NRR-PMDAPEm Resource

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Sent: Friday, May 20, 2016 3:24 PM
To: RulemakingComments Resource
Cc: Doyle, Daniel; Mohseni, Aby; Burnell, Scott; Bladey, Cindy; Dave Lochbaum; Gordon Thompson; Matthew G. McKinzie; Geoffrey Fettus; Thomas B. Cochran; Alemayehu, Bemnet; Ed Lyman; Robert Alvarez; Robert H. Leyse; Paul Gallay; Paul Gunter; Michel Lee; Mary Lampert; CHAIRMAN Resource; Valliere, Nanette; Moore, Johari; Patrick.Castlernan@nrc.gov; Frazier, Alan; Cubbage, Amy; Bloomer, Tamara; Krsek, Robert; michal_freedhoff@markey.senate.gov; Diane Curran; Jim Riccio; Richard Webster; Thomas Popik; Raymond Shadis; Clay Turnbull
Subject: [External_Sender] NRC–2014–0171
Attachments: 2.345 Petition for Reconsideration (Regarding PRM-50-108).pdf

Dear Rulemaking and Adjudications Staff:

Attached to this e-mail is a 10 C.F.R. § 2.345 petition for reconsideration, dated May 20, 2016, requesting that the NRC reconsider its denial of PRM-50-108.

The NRC published its decision to deny PRM-50-108 in the Federal Register on May 13, 2016. This 10 C.F.R. § 2.345 petition is being submitted within ten (10) days after the date of the NRC's Federal Register notice.

In accordance with requirements of 10 C.F.R. § 2.345, this petition demonstrates that there are clear and material errors in the NRC's decision to deny PRM-50-108.

In accordance with requirements of 10 C.F.R. § 2.345, this petition states the relief that is sought.

Sincerely,

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May 20, 2016

Annette L. Vietti-Cook
Secretary
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Rulemakings and Adjudications Staff

PETITION FOR RECONSIDERATION

This petition for reconsideration is submitted pursuant to 10 C.F.R. § 2.345 by Mark Edward Leyse ("Petitioner").

Petitioner requests that the U.S. Nuclear Regulatory Commission ("NRC") reconsider its denial of PRM-50-108. The NRC published its decision to deny PRM-50-108 in the Federal Register on May 13, 2016. This 10 C.F.R. § 2.345 petition is being submitted within ten (10) days after the date of the NRC's Federal Register notice.

I. CLEAR AND MATERIAL ERRORS IN THE NRC'S DECISION TO DENY PRM-50-108

In accordance with requirements of 10 C.F.R. § 2.345, in this section, Petitioner demonstrates that there are clear and material errors in the NRC's decision to deny PRM-50-108.

I.A. The NRC's Federal Register notice, denying PRM-50-108, does not address information PRM-50-108 provided indicating that regulations pertaining to Spent Fuel Pool ("SFP") Accident Evaluation Models are needed because the frequency of the type of events that could lead to SFP accidents is relatively high.

The NRC's denial of PRM-50-108 does not address information PRM-50-108 provided (on pages 39-42) indicating that regulations pertaining to SFP Accident Evaluation Models are needed. Regulations are needed because the frequency of the type of events that could lead to SFP accidents is relatively high. The information provided in PRM-50-108 included statements that the NRC published in the Federal Register on December 18, 2012 announcing that PRM-50-96[1] had been accepted.

[1] Thomas Popik, The Foundation for Resilient Societies, PRM-50-96, March 14, 2011, (ADAMS Accession No. ML110750145).

PRM-50-96 was submitted by Thomas Popik of The Foundation for Resilient Societies on March 14, 2011. PRM-50-96 requested that new regulations be enacted to help prevent SFP fires in the event of long-term power blackouts.

In its December 18, 2012 Federal Register notice announcing that PRM-50-96 had been accepted, the NRC stated that an extreme solar storm hitting Earth (geomagnetic disturbance)—with an intensity similar to that of the 1859 Carrington event[2]—could occur as frequently as once in 153 years to once in 500 years (6.5×10^{-3}/yr to 2.0×10^{-3}/yr) and initiate "a series of events potentially leading to core damage at multiple nuclear sites."[3]

(It is noteworthy that on July 23, 2012, there were two consecutive coronal mass ejections separated by about 10 to 15 minutes that caused an extreme solar storm—deemed to have an intensity similar to that of the Carrington event—in interplanetary space, which passed through Earth's orbit; the solar storm missed hitting Earth by nine days.[4])

In its May 13, 2016 Federal Register notice, denying PRM-50-108, the NRC makes statements that are contrary to what it stated in its December 18, 2012 Federal Register notice on PRM-50-96. In the May 13, 2016 Federal Register notice, the NRC states: "It is not necessary to require detailed annual evaluations of the progression of SFP severe accidents because the risk of an SFP severe accident is low. The NRC defines risk as the product of the probability and the consequences of an accident."[5]

The NRC needs to conduct probabilistic risk assessments ("PRA") that estimate the frequency of SFP fires that could occur at multiple nuclear sites in the event of long-term catastrophic grid failures—blackouts that would last months to years. The NRC needs to address the problem of blackouts that would last months to years. It is pertinent

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[2] The Carrington event in 1859 is the largest solar storm ever recorded.

[3] NRC, "Long-Term Cooling and Unattended Water Makeup of Spent Fuel Pools: Proposed Rules," Docket No. PRM–50–96, NRC–2011–0069, Federal Register, Vol. 77, No. 243, December 18, 2012, p. 74790.

[4] Ying D. Liu, "Observations of an Extreme Storm in Interplanetary Space Caused by Successive Coronal Mass Ejections," Nature Communications, March 18, 2014; and Robert Sanders, "Fierce solar magnetic storm barely missed Earth in 2012," University of California, Berkeley News Center, March 18, 2014.

[5] NRC, "Fuel-Cladding Issues in Postulated Spent Fuel Pool Accidents," Petition for Rulemaking; Denial, Docket No. PRM-50-108, NRC–2014–0171, Federal Register, Vol. 81, No. 93, May 13, 2016, p. 29762.

that in comments on COMSECY-13-0030, NRC Chairwoman, Allison M. Macfarlane, states that "[a] comprehensive safety and security case for spent fuel pools should consider *the full range of potential hazards* (natural or human-induced) that could initiate an accident…"[6] [emphasis added]. Unfortunately, recent NRC Post-Fukushima MELCOR simulations of BWR Mark I SFP accident/fire scenarios have only considered accidents that would be initiated by beyond-design-basis earthquakes: events that are assigned with very slight probabilities of occurring.[7]

I.B. The NRC's Federal Register notice, denying PRM-50-108, does not address information PRM-50-108 provided on an important April 2000 letter Dana A. Powers, Chairman of the Advisory Committee on Reactor Safeguards ("ACRS"), sent to Richard A. Meserve, Chairman of the NRC.

The NRC's denial of PRM-50-108 *does not address or even mention* an April 2000 letter Dana A. Powers, Chairman of the ACRS, sent to Richard A. Meserve, Chairman of the NRC. The letter criticizes the final draft of NUREG-1738, "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants."[8] (Discussion and quotes from the April 2000 ACRS letter are provided in PRM-50-108 on pages 5, 25, and 38.)

The ACRS letter states that the final draft for NUREG-1738 "relied on relatively geriatric work" for its *analysis of the interaction of air with zirconium fuel cladding*, pointing out that "[m]uch more is known now about air interactions with cladding," including knowledge gained "from studies being performed as part of a cooperative international program (PHEBUS FP[9]) in which NRC is a partner."[10]

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[6] NRC, "Staff Evaluation and Recommendation for Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel," COMSECY-13-0030, May 27, 2014, p. 4.

[7] Andrew Barto *et al*., NRC, "Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor," NUREG-2161, September 2014, (ADAMS Accession No. ML14255A365).

[8] T.E. Collins *et al*., NRC, "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants," NUREG-1738, February 2001, (ADAMS Accession No. ML010430066).

[9] PHEBUS FP is an experimental program that researched severe-accident reactor core damage.

[10] Dana A. Powers, Chairman of ACRS, Letter to Richard A. Meserve, Chairman of NRC, Regarding ACRS Recommendations for Improvements to the NRC Staff's "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants," April 13, 2000, (ADAMS Accession No. ML003704532), pp. 3-4.

The ACRS letter explains "that nitrogen from air depleted of oxygen will interact exothermically with zircaloy cladding. The reaction of zirconium with nitrogen is exothermic by about 86,000 calories per mole of zirconium reacted. Because the heat required to raise zirconium from room temperature to melting is only about 18,000 calories per mole, the reaction enthalpy with nitrogen is ample."[11] The letter goes on to further discuss the reaction of zirconium and air.

Regarding air interactions with zirconium as well as *neglecting* to model the affects of nitrogen, ***the ACRS concludes***: "Because of these findings, ***we do not accept*** the staff's claim that it has performed 'bounding' calculations of the heatup of Zircaloy clad fuel even when it neglects heat losses"[12] [emphasis added].

The NRC's Federal Register notice, denying PRM-50-108, mentions NUREG-1738 and other NRC studies as if they are *gold standards* of SFP-fire analysis. *Contrary* to the ACRS April 2000 letter, the NRC even claims that "previous studies (*i.e*., NUREG– 1738)…used *bounding or conservative estimates*"[13] [emphasis added].

As of 2016, the NRC's MELCOR computer safety model—used to simulate SFP accidents—***still does not*** model how nitrogen would affect zirconium fuel cladding. Nonetheless, the NRC's Federal Register notice, denying PRM-50-108, states: "The MELCOR computer code is the NRC's best estimate tool for severe accident analysis. It has been validated against experimental data, and it represents the current state of the art in severe accident analysis."[14]

The NRC's claim regarding MELCOR is a clear error. After 16 years time, the issues raised in the ACRS April 2000 letter remain unresolved. This is a reason that PRM-50-108 should be reconsidered. The NRC's philosophy of defense-in-depth requires the application of conservative models.[15] Therefore, MELCOR's model of air interactions with zirconium needs to be improved, as PRM-50-108 requests.

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[11] *Id.*, p. 4.
[12] *Id.*
[13] NRC, "Fuel-Cladding Issues in Postulated Spent Fuel Pool Accidents," Petition for Rulemaking; Denial, Docket No. PRM-50-108, NRC–2014–0171, p. 29764.
[14] *Id.*
[15] Charles Miller *et al*., NRC, "Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," SECY-11-0093, July 12, 2011, (ADAMS Accession No. ML111861807), p. 3.

I.C. The NRC's Federal Register notice, denying PRM-50-108, does not address information PRM-50-108 provided on limitations of MELCOR's SFP model.

The NRC's denial of PRM-50-108 does not address information that PRM-50-108 provided (on pages 24 to 31) documenting limitations of MELCOR.

Regarding limitations of MELCOR, in 2006, a Sandia National Laboratories report observed that MELCOR *does not* model the nitriding of zirconium fuel cladding, stating that fuel cladding would "combine with nitrogen if no oxygen or steam are available" and that the nitriding process is exothermic (heat-generating). MELCOR also *does not simulate* how nitrogen gas (in air) affects the oxidation of zirconium in air.[16] This is a serious flaw because the presence of nitrogen accelerates the oxidation (burning) and degradation of zirconium fuel-cladding *in air*,[17] which would affect the progression and severity of a SFP accident, including the amount of radioactive releases.[18]

The NRC's Federal Register notice, denying PRM-50-108, also does not address the fact that PRM-50-108 (on pages 30-31) provided an example of a particular SFP fire scenario that MELCOR simulated (in NUREG-2161) in which there would be a depletion of oxygen in an intact reactor building.[19] The MELCOR simulation would have had *different results* if it had realistically modeled the effects of nitrogen.

PRM-50-108 provided a criticism of MELCOR from the Paul Scherrer Institute ("PSI") (on pages 27 and 28).

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[16] K. C. Wagner, R. O. Gauntt, Sandia National Laboratories, Analysis and Modeling Division, "Mitigation of Spent Fuel Pool Loss-of-Coolant Inventory Accidents and Extension of Reference Plant Analyses to Other Spent Fuel Pools," SAND1A Letter Report, Revision 2, November 2006, (ADAMS Accession No. ML120970086), p. 12.; and L. Fernandez-Moguel, J. Birchley, European MELCOR User's Group, "PSI air oxidation model in MELCOR: Part 2: Analysis of experiments and model assessment," Stockholm, May 2013, which states: "Neither MELCOR nor SCDAP [a severe accident computer safety model] are able to predict a nitride reaction."

[17] J. Stuckert, M. Große, Z. Hózer, M. Steinbrück, Karlsruhe Institute of Technology, "Results of the QUENCH-16 Bundle Experiment on Air Ingress," KIT-SR 7634, May 2013, p. 1; and O. Coindreau, C. Duriez, S. Ederli, "Air Oxidation of Zircaloy-4 in the 600-1000°C Temperature Range: Modeling for ASTEC Code Application," Journal of Nuclear Materials 405, 2010, p. 208.

[18] J. Stuckert *et al*., "Results of the QUENCH-16 Bundle Experiment on Air Ingress," p. 1.

[19] Andrew Barto *et al*., NRC, "Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor," NUREG-2161, p. 145.

First, it needs to be clarified that the NRC used MELCOR version 1.8.6 (2005) for a post-Fukushima SFP safety study, NUREG-2161.[20] (There is also a MELCOR version 2.1 that has a SFP model that is functionally the same as version 1.8.6's.[21])

As PRM-50-108 states and quotes, PSI assessed MELCOR 1.8.6's ability to predict fuel-cladding behavior in accidents involving air ingress into the reactor vessel—which is pertinent to MELCOR's ability to predict zirconium-air reaction rates in SFP accidents—and "concluded that development of MELCOR was needed *to capture the accelerated cladding oxidation that can take place under air ingress conditions* (characterized by transition from formation of a protective oxide film to non-protective 'breakaway' oxidation at a significantly higher rate)"[22] [emphasis added].

I.D. The NRC's Federal Register notice, denying PRM-50-108, published on May 13, 2016, does not include information on the reaction of air and zirconium that was discussed in a draft of the Federal Register notice, dated November 19, 2016.

A draft of the NRC's Federal Register notice announcing the denial of PRM-50-108 is dated November 19, 2016 (according to the NRC's ADAMS Public Documents).[23] Unlike the Federal Register notice, denying PRM-50-108, published on May 13, 2016, the draft of the Federal Register notice discusses the reaction of air and zirconium. There are several paragraphs of information on the air-zirconium reaction in the draft that are not included in the published Federal Register notice. The draft of the Federal Register notice actually contains information on the air-zirconium reaction that supports accepting PRM-50-108 for consideration in the NRC's rulemaking process.

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[20] Andrew Barto *et al*., NRC, "Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor," NUREG-2161, September 2014, (ADAMS Accession No. ML14255A365), pp. 95-96.

[21] *Id*., p. 96.

[22] S. Güntay, J. Birchley, "MELCOR Further Development in the Area of Air Ingress and Participation in OECDNEA SFP Project to Be Performed in the Time Frame 2009-2012," April 2009, p. 2.

[23] NRC, "Draft of the Federal Register Notice Announcing the Denial of PRM-50-108," Enclosure 1 of SECY-15-0146, NRC-2014-0171, November 19, 2016, (ADAMS Accession No. ML14307A630).

Here are four quotes from the draft of the Federal Register notice that support the arguments of PRM-50-108:

1) "The NRC recognizes that the phenomena discussed in the petition [PRM-50-108] are important to realistically evaluate the initiation and progression of SFP fires in the unlikely event of a beyond design basis accident."[24]

2) "The petitioner pointed to a number of references published over the last few years to assert that the MELCOR computer code is inadequate."[25]

3) "As an additional heat source, nitriding is only important in oxygen-starved situations (*e.g.*, in cases where the reactor building is intact during the zirconium fire)."[26] (Keep in mind that, as mentioned above, PRM-50-108 provided an example of a SFP fire scenario in which there would be a depletion of oxygen in an intact reactor building.)

4) "Nitriding is most relevant when nuclear fuel is undergoing a severe accident in an air environment and oxygen-starved conditions develop because of rapid consumption of oxygen from the air."[27]

The fourth quote from the draft of the Federal Register notice is very important. The fact that oxygen-starved conditions develop because of the rapid consumption of oxygen (in air) is one of the primary reasons why Petitioner submitted PRM-50-108 to the NRC. The fact that MELCOR does not model this phenomenon is another reason why the NRC should reconsider its decision to deny PRM-50-108.

Here is some of the information on oxygen starvation that PRM-50-108 discusses and quotes. On page 21, PRM-50-108 states: "When zirconium reacts in air it is possible for the reaction to become oxygen-starved; however, if zirconium is locally oxygen-starved in air, nitrogen will react with it."

PRM-50-108 has information (on page 23) regarding the fact that *cladding degradation can be even much faster in oxygen starved situations* (in air), a 2008 *Journal of Nuclear Materials* paper states:

> Kinetic data of this study have been obtained mainly in high air flow conditions. *In real accidental situations, where oxygen starved situations are likely to occur, cladding degradation can be even much faster than*

[24] *Id*., p. 14.
[25] *Id*., p. 15.
[26] *Id*., p. 16.
[27] *Id*.

> *predictable from these high air flow data*, because of early initiation of the nitriding process, as shown by the few tests performed at the highest temperatures with insufficient air flow rate. All in all, more experimental investigations are required to address the various conditions that can be encountered in accidental situation[28] [emphasis added].

It is puzzling that the NRC did not include information on the air-zirconium reaction in its published Federal Register notice regarding its decision to deny PRM-50-108. That is, in the section of the notice in which the NRC explains that MELCOR "represents the current state of the art in severe accident analysis."[29]

One might even suspect that some information was not included in the published Federal Register notice precisely because it elucidated deficiencies of MELCOR. Here is an example of two deleted sentences indicating that the NRC is aware of MELCOR's deficiencies: "There are inherent uncertainties in the progression of severe accidents and there are many interrelated phenomena. Therefore, it is *neither desirable nor very practical* to develop a "conservative" computer safety model for severe accidents" [30] [emphasis added].

The fact that information on the air-zirconium reaction—relevant to what PRM-50-108 requested—was not published Federal Register notice is yet another reason why the NRC should reconsider its decision to deny PRM-50-108. Why was this information placed in the draft yet *not* included in the published Federal Register notice?

II. COMPELLING NEW INFORMATION

II.A. A December 2015 cyber-attack caused a blackout in Ukraine.

On May 18, 2016 the Committee on Homeland Security and Governmental Affairs, a chief oversight committee of the U.S. Senate, held a meeting: "Assessing the Security of Critical Infrastructure: Threat, Vulnerabilities, and Solutions." In his opening statement, the Chairman of the Committee, Ron Johnson, stated: "In December 2015, a cyber-attack on the control system of a Ukrainian electric grid left over 230,000 consumers without

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[28] C. Duriez, T. Dupont, B. Schmet, F. Enoch, "Zircaloy-4 and M5 High Temperature Oxidation and Nitriding in Air," Journal of Nuclear Materials 380 (2008), p. 44.

[29] NRC, "Fuel-Cladding Issues in Postulated Spent Fuel Pool Accidents," Petition for Rulemaking; Denial, Docket No. PRM-50-108, NRC–2014–0171, p. 29764.

[30] NRC, "Draft of the Federal Register Notice Announcing the Denial of PRM-50-108," Enclosure 1 of SECY-15-0146, NRC-2014-0171, November 19, 2016, p. 15.

power, in some cases for over six hours. The attack did not result in any physical damage to the grid, though it demonstrates how hackers could corrupt software-related assets."[31]

As mentioned above, a draft of the NRC's Federal Register notice announcing the denial of PRM-50-108 is dated November 19, 2016.[32] That means that PRM-50-108 was denied before the December 2015 cyber-attack caused a blackout in Ukraine. The Ukrainian blackout pertains to issues raised in PRM-50-108. That is another reason why the NRC's decision to deny PRM-50-108 should be reconsidered.

Incidentally, on May 18, 2016, Chairman Johnson also pointed out that experts argue that "a major solar weather event causing widespread power outages is inevitable."[33]

II.B. Deficiencies of MELCOR, regarding the air cooling of spent fuel assemblies in SFPs. This important information (published in 2014) was not provided in PRM-50-108.

According to a 2014 *Annals of Nuclear Energy* paper, severe accident codes, including MELCOR, use thermal hydraulic models that are not necessarily appropriate for SFPs. Regarding SFP modeling limitations, the paper states:

> The phenomena of natural convection and boiling in the fuel building. In fact, the conclusions on the coolability of [fuel assemblies] can be very different, in function of the calculations. Some studies show, for a loss of water transient (conducting to fast dewatering and air ingress in the [fuel assemblies]), that air flow is sufficient to remove the power, for other studies this conclusion depends on the air flow that could actually flow in the [fuel assemblies]. (Remark: Most of these calculations seem to *use thermal hydraulic parameters/models which seem not appropriate for SFP geometries*. Therefore, the gas flow is *strongly overestimated* and *non-conservative*. OECD SFP experiment showed ignition in a simulated 3 year old spent fuel element in air)[34] [emphasis added].

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[31] Ron Johnson, "Opening Statement: Assessing the Security of Critical Infrastructure: Threats, Vulnerabilities, and Solutions," Committee on Homeland Security and Governmental Affairs, May 18, 2016.

[32] NRC, "Draft of the Federal Register Notice Announcing the Denial of PRM-50-108," Enclosure 1 of SECY-15-0146, NRC-2014-0171, November 19, 2016.

[33] Ron Johnson, "Opening Statement: Assessing the Security of Critical Infrastructure: Threats, Vulnerabilities, and Solutions," Committee on Homeland Security and Governmental Affairs.

[34] J. Fleurot *et al*., "Synthesis of spent fuel pool accident assessments using severe accident codes," *Annals of Nuclear Energy*, 74, 2014, p. 70.

The fact that MELCOR's model of the air cooling of spent fuel assemblies is non-conservative is yet another reason the NRC should reconsider PRM-50-108.

III. THE RELIEF SOUGHT

In accordance with requirements of 10 C.F.R. § 2.345, in this section, Petitioner states the relief that is sought.

Petitioner requests that the NRC reconsider its denial of PRM-50-108. PRM-50-108's arguments for the requested regulations are fact-based and fully referenced. As discussed in Section I of this 10 C.F.R. § 2.345 petition, there are clear and material errors in the NRC's decision to deny PRM-50-108. The NRC itself has made conflicting statements about the frequency of SFP fires. The NRC needs to conduct PRAs that estimate the frequency of SFP fires in the event of blackouts that would last months to years. It is likely that such PRAs would reveal that the frequencies of SFP fires are relatively high and that the regulations (or a variation of such) requested in PRM-50-108 are needed to help improve public and plant-worker safety.

In accordance with NRC's philosophy of defense-in-depth, which requires the application of conservative models,[35] it is necessary to improve the performance of MELCOR and any other computer safety models that are intended to accurately simulate SFP accident/fire scenarios.

Respectfully submitted,

/s/

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[35] Charles Miller *et al.*, NRC, "Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," SECY-11-0093, p. 3.