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CONTROL OF COMBUSTIBLE GAS CONCENTRATIONS IN CONTAINMENT

A. INTRODUCTION

In September 2003, the U.S. Nuclear Regulatory Commission (NRC) issued a revision of Section 50.44, "Combustible Gas Control for Nuclear Power Reactors" (Ref. 1), which amended Title 10, Part 50, of the *Code of Federal Regulations* (10 CFR Part 50), "Domestic Licensing of Production and Utilization Facilities" (Ref. 2). This regulation is applicable to all reactor construction permits or operating licenses under 10 CFR Part 50, except for those facilities for which the certifications required under Section 50.82(a)(1) have been submitted, and to all reactor 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" (Ref. 3). This regulatory guide describes methods that are acceptable to the NRC staff for implementing the revised Section 50.44 for reactors, subject to the provisions of Sections 50.44(b) or 50.44(c).

This regulatory guide relates to information collections that are covered by the requirements of 10 CFR Parts 50 and 52, which the Office of Management and Budget (OMB) approved under OMB control numbers 3150-0011 and 3150-0151, respectively. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

B. DISCUSSION

Section 50.44 provides requirements for the mitigation of combustible gas generated by a beyond-design-basis accident. In existing light-water reactors, the principal combustible gas is hydrogen.

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 the following factors:

(1) fuel clad-coolant reaction between the fuel cladding and the reactor coolant

(2) molten core-concrete interaction in a severe core melt sequence with a failed reactor vessel

If a sufficient amount of combustible gas is generated, it may react with oxygen present in the containment at a rate rapid enough to lead to a containment breach 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)" (Ref. 4), 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 September 2003 revision of 10 CFR 50.44 eliminates requirements that pertain only to design-basis LOCAs.

Attachment 2 to SECY-00-0198 (Ref. 4) used the framework described in Attachment 1 to the paper with risk insights from NUREG-1150 (Ref. 5) and the integrated plant evaluation programs to evaluate the requirements in 10 CFR 50.44. In so doing, Attachment 2 noted 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 combustible gas 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 combustible gas 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 revised 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, combustible gas 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 combustible gas source term are capable of safely accommodating even greater amounts of combustible gas 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 combustible gas before it reaches concentrations that can be detrimental to containment integrity.

(3) For all applicants for and holders of a water-cooled reactor construction permit or operating license under 10 CFR Part 50, and all applicants for a light-water reactor design approval, or design certification, or combined license under 10 CFR Part 52 that are docketed after October 16, 2003, the effective date of the rule, the following requirements apply. All containments must have an inerted atmosphere or limit combustible gas concentrations in containment during and following an accident that releases an equivalent amount of combustible gas as would be generated from a 100% fuel-clad coolant reaction, uniformly distributed, to less than 10% (by volume) and must maintain containment structural integrity. The requirements of this paragraph apply only to water-cooled reactor designs 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 October 16, 2003.

(4) For all construction permits and operating licenses under 10 CFR Part 50, and all design approvals, design certifications, combined licenses, or manufacturing licenses under Part 52, for non-water-cooled reactors and water-cooled reactors that do not fall within the description in paragraph 3 (above), any of which are issued after October 16, 2003, applications subject to this paragraph must include the following:

 (a) information addressing whether accidents involving combustible gases are technically relevant for their design

 (b) if accidents involving combustible gases are found to be technically relevant, information demonstrating that the safety impacts of combustible gases during design-basis and significant beyond-design-basis accidents have been addressed to ensure adequate protection of public health and safety and common defense and security.

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

The hydrogen monitors should be able to assess the degree of core damage during a beyond-design-basis accident and confirm that random or deliberate ignition has taken place. Hydrogen monitors, in conjunction with oxygen monitors, are further relied on to implement severe accident management strategies to address a potential breach of containment integrity or to consider containment purging or venting.

C. REGULATORY POSITION

1. Combustible Gas Control Systems

The following design guidance is applicable to combustible gas control systems installed to mitigate the risk associated with combustible gas generation attributed 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 environment (including pressure, temperature, and radiation) in which the equipment is relied upon to function. This guidance was presented in SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs" (Ref. 6).

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). 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 to Regulatory Guide 1.155 (Ref. 7) 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. 8), NUREG-1503 (Ref. 9), and NUREG-1512 (Ref. 10).

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 Section 50.44. The staff considers that the combustible gas control systems installed and approved by the NRC as of October 16, 2003, are acceptable without modification.

2. Hydrogen and Oxygen Monitors

2.1 Hydrogen Monitors

Section 50.44 requires 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 October 16, 2003, are sufficient to meet these criteria. Non-safety-related commercial-grade hydrogen monitors can also be used to meet these criteria if they comply with the following criteria:

[1] 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."

(1) **Equipment Survivability:** The hydrogen monitoring equipment need not be qualified in accordance with 10 CFR 50.49. However, these systems are required to be functional, reliable, and capable of continuously measuring the appropriate parameter in the beyond-design-basis accident environment.

The evaluation of survivability should consider the effects of the post-accident environment for the specific type of facility and monitoring system design. The procurement for such equipment should address equipment reliability and operability in the beyond-design-basis accident environmental conditions for the specific facility and monitoring system design. Acceptable approaches for demonstrating equipment survivability are described in Chapter 19 of the ABWR FSER (Ref. 9) and the AP1000 FSER (Ref. 11).

(2) **Power Source:** The instrumentation should be energized from a high-reliability power source, not necessarily standby power, and should be backed up by batteries where momentary interruption is not tolerable.

(3) **Quality Assurance:** The instrumentation should be of high-quality commercial grade and should be selected to withstand the specified service environment.

(4) **Display and Recording:** The instrumentation signal may be displayed on an individual instrument or it may be processed for display on demand.

If direct and immediate trend or transient information is essential for operator information or action, the recording should be continuously available on redundant dedicated recorders. Otherwise, it may be continuously updated, stored in computer memory, and displayed on demand. Intermittent displays such as data loggers and scanning recorders may be used if no significant transient response information is likely to be lost by such devices.

(5) **Range:** If two or more instruments are needed to cover a particular range, overlapping of instrument span should be provided. If the required range of monitoring instrumentation results in a loss of instrumentation sensitivity in the normal operating range, separate instruments should be used.

(6) **Servicing, Testing, and Calibration:** Servicing, testing, and calibration programs should be specified to maintain the capability of the monitoring instrumentation. If the required interval between testing is less than the normal time interval between plant shutdowns, a capability for testing during power operation should be provided.

Whenever means for removing channels from service are included in the design, the design should facilitate administrative control of the access to such removal means.

The design should facilitate administrative control of the access to all setpoint adjustments, module calibration adjustments, and test points.

Periodic checking, testing, calibration, and calibration verification should be in accordance with the applicable portions of Regulatory Guide 1.118, "Periodic Testing of Electric Power and Protection Systems" (Ref. 12), pertaining to testing of instrument channels. (Note: Response time testing not usually needed.)

(7) **Human Factors:** The instrumentation should be designed to facilitate the recognition, location, replacement, repair, or adjustment of malfunctioning components or modules.

The monitoring instrumentation design should minimize the development of conditions that would cause meters, annunciators, recorders, alarms, etc., to give anomalous indications potentially confusing to the operator. Human factors analysis should be used in determining the type and location of displays.

To the extent practicable, the same instruments should be used for accident monitoring as are used for the normal operations of the plant to enable the operators to use, during accident situations, instruments with which they are most familiar.

(8) **Direct Measurement:** To the extent practicable, monitoring instrumentation inputs should be from sensors that directly measure the desired variables. An indirect measurement should be made only when it can be shown by analysis to provide unambiguous information.

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-00-0191, "High-Level Guidelines for Performance-Based Activities" (Ref. 13). 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 Three Mile Island (TMI) Action Plan Item II.F.1, Attachment 6, in NUREG-0737 (Ref. 14), 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 accident at TMI Unit 2. Since that requirement was issued, the staff has determined that the 30-minute requirement 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. 15), 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 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 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

Section 50.44 requires that equipment be provided for monitoring oxygen in containments that use an inerted atmosphere for combustible gas control. The revised rule requires 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. Existing oxygen monitoring systems approved by the NRC prior to October 16, 2003, are sufficient to meet these criteria. Non-safety-related oxygen monitors would also meet these criteria if they comply with the following provisions:

(1) **Equipment Survivability:** The oxygen monitoring equipment need not be qualified in accordance with 10 CFR 50.49. However, these systems are required to be functional, reliable, and capable of continuously measuring the appropriate parameter in the beyond-design-basis accident environment.

The evaluation of survivability should consider the effects of the post-accident environment for the specific type of facility and monitoring system design. The procurement for such equipment should address equipment reliability and operability in the beyond-design-basis accident environmental conditions for the specific facility and monitoring system design. Acceptable approaches for demonstrating equipment survivability are described in Chapter 19 of the ABWR FSER (Ref. 9) and the AP1000 FSER (Ref. 11).

(2) **Power Source:** The instrumentation should be energized from a high-reliability power source, not necessarily standby power, and should be backed up by batteries where momentary interruption is not tolerable.

(3) **Channel Availability:** The out-of-service interval should be based on normal technical specification requirements on out of service for the system it serves where applicable or where specified by other requirements.

(4) **Quality Assurance:** The recommendations of the following regulatory guides pertaining to quality assurance should be followed:

- Regulatory Guide 1.28, "Quality Assurance Program Requirements (Design and Construction)" (Ref. 16)
- Regulatory Guide 1.30, "Quality Assurance Requirements for the Installation, Inspection, and Testing of Instrumentation and Electric Equipment" (Ref. 17)
- Regulatory Guide 1.33, "Quality Assurance Program Requirements (Operation)" (Ref. 18)
- Regulatory Guide 1.176, "An Approach for Plant-Specific, Risk-Informed Decisionmaking: Graded Quality Assurance" (Ref. 19)

(5) **Display and Recording:** The instrumentation signal may be displayed on an individual instrument or it may be processed for display on demand.

If direct and immediate trend or transient information is essential for operator information or action, the recording should be continuously available on redundant dedicated recorders. Otherwise, it may be continuously updated, stored in computer memory, and displayed on demand. Intermittent displays such as data loggers and scanning recorders may be used if no significant transient response information is likely to be lost by such devices.

(6) **Range:** If two or more instruments are needed to cover a particular range, overlapping of instrument span should be provided. If the required range of monitoring instrumentation results in a loss of instrumentation sensitivity in the normal operating range, separate instruments should be used.

(7) **Interfaces:** The transmission of signals for other use should be through isolation devices that are designated as part of the monitoring instrumentation and that meet the provisions of the criteria presented here.

(8) **Servicing, Testing, and Calibration:** Servicing, testing, and calibration programs should be specified to maintain the capability of the monitoring instrumentation. If the required interval between testing is less than the normal time interval between plant shutdowns, a capability for testing during power operation should be provided.

Whenever means for removing channels from service are included in the design, the design should facilitate administrative control of the access to such removal means.

The design should facilitate administrative control of the access to all setpoint adjustments, module calibration adjustments, and test points.

Periodic checking, testing, calibration, and calibration verification should be in accordance with the applicable portions of Regulatory Guide 1.118, "Periodic Testing of Electric Power and Protection Systems," (Ref. 12) pertaining to testing of instrument channels. (Note: Response time testing not usually needed.)

The location of the isolation device should be such that it would be accessible for maintenance during accident conditions.

(9) **Human Factors:** The instrumentation should be designed to facilitate the recognition, location, replacement, repair, or adjustment of malfunctioning components or modules.

The monitoring instrumentation design should minimize the development of conditions that would cause meters, annunciators, recorders, alarms, etc., to give anomalous indications potentially confusing to the operator. Human factors analysis should be used in determining the type and location of displays.

To the extent practicable, the same instruments should be used for accident monitoring as are used for the normal operations of the plant to enable the operators to use, during accident situations, instruments with which they are most familiar.

(10) **Direct Measurement:** To the extent practicable, monitoring instrumentation inputs should be from sensors that directly measure the desired variables. An indirect measurement should be made only when it can be shown by analysis to provide unambiguous information.

3. Atmosphere Mixing Systems

Section 50.44 requires 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.[2]

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 October 16, 2003, to be acceptable without modification.

References 20 through 23 provide important insights into the potential for detonation of hydrogen-air mixtures.

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

Section 50.44 requires 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 following criteria of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Ref. 24) provide an acceptable method for demonstrating that the requirements are met:

(1) 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).

(2) 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.

As a minimum, the specific code requirements set forth for each type of containment should be met for a combination of dead load and an internal pressure of 45 psig. The staff will consider modest deviations from these criteria, if the applicant shows good cause.

These criteria, which no longer are contained in Section 50.44, remain acceptable to the NRC staff for meeting the current regulations. The acceptability of licensee analyses using the ASME Code criteria remains unaffected by this rulemaking.

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[2] The NRC staff believes that current lumped parameter analytical codes may overestimate mixing processes (in particular, natural convection). Applicants should substantiate the applicability of these codes to their analyses through sensitivity studies, validation with data, or other means.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide. No backfitting is intended or approved in connection with the issuance of this guide.

Except in those cases in which an applicant or licensee proposes or has previously established an acceptable alternative method for complying with the specified portions of the NRC's regulations, the NRC staff will use the methods described in this guide to evaluate (1) submittals in connection with applications for construction permits, standard plant design certifications, operating licenses, early site permits, and combined licenses; and (2) submittals from operating reactor licensees who voluntarily propose to initiate system modifications that have a clear nexus with the subject for which guidance is provided herein.

REGULATORY ANALYSIS / BACKFIT ANALYSIS

A separate regulatory analysis was not prepared for this guide. The regulatory analysis prepared for the revision of 10 CFR 50.44, "Standards for Combustible Gas Control System in Light-Water-Cooled Power Reactors" (Ref. 25), provides the regulatory basis for this guide and examines the costs and benefits for the rule as implemented by this guide.

The backfit analysis for this regulatory guide is available in Draft Regulatory Guide DG-1117, "Control of Combustible Gas Concentrations in Containment" (Ref. 26). The NRC issued DG-1117 in August 2002 to solicit public comment on the draft of this Revision 3 of Regulatory Guide 1.7.

REFERENCES

1. *Federal Register*, "Combustible Gas Control in Containment," Volume 68, No. 179, pp. 54123–54142, U.S. Nuclear Regulatory Commission, Washington, DC, September 16, 2003.[3]

2. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission, Washington, DC.[4]

3. 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC.[4]

4. 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)," U.S. Nuclear Regulatory Commission, Washington, DC, September 14, 2000.[5]

5. NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC, December 1990.[6]

6. SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," U.S. Nuclear Regulatory Commission, Washington, DC, April 2, 1993.[5]

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[3] All *Federal Register* notices listed herein were issued by the U.S. Nuclear Regulatory Commission, and are available electronically through the Federal Register Main Page of the public GPOAccess Web site, which the U.S. Government Printing Office maintains at http://www.gpoaccess.gov/fr/index.html. In addition, 68 FR 54123 is available electronically through the Electronic Reading Room on the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/cfr/fr/2003/20030916.pdf. Copies are also available for inspection or copying for a fee from the NRC's 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.

[4] All NRC regulations listed herein are available electronically through the Public Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/cfr/. Copies are also available for inspection or copying for a fee from the NRC's 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.

[5] All Commission papers (SECYs) listed herein were published by the U.S. Nuclear Regulatory Commission, and are available electronically through the Public Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/commission/secys/. Copies are also available for inspection or copying for a fee from the NRC's 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.

[6] 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 (NTIS) by writing NTIS at 5285 Port Royal Road, Springfield, Virginia 22161, online at http://www.ntis.gov, by telephone at (800) 553-NTIS (6847) or (703)605-6000, or by fax to (703) 605-6900. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR), which is located at 11555 Rockville Pike, Rockville, Maryland; the PDR's mailing address is USNRC PDR, Washington, DC 20555-0001. The PDR can also be reached by telephone at (301) 415-4737 or (800)397-4209, by fax at (301)415-3548, and by email to PDR@nrc.gov. In addition, NUREG-0737 and NUREG-1793 are available electronically through the Electronic Reading Room on the NRC's Public Web site http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/.

7. Regulatory Guide 1.155, "Station Blackout," U.S. Nuclear Regulatory Commission, Washington, DC.[7]

8. NUREG-1462, "Final Safety Evaluation Report Related to the Certification of the System 80+ Design, Docket No. 52-002" U.S. Nuclear Regulatory Commission, Washington, DC, August 1994.[6]

9. NUREG-1503, "Final Safety Evaluation Report Related to the Certification of the Advanced Boiling-Water Reactor Design, Docket No. 52-001," U.S. Nuclear Regulatory Commission, Washington, DC, July 1994.[6]

10. NUREG-1512, "Final Safety Evaluation Report Related to the Certification of the AP600 Standard Design, Docket No. 52-003," U.S. Nuclear Regulatory Commission, Washington, DC, September 1998.[6]

11. NUREG-1793, "Final Safety Evaluation Report Related to the Certification of the AP1000 Standard Design, Docket No. 52-006," U.S. Nuclear Regulatory Commission, Washington, DC, September 2004.[6]

12. Regulatory Guide 1.118, "Periodic Testing of Electric Power and Protection Systems," U.S. Nuclear Regulatory Commission, Washington, DC.[7]

13. SECY-00-0191, "High-Level Guidelines for Performance-Based Activities," U.S. Nuclear Regulatory Commission, Washington, DC, September 1, 2000.[5]

14. NUREG-0737, "Clarification of TMI Action Plan Requirements," U.S. Nuclear Regulatory Commission, Washington, DC, November 1980.[6]

15. "Confirmatory Order Modifying Post-TMI Requirements Pertaining to Containment Hydrogen Monitors for Arkansas Nuclear One, Units 1 and 2," U.S. Nuclear Regulatory Commission, Washington, DC, September 28, 1998.[8]

16. Regulatory Guide 1.28, "Quality Assurance Program Requirements (Design and Construction)," U.S. Nuclear Regulatory Commission, Washington DC.[7]

17. Regulatory Guide 1.30, "Quality Assurance Requirements for the Installation, Inspection, and Testing of Instrumentation and Electric Equipment," U.S. Nuclear Regulatory Commission, Washington, DC.[7]

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[7] All regulatory guides listed herein were published by the U.S. Nuclear Regulatory Commission or its predecessor, the U.S. Atomic Energy Commission. Most are available electronically through the Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/reg-guides/. Single copies of regulatory guides may also be obtained free of charge by writing the Reproduction and Distribution Services Section, ADM, USNRC, Washington, DC 20555-0001, 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 (NTIS). Details may be obtained by contacting NTIS at 5285 Port Royal Road, Springfield, Virginia 22161, online at http://www.ntis.gov, by telephone at (800) 553-NTIS (6847) or (703) 605-6000, or by fax to (703) 605-6900. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR), which is located at 11555 Rockville Pike, Rockville, Maryland; the PDR's mailing address is USNRC PDR, Washington, DC 20555-0001. The PDR can also be reached by telephone at (301) 415-4737 or (800) 397-4209, by fax at (301) 415-3548, and by email to PDR@nrc.gov.

[8] Copies are available electronically through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under Accession #ML021270103.

18. Regulatory Guide 1.33, "Quality Assurance Program Requirements (Operation)," U.S. Nuclear Regulatory Commission, Washington, DC.[7]

19. Regulatory Guide 1.176, "An Approach for Plant-Specific, Risk-Informed Decisionmaking: Graded Quality Assurance," U.S. Nuclear Regulatory Commission, Washington, DC.[7]

20. NUREG/CR-4905, "Detonability of H-Air-Diluent Mixtures," prepared by Sandia National Laboratory for the U.S. Nuclear Regulatory Commission, Washington, DC, June 1987.[6]

21. NUREG/CR-4961, "A Summary of Hydrogen-Air Detonation Experiments," prepared by Sandia National Laboratory for the U.S. Nuclear Regulatory Commission, Washington, DC, June 1987.[6]

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9 Copies may be purchased from the American Society of Mechanical Engineers, Three Park Avenue, NewYork, NY 10016-5990; phone (212) 591-8500; fax (212) 591-8501; www.asme.org.

10 This regulatory analysis is available electronically under Accession #ML031640482 in the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, and through the Public Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2003/secy2003-0127/2003-0127scy.pdf#pagemode=bookmarks. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR), which is located at 11555 Rockville Pike, Rockville, Maryland; the PDR's mailing address is USNRC PDR, Washington, DC 20555-0001. The PDR can also be reached by telephone at (301) 415-4737 or (800) 397-4209, by fax at (301) 415-3548, and by email to PDR@nrc.gov.

11 Draft Regulatory Guide DG-1117 is available electronically under Accession #ML022210067 in the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR), which is located at 11555 Rockville Pike, Rockville, Maryland; the PDR's mailing address is USNRC PDR, Washington, DC 20555-0001. The PDR can also be reached by telephone at (301) 415-4737 or (800) 397-4209, by fax at (301) 415-3548, and by email to PDR@nrc.gov.