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REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 1.136
(Task SC 814-5)

MATERIALS, CONSTRUCTION, AND TESTING OF CONCRETE CONTAINMENTS (Articles CC-1000, -2000, and -4000 through -6000 of the "Code for Concrete Reactor Vessels and Containments"[1])

A. INTRODUCTION

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," requires, in part, that structures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 requires, in part, that measures be established to ensure materials control and control of special processes, such as welding, and that proper testing be performed.

This guide describes bases acceptable to the NRC staff for implementing the above requirements with regard to the materials, construction, and testing of concrete containments.

The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

B. DISCUSSION

The American Society of Mechanical Engineers and the American Concrete Institute have jointly published the "Code for Concrete Reactor Vessels and Containments,"[1] which is referred to in this guide as the Code. The Code was formally issued for the first time in 1975, was reissued in 1977, and again in 1980. This revision to the guide endorses the following articles of the 1980 edition of the Code:

CC-1000, Introduction,
CC-2000, Material,
CC-4000, Fabrication and Construction,
CC-5000, Construction, Testing, and Examination, and
CC-6000, Structural Integrity Test of Concrete Containment Structures.

Consideration will be given to referencing the Code in the Code of Federal Regulations after sufficient experience has been accumulated with its use. In the interim, the NRC staff will set forth its position on the acceptability of the Code for licensing purposes in regulatory guides.

The NRC staff has evaluated the provisions contained in the articles listed above, but has made no attempt to coordinate all literature (standards, codes, guidelines, regulations, etc.) that may be relevant to the subject of this guide.

The referenced Code incorporates the recommendations of several regulatory guides in an acceptable manner. Hence, with the issuance of this revision to Regulatory Guide 1.136, the regulatory guides listed below will be withdrawn:

1.10 Mechanical (Cadweld) Splices in Reinforcing Bars of Category I Concrete Structures,

1.15 Testing of Reinforcing Bars for Category I Concrete Structures,

1.18 Structural Acceptance Test for Concrete Primary Reactor Containments,

1.19 Nondestructive Examination of Primary Containment Liner Welds,

1.55 Concrete Placement in Category I Structures, and

*The substantial number of changes in this revision from the October 1978 issue has made it impractical to indicate the changes with lines in the margin.

[1]The "Code for Concrete Reactor Vessels and Containments" is also known either as the ASME Boiler and Pressure Vessel Code, Section III, Division 2, 1980 Edition, or as ACI Standard 359-80. Copies of the Code and addenda thereto may be obtained from the American Society of Mechanical Engineers, United Engineering Center, 345 E. 47th Street, New York, New York 10017, or the American Concrete Institute, Box 19150, Detroit, Michigan 48219.

1.103 Post-tensioned Prestressing Systems for Concrete Reactor Vessels and Containments.

Because the Code provisions continue to change, the NRC staff plans to periodically update this guide to accommodate new and revised provisions of the Code.

In those areas where the provisions of the referenced Code are insufficient for licensing purposes, the staff has provided supplementary guidelines it considers to be needed. These guidelines are contained in the regulatory position. Brief reasons for recommending them are given below.

1. CC-2232.2(a) - Strength Tests[2]

The average strength of a design mix based on mean rather than maximum allowable values of air content and slump is not conservative relative to standard building construction practice. The limits in Regulatory Position C.1 are taken from Section 4.4.2 of ACI Standard 318-77, "Building Code Requirements for Reinforced Concrete."[3]

2. CC-2243 - Cement Grout for Grouted Tendon Systems

Regulatory Position C.2 recommends using the guidance in Regulatory Guide 1.107, "Qualification for Cement Grouting for Prestressing Tendons in Containment Structures," rather than paragraph CC-2243 with respect to grouting of prestressing tendons. The staff believes that the guide recommendations provide needed assurance for the integrity of grouted tendons that cannot be directly inspected during the life of the containment.

3. CC-2433.2.3 - Acceptance Standards

Experience with the use of alloy steel materials for anchor blocks and wedge blocks (such as AISI 4140) indicates that a high degree of hardness of these materials is a factor in causing cracking (presumably stress-corrosion) under certain inevitable environments. Also it is necessary to control the uniformity of hardness of these materials. A thorough surface examination and proper protection before and after installation of these materials and a close control in the amount and uniformity of hardness in these materials may eliminate cracking.

4. Protection of Prestressing Materials from Low-Temperature Effects

The testing of prestressing materials to qualify them against loss in ductility during cold temperatures is needed; therefore, the guidance in Regulatory Position C.4 is recommended.

5. CC-2441(g) - Tendon Ducts, Channels, Trumpets, and Transition Cones

Subparagraph CC-2441(g) addresses only the susceptibility of ducts to leakage under pressure. However, duct joints are more susceptible to leakage under pressure than the ducts. The recommended prequalification of ducts and duct joints in Regulatory Position C.5 would eliminate the potential for grease (or grout) leakage under maximum pressures.

6. CC-2463.1 - Static Tensile Test

Different systems of prestressing may require different numbers of tests for tendon systems to establish their adequacy for use. Variations within the tolerance limits of the construction specification in material properties and in geometry of anchorages and tendons must be realistically and adequately represented in the system testing. Therefore, Regulatory Position C.6 recommends that any system of prestressing be subjected to a sufficient number of tests to establish its adequacy before it is adopted for use.

7. CC-4240 - Curing

The 1980 version of the Code eliminates a specific requirement for curing concrete at temperatures higher than 40°F. The guide recommendation is in accordance with ACI 308-71, "Recommended Practice for Curing Concrete."[3]

8. CC-4333 4.2 - Splice Samples

The 1980 edition of the Code, in CC-4333.4.3, requires only a production-splice testing program, while the previous program permitted production- and sister-splice testing. As a result, CC-4333.4.2 now contradicts CC-4333.4.3. Regulatory Position C.8 provides guidance consistent with the requirements of CC-4333.4.3.

9. CC-4352 - Splices

Mechanical splices are considered to be weak links in the performance of reinforcing bars. Thus, staggering of mechanical splices in areas of high stress is being reemphasized in order to avoid a concentration of splices on one plane in such areas that may result in (1) unacceptable cracking and (2) increased steel congestion that has adverse effects on concrete placement. In addition, this recommendation is consistent with ACI 349-76, "Code Requirements for Nuclear Safety-Related Concrete Structures."[3]

10. CC-4454.1 - Procedure

The common practice in post-tensioning, as adopted by the American Concrete Institute (Section 18.18 of ACI 318-77), is to allow the discrepancy level of ±5% instead of the ±10% allowed by the Code. The guide recommendation is for ±5%.

[2] This alphanumeric citing identifies the article, and paragraph if applicable, of the "Code for Concrete Reactor Vessels and Containments" being discussed.

[3] Copies may be obtained from the American Concrete Institute, Box 19150, Detroit, Michigan 48219.

11. CC-4522.1 - Tolerances for Liner Shells and Heads

The non-mandatory guidelines of Appendix F to the Code are acceptable to the NRC staff although some of the guidelines are relaxed from the previous requirements of the 1977 edition of the Code.

Appendix F, paragraph F-1220(c), establishes non-cumulative plumbness tolerances for liner shells. Cumulative tolerances may be controlled in most cases by the out-of-roundness tolerances of paragraph F-1220(a). However, to ensure that a maximum cumulative plumbness tolerance is established for different containment configurations, an explicit recommendation is provided in Regulatory Position C.11.

12. CC-5210 - General

The locations of all major embedments, such as plates, embedded piping penetration sleeves, major structural framings, and anchor bolts, should be preplanned, identified on the design drawings, and documented on field changes thereto. This would permit verification that embedments have been placed with full consideration given to the resulting reduction in structural strengths, radiation shielding effectiveness, and hindrance to the placement and consolidation of concrete.

13. CC-6214 - Retest

The second sentence of CC-6214 permits the licensee the option of doing nothing even after studies have been made that indicate that acceptance criteria (c) and (d) of CC-6213 were still not met. The need to select one of the followup options in paragraph CC-6214 is defined in Regulatory Position C.13.

C. REGULATORY POSITION

The requirements specified in Articles CC-1000, -2000, and -4000 through -6000 of the "Code for Concrete Reactor Vessels and Containments," ASME Boiler and Pressure Vessel Code, Section III, Division 2, 1980 Edition, (also known as ACI Standard 359-80) are acceptable to the NRC staff for the materials, construction, and testing of concrete containments of nuclear power plants subject to the following:

1. CC-2232.2(a) - Strength Tests

When following the requirements in the second sentence of CC-2232.2(a), the word "maximum" should be used for the word "mean" whenever it appears, and "±0.75 in." should be used instead of "±0.75%."

2. CC-2243 - Cement Grout for Grouted Tendon Systems

Regulatory Guide 1.107, "Qualification for Cement Grouting for Prestressing Tendons in Containment Structures," should be used for guidance on qualifying grout for grouted tendon systems.

3. CC-2433.2.3 - Acceptance Standards

In addition to the requirements in subparagraph CC-2433.2.3, the following guidance should be used:

"The maximum hardness for material of anchor head assemblies and wedge blocks shall not exceed that of Rockwell C40. To maintain uniformity in hardness, the tolerance on a designated hardness number shall not exceed ±2."

4. Protection of Prestressing Materials from Low-Temperature Effects

In addition to the requirements in CC-2434, "Wedges and Anchor Nuts," the following guidance should be used:

"Materials for all load-bearing components of prestressing systems should be selected so that they can withstand the anticipated low-temperature effects without loss in their ductility. Methods and procedures similar to those used for materials of liners in CC-2520, 'Fracture Toughness Requirements for Materials,' are acceptable for qualifying the materials. Additionally, it should be demonstrated by suitable tests that with the maximum allowable flaw size (cracked buttonheads, wedges, and anchor nuts), the specific components will exhibit the required strength and ductility under the lowest anticipated temperatures."

5. CC-2441(g) - Tendon Ducts, Channels, Trumpets, and Transition Cones

Instead of "CC-2441(g) Ducts ...," the following should be used:

"CC-2441(g) Ducts and duct joints ...."

6. CC-2463.1 - Static Tensile Test

Instead of "CC-2463.1 Static Tensile Test. Two or more static tensile tests...," the following should be used:

"CC-2463.1 Static Tensile Tests. Static tensile tests...."

Any system of prestressing should be subjected to a sufficient number of tests to establish its adequacy. Justification that a sufficient number of tests have been performed as well as a description of the test program should be submitted to the NRC for review and approval.

7. CC-4240 - Curing

In addition to the requirements for curing concrete in subsubarticle CC-4240(d), the following guidance should be used:

"When the mean daily outdoor temperature is 40°F or higher, the minimum period of curing should be 7 days after placing concrete."

8. CC-4333.4.2 - Splice Samples

Instead of the requirements in subparagraph CC-4333.4.2, the following guidance should be used:

"Splice samples shall be production splices (cut directly from in-place reinforcement)."

9. CC-4352 - Splices

In addition to the requirements in paragraph CC-4352, the following guidance should be used:

"Mechanical splices located in areas of high stresses (maximum computed tensile stress $\geq 0.5\ F_y$) should have alternate bars spliced or adjacent splices staggered. If tests for slip (or internal plastic deformation) of the splice demonstrate that the slip is low (i.e., not to exceed 50% of the elongation of the unspliced bar along the spliced length), at $0.9\ F_y$, the adjacent splices need not be staggered."

10. CC-4464.1 - Procedure

Discrepancies of elongation of tendons should not exceed "±5%" of the discrepancies calculated instead of the "±10%" as discussed in the last two sentences of subparagraph CC-4464.1.

11. CC-4522.1 - Tolerances for Liner Shells and Heads

The NRC staff will use the guidelines of the non-mandatory Appendix F to the Code for the purpose of review and inspection.

A maximum cumulative deviation of the liner shell plumbness of 6" or a 1 in 200 ratio, whichever is less, should be used.

12. CC-5210 - General

The requirements of CC-5210 should be supplemented by an inspection to ensure that only those embedments shown on the design drawings (except minor embedments such as rebar supports and form ties), or covered by documented field changes and later placed on the as-built drawings, remain in the form after the concrete is placed. Additionally, the inspection should ensure that hollow tubes and pipe sections used as support systems or for other construction convenience, if left embedded in the concrete, are filled with concrete or grout as appropriate.

13. CC-6214 - Retest

There are two options permitted by the Code in the phrase in the second sentence of CC-6214 "...remedial measures may be undertaken or a retest may be conducted..."; one should be selected if the requirements of CC-6213(c) and (d) are not met.

D. IMPLEMENTATION

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

Except in those cases in which an applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used in the evaluation of the following applications that are docketed after May 1981.

1. Preliminary Design Approval (PDA) applications and Preliminary Duplicate Design Approval (PDDA) applications.

2. Final Design Approval, Type 2, (FDA-2) applications and Final Duplicate Design Approval, Type 2, (FDDA-2) applications.

3. Manufacturing License (ML) applications.

4. Construction Permit (CP) applications except for those portions of CP applications that reference standard designs (i.e., PDA, FDA-1, FDA-2, PDDA, FDDA-1, FDDA-2, or ML) or that reference qualified base plant designs under the replication option.