Appendix IV

Debris Transport Comparison

The Nuclear Energy Institute (NEI) guidance report (GR) baseline debris transport recommendations contain both conservative and nonconservative assumptions which were used to simplify the transport evaluation. To assess the effect of the nonconservative assumptions used in the baseline model, the baseline model was applied to the pressurized-water reactor (PWR) volunteer plant, whereby those baseline results could be compared with the detailed debris transport evaluation performed for the volunteer plant. The comparison supported the review and acceptance of the NEI baseline evaluation methodology by illustrating that the baseline predicted conservative debris transport results for the volunteer plant. Insights gained from this comparison regarding debris entrapment in the inactive pool and the transport of large debris support staff-imposed limitations on the acceptance of the baseline methodology.

Because the volunteer plant contains substantial quantities of both fibrous and reflective metal insulation (RMI), the baseline model was applied to both types of insulation debris. Appendix III documents the detailed sump pool debris transport analyses that were performed for the volunteer plant containment. Appendix VI documents the detailed blowdown and washdown debris transport analyses that were performed for the volunteer plant containment. Appendix IV compares the GR baseline analysis to the detailed analyses for the volunteer plant as documented in Appendices III and VI.

The comparison is based on the GR baseline two-group debris-size distributions (i.e., small fines and large-piece debris). The detailed analyses used a four-group distribution of fine debris, small pieces, large pieces, and intact pieces. The detailed four-group results were reduced to two groups by combining the fine and small-piece debris into the NEI small fine debris group and combining the large-piece and the intact-piece groups into the NEI large-piece group. This approach enabled a direct comparison.

The size distributions for both the NEI baseline results and the detailed analyses results were based on destruction pressures of 10 psi for the fibrous debris and 4 psi for the RMI debris. Appendix II documents the research used for the respective size distributions. The radii of the fibrous and RMI zone of influence (ZOI) for these pressures are 11.9D and 21.6D, where D is the diameter of the pipe that breaks (see Appendix I). In applying the baseline model to the volunteer plant, the comparison assumed that the containment was highly compartmentalized.

Table IV-1 and Table IV-2 compared the baseline and detailed analyses results by debris size for fibrous and RMI debris, respectively. Table IV-3 compares the overall transport fractions, which combine the small fine debris and the large-piece debris to obtain the total estimated screen accumulation. The respective debris-size distributions shown in Table IV-1 were used to calculate the overall transport results shown in Table IV-3. Note that the transport fractions in Table IV-1 and Table IV-2 pertain only to the respective size categories.

Table IV-1. Baseline Comparison with Detailed Volunteer-Plant Fibrous Transport Results

Transport Phase	Debris Transport Fractions			
	Small Fine Debris		Large-Piece Debris	
	Baseline	Detailed	Baseline	Detailed
Fraction of Debris Generated	0.60	0.53	0.40	0.47
Fraction of Debris Generated that Transports into Upward Levels by Blowdown	0.25	0.92	0	0.63
Fraction of Debris Generated that Transports Directly to Sump Pool Floor by Blowdown	0.75	0.08	1	0.37
Fraction of Debris Generated that Blows into Upper Levels and Washes Down into Sump Pool	1	0.71	0	0.21
Fraction of Debris Generated that Enters Sump Pool	1	0.73	1	0.50
Fraction of Debris Generated that Enters Inactive Sump Pool	0.14	0.03	N/A	0.07
Fraction of Debris Generated that Enters Active Sump Pool	0.86	0.70	1	0.43
Fraction of Debris that Enters Sump Pool that Transports to Sump Screens	1	0.98	0	0.76
Fraction of Debris Generated that Accumulates on Sump Screens	0.86	0.69	0	0.33

Table IV-2. Baseline Comparison with Detailed Volunteer-Plant RMI Transport Results

Transport Phase	Debris Transport Fractions			
	Small Fine Debris		Large-Piece Debris	
	Baseline	Detailed	Baseline	Detailed
Fraction of Debris Generated	0.75	0.02	0.25	0.98
Fraction of Debris Generated that Transports into Upward Levels by Blowdown	0.25	0.44	0	0.22
Fraction of Debris Generated that Transports Directly to Sump Pool Floor by Blowdown	0.75	0.56	1	0.78
Fraction of Debris Generated that Blows into Upper Levels and Washes Down into Sump Pool	0	0.55	0	0.32
Fraction of Debris Generated that Enters Sump Pool	0.75	0.80	1	0.85
Fraction of Debris Generated that Enters Inactive Pools	0.11	0.15	N/A	0
Fraction of Debris Generated that Enters Active Sump Pool	0.64	0.65	1	0.85
Fraction of Debris that Enters Sump Pool that Transports to Sump Screens	1	0.59	0	0.49
Fraction of Debris Generated that Accumulates on Sump Screens	0.64	0.39	0	0.42

Table IV-3. Comparison of Overall Baseline and Detailed Analysis Transport Fractions

Debris Type	Fraction of ZOI Insulation Debris Accumulated on Sump Screens	
	Baseline	Detailed
Fibrous Debris	0.52	0.52
RMI Debris	0.48	0.42

Substantial uncertainty exists in various aspects of the volunteer plant analyses that affect this comparison, including the following:

- uncertainties in determining the debris generation size distributions
- uncertainties in specifying various aspects of the blowdown and washdown debris transport and deposition processes
- uncertainties in estimating the locations where debris enters the sump pool and when the debris enters with respect to the formation of the pool
- uncertainties in estimating the quantities of debris transported into the inactive pool regions
- uncertainties in estimating debris transport within an established sump pool

The following four points apply to the comparison of the fibrous debris transport:

(1) The baseline recommendation for the debris-size distribution assumed 60 percent for the small fine debris, which is higher than the 53 percent determined from the integration of the air-jet debris generation data and used for the detailed analysis (Appendix II).

(2) The detailed analysis predicted that most of the smaller fibrous debris would be deposited in the upper levels during blowdown debris transport, rather than directly on the sump floor as proposed in the baseline model. Because the transport of this upper level debris to the sump pool by containment spray drainage (washdown) is delayed by a variable and indeterminate period of time, it must be postulated that relatively little of the debris reaches the sump floor in time to be entrained in the water flow filling the inactive pools (primarily the reactor cavity in the volunteer plant), which occurs relatively early in the accident sequence (less than 12 minutes). The detailed analyses predicted that, at the end of the blowdown/washdown transport, a significantly less amount of debris, compared to the baseline analyses, would enter the active sump pool.

(3) The baseline model sump pool transport onto the sump screen was 100 percent of debris entering the sump pool for small fine debris and 0 percent for large-piece debris. The baseline model predicted more small fine debris accumulation on the sump screens than did the detailed analyses. However, the detailed analyses predicted substantial accumulation of large-piece debris on the screens, whereas the baseline predicted none.

(4) The baseline and detailed analyses both predicted that approximately 52 percent of the fibrous debris generated within the ZOI would accumulate on the sump screens.

The following four points apply to the comparison of the RMI debris transport:

(1) The baseline recommends using more small fine RMI debris (75 percent of debris generated) than that was determined from the integration of the air-jet debris generation data and used for the detailed analysis (2 percent) (Appendix II). The primary reason for the large difference is the large increase in ZOI

volume predicted by the American National Standards Institute (ANSI)/American Nuclear Society (ANS)-58.2-1988 standard. When that standard is applied to jet impingement pressures as low as 4 psi, only a small amount of small fine debris is generated over much of the ZOI volume. Most of the ZOI debris is large-piece debris.

(2) The detailed analyses predicted lesser quantities of small fine RMI debris than fibrous debris would deposit in the upper levels of the containment (44 percent versus 92 percent of debris generated), although it was substantially more than the baseline model recommendation of 25 percent. A primary reason for this result was that so little blowdown debris transport data exist for RMI debris, and thus the blowdown analyses conservatively assumed a large fraction of debris depositing directly on the sump floor. Both the detailed and baseline analyses predicted that approximately the same amount of debris would enter the active sump pool at the end of the blowdown/washdown transport (65 percent versus 64 percent of debris generated).

(3) The baseline model sump pool transport was 100 percent for small fines and 0 percent for large-piece debris. The baseline model predicted more small fine debris accumulation on the sump screens than did the detailed analyses (64 percent versus 39 percent of debris generated). However, the detailed analyses predicted substantial accumulation of large-piece debris on the screens (42 percent of debris generated), whereas the baseline predicted none.

(4) The baseline method predicted slightly more RMI debris accumulation on the sump screens than did the detailed analyses (i.e., 48 percent as compared with 42 percent of the debris generated).

In conclusion, the application of the baseline methodology to the volunteer plant predicted approximately the same accumulation of fibrous debris and conservatively more RMI on the sump screen than did the detailed transport analyses. Although this comparison does not explicitly demonstrate that the baseline methodology is conservative relative to fibrous debris transport in the detailed volunteer plant evaluation, detail-specific conservatisms built into various aspects of the blowdown/washdown and pool debris transport analyses still support the overall conclusion that the baseline methodology is conservative with respect to its application to the volunteer plant. Even though the baseline and detailed evaluation arrived at the same fractions for sump screen debris accumulation, the intermediate steps disagreed. Because of the diversity among the PWR containment designs, this analysis does not conclusively demonstrate that the baseline methodology will be conservative for debris transport in all of the PWRs. In addition, the detailed volunteer plant analyses contained substantial sources of uncertainty.

Insights gained from this comparison regarding debris entrapment in the inactive pool and the transport of large debris support staff-imposed limitations on the acceptance of the baseline methodology to prevent an outlier plant from demonstrating adequate net positive suction head (NPSH) margin using the baseline methodology where adequate NPSH margin might not exist in reality. The limitations resulted from the following two concerns that should be addressed before accepting baseline method results for plant-specific analyses.

First, if a plant baseline analysis estimates a relatively large fraction of the debris trapped in the inactive pools, as could be the case with a large reactor cavity volume and a shallow sump pool, then the baseline inactive pool fraction should be more limited than the current baseline model. Note that the detailed analyses reported herein predicted that only approximately 3 percent of the small fibrous debris generated would trap in the inactive pool, as compared with 14 percent that was predicted using the baseline model. Based on this comparison, the staff limits the fraction of debris assumed to be trapped in the inactive pool to no more than approximately 15 percent, unless a higher fraction is adequately supported by analyses or experimental data. The 15-percent upper limit on the debris transport into the inactive pools does not make the inactive pool model conservative but serves to ensure that the baseline methodology, as a package, is conservative. If analytical refinements are made for debris transport, then the debris transport into the inactive pools must be evaluated in a conservative manner using models that describe the actual transport processes but not the model described in the baseline guidance.

Second, if the characteristic sump pool transport velocities are relatively high, such that large transport fractions for large debris are indicated, then the baseline method should be modified to include the transport of large debris. In the volunteer plant, for example, the detailed analysis predicted that approximately 98 percent of the RMI debris generated in the ZOI (based on a destruction pressure of 4 psi) were large pieces greater than 6 in. in size, of which about 42 percent would be transported to the sump screens. The characteristic transport velocities must be compared with typical debris transport velocities to determine whether the baseline method should be modified to include the transport of large debris. Characteristic transport velocities can be sufficiently estimated using recirculation flow rates and nominal sump dimensions to determine if a potential exists that substantial portions of the large debris will transport. If substantial transport of large debris is reasonably possible and if such transport can alter the outcome of the sump performance evaluation, the licensees should evaluate large debris transport.

REFERENCES

(ANSI/ANS-58.2, 1988) American National Standard/American Nuclear Society: "Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture," ANSI/ANS-58.2-1988, October 1988.