



REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 1.69

(Draft was issued as DG-1187, dated November 2008)

CONCRETE RADIATION SHIELDS AND GENERIC SHIELD TESTING FOR NUCLEAR POWER PLANTS

A. INTRODUCTION

Regulatory Guide 1.69 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. Also, it encompasses applicable material previously endorsed in Regulatory Guide 2.1, "Shield Test Program for the Evaluation of Installed Biological Shielding in Research and Training Reactors." Regulatory Guide 2.1 is outdated and it will be withdrawn.

As stated in Title 10, Section 20.1201, "Occupational Dose Limits for Adults," of the *Code of Federal Regulations* (10 CFR 20.1201) (Ref. 1), U.S. Nuclear Regulatory Commission (NRC) 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 protection 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, "Domestic Licensing of Production and Utilization Facilities" (Ref. 2), 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.

The NRC issues regulatory guides to describe and make available to the public methods that the NRC staff considers acceptable for use in implementing specific parts of the agency's regulations, techniques that the staff uses in evaluating specific problems or postulated accidents, and data that the staff needs in reviewing applications for permits and licenses. Regulatory guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions that differ from those set forth in regulatory guides will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

This guide was issued after consideration of comments received from the public.

Regulatory guides are issued in 10 broad divisions—1, Power Reactors; 2, Research and Test Reactors; 3, Fuels and Materials Facilities; 4, Environmental and Siting; 5, Materials and Plant Protection; 6, Products; 7, Transportation; 8, Occupational Health; 9, Antitrust and Financial Review; and 10, General.

Electronic copies of this guide and other recently issued guides are available through the NRC's public Web site under the Regulatory Guides document collection of the NRC's Electronic Reading Room at <http://www.nrc.gov/reading-rm/doc-collections/> and through the NRC's Agencywide Documents Access and Management System (ADAMS) at <http://www.nrc.gov/reading-rm/adams.html>, under Accession No. ML090820425.

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 3150-0011, 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. BACKGROUND

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 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 the 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 degrees Fahrenheit (F) (66 degrees Celsius (C)), under long-term normal operating conditions, or less than 350 degrees F (177 degrees C) under short-term accidental conditions. However, ACI 349-06 states that, at higher temperatures, 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 ANS Standards Committee developed a standard, “Standard Program for Testing Biological Shielding in Nuclear Reactor Plants, N 18.9-1972.” The NRC endorsed this document in Regulatory Guide 2.1. Standard N 18.9-1972 was revised in late 1973 and designated ANS-6.3.1. It was approved in 1980 as “ANSI/ANS 6.3.1-1980, “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

ANSI/ANS-6.4-2006, ACI 349-06, and ACI 349.1R-07 are 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 the 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. Applicant's referencing shielding codes other than the Los Alamos MCNP computer code must provide a justification to the NRC as to why these other codes represent an acceptable alternative shielding code to the MCNP computer code. The latest versions of codes which have been approved by the NRC are available through the Radiation Safety Information Computational Center (RSICC), Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6171.
- b. The 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 the 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. The design of the 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 data should be retained as documentation when software is used for the calculation. The software itself and other related documentation should be retained as well. It is not required that the software be updated regularly.

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

- a. Section 3.3.1: The exception portion of the section is not endorsed.
- 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.”

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 testing 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 regulatory guide. The NRC does not intend or approve any imposition or backfit in connection with its issuance.

In some cases, applicants or licensees may propose or use a previously established acceptable alternative 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.

REFERENCES ¹

1. 10 CFR Part 20, “Standards for Protection Against Radiation,” U.S. Nuclear Regulatory Commission, Washington, DC.²
2. 10 CFR Part 50, “Domestic 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. R.H. Olsher, “A Practical Look at Monte Carlo Variance Reduction Methods in Radiation Shielding,” *Nuclear Engineering and Technology*, Volume 38, No. 3, pp. 225–230, April 2006.
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 (Other Than Reactor Vessels and Containments),” U.S. Nuclear Regulatory Commission, Washington, DC, available electronically through the NRC’s Agencywide Documents Access and Management System (ADAMS), (<http://www.nrc.gov/reading-rm/adams.html>), under Accession No. ML082680089.

¹ Copies of the non-NRC documents included in these references may be obtained directly from the publishing organizations.

² 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; e-mail pdr.resource@nrc.gov.