

XI.S1 ASME SECTION XI, SUBSECTION IWE

Program Description

10 CFR 50.55a imposes the inservice inspection (ISI) requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section XI, Subsection IWE, for steel containments (Class MC) and steel liners for concrete containments (Class CC). The full scope of IWE includes steel containment shells and their integral attachments, steel liners for concrete containments and their integral attachments, containment hatches and airlocks and moisture barriers, and pressure-retaining bolting. This evaluation covers the 2004 edition,²⁰ as approved in 10 CFR 50.55a. ASME Code, Section XI, Subsection IWE, and the additional requirements specified in 10 CFR 50.55a(b)(2) constitute an existing mandated program applicable to managing aging of steel containments, steel liners of concrete containments, and other containment components for license renewal.

The primary ISI method specified in IWE is visual examination (general visual, VT-3, VT-1). Limited volumetric examination (ultrasonic thickness measurement) and surface examination (e.g., liquid penetrant) may also be necessary in some instances to detect aging effects. IWE specifies acceptance criteria, corrective actions, and expansion of the inspection scope when degradation exceeding the acceptance criteria is found.

Subsection IWE requires examination of coatings that are intended to prevent corrosion. AMP XI.S8 is a protective coating monitoring and maintenance program that is recommended to ensure Emergency Core Cooling System (ECCS) operability, whether or not the AMP XI.S8 is credited in AMP XI.S1.

The program attributes are augmented to incorporate aging management activities, recommended in the Final Interim Staff Guidance LR-ISG-2006-01, needed to address the potential loss of material due to corrosion in the inaccessible areas of the boiling water reactor (BWR) Mark I steel containment.

The attributes also are augmented to require surface examination for detection of cracking described in NRC Information Notice (IN) 92-20 and to address recommendations delineated in NUREG-1339 and industry recommendations delineated in the Electric Power Research Institute (EPRI) NP-5769, NP-5067, and TR-104213 for structural bolting. The program is also augmented to require surface examination of dissimilar metal welds of vent line bellows in accordance with examination Category E-F, as specified in the 1992 Edition of the ASME Code, Section XI, Subsection IWE. If surface examination is not possible, appropriate 10 CFR Part 50 Appendix J test may be conducted for pressure boundary components.

Evaluation and Technical Basis

- 1. Scope of Program:** The scope of this program addresses the components of steel containments and steel liners of concrete containments specified in Subsection IWE-1000 as augmented by LR-ISG-2006-01. The components within the scope of Subsection IWE are Class MC pressure-retaining components (steel containments) and their integral attachments, metallic shell and penetration liners of Class CC containments and their integral attachments, containment moisture barriers, containment pressure-retaining bolting, and metal containment surface areas, including welds and base metal. The concrete

²⁰ Refer to the GALL Report, Chapter I, for applicability of other editions of the ASME Code, Section XI.

portions of containments are inspected in accordance with Subsection IWL. Subsection IWE requires examination of coatings that are intended to prevent corrosion. XI.S8 is a protective coating monitoring and maintenance program that is recommended to ensure ECCS operability, whether or not the AMP XI.S8 is credited in AMP XI.S1.

Subsection IWE exempts the following from examination:

- (a) Components that are outside the boundaries of the containment, as defined in the plant-specific design specification;
- (b) Embedded or inaccessible portions of containment components that met the requirements of the original construction code of record;
- (c) Components that become embedded or inaccessible as a result of containment structure (i.e., steel containments [Class MC] and steel liners of concrete containments [Class CC]) repair or replacement, provided the requirements of IWE-1232 and IWE-5220 are met; and
- (d) Piping, pumps, and valves that are part of the containment system or that penetrate or are attached to the containment vessel (governed by IWB or IWC).

10 CFR 50.55a(b)(2)(ix) specifies additional requirements for inaccessible areas. It states that the licensee is to evaluate the acceptability of inaccessible areas when conditions exist in accessible areas that could indicate the presence of or result in degradation to such inaccessible areas. Examination requirements for containment supports are not within the scope of Subsection IWE.

2. **Preventive Action:** The ASME Code Section XI, Subsection IWE, is a condition monitoring program. The program is augmented to include preventive actions that ensure that moisture levels associated with an accelerated corrosion rate do not exist in the exterior portion of the BWR Mark I steel containment drywell shell. The actions consist of ensuring that the sand pocket area drains and/or the refueling seal drains are clear. The program is also augmented to require that the selection of bolting material installation torque or tension and the use of lubricants and sealants are in accordance with the guidelines of EPRI NP-5769, EPRI TR-104213, and the additional recommendations of NUREG-1339 to prevent or mitigate degradation and failure of structural bolting. If the structural bolting consists of ASTM A325, ASTM F1852, and/or ASTM A490 bolts, the preventive actions for storage, lubricants, and stress corrosion cracking potential discussed in Section 2 of RCSC (Research Council for Structural Connections) publication "Specification for Structural Joints Using ASTM A325 or A490 Bolts," need to be considered.
3. **Parameters Monitored or Inspected:** Table IWE-2500-1 references the applicable sections in IWE-2300 and IWE-3500 that identify the parameters examined or monitored. Non-coated surfaces are examined for evidence of cracking, discoloration, wear, pitting, excessive corrosion, arc strikes, gouges, surface discontinuities, dents, and other signs of surface irregularities. Painted or coated surfaces are examined for evidence of flaking, blistering, peeling, discoloration, and other signs of distress. Stainless steel penetration sleeves, dissimilar metal welds, bellows, and steel components that are subject to cyclic loading but have no current licensing basis fatigue analysis are monitored for cracking. The moisture barriers are examined for wear, damage, erosion, tear, surface cracks, or other defects that permit intrusion of moisture in the inaccessible areas of the pressure retaining surfaces of

the metal containment shell or liner. Pressure-retaining bolting is examined for loosening and material conditions that cause the bolted connection to affect either containment leak-tightness or structural integrity.

As recommended in LR-ISG-2006-01, license renewal applicants with BWR Mark I steel containments should monitor the sand pocket area drains and/or the refueling seal drains for water leakage. The licensees should ensure the drains are clear to prevent moisture levels associated with accelerated corrosion rates in the exterior portion of the drywell shell.

4. ***Detection of Aging Effects:*** The examination methods, frequency, and scope of examination specified in 10 CFR 50.55a and Subsection IWE ensure that aging effects are detected before they compromise the design-basis requirements. IWE-2500-1 and the requirements of 10 CFR 50.55a provide information regarding the examination categories, parts examined, and examination methods to be used to detect aging.

As indicated in IWE-2400, inservice examinations are performed in accordance with one of two inspection programs, A or B, on a specified schedule. Under Inspection Program A, there are four inspection intervals (at 3, 10, 23, and 40 years) for which 100% of the required examinations must be completed. Within each interval, there are various inspection periods for which a certain percentage of the examinations are to be performed to reach 100% at the end of that interval.

After 40 years of operation, any future examinations are performed in accordance with Inspection Program B. Under Inspection Program B, starting with the time the plant is placed into service, there is an initial inspection interval of 10 years and successive inspection intervals of 10 years each, during which 100% of the required examinations are to be completed. An expedited examination of containment is required by 10 CFR 50.55a, in which an inservice (baseline) examination specified for the first period of the first inspection interval for containment was to be performed by September 9, 2001. Thereafter, subsequent examinations are performed every 10 years from the baseline examination. Regarding the extent of examination, all accessible surfaces receive a visual examination as specified in Table IWE-2500-1 and the requirements of 10 CFR 50.55a. The acceptability of inaccessible areas of the BWR Mark I steel containment drywell is evaluated when conditions exist in the adjacent accessible areas that could indicate the presence of moisture or could result in degradation to such inaccessible areas. IWE-1240 requires augmented examinations (Examination Category E-C) of containment surface areas subject to degradation. A VT-1 visual examination is performed for areas accessible from both sides, and volumetric (ultrasonic thickness measurement) examination is performed for areas accessible from only one side.

The requirements of ASME Section XI, Subsection IWE and 10 CFR 50.55a are augmented to require surface examination, in addition to visual examination, to detect cracking in stainless steel penetration sleeves, dissimilar metal welds, bellows, and steel components that are subject to cyclic loading but have no current licensing basis fatigue analysis. Where feasible, Appendix J tests (AMP XI.S4) may be performed in lieu of the surface examination.

5. ***Monitoring and Trending:*** With the exception of inaccessible areas, all surfaces are monitored by virtue of the examination requirements on a scheduled basis.

IWE-2420 specifies that:

- (a) The sequence of component examinations established during the first inspection interval shall be repeated.
- (b) When examination results require evaluation of flaws or areas of degradation in accordance with IWE-3000, and the component is acceptable for continued service, the areas containing such flaws or areas of degradation shall be reexamined during the next inspection period listed in the schedule of the inspection program of IWE-2411 or IWE-2412, in accordance with Table IWE-2500-1, Examination Category E-C.
- (c) When the reexaminations required by IWE-2420(b) reveal that the flaws or areas of degradation remain essentially unchanged for the next inspection period, these areas no longer require augmented examination in accordance with Table IWE-2500-1 and the regular inspection schedule is continued.

Applicants for license renewal for plants with BWR Mark I containment should augment IWE monitoring and trending requirements to address inaccessible areas of the drywell. The applicant should consider the following recommended actions based on plant-specific operating experience.

- (a) Develop a corrosion rate that can be inferred from past ultrasonic testing (UT) examinations or establish a corrosion rate using representative samples in similar operating conditions, materials, and environments. If degradation has occurred, provide a technical basis using the developed or established corrosion rate to demonstrate that the drywell shell will have sufficient wall thickness to perform its intended function through the period of extended operation.
- (b) Demonstrate that UT measurements performed in response to U.S. Nuclear Regulatory Commission (NRC) Generic Letter (GL) 87-05 did not show degradation inconsistent with the developed or established corrosion rate.

6. Acceptance Criteria: IWE-3000 provides acceptance standards for components of steel containments and liners of concrete containments. IWE-3410 refers to criteria to evaluate the acceptability of the containment components for service following the preservice examination and each inservice examination. Most of the acceptance standards rely on visual examinations. Areas that are suspect require an engineering evaluation or require correction by repair or replacement. For some examinations, such as augmented examinations, numerical values are specified for the acceptance standards. For the containment steel shell or liner, material loss locally exceeding 10% of the nominal containment wall thickness or material loss that is projected to locally exceed 10% of the nominal containment wall thickness before the next examination are documented. Such areas are corrected by repair or replacement in accordance with IWE-3122 or accepted by engineering evaluation. Cracking of stainless steel penetration sleeves, dissimilar metal welds, bellows, and steel components that are subject to cyclic loading but have no current licensing basis fatigue analysis is corrected by repair or replacement or accepted by engineering evaluation.

7. Corrective Actions: Subsection IWE states that components whose examination results indicate flaws or areas of degradation that do not meet the acceptance standards listed in IWE-3500 are acceptable if an engineering evaluation indicates that the flaw or area of degradation is nonstructural in nature or has no effect on the structural integrity of the

containment. Components that do not meet the acceptance standards are subject to additional examination requirements, and the components are repaired or replaced to the extent necessary to meet the acceptance standards of IWE-3000. For repair of components within the scope of Subsection IWE, IWE-3124 states that repairs and reexaminations are to comply with IWA-4000. IWA-4000 provides repair specifications for pressure retaining components, including metal containments and metallic liners of concrete containments. As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the corrective actions.

If moisture has been detected or suspected in the inaccessible area on the exterior of the Mark I containment drywell shell or the source of moisture cannot be determined subsequent to root cause analysis, then:

- (a) Include in the scope of license renewal any components that are identified as a source of moisture, if applicable, such as the refueling seal or cracks in the stainless liners of the refueling cavity pools walls, and perform aging management review.
 - (b) Identify surfaces requiring examination by implementing augmented inspections for the period of extended operation in accordance with Subsection IWE-1240, as identified in Table IWE-2500-1, Examination Category E-C.
 - (c) Use examination methods that are in accordance with Subsection IWE-2500.
 - (d) Demonstrate, through use of augmented inspections performed in accordance with Subsection IWE, that corrosion is not occurring or that corrosion is progressing so slowly that the age-related degradation will not jeopardize the intended function of the drywell shell through the period of extended operation.
8. **Confirmation Process:** When areas of degradation are identified, an evaluation is performed to determine whether repair or replacement is necessary. If the evaluation determines that repair or replacement is necessary, Subsection IWE specifies confirmation that appropriate corrective actions have been completed and are effective. Subsection IWE states that repairs and reexaminations are to comply with the requirements of IWA-4000. Reexaminations are conducted in accordance with the requirements of IWA-2200, and the recorded results are to demonstrate that the repair meets the acceptance standards set forth in IWE-3500. As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the confirmation process.
9. **Administrative Controls:** IWA-6000 provides specifications for the preparation, submittal, and retention of records and reports. As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address administrative controls.
10. **Operating Experience:** ASME Section XI, Subsection IWE, was incorporated into 10 CFR 50.55a in 1996. Prior to this time, operating experience pertaining to degradation of steel components of containment was gained through the inspections required by 10 CFR Part 50, Appendix J and ad hoc inspections conducted by licensees and the NRC. NRC Information Notice (IN) 86-99, IN 88-82, IN 89-79, IN 2004-09, and NUREG-1522 described occurrences of corrosion in steel containment shells. NRC GL 87-05 addressed the potential for corrosion of BWR Mark I steel drywells in the "sand pocket region."

NRC IN 97-10 identified specific locations where concrete containments are susceptible to liner plate corrosion; IN 92-20 described an instance of containment bellows cracking, resulting in loss of leak tightness. More recently, IN 2006-01 described a through-wall cracking and its probable cause in the torus of a BWR Mark I containment. The cracking was identified by the licensee in the heat-affected zone at the high pressure cooling injection (HPCI) turbine exhaust pipe torus penetration.

The licensee concluded that the cracking was most likely initiated by cyclic loading due to condensation oscillation during HPCI operation. These condensation oscillations induced on the torus shell may have been excessive due to a lack of an HPCI turbine exhaust pipe sparger that many licensees have installed. Other operating experience indicates that foreign objects embedded in concrete have caused through-wall corrosion of the liner plate at a few plants with reinforced concrete containments.

The program is to consider the liner plate and containment shell corrosion and cracking concerns described in these generic communications. Implementation of the ISI requirements of Subsection IWE, in accordance with 10 CFR 50.55a, augmented to consider operating experience, and as recommended in LR-ISG-2006-01, is a necessary element of aging management for steel components of steel and concrete containments through the period of extended operation.

Degradation of threaded bolting and fasteners in closures for the reactor coolant pressure boundary has occurred from boric acid corrosion, stress corrosion cracking (SCC), and fatigue loading (NRC IE Bulletin 82-02, NRC GL 91-17). SCC has occurred in high strength bolts used for nuclear steam supply system component supports (EPRI NP-5769). The augmented ASME Section XI, Subsection IWE, incorporating recommendations documented in EPRI NP-5769 and TR-104213, is necessary to ensure containment bolting integrity.

References

- 10 CFR Part 50, Appendix B, *Quality Assurance Criteria for Nuclear Power Plants*, Office of the Federal Register, National Archives and Records Administration, 2009.
- 10 CFR Part 50, Appendix J, *Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors*, Office of the Federal Register, National Archives and Records Administration, 2009.
- 10 CFR 50.55a, *Codes and Standards*, Office of the Federal Register, National Archives and Records Administration, 2009.
- ASME Section XI, *Rules for Inservice Inspection of Nuclear Power Plant Components*, Subsection IWA, *General Requirements*, The ASME Boiler and Pressure Vessel Code, 2004 edition as incorporated by reference in 10 CFR 50.55a, The American Society of Mechanical Engineers, New York, NY.
- ASME Section XI, *Rules for Inservice Inspection of Nuclear Power Plant Components*, Subsection IWB, *Requirements for Class 1 Components of Light-Water Cooled Power Plants*, The ASME Boiler and Pressure Vessel Code, 2004 edition as incorporated by reference in 10 CFR 50.55a, The American Society of Mechanical Engineers, New York, NY.

ASME Section XI, *Rules for Inservice Inspection of Nuclear Power Plant Components*, Subsection IWC, *Requirements for Class 2 Components of Light-Water Cooled Power Plants*, The ASME Boiler and Pressure Vessel Code, 2004 edition as approved in 10 CFR 50.55a, The American Society of Mechanical Engineers, New York, NY.

ASME Section XI, *Rules for Inservice Inspection of Nuclear Power Plant Components*, Subsection IWE, *Requirements for Class MC and Metallic Liners of Class CC Components of Light-Water Cooled Power Plants*, The ASME Boiler and Pressure Vessel Code, 2004 edition as incorporated by reference in 10 CFR 50.55a, The American Society of Mechanical Engineers, New York, NY.

ASME Section XI, *Rules for Inservice Inspection of Nuclear Power Plant Components*, Subsection IWL, *Requirements for Class CC Concrete Components of Light-Water Cooled Power Plants*, The ASME Boiler and Pressure Vessel Code, 2004 edition as incorporated by reference in 10 CFR 50.55a, The American Society of Mechanical Engineers, New York, NY.

EPRI NP-5769, *Degradation and Failure of Bolting in Nuclear Power Plants*, Volumes 1 and 2, Electric Power Research Institute, April 1988.

EPRI NP-5067, *Good Bolting Practices, A Reference Manual for Nuclear Power Plant Maintenance Personnel*, Volume 1: Large Bolt Manual, 1987; Volume 2: Small Bolts and Threaded Fasteners, Electric Power Research Institute, 1990.

EPRI TR-104213, *Bolted Joint Maintenance & Application Guide*, Electric Power Research Institute, December 1995.

RCSC (Research Council on Structural Connections): *Specification for Structural Joints Using ASTM A325 or A490 Bolts*, 2004.

NRC IE Bulletin No. 82-02, *Degradation of Threaded Fasteners in the Reactor Coolant Pressure Boundary of PWR Plants*, U.S. Nuclear Regulatory Commission, June 2, 1982.

NRC Generic Letter 87-05, *Request for Additional Information Assessment of Licensee Measures to Mitigate and/or Identify Potential Degradation of Mark I Drywells*, U.S. Nuclear Regulatory Commission, March 12, 1987.

NRC Generic Letter 91-17, *Generic Safety Issue 79, Bolting Degradation or Failure in Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, October 17, 1991.

NRC Information Notice 86-99, *Degradation of Steel Containments*, U.S. Nuclear Regulatory Commission, December 8, 1986 and Supplement 1, February 14, 1991.

NRC Information Notice 88-82, *Torus Shells with Corrosion and Degraded Coatings in BWR Containments*, U.S. Nuclear Regulatory Commission, October 14, 1988 and Supplement 1, May 2, 1989.

NRC Information Notice 89-79, *Degraded Coatings and Corrosion of Steel Containment Vessels*, U.S. Nuclear Regulatory Commission, December 1, 1989 and Supplement 1, June 29, 1989.

NRC Information Notice 92-20, *Inadequate Local Leak Rate Testing*, U.S. Nuclear Regulatory Commission, March 3, 1992.

NRC Information Notice 97-10, *Liner Plate Corrosion in Concrete Containment*, U.S. Nuclear Regulatory Commission, March 13, 1997.

NRC Information Notice 2004-09, *Corrosion of Steel Containment and Containment Liner*, U.S. Nuclear Regulatory Commission, April 27, 2004.

NRC Information Notice 2006-01, *Torus Cracking in a BWR Mark I Containment*, U.S. Nuclear Regulatory Commission, January 12, 2006.

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NUREG-1522, *Assessment of Inservice Conditions of Safety-Related Nuclear Plant Structures*, June 1995.

Staff Position and Rationale for the Final License Renewal Interim Staff Guidance LR-ISG-2006-01, *Plant-Specific Aging Management Program for Inaccessible Areas of Boiling Water Reactor (BWR) Mark I Steel Containments Drywell Shell*, Nuclear Regulatory Commission, November 16, 2006.