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

September 22, 2015

The Honorable Stephen G. Burns
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: DRAFT REGULATORY BASIS FOR CONTAINMENT PROTECTION AND RELEASE REDUCTION FOR MARK I AND MARK II BOILING WATER REACTORS

Dear Chairman Burns:

During the 627th meeting of the Advisory Committee on Reactor Safeguards (ACRS), September 9-12, 2015, we reviewed SECY-15-0085, "Evaluation of the Containment Protection and Release Reduction for Mark I and Mark II Boiling Water Reactors Rulemaking Activities (10 CFR PART 50) (RIN-3150-AJ26)," dated June 18, 2015, and the staff document, "Draft Regulatory Basis for Containment Protection and Release Reduction for Mark I and Mark II Boiling Water Reactors (10 CFR Part 50)," dated May 2015. Our joint Subcommittees on Fukushima and Reliability and PRA also reviewed this matter during meetings on August 22 and November 19, 2014, and July 7 and August 18, 2015. During these meetings, we had the benefit of discussions with the NRC staff, representatives of the industry, and the public. We also had the benefit of the documents referenced.

CONCLUSIONS AND RECOMMENDATION

1. Severe accident water addition and severe accident water management systems can substantially mitigate radionuclide releases in the event of a severe accident. The effectiveness of this mitigation depends on proper implementation of design, operations, logistics, procedures, and training.

2. The staff should ensure that the Order EA-13-109 commitments related to severe accident water addition and severe accident water management are fulfilled and maintained by the licensees.

3. We agree with the staff's conclusion that the use of an engineered filtration containment venting system for boiling water reactors with Mark I and Mark II containments does not meet the threshold for a substantial safety enhancement.

BACKGROUND

As part of its response to the lessons learned from the Fukushima accident, the staff issued Order EA-12-050 on March 12, 2012, requiring all U.S. nuclear power plants with boiling water reactor (BWR) Mark I and Mark II containment designs to install reliable hardened vents. On November 26, 2012, the staff issued SECY-12-0157, in which they identified four options for containment venting system requirements for these plants and provided an evaluation considering various quantitative analyses and qualitative factors related to those options. The staff recommended the Commission approve Option 3 to require the installation of an engineered filtration vent system. We reviewed the draft SECY paper and issued our conclusions and recommendations in our November 8, 2012 letter.

In the staff requirements memorandum (SRM) to SECY-12-0157, dated March 19, 2013, the Commission directed the staff to: (1) issue a modification to Order EA-12-050 to require a containment venting system designed and installed to remain functional during severe accident conditions, and (2) develop technical bases and rulemaking for filtering strategies with drywell venting and severe accident management for BWR Mark I and Mark II containments.

In June 2013, Order EA-12-050 was rescinded and replaced with a new order, EA-13-109. The staff issued interim staff guidance (ISG) in two phases for the implementation of the new Order. We reviewed both phases. For the Phase 1 ISG, we issued our letter on October 18, 2013. For the Phase 2 ISG, we issued our letter on April 30, 2015.

In response to the Commission SRM to develop the technical basis and rulemaking for filtering strategies, the staff prepared the containment protection and release reduction (CPRR) regulatory basis document, SECY-15-0085. The draft CPRR regulatory basis describes the detailed analysis that was performed to determine the safety margin improvements that can be achieved by (1) implementing Order EA-13-109 and (2) adding engineered filtration systems.

On August 19, 2015, the Commission issued the SRM for SECY-15-0085. The Commission approved Alternative 1, implementation of the existing Order EA-13-109 without additional regulatory actions.

DISCUSSION

The purpose of this letter is to provide our evaluation of the work performed by the staff in examining the CPRR technical issues and alternatives. We review the safety margin improvements projected for the implementation of Order EA-13-109. Finally, we present our views pertaining to venting filtration systems.

Actions Taken Toward Implementation of Order EA-13-109

To assure a robust and effective response to the hardened vent Order EA-13-109, the staff developed a comprehensive program to evaluate containment venting strategies prior to and during a severe accident. The industry has demonstrated through analyses, and the staff has

validated, that water addition is a necessary part of the severe accident response in BWRs with Mark I and Mark II containments. The evaluations demonstrated that without water addition, the temperature in the drywell region would exceed that required for successful operation of a drywell venting system. This significant finding changed the course of the severe accident response strategy. Severe accident water addition (SAWA) can control the drywell temperatures, allow the wetwell venting system to better control pressure and protect the containment, and reduce release of radioactive materials.

The addition of severe accident water management (SAWM) strategies enables the continued use of the wetwell venting system to respond to the accident without the need for a drywell vent. The industry documented and justified these strategies in NEI-13-02. We reviewed this guidance, as well as the staff's review and approval of it, and found the strategies acceptable, as described in our April 30, 2015 letter.

The affected licensees are implementing the Order through a plant-specific overall integrated plan (OIP) issued in two phases. The Phase 1 (wetwell vent) plans were delivered to the Commission by June 30, 2014. By December 31, 2015, all licensees will submit an updated OIP including a description of how compliance with the Phase 2 (drywell vent or venting strategies) requirements will be achieved.

Analyses and Conclusions for the Containment Protection and Release Reduction Regulatory Basis

In support of their CPRR draft regulatory basis document, the staff performed technical analyses to examine capability and performance of venting and filtration systems. These analyses focus primarily on severe accident sequences that lead to plant conditions similar to those experienced at Fukushima, specifically an extended loss of all alternating current power (ELAP). The major contributor to these plant conditions is a seismic event, coupled with other external or internal events also specific to the site. The frequency of such events was determined to be extremely low through a detailed examination of causal factors, including the seismic events. The evaluation considered the likelihood of ELAP occurrence for each BWR Mark I and Mark II site and then assigned a conservative likelihood for the subsequent risk evaluation.

This detailed approach developed a core damage frequency from an ELAP event lower than that estimated for the analyses performed in SECY-12-0157. The current analysis approach is superior to the work that supported the conclusions in SECY-12-0157. In particular, we find improvement in major assumptions and analysis techniques, and in the interpretation of results. These include the delineation of accident sequences, system modeling, and analyses using the MELCOR and MACCS codes.

The staff has developed and presented the analysis results in a variety of ways to demonstrate the safety improvement associated with each of the proposed alternatives. Zero early fatalities were calculated in all cases using the MACCS code. With respect to the evaluations of

individual latent cancer fatality (ILCF) risk per reactor year, we find the display of the parametric uncertainty analyses results compelling. Having developed point-estimate risk evaluation results, the staff performed a parametric Monte Carlo uncertainty analysis considering uncertainty in specific parameters: seismic hazard curves, seismic fragility curves, random equipment failures, operator actions, and consequences.

The results are displayed in SECY-15-0085 as Figure 3-3, which depicts the ILCF risk values with uncertainty ranges for hardened vent operation, SAWA and SAWM, and filtration systems under a number of accident scenarios. These may be compared with the high-level conservative estimate of the risk, which was developed by multiplying the worst-case ELAP likelihood across the fleet by the worst consequence result derived from any of the analyses. A scenario with no water addition that artificially assumes successful performance of a drywell venting system regardless of operating conditions has a 95th percentile ILCF risk of $7x10^{9}$/reactor-year. This is a factor of 10 below the staff's high-level conservative estimate described above. Because of the high drywell temperatures that would develop during a severe accident without water addition, the staff noted that this scenario is not practically achievable. The realistically achievable cases for implementation of the Order incorporate water addition, which alone reduces risk below the values evaluated for the artificial scenario. When water addition is supplemented with an engineered filtration system, the risk is only marginally reduced.

Based on these results, the staff has concluded that the design and installation of an engineered filtration system for BWRs with Mark I and Mark II containments does not meet the threshold for a substantial safety enhancement. We agree with the staff's interpretations of these results and their conclusions.

Furthermore, the staff has performed additional sensitivity analyses in their MELCOR and MACCS evaluations to examine key assumptions in the modeling and input to enhance their confidence in the quantitative analyses and sharpen their understanding of these conclusions. Together, these provide clear documentation of the similarities and differences among options in this evaluation of the CPRR strategies. The documentation also demonstrates why the results and conclusions from this improved evaluation differ from those obtained using the SECY-12-0157 analysis performed three years ago.

Sensitivity of the calculated risk to evacuation assumptions has been evaluated by the staff for the realistic scenario including water addition. The sensitivity study was performed for a conservative case in which the severe accident occurs rapidly because backup water supply systems are assumed to fail at the outset of the event. For this case, the evacuation was completed just prior to the accident release. The sensitivity was examined by increasing the time to complete the evacuation, including a case in which no evacuation (sheltering only) is assumed. These results show that evacuation times can have an influence on the ILCF risk, but that it is not significant when considered in the context of the extremely low ILCF risks.

The industry analyses were performed by the Electric Power Research Institute using the MAAP severe accident analysis code. The results are very similar to those reported by the staff. They show water addition provides an important safety benefit by cooling the core debris and

improving venting capability from the wetwell or drywell airspace to protect the containment and reduce radionuclide releases. This similarity in results is significant because the conceptual approach in the MAAP code for modeling severe accident phenomena is different than that in the MELCOR code. These codes were developed and benchmarked under separate programs and by separate teams over several decades. The industry is using their analysis to evaluate the effectiveness of SAWA and SAWM and to examine the best location for water addition. The specific plans for water addition and water management system configurations and procedural details are expected to be provided in the licensees' OIP submittals by December 31, 2015.

Capabilities of Radionuclide Release Reduction by Engineered Filtration Systems

A common expectation is that the installation and operation of an engineered filtration system will prevent or reduce the release of significant amounts of radioactive materials in most severe accidents. There are several performance characteristics of external filter systems that should be considered in a comprehensive analysis of their capabilities, benefits, and limitations. We discuss these here to provide additional perspective for any future applications for which detailed filter system evaluations are required.

The key findings from the staff and industry analyses, which affect the capability of any internal or external venting filtration system for BWRs with Mark I and Mark II containments include:

- Without water addition under severe core melt accident conditions, the drywell region temperatures will rise rapidly to such extreme levels that successful venting or filtration system operation via a drywell venting system would be unlikely.

- Over-temperature, over-pressure, or liner melt-through that become possible without water addition create containment leak paths, which will bypass any filter system and reduce the mitigation it provides.

- Suppression pools in BWRs can attenuate the radionuclide release and modify the size distribution of radioactive particles that reach any external filter in a way that makes them more difficult to remove. As a result, improved decontamination by the suppression pool with water addition can decrease the effectiveness of external filters.

The engineered filtration system capability will depend on the progression of the severe accident. The system must survive following the conditions that created the circumstances for the severe accident, and it must continue to function successfully throughout its intended mission.

There is large uncertainty associated with the predicted performance of engineered filtration systems in a severe accident. Performance capability has been demonstrated by experiment under simulated conditions, but there is no actual operating experience or extensive full-scale testing. Analytical predictive capability is limited by availability of applicable, qualified benchmarking data representing a reasonable spectrum of severe accident events.

The staff calculations of offsite radioactive material releases include mechanistic predictions of natural aerosol settling, suppression pool decontamination, and unfiltered leakage from the plant. These calculations hypothesize the potential decontamination of aerosol that passes

through an external filter (i.e., decontamination factor = 10, 100, 1000). In contrast to experimental results, the decontamination factor was applied uniformly across all chemical groups that pass into the wetwell or drywell vent pathways, and the effectiveness was independent of particle sizes. They find the overall radionuclide release from the plant approaches a nonzero asymptote as the hypothesized effectiveness of the external filter is increased. This is because of unfiltered leakage from the plant. Unfiltered leakage could increase beyond design basis values depending on the progression of severe accidents.

An unplanned release of noble gas can occur if there is premature, inadvertent, or unnecessary actuation of the venting system. Radioactive shine from this cloud of radionuclides, estimated to be on the order of 200-300 million curies in a severe core melt accident, will affect onsite personnel and offsite members of the public.

When in operation, an engineered filtration system allows noble gases to escape the plant and retains an inventory of radioactive particulate. Radionuclide materials collected and stored by an engineered filtration system represent a potential source term that is subject to subsequent release due to causes related to the accident, an internal gas explosion, a secondary external event, an equipment malfunction, or an operational mishap.

SUMMARY AND CONCLUSIONS

We have examined the technical evaluations performed by the staff to support regulatory decision-making regarding CPRR for BWR Mark I and Mark II containments. The technical evaluations, sensitivity studies, and uncertainty analyses focus on the features most important to decide on a course of action. We agree with the staff's conclusions that there is substantial safety margin with the implementation of Order EA-13-109, and that a filtration system would not constitute a substantial safety enhancement. Water addition can improve protection against containment failure and reduce radioactive source terms in the event of a severe accident. The effectiveness of the SAWA / SAWM system depends on proper implementation of design, operations, logistics, procedures, and training. The staff should ensure that the Order EA-13-109 commitments related to SAWA / SAWM are fulfilled and maintained by the licensees.

Sincerely,

/RA/

John W. Stetkar
Chairman

REFERENCES

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4. U.S. Nuclear Regulatory Commission, Order EA-12-050, “Order Modifying Licenses with Regard to Reliable Hardened Containment Vents,” March 12, 2012 (ML12054A696).

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6. U.S. Nuclear Regulatory Commission, SECY-12-0157, “Consideration of Additional Requirements for Containment Venting Systems for Boiling Water Reactors with Mark I And Mark II Containments,” November 26, 2012 (ML12325A704).

7. ACRS letter, “ACRS Review of Staff’s Draft SECY Paper on Consideration of Additional Requirements for Containment Venting Systems for Boiling Water Reactors with Mark I And Mark II Containment Designs,” November 8, 2012 (ML12312A099).

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9. U.S. Nuclear Regulatory Commission, Order EA-13-109, “Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accidents,” June 6, 2013 (ML13143A321).

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11. ACRS letter, “Interim Staff Guidance JLD-ISG-2015-01, ‘Compliance With Phase 2 of Order EA-13-109, Order Modifying Licenses With Regard To Reliable Hardened Containment Vents Capable Of Operation Under Severe Accident Conditions’,” April 30, 2015 (ML15118A883).

12. Nuclear Energy Institute letter, NEI 13-02, Rev. 1, “Industry Guidance for Compliance with Order EA-13-109,” April 2015 (ML15120A359).

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15. AREVA Inc. letter, “Request for Clarification Related to the AREVA Filtered Containment Venting System to Support the Containment Protection and Release Reduction for Boiling Water Reactor with Mark I and Mark II Containments Rulemaking,” November 18, 2014 (ML14329A148).

16. Nuclear Energy Institute letter, “Initial Industry Response to Nuclear Regulatory Commission Request for Information Related to the Filtering Strategies and Severe Accident Management of Boiling Water Reactors with Mark I and II Containments Rulemaking,” May 31, 2014 (ML14202A418).

17. Nuclear Energy Institute letter, “Evaluation of the Containment Protection and Release Reduction (CPRR) for Mark I and Mark II Boiling Water Reactors Rulemaking (SECY-15-0085; June 18, 2015),” August 7, 2015 (ML15222B196).

14. U.S. Nuclear Regulatory Commission, SRM-SECY-15-0085, "Evaluation of the Containment Protection and Release Reduction for Mark I and Mark II Boiling Water Reactors Rulemaking Activities (10 CFR PART 50) (RIN-3150-AJ26)," August 19, 2015 (ML15231A471).

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