BOILING WATER REACTOR (BWR) TECHNICAL ISSUE #7, "ZONE OF INFLUENCE (ZOI) ADJUSTMENT FOR AIR JET TESTING (AJT)"

The BWR Owners' Group (BWROG) issued report NEDO-32686-A, "Utility Resolution Guidance (URG) for Emergency Core Cooling System (ECCS) Suction Strainer Blockage" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML092530449) to provide operators guidance for responding to NRC Bulletin 96-03, "Potential Plugging of [ECCS] Strainers by Debris." The URG provides guidance for performing plant-specific analysis consistent with Regulatory Guide (RG) 1.82, Revision 2, "Water Sources for Long-Term Cooling Following a Loss-of-Coolant Accident." As part of this guidance, the URG provides recommended destruction pressures for various types of insulation. Destruction pressures were determined using air jet testing. Given the information available at the time, the NRC considered the URG values to be adequate damage pressures, with some modifications, as documented in the URG Safety Evaluation (SE) (ADAMS Accession No. ML092530482).

The Nuclear Energy Institute (NEI) developed a Guidance Report (GR), NEI 04-07, "Pressurized Water Reactor (PWR) Sump Performance Evaluation Methodology" (ADAMS Accession No's. ML050550138 and ML050550156) to address similar ECCS suction strainer (sump strainer) blockage issues for PWRs. The NRC reviewed the differences in methodologies used to evaluate BWR and PWR ECCS recirculation strainer plugging. During review of the PWR GR, the NRC staff questioned whether the insulation destruction pressures from the GR (which were based on URG pressures) were valid for application to PWRs. Because the NRC staff reviewers of NEI 04-07 were concerned that damage to material could occur at pressures lower than those approved in the BWR URG, the destruction pressures for some materials were reduced for PWRs. As a result of knowledge gained during the resolution of the sump strainer issues for PWRs, the NRC staff has considered whether a reduction in insulation damage pressure should be applied to BWRs in order to avoid non-conservative treatment of debris generation.

The BWROG and NRC staff met several times to discuss the technical issues (see ADAMS Accession No's. ML092010500, ML102360065, and ML103010398 for meeting summaries). The BRWOG presented a draft paper on the application of a reduction in insulation destruction pressures for BWRs (ADAMS Accession Number ML103000334). The issue was discussed again in a November 17, 2010 meeting (ADAMS Accession Number ML110470367). As a result of the meeting, the BWROG submitted a letter, BWROG-11017 dated April 7, 2011, "BWROG ECCS Suction Strainers Action Item No. 2 Status" (ADAMS Accession No. ML110980602) that presented the BWROG position. The NRC staff has reviewed the documents associated with this issue and has concluded for almost all insulation types that a reduction in destruction pressure is not required to ensure adequate debris generation evaluations.

When the NRC staff wrote the URG safety evaluation they determined that some of the damage pressures should be reduced below those recommended by the BWROG. Using the experimental data from the URG testing and the NPARC computer code, the NRC staff determined the damage pressure of 190 psi for NUKON® and DPSC MIRROR® insulation with Sure-Hold bands should be reduced to 150 psi. The NRC staff also determined that the calcium silicate with jacketing destruction pressure should be reduced from 160 psi to 150 psi. This is reflected in Table B-1 of Appendix B of the safety evaluation and in the first column of the table below. These values are not reflected in Table 2 of the URG. Below is a table comparing the

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insulation ZOI radius at various destruction pressures for the URG SE values, the URG SE values with a 40 percent reduction, the NEI 04-07 values for PWRs, and values for BWRs using the reduced destruction pressure and BWR thermal-hydraulic conditions in the approved PWR model.

Insulation	URG SE		60% URG SE		NEI 04-07 SE		NEI 04-07 – BWR	
	PSI	ZOI radius	PSI	ZOI radius *	PSI	ZOI radius**	PSI	ZOI Radius@
Darchem DARMET®	190	6.1	114	7.1	114	2.0	114	1.2
Transco RMI	190	6.1	114	7'1	114	2.0	114	1.2
Jacketed NUKON® w/ Sure-Hold bands	150	6.6	90	7.4	90	2.4	90	1.5
DPSC MIRROR® w/ Sure-Hold bands	150	6.6	90	7.4	90	2.4	90	1.5
Calcium Silicate w/jacketing	150	6.6	90	7.4	24	5.45	24	4.0
K-wool	40	7.9	24	8.8	24	5.4	24	4.0
Temp-mat™	17	9.2	10.2	10.4	10.2	11.7	10.2	7.5
Knaupf®	10	10.4	6	11.4	6	17.0	6	11.5
Jacketed NUKON®	10	10.4	6	11.4	6	17.0	6	11.5
Unjacketed NUKON®	10	10.4	6	11.4	6	17.0	6	11.5
Koolphen-K®	6	11.4	3.6	12.1	3.6	22.9	3.6	14
DPSC MIRROR® w/ standard bands	4	11.9	2.4	12.6	2.4	28.6	2.4	18
Min-K®	4	11.9	2.4	12.6	2.4	28.6	2.4	18

*Values based on linear interpolation of URG methodology

@Values estimated from ANSI jet model curve based on average of 1040 psia and 550/420 °F initial conditions, estimated from NRC SE on NEI 04-07, Appendix I of the SE, Figure I-18

**PWR ZOI based on 2250 psia, 540 °F initial conditions

With the exception of materials with destruction pressures below 6 PSID, the radius of the ZOI calculated for each type of insulation using the URG method with a reduced destruction pressure is essentially the same or larger than a ZOI calculated for BWR conditions using the PWR approved model. The two shaded columns above compare the ZOI values for these conditions. This shows that the BWR model is at least as conservative as the PWR model for destruction pressures equal to or greater than 6 psi when appropriate thermal-hydraulic conditions are used as inputs. Therefore, the insulation types with destruction pressures less than 6 psig should be evaluated to determine whether a larger ZOI is appropriate for BWR debris generation evaluations. These materials are Koolphen-K®, DPSC MIRROR® w/ standard bands, and Min-K®. Each of these insulation types is discussed below.

The transportable debris produced by MIRROR® insulation at the low destruction pressure has not proved to be problematic with respect to strainer head loss for PWRs. Guidance for BWRs required that the head loss from reflective metal insulation (RMI) be added to the head loss from other debris types. During research to resolve the PWR strainer issue, testing that combined RMI and other debris types did not find that head losses were significantly increased by the inclusion of RMI in the debris bed. This research also found that it was unlikely that RMI head loss would contribute significantly to strainer head losses. Except for unique cases, PWRs are not required to evaluate the head loss effects of RMI in a debris bed. Based on this research, the NRC staff concluded that it is unlikely that the total head loss from a debris bed would be equal to the RMI head loss plus the non-RMI debris head loss or that the additional RMI debris that may occur from a larger ZOI would increase RMI head losses significantly. Therefore, the NRC staff concluded that it is not necessary to require BWR licensees to recalculate the amount of RMI debris that may be caused if the destruction pressure were reduced.

Reducing the destruction pressure for rigid phenolic insulations (Koolphen K®) and for micorporous insulations (Min-K®, Microtherm®) to those pressures used for PWR evaluations increases the URG ZOI radius by roughly 5 percent. Use of the PWR model for BWR conditions results in larger ZOIs than those calculated by the BWR model with both the original and reduced destruction pressures for these insulations.

Koolphen K® is installed on cooling water pipes and is rated for maximum temperatures of about 250 ^{o}F. Koolphen K® is a closed cell insulation, is much less dense than water, and will float. In evaluating floatable materials for PWRs, the NRC staff determined that they would be unlikely to adversely affect strainer head loss because significant amounts would not reach the strainer surface. The NRC staff concluded that although a larger ZOI may be justified for Koolphen K® its transport properties would limit the amount of debris that could reach the strainer. Because of the reduced transport, existing ZOIs are adequate, and re-evaluating the ZOI for Koolphen K® to account for a reduced destruction pressure is not required.

Microporous debris has been shown, through industry testing for PWR strainers, to have the ability to result in significant head losses. The BWROG URG recommends a 4-psi destruction pressure for Min-K® insulation. This is the lowest destruction pressure assigned to any material by that document. At the time that the NRC staff evaluated the URG, the NRC staff considered this an adequate damage pressure as documented in the URG Safety Evaluation. However, the head loss characteristics of microporous debris were not understood at that time. The URG stated goal of the insulation destruction testing was to “determine the stagnation pressure at which specific insulation materials in use at commercial U.S. BWRs will not undergo damage when subjected to air jet pressures typical of an operating BWR.” However, only one air jet test was performed on Min-K® insulation. The test was performed with a target stagnation pressure of about 4 psi. In the test documentation it was stated that less than 35 percent of the insulation was recoverable indicating that the majority of the insulation was reduced to fine easily transportable debris. Contrary to the URG stated goal, the single test performed did not establish a minimum pressure that will not damage Min-K®. One mitigating factor for the single destruction test of Min-K® is that it was not jacketed. It is unlikely that significant damage would occur to a jacketing system at a destruction pressure of 4 psi.

The NRC staff evaluated air jet test results to determine the extent of protection provided by a jacketing system over the underlying insulation. With respect to the test of jacketed calcium silicate at 10 psi, there was no damage identified to this insulation system and the jacket remained intact. A test of jacketed Nukon® at 12 psi resulted in significant damage to the insulation including the jacket. The underlying insulation also has an influence on the ability of the jacketed system to resist damage. The increased resistance to damage would also depend on the jacketing system design and physical condition of the jacketing. Because the pressure that is of concern is well below 10 psig, the NRC staff has confidence that jacketing applied to microporous insulation would provide significant protection at 4 psig and that jacketed Min-K® would have a higher destruction pressure than unjacketed Min-K® at these low pressures. Therefore, the NRC staff concluded that it is not likely for jacketed microporous insulation to become significantly damaged at pressures lower than 4 psi. Based on the above observations the NRC staff concluded that for jacketed microporous insulation systems, in good condition, 4 psi is an acceptable destruction pressure. Microporous insulation systems that are not jacketed should be considered to be damaged at any pressure above 2.4 psi. This pressure is equal to a ZOI of about 12.6D as calculated using the BWR methodology.

However, the NRC staff concluded that a change to the URG to increase the ZOI size is not required as long as BWRs implement guidance to evaluate the potential for directed jets to generate problematic debris (Issue #12). Although the URG damage pressure for microporous insulation may not be bounding, the evaluation of problematic materials outside the spherical ZOI will identify any significant amounts of this type of insulation that could be damaged by a loss-of-coolant accident (LOCA) jet.

In this evaluation, the NRC staff compared the BWR and PWR methodologies with the understanding that each has its own set of conservatisms and assumptions that account for unknowns and tend to make the results conservative. Because of significant unknowns in this area, the degree of conservatism of each methodology is not known. The NRC staff concluded for all insulation types, except unjacketed microporous, that the BWR methodology provides conservatism on par with the PWR methodology. By looking for problematic debris sources outside the spherical ZOI, BWR licensees will discover microporous insulation that could become debris and affect their head loss evaluations.

The NRC staff agrees that Issue #7 can be closed contingent upon BWR licensees performing an adequate evaluation of the potential for problematic debris generation due to directed jets impacting materials outside of their URG/SE defined spherical ZOIs.