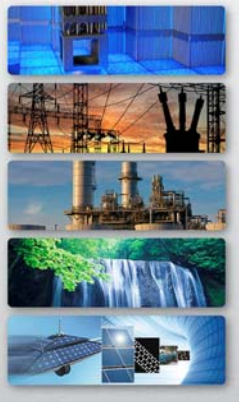

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Nondestructive Examination for Detection and Evaluation of Containment Degradation Mechanisms

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United States Nuclear Regulatory Information Conference (RIC)
Containment Degradation Research and Implications Session
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Current Containment Examination Requirements

- **10CFR50.55a, Reference to ASME Section XI**
- **10CFR50, Appendix J, Type A and Type B Tests**
- **ASME Section XI, Subsections IWE & IWL**
  - **General Visual**
  - **Detailed Visual**
  - **Visual VT-1 and VT-1C**
  - **Visual VT-2**
  - **Visual VT-3 and VT-3C**
  - **Ultrasonic Thickness Measurements**
- **Maintenance Rule**
- **Protective Coatings Program**

Current Containment Examination Requirements – Metallic Liners

- 10CFR50.55a
- ASME Section XI, Subsection IWE (2004 Edition)
  - **General Visual**
    - IWE-2310(a) **The Owner shall define requirements for visual examination of containment surfaces.** Visual examinations shall be performed, either directly or remotely, by line of sight from available viewing angles from floors, platforms, walkways, ladders, or other permanent vantage points, unless temporary access is required by the inspection plan. The visual examinations shall be performed with adequate illumination, sufficient to detect evidence of degradation.
    - IWE-2310(b) General visual examinations shall be performed in accordance with IWE-2500 and Table IWE-2500-1, Examination Category E-A, to assess the general condition of the containment surfaces.

Current Containment Examination Requirements – General Visual & VT-3

TABLE IWE-2500-1—Examination Categories

Examination Category E-A, Containment Surfaces As Modified By 10CFR50.55a(B)(2)(ix)(G)

Item No.	Parts Examined	Examination[1] Requirements/ Fig. No.	Examination Method	Acceptance Standard	Extent and Frequency of Examination: First Inspection Interval	Extent and Frequency of Examination: Successive Inspection Intervals	Deferral of Inspection to End of Interval
E1.10	Containment Vessel Pressure Retaining Boundary						
E1.11	Accessible Surface Areas	IWE-2310	General Visual	IWE-3510	100% During each Inspection Period	100% During each Inspection Period	NA
E1.11	Pressure Retaining Bolting[2]	IWA-2200**	VT-3	IWE-3510	100%	100%	NA
E1.12	Wetted Surfaces of Submerged Areas	~~IWE-2310~~ IWA-2200**	~~General Visual~~ VT-3	IWE-3510	100%	100%	Permissible
E1.20	BWR Vent System Accessible Surface Areas[1,3]	~~IWE-2310~~ IWA-2200**	~~General Visual~~ VT-3	IWE-3510	100%	100%	Permissible
E1.30	Moisture Barriers[4]	~~IWE-2310~~ Fig. IWE-2500-1 IWA-2200**	~~General Visual~~ VT-3	IWE-3510	100% During each Inspection Period	100% During each Inspection Period	NA

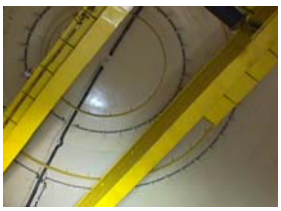
Current Containment Examination Requirements – Metallic Liners

- **General Visual**
  - ***IWE-3510.1 Visual Examinations—General***
    - "**The Owner shall define acceptance criteria for visual examination of containment surfaces**."
    - It is acceptable to use Visual, VT-3 certified personnel for the General visual examinations, if they meet the requirements of IWA-2300 and have received additional instruction on containment inspection as specified by the Responsible Individual directing the program required per IWE-2320.

NOTE: Some utilities perform the required "General" visual examination to the Visual VT-3 criteria with Visual VT-3 certified personnel.

Current Containment Examination Requirements – Metallic Liners

- **Example of one utility's containment dome without and with auxiliary lighting:**

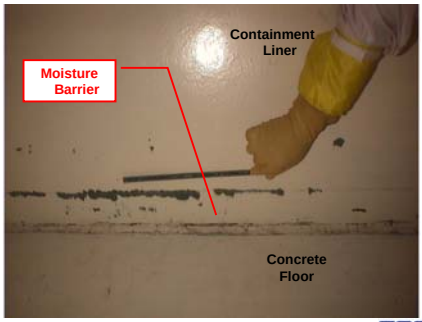


Current Containment Examination Requirements – Metallic Liners

- **General Visual**
  - ***IWE-3510.4 Visual Examination of Moisture Barriers***
    - "Moisture barriers with wear, damage, erosion, tear, surface cracks, or other defects that permit intrusion of moisture against inaccessible areas of the pressure retaining surfaces of the metal containment shell or liner shall be corrected by corrective measures."
    - This is an area that a number of instances of coating degradation and liner corrosion has been reported.

Current Containment Examination Requirements – Metallic Liners

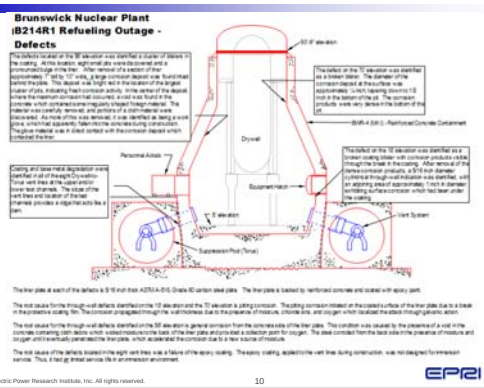
- **Moisture Barrier**



Current Containment Examination Requirements – Metallic Liners

- **The implementation of the Section IWE "General" Visual examination requirements for conducting the examination and the acceptance criteria is determined by the "Owners" "Responsible Individual."**
- **These requirements vary widely among the utilities.**
- **The personnel qualification of "General" visual examiners also varies widely among the utilities.**
- **The Section IWE "General" and "Detailed" visual examinations are NOT prescriptively defined in Section XI, Section IWA as are Visual VT-1, VT-2 and VT-3.**

Current Containment Examination Requirements – Brunswick Liner Corrosion



Current Containment Examination Requirements – North Anna Liner Corrosion

Current Containment Examination Requirements – North Anna Liner Corrosion

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Current Containment Examination Requirements – Beaver Valley Liner Blister

Current Containment Examination Requirements – Beaver Valley Liner Corrosion

Current Containment Examination Requirements – Koeberg Liner Corrosion

- In outage 117 corrosion was detected below a coating blister on the containment liner. The condition was documented; an engineering evaluation performed; and it was identified for tracking.
- The disposition of the condition was evaluated to be a coating failure resulting from borated water spillage. (Outage 118 condition assessment disproved this.)
- The area of degradation was ground and recoated (3 areas of local thinning were detected)
- Examination in 2009 confirmed the recoated liner to be in a good condition
- Examination in outage 118 revealed an area of blistering of the coating with the steel liner corroded

Current Containment Examination Requirements – Koeberg Liner Corrosion

- Outage 118 Containment Liner Blistered Coating

Current Containment Examination Requirements – Koeberg Liner Corrosion

- Containment Liner Coating Blister Removed

Current Containment Examination Requirements – Koeberg Liner Corrosion

- Containment Liner Coating Removed

Current Containment Examination Requirements – Koeberg Liner Corrosion

- **Debris (wood and wire) removed from concrete behind the containment liner**

Current Containment Examination Requirements – Metallic Liners

- **General Visual**
  - **Visual examination is effective in detecting containment liner degradation despite the utility variations in Owner defined requirements and implementation of the Subsection IWE "General" visual examinations.**
  - **Standardization of approach would help to assure future confidence in early detection significant corrosion.**
  - **General visual does not provide early detection of corrosion from the back of the liner.**
  - **Other examination methods are needed.**

Current Containment Examination Requirements – Metallic Liners UT Thickness

- Subsection IWE, Category E-C

TABLE IWE-2500-1 (CONT'D)
EXAMINATION CATEGORIES

EXAMINATION CATEGORY E-C, CONTAINMENT SURFACES REQUIRING AUGMENTED EXAMINATION

Item No.	Parts Examined	Examination Requirements/ Fig. No.	Examination Method	Acceptance Standard	Extent and Frequency of Examination: 1st Inspection Interval	Extent and Frequency of Examination: Successive Inspection Intervals	Deferral of Inspection to End of Interval
E4.10	Containment Surface Areas[1]						
E4.11	Visible Surfaces	IWE-2510(c) IWE-2500(b)(1)	Detailed Visual	IWE-3511	100% of surface areas identified by IWE-1242[2]	100% of surface areas identified by IWE-1242[2]	Not permissible
E4.12	Surface Area Grid Minimum Wall Thickness Location	IWE-2500(b)(2) IWE-2500(b)(3) IWE-2500(b)(4)	Ultrasonic Thickness	IWE-3511	100% of minimum wall thickness locations during each inspection period, established in accordance with IWE-2500(b)(3)[2] and IWE-2500(b)(4)[2]	100% of minimum wall thickness locations during each inspection period, established in accordance with IWE-2500(b)(3)[2] and IWE-2500(b)(4)[2]	Not permissible

NOTES:
(1) Containment surface areas requiring augmented examination are those identified in IWE-1240.
(2) The extent of examination shall be 100% for each inspection period until the areas examined remain essentially unchanged for the next inspection period. Such areas no longer require augmented examination in accordance with IWE-2420(c).

Current Containment Examination Requirements – Metallic Liners UT Thickness

- Subsection IWE, Category E-C(b)

(3) When ultrasonic thickness measurements are performed, grids not exceeding one foot square shall be used. The number and location of the grids shall be determined by the Owner.

(4) Ultrasonic thickness measurements shall be used to determine the minimum wall thickness within each grid. The location of the minimum wall thickness within each grid shall be marked or recorded such that periodic reexamination can be performed in accordance with the requirements of Table IWE-2500-1, Examination Category E-C. A sampling plan may be used to determine the number and location of ultrasonic thickness measurement grids within each contiguous examination area provided.

(a) Acceptance of the examination area is based on a statistical confidence level of at least 95%; that 95% of all grids within the examination area will meet the acceptance standards of IWE-3500; and

(b) grid locations are initially selected at random from within each examination area.

Current Containment Examination Requirements – Metallic Liners UT Thickness

- Based on operating experience to date, and the Code requirement of one square foot minimum girding, UT thickness measures would **NOT** provide a high level of assure of detection of localized thru-wall corrosion.

Current Containment Examination Requirements – Metallic Liners Guided Wave Examination

- **In August 2000, EPRI published a Technical Report (TR-1000105), *Experimental Validation of Concrete Effects on Guided Waves in Plate***
- **Guided waves can travel a long distance, e.g., 100 feet along a structure**
- **The study demonstrated that guided waves could be used to detect corrosion notch-type discontinuities as well as gradual wall thinning in containment liner plates.**
- **Constructional features such as welds, sealant, paint were found to have no significant effect on detection.**
- **Quantitative determination of wall thinning will require additional investigation.**

Current Containment Examination Requirements – Metallic Liners Guided Wave Examination

- In 2006, the Japanese Institute of Nuclear Safety Systems, published a report, *An Ultrasonic Technique for the Testing of Nuclear Containment Vessel Plates Embedded in Concrete, by Hitoshi Ishida*

Results found that echoes from 9.5 and 19 mm deep artificial hollows at about 1.5 m, and 8 mm diameter stud bolts at various distances between about 0.7 and 1.7 m, could be detected clearly. Multiple echoes between the front and back sidewalls of the steel plate (equivalent to a distance of about 12 m) could be detected. The echo from the hollow with a depth of 9.5 mm could be detected at about 3.6 m with a reflection at the sidewall of the mock-up. The divergence angle and the –6 dB divergence angle of the ultrasonic beam from the large element (combined three elements) transducer were approximately 7 and 3° respectively. The maximum detection distance for an 8 mm diameter stud bolt was evaluated to be about 2.9 to 3.6 m.

Current Containment Examination Requirements – Metallic Liners Guided Wave Examination

- A significant amount of additional development in guided wave technology exhibits even greater promise in detection of corrosion degradation of plates; however, effective evaluation, i.e., % thru-wall has not been demonstrated.
- A large area discontinuity of only a slight reduction of wall thickness due to corrosion may produce essentially the same response as a small area thru-wall discontinuity.
- Thus, detected conditions **CANNOT** be effectively evaluated to determine if they pose significant condition.
- Based on a risk based approach, the impact of having to access a detected discontinuity in a highly inaccessible area that poses no safety significance, is not appropriate.
- **Research efforts are continuing to better characterize guided wave examination data.**

EPRI Containment Related Research Projects

- Quantifying Nuclear Post-tensioned Containment Structures by the Use of Ultrasonic Wave Speed Measurements (2011)
- NDE for Tanks and Containment Liners (2011 – 2013)
- Integrated Guided Wave Project
- Buried Pipe Guided Wave Personnel Resource Development; Buried Pipe Guided Wave Data Analysis Development; Buried Pipe Guided Wave Structural Health Monitoring

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EPRI Containment Related Research Projects

- Tendon Tensioning

Quantifying Nuclear Post-tensioned Containment Structures by the Use of Ultrasonic Wave Speed Measurements

- Background
  - The qualification of post-tensioned tendons in nuclear containments is currently made by periodically measuring lift off loads for a sample of tendon assemblies.
  - The testing is required at five-year intervals and generally costs approximately $500,000/unit and poses a number of personnel safety concerns.
  - There are currently thirty-eight units with post-tensioned tendons and some of the new plant designs include these.

Quantifying Nuclear Post-tensioned Containment Structures by the Use of Ultrasonic Wave Speed Measurements

- Project Scope
  - To further evaluate the possibility of using ultrasonic wave speed measurements to determine the loads in individual tendon wires using the acoustoelastic effect.
  - Wave speed measurements for determination of loads are expected to be inexpensive, fast, simple and may provide an acceptable alternative to the mechanical testing that is required now.
  - In 2000 a proof of principle study was conducted to determine practical feasibility of using wave speed measurements to replace the lift off tests. The results indicate that acoustoelastic constants may be used to infer load and changes in load in tendon wires.

Quantifying Nuclear Post-tensioned Containment Structures by the Use of Ultrasonic Wave Speed Measurements

- Measurements of L-wave sound velocity were measured as a function of applied loads to determine the acoustoelastic behavior in tendon wires. The feasibility of measuring sound velocity in tendon wires encased in protective grease also was demonstrated.
- Measurements were made of the acoustoelastic constants for different samples of tendon wires. Changes in stress may be measured to within ±5 ksi. The uncertainty in the absolute values of acoustoelastic constants was limited in the study by the data analysis and may be improved.

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NDE for Tanks and Containment Liners

- Background
  - Industry needs a single source guide of information on all commercially available NDE tools, inspection techniques, and delivery systems
  - Advanced NDE is required to support license renewal requirements
  - There is increasing attention to assessing the condition of containment liners
  - Reliable inspection results are needed to support structural integrity and reliability assessment for aging plant components.

NDE for Tanks and Containment Liners

- Project Scope
  - *The project will identify gaps and advanced NDE tools to examine containment liners*
  - *Results from this project may leverage inspection tool and techniques for other vessels, such as tanks, fuel pools, and transfer canals.*
- Project results will include:
  - In 2011 this project will compile a reference guide of NDE techniques and evaluate advanced NDE methods to examine containment liners
  - Technical report describing NDE equipment and inspection methodology approach by December 2012 and December 2013 (if on-going)

NDE for Tanks and Containment Liners

- The project will provide a reference guide of NDE techniques and evaluate advanced NDE to test containment liners
- NDE is required to support license renewal requirements
  - The Reference guide will provide information on “ready now” commercially available NDE tools, inspection techniques, and delivery systems
  - Evaluation of Advanced NDE will look at improved technology to fill inspection gaps

EPRI Containment Related Research Projects

- Quantifying Nuclear Post-tensioned Containment Structures by the Use of Ultrasonic Wave Speed Measurements (2011)
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Integrated Guided Wave Project

- Under ideal conditions, GWs are capable of traveling significant distances within components such as piping, tubing, plate, cable, or rod. The potential exists to use GWs to examine large volumes quickly and to examine inaccessible portions of a component. Despite these benefits, GW technology has not been widely applied in the nuclear industry, largely because of the complexity involved in applying the technology and interpreting subsequent data.
- Guided waves (GW) technology has the potential to be effectively used to examine a number of components very efficiently; however the technology is relatively new and complex hence needs to be better understood and developed to avoid misuse.

Integrated Guided Wave Project

- This project combines multiple previously identified GW proposals to gain efficiencies. The project includes:
  - assembling a GW examination of buried pipe “best practices” document,
  - assessing the technology for examining containment liners, and
  - flow accelerated corrosion (FAC).
- Containment Liners – Further develop GW technology to examine containment liners. The work will further develop the state of the art documented in 2000 in EPRI report TR-1000105. The initial step is to assess new GW technology and develop a plan to develop the technology. Development work will proceed based on the plan.
- The final report will be issued in 2011 for inclusion of results to support a joint project with the Pipeline Research Council International (PRCI).

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Integrated Guided Wave Project

- Guided waves (GW) technology has the potential to be effectively used to examine a number of components very efficiently; however the technology is relatively new and complex hence needs to be better understood and developed to avoid misuse. This proposal combines multiple 2007 GW proposals into one to gain efficiencies as was requested by the NDE PGSC. The project includes assembling a GW examination of buried pipe "best practices" document, assessing the technology for examining the containment liner, and FAC. The final report will be issued in 2011 to allow for inclusion of results from a joint project with Pipeline Research Council International (PRCI).

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