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 coating destruction pressure and provide information relative to coating debris sizes generated from within the zone of influence (ZOI). Testing used 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 loss-of-coolant accident (LOCA) jet. The test lasted 60 seconds. A 15-degree waterjet tip and angles of attack directing the waterjet normal to the surface and at 45 degrees to the surface were used from multiples distances. Surface temperatures were measured during testing and ranged from 80 °F to 150 °F. 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 inorganic zinc 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 few, if any, other test data available which attempt to define the impingement effects of a LOCA jet on coatings. The guidance report (GR) identifies this lack of data. The test protocols used in the past and as currently specified in American Society for Testing and Materials D3911 to design-basis accident (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’s position 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 were offered combining both the effects of mechanical insult and elevated temperatures (LOCA initial conditions), nor were 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. Testing should use coatings that can be correlated to qualified plant coatings, includingcoating aged 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”

Appendix B to the GR provides a simplified example of a method for determining the amount of latent debris on containment surfaces. Appendix B does not contain new or unique information and is not totally consistent with Section 3.5 of the GR, which contains the detailed guidance for evaluating Latent Debris. 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 computational fluid dynamics (CFD) methods.

The staff agrees with the GR statement that the network method does not attempt to analyze the movement of debris during filling operations. The staff recommends CFD simulation to characterize the hydraulic flow conditions of the sump pool formation needed to estimate debris transport due to sheeting flow across the sump floor, which has been observed to effectively transport debris.

The staff agrees with the GR statement that the network method does not calculate turbulent effects or vertical velocities. The GR offers discussion of vertical and horizontal turbulent velocities to support debris transport estimates. The GR also offers a cone-of-influence model emanating from a point source for estimating transport velocities from the point source. The staff recommends CFD simulations to characterize sump pool turbulence, which affects debris suspension and potential debris erosion, and for estimating velocities from the various water entrance locations. Turbulence is a general term representing turbulent velocity fluctuations that are not adequately represented by bulk flow velocities as described in the GR. Typical CFD codes have models to describe turbulence that address localized complex flow interactions, e.g., inertial effects. The cone-of-influence model assumes uniform spreading of the flow from a source point, which does not represent the complex flows illustrated in GR Figure 4-4.

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 two orders of magnitude larger than the flow difference between the two methods. The staff does not consider this approach 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 that discrepancies can also exist with respect to flow direction.

In addition, 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 encapsulating 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 does the document explicitly define the method. It does discuss friction factors, choosing a velocity for the Reynolds number assumed for the flow, and iterating to arrive at the correct velocity, but it does not provide any equations or methodology to follow. The appendix should include these conditions and cite appropriate references for both the methodology and previously published applications to this type of flow problem.

Other issues the staff identified in Appendix C include the following:

- Figure 4-4 shows the nodal sections, but no description of how the CFD flow rates were calculated.
- 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.
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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 American National Standards Institute/American Nuclear Society (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 safety evaluation report (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.

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.)