	**Final**
CEFLASH-4A		
Blowdown PCT (deg F)	1485.4	1485.4
Time of Blowdown PCT (sec)	5.55	5.55
Blowdown PCT Node	14	14
Time of Annulus Downflow (TAD) (sec)	23.99	23.99
COMPERC-II		
Contact Time (sec)	41.00	41.00
SITs Empty Time (sec)	99.87	99.87
Time of 1 inch/sec Core Reflood (sec)	100.23	100.23
First Reflood Rate (in/sec)	1.5433	1.5433
Second Reflood Rate (in/sec)	1.1449	1.1449
Third Reflood Rate (in/sec)	0.6636	0.6636
STRIKIN-II		
Reflood PCT (deg F)	**2154.7**	**2154.7**
Time of Reflood PCT (sec)	240.42	240.42
Reflood PCT Node	12	12
Rupture Node	13	13
Rupture Time (sec)	47.37	47.37
Rupture Temperature (deg F)	1591.2	1591.2
Rupture Strain (%)	40.93	40.93
Blockage (%)	30.26	30.26
Peak Local Oxidation (PLO) (%)	**16.9**	**16.9**
PLO Node	13	13
Hot Rod Peak Fuel Avg Temp at TAD (deg F)	1209.1	1209.1
Node of Peak Fuel Avg Temp at TAD	13	13
COMZIRC		
Max Core Wide Oxidation (%)	**0.988**	**0.988**

RAI 10 - *The reanalyzed LBLOCA cases, the local cladding oxidation case (on page 3 of the supplementary LOCA analysis) and PCT case (on page 14), are the limiting cases identified in the AOR analysis that was performed with the earlier version of the optional steam cooling model. Provide the results of an analysis to demonstrate that those two cases remain to be the limiting cases considering postulated LBLOCA cases of different sizes, locations, initial conditions and single failure assumptions when the NRC-approved version of model is used to perform LBLOCA analyses.*

Entergy Response:

The limiting cases for peak cladding temperature and local cladding oxidation percentage as identified by the extensive sensitivity studies in the Waterford 3 AOR using the earlier version of the optional steam cooling model are not impacted by the minor differences with the final optional steam cooling model. As demonstrated by the comparisons provided in the Reference 3 letter and in the response to RAI 9, the tabulation of key parameters shows that there is no impact in the calculated results to the level of precision shown using the final optional steam

cooling model. This conclusion is the same regardless of the boundary conditions for any given case because of the nature of the differences between the final optional steam cooling model and the earlier model. Therefore, the limiting cases have been identified in the AOR and do not change with the use of the final optional steam cooling model.

In particular, for application of the LBLOCA Evaluation model to Waterford 3, the limiting peak cladding temperature condition occurs exclusively on the node below the rupture node elevation for all limiting cases in the spectrum of studies included in the AOR. This is a direct consequence of the limiting core reflood rates calculated for the assumed ECCS equipment boundary conditions. The occurrence of this limiting condition below the rupture node elevation for peak cladding temperature is not impacted by the Appendix K reflood steam cooling model requirements or the optional steam cooling model, which only apply to the rupture node elevation and above in the Westinghouse 1999 EM for LBLOCA. Therefore, limiting peak cladding temperature cases are not impacted by the use of the optional steam cooling model in either its final version or the earlier version.

The determination of the limiting cases for LBLOCA is dominated by the selected boundary conditions as listed in the RAI. The specified break size and location and the assumed ECCS equipment specifications impact the calculated system responses for the blowdown period by CEFLASH-4A and for the reflood period by COMPERC-II. Neither of these two licensed computer codes or their calculated results is impacted by the optional steam cooling model. Therefore, the reactor coolant systems blowdown and reflood thermal-hydraulic results, which are transferred to the hot rod heatup calculation as boundary conditions, are not impacted by the optional steam cooling model.

The Westinghouse optional steam cooling model is used in the STRIKIN-II computer code for calculating hot rod heatup at and above the rupture node elevation when the core reflood rate is less than 1 in/sec. The specified fuel design type and the time-in-life control the selection of the initial conditions for rod internal pressure and fuel stored energy for the hot rod heatup calculation, which ultimately lead to the determination of the limiting cases. The time of less than 1 in/sec core reflood occurs late in the reflood process. The effects of initial fuel stored energy and rod internal pressure have already influenced the hot rod heatup calculation through the blowdown period and early reflood period before the time of 1 in/sec core reflood. Therefore, the determination of the limiting cases as influenced by fuel type and time-in-life is not impacted by the optional steam cooling model.

Finally, cladding rupture is calculated to occur before the time of less than 1 in/sec core reflood in the AOR spectrum of cases. This is the last critical mechanism having the potential of influencing the determination of limiting peak cladding temperature or cladding oxidation. As stated previously, the limiting peak cladding temperature occurs below the rupture node elevation and is not impacted by the steam cooling model, which applies only to the rupture node and above when the core reflood rate is less than 1 in/sec.

The optional steam cooling model is used to improve the steam cooling heat transfer imposed on the rupture node where peak local oxidation occurs. As documented in Section 3.0 of the Reference 3 letter, the final optional steam cooling model included the following four features that are different from the earlier version:

1. the approved spacer grid rewet temperature criterion required by the final SER,
2. final formulation of calculated parameters required by the SER,
3. code logic to ensure that SER imposed limitations on the calculated heat transfer coefficients are satisfied, and
4. computational constraints to confirm that the calculations were within the allowed range of applicability for flow blockage and Reynolds number.

These four features were implemented (1) to address NRC issues, (2) to facilitate showing compliance with required limitations and constraints, and (3) to assure that application of the optional steam cooling model would be constrained to its range of applicability. As has been demonstrated, the impact of these changes on the calculated results is negligible. The comparisons of key parameters provided earlier have demonstrated that the impact of these changes on the calculated local oxidation is at least one order of magnitude less significant than the numeric precision of the reported results. This is much less significant than the choice of any of the other specified boundary conditions on the determination of the limiting oxidation percentage.

The primary reason that the methodology changes associated with the final optional steam cooling model have no significant impact for the spectrum of Waterford 3 cases is that for the limiting oxidation calculation on the rupture node, the steam cooling heat transfer coefficient is constrained to be no better than the heat transfer coefficient calculated with the FLECHT correlation. The FLECHT heat transfer coefficients are dependent on the COMPERC-II calculated reflood rates and are not influenced by the optional steam cooling model. (As required by the limitations and constraints on the use of the model, the impact with or without the optional steam cooling model was documented by the graphical comparisons in Section 3.3 of the Reference 3 letter.) Referring to Figure 3.3-5 of the Reference 3 letter, the FLECHT correlation is the source of the steam cooling heat transfer coefficient on the rupture node where peak local oxidation occurs until near the end of the transient at roughly 470 seconds. The final coding changes alter the spacer grid steam cooling calculation slightly, but the value of the steam cooling heat transfer coefficient utilized in the rupture node calculation is not changed since it is limited by the FLECHT value for almost the entire reflood period. The only impact of the change in the optional steam cooling model would be seen as a slightly earlier time when the grid heat transfer value dropped below the FLECHT value at or near the end of the transient (around 470 seconds), which is after the cladding temperature had turned around and after the oxidation calculation had reached its limit. Thus, there is no significant impact on the rupture node results or on the determination of the limiting cases.

It is therefore demonstrated by comparative analysis that the identified limiting cases for peak cladding temperature and local cladding oxidation remain the limiting cases as determined by the Waterford 3 AOR.