

Status of BWR Vessel and Internals Inspection in the U.S.A.

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ABSTRACT

Concerns over the potential cracking of low alloy steel pressure vessel and its internal attachment welds made of Inconel material have presented U.S. BWR plants with significant challenges in inspecting hard-to-access vessel seam welds and internal components. Inspection access studies are being performed to determine inspection coverage and to define inspection hardware needs. A number of older BWR plants have begun to inspect their vessel seam welds from the interior wall of the vessel and through the cladding. Technologies under development are expected to enable U.S. BWR plants to access all important vessel seam welds, including those in the beltline region. Research efforts to establish degradation susceptibility and inspection priority of BWR internals are ongoing and rules for their inservice inspections are under development.

1 INTRODUCTION

Recent observations of stress corrosion cracking (SCC) in BWR components other than piping have drawn attention to consequences of corrosion assisted damage to major BWR internal components and the BWR reactor pressure vessel (RPV), particularly at attachment welds. Early models of BWR vessels were designed and fabricated with inadequate considerations to access for inservice inspections (ISI). Consequently the older BWR plants had received exemption from the first, and in some cases the second 10-year vessel examinations that are required by the American Society of Mechanical Engineers (ASME) Section XI Code. The U.S. Nuclear regulatory commission (NRC) has indicated that it no longer grants blanket exemptions and expects the plant operators to examine as much of the vessel seam welds as possible. Additionally, the new stringent code rules for RPV seam weld examinations and qualification of personnel and procedures are having a major impact on the ISI programs of U.S. utilities for their reactor vessels.

2 BWR EXPERIENCE WITH RPV AND INTERNALS CRACKING

SCC of vessel cladding is possible in BWR plants and cases have been observed where the cracking had penetrated into the low alloy steel (LAS) base

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material. A EWR3 plant in the U.S. has seen cladding/LAS cracking near head spray nozzle with slight penetration into the base material. In 1990 SCC was detected in cladding near lower girth weld in the RPV top head of a EWR3 plant. And in another plant, a EWR4 model, a large UT reflector was detected at the upper girth weld in the unclad top head of RPV. This UT indication was determined as not being service induced. Many of the older EWR plants have stainless steel filler metal at nozzle and attachment welds. However, the majority of newer plants have the IGSCC susceptible Inconel 182 weld material in control rod drive penetrations and shroud support-to-vessel welds. Almost all U.S. EWR plants have Inconel 182 weld metal in either the vessel, the safe ends, or both. Internal structures that have failed include access hole covers, recirculation safe-ends at thermal shields, control blade sheaths, numerous feedwater spargers and shroud head bolts, and a steam drier bracket. There have been no observed failures in core supports to date.

It is suspected that additional SCC failures of cladding/LAS and Inconel 182 welds may be discovered as qualified and effective NDE methods are implemented on more of the vessel welds and its internal components and attachments.

3 INSERVICE INSPECTION REQUIREMENTS

Inservice inspection of EWR RPV and its internals are governed by the requirements of the ASME Section XI. Additionally, the 1989 Edition of the ASME Section XI Code¹ contains the rules for qualification of NDE personnel for ultrasonic examination (Appendix VII) and the rules for performance demonstration for ultrasonic examination systems (Appendix VIII). Details of Appendix VIII as it applies to RPV examinations and the U.S. utilities' initiative to address its requirements are subject of another presentation (paper G18/1) at this conference.

3.1 ISI requirements for RPV welds

The extent and frequency of EWR RPV inspection requirements for the U.S. plants have changed considerably over the last 20 years. During this period the inspection requirements have changed from effectively 1% of RPV welds per interval in the early 1970's to about 15% of all RPV welds prior to 1988, to where the current ASME Sec.XI Code requires 100% of all shell welds and accessible head welds per each 10-year interval. The current requirements have had a major impact on the U.S. EWR plants in that not only do they have to conduct much more extensive examinations, but that not all of the RPV welds are readily accessible.

3.2 ISI requirements for internals and core support structures

The present requirements, defining the extent of examinations, are contained in Table IWB 2500-1 (Category B-N-2) of ASME Section XI. These requirements are not very specific or rigorous. They are limited to a basic visual examination of accessible surfaces and welds of interior attachments, and their practice varies from plant to plant depending to a great extent on the implementing organization. Concerns over the observed and potential failures of specific internal components and attachment welds, and the prospects for license extension of nuclear plants has lead to a new initiative by the ASME Sec. XI to prepare the rules for inservice inspection of core support and internal structures. These rules are currently under development and will be

incorporated in the Subsection IWG of Sec. XI. It is important to note that these rules are being developed during the time that ASME is moving more and more towards risk-based inspections and has access to the industry's operational experience with various components. EWR industry initiatives through EWR Owners Group and EPRI research are establishing cracking susceptibility and consequences of cracking of support structures and internal components as a means of prioritizing their inspection needs and making recommendations to the ASME Code and the U.S. NRC.

4 INSPECTION ACCESSIBILITY

Early models of EWR plants in the U.S. were designed and fabricated when ISI rules were still being developed. Hence, inadequate considerations were given for volumetric examination of RFV welds from the outside. Additionally, with so few removable parts in EWR vessel, core support structure and many of the internal components were considered inaccessible and consequently designed not to need any detailed ISI during the plant life beyond periodic visual checks of their functional characteristics.

4.1 Inspection accessibility of RFV shell welds

Majority of the EWR vessel weld examinations within the last two decades have been limited to the examination of the upper vessel head region which becomes accessible during refueling and nozzle-to-vessel welds, which are typically accessible with conventional equipment through the nozzle openings. Most of the EWR2 and EWR3 models and some of the EWR4 models were designed with insulation that attaches to the reactor vessel with minimal standoff from the outer diameter of the vessel. This insulation was not designed for removal with the exception of the vessel nozzle penetrations and a few locations in the upper most course of the vessel shell where removable panels were installed over the welds. As a result of restricted access to the outside wall of the vessel, these plants received relief from the ASME Sec. XI inspection requirements.

Accessibility studies of early EWR designs, namely EWR2, EWR3, and EWR4 models, conducted within the last two years indicate that even though these models generally have a very limited inspection access from the outside, they can be partially accessed from the inside with properly designed NDE tools. With a combination of examinations from the outside and inside of the vessel, nearly 100% of the vessel shell welds in these models can be ultrasonically examined. The ultimate inspection accessibility of each EWR plant depends on its particular design and fabrication as well as the inspection equipment that it plans to deploy. For this reason, U.S. EWR plants have begun to conduct accessibility studies of their vessels to determine their realistic inspection coverage with the existing as well as developing inspection hardware.

Additionally, computer models^{2,3} have been developed to aid EWR plants to utilize their design and fabrication drawings along with in-plant measurements to determine inspection accessibility of their specific RFV welds and internal components. Figure 1 shows an example of the computer generated model of EWR RFV for inspection access studies.

Later models of EWR's, namely EWR5 and EWR6 are designed and fabricated so that effectively 100% of RFV seam welds are accessible from the outside. Many of these plants generally have permanent tracks mounted on the exterior of the vessel for ultrasonic examination scanners.

4.2 Inspection accessibility of internals and attachment welds

Components and attachment welds inside the EWR vessel were not designed to have access for any elaborate inservice examinations such as ultrasonic and eddy current.

Some of the RPV internal components such as steam dryer and separator are designed for easy removal for refueling activities. Other components are bolted, welded, and interference fit. Among them are core spray spargers, and the retention bolting on the top of jet pumps. While a few utilities have had to replace sections of their spargers, none have removed any of these components in order to examine attachment welds or other internal components. Removal of jet pump mixing sections and diffusers for alleviating examination restrictions has neither been attempted nor evaluated. In general, majority of the components and attachment welds above the core are accessible for visual examinations with a TV camera or even ultrasonic tests in some limited cases.

However, components and attachment welds below the core plate are generally not accessible, even for visual examinations. This is mostly due to the concern in getting a camera below the core plate and being able to maneuver and retrieve it reliably.

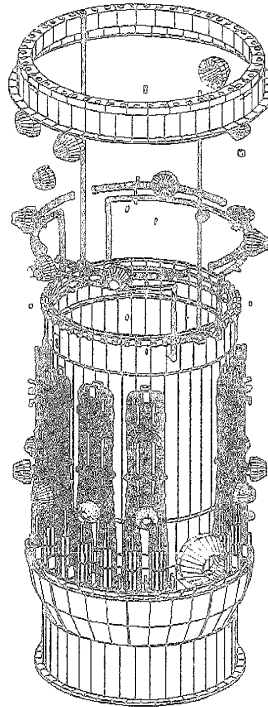


Figure 1. Computer Model of EWR Pressure Vessel With Transparent Shell.

5. EWR INSPECTION TOOL DEVELOPMENT

The new requirements for 100% inspection of RPV welds coupled with regulatory pressure and concern over the inadequate inspection of RPV welds in the beltline region of older EWR's has provided the impetus for development of new inspection tools that can perform the mandatory inspections from inside the EWR vessel. Two such systems have been developed by inspection vendors. Both systems are designed to operate with the core flooded and with minimum of interference with other activities that may be going on at the refueling bridge during an outage. Their primary mechanical feature is the ability to negotiate the geometry and the limited space around the core region between the jet pumps and the vessel wall.

5.1 GERIS 2000-ID system

The GERIS 2000-ID inspection system⁴ is a development effort of GE and MAN Energie of Germany, designed to function in all EWR vessel sizes.

It consists of a vertical mast attached to a circumferential car which is guided by rings temporarily placed on the vessel and core shroud flanges. Figure 2 shows the elements of the GERIS 2000 system. The design of the manipulator is such that it does not block access to the core while mounted inside the vessel.

A key design feature is the manipulator's linked belt mechanism which can be extended from inside the upper mast assembly to reach the vessel belt line region. The system permits seam weld examination of the beltline region, all the way down to the core shroud support ledge without removing manipulator from the reactor or impacting other core access activities. Transducers mounted on the upper and the lower portion of the mast can perform Code-required exams in all four directions simultaneously. The system's electronics permit rapid data acquisition and processing with capability for 3D graphics, B- and C-scan imaging of ultrasonic data.

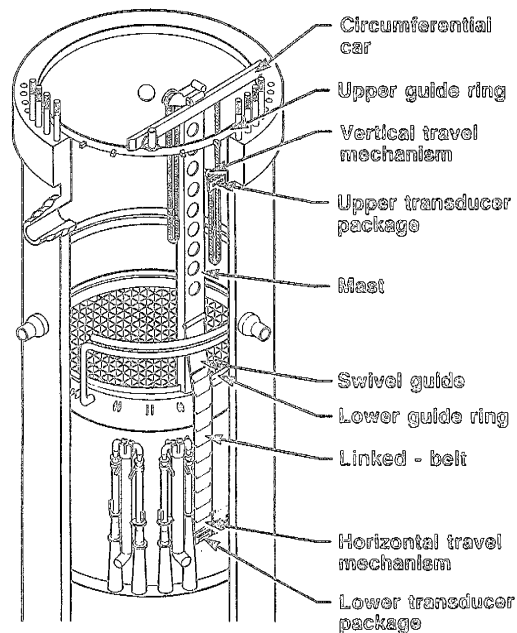


Figure 2. Elements of GE's RPV Inspection System, GERIS 2000-ID

5.2 TRC system

The TRC system designed for use on the U.S. EWR's is a modification⁵ of an existing inspection tool, SESAM, which TRC of Sweden had developed and extensively used on ABB Atom designed EWR's in Europe. It consists of an extendable mast that rides on a ring around the vessel flange. The mast and scanner assemblies occupy only a small cross section of the vessel and ride close to the vessel wall thereby allowing other in-vessel activities to be performed during the examination. The necessary end effectors and extensions are placed onto the mast to accomplish examinations of the upper core as well as the beltline region of the vessel. The system is designed to be used with different RPV data acquisition system. To date it has been used with Westinghouse's UDRPS and Southwest Research Institute's EDAS data acquisition and processing systems.

6. RECENT RPV EXAMINATIONS

EWR utilities in the U.S. have started planning for expanded examinations of their RPV seam welds in response to the new ASME requirements. Even though majority of plants have several years before they must adopt the new requirements, a number of older plants have already embarked on measures to enable them to meet the new requirements. These measures include detailed inspection accessibility studies and deployment of inspection hardware for examinations from inside of the vessel.

In 1989, Millstone unit 1, a EWR3 model, was the first EWR plant in the U.S. to examine the flange ligament areas and the shell welds in the upper portion of the vessel from inside of the vessel using the TRC inspection tool⁶. Subsequent to the Millstone examination and a few months later, Monticello, another EWR3 model used the TRC equipment to examine the circumferential and longitudinal shell welds between the vessel upper flange and the top of the jet pumps⁷.

As of this writing, April 1991, the Monticello plant is using a further modified TRC tool coupled with UDRFS ultrasonic system to inspect the beltline region of RPV from inside the vessel. Nine Mile Point unit 1, a EWR2 model (without jet pumps) is also planning on using the TRC tool with the Southwest Research Institute's EDAS system for their upcoming vessel inspection in 1992.

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