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CONTROL OF COMBUSTIBLE GAS CONCENTRATIONS IN CONTAINMENT

A. INTRODUCTION

The NRC has issued a proposed revision to Section 50.44, “Standards for Combustible Gas Control System in Light-Water-Cooled Power Reactors,” which will become an amendment to 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities.” This proposed regulation will be applicable to all construction permits or operating licenses under this part, and to all design approvals, design certifications, combined licenses or manufacturing licenses under 10 CFR Part 52, “Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants,” that are issued after the effective date of the rule. This regulatory guide is being developed to describe methods that would be acceptable to the NRC staff for implementing the proposed Section 50.44.

Regulatory guides are issued to describe to the public methods acceptable to the NRC staff for implementing specific parts of the NRC's regulations, to explain techniques used by the staff in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with regulatory guides is not required. Regulatory guides are issued in draft form for public comment to involve the public in developing the regulatory positions. Draft regulatory guides have not received complete staff review; they therefore do not represent official NRC staff positions.

The information collections contained in this draft regulatory guide are covered by the requirements of 10 CFR Part 50, which were approved by the Office of Management and Budget, approval number 3150-0011. If a means used to impose an information collection does not display a currently valid OMB control number, the NRC may not conduct or sponsor, and a person is not required to respond to, the information collection.

This regulatory guide is being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. It has not received complete staff review or approval and does not represent an official NRC staff position.

Public comments are being solicited on this draft guide (including any implementation schedule) and its associated regulatory analysis or value/impact statement. Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Rules and Directives Branch, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001. Comments may be submitted electronically or downloaded through the NRC’s interactive web site at <WWW.NRC.GOV> through Rulemaking. Copies of comments received may be examined at the NRC Public Document Room, 11555 Rockville Pike, Rockville, MD. Comments will be most helpful if received by **October 16, 2002.**

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B. DISCUSSION

The Proposed Section 50.44 provides requirements for the mitigation of combustible gas generated by a beyond-design-basis accident. In an accident more severe than the design-basis loss-of-coolant accident (LOCA), combustible gas is predominately generated within the containment as a result of:

1. Fuel clad-coolant reaction between the fuel cladding and the reactor coolant, and
2. Molten core-concrete interaction in a severe core melt sequence with a failed reactor vessel.

If a sufficient amount of hydrogen is generated, it may react with oxygen present in the containment at a rate rapid enough to lead to the breaching of the containment or a leakage rate in excess of technical specification limits. Additionally, damage to systems and components essential to continued control of the post-accident conditions could occur.

In 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)," dated September 14, 2000 (Ref. 1), the NRC staff recommended changes to 10 CFR 50.44 that reflect the position that only combustible gas generated by a beyond-design-basis accident is a risk-significant threat to containment integrity. Based on those recommendations, the proposed revision to 10 CFR 50.44 eliminates requirements that pertain to only design-basis LOCAs.

Attachment 2 to SECY-00-198 (Ref. 1) used the framework described in Attachment 1 to the paper with risk insights from NUREG-1150 (Ref. 2) and the integrated plant evaluation programs to evaluate the proposed requirements in 10 CFR 50.44. It was noted in Attachment 2 that containment types that rely on pressure suppression concepts (i.e., ice baskets or water pools) to condense the steam from a design-basis LOCA have smaller containment volumes, and in some cases lower design pressures, than pressurized water reactor (PWR) large-volume or subatmospheric containments. Consequently, the smaller volumes and lower design pressures associated with pressure suppression containment designs make them more vulnerable to hydrogen deflagrations during degraded core accidents because the pressure loads could cause structural failure of the containment. Also, because of the smaller volume of these containments, detonable mixtures could be formed. A detonation would impose a dynamic pressure load on the containment structure that could be more severe than the static load from an equivalent deflagration. However, the staff noted in SECY-00-0198 that the risk of early containment failure from hydrogen combustion in these types of containments can be limited by the use of mitigative features: (1) inerting in Mark I and II containments and (2) using igniter systems in Mark III and ice condenser containments. As a result, the proposed Section 50.44 has the following requirements:

1. All boiling water reactor (BWR) Mark I and II type containments must be inerted. By maintaining an oxygen-deficient atmosphere, hydrogen combustion that could threaten containment integrity is prevented.

2. All BWRs with Mark III type containments and all PWRs with ice condenser type containments must have the capability to control combustible gas generated from a metal-water reaction involving 75% of the fuel cladding surrounding the active fuel region (excluding the cladding surrounding the plenum volume) so that there is no loss of containment structural integrity. The deliberate ignition systems provided to meet this existing hydrogen source term are capable of safely accommodating even greater amounts of hydrogen associated with even more severe core melt sequences that fail the reactor vessel and involve molten core-concrete interaction. Deliberate ignition systems, if available, generally consume the hydrogen before it reaches concentrations that can be detrimental to containment integrity.

3. For all applicants for and holders of a construction permit or operating license under 10 CFR Part 50, and all applicants for a design approval, design certification, or combined license under 10 CFR Part 52 that are issued after the effective date of the rule, the following requirement applies. All containments must have an inerted atmosphere or limit hydrogen concentrations in containment during and following an accident that releases an equivalent amount of hydrogen as would be generated from a 100% fuel-clad coolant reaction, uniformly distributed, to less than 10% and must maintain containment structural integrity.

The combustible gas control systems, the atmosphere mixing systems, and the provisions for measuring and sampling that would be required by Section 50.44 are risk-significant as they have the ability to mitigate the risk associated with combustible gas generation caused by beyond-design-basis accidents. The recommended treatments for those systems are delineated in the Regulatory Position.

C. REGULATORY POSITION

1. COMBUSTIBLE GAS CONTROL SYSTEMS

For all construction permits or operating licenses under 10 CFR Part 50, and to all design approvals, design certifications, combined licenses, or manufacturing licenses under 10 CFR Part 52, that are issued after the effective date of the rule, the following design guidance is applicable to combustible gas control systems installed to mitigate the risk associated with combustible gas generation due to beyond design basis accidents. Structures, systems, and components (SSCs) installed to mitigate the hazard from the generation of combustible gas in containment should be designed to provide reasonable assurance that they will operate in the severe accident environment for which they are intended and over the time span for which they are needed. Equipment survivability expectations under severe accident conditions should consider the circumstances of applicable initiating events (such as station blackout[1] or earthquakes) and the

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[1] The Proposed Section 50.44 does not require the deliberate ignition systems used by BWRs with Mark III type containments and PWRs with ice condenser type containments to be available during station blackout events. The deliberate ignition systems should be available upon restoration of power. Additional guidance concerning the availability of deliberate ignition systems during station blackout sequences is being developed as part of the staff's review of Generic Safety Issue 189, "Susceptibility of Ice Condenser and Mark III Containments to Early Failure from Hydrogen Combustion During a Severe Accident."

environment (including pressure, temperature, and radiation) in which the equipment is relied upon to function. This guidance was contained in SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," dated April 2, 1993 (Ref. 3).

The required system performance criteria will be based on the results of design-specific reviews that include probabilistic risk-assessment as required by 10 CFR 52.47(a)(v). Because these requirements address beyond-design-basis combustible gas control, SSCs provided to meet these requirements need not be subject to the environmental qualification requirements of 10 CFR 50.49, quality assurance requirements of Appendix B to 10 CFR Part 50, and redundancy/diversity requirements of Appendix A to 10 CFR Part 50. Guidance such as that found in Appendices A and B of Regulatory Guide 1.155 (Ref. 4) is appropriate for equipment used to mitigate the consequences of severe accidents. This guidance was used to review the design of evolutionary and passive plant designs as documented in NUREG-1462 (Ref. 5), NUREG-1503 (Ref. 6), and NUREG-1512 (Ref. 7).

The combustible gas control systems in all BWRs with Mark III-type containments and all PWRs with ice condenser type containments must meet the requirements in the Proposed Section 50.44. The staff considers that the combustible gas control systems installed and approved by the NRC as of the effective date of the rule are acceptable without modification.

2. OXYGEN AND HYDROGEN MONITORS

2.1 Hydrogen Monitors

The Proposed Section 50.44 would require that equipment be provided for monitoring hydrogen in the containment. The equipment for monitoring hydrogen must be functional, reliable, and capable of continuously measuring the concentration of hydrogen in the containment atmosphere following a beyond-design-basis accident for accident management, including emergency planning. Safety-related hydrogen monitoring systems installed and approved by the NRC prior to the effective date of the rule are sufficient to meet these criteria. Non-safety-related commercial grade hydrogen monitors can also be used to meet these criteria if they:

1. Comply with the Category 3 design and qualification criteria of Regulatory Guide 1.97 (Ref. 8) for monitors used as diagnostic or backup indicators.

2. Comply with the Category 2 power source design and qualification criteria as specified in Table 1 of Regulatory Guide 1.97 (Ref. 8).

The above provisions can be met with a program based on compliance with a pre-specified, structured program of testing and calibration; alternatively, these items can be met with a less-prescriptive, performance-based approach to assurance of the hydrogen monitoring function. Such an approach is consistent with SECY-00-191, "High-Level Guidelines for Performance-Based Activities" (Ref. 9). Specifically, assurance of the reliability, availability, and capability of the hydrogen monitoring function can be derived through tracking actual reliability performance (including calibration) against targets established by the licensee based on the significance of this function, which is determined on a plant-specific basis. Thus, for hydrogen monitoring, it is acceptable to accomplish the functions of servicing, testing, and calibration within the maintenance rule program provided that applicable targets are established based on the functions of the hydrogen monitors delineated above.

Section 50.44 also requires that hydrogen monitors be functional. Functional requirements can be found in TMI Action Item II.F.1, Attachment 6, in NUREG-0737 (Ref. 10), 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 following the Three Mile Island Unit 2 accident. Since that requirement was issued, the staff has determined that 30 minutes can be overly burdensome. Through the "Confirmatory Order Modifying Post-TMI Requirements Pertaining to Containment Hydrogen Monitors for Arkansas Nuclear One, Units 1 and 2" (Ref. 11), dated September 28, 1998, the staff 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 these requirements:

i. Procedures shall be established for ensuring that indication of hydrogen concentration in the containment atmosphere is available in a sufficient 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.

ii. Hydrogen monitoring will be initiated on the basis of:

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

    (2) The use of the indication of hydrogen concentration by decision makers for severe accident management and emergency response.

    (3) 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 staff has found that adoption of this functional requirement by licensees results in the hydrogen monitors being functional within 90 minutes after the initiation of safety injection. This period of time includes equipment warm-up but not equipment calibration.

2.2 Oxygen Monitors

The Proposed Section 50.44 would require that equipment be provided for monitoring oxygen in containments that use an inerted atmosphere for combustible gas control. The proposed rule would require the equipment for monitoring oxygen to be functional, reliable, and capable of continuously measuring the concentration of oxygen in the containment atmosphere following a beyond design-basis accident for combustible gas control and accident management, including emergency planning. Safety-related oxygen monitoring systems installed and approved by the NRC prior to the effective date of the rule are sufficient to meet this criterion. Non-safety-related oxygen monitors would also meet these criteria if they meet the Category 2 design and qualification criteria of Regulatory Guide 1.97 (Ref. 8) for monitors designated for indicating system operating status.

3. ATMOSPHERE MIXING SYSTEMS

The Proposed Section 50.44 would require that all containments have a capability for ensuring a mixed atmosphere. This capability may be provided by an active, passive, or combination system. Active systems may consist of a fan, a fan cooler, or containment spray. For passive or combination systems that use convective mixing to mix the combustible gases, the containment internal structures should have design features that promote the free circulation of the atmosphere. All containment types should have an analysis of the effectiveness of the method used for providing a mixed atmosphere. This analysis should demonstrate that combustible gases will not accumulate within a compartment or cubicle to form a combustible or detonable mixture that could cause loss of containment integrity.

Atmosphere mixing systems prevent local accumulation of combustible or detonable gases that could threaten containment integrity or equipment operating in a local compartment. Active systems installed to mitigate this threat should be reliable, redundant, single-failure proof, able to be tested and inspected, and remain operable with a loss of onsite or offsite power. The NRC staff considers atmosphere mixing systems installed and approved by the NRC as of the effective date of the rule to be acceptable without modification.

4. HYDROGEN GAS PRODUCTION

Materials within the containment that would yield hydrogen gas by corrosion from the emergency cooling or containment spray solutions should be identified, and their use should be limited as much as practicable.

5. CONTAINMENT STRUCTURAL INTEGRITY

The Proposed Section 50.44 would require that containment structural integrity be demonstrated by use of an analytical technique that is accepted by the NRC staff. This demonstration 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 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. The following criteria of the ASME Boiler and Pressure Vessel Code provide an acceptable method for demonstrating that the requirements are met.

i. That steel containments meet the requirements of the ASME Boiler and Pressure Vessel Code (Edition and Addenda as incorporated by reference in 10 CFR 50.55a(b)(1)), Section III, Division 1, Subsubarticle NE - 3220, Service Level C Limits, considering pressure and dead load alone (evaluation of instability is not required); and

ii. That concrete containments meet the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Division 2, Subsubarticle CC - 3720, Factored Load Category, considering pressure and dead load alone.

These criteria, while being removed from the existing regulations, are acceptable to the NRC staff for meeting the proposed regulations. The acceptability of licensee analyses using the ASME Code criteria remains unaffected by this proposed rulemaking.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this draft regulatory guide.

This draft guide has been released to encourage public participation in its development. Except in those cases in which an applicant or licensee proposes an acceptable alternative method for complying with the specified portions of the NRC's regulations, the methods to be described in the active guide reflecting public comments will be used in the evaluation of submittals in connection with combustible gas concentrations in containment.

REFERENCES

1. 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.[2]

2. USNRC, “Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants,” NUREG-1150, December 1990.[3]

3. SECY-93-087, “Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-water Reactor (ALWR) Designs,” USNRC, April 2, 1993.[1]

4. USNRC, “Station Blackout,” Regulatory Guide 1.155, August 1988.[3]

5. USNRC, “Final Safety Evaluation Report Related to the Certification of the Advance Boiling Reactor Design,” NUREG-1462, August 1994.[2]

6. USNRC, “Final Safety Evaluation Report Related to the Certification of the System 80+ Design, Docket No. 52-002,” NUREG-1503, July 1994.[2]

7. USNRC, “Final Safety Evaluation Report Related to the Certification of the AP600 Standard Design, Docket No. 52-003,” NUREG-1512, September 1998.[2]

8. USNRC, “Instrumentation for Light-Water-Cooled Nuclear Power Plants To Assess Plant and Environs Conditions During and Following an Accident,” Regulatory Guide 1.97, Revision 3, May 1983.[4]

9. USNRC, "High-Level Guidelines for Performance-Based Activities," SECY-00-0191, September 1, 2000.[1]

10. USNRC, "Clarification of TMI Action Plan Requirements," NUREG-0737, November 1980.[2]

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[1] Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike (first floor), Rockville, MD; the PDR’s mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or 1-(800)397-4209; fax (301)415-3548; e-mail <PDR@NRC.GOV>.

[3] Copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202)512-1800); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161; <http://www.ntis.gov/ordernow>, telephone (703)487-4650; . Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR’s mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or (800)397-4209; fax (301)415-3548; email is PDR@NRC.GOV.

[4] Single copies of regulatory guides, both active and draft, and draft NUREG documents may be obtained free of charge by writing the Reproduction and Distribution Services Section, OCIO, USNRC, Washington, DC 20555-0001, or by fax to (301)415-2289, or by email to <DISTRIBUTION@NRC.GOV>. Active guides may also be purchased from the National Technical Information Service on a standing order basis. Details on this service may be obtained by writing NTIS, 5285 Port Royal Road, Springfield, VA 22161; telephone (703)487-4650; online <http://www.ntis.gov/ordernow>. Copies of active and draft guides are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR’s mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or (800)397-4209; fax (301)415-3548; email <PDR@NRC.GOV>.

11. USNRC, "Confirmatory Order Modifying Post-TMI Requirements Pertaining to Containment Hydrogen Monitors for Arkansas Nuclear One, Units 1 and 2," September 28, 1998.[1]

REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this guide. The draft regulatory analysis prepared for the revision to 10 CFR 50.44, “Standards for Combustible Gas Control System in Light-water-Cooled Power Reactors,” provides the regulatory basis for this guide and examines the costs and benefits for the rule as implemented by the guide. A copy of this regulatory analysis is available for inspection or copying for a fee in the NRC Public Document Room, located at 11555 Rockville Pike (first floor), Rockville, Maryland. This regulatory analysis is also available in the NRC’s Electronic Reading Room, in the ADAMS system, under Accession Number ML021080807.

BACKFIT ANALYSIS

This regulatory guide is being developed to describe a voluntary method that is acceptable to the NRC staff for complying with the requirements of 10 CFR 50.44, “Standards for Combustible Gas Control System in Light-water-Cooled Power Reactors.” Compliance with this regulatory guide is not a requirement, and a licensee may chose this or another way to achieve compliance with these rules. This regulatory guide does not require a backfit analysis as described in 10 CFR 50.109(c) because it does not impose a new or amended provision in the NRC’s rules or a regulatory staff position interpreting the NRC’s rules that is either new or different from a previous staff position; nor does it require the modification of or addition to systems, structures, components, or design of a facility, or the procedures or organization required to design, construct, or operate a facility.