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CONSTRUCTION RULES, PRESERVICE INSPECTION RULES, AND NUCLEAR SAFETY

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ABSTRACT

Construction of nuclear sites is an important topic, as governments and utilities are seeking to decarbonize. The rules governing construction and preservice examination play a vital role in providing stakeholder confidence that safety-related nuclear components will perform their intended function under normal operating and accident conditions. Construction rules provide sound fabrication procedures, while preservice examination provides an important verification step prior to placing the finished component into service. This paper reviews the construction and preservice examination rules for U.S. nuclear plants and discusses how they interact.

Keywords: Construction, Preservice Inspection

1. INTRODUCTION

In the U.S., the regulations addressing construction of nuclear components are found in Title 10 of the Code of Federal Regulations, Part 50.55a (10 CFR 50.55a) [1]. The U.S. Nuclear Regulatory Commission (NRC) incorporates by reference the American Society of Mechanical Engineers Boiler and Pressure Vessel Code Section III (Section III), "Rules for Construction of Nuclear Facility Components" [2-3]. As part of the licensing process in the U.S., applicants for construction permits must establish which edition of Section III they will comply with in the design specifications.

Similarly, the NRC incorporates by reference the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section XI (Section XI), Division 1, "Rules for Inspection and Testing of Components of Light-Water-Cooled Plants" in 10 CFR 50.55a [4]. While many of the rules of Section XI apply after initial plant startup, the preservice inspection rules have implications for Owner activities in the design and construction phases. This paper explores the interdependencies of Sections III and XI.

Finally, licensing requirements also play an important role in governing Owner responsibilities during design and construction of nuclear power plants. Regulations and Code requirements interact and complement each other. In some cases, regulatory requirements may override Code requirements, such as conditions placed on Section III in 10 CFR 50.55a(b)(1) [1]. Given these complexities, this paper holistically explores a range of requirements that govern Owner activities during the design and construction phases.

The fact that the rules for construction and examination of nuclear components in the U.S. stem from a variety of sources leads to complexity in interpreting the requirements. Efficient construction and commissioning of nuclear sites necessitates a common understanding of the requirements among all stakeholders. As such, this paper seeks to clarify the requirements and elucidate how the requirements contribute to nuclear safety and stakeholder confidence.

2. ASME SECTION III CONSTRUCTION REQUIREMENTS

Section III is divided in several subsections, mostly corresponding to component classification:

- Subsection NCA – General Requirements
- Subsection NB – Class 1 Components
- Subsection NCD – Class 2 and 3 Components
- Subsection NE – Class MC Components
- Subsection NF – Supports
- Subsection NG – Core Support Structures

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This paper draws upon on the requirements of Subsections NCA and NB to illustrate the overall process of nuclear design and construction according to Section III.

2.1 Certificates of Authorization

NCA-3211.4 requires both an Owner and an organization intending to construct items that require an ASME Certification Mark to obtain a Certificate of Authorization. The Owner and the Certificate Holder are then responsible for various provisions in ASME BPV Code Section III. The Certificate Holder is authorized to apply the ASME Certification Mark to a component manufactured in accordance with the rules of Section III. NCA-8120 provides additional details on Certificates. The Certificate types issued by ASME are classified according to the component and are summarized in Table NCA-8100-1 [2].

2.2 ASME Certification Mark

The ASME Certification Mark is a stamp that signifies that the component has been constructed in compliance with all the relevant provisions of ASME BPV Code Section III. Such provisions include all pressure test requirements and nondestructive examination requirements. The stamp is applied to a nameplate affixed to the component.

2.3 Reports

NCA-1200 requires that various documents be written for each nuclear component. For example, the requirements for the Design Specification are described in NCA-3211.19. NCA-8400 specifies that Data Reports be signed by the Certificate Holder or the Owner. The N-5 Data Report is filled out by the Certificate Holder certifying that nuclear plant components were assembled or installed in accordance with the requirements of Section III. The N-3 Data Report, on the other hand, is filled out by the Owner certifying that components installed at the facility comply with the requirements of Section III and are stamped by the appropriate Certificate Holder (see NCA-8420) [2].

2.4 Examinations and Tests

Examination and testing are an integral part of ASME BPV Code Section III construction rules. NCA-8310(a) states, "…the Certification Mark shall not be applied until completion of the required examination and testing." Further, NCA-8321 states, "The Certification mark with the N Designator shall be applied…after the pressure test requirements have been satisfied and all other examinations, tests, and inspections have been satisfactorily completed" [2].

The complete set of examination and test requirements may be found in different articles of Sections III and XI and may depend upon the component being constructed. One example is NB-5210 regarding Category A Vessel Welded Joints, which includes axial shell welds in vessels. NB-5210 requires examination with a volumetric technique along with either liquid penetrant or magnetic particle. Endnote 16 of Subsection NB further clarifies that a radiographic examination is required to meet volumetric examination requirement. NB-5280 further states, "Examinations required by NCA-3211.19(b)(3) shall be completed prior to completion of the N-5 Data Report."

NCA-3200 describes various responsibilities of the Certificate Holder. NCA-3211.19(b) requires that the Design Specification identify components that require a preservice examination and the Edition of Section XI the preservice examination will comply with. When Section III uses the words "preservice examination," the context is always examinations performed according to Section XI. While Section III is not explicit about which components require a Section XI preservice examination, Section XI and 10 CFR 50.55a(g) describe which components receive preservice examination. Therefore, Section III invokes the preservice examination rules of Section XI as part of the required examinations and tests to be performed prior to applying the Certification Mark [3-4].

2.5 Flaw Acceptance

In Article NB-5300, Section III provides rules on flaw acceptance so that the Owner or Certificate Holder can appropriately disposition fabrication flaws discovered during the required examinations and tests. NB-5320 and -5330, for example, describe volumetric examination acceptance standards for examinations performed under Article NB-5200. For preservice examinations (i.e., those examinations performed in accordance with Section XI), NB-5332 states that flaws exceeding the standards of Section XI IWB-3000 "are not acceptable for service and shall be repaired" [3-4]. For U.S. plants, 10 CFR 50.55a(b)(2)(xli) prohibits the use of analytical evaluation for the acceptance of flaws found during preservice examination [1].

3. ASME SECTION XI PRESERVICE EXAMINATION REQUIREMENTS

While Section III invokes Section XI, Section XI itself provides rules for preservice examinations. IWB-2200 states that all examinations required by Table IWB-2500-1 shall be completed prior to plant startup. Therefore, all components subject to the inservice examination requirements of Section XI should also receive a preservice examination. IWB-3110 states that preservice examination results shall be compared to the acceptance standards specified in IWB-3112. IWB-3131 states that volumetric and surface examination results shall be compared with recorded results of the preservice examination and with results of prior inservice examinations [4].

The preservice examination rules of Section XI do not just apply to new construction. They apply to repair/replacement activities, as well. Specifically, IWA-4530 states that, when items requiring preservice or inservice inspection are repaired or replaced, the Owner must comply with the applicable preservice examination requirement (e.g., IWB-2200) [4].

Section XI, Table IWB-2500-1, requires a volumetric examination technique [4]. U.S. licensees employ the ultrasonic technique to satisfy this requirement because it does not restrict personnel access, thereby allowing maintenance activities to continue, and is efficient in detecting service induced flaws. Therefore, in combination with the radiography technique employed to satisfy Section III construction requirements, the manufactured component receives examination from two diverse nondestructive examination methods. Further discussion of the benefits of each examination method will be discussed below. The Section XI flaw acceptance rules associated with the preservice examination provide an objective, formalized process the Owner must go through to demonstrate adequate structural integrity of newly installed items. With such rules in place, various stakeholders have confidence that the Owner is making decisions that are compatible with nuclear safety. Without such rules in place, these decisions would be left up to individual Owners, leading to inconsistency across reactor fleets and eroded stakeholder trust.

4. LICENSING AND TRANSITION FROM SECTION III TO SECTION XI

Within its regulations (e.g., 10 CFR 50.55a(g)(3)(ii)), the NRC requires that ASME Code components must meet the preservice inspection requirements in Section III and Section XI of the ASME Code incorporated by reference in 50.55a and be applied to the construction of a particular component. Through a rulemaking process of “incorporation by reference,” the NRC approves or mandates the use of certain parts of editions of these ASME Codes in § 50.55a. The NRC's use of the ASME Codes is consistent with the National Technology Transfer and Advancement Act of 1995, Public Law 104–113 (NTTAA), which directs Federal agencies to adopt voluntary consensus standards instead of developing “government-unique” (i.e., Federal agency-developed) standards, unless otherwise impractical.

According to the forgoing discussion, the rules governing construction activities are found in both Section III and Section XI. This situation may lead to confusion on when the Owner and Certificate Holder are governed by the rules of Section III and when they are governed by the rules of Section XI. This question is inherently tied to the licensing process under which the facility is built and operated. U.S. rules for licensing nuclear power plants are found in 10 CFR 50 and 10 CFR 52 [1].

4.1 10 CFR 50

10 CFR 50 is the regulation governing NRC’s licensing process for nuclear power reactors. Part 50 is a two-step process, where the NRC issues a construction permit that allows the applicant to construct the facility but not operate it. The construction permit is later converted to an operating license, subject to applicant actions and Commission approval (e.g., submission and approval of the facility’s final safety analysis report). The rules of Section III primarily govern under the construction permit, and the rules of Section XI primarily govern under the operating license. However, some rules of Section XI must be satisfied during construction because Section III references Section XI. The Owner and the Certificate Holder are responsible for ensuring that all the rules of Section III are met, including Section XI PSI requirements as referenced by Section III, prior to applying the Certification Mark and certifying the N-3 and N-5 data reports. Once the components are fabricated and installed in the system, including the applicable nondestructive examination under Section III, the rules of Section XI may be applied prior to issuing the operating license.

4.2 10 CFR 52

10 CFR 52 was promulgated by the NRC on April 18, 1989 [5] with the aim of accommodating light water reactor designs with passive emergency cooling systems under development at the time. 10 CFR 52 allows for standard design certifications, which multiple applicants can reference without the need for separate regulatory review of standardized design aspects. This licensing process consists of a single combined construction and operating license, in contrast to the two-step process of 10 CFR 50. This process requires inspections, tests, and acceptance criteria (ITAAC), which provide a process that ensures the facility is constructed according to all the applicable requirements under the license (e.g., ASME requirements).

After the ITAAC are complete, including the ITAAC that the components meet the requirements of Section III, the Commission makes a finding under 10 CFR 52.103(g) that the ITAAC are met, allowing the licensee to load fuel and operate the facility. This finding by the Commission provides a natural break point to distinguish when the rules of Section III end and the rules of Section XI take effect. While Section III is governing up to the finding under 10 CFR 52.103(g), some rules of Section XI must also be satisfied at this time, since Section III references Section XI. The Owner and the Certificate Holder are responsible for ensuring that all the rules of Section III are met, including Section XI PSI requirements as referenced by Section III, prior to applying the Certification Mark and certifying the N-3 and N-5 data reports. This process is visually represented by the flowchart in the Appendix.

5. DISPOSITION OF EXAMINATION RESULTS AND NUCLEAR SAFETY

Radiographic and ultrasonic examination methods are fundamental to ensuring that nuclear components are structurally sound when installed and remain so throughout the service life. Depending upon the exact component being constructed, Section III may require a volumetric examination and liquid penetrant or magnetic particle surface examination (e.g., NB-5210). In the U.S., the volumetric examination method employed during construction is radiography. The Section XI PSI requirements, on the other hand, allow use of the ultrasonic examination method.

NUREG/CR-7204 provides information on the physics associated with radiography and ultrasonic examination methods, as well as their differences in capabilities [6]. Based on these differences, each method is better suited to a specific flaw type. Radiography has a particular strong ability to detect and characterize non-planar or volumetric flaws such as porosity and slag, while ultrasonic examination is better suited to detect planar flaw, such as cracks. As stated previously, radiography is typically performed during construction of a component in accordance with Section III and examines the entire volume of the weld and the adjacent base material for fabrication flaws. However, the PSI examination using Section XI only exams the inner diameter (inner one-third) of the weld volume and its heat affected zone, concentrating on detecting surface connected cracks that typically occur during service. Over the years, ultrasonic techniques and procedures have been developed to concentrate on inner diameter to detect inservice degradation (planar flaws) at the inner diameter of piping in lieu of the entire weld volume. Since most construction flaws are volumetric and not crack-like, radiography is better at characterizing and determining the acceptability of these types of construction flaws. On the other hand, flaws detected by ultrasonic techniques are difficult to characterize in order to meet the Section III acceptance criteria.

Since radiography and ultrasonic examination methods use different physics principles, and each has its own strengths, these two methods are considered complementary, rather than interchangeable. Therefore, it is possible that a planar defect is missed during the Section III examination but found during the PSI examination. However, Section XI requires that a flaw found during PSI be dispositioned according to the acceptance standards and therefore provides a substantial benefit to nuclear safety, since the diverse methods employed at each stage are complementary.

The dispositioning of both the Section III and Section XI examinations assures that the fabricated component does not contain deleterious flaws and is capable of performing its safety function. As discussed above, the construction examination using radiography, and the PSI examination using ultrasonic provide complementary assurance that the welds do not contain flaws that exceed the ASME Code acceptance criteria as approved and modified by the regulation in 50.55a. However, there are some interpretations that once a PSI examination has been completed, components that contain indications identified during PSI (ultrasonic examination) that do not meet the acceptance standards of ASME Code Section XI IWB-3500, can be placed in service if the weld has been examined and found to be acceptable in accordance with ASME Section III required fabrication examination (radiography). This is interpretation is also based on the premise that the PSI examination is only for providing a baseline for future inservice examinations. While PSI examinations does provide a baseline for future inservice examinations, it also provides assurance that the components will be able to perform their intended safety function while also meeting all of the ASME Code requirements as specified by 10 CFR 50.55a(g).

In order to verify that the components have been constructed in accordance with ASME Code, Section III, documentation such as data reports must exist that demonstrates that relevant indications from PSI (both planar and non-planar) have been evaluated and found acceptable for service or repaired. Therefore, a weld cannot be determined to have been constructed to the requirements of ASME Code, Section III until all required PSI has been performed and all relevant indications from the PSI have been dispositioned as acceptable for service or repaired to ensure the components has been constructed as designed and can enter operation safely. Therefore, PSI must be performed, flaws must be evaluated, and unacceptable flaws found during PSI must be removed or repaired to ensure the structural integrity of safety-related components so that the components can perform their intended safety function.

6. CONCLUSIONS

Compliance with consensus codes and standards fosters consistency among various Owners and confidence among stakeholders. Through compliance, Owner decisions regarding structural integrity of nuclear components are governed by objective criteria established independently of the Owner, rather than Owner-controlled processes. The use of complimentary examination techniques assures nuclear safety through detection of a variety of flaw types that may impact structural integrity of safety-related nuclear components. As such, the licensing, regulatory, Section III, and Section XI requirements holistically provide formalized, objective rules to demonstrate the structural integrity of newly constructed components.

REFERENCES

[1] Code of Federal Regulations, Title 10, “Energy.”

[2] ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Facility Components, Subsection NCA, "General Requirements for Division 1 and Division 2," American Society of Mechanical Engineers, 2023 Edition.
[3] ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Facility Components, Division 1, Subsection NB, "Class 1 Components," American Society of Mechanical Engineers, 2023 Edition.
[4] ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, Division 1, "Rules for Inspection and Testing of Components of Light-Water-Cooled Plants," American Society of Mechanical Engineers, 2023 Edition.
[5] Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Reactors, 54 Federal Register 15,372 (April 18, 1989).
[6] NUREG/CR-7204, "Applying Ultrasonic Testing in Lieu of Radiography for Volumetric Examination of Carbon Steel Piping," U.S. Nuclear Regulatory Commission, September 2015.

APPENDIX

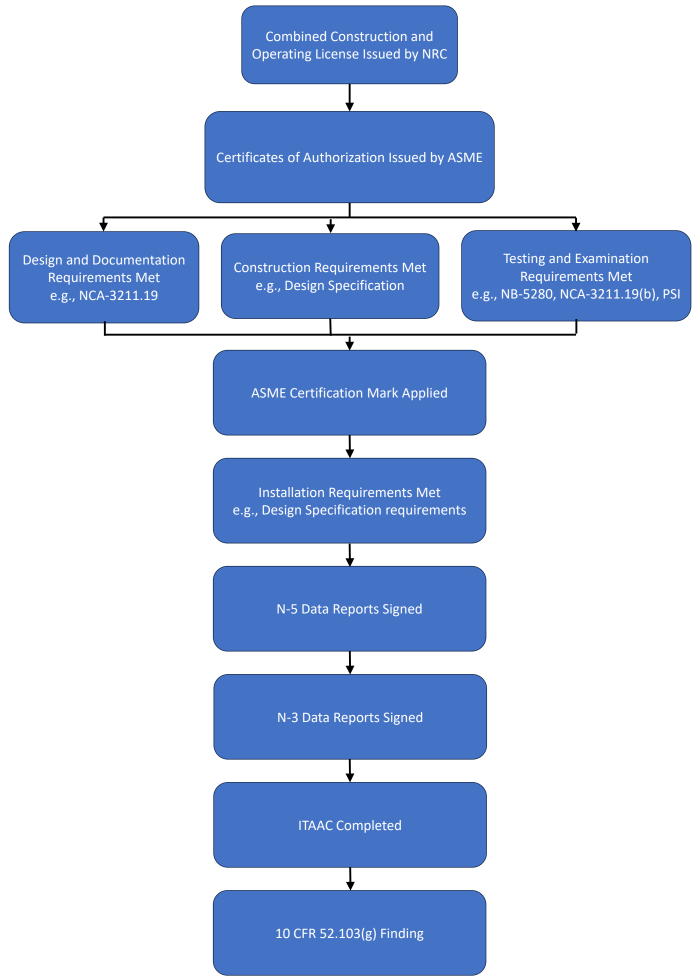
GLOSSARY

This section defines important terms as used in this paper. Where possible, the authors excerpted the following definitions from the glossaries of Section III and Section XI. However, readers should refer to the Section III and Section XI glossaries when interpreting Code requirements.

Analytical Evaluation: a quantitative process under the rules of Section XI to determine the acceptability of postulated or actual flaws and whether a component is acceptable for continued service
Certification Mark: an ASME symbol identifying a product as meeting Code requirements
Certificate Holder: an organization holding a Certificate of Authorization issued by ASME
Certificate of Authorization: a document issued by ASME that authorizes the use of a Certification Mark and appropriate designator for a specified scope of activity
Design Specification: a document required by Section III NCA-1210 for the construction of nuclear power plant components that conforms to the provisions of Section III NCA-3211.19
N-3 Data Report: a report prepared by the Owner that certifies components installed at the Owner's facility meet the requirements of Section III
N-5 Data Report: a report prepared by the Certificate Holder that certifies components installed at the Owner's facility meet the requirements of Section III
Owner: the organization legally responsible for construction or operation of a nuclear power plant

FLOWCHART

The following flowchart illustrates U.S. construction rules under 10 CFR 52.



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