UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

October 18, 2012

Mr. R.W. Borchardt
Executive Director of Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: DRAFT SAFETY EVALUATION OF WCAP-16793-NP, REVISION 2, "EVALUATION OF LONG-TERM COOLING CONSIDERING PARTICULATE, FIBROUS AND CHEMICAL DEBRIS IN THE RECIRCULATING FLUID"

Dear Mr. Borchardt:

During the 598th meeting of the Advisory Committee on Reactors Safeguards (ACRS), October 4-5, 2012, we reviewed the staff's draft safety evaluation of WCAP-16793-NP, Revision 2, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," and its use towards closure of Generic Safety Issue (GSI)-191, "Assessment of Debris Accumulation on PWR Sump Performance". Our Subcommittee on Thermal-Hydraulics Phenomena reviewed the draft safety evaluation associated with WCAP-16793-NP, Revision 0, on March 19, 2008, and WCAP-16793-NP, Revision 2, on May 8-9, 2012. During these meetings we had the benefit of discussions with representatives of the NRC staff, and the Pressurized-Water Reactor (PWR) Owners Group. We also had the benefit of the documents referenced.

CONCLUSIONS AND RECOMMENDATIONS

1. The draft safety evaluation of WCAP-16793-NP, Revision 2, including the conditions and limitations specified therein should be finalized and issued to support closure of Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors."

2. We concur with the conclusions in the staff's draft safety evaluation that WCAP-16793-NP, Revision 2, can be used to evaluate the effects of in-vessel debris on long-term core cooling, and that 15 grams per assembly is an acceptable limit on fiber that bypasses the sump strainers provided the other conditions and limitations in the draft safety evaluation are met.

BACKGROUND

Generic Letter 2004-02 was issued in September 2004, as a result of the NRC's evaluation of GSI-191. Generic Letter 2004-02 requested PWR licensees to evaluate emergency core cooling system and containment spray system performance taking into account the adverse effects of debris following a loss-of-coolant accident (LOCA), including the potential to form blockages within reactor fuel assemblies.

The introduction of much larger sump strainers in all PWRs, and associated testing, helped resolve concerns regarding their performance following transition to the recirculation phase after a LOCA. The downstream effects of debris that bypasses the sump strainers also needed to be addressed. To this end, the PWR Owners Group developed and issued WCAP-16793-NP, Revision 0, as guidance for evaluating the in-vessel effects of debris and chemicals on long-term post-LOCA cooling.

In June 2007, the PWR Owners Group requested that NRC review WCAP-16793-NP, Revision 0, for generic application to PWRs. The scope of the WCAP included assessment of the effects of both in-vessel blockages that could be formed by debris that passed through the strainers and plate-out on fuel cladding.

The ACRS Subcommittee on Thermal-Hydraulic Phenomena held a meeting to discuss WCAP-16793-NP, Revision 0, in March 2008. As a result there were several staff requests for additional information which led the PWR Owners Group to expand their program, revise the WCAP, and request a second review. The expanded scope included limits on the amount of debris mass (particulate, fibrous, and chemical) that could bypass the sump strainer and enter the core without compromising long-term core cooling. Following additional staff requests for information and responses by the PWR Owners Group that included additional testing, the PWR Owners Group again revised the WCAP-16793-NP and requested a final NRC review of Revision 2. WCAP-16793-NP, Revision 2, specifies a revised limit on the amount of fibrous mass that can bypass the sump strainers while still maintaining acceptable long-term core cooling.

The staff has now issued a draft safety evaluation of WCAP-16793-NP, Revision 2, finding the guidance contained therein acceptable subject to several conditions. In Revision 2, the amount of fibrous mass that is allowed to bypass the sump strainer and enter the reactor core is identified as the most important variable. The staff evaluation found that taking into account the many uncertainties in the experimental conditions and measurements, up to 15 grams of fiber per fuel assembly could be carried to the core inlet while still not compromising long-term core cooling. Licensees will have to submit additional analyses and information to justify any fiber amount that exceeds this limit.

DISCUSSION

Licensees will use WCAP-16793-NP, Revision 2, to demonstrate with “reasonable assurance,” that in-vessel debris effects will not compromise long-term core cooling over an extended period of time following a LOCA. Debris that bypasses the sump screens can potentially impair cooling within the reactor core both by forming a debris layer that blocks flow through the fuel assemblies, and by collecting on fuel surfaces and reducing heat transfer from the fuel. A hot leg break is the limiting condition since the greatest amount of water will recirculate through the reactor vessel, thus offering the opportunity for the largest amount of debris to be captured in the core.

Two acceptance criteria were proposed to demonstrate that long-term core cooling will be maintained following a LOCA: (1) that the LOCA post-quench fuel clad temperature does not exceed 800^{o} F for 30 days, and (2) that the thickness of the cladding oxide and fuel deposits does not exceed 0.050 inch in any fuel region.

A series of prototypical fuel assembly tests using a common protocol were performed by the PWR Owners Group at two facilities: the Westinghouse Science and Technology Center in Churchill, Pennsylvania and the Continuum Dynamics, Inc. facility in Ewing, New Jersey, for Westinghouse and AREVA fuel designs, respectively. One-third height fuel assemblies with representative inlet bottom nozzles and upper grid spacers were used. Sixty-seven tests were performed at the two facilities including cross-tests to ensure consistency. The test program was intended to demonstrate generically for all operating PWRs that the acceptance criteria would be met.

In most tests a constant flow was maintained. The measured pressure drop or head loss across the fuel assembly was compared to that available in the reactor system under break conditions to determine whether adequate pressure (or flow) was available to ensure long-term core cooling would not be compromised once a debris bed had formed.

For most tests, the debris mix was simulated with Nukon® fiber (approximately 7 microns in diameter), silicon carbide particulates (silicon carbide of 10 microns nominal diameter), and aluminum oxyhydroxide as the chemical surrogate. The test protocol varied the amount and type of debris that entered the loop over a broad range of values. Fiber amounts ranged from 15 to 200 grams, particulates from 15 to 13,154 grams, and chemicals from 16.5 to 5900 grams. Most of the fibers were short (< 500 microns); the distribution of lengths was based on the observed distributions of bypass fiber lengths in sump strainer tests.

The flow rate influenced where the debris beds formed within the fuel assembly. The beds tended to form higher up in the spacer grids at a higher flow rate, whereas at low flow, a debris bed tended to form around the inlet nozzle. The particle to fiber ratio also influenced the debris bed morphology. As the ratio approached 1.0, the bed was more affected by chemical addition which led to substantial increases in the pressure drop. Overall, the total amount of fiber was the most significant variable. Without a fiber bed, particulates and chemical precipitates would pass through the fuel assembly with little resistance.

Most of the tests were performed at room temperature based on the assumption that the higher viscosity at lower temperatures would conservatively increase the pressure across the debris bed. One test performed at a higher temperature, however, had the opposite effect (increase in pressure drop), while another test showed little effect. From these two tests it is still not certain that higher temperatures would improve the margin for core cooling, but in either case, pressure losses were found to be within an acceptable range.

The PWR Owners Group conducted tests over a wide range of conditions. Only the two tests performed with 15 grams of fiber per assembly gave acceptable pressure losses taking into account uncertainties. Differences in test results were observed between cross-tests performed at the Westinghouse and Continuum Dynamics facilities. These differences could not be fully reconciled and may be due to differences in water chemistry between the sites. Apparently, the tap water used in the AREVA fuel tests in Ewing, New Jersey, leads to significantly higher pressure losses in otherwise identical tests.

The acceptability of 15 grams per fuel assembly indicated in the PWR Owners Group tests is also supported by recent tests conducted for similar core fiber loadings and test conditions for some of the new PWR designs. Although uncertainties in the results remain, we concur with the staff's conclusion that in-vessel fiber loadings of 15 grams per fuel assembly, subject to the other limitations and conditions in their safety evaluation, will not compromise acceptable long-term core cooling.

In a September 20, 2012 letter to us, the PWR Owners Group has indicated that they consider the 15 grams per fuel assembly "to be a floor for fiber limits, as relaxation of the available conservatisms in favor of more prototypical conditions will yield higher fiber limits." The PWR Owners Group has recently instituted a comprehensive program to address such issues related to in-vessel debris effects and related boric acid precipitation. The program results will be documented in new topical reports and submitted for NRC review. The letter indicates that the PWR Owners Group will keep us apprised of interim program results and we look forward to our further interactions in this regard.

In addition to affecting the debris bed, chemical precipitates can also deposit on the fuel rods and adversely affect long-term core cooling by either restricting coolant flow through the core, or by impeding decay heat removal by insulating the rods and reducing heat transfer to the coolant. To address fuel clad deposition issues, the PWR Owners Group developed the LOCA deposition model (LOCADM) to predict chemical deposition on fuel rod cladding from debris and chemicals that could enter the core during the recirculation phase. Using typical sump chemical inputs, LOCADM predicts both the deposition thickness and cladding surface temperatures as a function of time at a number of core locations. The staff found LOCADM with the chemical effects source term method developed in WCAP-16530-NP-A, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," acceptable for determining cladding deposition thickness, and accepted the model for use by licensees to demonstrate compliance with the WCAP-16793-NP, Revision 2, acceptance bases of maximum cladding temperature of 800 °F and maximum cladding oxide and deposit thickness of 0.050 inches. We concur with the staff's assessment.

We commend the staff for their efforts toward resolving this complex issue and we look forward to future interactions.

Sincerely,

/RA/

J. Sam Armijo
Chairman

REFERENCES

1. U.S. Nuclear Regulatory Commission, Generic Letter 2004-02, “Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,” September 13, 2004, (ML042360586)

2. Advisory Committee on Reactor Safeguards report, to the Chairman, U.S. Nuclear Regulatory Commission, “Status of Resolution of Generic Safety Issue-191, ‘Assessment of Debris Accumulation on PWR Sump Performance,’” October 22, 2008 (ML082810710)

3. Advisory Committee on Reactor Safeguards report, to the Chairman, U.S. Nuclear Regulatory Commission, “Long-Term Core Cooling for the Westinghouse AP1000 Pressurized Water Reactor,” December 20, 2010 (ML103410348)

4. SECY 10-0113, “Closure Options for Generic Safety Issue-191, Assessment of Debris Accumulation on Pressurized Water Reactor Sump Performance,” August 26, 2010 (ML101820212)

5. Staff Requirements Memorandum SECY-10-0113, “Closure Options for Generic Safety Issue-191, Assessment of Debris Accumulation on Pressurized Water Reactor Sump Performance,” December 23, 2010 (ML103570354)

6. Andreychek, T. S., et al, WCAP-16793-NP, Revision 0, “Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid,” Westinghouse Electric Company, May 2007 (ML071580139)

7. Andreychek, T. S., et al, WCAP-16793-NP, Revision 2, “Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid,” Westinghouse Electric Company, October 2011 (ML11292A021)

8. Baier, S. L., et al, WCAP-17057-P, Revision 1, “GSI-191 Fuel Assembly Test Report for PWROG,” September 2011 ((ML11293A104, ML11293A095, ML11293A096, ML11293A099, ML11293A100, ML11293A101, ML11293A102) (proprietary), and ML11293A103 (non-proprietary))

9. Lane, A. E., et al, WCAP-16530-NP-A, “Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191,” March 2008 (ML081150379)

10. AREVA NP Inc., EIR 51-9170258-000, “GSI-191 FA Test Report for PWROG – Low Particulate-to-Fiber Ratio Tests,” October 2011 (ML11292A017)

11. U.S. Nuclear Regulatory Commission, "Draft Safety Evaluation by the Office of Nuclear Reactor Regulation Topical Report WCAP-16793-NP, Revision 2 'Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid,'" September 2012 (ML121020118)

12. PWR Owners Group letter to Advisory Committee on Reactor Safeguards, "GSI-191 In-Vessel Debris Program (PA-SEE-0312 Rev. 4 and PA-SEE-0872 Rev.0)," September 20, 2012 (ML122900033)

11. U.S. Nuclear Regulatory Commission, "Draft Safety Evaluation by the Office of Nuclear Reactor Regulation Topical Report WCAP-16793-NP, Revision 2 'Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid,'" September 2012 (ML121020118)

12. PWR Owners Group letter to Advisory Committee on Reactor Safeguards, "GSI-191 In-Vessel Debris Program (PA-SEE-0312 Rev. 4 and PA-SEE-0872 Rev.0)," September 20, 2012 (ML122900033)

Accession No: ML12290A654 **Publicly Available Y** **Sensitive N**
Viewing Rights: ☒ NRC Users or ☐ ACRS Only or ☐ See Restricted distribution

OFFICE	ACRS	SUNSI Review	ACRS	ACRS	ACRS
NAME	MBanks	MBanks	HGonzalez	EMHackett/HG	EMH for JSA/HG
DATE	10/18/12	10/18/12	10/18/12	10/18/12	10/18/12

OFFICIAL RECORD COPY

Letter to R.W. Borchardt, Executive Director for Operations, from J. Sam Armijo, ACRS Chairman dated October 18, 2012

SUBJECT: DRAFT SAFETY EVALUATION OF WCAP-16793-NP, REVISION 2, "EVALUATION OF LONG-TERM COOLING CONSIDERING PARTICULATE, FIBROUS AND CHEMICAL DEBRIS IN THE RECIRCULATING FLUID"

ML#12290A654

Distribution:
ACRS Staff
ACRS Members
L. Mike
A. Lewis
K. Remsburg
C. Jaegers
R. Boyer
M. Orr
RidsSECYMailCenter
RidsEDOMailCenter
RidsNMSSOD
RidsNSIROD
RidsFSMEOD
RidsRESOD
RidsOIGMailCenter
RidsOGCMailCenter
RidsOCAAMailCenter
RidsOCAMailCenter
RidsNRRPMAAdamsResource
RidsNROOD
RidsOPAMail
RidsRGN1MailCenter
RidsRGN2MailCenter
RidsRGN3MailCenter
RidsRGN4MailCenter