



DRAFT REGULATORY GUIDE

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DRAFT REGULATORY GUIDE DG-1187

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CONCRETE RADIATION SHIELDS AND GENERIC SHIELD TESTING FOR NUCLEAR POWER PLANTS

A. INTRODUCTION

As stated in Title 10, Section 20.1201 (Ref. 1), "Occupational Dose Limits for Adults," of the *Code of Federal Regulations* (10 CFR 20.1201), licensees shall control the occupational dose to individual adults to the limits stated therein. Furthermore, 10 CFR 20.1101(b) provides that licensees shall use, to the extent practicable, procedures and engineering controls based upon sound radiation principles to achieve occupational doses and doses to members of the public that are as low as reasonably achievable. General Design Criterion 1, "Quality Standards and Records," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 (Ref. 2), "Domestic Licensing of Production and Utilization Facilities," requires that structures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 requires that measures be established to ensure design control and inspection and test controls. Appendix B also requires that activities affecting quality be accomplished under suitably controlled conditions. This guide describes a method acceptable to the NRC staff for complying with the regulations with regard to the design and construction of concrete radiation shields in nuclear power plants.

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to

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 final staff review or approval and does not represent an official NRC final 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 Rulemaking, Directives, and Editing Branch, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001; e-mailed to nrcprep.resource@nrc.gov; submitted through the NRC's interactive rulemaking Web page at <http://www.nrc.gov>; faxed to (301) 415-5144; or hand-delivered to the Rulemaking, Directives, and Editing Branch, Office of Administration, U.S. NRC, 11555 Rockville Pike, Rockville, Maryland 20852, between 7:30 a.m. and 4:15 p.m. on Federal workdays. Copies of comments received may be examined at the NRC's Public Document Room, 11555 Rockville Pike, Rockville, MD. Comments will be most helpful if received by January 9, 2009.

Electronic copies of this draft regulatory guide are available through the NRC's interactive rulemaking Web page (see above); the NRC's public Web site under Draft Regulatory Guides in the Regulatory Guides document collection of the NRC's Electronic Reading Room at <http://www.nrc.gov/reading-rm/doc-collections/>; and the NRC's Agencywide Documents Access and Management System (ADAMS) at <http://www.nrc.gov/reading-rm/adams.html>, under Accession No. ML082190117.

applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required.

This regulatory guide contains information collection requirements covered by 10 CFR Parts 20 and 50 that the Office of Management and Budget (OMB) approved under OMB control numbers 3150-0014 and -0011, 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

Subcommittee ANS-6, Radiation Protection and Shielding, of the American Nuclear Society (ANS) developed a standard prescribing requirements and recommendations pertaining to calculation methods and concrete shielding data for determining the required concrete thickness for radiation shielding in nuclear power plants. The American National Standards Institute (ANSI) published this standard in the American Nuclear Society's ANSI/ANS-6.4-2006, "Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants" (Ref. 3). The standard also discusses aggregates, design of concrete mixtures and placement, reinforcing steel, and general effects of heat exposure on structural characteristics (thermal and mechanical properties) and on attenuation characteristics of the concrete shield. Structural requirements and considerations for concrete radiation shields are outside the scope of this standard.

Technical Committee 349, Concrete Nuclear Structures, of the American Concrete Institute (ACI 349) developed ACI 349-06, "Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary" (Ref. 4), prescribing the minimum standards for design and construction of nuclear safety-related concrete structures and structural members for nuclear power generating stations. The design and loading conditions considered in this standard, including thermal and seismic effects and impact and impulsive loads, are unique to nuclear facilities. ACI 349 has also published a companion committee report, ACI 349.1R-07, "Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures" (Ref. 5), outlining specific guidelines for considering thermal effects, including the effect of gradient temperature distribution on the structural design of reinforced concrete frames and axisymmetric shells. The design guidelines prescribed in ACI 349.1R-07 conform to the standards specified in Appendix E, "Thermal Consideration," to ACI 349-06. The structural design procedures prescribed by ACI 349-06 and ACI 349.1R-07 are based on a strength design method and are applicable when the concrete surface temperature is less than 150 °F (66 °C), under long-term normal operation conditions, or less than 350 °F (177 °C) under short-term accidental conditions. At higher temperatures, ACI 349-06 states that the concrete should be tested to evaluate the reduction in strength, and that this reduction should be applied to the design of the concrete.

Working Group ANS 6-3 of the American Nuclear Society Standards Committee, developed a standard, "Standard Program for Testing Biological Shielding in Nuclear Reactor Plants, N 18.9-1972." This document was endorsed in the NRC's Regulatory Guide 2.1, "Shield Test Program for the Evaluation of Installed Biological Shielding in Research and Training Reactors." N 18.9-1972 was revised in late 1973 and designated ANS-6.3.1. It was approved in 1980 as American National Standard Program for Testing Radiation Shields in Light Water Reactors (LWR), revised as ANS-6.3.1-1987 and subsequently reaffirmed (R2007), on April 20, 2007 (Ref. 6).

C. REGULATORY POSITION

The NRC has generally endorsed the standards and recommended practices contained in ANSI/ANS-6.4-2006, ACI 349-06, and ACI 349.1R-07 as acceptable for the construction of radiation shielding structures of hot laboratories, radiochemical plants, experimental facilities, nuclear fuel fabrication plants, and the shielding structures for nuclear power plants, with a few exceptions. Section C.1 lists specific guidelines for combined use of the above standards in the design and construction of the concrete radiation shields for nuclear power plants. Section C.2 lists the specific provisions of the above standards that the NRC has not endorsed. Section C.3 endorses ANSI/ANS-6.3.1-1987; R2007 which describes a test program to be used in evaluating biological radiation shielding in nuclear reactor facilities under normal operating conditions including anticipated operational occurrences.

1. Guidelines for Use of ANSI/ANS-6.4-2006, ACI 349-06, and ACI 349.1R-07

- a. The minimum thickness of concrete radiation shields, based on radiation shielding requirements, should be determined using the following approach:
 - (1) Use ANSI/ANS-6.4-2006, Chapters 6, 7, and 8 as an overview of the historic calculation methodology for concrete radiation shields.
 - (2) Use the Monte Carlo technique for radiation shielding calculations (e.g., Richard H. Olsher, "A Practical Look at Monte Carlo Variance Reduction Methods in Radiation Shielding") (Ref. 7).
 - (3) Use the latest version of the software for radiation shielding calculations, i.e., MCNP Monte Carlo Team, X-5, (Ref. 8). The concrete composition input parameters for the MCNP5 calculations should correspond to the specific concrete used for the radiation shields.
- b. Minimum thickness of concrete radiation shields, based on structural requirements, and other structural dimensions and reinforcement requirements should be determined in accordance with the provisions of ACI 349-06 and ACI 349.1R-07 for applicable normal loads, severe and extreme environmental loads, and abnormal loads as defined in Section 9.1 of ACI 349-06.
- c. The final minimum thickness of a concrete shield structure should be the greater of the following two values:
 - (1) Thickness determined based on radiation shielding requirements in accordance with Regulatory Position C.1.a.
 - (2) Thickness determined based on structural requirements in accordance with Regulatory Position C.1.b.
- d. Load and strength reduction factors for structural design of concrete shield structures and related members should be based on those prescribed in ACI 349-06, Sections 9.2 and 9.3, respectively.
- e. Design of concrete for shielding structures, including materials selection, durability requirements, quality control, mixing, placement, formwork, embedded pipes, construction joints, reinforcement, analysis and design, should conform to provisions outlined in Chapters 3 through 8 of ACI 349-06.

2. Exceptions for Use of ACI 349-06, and ACI 349.1R-07

ACI 349-06, Section 1.2.2, states that input and output should be retained as documentation when software is used for the calculation. The software itself and other related documentation should be retained as well.

The NRC does not endorse the following sections of ACI 349-06:

- a. Section 3.3.1: The exception portion of the section.
- b. Section 3.3.2: “These limitations may be waived if, in the judgment of the engineer, workability and methods of consolidation are such that concrete can be placed without honeycombs or voids.”
- c. Section 5.4.1: “If data required by 5.3 are not available, concrete proportions shall be based on other experience or information, if approved by the engineer. The required average compressive strength $f_{c'}$ of concrete produced with materials similar to those proposed for use shall be at least 1200 psi greater than f_c . This alternative shall not be used if f_c is greater than 5000 psi.”
- d. Section 5.6.2.3: “When total quantity of a given class of concrete is less than 50 yd³, strength tests may be waived by the engineer if the engineer has been provided adequate evidence of satisfactory strength.” Instead, follow the provisions of regulatory position 5 of regulatory guide 1.142, “Safety Related Concrete Structures for Nuclear Power Plants,” (Ref. 9) for strength testing.
- e. Section 7.10.3: “It shall be permitted to waive the lateral reinforcement requirements of 7.10, 10.16, and 18.11 where tests and structural analysis show adequate strength and feasibility of construction.”
- f. Section 8.6.1: “Use of any set of reasonable assumptions shall be permitted for computing relative flexural and torsional stiff-nesses of columns, walls, floors, and roof systems. The assumptions adopted shall be consistent throughout analysis.”

3. Radiation Shield Test Programs

The NRC endorses the standard ANSI/ANS-6.3.1-1987; R2007, “Program for Testing Radiation Shields in Light Water Reactors (LWR)” for the testing of radiation shields. The standard describes a test program to be used in evaluating biological radiation shielding in nuclear reactor facilities under normal operating conditions including anticipated operational occurrences.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC’s plans for using this draft regulatory guide. The NRC does not intend or approve any imposition or backfit in connection with its issuance.

The NRC has issued this draft guide to encourage public participation in its development. The NRC will consider all public comments received in development of the final guidance document. In some cases, applicants or licensees may propose an alternative or use a previously established acceptable method for complying with specified portions of the NRC’s regulations. Otherwise, the methods described in this guide will be used in evaluating compliance with the applicable regulations for license applications, license amendment applications, and amendment requests.

REGULATORY ANALYSIS

The NRC staff did not prepare a separate regulatory analysis for this regulatory guide. The regulatory basis for this guide is the regulatory analysis (NUREG/BR-0184) prepared for 10 CFR Part 20, "Standards for Protection Against Radiation," promulgated May 21, 1991. That regulatory analysis examined the costs and benefits of the rule as implemented by this guide. A copy of the regulatory analysis is available for inspection and may be copied (for a fee) at the NRC Public Document Room, located at One White Flint North, 11555 Rockville Pike, Rockville, Maryland 20852.

REFERENCES

1. 10 CFR Part 20, “Standard for Protection Against Radiation,” U.S. Nuclear Regulatory Commission, Washington, DC.
2. 10 CFR Par 50, “Licensing of Production and Utilization Facilities,” U.S. Nuclear Regulatory Commission, Washington, DC.
3. ANSI/ANS-6.4-2006, “Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants,” American National Standards Institute, La Grange Park, IL, 2006.
4. ACI 349-06, “Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary,” American Concrete Institute, Farmington Hills, MI, 2007.
5. ACI 349.1R-07, “Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures,” American Concrete Institute, Farmington Hills, MI, 2007.
6. ANSI/ANS-6.3.1-1987; R2007, “Program for Testing Radiation Shields in Light Water Reactors (LWR),” American National Standards Institute, La Grange Park, IL, 2006.
7. Olsher, Richard H., “A Practical Look at Monte Carlo Variance Reduction Methods in Radiation Shielding,” *Nuclear Engineering and Technology*, Vol. 38, No. 3, April 2006, pp. 225–230.
8. MCNP Monte Carlo Team, X-5, “MCNP5_RSICC_1.30, LA-UR-04-5921,” Los Alamos National Laboratory, Los Alamos, NM, 2004.
9. Regulatory Guide 1.142, “Safety Related Concrete Structures for Nuclear Power Plants.”