Review of NEI Guidance Appendices

Review of Appendix A, "Defining Coating Destruction Pressures and Coating Debris Sizes for DBA-Qualified and Acceptable Coatings in Pressurized Water Reactor (PWR) Containments"

The Appendix A test program outlined the Industry's effort to determine the minimum coatings destruction pressure and provide information relative to coating debris sizes generated from within the ZOI. Testing utilized high pressure water to determine the jet effect on qualified coatings. A 3500 psig high pressure washer with a heated reservoir was used to simulate the LOCA jet. Test duration was 60 seconds. A 15 degree waterjet tip and angles of attack directing the waterjet normal to the surface and at 45 to the surface were used from multiples distances. Surface temperatures were measured during testing and were in the ranges of 150F and 80F. Coatings were applied to both steel and concrete substrates. The coating systems are characterized as untopcoated inorganic zinc (steel substrate only), inorganic zinc primer with epoxy topcoat (steel substrate only) and a self-priming epoxy all of which are representative of coating systems currently employed as qualified systems in power plants.

Testing concluded that erosion was the primary mode of coating degradation from interaction with the waterjet in all test cases. The untopcoated inorganic zinc coating failed at a distance up to 3 times greater than the epoxy. The industry concluded that a damage pressure of 333 psig for untopcoated IOZ and 1000 psig for epoxy systems should be used as the corresponding coating destruction pressures. Testing showed that an elevated surface temperature impacted the amount of coating degradation and increased fluid jet temperature resulted in coating degradation at lower jet pressures.

The test program was a good first attempt to define the destruction pressure and debris characteristics associated with LOCA jet interaction with qualified coatings. There appears to be little, if any, other test data available which attempts to define the impingement effects of a LOCA jet on coatings. This lack of data was identified in the GR. The test protocols used in the past and as currently specified in ASTM D3911 to DBA qualify coatings for nuclear service specifically prohibits fluid impingement onto the coated sample surface. The staff believes that the Appendix A test did provide valuable information by identifying erosion as a destruction mechanism for coatings and that the debris size would be characteristic of the basic material constituent under the conditions modeled during the test. The staff also believes that the test illustrated the effect that temperature plays in coating degradation. However, the staff positions is that the test did not provide sufficient justification supporting the destruction pressures and corresponding ZOI identified in the GR. No method was provided which could be used to correlate the waterjet test conditions with LOCA jet conditions. No test data was offered combining both the effects of mechanical insult and elevated temperatures (LOCA initial conditions). Nor was data provided on the effects of rapid thermal transients or pressure shock on the performance of qualified coatings. Therefore, the staff found the waterjet testing to be inconclusive.

The staff believes that a test program should be considered which will accurately estimate the coating ZOI based upon a representative LOCA jet (pressure and temperature) interacting with surfaces covered by qualified coatings. Such a test should combine the erosion effects of a water laden steam jet with the combined thermal and pressure transients associated with a LOCA. Coatings which can be correlated to qualified plant coatings should be used for the testing. This includes aging the coating to account for the effects of normal plant operation and the effects of radiation exposure. Provisions should also be established for characterization of coating debris and assessment of the failure mechanism. Such testing could lead to an understanding that debris may be generated in forms other than small particulate from erosion which may ultimately lead to a more realistic assessment of the coating debris contribution.

Review of Appendix B, "Example of a Latent Debris Survey"

This Appendix in the GR provides a simplified example of a method for determining the amount of latent debris on containment surfaces. This Appendix does not contain new or unique information, and is not totally consistent with Section 3.5 of the GR where the detailed guidance for evaluating Latent Debris is contained. In the evaluation of Section 3.5, the staff provides a more comprehensive and accurate method for evaluation of Latent Debris. As such, a separate evaluation of this Appendix is not required.

Review of Appendix C, "Comparison of Nodal Network and CFD Analysis"

The staff has reviewed the Appendix C comparison between the nodal network and CFD methods and finds that the conclusion of a "good comparison" is not supported by independent analysis and evaluations. The error values reported are computed by subtracting flow rates of the nodal network from the CFD and dividing by the total flow in the containment pool. The flows computed for the network sections are approximately 1000 gpm (order of magnitude). The total flow is 21,000 gpm, more than an order of magnitude larger than the individual flow rates, and almost 2 orders of magnitude larger than the flow difference between the two methods. The staff does not consider this approach to be a valid method for comparing nodal network results to those achieved with CFD analysis.

The staff finds that normalizing the flow error between the two methods by the total recirculation flow rate is incorrect, and minimizes the significance of the errors between the two methods. Particles/debris respond to local velocities, not normalized values. Comparison of the nodal values to the CFD values shows that there is quite a discrepancy in the associated local velocity values and discrepancies can also exist with respect to flow direction.

Also, in the information presented in the GR it is not clear how the flow channels were selected. In Figure 4-4 of the GR, the flow channels were determined by using the CFD analysis and essentially encapsulate the high velocity regions. Where the velocities are uniform across the channel, the comparison is fairly good in absolute terms, but not their "error" terms. When there is a gradient of velocity across the channel, the difference in the CFD versus nodal network velocity is quite large. Without the CFD analysis, the GR does not provide guidance for selecting the channel network. Even when the CFD results are known, the nodal network does not give a reasonable answer. The staff finds that relying on such a method for general use, where the flows are not known a priori is a difficult method to implement.

Appendix C does not provide a reference for the nodal analysis method used, nor is the method explicitly defined in the document. There is discussion about friction factors, having to choose a velocity for the Reynolds number assumed for the flow and needing to iterate to arrive at the correct velocity, but there are no equations or methodology outlined to follow. These conditions should be included and appropriate references cited for both the methodology and previously published applications to this type of flow problem.

Other issues the staff identified in Appendix C include:

A description of how the CFD flow rates were calculated for the nodal sections shown in Figure 4-4 is not provided.

Figure 4-4 is not a "composite" of the CFD results, it is exactly the case for a large loca break in the lower right quadrant, not a composite of all break locations and flows.

On Page C-4 – the threshold velocities quoted are to initiate motion of debris, not to sustain motion. The velocity required to sustain the debris motion may in fact be much lower, i.e., starting vs. rolling friction.

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Review of Appendix D, "Isobar Maps for Zone of Influence Determination"

The staff evaluation of GR Section 3.4.2.2 compared the ZOI isobars set forth in Appendix D of the GR with isobars independently calculated using the methodology of ANSI/ANS 58.2-1988. The comparison showed good agreement between the calculations for downrange behavior (Zone 3), but discrepancies exist in Zones 1 and 2. As indicated in Figure 3-1 of this SER, it appears that contour termination points on the centerline are not accurate and that the quadratic behavior of the Zone 2 isobar equations is not implemented correctly. These differences will have a negligible effect on volume integrals for jet pressures less than 20 psig, but may become more of a concern for higher pressures near the break. To quantify the magnitude of the difference, Table D-1 presents a comparison of ZOI radii computed from both methods. In particular, the GR approach may not have preserved the system stagnation pressure throughout the volume of the liquid core region as specified by the standard. However, in application of the calculated values as documented in Table 3-1 of the GR, the recommended value of 1.0 is provided for both the 1000 and 333 psig destruction pressures. The staff considers that using the recommended value of 1.0 is necessary for these pressures for a conservative treatment.

Table D-1. Comparison of Computed Spherical ZOI Radii from Independent Evaluations of the ANSI Jet Model

Impingement Pressure (psig)	ZOI Radius/Break Diameter	
	Guidance Report	SER Appendix I
1000	0.24	0.89[a]
333	0.55	0.90
190	1.11	1.05
150	1.51	1.46
40	3.73	4.00
24	5.45	5.40
17	7.72	7.49
10	12.07	11.92
6	16.97	16.95
4	21.53	21.60

[a] The core volume at stagnation pressure P0 gives a minimum possible ZOI radius of 0.88 diameters.

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Review of Appendix E, "Additional Information Regarding Debris Head Loss"

The GR Appendix E contains additional information regarding the estimation of head loss associated with debris beds. The supporting Appendix E repeats the text found in Section 4.2.5, and provides tables that summarize available domestic and international head loss testing and results. No head loss refinements are offered other than those given in Section 3.7.2.3.2.3. (See SER Section 3.7.2.3.2.3, "Thin Fibrous Beds," for the staff evaluation of that section.)