[7590-01-P]

NUCLEAR REGULATORY COMMISSION

10 CFR Part 50

[Docket Nos. PRM-50-103; NRC-2011-0189]

Measurement and Control of Combustible Gas Generation and Dispersal

AGENCY: Nuclear Regulatory Commission.

ACTION: Petition for rulemaking; denial.

SUMMARY: The U.S. Nuclear Regulatory Commission (NRC) is denying a petition for rulemaking (PRM), dated October 14, 2011, submitted by Mr. Jordan Weaver (the petitioner) on behalf of the Natural Resources Defense Council, Inc. The petitioner requested that the NRC amend its regulations regarding the measurement and control of combustible gas generation and dispersal within a power reactor system. The petition was assigned Docket No. PRM-50-103 and the NRC published a notice of docketing in the *Federal Register* on January 5, 2012. The NRC is denying the petition because the issues raised by the petitioner had been considered by the NRC in other NRC processes and the petitioner presented no sufficient new information or arguments to warrant the requested changes to the regulations.

DATES: The docket for the petition for rulemaking, PRM-50-103, is closed on **[INSERT DATE OF PUBLICATION IN THE *FEDERAL REGISTER*]**.

ADDRESSES: Please refer to Docket ID NRC-2011-0189 when contacting the NRC about the availability of information for this petition. You may obtain publicly-available information related to this petition by any of the following methods:

- **Federal Rulemaking Web Site:** Public comments and supporting materials related to this petition can be found at https://www.regulations.gov by searching on the petition Docket ID NRC-2011-0189. Address questions about NRC dockets to Carol Gallagher; telephone: 301-415-3463; e-mail: Carol.Gallagher@nrc.gov. For technical questions, contact the individuals listed in the FOR FURTHER INFORMATION CONTACT section of this document.

- **The NRC's Agencywide Documents Access and Management System (ADAMS):** You may obtain publicly-available documents online in the ADAMS Public Document collection at https://www.nrc.gov/reading-rm/adams.html. To begin the search, select "Begin Web-based ADAMS Search." For problems with ADAMS, please contact the NRC's Public Document Room (PDR) reference staff at 1-800-397-4209, at 301-415-4737, or by e-mail to pdr.resource@nrc.gov. For the convenience of the reader, instructions about obtaining materials referenced in this document are provided in Section IV, "Availability of Documents."

- **The NRC's PDR:** You may examine and purchase copies of public documents at the NRC's PDR, O1-F21, One White Flint North, 11555 Rockville Pike, Rockville, Maryland 20852.

FOR FURTHER INFORMATION CONTACT: Joseph Sebrosky, Office of Nuclear Reactor Regulation; telephone: 301-415-1132; e-mail: Joseph.Sebrosky@nrc.gov; or Edward M. Lohr, Office of Nuclear Material Safety and Safeguards; telephone: 301-415-0253; e-mail: Edward.Lohr@nrc.gov. Both are staff of the U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001.

SUPPLEMENTARY INFORMATION:

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I. The Petition

Section 2.802 of title 10 of the *Code of Federal Regulations* (10 CFR), "Petition for rulemaking—requirements for filing," provides an opportunity for any interested person to petition the Commission to issue, amend, or rescind any regulation. The NRC received a petition for rulemaking, dated October 14, 2011, from Mr. Jordan Weaver on behalf of the Natural Resources Defense Council, Inc. The NRC published a notice of docketing in the *Federal Register* on January 5, 2012. The petitioner requested that the NRC amend its regulations regarding the measurement and control of combustible gas generation and dispersal within a power reactor system.

When the NRC published the notice of docketing in 2012, the NRC elected not to seek public comment, because the staff was addressing the issues raised in the petition in the context of an ongoing effort at the time. Recommendations on that effort in response to the Fukushima Dai-ichi accident in Japan, SECY-11-0093, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," (Near-Term Task Force Report) had not yet been resolved.

The NRC was in the process of holding public meetings on the Near-Term Task Force Report recommendations and indicated in the notice of docketing for the petition that "the NRC is not requesting public comment at this time but may do so in the future, if it decides public comment would be appropriate." Because the NRC held several public meetings on the Near-Term Task Force Report recommendations and on the subjects raised by the petitioner, the NRC determined that additional public input was not needed to resolve the issues raised in this petition.

The NRC identified six issues in the petition. The petitioner raised various issues related to pressurized-water reactors (PWRs); boiling-water reactors (BWRs); or specific containment designs such as BWR Mark I, Mark II, or Mark III containments or PWR large dry containments, sub-atmospheric containments, and ice condenser containments.

II. Reasons for Denial

The NRC is denying the petition because the issues raised by the petitioner had been considered by the NRC in other NRC processes and the petitioner did not present sufficient new information or arguments to warrant the requested changes to the NRC's regulations in light of the NRC's relevant past decisions and current policies. The NRC completed an assessment of potential regulatory changes related to hydrogen control following the March 2011 Fukushima accident in Japan. This assessment is summarized in SECY-16-0041, "Closure of Fukushima Tier 3 Recommendations Related to Containment Vents, Hydrogen Control, and Enhanced Instrumentation." In SECY-16-0041, the NRC addressed recommendation 6 of the Near-Term Task Force Report involving hydrogen control and mitigation inside containment or in other buildings, and other recommendations from the report provided in connection with implementing lessons learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant.

The NRC's response to Near-Term Task Force recommendation 6, as documented in SECY-16-0041, was based on a detailed holistic review of hydrogen control measures for power reactors. In SECY-16-0041, the NRC provided a high-level summary of the studies and evaluations related to hydrogen control, including studies issued in September of 2003 that supported requirements found in 10 CFR 50.44, "Combustible gas control for nuclear power reactors." In SECY-16-0041, the NRC discusses hydrogen-related issues that have been addressed in major studies, such as those documented in NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," and NUREG-1935, "State-of-the-Art Reactor Consequence Analyses (SOARCA) Report." Additionally, the NRC has been participating in various international efforts, including a working group studying hydrogen generation, transport, and risk management organized by the Organisation for Economic Cooperation and Development/Nuclear Energy Agency.

In SECY-16-0041, the NRC concluded that additional regulatory actions were not needed based on: (1) the evaluations of event frequencies, plant responses, the timing of barrier failures, and conditional release fractions, and; (2) the significant margin that exists between the NRC's quantitative health objectives as described in the NRC's "Safety Goal Policy Statement," and estimated plant risks that might be reduced by improvement in hydrogen control.

The NRC, in SECY-16-0041, documented that existing NRC requirements and programs undertaken by licensees addressed the risks to public health and safety from hydrogen generation during severe accidents; therefore, additional requirements would not provide a substantial safety improvement. For new reactors licensed after 2003, NRC regulations include more stringent hydrogen control and mitigation requirements. The NRC also documented in SECY-16-0041 that changes to NRC regulations related to hydrogen control and mitigation requirements for new reactors licensed after 2003 were not warranted.

In PRM-50-103, the petitioner raised six issues and requested that the NRC address them in rulemaking. While the NRC's assessment in SECY-16-0041 of Near-Term Task Force Report recommendation 6, is closely related to the issues raised in PRM-50-103, SECY-16-0041 does not specifically address every aspect of the six issues raised in the petition. The conclusions in SECY-16-0041 and other sources are referenced in addressing the specific issues raised in PRM-50-103. The following explains each issue raised in the petition, the NRC's detailed response, and as appropriate, supplemental information beyond that provided in SECY-16-0041.

Issue 1: The petitioner requested that the NRC revise § 50.44 "to require that all PWRs (with large dry containments, sub-atmospheric containments, and ice condenser containments) and [BWRs with Mark III containments] operate with systems for combustible gas control that would effectively and safely control the potential *total* quantity of hydrogen that could be generated in different severe accident scenarios….” The petitioner stated that the total quantity of hydrogen could exceed the amount generated from the metal-water reaction of 100 percent of the fuel cladding because of contributions produced by the metal-water reaction with non-fuel components of the reactor.

Response to Issue 1: The NRC has evaluated requirements related to hydrogen control for these containment types on several occasions. For example, hydrogen-related issues have been addressed in major studies, such as those documented in NUREG-1150 and NUREG-1935. In SECY-16-0041, the NRC provided a detailed assessment of whether additional hydrogen controls were warranted for large dry containments, ice condenser containments, and Mark III containments. The NRC concluded that the risks to public health and safety from hydrogen generation during severe accidents were addressed by existing NRC requirements and programs undertaken by licensees and that additional requirements for existing operating reactors would, therefore, not provide a substantial increase in the overall protection of the public health and safety and that changes to requirements were not warranted.

For large dry and sub-atmospheric containments, § 50.44 does not include a requirement to assume a particular percentage of hydrogen generated from metal-water reactions for existing operating reactors. The NRC’s *Federal Register* notice for the final rule “Combustible Gas Control in Containment,” published on September 16, 2003, stated that combustible gas generated from severe accidents was not risk significant for large dry and sub-atmospheric containments “because of the large volumes, high failure pressures, and likelihood of random ignition to help prevent the build-up of detonable hydrogen concentrations.”

As documented in the draft report, “State-of-the-Art Reactor Consequence Analysis Project - Uncertainty Analysis of the Unmitigated Short-Term Station Blackout of the Surry Power Station” the MELCOR best-estimate computer program was used to model the progression of hypothetical severe accidents at Surry Power Station. Sandia National Laboratories developed the MELCOR computer program for the NRC to model the progression of severe accidents in nuclear power plants. The Surry Power Station MELCOR uncertainty analysis showed that the hydrogen that is produced in-vessel can vary between 250 kilograms (5th percentile) to 600 kilograms (95th percentile) with a mean of about 400 kilograms at 48 hours after the start of an accident. The corresponding fraction of cladding oxidized varies from 35 percent to 83 percent equivalent cladding mass with a mean of 55 percent. The typical timing for rapid initial hydrogen generation is about one to two hours after the start of hydrogen generation. None of the cases in the uncertainty analysis indicated early containment failure as a result of hydrogen combustion. In the hypothetical severe accident, any containment failure would occur later, as a result of continued heat up of the containment, due to core–concrete interaction if cooling to the containment were not restored. The analysis also did not predict late failure due to hydrogen combustion because after breach of the reactor pressure vessel, which would occur prior to containment failure, ignition sources would be available to burn the hydrogen at lower flammability levels.

NUREG/CR-7110, “State-of-the-Art Reactor Consequence Analyses Project,” Volume 2, “Surry Integrated Analysis” considered hydrogen generated from non-cladding sources. That analysis showed that high-steam concentrations are typically associated with scenarios that lead to large amounts of hydrogen generation from metal-water reactions. These high steam concentrations are sufficient to inert the containment and suppress hydrogen combustion in containments with large volumes.

In reviewing the issues raised in the petition, the NRC also considered safety gains attributable to NRC Order EA-12-049, “Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events,” (codified in 10 CFR 50.155) which requires mitigation strategies for each operating reactor to reduce the risk of core damage from an extended loss of alternating current power event. Also, based on Commission direction in SRM-SECY-15-0065, “Proposed Rulemaking: Mitigation of Beyond-Design-Basis Events,” the staff revised the Reactor Oversight Process to cover licensees’ implementation and maintenance of severe accident management guidelines. The severe accident management guidelines address hydrogen generation in large dry and sub-atmospheric containments to minimize the potential for containment failure from hydrogen combustion events.

For ice condenser and BWR Mark III containments, § 50.44(b)(2)(ii), (b)(3), and (b)(5) require the capability for controlling combustible gas (i.e., hydrogen igniters) and the performance of an evaluation of equipment survivability and an evaluation of the consequences of large amounts of hydrogen generated if there is an accident (hydrogen resulting from the metal-water reaction of up to and including 75 percent of the fuel cladding surrounding the active fuel region, excluding the cladding surrounding the plenum volume). As discussed in SECY-16-0041, the NRC performed additional analyses for these containments to determine if additional regulatory actions were warranted relative to hydrogen control. The NRC determined that such actions were not needed based on the underlying requirements in § 50.44 as supplemented by additional guidance to include backup power supplies for hydrogen igniters under NRC Order EA-12-049. The Order requirements have been made generically applicable in “§ 50.155, “Mitigation of beyond-design-basis events.”

As documented in SECY-16-0041, the NRC has performed assessments using best estimate simulations with MELCOR, consistent with the approach used in prior State-of-the-Art Consequence Analyses efforts. Additional assessments are documented in NUREG/CR-7245, “State-of-the-Art Consequence Analyses (SOARCA) Project - Sequoyah Integrated Deterministic and Uncertainty Analyses,” dated November 2017. The NUREG/CR-7245 assessment included hydrogen generated from non-cladding sources. Based on the results of these studies, the NRC concluded that early containment failures could only occur on the first hydrogen burn for ice condenser containments in those cases where the hydrogen igniters were not credited. Subsequent hydrogen burns do not challenge ice condenser containment integrity because they occur closer to the lower flammability limit of hydrogen due to the presence of active ignition sources (e.g., hot gases from the primary system or ex-vessel debris). The total amount of hydrogen produced by the first deflagration varies between 5 to 50 percent of equivalent cladding mass oxidized. Therefore, the NRC concluded in SECY-16-0041 that the existing requirement to consider hydrogen generation from a 75 percent cladding mass oxidation for ice condenser containments is appropriate. In cases crediting hydrogen igniters, containment failure was delayed and only occurred as a result of overpressure if heat removal systems were not restored.

For BWR Mark III containments, calculations were performed in resolving Near-Term Task Force recommendation 5.2 related to reliable hardened vents for containments other than BWR Mark I and Mark II. Further, analysis performed in response to Near-Term Task Force recommendation 6, associated with hydrogen control measures, showed that the total in-vessel hydrogen generation by the time of lower head failure is about 90 percent of equivalent cladding mass oxidized. The outcomes of these calculations indicate that containment failure by overpressure is significantly delayed in this scenario.

Licensees with Mark III containments have extended reactor core isolation cooling system operation by cooling water in the suppression pool in compliance with NRC Order EA-12-049, made generically applicable in § 50.155. This change decreases the likelihood of fission product barrier breaches.

An assessment of event frequencies, plant responses, the timing of barrier failures, radioactive releases, and other factors show substantial margin to the quantitative health objectives of the Commission's Safety Goal Policy Statement. Therefore, even if hydrogen generation is assumed to be 90 percent of equivalent cladding mass oxidized, the NRC determined that additional regulatory actions are not warranted above those found in § 50.44 and in response to NRC Order EA-12-049.

The petitioner's request also applied to new reactors. Section 50.44(c) sets forth combustible gas control requirements for water-cooled nuclear power reactor designs licensed after 2003 with characteristics (e.g., type and quantity of cladding materials) such that the potential for production of combustible gases is comparable to light-water reactor designs licensed as of 2003. These requirements are more conservative than those for operating reactors.

Section 50.44(c)(2) requires a system for hydrogen control that can safely accommodate hydrogen generated by the equivalent of a 100 percent fuel clad metal-water reaction and that is capable of precluding uniformly distributed concentrations of hydrogen from exceeding 10 percent (by volume). If these conditions cannot be satisfied, an inerted atmosphere must be provided within the containment. As a result, new plants have design features such as hydrogen igniters for AP1000 design reactors and inerted containments and passive autocatalytic recombiners for the Economic Simplified Boiling-Water Reactors. As described in SECY-16-0041, the NRC assessed the potential for further hydrogen control enhancements and found that such measures would not be justified under the issue finality provisions of 10 CFR part 52, "Licenses, certifications, and approvals for nuclear power plants" (similar to the backfit requirements defined in § 50.109, "Backfitting"). In addition, based on the analyses for the various containment types, the NRC concludes that changing the existing § 50.44(c) requirements is not warranted.

The NRC also considered the petitioner's position that a hydrogen detonation inside containment can result in internally generated missiles that could damage structures, systems, and components used to maintain key safety functions of ensuring core cooling and containment integrity, as well as the petitioner's position that these types of events should be analyzed. While SECY-16-0041 does not specifically address this issue, the conclusions in that paper are based, in part, on the low risk associated with core damage events that could lead to the generation of large amounts of hydrogen. Given the low probability of missiles being generated from a hydrogen combustion event (which assumes the core is substantially degraded) the estimated plant risks that might be reduced by a proposed requirement to consider missiles generated from a hydrogen combustion event are not substantial.

Therefore, the NRC concludes that the issues raised by the petitioner have been considered by the NRC in other NRC processes and the petitioner did not present sufficient new information or arguments to warrant the requested amendment in light of the NRC's relevant past decisions and current policies. The NRC determined that the analyses and plant changes requested by the petitioner in issue 1 of the petition for existing operating reactors would not provide substantial safety enhancements. For reactors licensed after 2003 (new reactors), the NRC determined that changes to the requirements in § 50.44(c)(2) are not warranted. The NRC continues to conclude that the current design and licensing requirements for operating and new reactors for the control of hydrogen provide adequate protection of public health and safety.

Issue 2: The petitioner requested that the NRC revise § 50.44 to "require that [BWRs with Mark I and Mark II containments] operate with systems for combustible gas control or inerted containments that would effectively and safely control the potential total quantity of hydrogen that could be generated in different severe accident scenarios." The petitioner stated that the total quantity of hydrogen could exceed the amount generated from the metal-water reaction of 100 percent of the fuel cladding because of contributions produced by the metal-water reaction with non-fuel components of the reactor.

Response to Issue 2: The NRC has evaluated requirements related to hydrogen control for BWRs with Mark I and Mark II containments on several occasions. In SECY-16-0041, the NRC provided a detailed assessment of whether additional hydrogen controls were warranted for these containment types. The NRC concluded that additional requirements or guidance beyond § 50.44, those associated with NRC Order EA-13-109, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation under Severe Accident Conditions," and the severe accident management guidelines were not warranted. For hydrogen combustion events outside primary containment, assessments performed with best estimate simulations (e.g., NUREG-1935) included hydrogen generated from non-cladding sources.

In resolving issue 2, the NRC considered the international evaluations referenced by the petitioner in support of the request to modify the NRC's regulations. The NRC participated in the international working groups that developed these evaluations and used them in developing current NRC regulations and guidance.

Under § 50.44, BWRs with Mark I and Mark II containments have an inerted atmosphere within the primary containment that greatly reduces the possibility of hydrogen combustion.

The analyses in NUREG/CR-7155, "State-of-the-Art Reactor Consequence Analyses Project - Uncertainty Analysis of the Unmitigated Long-Term Station Blackout of the Peach Bottom Atomic Power Station," predicted that the hydrogen that is produced in-vessel during an unmitigated long-term station blackout at a BWR with a

Mark I containment can vary between about 1100 kilograms (5th percentile) and about 1600 kilograms (95th percentile) with a mean of about 1300 kilograms. This corresponds to a fraction of equivalent cladding mass oxidized that varies from 62 percent to 90 percent, with a mean at 73 percent. The more recent calculations in support of the NRC's evaluation of a potential rulemaking on containment protection and release reduction (NUREG-2206, "Technical Basis for the Containment Protection and Release Reduction Rulemaking for Boiling Water Reactors with Mark I and Mark II Containments"), showed that equivalent cladding mass oxidation fraction varies between 60 percent and 77 percent, with a typical timing for rapid initial hydrogen generation of about 2 to 3 hours after the start of hydrogen generation. The assessment in SECY-16-0041 concluded that adding hydrogen control measures beyond those already included in NRC regulations, Order EA-13-109, and the severe accident management guidelines would not provide a substantial safety improvement, and therefore, were not warranted.

In 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)," the Commission directed the staff not to undertake rulemaking and to "leverage the draft regulatory basis to the extent applicable to support resolution of the post-Fukushima Tier 3 item related to containments of other designs." In SECY-16-0041, the NRC evaluated the technical analyses for Order EA-13-109, and the proposed Containment Protection and Release Reduction draft regulatory basis for rulemaking, "Draft Regulatory Basis for Containment Protection and Release Reduction for Mark I and Mark II Boiling Water Reactors (10 CFR Part 50)." Order EA-13-109 and the Containment Protection and Release Reduction draft regulatory basis show that the threat of explosions from combustible gases outside primary containment is significantly reduced by effective venting strategies. Additionally, the implementation of Order EA-13-109 included the severe accident water addition/severe accident water management approaches to further control containment conditions in the event of a severe accident. In SECY-16-0041, the NRC considered additional measures for hydrogen control and mitigation within containments and adjacent buildings that were being pursued in some countries. Examples of these measures include the installation of passive autocatalytic recombiners and venting capabilities to release hydrogen from BWR reactor buildings. The NRC concluded that these additional measures would not themselves directly support the cooling of core debris, but could help, for some selected scenarios, to maintain barriers to the release of radioactive material and prevent explosions that could hamper severe accident management activities. The potential benefits of the measures requested by the petitioner would be comparable or less than the alternatives analyzed in SECY-16-0041, which the NRC determined to be below the threshold for warranting further regulatory actions.

Therefore, the NRC concludes that the issues raised by the petitioner have been considered by the NRC in other NRC processes and the petitioner did not present sufficient new information or arguments to warrant the requested requirement in light of the NRC's relevant past decisions and current policies. The NRC determined that the analyses and plant changes requested by the petitioner in issue 2 of the petition would not provide substantial safety enhancements. The NRC continues to conclude that the current design and licensing requirements for the control of hydrogen provide adequate protection of public health and safety.

Issue 3: The petitioner requested that the NRC revise § 50.44 "to require that PWRs and [BWRs with Mark III containments] operate with systems for combustible gas control that would be capable of precluding local concentrations of hydrogen in the containment from exceeding concentrations that would support combustions, fast deflagrations, or detonations that could cause a loss of containment integrity or loss of necessary accident mitigating features."

Response to Issue 3: As discussed in the portion of this document entitled "Response to Issue 1," additional hydrogen controls for large dry and sub-atmospheric containments do not yield a substantial safety benefit. The NRC provides additional insights on the basis for the removal of the requirements for hydrogen recombiners for these containment types in the *Federal Register* notice for the § 50.44 final rule, "Combustible Gas Control in Containment," which references Attachment 2 to SECY-00-0198, "Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR PART 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.44 (Combustible Gas Control)." Attachment 2 provides a discussion regarding why the large volumes and likelihood of spurious ignition in large dry and sub-atmospheric containment help prevent the build-up of detonable concentrations.

The petitioner stated that the small volumes and confined spaces found in ice condenser and BWR Mark III containments make them susceptible to hydrogen pocketing. The NRC's analyses documented in SECY-16-0041 confirm that hydrogen accumulation and potential combustion could challenge the integrity of these containment types if igniters were not required.

However, to meet the requirements of § 50.44(b)(2)(ii), (b)(3), and (b)(5), ice condenser and BWR Mark III containments must have hydrogen igniters for combustible gas control. The hydrogen igniters address the threat from combustible gas buildup. In response to Order EA-12-049, as made generically applicable in 10 CFR 50.155, licensees with these containment types have taken action to ensure power is available to the igniter systems during station blackout conditions. These licensees follow the severe accident management guidelines to minimize the potential for containment failure from hydrogen combustion events. The location of the igniters prevents hydrogen (or any other combustible gas) from accumulating in large quantities.

The petitioner's request also applied to new reactors. As discussed in the portion of this document entitled "Response to Issue 1," § 50.44(c) sets forth combustible gas control requirements for water-cooled nuclear power reactor designs licensed after 2003, which are more stringent than those for existing operating reactors. As a result, new plants have design features such as hydrogen igniters for AP1000 design reactors and inerted containments and passive autocatalytic recombiners for the Economic Simplified Boiling-Water Reactors. As described in SECY-16-0041, the NRC assessed the potential for further hydrogen control enhancements for existing operating reactors and found that such measures would not be justified under the issue finality provisions of 10 CFR part 52 (similar to backfit requirements defined in § 50.109, "Backfitting").

Therefore, as it relates to issue 3 of the petition, the NRC concludes that the petitioner did not present sufficient new information or arguments to warrant the requested requirement in light of the NRC's relevant past decisions and current policies. Although SECY-16-0041 did not specifically consider this issue, the NRC's assessments in SECY-16-0041 did consider the contributions to the risk to public health and safety from severe accidents and related hydrogen generation and concluded that those contributions were not substantial. The NRC determined that the analyses and plant changes requested by the petitioner in issue 3 of the petition for existing operating reactors would not provide substantial safety enhancements and therefore, they were not warranted. For reactors licensed after 2003, the NRC also determined that changes to the requirements in § 50.44(c)(2) are not warranted. The NRC continues to conclude that the current design and licensing requirements for the control of hydrogen for operating and new reactors provide adequate protection of public health and safety.

Issue 4: The petitioner stated that "[t]he current requirement that hydrogen monitors be functional within 90-minutes after the initiation of safety injection is inadequate for protecting public and plant worker safety." To correct this issue, the petitioner requested that the NRC revise § 50.44 to "require that PWRs and [BWRs with

Mark III containments] operate with combustible gas and oxygen monitoring systems that are qualified in accordance with 10 C.F.R. § 50.49." The petitioner also requested that NRC revise § 50.44 "to require that after the onset of a severe accident, combustible gas monitoring systems be functional within a timeframe that enables the proper monitoring of quantities of hydrogen indicative of core damage and indicative of a potential threat to the containment integrity."

Response to Issue 4: Hydrogen monitoring in containment in § 50.44 includes requirements that hydrogen monitors be functional. Functional requirements are also provided in Item II.F.1, Attachment 6, of NUREG-0737, "Clarification of TMI Action Plan Requirements," which states that hydrogen monitors are to be functioning within 30 minutes of the initiation of safety injection. This requirement was imposed by confirmatory orders in 1983 following the accident at Three Mile Island Unit 2.

Since NUREG-0737 was issued, the NRC has determined that the 30-minute requirement can be unnecessarily stringent. This is documented in the *Federal Register* notice for the § 50.44 final rule and in Regulatory Guide 1.7, Revision 3, "Control of Combustible Gas Concentrations in Containment." Through a confirmatory order, "Confirmatory Order Modifying Post-TMI Requirements Pertaining to Containment Hydrogen Monitors for Arkansas Nuclear One, Units 1 and 2 (TAC NOS. MA1267 and 1268)," the NRC developed a method for licensees to adopt a risk-informed functional requirement in lieu of the 30-minute requirement. As described in the confirmatory order, an acceptable functional requirement would meet the following requirements:

(1) Procedures shall be established for ensuring that indication of hydrogen concentration in the containment atmosphere is available in a sufficiently timely manner to support the role of information in the emergency plan (and related procedures) and related activities such as guidance for the severe accident management plan.

(2) Hydrogen monitoring will be initiated on the basis of the following considerations:

a. The appropriate priority for establishing indication of hydrogen concentration within containment in relation to other activities in the control room.

b. The use of the indication of hydrogen concentration by decision-makers for severe accident management and emergency response.

c. Insights from experience or evaluation pertaining to possible scenarios that result in significant generation of hydrogen that would be indicative of core damage or a potential threat to the integrity of the containment building.

The NRC has determined that adoption of this risk-informed functional requirement by licensees results in the hydrogen monitors being functional within 90 minutes after the initiation of safety injection.

Subsequent to the issuance of the confirmatory order, the NRC issued a notice of availability of a model in the *Federal Register* titled, "Notice of Availability of Model Application Concerning Technical Specification Improvement to Eliminate Hydrogen Recombiner Requirement, and Relax the Hydrogen and Oxygen Monitor Requirements for Light Water Reactors Using the Consolidated Line Item Improvement Process." The notice stated that this model was available for referencing in license amendment applications for licensees wanting to relax safety classifications and the licensee commitments to certain design and qualification criteria for hydrogen monitors. This allowed licensees to choose to remove containment hydrogen monitoring requirements from their license through a license amendment process. One such license amendment was approved for Arkansas Nuclear One, Unit 1 in August 2004. The NRC based its approval of the license amendment request on the conclusion that the hydrogen monitors were not risk-significant. However, because the monitors are needed to diagnose the course of beyond-design-basis accidents, each licensee choosing this approach should verify that it has a hydrogen monitoring system capable of diagnosing beyond-design-basis accidents and make a regulatory commitment to maintain the system.

Section 50.44 requires that equipment used for monitoring hydrogen in containment is functional, reliable, and capable of continuously measuring the concentration of hydrogen in the containment atmosphere following a significant beyond-design-basis accident. The *Federal Register* notice for the § 50.44 final rule states that the NRC determined that the monitoring equipment need not be qualified in accordance with § 50.49 because the requirements found in § 50.44 address beyond-design-basis combustible gas control. As a result of the Fukushima lessons learned, the NRC also reviewed whether enhancements to reactor and containment instrumentation to withstand beyond-design-basis accident conditions were warranted. As documented in Enclosure 2 to SECY-16-0041, the NRC concluded that regulatory actions to require enhancements to reactor and containment instrumentation to support the response to severe accidents would not provide a substantial safety enhancement and, therefore, were not warranted.

Additionally, the NRC has revised the Reactor Oversight Process to address licensees' implementation and maintenance of severe accident management guidelines. The severe accident management guidelines are based on the concept of using available resources (including instrumentation) to mitigate a severe accident, such that if a key instrument is not available for any reason, alternate instruments are used. The instrumentation available that might be used before, during, and after a severe accident is discussed in Regulatory Guide 1.97, Revision 3, "Instrumentation for Light-Water Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident," licensing documents, severe accident management guidelines, and supporting technical guidance documents. The severe accident management guidelines include guidance to address hydrogen generation from metal-water reactions and actions to take to minimize the potential for containment failure from hydrogen combustion events.

The petitioner stated that effective and safe use of hydrogen igniters in ice condenser and BWR Mark III containments is a complex issue that requires thorough analysis, including consideration of the safety of using the igniters at certain times in a severe accident. The severe accident management guidelines for ice condenser and Mark III containments include guidelines for the use of the igniters.

Therefore, as it relates to issue 4 of the petition, the NRC concludes that the petitioner did not present sufficient new information or arguments to warrant the requested requirement in light of the NRC's relevant past decisions and current policies. The NRC determined that the analyses and plant changes requested by the petitioner in issue 4 of the petition would not provide substantial safety enhancements.

Issue 5: The petitioner requested that the NRC revise § 50.44 to "require that licensees of PWRs and [BWRs with Mark III containments] perform analyses that demonstrate containment structural integrity would be retained in the event of a severe accident." Additionally, the petitioner requested that the NRC revise § 50.44 to require licensees of Mark Is and Mark IIs to perform analyses "using the most advanced codes, which demonstrate containment structural integrity would be retained in the event of a severe accident."

Response to Issue 5: For large dry and sub-atmospheric PWR containments, § 50.44 does not require that containment structural integrity analysis is performed for hydrogen combustion events. Studies, including "Feasibility Study for a Risk-Informed Alternative to 10 CFR 50.44 'Standards for Combustible Gas Control System in Light-water cooled Power Reactors'" (Attachment 2 to SECY-00-0198), NUREG-1935, SECY-

16-0041 evaluations, and "State-of-the-Art Reactor Consequence Analysis Project - Uncertainty Analysis of the Unmitigated Short-Term Station Blackout of the Surry Power Station" (draft report), have indicated that these containments have very large internal volumes and are not predicted to fail until they reach about three times their design pressure. These studies also have determined that these containments have significant capacity for withstanding the pressure load associated with hydrogen deflagrations. Detonations of sufficient magnitude to cause failure of these types of containments were determined to have a low probability of occurrence.

In SECY-16-0041, the NRC determined that the longer times to over-pressurize large dry containments in long-term station blackout scenarios provides additional opportunities for emergency responders to restore key safety functions prior to the containment being breached. The low latent cancer fatality risks estimated in NUREG-1935 reflect the ability of large dry containments to limit the release of radioactive material for many hours. These estimates confirm the NRC's assessment of the adequacy of containment performance and finding that additional regulatory actions, such as requiring improved containment vents, are not warranted for large dry containments. Therefore, the staff concludes requiring licensees to perform detailed structural analysis of the containment using different or advanced codes (as the petitioner requested) to demonstrate that containment structural integrity would be retained in the event of a severe accident is not warranted.

For ice condenser and BWRs with Mark III containments, § 50.44(b)(5)(v)(A) requires demonstration of containment structural integrity by use of an analytical technique accepted by the NRC for hydrogen combustion events. The demonstration must include sufficient supporting justification to show that the technique describes the containment response to the structural loads involved. In SECY-16-0041, additional analyses performed by the NRC confirmed that hydrogen accumulation and potential combustion could challenge the integrity of these containments and showed the benefit of igniters to address this concern. Therefore, the NRC continues to find that the structural analysis associated with hydrogen deflagration events regarding the use of the igniters that is required by § 50.44(b)(5)(v)(A) is appropriate.

Further, the NRC concludes that the additional requirements proposed by the petitioner to use the most advanced codes, such as computational fluid dynamic codes, to model hydrogen distribution in the containment and loads from flame acceleration, are not required. In SECY-16-0041, the NRC assessed whether additional regulatory requirements, such as a hardened containment vent or additional hydrogen control and mitigation, were warranted for these containment types. The assessments, which used the best-estimate computer program MELCOR, concluded that sufficient safety margins exist between estimated plant risks that might be influenced by improvements in containment performance or hydrogen control and the NRC's quantitative health objectives described in the NRC's "Safety Goal Policy Statement." Therefore, because the requirements for existing structural analysis for these containment designs provide sufficient margin to ensure safety, the staff concluded that requiring licensees to continually update this structural evaluation using updated codes would not provide a substantial safety benefit and that no regulatory action is warranted.

For BWRs with Mark I and Mark II containments, § 50.44 does not require that containment structural integrity analysis be performed for hydrogen combustion events. Under § 50.44, BWR Mark I and Mark II primary containments are inerted. Because the primary containments are inerted, hydrogen combustion inside the primary containment is highly unlikely, rendering performance of primary containment structural analysis associated with hydrogen combustion events unnecessary. In addition, for BWR Mark I and Mark II containments, Order EA-13-109 requires the installation of reliable hardened containment vents capable of operation under severe accident conditions. In SECY-16-

0041, the technical analyses for Order EA-13-109 and NUREG-2206 show that the threat of explosions from combustible gasses in secondary containment is significantly reduced by effective venting strategies and that severe accident water addition/severe accident water management approaches are used as part of the implementation of Order EA-13-109.

Severe accident management guidelines also include specific measures to monitor and vent BWR Mark I and Mark II containments to address containment over-pressurization events and hydrogen issues. This provides further risk reduction by improving the control of hydrogen in BWR Mark I and Mark II containments. Using different or advanced codes (as the petitioner requested) to demonstrate that containment structural integrity would be retained in the event of a severe accident, is not necessary for these containment designs because: 1) hydrogen combustion events are highly unlikely in the primary containment given the inerted containment, 2) the severe accident hardened containment vents being installed in these primary containments reduce the already low likelihood of containment failure to levels below the levels where additional regulatory actions are warranted, and 3) as documented in SECY-16-0041, reduction of pressure in the primary containment using the severe accident capable hardened vents reduces the already low likelihood of secondary containment failure due to hydrogen combustion events to levels below where additional regulatory actions are warranted.

For new reactors, § 50.44(c) sets forth combustible gas control requirements for water-cooled nuclear power reactor designs licensed after 2003 with characteristics (e.g., type and quantity of cladding materials) such that the potential for production of combustible gases is comparable to light-water reactor designs licensed as of 2003. These requirements are more stringent than those for existing operating reactors. Section 50.44(c)(5) requires a structural analysis that demonstrates containment structural integrity. This demonstration must use an analytical technique accepted by the NRC and must include sufficient supporting justification to show that the technique describes the containment response to the structural loads involved. The analysis must address an accident that releases hydrogen generated from a 100 percent fuel clad coolant reaction accompanied by hydrogen burning. Systems necessary to ensure containment integrity must also be demonstrated to perform their function under these conditions. Therefore, for reactors licensed after 2003 with similar characteristics to current pressurized water reactors and Mark III boiling water reactors, the kind of structural analysis requested by the petitioner is already required.

Therefore, as it relates to issue 5 of the petition, the NRC concludes that the petitioner did not present sufficient new information or arguments to warrant the requested amendments in light of the NRC's relevant past decisions and current policies. The NRC determined that the analyses and plant changes for operating reactors requested by the petitioner in issue 5 of the petition would not provide substantial safety enhancements. For reactors licensed after 2003, for reasons stated in previous paragraphs, the NRC determined that changes to the requirements in § 50.44(c)(5) are not warranted. The NRC continues to conclude that the current design and licensing requirements for the control of hydrogen for operating and new reactors provide adequate protection of public health and safety.

Issue 6: The petitioner requested that the NRC revise § 50.44 to "require that licensees of PWRs with ice condenser containments and [BWRs with Mark III containments] (and any other NPPs that would operate with hydrogen igniter systems) perform analyses that demonstrate hydrogen igniter systems would effectively and safely mitigate hydrogen in different severe accident scenarios."

Response to Issue 6: In SECY-16-0041, the NRC's assessment concluded that hydrogen igniters would likely delay containment failures in ice condenser and BWR

Mark III containments. The NRC determined that additional improvements beyond those already included in NRC regulations and Order EA-12-049 would not provide a substantial safety improvement.

The NRC concluded that compliance with Order EA-12-049, as made generically applicable in 10 CFR 50.155, ensures that additional mitigation strategies are available for each operating reactor to reduce the risk of core damage from an extended loss of alternating current power event. The NRC has revised the reactor oversight process to cover licensees' implementation and maintenance of severe accident management guidelines. The severe accident management guidelines include guidance to address hydrogen generation in these containment designs and the use of the igniters to minimize the potential for containment failure from hydrogen detonation.

For new reactors, § 50.44(c) sets forth combustible gas control requirements for water-cooled nuclear power reactor designs licensed after 2003 that are more stringent than those requirements for existing operating reactors. As a result, new plants have design features such as hydrogen igniters for AP1000 design reactors. As described in SECY-16-0041, the NRC assessed potential further hydrogen control enhancements and found that such measures were not warranted. The NRC further notes that development of severe accident management guidelines, which include guidance for the use of the igniters to minimize the potential for containment failure for hydrogen detonation, is addressed by combined license holders for the AP1000 design in accordance with the AP1000 design certification.

Therefore, the NRC determined that the analyses and plant changes requested by the petitioner in issue 6 of the petition for existing operating reactors would not provide substantial safety enhancements. For reactors licensed after 2003, the NRC determined that changes to the requirements in § 50.44(c) are not needed for the reasons discussed. The NRC concludes that the current design and licensing requirements for the control of hydrogen for both operating and new reactors provide adequate protection of public health and safety.

III. Availability of Documents

The documents identified in the following table are available to interested persons through one or more of the following methods, as indicated.

DOCUMENT	ADAMS ACCESSION NO. / WEB LINK / *FEDERAL REGISTER* CITATION
Petition for rulemaking from the Natural Resources Defense Council, Inc., October 14, 2011.	ML11301A094
Federal Register notice, "Measurement and Control of Combustible Gas Generation and Dispersal," January 5, 2012.	77 FR 441
SECY-16-0041, "Closure of Fukushima Tier 3 Recommendations Related to Containment Vents, Hydrogen Control, and Enhanced Instrumentation," March 31, 2016.	ML16049A079 (Package)
SECY-11-0093, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," July 12, 2012.	ML11186A950 (Package)
Federal Register notice for the final rule, "Combustible Gas Control in Containment," September 16, 2003.	68 FR 54123
NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," December 1990.	ML120960691
NUREG-1935, "State-of-the-Art Reactor Consequence Analyses (SOARCA) Report," November 2012.	ML12332A053 (Package)
"Safety Goals for the Operations of Nuclear Power Plants; Policy Statement Correction and Republication," August 21, 1986.	ML011210381
Draft report "State-of-the-Art Reactor Consequence Analysis Project - Uncertainty Analysis of the Unmitigated Short-Term Station Blackout of the Surry Power Station," August 2015.	ML15224A001
NUREG/CR-7245, "State-of-the-Art Reactor Consequence Analyses (SOARCA) Project - Sequoyah Integrated	ML17340B209

Deterministic and Uncertainty Analyses," November 2017.	
NUREG/CR-7110, Vol. 2, "State-of-the-Art Reactor Consequence Analyses Project - Volume 2: Surry Integrated Analysis," January 2012.	ML120260681
Order EA-12-049, "Order Modifying Licenses With Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," March 12, 2012.	ML12054A735
Order EA-13-109, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions," June 6, 2013.	ML13130A067
SRM-SECY-15-0065, "Proposed Rulemaking: Mitigation of Beyond-Design-Basis Events (RIN 3150-AJ49)," August 27, 2015.	ML15239A767
SRM-SECY-16-0142, "Final Rule: Mitigation of Beyond-Design-Basis Events (RIN 3150-AJ49)," January 24, 2019.	ML19023A038
Federal Register notice, "Policy Statement on Severe Reactor Accidents Regarding Future Designs and Existing Plants," August 8, 1985.	50 FR 32138
NUREG/CR-7155, "State-of-the-Art Reactor Consequence Analyses Project - Uncertainty Analysis of the Unmitigated Long-Term Station Blackout of the Peach Bottom Atomic Power Station," May 2016.	ML16133A461
NUREG-2206, "Technical Basis for the Containment Protection and Release Reduction Rulemaking for Boiling Water Reactors with Mark I and Mark II Containments," March 2018.	ML18065A048
"Draft Regulatory Basis for Containment Protection and Release Reduction for Mark I and Mark II Boiling Water Reactors (10 CFR Part 50)," May 2015.	ML15022A214
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
SECY-00-0198, "Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR PART 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.44 (Combustible Gas Control)," September 14, 2000.	ML003747725 (Package)
NUREG-0737, "Clarification of TMI Action Plan Requirements," November 1980.	ML051400209
Regulatory Guide 1.7, Revision 3, "Control of Combustible Gas Concentrations in Containment," March 2007.	ML070290080
"Confirmatory Order Modifying Post-TMI Requirements Pertaining to Containment Hydrogen Monitors for Arkansas Nuclear One, Units 1 and 2 (TAC NOS. MA1267 and 1268)," September 28, 1998.	ML021270103

Federal Register notice, "Notice of Availability of Model Application Concerning Technical Specification Improvement to Eliminate Hydrogen Recombiner Requirement and Relax the Hydrogen and Oxygen Monitor Requirements for Light Water Reactors Using the Consolidated Line Item Improvement Process," September 25, 2003.	68 FR 55416
License amendment, "Arkansas Nuclear One, Unit 1, License Amendment 222 regarding Elimination of Requirements for Hydrogen Recombiners and Hydrogen Monitors," August 12, 2004.	ML042290464 (Package)
Regulatory Guide 1.97, Revision 3, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident," May 1983	ML003740282

IV. Conclusion

For the reasons cited in this document, the NRC is denying PRM-50-103. The petitioner did not present sufficient new information or arguments to warrant the requested requirements. The NRC continues to conclude that the current design and licensing requirements for the control of hydrogen for operating and new reactors provide adequate protection of public health and safety.

Dated at Rockville, Maryland, this 15th day of September, 2020.

For the Nuclear Regulatory Commission.

Annette L. Vietti-Cook,
Secretary of the Commission.

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