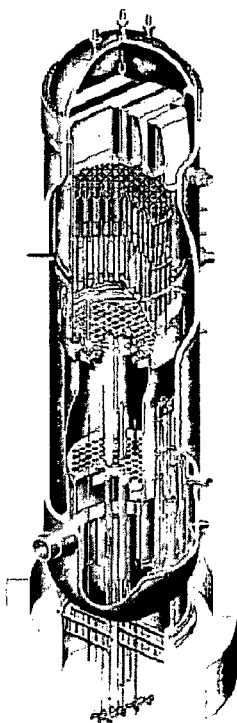


# TR-105696-R12 (BWRVIP-03NP) Revision 12: BWR Vessel and Internals Project

## Reactor Pressure Vessel and Internals Examination Guidelines



### **NON-PROPRIETARY INFORMATION**

NOTICE: This report contains the non-proprietary information that is included in the proprietary version of this report. The proprietary version of this report contains proprietary information that is the intellectual property of EPRI. Accordingly, the proprietary report is available only under license from EPRI and may not be reproduced or disclosed, wholly or in part, by any licensee to any other person or organization.



**TR-105696-R12 (BWRVIP-03NP)**  
**Revision 12: BWR Vessel and Internals**  
**Project**

Reactor Pressure Vessel and Internals Examination  
Guidelines

**1019075NP**

Final Report, February 2010

EPRI Project Manager  
J. Landrum

## **DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES**

THIS DOCUMENT WAS PREPARED BY THE ORGANIZATION(S) NAMED BELOW AS AN ACCOUNT OF WORK SPONSORED OR COSPONSORED BY THE BWR VESSEL AND INTERNALS PROJECT (BWRVIP) AND ELECTRIC POWER RESEARCH INSTITUTE, INC. (EPRI). NEITHER BWRVIP, EPRI, ANY MEMBER OF EPRI, ANY COSPONSOR, THE ORGANIZATION(S) BELOW, NOR ANY PERSON ACTING ON BEHALF OF ANY OF THEM:

(A) MAKES ANY WARRANTY OR REPRESENTATION WHATSOEVER, EXPRESS OR IMPLIED, (I) WITH RESPECT TO THE USE OF ANY INFORMATION, APPARATUS, METHOD, PROCESS, OR SIMILAR ITEM DISCLOSED IN THIS DOCUMENT, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, OR (II) THAT SUCH USE DOES NOT INFRINGE ON OR INTERFERE WITH PRIVATELY OWNED RIGHTS, INCLUDING ANY PARTY'S INTELLECTUAL PROPERTY, OR (III) THAT THIS DOCUMENT IS SUITABLE TO ANY PARTICULAR USER'S CIRCUMSTANCE; OR

(B) ASSUMES RESPONSIBILITY FOR ANY DAMAGES OR OTHER LIABILITY WHATSOEVER (INCLUDING ANY CONSEQUENTIAL DAMAGES, EVEN IF BWRVIP, EPRI OR ANY EPRI REPRESENTATIVE HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES) RESULTING FROM YOUR SELECTION OR USE OF THIS DOCUMENT OR ANY INFORMATION, APPARATUS, METHOD, PROCESS, OR SIMILAR ITEM DISCLOSED IN THIS DOCUMENT.

ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

**Electric Power Research Institute (EPRI)**

### **NON-PROPRIETARY INFORMATION**

**NOTICE:** This report contains the non-proprietary information that is included in the proprietary version of this report. The proprietary version of this report contains proprietary information that is the intellectual property of EPRI. Accordingly, the proprietary report is available only under license from EPRI and may not be reproduced or disclosed, wholly or in part, by any Licensee to any other person or organization.

### **NOTE**

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail [askepri@epri.com](mailto:askepri@epri.com).

Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute, Inc.

Copyright © 2010 Electric Power Research Institute, Inc. All rights reserved.

## CITATIONS

---

This report was prepared by

Electric Power Research Institute (EPRI)  
Nondestructive Evaluation Program  
1300 West W.T. Harris Boulevard  
Charlotte, NC 28262

Principal Investigator  
BWRVIP Inspection Focus Group

This report describes research sponsored by EPRI and its BWRVIP participating members.

The report is a corporate document that should be cited in the literature in the following manner:

*TR-105696-R12 (BWRVIP-03NP) Revision 12: BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines.* EPRI, Palo Alto, CA: 2010. 1019075NP.

# PRODUCT DESCRIPTION

---

In 1990, a visual examination of the core shroud of a Swiss boiling water reactor (BWR) revealed the presence of intergranular stress corrosion cracking. Since that event, examinations of other BWR vessel internal components have revealed an industry-wide cracking problem. In 1994, domestic BWR-owning utilities formed the Boiling Water Reactor Vessel & Internals Project (BWRVIP), which is chartered to support a program addressing the problems of reactor internals, internal attachments, vessel welds, and vessel nozzles. Most international BWR owners have become members. This annual report defines inspection standards and documented inspection techniques for BWR vessel internal components.

## **Results and Findings**

Procedure standards have been developed for ultrasonic, visual, and eddy current inspection. Many inspection techniques have been demonstrated and documented. In support of these demonstrations, realistic mockups of reactor internal components have been manufactured with controlled flaws. BWR owners can use these documented techniques to inspect their vessel internal components in compliance with BWRVIP guidance.

## **Challenges and Objectives**

In-service inspection program managers and BWR vessel internals program managers use this document to ensure that their components are inspected in compliance with BWRVIP guidance.

## **Applications, Value, and Use**

The information contained in this report is applied by all BWR owners in the preparation for and during refueling outages. It is updated annually.

## **EPRI Perspective**

This report provides the BWR fleet with inspection options for all of the safety-related vessel internal components, and provides a stable mechanism for documenting the capability of the evolving inspection technology. It is the sole resource for internals inspection information for BWR owners.

## **Approach**

The BWRVIP strives to make effective inspection techniques available by developing inspection standards that can ensure the structural integrity of the components and providing demonstrated, documented techniques for effectively examining the susceptible components.

**Keywords**

BWRVIP  
NDE  
Internals  
Inspection  
Ultrasound  
Vessel



## EXECUTIVE SUMMARY

---

This document presents findings and products of the Inspection Focus Group of the Boiling Water Reactor Vessel and Internals Project (BWRVIP). An overview of the structure of the BWRVIP is presented, with an outline of the goals and approach of the Focus Group.

The Inspection Focus Group has developed guideline documents which establish protocols for utilities and nondestructive evaluation (NDE) vendor companies to follow in order to gain access to BWRVIP-owned mockups; to perform formal demonstrations of NDE techniques using BWRVIP mockups; and to perform their own demonstrations of NDE techniques or inspection tooling in a manner acceptable to the Focus Group. These documents are included in their entirety.

The Focus Group has conducted extensive investigations and demonstrations of NDE techniques appropriate for inspection of BWR internals. These efforts have included the design, fabrication, and inspection of a series of realistic mockups containing realistic simulations of the degradation mechanisms of concern. These investigations result in the development of evaluation factors, which are numerical values, related to the uncertainties inherent in delivering and executing an NDE technique in a BWR. These evaluation factors are combined with the actual results of an inspection to form input into a fracture-mechanics assessment of the component's serviceability.

The Focus Group's activities are ongoing. The various components of BWR vessels and internals are being addressed in concert with other technical Committee efforts. For components addressed to date, this report includes data on mockup fabrication, NDE uncertainty measurements and evaluation factors, and procedure standards for ultrasonic examination, eddy current examination, and visual examination.

This is a living document. Updates to the included data on components that have already been addressed, and new report sections on components that have not yet been addressed, will be supplied as they are developed. A history of changes is included within the document.

# HISTORY OF CHANGES TO THIS DOCUMENT

## REVISION 12

This is a living document. Updates to the included data will be added as they are developed. Minor or editorial changes may not appear in this summary listing of significant changes. This document supersedes the November 21, 1994, Inspection Committee document *BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard and Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)* (EPRI Report TR-105696, October 1995). The changes listed below supersede the affected paragraphs of *TR-105696-R11 (BWRVIP-03) Revision 11: Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines* (EPRI Report 1016584, December 2008).

Affected Section(s)	Description of Change
xxxiii	Updated the Inspection Focus Group roster.
4.3.1.10	Added new radial ring segment mockup.
4.3.1.11	Added new top guide support ring-to-cylinder mockup.
Table 4.4.2-1	Updated to reflect archival of NDE demonstrations and to document new demonstrations.
4.4.10, 4.4.11, 4.4.12, 4.4.13, 4.4.14, 4.4.15, 4.4.19, 4.4.20, 4.4.25, 4.4.26, 4.4.28, 4.4.29, 4.4.30, 4.4.34, 4.4.39	Revised to reflect UT demonstrations that have been archived.
4.4.59–4.4.61	New sections: new NDE technique demonstrations.
4.7.8	New section: new delivery tool demonstration.
5.3.1	Revised section to incorporate new NDE mockup for weld H7.
5.4.7, 5.4.8, 5.4.9, 5.4.10, 5.4.13, 5.4.15, 5.4.16, 5.4.20, 5.4.21, 5.4.22, 5.4.33, 5.4.34, 5.4.35	Revised to reflect UT demonstrations that have been archived.



---

5.4.47–5.4.49	New sections: new NDE technique demonstrations.
Table 6.4.2.-1	Updated to reflect archival of NDE demonstrations.
6.4.3–6.4.4	Revised to reflect UT demonstrations that have been archived.
7.4.2	Revised to reflect UT demonstration that has been archived.
8.4.3	Revised to reflect UT demonstration that has been archived.
10.3.5	Updated to include new description and drawings of jet pump beam mockups.
10.4.8, 10.4.13, 10.4.14, 10.4.17, 10.4.18	Revised to reflect UT demonstrations that have been archived.
10.4.22	New section: new NDE technique demonstration.
13.3	Added new control rod drive housing NDE mockup.
13.4.1	New section: new NDE technique demonstration.
15	New section: added new section addressing access hole covers.

# HISTORY OF CHANGES TO THIS DOCUMENT

## REVISION 11

---

This is a living document. Updates to the included data will be added as they are developed. Minor or editorial changes may not appear in this summary listing of significant changes. This document supersedes the November 21, 1994, Inspection Committee document *BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard* and *Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)* (EPRI Report TR-105696, October 1995). The changes listed below supersede the affected paragraphs of *TR-105696-R10 (BWRVIP-03) Revision 10: Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines* (EPRI Report 1014993, December 2007).

Affected Section(s)	Description of Change
xxxix	Updated the Inspection Focus Group roster.
2.6, Para. 3.3	Clarified requirement for qualifications of UT analysis personnel with regard to automated versus manual IGSCC qualifications.
2.6, Para. 4.2	Updated UT technique parameters to include key elements associated with application of phased array techniques.
2.6, Para. 4.3	Added guidance to assist with updates of UT hardware and software for evaluating impact on published BWRVIP demonstrations.
2.6, Para. 9.1	Clarified requirement for UT data analyst to review examination data quality.
Table 4.4.2-1	Updated to reflect new NDE technique demonstration.
4.4.58	New section: new NDE technique demonstration.
6.3.1.6	New section: new NDE mockups for core spray.
10.3.3	Updated to reflect the addition of an NDE mockup for the jet pump downcomer mixer weld.
10.4.19–10.4.21	New sections: new NDE technique demonstrations.

# HISTORY OF CHANGES TO THIS DOCUMENT

## REVISION 10

---

This is a living document. Updates to the included data will be added as they are developed. Minor or editorial changes may not appear in this summary listing of significant changes. This document supersedes the November 21, 1994, Inspection Committee document *BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard and Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)* (EPRI Report TR-105696, October 1995). The changes listed below supersede the affected paragraphs of *TR-105696-R9 (BWRVIP-03) Revision 9: Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines* (EPRI Report 1013394, December 2006).

<b>Affected Section(s)</b>	<b>Description of Change</b>
xxvii	Updated the Inspection Focus Group roster.
2.5, Para. 2.3	Clarified requirement for performing a VT-1 or VT-3 in accordance with a BWRVIP document versus in accordance with the utility's ASME Section XI requirements.
2.5, Para. 3.6	Changed the definition of Enhanced VT-1 (EVT-1) from requiring ½ mil resolution to requiring the capability of resolving the ASME Code Section XI VT-1 0.044 inch characters.
2.5, Para. 5.1	Deleted the requirement for the ½ mil SRCS and added the requirement for ASME Code Section XI VT-1 0.044 inch characters as a required SRCS.
2.5, Para. 6.3.2	Updated to reflect requirement for resolving the ASME Code Section XI VT-1 0.044 inch characters.
2.5, Para. 6.5.5	Added requirement for camera motion (speed) during examination to not exceed 0.5 inch/sec.
2.5, Para. 6.5.6	Changed requirement for camera angle to not exceed 30 degrees from perpendicular to the surface.

---

Table 4.4.2-1	Updated to reflect new NDE technique demonstrations and included reference to vertical welds in the applicable weld(s) column.
4.4.47–4.4.57	New sections: new NDE technique demonstrations.
5.4.40–5.4.46	New sections: new NDE technique demonstrations.
Table 6.4.2-1	Updated to reflect new NDE technique demonstrations.
6.4.40–6.4.43	New sections: new NDE technique demonstrations.
10.4.18	New section: new NDE technique demonstration.

# HISTORY OF CHANGES TO THIS DOCUMENT

## REVISION 9

---

This is a living document. Updates to the included data will be added as they are developed. Minor or editorial changes may not appear in this summary listing of significant changes. This document supersedes the November 21, 1994, Inspection Committee document *BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard and Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)* (EPRI Report TR-105696, October 1995). The changes listed below supersede the affected paragraphs of *TR-105696-R8 (BWRVIP-03) Revision 8: Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines* (EPRI Report 1011689, December 2005).

<b>Affected Section(s)</b>	<b>Description of Change</b>
xxvii	Updated the Inspection Focus Group roster.
Chapter 1	Updated to include NEI 03-08 Implementation Requirements.
Table 4.4.2-1	Updated to reflect new NDE technique demonstrations.
4.4.42–4.4.46	New sections: new NDE technique demonstrations.
5.3.2	Added two new shroud support mockups.
Table 6.4.2-1	Updated to reflect new NDE technique demonstrations.
6.4.36–6.4.39	New sections: new NDE technique demonstrations.
10.4.14	Corrected errata.
10.4.15–10.4.17	New sections: new NDE technique demonstrations.

# HISTORY OF CHANGES TO THIS DOCUMENT

## REVISION 8

---

This is a living document. Updates to the included data will be added as they are developed. Minor or editorial changes may not appear in this summary listing of significant changes. This document supersedes the November 21, 1994, Inspection Committee document *BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard and Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)* (EPRI Report TR-105696, October 1995). The changes listed below supersede the affected Paragraphs of *TR-105696-R7 (BWRVIP-03) Revision 7: Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines* (EPRI Report 1009910, December 2004).

<b>Affected Section(s)</b>	<b>Description of Change</b>
xxv	Updated the Inspection Focus Group roster.
2.5, Para. 4.3	Added guidance for visual examination training, regarding detection and reporting of unusual crud deposits on the vessel interior or internals.
2.5, Para. 6.3.2	Clarified EVT-1 guidance to require that the resolution targets must be seen as a dark object; detection only of the bright, glinting reflection of the lights is not adequate.
2.6, Para. 3.1	Clarified UT personnel requirements to include CP-189 in addition to ASNT-TC-1A.
2.6, Para. 3.3	Corrected errata.
2.6, Para. 7.3	Clarified discussion of one-sided UT access. This change was also made in many report sections documenting individual technique demonstrations.
2.6, Para. 7.5	Clarified requirement for adequate recording of transducer position data in ultrasonic examination.
2.6, Para. 11.0	New paragraph, providing background information on UT with one-sided access.

---

2.7, Para. 3.1	Clarified ET personnel requirements to include CP-189 in addition to ASNT-TC-1A.
4.4.36, 5.4.21	Corrected errata.
4.4.37–4.4.41	New sections: New NDE technique demonstrations.
4.7.6–4.4.7	New sections: New delivery system demonstrations.
5.4.37–5.4.39	New sections: New NDE technique demonstrations.
5.6.4	New section: New delivery system demonstration.
10.3.5	Added documentation of new jet pump beam mockups.
10.4.1	Modified discussion of single-side access, for consistency with similar discussions elsewhere in the document.
10.4.11–10.4.14, 10.5.2	New sections: New NDE technique demonstrations.
10.6.4	New section: New delivery system demonstration.

# HISTORY OF CHANGES TO THIS DOCUMENT

## REVISION 7

---

This is a living document. Updates to the included data will be added as they are developed. Minor or editorial changes may not appear in this summary listing of significant changes. This document supersedes the November 21, 1994 Inspection Committee document *BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard and Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)* (EPRI Report TR-105696, October 1995). The changes listed below supersede the affected Paragraphs of *TR-105696-R6 (BWRVIP-03) Revision 6: Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines*, (EPRI Report 1008061, December 2003).

<b>Affected Section(s)</b>	<b>Description of Change</b>
xxxiii	Updated the Inspection Focus Group roster.
Chapter 1	Replaced all references to Inspection Committee with Focus Group.
2.5, Para. 3.5	Removed recording medium, water clarity, and lighting from list of key elements.
2.5, Para. 6.2	Changed title from Minimum Water Clarity to Environmental Conditions.
2.5, Para. 6.2.2	Added lighting conditions as an environmental condition, along with water clarity.
2.6, Para. 3.3, 4.1	Clarified UT qualifications that are required for standby liquid control welds and recognizes the recent availability of qualified manual examiners.
2.6, Para. 5.2	Clarified acceptability of normal variation in transducer frequency.
4.3.1.8, 4.3.1.9	New sections: Added documentation of new mockups BWRVIP-SSC-1 and BWRVIP-H6OH.
4.4.2	Added new Demonstration References for UT Demonstrations 33 and 34.



- 
- 4.4.35, 4.4.36 New sections: New NDE technique demonstrations.
- 5.3.2 Changed the word six to seven in the first line of the third paragraph.
- 5.4.21 Corrected an erratum and clarified the description of a technique's performance.
- 5.4.29–36 New sections: New NDE technique demonstrations.
- 10.2 Added a paragraph providing VT-1 guidance for viewing jet pump wedges.
- 11.1 Updated BWRVIP-27 to BWRVIP-27A where necessary.
- 11.2.3, 11.2.4 Updated guidance for SLC examination to include all allowable inspection alternatives: volumetric every ten years, surface examination every other outage, or enhanced leakage inspection every outage. Enhanced leakage inspection is to be performed with the insulation removed.

# HISTORY OF CHANGES TO THIS DOCUMENT

## REVISION 6

---

This is a living document. Updates to the included data will be added as they are developed. Minor or editorial changes may not appear in this summary listing of significant changes. This document supersedes the November 21, 1994 Inspection Committee document *BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard* and the October 1995 document *Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)*. The changes listed below supersede the affected paragraphs of *TR-105696R5 (BWRVIP-03) Revision 5: Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines, December 2002*.

Affected Section(s)	Description of Change
xix	Updated the Inspection Focus Group roster.
5.4.27 – 5.4.28	New sections: New NDE technique demonstrations.
5.6.3	New section: New NDE delivery system demonstration.
6.4.32 - 6.4.35	New sections: New NDE technique demonstrations.
All NDE technique and delivery system demonstrations	Added the publication date of each demonstration.
Many UT demonstrations	Where appropriate, added a note stating the need to ultrasonically examine stainless steel and nickel-alloy welds from both directions if possible. (The same note was already present in generic form in Section 2.6, the UT Standard. This action identifies more clearly which UT technique demonstrations it applies to.)

# HISTORY OF CHANGES TO THIS DOCUMENT

## REVISION 5

This is a living document. Updates to the included data will be added as they are developed. Minor or editorial changes may not appear in this summary listing of significant changes. This document supersedes the November 21, 1994 Inspection Committee document *BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard* and the October 1995 document *Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)*. The changes listed below supersede the affected paragraphs of *TR-105696R4 (BWRVIP-03) Revision 4: Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines*.

<b>Affected Section(s)</b>	<b>Description of Change</b>
xvii	Updated the Inspection Focus Group roster.
2.5, Para. 8.1.2	Clarifies documentation of EVT-1 examination coverage to recognize access limitations. Documentation must include an estimate of the percentage of the examination area that was covered with EVT-1 quality.
2.6 and 2.7, Para. 2.4	New paragraphs. References ASNT CP-189 in addition to SNT-TC-1A for qualification and certification of examination personnel.
2.6, Para. 3.3	Clarifies qualification requirements for personnel performing UT. Provides personnel qualification requirements for examining standby liquid control welds, and for determining whether flaws have propagated into the pressure vessel. Deleted Paragraph 3.3.3.2, which was made redundant by this change.
2.6, Para. 7.3	New paragraph. States the need to ultrasonically examine stainless steel and nickel-alloy welds from both directions.
4.4.2, 6.4.2	Updated demonstration tables.
4.4.33–4.4.34	New sections: New NDE technique demonstrations.
4.7.5	New section: New NDE delivery system demonstration.
6.3.1.4	Added documentation of core spray tee box mockup BWRVIP-N.
6.4.18, 6.4.19 and 6.4.24	Withdrew UT demonstrations for core spray hidden weld P9 because of recent findings from a new, more comprehensive set of mockups.
6.4.26–6.4.31	New sections: New NDE technique demonstrations.
10.4.10	New section: New NDE technique demonstration.

## HISTORY OF CHANGES TO THIS DOCUMENT REVISION 4

---

This is a living document. Updates to the included data will be added as they are developed. Minor or editorial changes may not appear in this summary listing of significant changes. This document supersedes the November 21, 1994 Inspection Committee document *BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard* and the October 1995 document *Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)*. The changes listed below supersede the affected paragraphs of *TR-105696R3 (BWRVIP-03) Revision 3 December 2000: Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines*.

<b>Affected Section(s)</b>	<b>Description of Change</b>
xvii	Updated the Committee roster.
2.6, Para. 3.3	Clarifies prerequisite for UT data analysis personnel: their IGSCC qualification must be on non-overlaid components.
4.1, 5.1, 6.1, 7.1, 8.2, 9.2, 10.2, 11.2, 12.2, 13.2	Clarifies that examination procedures must be appropriate to the specific configuration of the plant. Previously "utility-specific" procedures were called for. This change of wording is intended to remove any suggestion that the procedures must be tied administratively to the specific utility.
4.4.2, 6.4.2	Updated demonstration tables.
4.4.29–4.4.32	New sections: New NDE technique demonstrations.
5.3.5	New section: Description of BWR/2 H8/H9 mockups.
5.4.23–5.4.26	New sections: New NDE technique demonstrations.
5.6.2	New section: New NDE delivery system demonstration.
6.4.21–6.4.25	New sections: New NDE technique demonstrations.
8.4.4	New section: New NDE technique demonstration.
TOC, Figure 6.3.1.5-1, 11.2.3	Correction of errata.

# HISTORY OF CHANGES TO THIS DOCUMENT

## REVISION 3

---

This is a living document. Updates to the included data will be added as they are developed. Minor or editorial changes may not appear in this summary listing of significant changes. This document supersedes the November 21, 1994 Inspection Committee *document BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard* and the October 1995 *document Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)*. The changes listed below supersede the affected paragraphs of the December 1999 *document Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03) Revision 2*.

### **Affected Section(s)    Description of Change**

1	Updated the Committee roster.
2.5, Para. 8.1.3	For EVT-1, recommends that the method of measuring flaw length (estimation or ruler) be recorded.
5.3.4	Updated the description of shroud support mockups.
5.4.21, 5.4.22	New sections: New NDE technique demonstrations.
6.2.2, 9.2, 10.2	Updates status of hidden welds.
6.3.1.5	New section: description of BWR/6 core spray mockup.
6.4.20	New section: New NDE technique demonstration.
10.4.9, 10.5.1	New sections: New NDE technique demonstrations.
13.3	Updated the status of control rod guide tube mockup.

# HISTORY OF CHANGES TO THIS DOCUMENT

## REVISION 2

---

This is a living document. Updates to the included data will be added as they are developed. Minor or editorial changes may not appear in this summary listing of significant changes. This document supersedes the November 21, 1994 Inspection Committee document *BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard* and the October 1995 document *Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)*. The changes listed below supersede the affected paragraphs of the March 1999 document *Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03) Revision 1*.

Affected Section(s)	Description of Change
1	Updated the Committee roster.
2.6, Paragraph 3.3	Modified the personnel qualification requirements for selected examinations.
3.0	Correction: Changed heading numbers to correspond with rest of the document.
4.3.1.7	New section: Description of new mockup BWRVIP-H1.
4.4.28	New section: New NDE technique demonstration.
5.4.20	New section: New NDE technique demonstration.
6.3.1.2	Correction: Figure 6.3.1.2-4 correct image inserted.
6.4.18-19	New sections: New NDE technique demonstrations.
8.4.3	New section: New NDE technique demonstration.

# HISTORY OF CHANGES TO THIS DOCUMENT

## REVISION 1

---

This is a living document. Updates to the included data on components that had already been addressed, and new report sections on components that had not yet been addressed, will be added as they are developed. Minor or editorial changes may not appear in this listing. This document supersedes the November 21, 1994 Inspection *Committee document BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard* and the October 1995 document *Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines (BWRVIP-03)*.

<b>Affected Section(s)</b>	<b>Description of Change</b>
1	Updated the Committee roster and Acknowledgments.
2.1 - 2.4	Changes to administrative procedures, made necessary by discontinuation of referenced Inspection Committee working groups. Revised key elements for visual inspection.
2.5	New section: "Generic Standards for Visual Examination of Reactor Pressure Vessel Internals, Components, and Associated Repairs."
2.6	New section: "Generic Standards for Ultrasonic Examination of BWR Vessel Internal Components."
2.7	New section: "Generic Standards for Eddy Current Examination of BWR Vessel Internal Components."
3.0	New section: "Demonstration of Accuracy of Flaw Length Measurement by Visual Examination." This section replaces the existing Section 3.
3.0	Correction: Changed heading numbers to correspond with rest of the document.
4	Added reference to generic NDE standards, Sections 2.5 – 2.7.
4.3	Added documentation of new mockups.

---

4.4.19 – 4.4.26, 4.6.5 – 4.6.6, 4.7.3	New sections: Documentation of NDE demonstrations conducted since issuance of prior documents.
4A, 4B, 4C	Deleted. Shroud-specific NDE standards deleted, references to generic standards in Sections 2.5 – 2.7 added.
5	Added reference to generic NDE standards, Sections 2.5 – 2.7.
5.3	Added documentation of new mockups.
5.4.10 – 5.4.18	New sections: Documentation of NDE demonstrations conducted since issuance of prior documents.
6	New section: Core Spray Piping and Sparger. These components had not been addressed in prior documents, except for Section 6A, “Standards for Visual Inspection of Core Spray Piping, Spargers, and Associated Components.”
6A	Section 6A, “Standards for Visual Inspection of Core Spray Piping, Spargers, and Associated Components,” is now deleted and Section 2.5 is referenced instead. New Section 6A: “Investigation of Core Spray Internal Piping Overlay Inspection.”
7	New section: Top Guide.
8	New section: Core Plate.
9	New section: LPCI Coupling.
10	New section: Jet Pump Assembly.
11	New section: Standby Liquid Control.
12	New section: Vessel Attachments.
13	New section: Lower Plenum.
14	New section: Vessel Penetrations.



## BWRVIP INSPECTION FOCUS GROUP

---

Richard Ciemiewicz, Technical Chairman    *Exelon Corporation*  
David Potter, Vice Technical Chairman    *Xcel Energy Services, Inc.*

Steve Brown	Entergy Operations, Inc.
Frank Dohmen	FPL Energy Duane Arnold
David Galbally	Iberdrola Generacion, S.A.
Stan Gorski	FirstEnergy Nuclear Operating Company
Patrick Gräedel	BKW FMB Energie AG (KKM)
Fred Habib	PPL Susquehanna, LLC
Rick Hambleton	Detroit Edison Company
Thomas Jones	Xcel Energy Services, Inc.
Scott Larson	Progress Energy, Inc.
Tim McClure	Nebraska Public Power District
Marco A. Sanchez Medel	Comisión Federal de Electricidad (CFE)
Ryohei Okada	Tokyo Electric Power Company
Tony Oliveri	PSEG Nuclear, LLC
Douglas Ramey	Energy Northwest
Rudy Schwammberger	Kernkraftwerk Leibstadt AG
Rick Seals	Tennessee Valley Authority
Dave Anthony	Exelon Corporation
Porfirio Perez Tegedor	Iberdrola Generacion, S.A.
Kevin White	Southern Nuclear Operating Company
Norimichi Yamashita	Tokyo Electric Power Company

Jeff Landrum, *EPRi Task Manager*

## ACKNOWLEDGMENTS

---

The BWRVIP Inspection Focus Group acknowledges the support of General Electric, Visual Inspection Technologies, Imaging and Sensing Technologies, RJ Electronics, and Framatome Technologies in providing personnel and equipment for demonstration of visual examination techniques.

The staff of the EPRI NDE Center are acknowledged for their successful completion of this document:

Mark Dennis  
Jeff Landrum  
Greg Selby  
Paul Zayicek

# CONTENTS

---

<b>*1 BWRVIP OVERVIEW AND BACKGROUND</b> .....	<b>1-1</b>
1.1 BWRVIP.....	1-1
1.2 BWRVIP Inspection Focus Group.....	1-1
1.3 General Approach to Inspection Support.....	1-2
1.4 Implementation Requirements.....	1-3
<b>2 GENERAL PROCEDURES</b> .....	<b>2-1</b>
2.1 Guidelines for Use of BWRVIP Mockups.....	2-2
1.0 Purpose.....	2-2
2.0 Reference.....	2-2
3.0 Guidelines for Usage.....	2-2
4.0 Guidelines for Use Prioritization.....	2-4
2.2 Protocol for NDE Technique Demonstrations on BWRVIP Mockups.....	2-5
1.0 Purpose.....	2-5
2.0 Responsibilities.....	2-5
3.0 Prerequisites.....	2-5
4.0 Demonstration Plan.....	2-6
5.0 Demonstration Process.....	2-6
6.0 Results Reporting and Documentation.....	2-7
2.3 Guidelines for Determining NDE Technique Uncertainty.....	2-8
1.0 Purpose.....	2-8
2.0 References.....	2-8
3.0 Responsibilities.....	2-8
4.0 Demonstration Process.....	2-9
5.0 Documentation.....	2-11
2.4 Guidelines for Determining Inspection Tool Positioning Uncertainty.....	2-13
1.0 Purpose.....	2-13
2.0 References.....	2-13

3.0	Responsibilities .....	2-13
4.0	Guidelines for Uncertainty Measurements .....	2-14
5.0	Demonstration Plan.....	2-14
6.0	Demonstration Process.....	2-14
7.0	Documentation .....	2-15
2.5	Generic Standards for Visual Inspection of Reactor Pressure Vessel Internals, Components, and Associated Repairs .....	2-16
1.0	Purpose.....	2-16
2.0	Scope .....	2-16
3.0	Definitions .....	2-16
4.0	Personnel Training/Experience .....	2-17
5.0	Equipment Requirements.....	2-19
6.0	Inspection Requirements .....	2-22
7.0	Evaluation of Indications .....	2-26
8.0	Documentation of Results .....	2-27
2.6	Generic Standards for Ultrasonic Examination of BWR Vessel Internal Components.....	2-28
1.0	Scope .....	2-28
2.0	References.....	2-28
3.0	Personnel .....	2-28
4.0	Technique Demonstrations .....	2-31
5.0	Equipment.....	2-31
6.0	Calibration .....	2-32
7.0	Examination .....	2-33
8.0	Recording.....	2-34
9.0	Evaluation .....	2-35
10.0	Reporting.....	2-35
11.0	Examination of Stainless Steel and Nickel-Alloy Welds with Single-Sided Access.....	2-36
2.7	Generic Standards for Eddy Current Examination of BWR Vessel Internal Components.....	2-40
1.0	Scope .....	2-40
2.0	References.....	2-40
3.0	Personnel .....	2-40
4.0	Technique Demonstration .....	2-41
5.0	Equipment.....	2-41

6.0	Calibration .....	2-42
7.0	Examination .....	2-42
8.0	Recording .....	2-44
9.0	Evaluation .....	2-44
10.0	Reporting.....	2-44

**3 DEMONSTRATION OF ACCURACY OF FLAW LENGTH MEASUREMENT BY VISUAL EXAMINATION..... 3-1**

3.1	Summary .....	3-1
3.2	Demonstration .....	3-1
3.2.1	Vendors.....	3-2
3.2.2	Mockups.....	3-2
3.2.3	Flaws.....	3-2
3.2.4	Cameras.....	3-3
3.2.5	Measurement Techniques.....	3-3
3.3	Sizing Performance.....	3-3
3.3.1	Estimation .....	3-3
3.3.2	Measurement by Ruler.....	3-5

**4 SHROUD ..... 4-1**

4.1	Summary .....	4-1
4.2	Inspection Considerations .....	4-2
4.3	Applicable Mockups .....	4-3
4.3.1	Shroud Weld Mockups .....	4-3
4.3.1.1	NDE Center's Original H3 Mockup.....	4-4
4.3.1.2	Utility H3 and H4 Mockups.....	4-4
4.3.1.3	Shroud Block BWRVIP-A: Ring-to-Cylinder .....	4-4
4.3.1.4	Shroud Block BWRVIP-B: Ring-to-Cylinder .....	4-6
4.3.1.5	Shroud Block BWRVIP-C: Cylinder-to-Cylinder .....	4-8
4.3.1.6	Shroud Mockup BWRVIP-G and H: Ring Segment Welds.....	4-10
4.3.1.7	Shroud Mockup BWRVIP-H1: Shroud Weld H1.....	4-13
4.3.1.8	Shroud Mockup BWRVIP-SSC1: Shroud Scallops .....	4-13
4.3.1.9	Shroud Mockup BWRVIP-H6OH: Overhanging Core Plate Support Ring.....	4-15
4.3.1.10	Shroud Mockup BWRVIP-TGSR: Radial Ring Segment Mockup .....	4-16
4.3.1.11	BWRVIP-H2/H3: Top Guide Support Ring-to-Cylinder Mockup.....	4-17

4.3.2	Special Purpose Mockups.....	4-20
4.3.2.1	Surface Roughness.....	4-20
4.3.2.2	Multiple Parallel Cracks.....	4-21
4.3.2.3	EDM Notches in Weld Toe.....	4-22
4.4	UT Technique Demonstrations for Core Shroud Welds.....	4-23
*4.4.1	General Findings for UT.....	4-23
*4.4.1.1	Detection of Shallow Reflectors.....	4-23
*4.4.1.2	Detection of Skewed Reflectors.....	4-23
*4.4.1.3	Effect of Multiple Parallel Defects.....	4-24
*4.4.1.4	Effect of Roughness of Scanning Surface.....	4-24
4.4.2	UT Demonstration Summary.....	4-25
4.4.3	UT Demonstration 1.....	4-28
4.4.4	UT Demonstration 2.....	4-29
4.4.5	UT Demonstration 3.....	4-30
4.4.6	UT Demonstration 4.....	4-32
4.4.7	UT Demonstration 5.....	4-33
4.4.8	UT Demonstration 6.....	4-34
4.4.9	UT Demonstration 7.....	4-35
4.4.10	UT Demonstration 8.....	4-36
4.4.11	UT Demonstration 9.....	4-37
4.4.12	UT Demonstration 10.....	4-38
4.4.13	UT Demonstration 11.....	4-39
4.4.14	UT Demonstration 12.....	4-40
4.4.15	UT Demonstration 13.....	4-41
4.4.16	UT Demonstration 14.....	4-42
4.4.17	UT Demonstration 15.....	4-43
4.4.18	UT Demonstration 16.....	4-44
4.4.19	UT Demonstration 17.....	4-47
4.4.20	UT Demonstration 18.....	4-48
4.4.21	UT Demonstration 19.....	4-49
4.4.22	UT Demonstration 20.....	4-50
4.4.23	UT Demonstration 21.....	4-52
4.4.24	UT Demonstration 22.....	4-53
4.4.25	UT Demonstration 23.....	4-54
4.4.26	UT Demonstration 24.....	4-55

---

4.4.27	UT Demonstration 25.....	4-56
4.4.28	UT Demonstration 26.....	4-59
4.4.29	UT Demonstration 27.....	4-60
4.4.30	UT Demonstration 28.....	4-61
4.4.31	UT Demonstration 29.....	4-62
4.4.32	UT Demonstration 30.....	4-64
4.4.33	UT Demonstration 31.....	4-66
4.4.34	UT Demonstration 32.....	4-67
4.4.35	UT Demonstration 33.....	4-68
4.4.36	UT Demonstration 34.....	4-70
4.4.37	UT Demonstration 35.....	4-72
4.4.38	UT Demonstration 36.....	4-74
4.4.39	UT Demonstration 37.....	4-76
4.4.40	UT Demonstration 38.....	4-77
4.4.41	UT Demonstration 39.....	4-80
4.4.42	UT Demonstration 40.....	4-82
4.4.43	UT Demonstration 41.....	4-85
4.4.44	UT Demonstration 42.....	4-87
4.4.45	UT Demonstration 43.....	4-89
4.4.46	UT Demonstration 44.....	4-91
4.4.47	UT Demonstration 45.....	4-94
4.4.48	UT Demonstration 46.....	4-96
4.4.49	UT Demonstration 47.....	4-99
4.4.50	UT Demonstration 48.....	4-101
4.4.51	UT Demonstration 49.....	4-103
4.4.52	UT Demonstration 50.....	4-106
4.4.53	UT Demonstration 51.....	4-108
4.4.54	UT Demonstration 52.....	4-110
4.4.55	UT Demonstration 53.....	4-112
4.4.56	UT Demonstration 54.....	4-114
4.4.57	UT Demonstration 55.....	4-117
4.4.58	UT Demonstration 56.....	4-119
4.4.59	UT Demonstration 57.....	4-123
4.4.60	UT Demonstration 58.....	4-126
4.4.61	UT Demonstration 59.....	4-128

4.5	VT Technique Demonstrations for Core Shroud Welds.....	4-131
*4.5.1	VT General Findings .....	4-131
4.5.1.1	Training .....	4-131
*4.5.2	VT Demonstration 1 .....	4-131
4.6	ET Technique Demonstrations for Core Shroud Welds.....	4-134
4.6.1	ET General Findings .....	4-134
4.6.1.1	Detection of Skewed Reflectors .....	4-135
4.6.1.2	Effect of Scanning on a Rough Surface .....	4-135
4.6.1.3	Scan Pattern .....	4-136
*4.6.2	ET Demonstration 1 .....	4-137
4.6.2.1	Crack Length Measurement.....	4-137
4.6.2.2	Optimum Parameters for ET Imaging.....	4-137
*4.6.3	ET Demonstration 2 .....	4-140
4.6.4	ET Demonstration 3 .....	4-141
4.6.4.1	Data Acquisition .....	4-141
4.6.4.2	Data Evaluation.....	4-141
4.6.5	ET Demonstration 4 .....	4-142
4.6.6	ET Demonstration 5 .....	4-143
4.7	Delivery System Demonstrations for Core Shroud Welds .....	4-147
*4.7.1	Delivery System Demonstration 1.....	4-148
*4.7.2	Delivery System Demonstration 2.....	4-149
4.7.3	Delivery System Demonstration 3.....	4-150
4.7.4	Delivery System Demonstration 4.....	4-151
4.7.5	Delivery System Demonstration 5.....	4-153
4.7.6	Delivery System Demonstration 6.....	4-155
4.7.7	Delivery System Demonstration 7 .....	4-157
4.7.7.1	Flaw Length Measurement Within a Single Scan .....	4-157
4.7.7.2	Flaw Length Measurement Using More Than One Scan.....	4-157
4.7.8	Delivery System Demonstration 8.....	4-159
4.7.8.1	Horizontal Welds .....	4-160
4.7.8.2	Vertical Welds .....	4-160
4.7.8.3	H2/H3 Welds (Scanned from the Ledge) .....	4-161
*4.8	References .....	4-163
<b>5</b>	<b>SHROUD SUPPORT .....</b>	<b>5-1</b>



5.1	Summary .....	5-1
5.2	Inspection Considerations .....	5-2
5.2.1	Chicago Bridge & Iron/CBI Nuclear Shroud Supports.....	5-2
5.2.2	Babcock & Wilcox Shroud Supports .....	5-3
5.2.3	Combustion Engineering Shroud Supports.....	5-4
5.2.3.1	Gusset Supports .....	5-4
5.2.3.2	Cone Skirt Support.....	5-5
5.2.3.3	Heavy Steel Baffle Plate.....	5-6
5.2.4	Inspection Access .....	5-7
5.3	Applicable Mockups.....	5-7
5.3.1	Shroud Support Mockup BWRVIP-D: Weld H7.....	5-7
5.3.2	Shroud Support Mockups BWRVIP-E, BWRVIP-E1, and BWRVIP-E2: Weld H9.....	5-12
5.3.3	Shroud Support Mockup BWRVIP-F: Weld H8 .....	5-33
5.3.4	Shroud Support Mockups BWRVIP-P, BWRVIP-Q1, BWRVIP-Q2 .....	5-39
5.3.5	Shroud Support Mockups BWRVIP-B2SS1 and BWRVIP-B2SS2 .....	5-41
5.4	UT Technique Demonstrations for Core Shroud Support Welds .....	5-42
5.4.1	General Findings for UT.....	5-42
5.4.1.1	Effect of Alloy 82/182 Weld Material .....	5-43
5.4.1.2	Effect of Mismatch in the Fit-up of Weld H7 .....	5-43
5.4.2	UT Demonstration 1 .....	5-44
5.4.3	UT Demonstration 2.....	5-45
5.4.4	UT Demonstration 3.....	5-46
5.4.5	UT Demonstration 4.....	5-47
5.4.6	UT Demonstration 5.....	5-48
5.4.7	UT Demonstration 6.....	5-51
5.4.8	UT Demonstration 7.....	5-52
5.4.9	UT Demonstration 8.....	5-53
5.4.10	UT Demonstration 9.....	5-54
5.4.11	UT Demonstration 10.....	5-55
5.4.12	UT Demonstration 11.....	5-56
5.4.13	UT Demonstration 12.....	5-57
5.4.14	UT Demonstration 13.....	5-58
5.4.15	UT Demonstration 14.....	5-59
5.4.16	UT Demonstration 15.....	5-60

5.4.17	UT Demonstration 16.....	5-61
5.4.18	UT Demonstration 17.....	5-62
5.4.19	UT Demonstration 18.....	5-65
5.4.20	UT Demonstration 19.....	5-67
5.4.21	UT Demonstration 20.....	5-68
5.4.22	UT Demonstration 21.....	5-69
5.4.23	UT Demonstration 22.....	5-70
5.4.24	UT Demonstration 23.....	5-72
5.4.25	UT Demonstration 24.....	5-74
5.4.26	UT Demonstration 25.....	5-76
5.4.27	UT Demonstration 26.....	5-77
5.4.28	UT Demonstration 27.....	5-79
5.4.29	UT Demonstration 28.....	5-83
5.4.30	UT Demonstration 29.....	5-85
5.4.31	UT Demonstration 30.....	5-89
5.4.32	UT Demonstration 31.....	5-92
5.4.33	UT Demonstration 32.....	5-94
5.4.34	UT Demonstration 33.....	5-95
5.4.35	UT Demonstration 34.....	5-96
5.4.36	UT Demonstration 35.....	5-97
5.4.37	UT Demonstration 36.....	5-100
5.4.38	UT Demonstration 37.....	5-101
5.4.39	UT Demonstration 38.....	5-102
5.4.40	UT Demonstration 39.....	5-104
5.4.41	UT Demonstration 40.....	5-106
5.4.42	UT Demonstration 41.....	5-108
5.4.43	UT Demonstration 42.....	5-110
5.4.44	UT Demonstration 43.....	5-112
5.4.45	UT Demonstration 44.....	5-114
5.4.46	UT Demonstration 45.....	5-116
5.4.47	UT Demonstration 46.....	5-118
5.4.48	UT Demonstration 47.....	5-122
5.4.49	UT Demonstration 48.....	5-126
5.5	ET Technique Demonstrations for Core Shroud Support Welds .....	5-129
5.5.1	General Findings for ET.....	5-129

5.5.2	ET Demonstration 1 .....	5-129
5.6	Delivery System Demonstrations for Core Shroud Support Welds.....	5-130
5.6.1	Delivery System Demonstration 1 .....	5-130
5.6.2	Delivery System Demonstration 2.....	5-131
5.6.3	Delivery System Demonstration 3.....	5-132
5.6.4	Delivery System Demonstration 4.....	5-134
<b>6</b>	<b>CORE SPRAY PIPING AND SPARGER .....</b>	<b>6-1</b>
6.1	Summary .....	6-1
6.2	Inspection Considerations .....	6-2
6.2.1	Downcomer Sleeve .....	6-7
6.2.2	Tee Box Assembly .....	6-8
6.2.3	Shroud Connection Region .....	6-9
6.3	Applicable Mockups .....	6-9
6.3.1	Core Spray Mockups.....	6-9
6.3.1.1	Downcomer Sleeve Joint Mockup (BWRVIP-J) .....	6-10
6.3.1.2	BWR/2 Shroud Penetration Mockup (BWRVIP-K) .....	6-15
6.3.1.3	BWR/3-5 Shroud Penetration Mockup (BWRVIP-L) .....	6-20
6.3.1.4	BWR/3-5 Core Spray Header Tee Box Mockups (BWRVIP-M and -N) .....	6-24
6.3.1.5	BWR/6 Core Spray Pipe Coupling Assembly Mockup (BWRVIP-CS6) .....	6-24
6.3.1.6	BWR/3-6 P4a, P4b, and P4c Pipe-to-Elbow Mockups (BWRVIP-P4-1 and BWRVIP-P4-2).....	6-30
6.4	UT Technique Demonstrations for Core Spray Welds.....	6-33
6.4.1	General Findings for UT.....	6-33
6.4.1.1	Detection and Sizing of Flaws Parallel to the Weld.....	6-33
6.4.1.2	Detection of Flaws Transverse to the Weld.....	6-33
6.4.1.3	Effect of Roughness of Scanning Surface.....	6-33
6.4.2	UT Demonstration Summary.....	6-34
6.4.3	UT Demonstration 1 .....	6-36
6.4.4	UT Demonstration 2.....	6-37
6.4.5	UT Demonstration 3 .....	6-38
6.4.6	UT Demonstration 4 .....	6-39
6.4.7	UT Demonstration 5.....	6-40
6.4.8	UT Demonstration 6.....	6-41
6.4.9	UT Demonstration 7 .....	6-42

---

6.4.10	UT Demonstration 8.....	6-43
6.4.11	UT Demonstration 9.....	6-45
6.4.12	UT Demonstration 10.....	6-47
6.4.13	UT Demonstration 11.....	6-49
6.4.14	UT Demonstration 12.....	6-50
6.4.15	UT Demonstration 13.....	6-52
6.4.16	UT Demonstration 14.....	6-54
6.4.17	UT Demonstration 15.....	6-55
6.4.18	UT Demonstration 16.....	6-56
6.4.19	UT Demonstration 17.....	6-57
6.4.20	UT Demonstration 18.....	6-58
6.4.21	UT Demonstration 19.....	6-59
6.4.22	UT Demonstration 20.....	6-61
6.4.23	UT Demonstration 21.....	6-62
6.4.24	UT Demonstration 22.....	6-63
6.4.25	UT Demonstration 23.....	6-64
6.4.26	UT Demonstration 24.....	6-65
6.4.27	UT Demonstration 25.....	6-67
6.4.28	UT Demonstration 26.....	6-68
6.4.29	UT Demonstration 27.....	6-70
6.4.30	UT Demonstration 28.....	6-71
6.4.31	UT Demonstration 29.....	6-73
6.4.32	UT Demonstration 30.....	6-74
6.4.33	UT Demonstration 31.....	6-77
6.4.34	UT Demonstration 32.....	6-78
6.4.35	UT Demonstration 33.....	6-79
6.4.36	UT Demonstration 34.....	6-81
6.4.37	UT Demonstration 35.....	6-82
6.4.38	UT Demonstration 36.....	6-83
6.4.39	UT Demonstration 37.....	6-84
6.4.40	UT Demonstration 38.....	6-85
6.4.41	UT Demonstration 39.....	6-87
6.4.42	UT Demonstration 40.....	6-89
6.4.43	UT Demonstration 41.....	6-90

<b>6 A INVESTIGATION OF CORE SPRAY INTERNAL PIPING OVERLAY INSPECTION .....</b>	<b>6A-1</b>
6A.1    Materials.....	6A-1
6A.1.1    Probes .....	6A-1
6A.1.2    Ultrasonic Instrument.....	6A-2
6A.1.3    Mockups .....	6A-2
6A.2    Surface Condition.....	6A-5
6A.3    Examination Results .....	6A-5
6A.4    Conclusions.....	6A-6
6A.5    References.....	6A-6
<b>7 TOP GUIDE .....</b>	<b>7-1</b>
7.1    Summary .....	7-1
7.2    Inspection Considerations .....	7-2
7.2.1    Aligner Pin Assemblies .....	7-2
7.2.2    Hold-Down Assemblies .....	7-5
7.2.3    Wedges .....	7-7
7.2.4    BWR/6 Hold-Down Studs.....	7-9
7.2.5    Rim-to-Bottom Plate Weld.....	7-9
7.2.6    Grid Beams .....	7-10
7.3    Applicable Mockups.....	7-12
7.3.1    Top Guide Grid Mockup BWRVIP-I.....	7-12
7.4    UT Technique Demonstrations for Top Guide Components.....	7-16
7.4.1    General Findings for UT.....	7-16
7.4.1.1    Grid Beams .....	7-17
7.4.2    UT Demonstration 1 .....	7-18
<b>8 CORE PLATE.....</b>	<b>8-1</b>
8.1    Summary .....	8-1
8.2    Inspection Considerations .....	8-2
8.2.1    Rim Hold-Down Bolt Locations .....	8-2
8.3    Applicable Mockups.....	8-3
8.4    UT Technique Demonstrations for Core Plate Rim Hold-Down Bolts.....	8-5
8.4.1    UT Demonstration 1 .....	8-5
8.4.2    UT Demonstration 2 .....	8-6
8.4.3    UT Demonstration 3 .....	8-7

8.4.4	UT Demonstration 4 .....	8-8
<b>9</b>	<b>LPCI COUPLING .....</b>	<b>9-1</b>
9.1	Summary .....	9-1
9.2	Inspection Considerations .....	9-1
9.3	Applicable Mockups .....	9-3
9.4	UT Technique Demonstrations for LPCI Coupling Welds .....	9-3
<b>10</b>	<b>JET PUMP ASSEMBLY .....</b>	<b>10-1</b>
10.1	Summary .....	10-1
10.2	Inspection Considerations .....	10-2
10.3	Applicable Mockups .....	10-3
10.3.1	Mockup BWRVIP-U .....	10-3
10.3.2	Mockup BWRVIP-V .....	10-3
10.3.3	Mockups BWRVIP-Z3 and BWRVIP-Z3R .....	10-3
10.3.4	Mockup BWRVIP-Z4 .....	10-3
10.3.5	Jet Pump Beam Mockups .....	10-4
10.4	UT Technique Demonstrations .....	10-12
10.4.1	General Findings for UT .....	10-12
10.4.2	UT Demonstration 1 .....	10-13
10.4.3	UT Demonstration 2 .....	10-14
10.4.4	UT Demonstration 3 .....	10-15
10.4.5	UT Demonstration 4 .....	10-17
10.4.6	UT Demonstration 5 .....	10-18
10.4.7	UT Demonstration 6 .....	10-19
10.4.8	UT Demonstration 7 .....	10-20
10.4.9	UT Demonstration 8 .....	10-21
10.4.10	UT Demonstration 9 .....	10-22
10.4.11	UT Demonstration 10 .....	10-24
10.4.12	UT Demonstration 11 .....	10-27
10.4.13	UT Demonstration 12 .....	10-28
10.4.14	UT Demonstration 13 .....	10-29
10.4.15	UT Demonstration 14 .....	10-30
10.4.16	UT Demonstration 15 .....	10-33
10.4.17	UT Demonstration 16 .....	10-36

10.4.18	UT Demonstration 17.....	10-37
10.4.19	UT Demonstration 18.....	10-38
10.4.20	UT Demonstration 19.....	10-42
10.4.21	UT Demonstration 20.....	10-44
10.4.22	UT Demonstration 21.....	10-46
10.5	ET Technique Demonstrations.....	10-50
10.5.1	ET Demonstration 1.....	10-50
10.5.2	ET Demonstration 2.....	10-51
10.6	Delivery System Demonstrations.....	10-52
10.6.1	Delivery System Demonstration 1.....	10-52
10.6.2	Delivery System Demonstration 2.....	10-53
10.6.3	Delivery System Demonstration 3.....	10-54
10.6.4	Delivery System Demonstration 4.....	10-55
<b>11</b>	<b>STANDBY LIQUID CONTROL.....</b>	<b>11-1</b>
11.1	Summary.....	11-1
11.2	Inspection Considerations.....	11-2
11.2.1	Nozzle-to-Vessel Weld.....	11-2
11.2.2	Penetration-to-Vessel Weld.....	11-2
11.2.3	Nozzle-to-Safe-End Weld.....	11-3
11.2.4	Penetration-to-Safe-End Extension Weld.....	11-3
11.3	Applicable Mockups.....	11-4
11.3.1	Mockup BWRVIP-X1.....	11-4
11.3.2	Mockup BWRVIP-X2.....	11-4
11.3.3	Mockup BWRVIP-Y3.....	11-4
11.3.4	Mockup BWRVIP-Y4.....	11-4
11.3.5	Mockup BWRVIP-Y5.....	11-4
11.4	UT Technique Demonstrations for SLC Components.....	11-5
11.4.1	General Findings for UT.....	11-5
11.4.2	UT Demonstration 1.....	11-5
11.4.3	UT Demonstration 2.....	11-6

---

<b>12 VESSEL ATTACHMENTS .....</b>	<b>12-1</b>
12.1 Summary .....	12-1
12.2 Inspection Considerations .....	12-2
12.3 Applicable Mockups .....	12-2
12.4 UT Technique Demonstrations for Vessel Attachment Welds .....	12-2
<b>13 LOWER PLENUM .....</b>	<b>13-1</b>
13.1 Summary .....	13-1
13.2 Inspection Considerations .....	13-2
13.3 Applicable Mockups .....	13-2
13.3.1 BWRVIP-CRDH1 .....	13-3
13.4 UT Technique Demonstrations for Lower Plenum Welds .....	13-5
13.4.1 UT Demonstration 1 .....	13-5
<b>14 INSTRUMENT PENETRATIONS .....</b>	<b>14-1</b>
14.1 Summary .....	14-1
14.2 Inspection Considerations .....	14-1
<b>15 ACCESS HOLE COVERS .....</b>	<b>15-1</b>
15.1 Summary .....	15-1
15.2 Inspection Considerations .....	15-2
15.2.1 Thin Access Hole Covers .....	15-4
15.2.2 Intermediate Thickness Access Hole Covers .....	15-5
15.2.3 Thick Access Hole Covers .....	15-6
15.2.4 Non-Creviced Retrofit Design for Some BWR/4 and BWR/5 Plants .....	15-6
15.2.5 Non-Creviced Single Access Hole Cover Design .....	15-7
15.3 Applicable Mockups .....	15-8
15.3.1 Access Hole Cover Mockups .....	15-8
15.3.1.1 BWRVIP-AHC1 .....	15-9
15.3.1.2 BWRVIP-AHC2 .....	15-10
15.3.1.3 BWRVIP-AHC3 and BWRVIP-AHC4 .....	15-11
15.3.1.4 BWRVIP-AHC5 .....	15-12
15.3.1.5 BWRVIP-AHC6 .....	15-13



---

15.4	UT Technique Demonstrations for Access Hole Covers .....	15-14
15.4.1	UT Demonstration Summary .....	15-14
15.4.2	UT Demonstration 1 .....	15-15
15.5	References .....	15-18

\* This section, its subsections, and all associated figures and tables are not proprietary. All sections that are NOT marked with an asterisk, their subsections, and associated figures and tables, are proprietary.

# LIST OF FIGURES

Figure 2.5.8.1-1. System Setup .....	2-27
Figure 4.3.1.3-1. Design of Shroud Mockup BWRVIP-A .....	4-5
Figure 4.3.1.3-2. Cross Section of Weld in Mockup BWRVIP-A .....	4-6
Figure 4.3.1.4-1. Design of Shroud Mockup BWRVIP-B .....	4-7
Figure 4.3.1.4-2. Cross Section of Weld in Mockup BWRVIP-B .....	4-8
Figure 4.3.1.5-1. Design of Shroud Mockup BWRVIP-C .....	4-9
Figure 4.3.1.5-2. Cross Section of Weld in Mockup BWRVIP-C .....	4-10
Figure 4.3.1.6-1. Mockup BWRVIP-G and BWRVIP-H, Representing the Ring Segment Weld .....	4-11
Figure 4.3.1.6-2. Cross Section of Mockup BWRVIP-G and BWRVIP-H .....	4-12
Figure 4.3.1.6-3. Shroud Ring Segment Weld .....	4-12
Figure 4.3.1.7-1. Mockup BWRVIP-H1: Shroud Weld H1 .....	4-165
Figure 4.3.1.8-1. Mockup BWRVIP-SSC1 .....	4-14
Figure 4.3.1.8-2. Mockup BWRVIP-SSC1; Detail of Notches 1-4 .....	4-14
Figure 4.3.1.8-3. Mockup BWRVIP-SSC1; Detail of Notches 5-8 .....	4-15
Figure 4.3.1.9-1. Illustration of the Overhanging Configuration of Weld H6b .....	4-16
Figure 4.3.1.9-2. BWRVIP-H6OH, Representing the Overhanging Core Plate Support Ring Weld Configuration .....	4-166
Figure 4.3.1.10-1. BWRVIP-TGSR Mockup (Photograph) .....	4-17
Figure 4.3.1.10-2. Configuration Drawing of Mockup BWRVIP-TGSR .....	4-167
Figure 4.3.1.10-3. Flaw Details for Mockup BWRVIP-TGSR .....	4-168
Figure 4.3.1.11-1. Typical Phased Array Technique for Examination of Core Shroud H2 Welds .....	4-18
Figure 4.3.1.11-2. Typical Phased Array Technique for Examination of Core Shroud H3 Welds .....	4-18
Figure 4.3.1.11-3. Photograph of BWRVIP-H2/H3 Mockup .....	4-19
Figure 4.3.1.11-4. Configuration of BWRVIP-H2/H3 (Side View) .....	4-19
Figure 4.3.1.11-5. Configuration of BWRVIP-H2/H3 (End View) .....	4-169
Figure 4.3.1.11-6. BWRVIP-H2/H3 Ring Segment Weld Flaws .....	4-170
Figure 4.3.1.11-7. BWRVIP-H2/H3 Ring-to-Cylinder Weld Flaws (Flaws 1 Through 4) .....	4-171
Figure 4.3.1.11-8. BWRVIP-H2/H3 Ring-to-Cylinder Weld Flaws (Flaws 5 Through 8) .....	4-172
Figure 4.3.1.11-9. BWRVIP-H2/H3 Flaw Details .....	4-173
Figure 4.3.2.1-1. Surface Roughness Mockup .....	4-21

Figure 4.3.2.2-1. Mockup With Multiple, Parallel EDM Notches .....	4-22
Figure 4.4.5-1. Principle of Operation of Creeping-Wave Probes.....	4-31
Figure 4.4.5-2. Principle of Operation of LLT Technique .....	4-31
Figure 4.4.40-1. Illustration of Sector-Scan Examination of Weld H2 and Full-Vee Linear-Scan Examination of Weld H3 .....	4-79
Figure 4.4.46-1. GE Immersion UT Technique for Weld H1 .....	4-92
Figure 4.4.51-1. Configuration of H1 Inspection Using Array Probe at the Top of the Shroud Flange.....	4-104
Figure 4.4.57-1. Probe Scan Line Locations for Mockup BWRVIP-A .....	4-118
Figure 4.4.57-2. Probe Scan Line Locations for Mockup BWRVIP-B .....	4-118
Figure 4.4.58-1. BWRVIP-A and BWRVIP-B Scan Surface .....	4-120
Figure 4.4.58-2. BWRVIP-A and BWRVIP-B (H3 and H6/H6B) Scan Surface.....	4-121
Figure 4.4.58-3. BWRVIP-C (H4/H5) Flaws Connected to the Scan Surface.....	4-121
Figure 4.4.58-4. BWRVIP-C (H4/H5) Flaws Connected Opposite to the Scan Surface .....	4-121
Figure 4.4.59-1. Surface Distance of First and Fourth Scan Lines .....	4-124
Figure 4.4.60-1. Vertical Ring Segment Weld Orientation .....	4-126
Figure 4.5.2-1. VT Length Measurement Performance on Simulated Cracks (Pieces of Tape) in NDE Center's 20-foot-deep Water Tank .....	4-134
Figure 4.6.1-1. Cross-Wound ET Probe .....	4-135
Figure 4.6.1.2-1. Eddy Current Image of Surface Roughness Mockup .....	4-136
Figure 4.6.2.2-1. Amplitude and Phase Eddy Current Images of Mockup BWRVIP-A. (a) Amplitude, raw. (b) Amplitude, thresholded.....	4-138
Figure 4.6.2.2-1 (continued). Amplitude and Phase Eddy Current Images of Mockup BWRVIP-A. (c) Phase, raw. (d) Phase, thresholded.....	4-139
Figure 4.6.6-1. Eddy Current Surface Probe .....	4-143
Figure 4.6.6-2. Eddy Current Responses from Ring Segment Weld Mockup.....	4-144
Figure 4.6.6-3. Eddy Current Responses Obtained from Surface Flaws of Various Depths.....	4-145
Figure 4.6.6-4. Shroud Mockup Containing Rough Weld Surface .....	4-145
Figure 4.6.6-5. Eddy Current Response from Shroud Mockup with Rough Weld Surface ....	4-146
Figure 4.7.8-1. Illustration of Potential Location Error for BWR Vertical Weld UT Inspections .....	4-161
Figure 4.7.8-2. Illustration of Potential Location Error for Depth Sizing When Scanning on the H2/H3 Ledge .....	4-162
Figure 5.2.1-1. CB&I/CBIN, B&W Shroud Support Configuration.....	5-3
Figure 5.2.3.1-1. CE Shroud Support Configuration .....	5-4
Figure 5.2.3.2-1. BWR/2 Cone Skirt Shroud Support Configuration.....	5-5
Figure 5.2.3.3-1. Hatch Unit 2 Shroud Support Configuration .....	5-6
Figure 5.3.1-1. Configuration of Mockup BWRVIP-D, Representing Weld H7.....	5-8
Figure 5.3.1-2. Cross Section of Mockup BWRVIP-D.....	5-9
Figure 5.3.1-3. Distribution of Flaws in Mockup BWRVIP-D.....	5-9

---

Figure 5.3.1-4. BWRVIP-D2 Flaws 5J Through 5Q .....	5-11
Figure 5.3.1-5. BWRVIP-D2 Flaws 5R Through 5U.....	5-12
Figure 5.3.2-1. Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details .....	5-14
Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details.....	5-15
Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details.....	5-16
Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details.....	5-17
Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details.....	5-18
Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details.....	5-19
Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details.....	5-20
Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details.....	5-21
Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details.....	5-22
Figure 5.3.2-2. Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details .....	5-23
Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-24
Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-24
Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-25
Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-25
Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-26
Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-26
Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-27
Figure 5.3.2-3. Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details .....	5-28
Figure 5.3.2-3 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-29
Figure 5.3.2-3 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-29
Figure 5.3.2-3 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-30

Figure 5.3.2-3 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-30
Figure 5.3.2-3 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-31
Figure 5.3.2-3 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-31
Figure 5.3.2-3 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details.....	5-32
Figure 5.3.3-1. Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details .....	5-33
Figure 5.3.3-1 (continued). Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details.....	5-34
Figure 5.3.3-1 (continued). Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details.....	5-35
Figure 5.3.3-1 (continued). Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details.....	5-36
Figure 5.3.3-1 (continued). Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details.....	5-37
Figure 5.3.3-1 (continued). Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details.....	5-38
Figure 5.3.3-1 (continued). Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details.....	5-39
Figure 5.3.4-1. Shroud Support Mockup BWRVIP-P .....	5-40
Figure 5.3.5-1. Mockup BWRVIP-B2SS1. ....	5-41
Figure 5.3.5-2. Mockup BWRVIP-B2SS2. ....	5-42
Figure 5.4.18-1. Configuration for Inspecting Weld H10 from the Outside of the Bottom Head of the Pressure Vessel .....	5-64
Figure 5.4.28-1. Setting the Sensitivity for Inspection of Weld H9.....	5-80
Figure 5.4.28-2. Geometry for Inspection of Weld H8 .....	5-81
Figure 5.4.28-3. Coverage for Inspection of Weld H8.....	5-81
Figure 5.4.28-4. Some Potential Flaw Locations and Orientations in Weld H8 .....	5-82
Figure 5.4.30-1. Setting the Sensitivity for Inspection of Weld H9.....	5-86
Figure 5.4.30-2. Geometry for Inspection of Weld H8 .....	5-87
Figure 5.4.30-3. Coverage for Inspection of Weld H8.....	5-87
Figure 5.4.30-4. Some Potential Flaw Locations and Orientations in Weld H8 .....	5-88
Figure 5.4.31-1. Example Display Showing Responses of Weld Crown Geometry in Mockup BWRVIP-E.....	5-90
Figure 5.4.31-2. Response from Flaw 6b in Mockup BWRVIP-E .....	5-91
Figure 5.4.36-1. Geometry for Inspection of Weld H8 .....	5-98
Figure 5.4.36-2. Coverage for Inspection of Weld H8.....	5-98
Figure 5.4.36-3. Some Potential Flaw Locations and Orientations in Weld H8 .....	5-99
Figure 5.4.47-1. Scan Line Positions .....	5-119

Figure 5.4.47-2. Inside Surface Flaw Depth Sizing Error If Correction Is Not Used .....	5-120
Figure 5.4.47-3. Outside Surface Flaw Depth Sizing Error If Correction Is Not Used.....	5-120
Figure 5.4.47-4. Geometric Reflector Used to Measure the Amount of Weld Mismatch .....	5-121
Figure 5.4.48-1. Geometry and Ultrasonic Beam Simulation for Inspection of Weld H8 .....	5-123
Figure 5.4.48-2. Coverage for Inspection of Weld H8.....	5-124
Figure 5.4.48-3. Some Potential Flaw Locations and Orientations in Weld H8 .....	5-124
Figure 5.4.48-4. Setting the Sensitivity for Inspection of Weld H8.....	5-125
Figure 6.2-1. Typical BWR/2 Core Spray Piping Configuration .....	6-4
Figure 6.2-2. Typical BWR/3-5 Core Spray Piping Configuration .....	6-5
Figure 6.2-3. Typical BWR/6 Core Spray Piping Configuration .....	6-6
Figure 6.2-4. Typical Core Spray Sparger .....	6-7
Figure 6.3.1.1-1. Mockup BWRVIP-J: Downcomer Slip Joint .....	6-11
Figure 6.3.1.1-2. Downcomer Sleeve Mockup (BWRVIP-J) .....	6-12
Figure 6.3.1.1-3. Mockup BWRVIP-J: Downcomer Slip Joint: Configuration.....	6-13
Figure 6.3.1.1-4. Mockup BWRVIP-J: Downcomer Slip Joint: Flaw Details.....	6-14
Figure 6.3.1.2-1. BWRVIP-K Mockup: Shroud Penetration (BWR/2).....	6-16
Figure 6.3.1.2-2. BWR/2 Shroud Penetration Mockup (BWRVIP-K).....	6-17
Figure 6.3.1.2-3. Mockup BWRVIP-K: BWR/2 Shroud Penetration: Configuration.....	6-18
Figure 6.3.1.2-4. Mockup BWRVIP-K: BWR/2 Shroud Penetration: Flaw Details .....	6-19
Figure 6.3.1.3-1. BWRVIP-L Mockup: Shroud Penetration (BWR/3-5).....	6-21
Figure 6.3.1.3-2. BWR/3-5 Shroud Penetration Mockup (BWRVIP-L).....	6-22
Figure 6.3.1.3-3. Mockup BWRVIP-L: BWR/3-5 Shroud Penetration: Configuration.....	6-22
Figure 6.3.1.3-4. Mockup BWRVIP-L: BWR/3-5 Shroud Penetration: Flaw Details.....	6-23
Figure 6.3.1.4-1. BWRVIP-M Mockup: Header Tee Box .....	6-25
Figure 6.3.1.4-2. BWR/3-5 Core Spray Header Tee Box Mockup (BWRVIP-M) .....	6-26
Figure 6.3.1.4-3. Mockup BWRVIP-M: BWR/3-5 Header Tee Box: Configuration.....	6-27
Figure 6.3.1.4-4. Mockup BWRVIP-M: BWR/3-5 Header Tee Box: Flaw Details .....	6-28
Figure 6.3.1.5-1. BWRVIP/6 Core Spray Pipe Coupling Assembly Mockup BWRVIP- CS6: Weld Configuration and Flaw Details .....	6-29
Figure 6.3.1.6-1. Photograph of BWRVIP-P4-1 and BWRVIP-P4-2 .....	6-30
Figure 6.3.1.6-2. Flaw Details of BWRVIP-P4-1 .....	6-31
Figure 6.3.1.6-3. Flaw Details of BWRVIP-P4-2 .....	6-32
Figure 6.4.32-1. Correspondence of Flaws in Mockup BWRVIP-J to the Inspection Configuration of BWR/2 Weld P8 .....	6-75
Figure 6.4.32-2. Inability to Detect OD Pipe-side Flaws Using the Single-stroke Scan Technique .....	6-76
Figure 6.4.35-1. Detection Paths for Flaws in Mockup BWRVIP-K.....	6-80
Figure 6A.1.3-1. Mockup BWRVIP-CSRA: Weld Overlay Repair with Cracks Propagating from Existing Throughwall Defects: Configuration and Flaw Details .....	6A-3

Figure 6A.1.3-2. Mockup BWRVIP-CSRC: Weld Overlay Repair with Sidewall Lack of Fusion: Configuration and Flaw Details .....	6A-4
Figure 7.2.1-1. Typical Vertical Aligner Pin Assembly .....	7-4
Figure 7.2.1-2. Aligner Pin Assembly Variations.....	7-5
Figure 7.2.2-1. Hold-Down Assembly .....	7-6
Figure 7.2.2-2. Hold-Down Assembly .....	7-7
Figure 7.2.3-1. Lateral Restraint Brackets and Wedges .....	7-8
Figure 7.2.4-1. Hold-Down Assembly .....	7-9
Figure 7.2.5-1. Rim-to-Bottom Plate Weld.....	7-10
Figure 7.2.6-1. Configuration of Top Guide Grid, Fuel Channels, and Control Blades .....	7-12
Figure 7.3.1-1. Configuration of Top Guide Grid Mockup BWRVIP-I.....	7-13
Figure 7.3.1-2. Top Guide Grid Mockup BWRVIP-I, Plate BWRVIP-I-A: Configuration and Flaw Details.....	7-14
Figure 7.3.1-3. Top Guide Grid Mockup BWRVIP-I, Plate BWRVIP-I-B: Configuration and Flaw Details.....	7-14
Figure 7.3.1-4. Top Guide Grid Mockup BWRVIP-I, Plate BWRVIP-I-C: Configuration and Flaw Details.....	7-15
Figure 7.3.1-5. Top Guide Grid Mockup BWRVIP-I, Plate BWRVIP-I-D: Configuration and Flaw Details.....	7-15
Figure 7.3.1-6. Top Guide Grid Mockup BWRVIP-I, Plate BWRVIP-I-E: Configuration and Flaw Details.....	7-16
Figure 8.3-1. EDM Notches in Upper and Lower Threaded Regions of Core Plate Bolt Mockup .....	8-4
Figure 10.3.1-1. Jet Pump Riser Mockup BWRVIP-U: Configuration and Flaw Details.....	10-57
Figure 10.3.2-1. Jet Pump Riser Mockup BWRVIP-V: Configuration and Flaw Details.....	10-58
Figure 10.3.3-1. Jet Pump Mixer Mockup BWRVIP-Z3: Configuration and Flaw Details.....	10-59
Figure 10.3.4-1. Jet Pump Mixer Mockup BWRVIP-Z4: Configuration .....	10-60
Figure 10.3.4-2. Jet Pump Mixer Mockup BWRVIP-Z4: Flaw Details .....	10-61
Figure 10.3.5-1. EPRI Jet Pump Beam Mockup A.....	10-4
Figure 10.3.5-2. EPRI Jet Pump Beam Mockup B (No Flaws) .....	10-5
Figure 10.3.5-3. EPRI Jet Pump Beam Mockup C .....	10-6
Figure 10.3.5-4. Jet Pump Beam Mockup BWRVIP-G2JPB1.....	10-7
Figure 10.3.5-5. Jet Pump Beam Mockup BWRVIP-G2JPB2.....	10-8
Figure 10.3.5-6. Jet Pump Beam Mockup BWRVIP-G2JPB3.....	10-9
Figure 10.3.5-7. Jet Pump Beam Mockup BWRVIP-G2JPB4.....	10-10
Figure 10.3.5-8. Jet Pump Beam Taper-to-Radius Transition Mockups (Perspective Drawing).....	10-11
Figure 10.3.5-9. Jet Pump Beam Taper-to-Radius Transition Mockups (Photo) .....	10-11
Figure 10.3.5-10. Jet Pump Beam Taper-to-Radius Transition Mockups (Side View Drawing).....	10-12
Figure 10.4.16-1. LaSalle 1, Fermi Jet Pump Adapter Configuration .....	10-33

Figure 10.4.16-2. Demonstration for Weld AD-1.....	10-34
Figure 10.4.16-3. Demonstration for Weld AD-2.....	10-35
Figure 10.4.16-4. Demonstration for Weld DF-3.....	10-35
Figure 10.4.19-1. Area BB-2 and BB-3 Examination Technique .....	10-39
Figure 10.4.19-2. Jet Pump Beam Taper-to-Radius Transition Mockups .....	10-41
Figure 10.4.22-1. Fermi-2 and LaSalle-1 ("U-Shaped") Curved Adapter Configuration.....	10-47
Figure 10.4.22-2. Fermi-2 and LaSalle-1 DF-3 Weld Inspection Location .....	10-48
Figure 11.3.1-1. SLC Nozzle Mockup BWRVIP-X1: Configuration and Flaw Details .....	11-7
Figure 11.3.2-1. SLC Nozzle Mockup BWRVIP-X2: Configuration and Flaw Details .....	11-8
Figure 11.3.3-1. SLC Penetration Mockup BWRVIP-Y3: Configuration and Flaw Details .....	11-9
Figure 11.3.4-1. SLC Penetration Mockup BWRVIP-Y4: Configuration and Flaw Details ....	11-10
Figure 11.3.5-1. SLC Penetration Mockup BWRVIP-Y5: Configuration and Flaw Details ....	11-11
Figure 13.3.1-1. BWRVIP-CRDH1 Mockup (Photograph) .....	13-4
Figure 15.1-1. Access Hole Cover .....	15-1
Figure 15.2-1. Examples of Shroud Support Plate Side Ultrasonic Examination Techniques.....	15-3
Figure 15.2-2. Retrofit Top Hat Access Hole Cover Configuration .....	15-4
Figure 15.2.1-1. Thin AHC and Conventional Shroud Support Plate with Ledge .....	15-5
Figure 15.2.2-1. Intermediate Thickness Access Hole Cover and Conventional Shroud Support Plate Without Ledge .....	15-5
Figure 15.2.3-1. Thick Access Hole Cover and Conventional Shroud Support Plate with Ledge .....	15-6
Figure 15.2.4-1. Retrofit Design for Some BWR/4 and BWR/5 Plants.....	15-7
Figure 15.2.5-1. BWR/6 Single Oval Design.....	15-8
Figure 15.3.1.1-1. BWRVIP-AHC1 Mockup (Photograph) .....	15-9
Figure 15.3.1.1-2. Bottom Side of BWRVIP-AHC1 Mockup (Photograph) .....	15-10
Figure 15.3.1.1-3. Configuration Drawing of BWRVIP-AHC1 .....	15-19
Figure 15.3.1.1-4. Partial Top View of BWRVIP-AHC1 (1 of 2).....	15-20
Figure 15.3.1.1-5. Partial Top View of BWRVIP-AHC1 (2 of 2).....	15-21
Figure 15.3.1.1-6. BWRVIP-AHC1 (Flaws 1a Through 1e).....	15-22
Figure 15.3.1.1-7. BWRVIP-AHC1 (Flaws 1f Through 1i).....	15-23
Figure 15.3.1.1-8. BWRVIP-AHC1 (Flaws 1j Through 1n).....	15-24
Figure 15.3.1.2-1. BWRVIP-AHC2 Mockup (Photograph).....	15-11
Figure 15.3.1.2-2. Configuration Drawing for BWRVIP-AHC2.....	15-25
Figure 15.3.1.2-3. BWRVIP-AHC2 Flaw Drawings (Flaws 2a Through 2d).....	15-26
Figure 15.3.1.2-4. BWRVIP-AHC2 Flaw Drawings (Flaws 2e Through 2h).....	15-27
Figure 15.3.1.2-5. BWRVIP-AHC2 Flaw Drawings (Flaws 2i Through 2l) .....	15-28
Figure 15.3.1.3-1. BWRVIP-AHC3 and BWRVIP-AHC4 (Photograph).....	15-12
Figure 15.3.1.3-2. Configuration Drawing of BWRVIP-AHC3 .....	15-29



---

Figure 15.3.1.3-3. Flaw Detail Drawing of BWRVIP-AHC3.....	15-30
Figure 15.3.1.3-4. Configuration Drawing of BWRVIP-AHC4 .....	13-31
Figure 15.3.1.3-5. Flaw Detail Drawing of BWRVIP-AHC4.....	15-32
Figure 15.3.1.4-1. BWRVIP-AHC5 Mockup (Photograph) .....	15-13
Figure 15.3.1.4-2. BWRVIP-AHC5 (Flaw Table and Configuration Dimensions).....	15-33
Figure 15.3.1.4-3. BWRVIP-AHC5 (Ring-to-Cover Weld Flaw Locations).....	15-34
Figure 15.3.1.4-4. BWRVIP-AHC5 (Ring-to-Cover Weld Flaw Details) .....	15-35
Figure 15.3.1.4-5. BWRVIP-AHC5 (Adapter Ring-to-Ring Weld Flaw Locations) .....	15-36
Figure 15.3.1.4-6. BWRVIP-AHC5 (Adapter Ring-to-Ring Weld Flaw Details).....	15-37
Figure 15.3.1.5-1. BWRVIP-AHC6 Mockup (Photograph) .....	15-13
Figure 15.3.1.5-2. Configuration Drawing of BWRVIP-AHC6 .....	15-38
Figure 15.3.1.5-3. Flaw Detail Drawing for BWRVIP-AHC6 (Flaws 6a Through 6d) .....	15-39
Figure 15.3.1.5-4. Flaw Detail Drawings for BWRVIP-AHC6 (Flaws 6e Through 6h).....	15-40
Figure 15.4.2-1. Surface Distance Required for Azimuthal (Sector) Scan.....	15-16
Figure 15.4.2-2. Surface Distance Required for Linear Scans (Electronic Raster).....	15-16

## LIST OF TABLES

Table 3.3.1-1. Sizing Performance of Length Estimation Techniques .....	3-4
Table 3.3.2-1. Sizing Performance of Length Measurement by Ruler .....	3-5
Table 4.1-1. Where to Find Evaluation Factors for the Shroud.....	4-2
Table 4.3.1.8-1. Notches in Mockup BWRVIP-SSC-1 .....	4-13
Table 4.4.2-1. UT Demonstration Summary .....	4-25
Table 4.4.18-1. Definition of Scan Patterns Used in UT Demonstration 16.....	4-45
Table 4.4.18-2. Results of UT Demonstration 16.....	4-46
Table 4.4.27-1. Sizing Performance and Evaluation Factors for UT Demonstration 25 .....	4-56
Table 4.4.36-1. Crack Location and Orientation Categories in Mockup BWRVIP-H6OH .....	4-71
Table 4.4.41-1. Linear Scans Performed in Various Shroud Inspection Situations .....	4-81
Table 4.4.42-1. Sizing Performance and Evaluation Factors for UT Demonstration 40 .....	4-82
Table 4.4.55-1. Crack Location and Orientation Categories in Mockup BWRVIP-H6OH .....	4-112
Table 4.4.56-1. Crack Location and Orientation Categories in Mockup BWRVIP-H6OH .....	4-114
Table 4.4.61-1. Focal Law Groups for Demonstration 59 .....	4-128
Table 4.5.2-1. Data and Analysis from Shroud VT Demonstration 1. ....	4-133
Table 4.7.4-1. Evaluation Factors for Carousel Scanner .....	4-151
Table 4.7.8-1. Evaluation Factors for TS <sup>2</sup> .....	4-159
Table 5.3.4-1. Configuration of Cracks in Shroud Support Mockup BWRVIP-P .....	5-40
Table 5.3.4-2. Configuration of EDM Notches in Shroud Support Mockup BWRVIP-Q1.....	5-41
Table 5.4.6-1. Definition of Scan Patterns Used in UT Demonstration 5.....	5-49
Table 5.4.6-2. Results of UT Demonstration 5.....	5-50
Table 5.4.19-1. Sizing Performance and Evaluation Factors for UT Demonstration 18 .....	5-65
Table 5.4.39-1. Linear Scans Performed in Various Shroud Inspection Situations .....	5-103
Table 5.4.49-1. Search Unit Angles and Beam Orientations for Demonstration 48.....	5-127
Table 5.4.49-2. Summary of Detection Results for Demonstration 48.....	5-127
Table 6.4.2-1. UT Demonstration Summary. ....	6-34
Table 10.4.15-1. Examination Sequence .....	10-32
Table 13.3.1-1. Specifications of Applicable Flaws for BWRVIP-CRDH1.....	13-3
Table 15.4.1-1. UT Demonstration Summary .....	15-14
Table 15.4.2-1. Demonstrated Examination Groups and Scan/Index Resolutions.....	15-17

# 1

## **BWRVIP OVERVIEW AND BACKGROUND**

---

In 1990 a visual examination (VT) of the core shroud of a Swiss boiling water reactor (BWR) revealed the presence of cracking adjacent to one of the horizontal welds. A boat sample was taken, and its analysis identified the flaw mechanism as intergranular stress corrosion cracking (IGSCC). Since that event, examinations of other BWR shrouds have revealed an industry-wide problem with IGSCC and irradiation-assisted stress corrosion cracking (IASCC) associated with core shroud welds. As a result of this and degradation of other in-vessel components, domestic BWR-owning utilities have formed the Boiling Water Reactor Vessel and Internals Project (BWRVIP), which is chartered to support a program addressing the problems of reactor internals, internal attachments, vessel welds, and vessel nozzles. The inspection guidance provided herein supplements mandated examinations so that BWR owners can assure safety and assess component integrity in support of business decisions.

### **1.1 BWRVIP**

BWRVIP was established by executive participants from each domestic BWR-owning utility. The BWRVIP's technical program is managed by the Electric Power Research Institute (EPRI). The Executive Operating Committee of BWRVIP oversees the activities of BWRVIP's five technical committees and focus groups:

- The Assessment Committee
- The Inspection Focus Group
- The Repair Focus Group
- The Mitigation Committee
- The Integration Committee

The Inspection Focus Group is tasked with producing nondestructive evaluation (NDE) techniques for assessing the integrity of the affected components. This document presents findings and products of the Inspection Focus Group.

### **1.2 BWRVIP Inspection Focus Group**

The Focus Group comprises NDE and inservice inspection (ISI) representatives of BWR utilities, and is supported by EPRI task managers, the EPRI NDE Center, and NDE vendor company representatives. The Focus Group established the NDE Methods Working Group and the Qualification and Data Management Working Group to perform and direct activities in support of its goals.

The Focus Group is chartered to ensure the availability of effective, predictable, and cost-effective inspection techniques to determine the condition of BWR vessel welds, internals, vessel attachments, and penetrations which are potentially susceptible to degradation.

To satisfy this charter, the Focus Group has set the following goals:

- To provide demonstrated, documented NDE techniques for effectively examining the susceptible components.
- To develop inspection standards that can ensure the structural integrity of the components.
- To liaise with regulatory agencies on inspection issues.
- To develop and maintain an internal budget and financial controls.
- To develop short, medium, and long range plans based on utility inspection needs.
- To interface with the other Committees of BWRVIP.
- To provide training, when necessary, to support the industry's inspection needs.

This document presents the Focus Group's activities toward the first two goals. It provides measurements of the uncertainty of NDE techniques as applied to examinations of BWR internal components, to be included with flaw size measurements in calculations of the serviceability of components for subsequent operation; guidance for utilities or vendors to perform measurements of uncertainty that can be recognized by the Focus Group; standards for NDE procedures for examination of internal components; and a referenceable vehicle for regulatory review and approval.

### **1.3 General Approach to Inspection Support**

The Assessment Committee and Repair Focus Group identify those structures that require inspection because of their safety function, susceptibility to degradation, or pre- and post-repair inspection needs. The degradation mechanism, likely flaw locations and orientations, and the degradation severity that must be detected are also identified. The Inspection Focus Group then develops, demonstrates, and documents NDE techniques capable of establishing component and component repair integrity. Alternatively, the Focus Group may witness and document such demonstrations by NDE vendor companies.

The design and fabrication of realistic component mockups are an important part of the Inspection Focus Group's program. The mockups are designed to represent the materials and welding techniques used in the original construction of the components. Intentional defects in the mockups are of the size, location, and orientation of concern, and are designed to resemble the suspect degradation mechanism in their response to NDE techniques.

The Inspection Focus Group also supports BWR internals inspections by providing specific training to spread the knowledge that has been gained through individual plant experiences. Training courses in visual and ultrasonic examination of core shroud welds, and in access and other inspection issues for internal components located below the core plate, have been offered or are planned.

The Focus Group has provided on-site advisory support to requesting member utilities during their internals inspection outages. EPRI and the EPRI NDE Center, directed by the Focus Group, have assisted in on-site advisory support and also have performed off-site data reviews and supporting laboratory work.

## **1.4 Implementation Requirements**

In accordance with the requirements of Nuclear Energy Institute (NEI) 03-08, Guideline for the Management of Materials Issues, this report is considered to be “needed.”

# 2

## GENERAL PROCEDURES

---

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 2.1 Guidelines for Use of BWRVIP Mockups

### 1.0 Purpose

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 2.0 Reference

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 3.0 Guidelines for Usage

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.0 Guidelines for Use Prioritization**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 2.2 Protocol for NDE Technique Demonstrations on BWRVIP Mockups

### 1.0 Purpose

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 2.0 Responsibilities

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 3.0 Prerequisites

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.0 Demonstration Plan**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**5.0 Demonstration Process**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 6.0 Results Reporting and Documentation

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 2.3 Guidelines for Determining NDE Technique Uncertainty

### 1.0 Purpose

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 2.0 References

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 3.0 Responsibilities

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.0 Demonstration Process**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**5.0 Documentation**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 2.4 Guidelines for Determining Inspection Tool Positioning Uncertainty

### 1.0 Purpose

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 2.0 References

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 3.0 Responsibilities

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.0 Guidelines for Uncertainty Measurements**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**5.0 Demonstration Plan**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**6.0 Demonstration Process**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**7.0 Documentation**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 2.5 Generic Standards for Visual Inspection of Reactor Pressure Vessel Internals, Components, and Associated Repairs

### 1.0 Purpose

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 2.0 Scope

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 3.0 Definitions

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.0 Personnel Training/Experience**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**5.0 Equipment Requirements**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 6.0 Inspection Requirements

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 7.0 Evaluation of Indications

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 8.0 Documentation of Results

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 2.5.8.1-1. System Setup**



## 2.6 Generic Standards for Ultrasonic Examination of BWR Vessel Internal Components

### 1.0 Scope

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 2.0 References

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 3.0 Personnel

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.0 Technique Demonstrations**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **5.0 Equipment**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**6.0 Calibration**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**7.0 Examination**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**8.0 Recording**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 9.0 Evaluation

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 10.0 Reporting

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**11.0 Examination of Stainless Steel and Nickel-Alloy Welds with Single-Sided  
Access**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 2.7 Generic Standards for Eddy Current Examination of BWR Vessel Internal Components

### 1.0 Scope

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 2.0 References

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 3.0 Personnel

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.0 Technique Demonstration**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**5.0 Equipment**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**6.0 Calibration**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**7.0 Examination**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



## 8.0 Recording

[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 9.0 Evaluation

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 10.0 Reporting

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

# 3

## DEMONSTRATION OF ACCURACY OF FLAW LENGTH MEASUREMENT BY VISUAL EXAMINATION

---

### 3.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 3.2 Demonstration

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**3.2.1 Vendors**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**3.2.2 Mockups**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**3.2.3 Flaws**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**3.2.4 Cameras**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**3.2.5 Measurement Techniques**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**3.3 Sizing Performance**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**3.3.1 Estimation**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 3.3.1-1. Sizing Performance of Length Estimation Techniques**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**3.3.2 Measurement by Ruler**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 3.3.2-1. Sizing Performance of Length Measurement by Ruler**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



# 4

## SHROUD

---

### 4.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.1-1. Where to Find Evaluation Factors for the Shroud**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## **4.2 Inspection Considerations**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.3 Applicable Mockups**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.3.1 Shroud Weld Mockups**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

4.3.1.1 NDE Center's Original H3 Mockup

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

4.3.1.2 Utility H3 and H4 Mockups

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

4.3.1.3 Shroud Block BWRVIP-A: Ring-to-Cylinder

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.3-1. Design of Shroud Mockup BWRVIP-A**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.3-2. Cross Section of Weld in Mockup BWRVIP-A**

4.3.1.4 Shroud Block BWRVIP-B: Ring-to-Cylinder

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.4-1. Design of Shroud Mockup BWRVIP-B**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.4-2. Cross section of Weld in Mockup BWRVIP-B**

4.3.1.5 Shroud Block BWRVIP-C: Cylinder-to-Cylinder

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.5-1. Design of Shroud Mockup BWRVIP-C**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.5-2. Cross Section of Weld in Mockup BWRVIP-C**

4.3.1.6 Shroud Mockup BWRVIP-G and H: Ring Segment Welds

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.6-1. Mockup BWRVIP-G and BWRVIP-H, Representing the Ring Segment Weld**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.6-2. Cross Section of Mockup BWRVIP-G and BWRVIP-H**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.6-3. Shroud Ring Segment Weld**

4.3.1.7 Shroud Mockup BWRVIP-H1: Shroud Weld H1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

4.3.1.8 Shroud Mockup BWRVIP-SSC1: Shroud Scallops

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.3.1.8-1. Notches in Mockup BWRVIP-SSC-1**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.8-1. Mockup BWRVIP-SSC1**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.8-2. Mockup BWRVIP-SSC1; Detail of Notches 1-4**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.8-3. Mockup BWRVIP-SSC1; Detail of Notches 5-8**

4.3.1.9 Shroud Mockup BWRVIP-H6OH: Overhanging Core Plate Support Ring

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.9-1. Illustration of the Overhanging Configuration of Weld H6b**

4.3.1.10 Shroud Mockup BWRVIP-TGSR: Radial Ring Segment Mockup

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.10-1. BWRVIP-TGSR Mockup (Photograph)**

4.3.1.11 BWRVIP-H2/H3: Top Guide Support Ring-to-Cylinder Mockup

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.11-1. Typical Phased Array Technique for Examination of Core Shroud H2  
Welds**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.11-2. Typical Phased Array Technique for Examination of Core Shroud H3  
Welds**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.11-3. Photograph of BWRVIP-H2/H3 Mockup**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.11-4. Configuration of BWRVIP-H2/H3 (Side View)**

### 4.3.2 Special Purpose Mockups

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.3.2.1 Surface Roughness

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.2.1-1. Surface Roughness Mockup**

4.3.2.2 Multiple Parallel Cracks

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.2.2-1. Mockup With Multiple, Parallel EDM Notches**

4.3.2.3 EDM Notches in Weld Toe

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 4.4 UT Technique Demonstrations for Core Shroud Welds

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 4.4.1 General Findings for UT

Investigations of shroud UT have included a review of field UT data, UT experiments on shroud weld and other mockups, and demonstrations by NDE vendor companies. The investigations support the use of UT for characterizing shroud welds, measurement of flaw characterization uncertainty, and a UT procedure standard.

#### 4.4.1.1 Detection of Shallow Reflectors

The ability of UT techniques to detect shallow cracking connected to the examination surface is an important factor in assessing the serviceability of a shroud weldment. This capability is different for each probe.

The creeping wave probe is capable of detecting very shallow defects. This probe was used to detect EDM notches 0.05-inch and 0.02-inch deep in the diametrical shrink area of a stainless steel pipe weld selected for the geometrical similarity of its weld crown to that of mockup BWRVIP-A. The signal-to-noise ratio (SNR) was at least 14 dB. The sensitivity is comparable or better for flaws connected to the opposite surface, when scanning on the shroud cylinder.

Dual probes configured to focus at a certain depth in the component are not optimized for sensitivity to shallow flaws connected to the scanning surface, yet still can be effective for their detection. For example, a dual, 4 MHz, 60° longitudinal-wave probe configured to focus at 0.8-inch depth was used to examine mockup BWRVIP-A. Detection of crack 1c, at 0.2-inch deep the shallowest crack in BWRVIP-A, was unambiguous.

Single-element probes may also have difficulties with shallow flaws connected to the examination surface. Their presence may be obscured by irrelevant indications generated within the wedge, which are not present for dual probes. Single-element shear-wave probes can detect shallow reflectors connected to the examination surface at the full vee path, which is only available when scanning on the shroud cylinder.

#### 4.4.1.2 Detection of Skewed Reflectors

Shroud weld scans are normally conducted with the sound beams directed perpendicular to the weld. Circumferential cracking near horizontal shroud welds has been observed to be nominally parallel to the weld, but it frequently exhibits a tendency to meander. In a manually-scanned experiment on crack 1c in BWRVIP-A, the creeping wave probe was skewed until the signal disappeared into the baseline noise and the probe skew angle was measured. The probe was

skewed 30 degrees one direction and 38 degrees in the other direction before losing the ultrasonic signal. This experiment shows that cracks up to about 35-degrees off axis can be detected with the creeping wave probe.

#### 4.4.1.3 Effect of Multiple Parallel Defects

The mockup shown in Figure 4.3.2.2-1 was examined using a dual, 4 MHz, 60° longitudinal-wave probe configured to focus at 0.8-inch depth. The probe was scanned on the surface to which the notches are connected. The 0.10-inch deep notch was not detected. The three remaining notches were all detected and sized without difficulty.

#### 4.4.1.4 Effect of Roughness of Scanning Surface

Visual examination records from several plants show that some core plate support rings and top guide support rings bear distinct and regular machining marks on their surfaces. To determine whether this roughness could potentially degrade the effectiveness of UT when the probes are scanned on these surfaces, the dimensions of the machining marks were obtained from photographs of boat samples removed from the core plate support rings of two BWR plants. The surface of a test plate was scored in a precise fashion to reproduce the two measured surface conditions. A third area was prepared with a surface twice as rough as the worst surface present in any of the available boat sample pictures. A smooth area in a separate plate was used as a control. EDM notches and side-drilled holes were machined into each area. The test plate is shown in Figure 4.3.2.1-1.

Measurements using 60° longitudinal-wave, 45° shear-wave, and creeping-wave probes showed that the surface roughnesses obtained from the boat samples did not degrade detection and sizing performance on the EDM notches. In some cases the response amplitude was reduced by several dB but the SNR was not degraded significantly.

Recorded data from field examinations of BWR core shrouds, including an examination of the area where one of the reference surface boat samples was removed, were reviewed and the baseline noise levels noted. Baseline noise levels observed during the NDE Center's scans of mockup BWRVIP-A were also noted. The sensitivities of all the scans, including those of the roughness mockup, were nearly identical (within 3 dB). In all cases, the baseline noise level was about 10% of full screen height.



#### 4.4.2 UT Demonstration Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.4.2-1. UT Demonstration Summary**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.4.2-1. UT Demonstration Summary (continued)**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.4.2-1. UT Demonstration Summary (continued)**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **4.4.3 UT Demonstration 1**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.4 UT Demonstration 2**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 4.4.5 UT Demonstration 3

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.5-1. Principle of Operation of Creeping-Wave Probes**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.5-2. Principle of Operation of LLT Technique**

#### 4.4.6 UT Demonstration 4

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



#### 4.4.7 UT Demonstration 5

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.8 UT Demonstration 6

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.9 UT Demonstration 7

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.10 UT Demonstration 8

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.11 UT Demonstration 9**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.4.12 UT Demonstration 10**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.13 UT Demonstration 11**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.14 UT Demonstration 12

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



**4.4.15 UT Demonstration 13**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.16 UT Demonstration 14

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.17 UT Demonstration 15

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.4.18 UT Demonstration 16**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.4.18-1. Definition of Scan Patterns Used in UT Demonstration 16**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.4.18-2. Results of UT Demonstration 16**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.19 UT Demonstration 17**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.20 UT Demonstration 18**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



#### 4.4.21 UT Demonstration 19

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.22 UT Demonstration 20

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 4.4.23 UT Demonstration 21

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.24 UT Demonstration 22

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.25 UT Demonstration 23

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.4.26 UT Demonstration 24**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.4.27 UT Demonstration 25**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.4.27-1. Sizing Performance and Evaluation Factors for UT Demonstration 25**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.4.28 UT Demonstration 26**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.29 UT Demonstration 27**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.4.30 UT Demonstration 28**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.31 UT Demonstration 29

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

February 2010

[[

**Content Deleted -  
EPRI Proprietary Information**

/

]] TS

### 4.4.32 UT Demonstration 30

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 4.4.33 UT Demonstration 31

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.34 UT Demonstration 32**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.35 UT Demonstration 33

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.36 UT Demonstration 34

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.4.36-1. Crack Location and Orientation Categories in Mockup BWRVIP-H6OH**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 4.4.37 UT Demonstration 35

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.4.38 UT Demonstration 36**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.39 UT Demonstration 37

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.40 UT Demonstration 38

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.40-1. Illustration of Sector-Scan Examination of Weld H2 and Full-Vee Linear-Scan Examination of Weld H3**

#### 4.4.41 UT Demonstration 39

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.4.41-1. Linear Scans Performed in Various Shroud Inspection Situations**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.4.42 UT Demonstration 40**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.4.42-1. Sizing Performance and Evaluation Factors for UT Demonstration 40**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**4.4.43 UT Demonstration 41**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.44 UT Demonstration 42**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



#### 4.4.45 UT Demonstration 43

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.46 UT Demonstration 44**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.46-1. GE Immersion UT Technique for Weld H1**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.47 UT Demonstration 45

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.48 UT Demonstration 46

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.49 UT Demonstration 47

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.50 UT Demonstration 48**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.51 UT Demonstration 49**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.51-1. Configuration of H1 Inspection Using Array Probe at the Top of the Shroud Flange**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.52 UT Demonstration 50

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.53 UT Demonstration 51

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.54 UT Demonstration 52**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.55 UT Demonstration 53

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.4.55-1. Crack Location and Orientation Categories in Mockup BWRVIP-H6OH**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.56 UT Demonstration 54

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.4.56-1. Crack Location and Orientation Categories in Mockup BWRVIP-H6OH**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.4.57 UT Demonstration 55**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.57-1. Probe Scan Line Locations for Mockup BWRVIP-A**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.57-2. Probe Scan Line Locations for Mockup BWRVIP-B**

**4.4.58 UT Demonstration 56**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS.

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.58-1. BWRVIP-A and BWRVIP-B Scan Surface**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.58-2. BWRVIP-A and BWRVIP-B (H3 and H6/H6B) Scan Surface**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.58-3. BWRVIP-C (H4/H5) Flaws Connected to the Scan Surface**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.58-4. BWRVIP-C (H4/H5) Flaws Connected Opposite to the Scan Surface**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.59 UT Demonstration 57

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.59-1. Surface Distance of First and Fourth Scan Lines**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.60 UT Demonstration 58

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.4.60-1. Vertical Ring Segment Weld Orientation**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.4.61 UT Demonstration 59

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.4.61-1. Focal Law Groups for Demonstration 59**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 4.5 VT Technique Demonstrations for Core Shroud Welds

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 4.5.1 VT General Findings

Crack length measurement uncertainty has two components. First, the length can be measured only over that part of the crack which is visible. If part of the crack is not seen — because of poor cleaning or extreme tightness, for example — the length measurement will be correspondingly inaccurate. Second, since the cameras and lights are manipulated manually on the ends of long poles or ropes, length measurement becomes in large part an exercise in estimating distance from visible landmarks such as shroud lugs.

#### 4.5.1.1 Training

The Committee conducted two workshops for utility personnel to train the trainer for shroud visual examinations. The first workshop was held August 17, 1994, with 18 participants. The second workshop was held September 8, 1994, with 20 participants.

The lessons learned by utilities who have visually detected shroud cracking have been assembled into a one-day training course. Excerpts from videotape records of actual shroud visual examinations were assembled to illustrate cracking characteristics to look for, necessary surface cleaning, lighting conditions, camera sensitivity and distance, and other important VT parameters.

The NDE Center has documented participation in this course with transcripts and CEUs for all who have completed the training.

### 4.5.2 VT Demonstration 1

Applicable welds: H1-H6B; vertical shroud welds  
Performed by: BWRVIP Inspection Committee

Resolution: 0.0005" wire  
Manipulation: Manual, using poles and ropes  
Length error: 2.32" RMS

Length evaluation factor: 1.16"  
Published: Revision 0, October 1995

It is expected that variations in crack tightness will affect the capability of the visual method to determine the actual length of the cracking. Experiments have been made at the NDE Center on camera resolution using 0.0005-inch diameter stainless steel wires. Three cameras were lowered into a 20-foot deep, water-filled tank. Various lighting intensities, camera angles, and camera-to-object distances were evaluated. The 0.0005-inch wires were placed on the white background of the tank, on a stainless steel shroud mockup, and on a rusted section of carbon steel. Each of the wires was detectable with each of the cameras utilized. The wire on the painted surface was easily detected at about 16 inches with each camera system. The wire on the stainless steel shroud mockup was difficult to detect and required much manipulation of the camera before the wire was seen. The wire on the carbon steel was easily detected by reflection of the light from the external lights on the cameras. This particular detection was related to light reflection and not to contrast or to the type of steel. Care should be taken to ensure that the detection of the 0.0005-inch diameter wire is essentially representative of detection of a crack of the same width.

Visual examination of shrouds is typically performed from the refueling bridge by manipulating a camera attached to a pole or ropes (much like a string puppet). Location of the view observed from the camera is then limited to an operator's assessment of where the camera is pointed and where the camera is located within the top guide cell. At times, physical objects exist at known locations within the reactor and estimates of distance from these objects may result in a more accurate measurement.

The accuracy of this system has been assessed by having two individuals, experienced in shroud visual examinations, manipulate a camera in a similar fashion in a 20-foot deep, water-filled tank at the NDE Center. Strips of tape (1/8-inch wide) were placed near the bottom of the tank and their actual lengths measured. Fifteen strips of tape, from 3.4-inches to 141-inches long, were placed on the inside surface of the tank. Ten strips of tape, from 3.2-inches to 46-inches long, were placed on the outside surface of a shroud mockup within the tank. The shroud mockup was stainless steel and consisted of a vessel wall, jet pumps, and the shroud wall.

The results of the length measurements (see Table 4.5.2-1) show that, in general, the indications tended to be undersized. The average error of the 25 measurements was -0.79 inch, while the average of the absolute value of the errors was 1.81 inch. The average undersize was 1.91 inch, with the maximum undersize being 5.81 inches out of a true length of 71.06 inches. The average oversize was 1.60 inch, with the maximum oversize being 14.75 inches out of a true length of 47.5 inches. The RMS error of the entire data set was 2.32 inches.

Length measurement errors were also considered as a percentage of the actual length. This method of analysis is perhaps a bit misleading because length measurement errors do not seem to be related to actual length. This results in some very high percentages for the short indications. As shown in Figure 4.5.2-1, once the flaws are at least about 12-inches long, the error is always less than 10% of the true length.

This experiment only determined the amount of uncertainty in defining the lengths of unambiguous indications. The resolution of the system in defining the end points of cracks was not considered in these measurements.

February 2010

**Table 4.5.2-1. Data and Analysis from Shroud VT Demonstration 1****Visual exam of shroud -- NDEC demo 8/31/94**

True length	Measured	Error	Abs. Error	Sq. Error	Neg. Errors	Pos. Errors
141.25	146	4.75	4.75	22.5625	0	4.75
47.5	48.25	0.75	0.75	0.5625	0	0.75
71.0625	65.25	-5.8125	5.8125	33.7852	-5.8125	0
5.875	5.25	-0.625	0.625	0.3906	-0.625	0
100.25	97.25	-3	3	9.0000	-3	0
16.4375	15	-1.4375	1.4375	2.0664	-1.4375	0
72.4375	68.5	-3.9375	3.9375	15.5039	-3.9375	0
32.9375	31	-1.9375	1.9375	3.7539	-1.9375	0
16.75	17.5	0.75	0.75	0.5625	0	0.75
12.375	10	-2.375	2.375	5.6406	-2.375	0
3.4375	3.25	-0.1875	0.1875	0.0352	-0.1875	0
10.8125	12	1.1875	1.1875	1.4102	0	1.1875
51.6875	53	1.3125	1.3125	1.7227	0	1.3125
23.9375	23.75	-0.1875	0.1875	0.0352	-0.1875	0
60.25	58.7	-1.55	1.55	2.4025	-1.55	0
34.25	36.8	2.55	2.55	6.5025	0	2.55
19.75	17.25	-2.5	2.5	6.2500	-2.5	0
46	44.85	-1.15	1.15	1.3225	-1.15	0
13.125	10.4	-2.725	2.725	7.4256	-2.725	0
3.1875	2.75	-0.4375	0.4375	0.1914	-0.4375	0
29	28.75	-0.25	0.25	0.0625	-0.25	0
4.625	3.5	-1.125	1.125	1.2656	-1.125	0
16	17.25	1.25	1.25	1.5625	0	1.25
7.875	4.6	-3.275	3.275	10.7256	-3.275	0
15.875	16.1	0.225	0.225	0.0506	0	0.225
Total error		-19.7375	45.2875		-32.5125	12.7750
<b>Average error</b>		-0.7895	1.8115		-1.9125	1.5969
<b>Standard Deviation</b>		2.2287				
		Sum Sq Error		134.7927		
		Avg Sq Error		5.3917		
		<b>RMS Error</b>		<b>2.3220</b>		

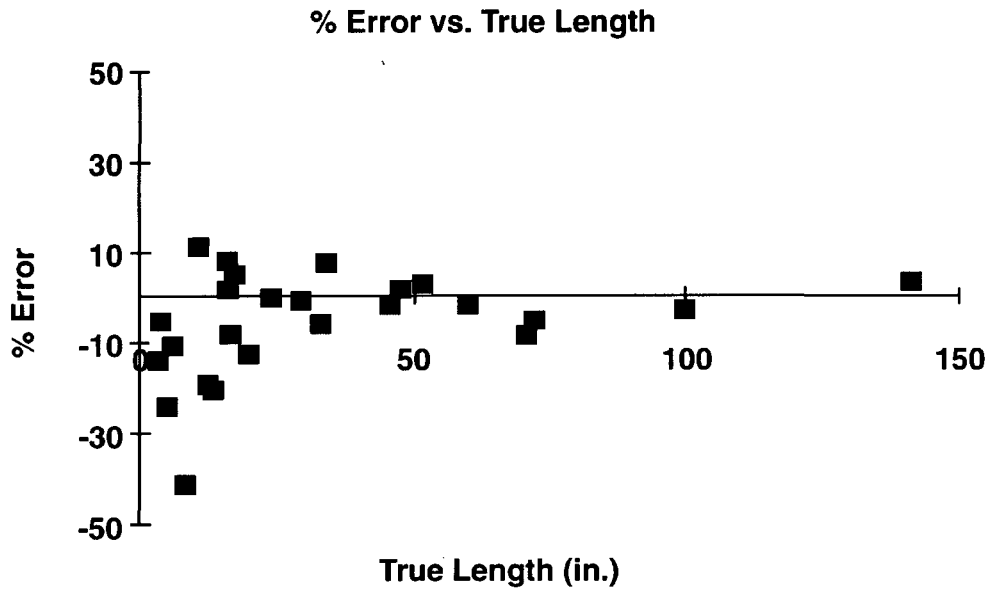


Figure 4.5.2-1. VT Length Measurement Performance on Simulated Cracks (Pieces of Tape) in NDE Center's 20-foot-deep Water Tank

#### 4.6 ET Technique Demonstrations for Core Shroud Welds

[[

Content Deleted -  
EPRI Proprietary Information

]] TS

##### 4.6.1 ET General Findings

[[

Content Deleted -  
EPRI Proprietary Information

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.6.1-1. Cross-Wound ET Probe**

4.6.1.1 Detection of Skewed Reflectors

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

4.6.1.2 Effect of Scanning on a Rough Surface

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.6.1.2-1. Eddy Current Image of Surface Roughness Mockup**

4.6.1.3 Scan Pattern

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



#### 4.6.2 ET Demonstration 1

Applicable welds:	H1-H6B; vertical shroud welds
Company:	EPRI NDE Center
Probe:	Cross-wound, ~ 0.1 inch diameter
Frequency:	300 kHz
Technique:	C-scan imaging of amplitude and phase
Scan increment:	0.05 inch
Length error:	+0.098" average, 0.125" RMS (conventional image)
Length error:	-0.0015" average, 0.082" RMS (derivative image)
Length evaluation factor:	0.062" (conventional image)
Length evaluation factor:	0.041" (derivative image)
Published:	Revision 0, October 1995

##### 4.6.2.1 Crack Length Measurement

Experiments were conducted with the cross-wound surface probe to determine the length accuracy on BWRVIP-A. All data was acquired using an Amdata IntraSpect/ET computerized data acquisition and imaging system. The use of an imaging system permits the data to be evaluated by reviewing phase and amplitude C-scan presentations that show the ET data from large areas of the weld at once so the analyst can better discriminate anomalous signals. The ability to image the data and to look at both signal phase and amplitude information is important because the ET method is sensitive to other mechanical and metallurgical characteristics of the weld not associated with known flaws. These characteristics include geometric effects, probe-to-material spacing (lift-off), and permeability variations associated with the inherent weld properties.

All cracks were detected. The indications were analyzed using the C-scan images obtained on Amdata's IntraSpect/ET system. The system includes a feature that allows spatial derivative C-scan images to be produced. The gradient of the signal can be shown in addition to its normal values. This permits defects such as cracks, which show a very rapid rate of change in either vertical amplitude or phase angle, to be displayed more clearly in the presence of noise (i.e., lift-off, conductivity shifts, etc.). Using the derivative of the amplitude display, the lengths were measured on all 6 cracks and the average error was found to be -0.0015 inch, with an RMS error of 0.082 inch. Using a more conventional analysis process, the phase image was displayed in a non-derivative manner and the lengths of the cracks were measured. The average error on the 6 cracks was found to be +0.0985 inch with an RMS error of 0.125 inch.

##### 4.6.2.2 Optimum Parameters for ET Imaging

A careful selection of the imaging parameters and display threshold levels are necessary to obtain an ET C-scan image which presents flaw indications clearly while minimizing the visibility of irrelevant indications. For BWRVIP-A; data was acquired using a balance or null

point established on an unflawed region of the mockup in an area clearly away from any influence of the weld's mechanical or metallurgical effects. At this setting, excellent flaw detection and discrimination of flaws located in the base material region can be achieved. To optimize the C-scans for a good analysis of the heat affected zone and weld region, it was necessary to change the balance point for these specific areas. Both amplitude and phase C-scans were used to provide confirmation of flawed areas. Figure 4.6.2.2-1 shows the amplitude and phase C-scans for BWRVIP-A, balanced at a point in the heat affected zone. At some point during analysis of the C-scans, it may be useful to employ an amplitude threshold to help eliminate signals caused by noise. For BWRVIP-A, this was achieved by using the amplitude response from an EDM notch (0.005 wide, 0.040 deep, and 0.250 inch long) contained in the calibration standard.

In addition to reviewing the amplitude and phase C-scans, the ET signal response (Lissajous pattern) should be analyzed for any area that appears suspicious from the C-scans. The signal response from other frequencies may also be used as an aid in evaluation. BWRVIP-A was also scanned using 600 kHz and excellent detection and discrimination were achieved.

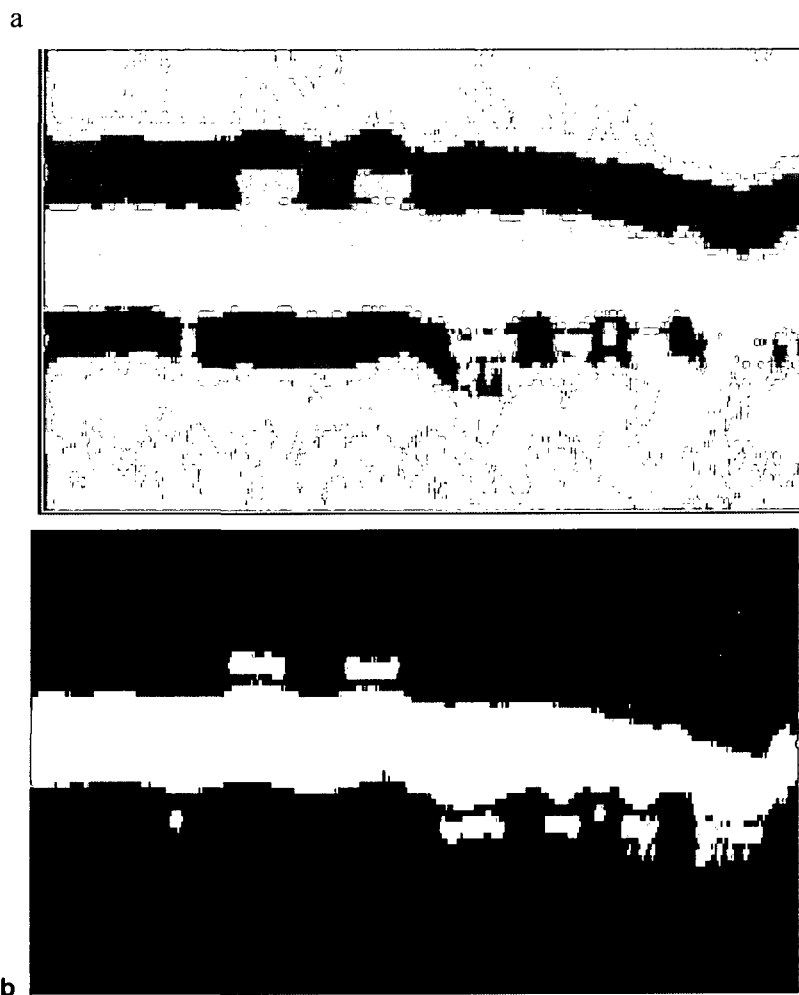


Figure 4.6.2.2-1. Amplitude and Phase Eddy Current Images of Mockup BWRVIP-A.  
(a) Amplitude, raw. (b) Amplitude, thresholded

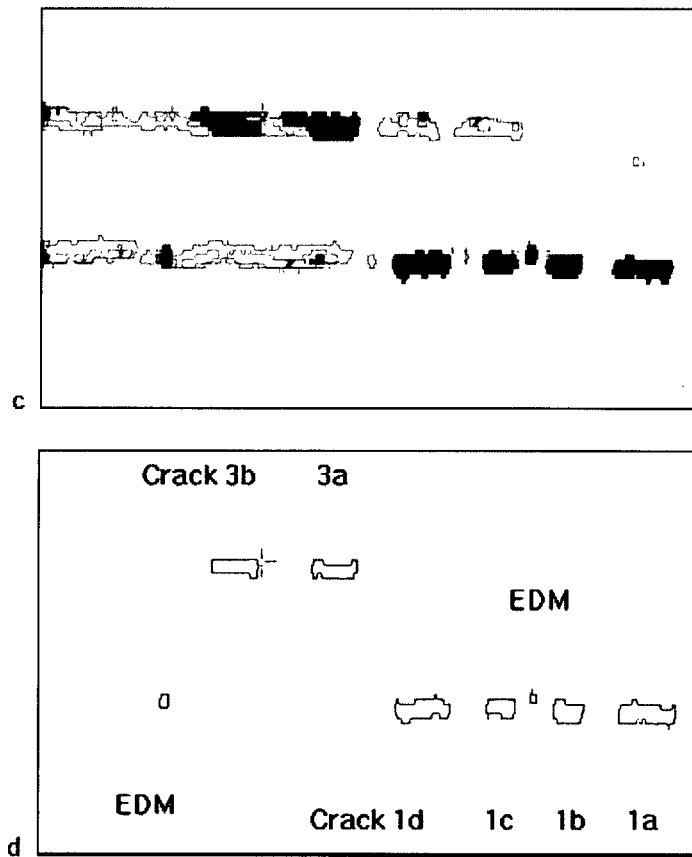


Figure 4.6.2-1 (continued). Amplitude and Phase Eddy Current Images of Mockup BWRVIP-A. (c) Phase, raw. (d) Phase, thresholded

### 4.6.3 ET Demonstration 2

Applicable welds:	H1-H6B; vertical shroud welds
Company:	R/Dtech
Probe:	Pancake, 0.09-inch diameter
Technique:	C-scan imaging of amplitude
Length error:	+0.24" average, 0.50" RMS
Length evaluation factor:	0.25"
Published:	Revision 0, October 1995

BWRVIP-A was scanned by R/Dtech using a Tecrad TC5700 multi-function NDE system, a Tecrad Tomoscan imaging system, and a 0.090-inch diameter pancake coil. The scans were performed from the cracked surfaces on each side of the weld.

R/Dtech personnel performed the scans and analyzed the data. Each of the six cracks was identified. Though the analyst did not report more than the six cracks that were actually present, indications similar to the crack indications were present in the data at the fusion line of the weld. Since no objective criteria were submitted to support the analyst's flaw/non-flaw decisions, it is considered that the demonstration was successful with respect to flaw detection but was incomplete with regard to flaw discrimination.

A review of the true crack lengths versus the detected crack lengths by ET performed with this system showed that the uncertainty is greater than that determined for the cross-wound probe reported above. With the R/Dtech analysis, the average error was +0.24 inch and the RMS error was 0.50 inch.

### 4.6.4 ET Demonstration 3

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.6.4.1 Data Acquisition

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.6.4.2 Data Evaluation

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.6.5 ET Demonstration 4

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.6.6 ET Demonstration 5

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.6.6-1. Eddy Current Surface Probe**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.6.6-2. Eddy Current Responses from Ring Segment Weld Mockup**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.6.6-3. Eddy Current Responses Obtained from Surface Flaws of Various Depths**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.6.6-4. Shroud Mockup Containing Rough Weld Surface**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.6.6-5. Eddy Current Response From Shroud Mockup with Rough Weld Surface**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.7 Delivery System Demonstrations for Core Shroud Welds

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.7.1 Delivery System Demonstration 1

Manipulator:	OD Tracker
Manufacturer:	GE
Demonstration mockup:	GE Training Center, San Jose
Length error contribution:	0.5% of measured length (single placement of the scanner) 1° of azimuth (multiple placements)
Length evaluation factor:	0.25% of measured length (single placement of the scanner) 0.5° of azimuth (multiple placements)
Published:	Revision 0, October 1995

This scanner rides on the steam dam above the H1 weld and carries different arms and scan heads for each horizontal weld. The probe position uncertainty may be a function of both the uncertainty of the position of the main body of the scanner, and a different uncertainty associated with each of the arms specialized for individual welds. The uncertainty associated with the scanner was determined to be 0.037 inch out of a total travel of 6.935 inch (or about 1/2%). When the scanner arm was returned to the origin, it was within 0.0005 inch each time.

The largest uncertainty associated with this delivery system is probably associated with the placement of the scanner on the shroud. The OD Tracker is placed on the steam dam and driven to contact with a set of shroud lugs. The arm then scans while the main body remains stationary. The main body is then driven to the next set of shroud lugs, without encoders.

If the indication being measured is fully contained within a single scan area, not requiring movement of the main body, then only the scanner contributes to length measurement uncertainty. If the indication is long enough to require multiple placements of the scanner, then the placement inaccuracy must be included. Typical drawings show lug placement to be within 1/2 degree of azimuth, which corresponds to about 0.96 inch for a 220-inch diameter shroud. Tolerances for the dimension of the outside of the lug to the centerline are typically +0.095, -0.075 inch. This results in uncertainties of approximately 1 inch.

#### 4.7.2 Delivery System Demonstration 2

Manipulator:	Suction Cup Scanner
Manufacturer:	GE
Demonstration mockup:	GE Training Center, San Jose
Length error contribution:	0.5% of measured length (single placement of the scanner) (application-dependent for multiple placements)
Length evaluation factor:	0.25% of measured length (single placement of the scanner) (application-dependent for multiple placements)
Published:	Revision 0, October 1995

This is a small scanner that is manually positioned and then attaches itself to the shroud wall. This scanner can be placed on the outside or inside surface of the shroud. Probe position uncertainty for this system will include the uncertainty of the encoders or stepping motors carried on the system, and also the uncertainty of the position at which the scanner was mounted. Testing at GE's San Jose facility resulted in essentially the same scanner uncertainty as was observed with the OD Tracker.

The uncertainty associated with the placement of the scanner on the shroud may depend on the availability and selection of landmarks. This uncertainty component must be developed separately as specified in Section 2.4.

### 4.7.3 Delivery System Demonstration 3

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.7.4 Delivery System Demonstration 4

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.7.4-1. Evaluation Factors for Carousel Scanner**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



#### **4.7.5 Delivery System Demonstration 5**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **4.7.6 Delivery System Demonstration 6**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.7.7 Delivery System Demonstration 7

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

##### 4.7.7.1 Flaw Length Measurement Within a Single Scan

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

##### 4.7.7.2 Flaw Length Measurement Using More Than One Scan

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 4.7.8 Delivery System Demonstration 8

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 4.7.8-1. Evaluation Factors for TS<sup>2</sup>**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

4.7.8.1 Horizontal Welds

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

4.7.8.2 Vertical Welds

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.7.8-1. Illustration of Potential Location Error for BWR Vertical Weld UT Inspections**

4.7.8.3 H2/H3 Welds (Scanned from the Ledge)

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.7.8-2. Illustration of Potential Location Error for Depth Sizing When Scanning on the H2/H3 Ledge**

## 4.8 References

1. Caine, T. A.; Mehta, H. S. *BWR Core Shroud Inspection and Flaw Evaluation Guidelines*. GE Nuclear Energy, San Jose, CA. GENE-523-113-0894. September 1994.
2. MacDonald, D. E. *IGSCC Detection in BWR Piping Using the Minac*. Electric Power Research Institute, Palo Alto, CA. EPRI NP-3828. February 1985.
3. Walker, S. M. Personal Communication to Dr. Mohamad Behraves, "Report on location and width of IGSCC." EPRI NDE Center, December 15, 1987.

“This page has been intentionally left blank”

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 4.3.1.7-1. Mockup BWRVIP-H1 Shroud Weld H1**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.9-2. BWRVIP-H6OH, Representing the Overhanging Core Plate Support Ring Weld Configuration**

[[



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.10-2. Configuration Drawing of Mockup BWRVIP-TGSR**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.10-3. Flaw Details for Mockup BWRVIP-TGSR**





[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 4.3.1.11-5. Configuration of BWRVIP-H2/H3 (End View)**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.11-6. BWRVIP-H2/H3 Ring Segment Weld Flaws**



[[

**Content Deleted -  
EPRI Proprietary Information**

Figure 4.3.1.11-7. BWRVIP-H2/H3 Ring-to-Cylinder Weld Flaws (Flaws 1 Through 4)

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 4.3.1.11-8. BWRVIP-H2/H3 Ring-to-Cylinder Weld Flaws (Flaws 5 Through 8)**



[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 4.3.1.11-9. BWRVIP-H2/H3 Flaw Details**

]] TS

"This page has been intentionally left blank"



# 5

## SHROUD SUPPORT

---

### 5.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## **5.2 Inspection Considerations**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.2.1 Chicago Bridge & Iron/CBI Nuclear Shroud Supports**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.2.1-1. CB&I/CBIN, B&W Shroud Support Configuration**

### **5.2.2 Babcock & Wilcox Shroud Supports**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.2.3 Combustion Engineering Shroud Supports

[[

Content Deleted -  
EPRI Proprietary Information

]] TS

#### 5.2.3.1 Gusset Supports

[[

Content Deleted -  
EPRI Proprietary Information

]] TS

[[

Content Deleted -  
EPRI Proprietary Information

]] TS

Figure 5.2.3.1-1. CE Shroud Support Configuration

5.2.3.2 Cone Skirt Support

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.2.3.2-1. BWR/2 Cone Skirt Shroud Support Configuration**

5.2.3.3 Heavy Steel Baffle Plate

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.2.3.3-1. Hatch Unit 2 Shroud Support Configuration**

### 5.2.4 Inspection Access

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.3 Applicable Mockups

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 5.3.1 Shroud Support Mockup BWRVIP-D: Weld H7

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.1-1. Configuration of Mockup BWRVIP-D, Representing Weld H7**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.1-2. Cross Section of Mockup BWRVIP-D**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.1-3. Distribution of Flaws in Mockup BWRVIP-D**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.1-4. BWRVIP-D2 Flaws 5J Through 5Q**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.1-5. BWRVIP-D2 Flaws 5R Through 5U**

**5.3.2 Shroud Support Mockups BWRVIP-E, BWRVIP-E1, and BWRVIP-E2:  
Weld H9**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-1. Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details**



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details.**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-1 (continued). Mockup BWRVIP-E, Representing Weld H9: Configuration and Flaw Details**

February 2010

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-2. Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details**



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-2 (continued). Mockup BWRVIP-E1, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-3. Mockup BWRVIP-E2, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-3 (continued). Mockup BWRVIP-E2, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-3 (continued). Mockup BWRVIP-E2, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-3 (continued). Mockup BWRVIP-E2, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-3 (continued). Mockup BWRVIP-E2, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-3 (continued). Mockup BWRVIP-E2, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-3 (continued). Mockup BWRVIP-E2, Representing Weld H9: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.2-3 (continued). Mockup BWRVIP-E2, Representing Weld H9: Configuration and Flaw Details**

### 5.3.3 Shroud Support Mockup BWRVIP-F: Weld H8

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.3-1. Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.3-1 (continued). Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details**



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.3-1 (continued). Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.3-1 (continued). Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.3-1 (continued). Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.3-1 (continued). Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.3-1 (continued). Mockup BWRVIP-F, Representing Weld H8: Configuration and Flaw Details**

**5.3.4 Shroud Support Mockups BWRVIP-P, BWRVIP-Q1, BWRVIP-Q2**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 5.3.4-1. Configuration of Cracks in Shroud Support Mockup BWRVIP-P**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.4-1. Shroud Support Mockup BWRVIP-P**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Table 5.3.4-2. Configuration of EDM Notches in Shroud Support Mockup BWRVIP-Q1**

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**5.3.5 Shroud Support Mockups BWRVIP-B2SS1 and BWRVIP-B2SS2**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.5-1. Mockup BWRVIP-B2SS1**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.3.5-2. Mockup BWRVIP-B2SS2**

## **5.4 UT Technique Demonstrations for Core Shroud Support Welds**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.4.1 General Findings for UT**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



5.4.1.1 Effect of Alloy 82/182 Weld Material

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

5.4.1.2 Effect of Mismatch in the Fit-up of Weld H7

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.4.2 UT Demonstration 1**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.3 UT Demonstration 2

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.4 UT Demonstration 3

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 5.4.5 UT Demonstration 4

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.4.6 UT Demonstration 5**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 5.4.6-1. Definition of Scan Patterns Used in UT Demonstration 5**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 5.4.6-2. Results of UT Demonstration 5**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



### **5.4.7 UT Demonstration 6**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.8 UT Demonstration 7

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.4.9 UT Demonstration 8**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.10 UT Demonstration 9

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.4.11 UT Demonstration 10**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.12 UT Demonstration 11

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.4.13 UT Demonstration 12**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.14 UT Demonstration 13

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



**5.4.15 UT Demonstration 14**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.16 UT Demonstration 15

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.4.17 UT Demonstration 16**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.18 UT Demonstration 17

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.18-1. Configuration for Inspecting Weld H10 from the Outside of the Bottom Head of the Pressure Vessel**

### 5.4.19 UT Demonstration 18

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Table 5.4.19-1. Sizing Performance and Evaluation Factors for UT Demonstration 18**

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



**5.4.20 UT Demonstration 19**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.21 UT Demonstration 20

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**5.4.22 UT Demonstration 21**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.23 UT Demonstration 22

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.4.24 UT Demonstration 23**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**5.4.25 UT Demonstration 24**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.26 UT Demonstration 25

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.27 UT Demonstration 26

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.28 UT Demonstration 27

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

[[

]] TS

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.28-1. Setting the Sensitivity for Inspection of Weld H9**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.28-2. Geometry for Inspection of Weld H8**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.28-3. Coverage for Inspection of Weld H8**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.28-4. Some Potential Flaw Locations and Orientations in Weld H8**



### 5.4.29 UT Demonstration 28

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.30 UT Demonstration 29

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

[[

]] TS

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.30-1. Setting the Sensitivity for Inspection of Weld H9**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.30-2. Geometry for Inspection of Weld H8**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.30-3. Coverage for Inspection of Weld H8**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.30-4. Some Potential Flaw Locations and Orientations in Weld H8**

**5.4.31 UT Demonstration 30**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

[[

]] TS

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.31-1 Example Display Showing Responses of Weld Crown Geometry in Mockup  
BWRVIP-E**



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.31-2 Response from Flaw 6b in Mockup BWRVIP-E**

**5.4.32 UT Demonstration 31**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.33 UT Demonstration 32

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**5.4.34 UT Demonstration 33**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.4.35 UT Demonstration 34**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.36 UT Demonstration 35

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.36-1. Geometry for Inspection of Weld H8**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.36-2. Coverage for Inspection of Weld H8**



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.36-3. Some Potential Flaw Locations and Orientations in Weld H8**

### 5.4.37 UT Demonstration 36

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.38 UT Demonstration 37

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.4.39 UT Demonstration 38**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 5.4.39-1. Linear Scans Performed in Various Shroud Inspection Situations**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.4.40 UT Demonstration 39**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.41 UT Demonstration 40

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.42 UT Demonstration 41

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **5.4.43 UT Demonstration 42**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 5.4.44 UT Demonstration 43

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**5.4.45 UT Demonstration 44**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.4.46 UT Demonstration 45

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**5.4.47 UT Demonstration 46**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.47-1. Scan Line Positions**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.47-2. Inside Surface Flaw Depth Sizing Error If Correction Is Not Used**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.47-3. Outside Surface Flaw Depth Sizing Error If Correction Is Not Used**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.47-4. Geometric Reflector Used to Measure the Amount of Weld Mismatch**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**5.4.48 UT Demonstration 47**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.48-1. Geometry and Ultrasonic Beam Simulation for Inspection of Weld H8**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.48-2. Coverage for Inspection of Weld H8**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.48-3. Some Potential Flaw Locations and Orientations in Weld H8**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 5.4.48-4. Setting the Sensitivity for Inspection of Weld H8**

### **5.4.49 UT Demonstration 48**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 5.4.49-1. Search Unit Angles and Beam Orientations for Demonstration 48**

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 5.4.49-2. Summary of Detection Results for Demonstration 48**

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 5.5 ET Technique Demonstrations for Core Shroud Support Welds

[[

Content Deleted -  
EPRI Proprietary Information

]] TS

### 5.5.1 General Findings for ET

[[

Content Deleted -  
EPRI Proprietary Information

]] TS

### 5.5.2 ET Demonstration 1

[[

Content Deleted -  
EPRI Proprietary Information

]] TS

## 5.6 Delivery System Demonstrations for Core Shroud Support Welds

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.6.1 Delivery System Demonstration 1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



## 5.6.2 Delivery System Demonstration 2

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 5.6.3 Delivery System Demonstration 3

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 5.6.4 Delivery System Demonstration 4

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

# 6

## CORE SPRAY PIPING AND SPARGER

---

### 6.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**6.2 Inspection Considerations**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.2-1. Typical BWR/2 Core Spray Piping Configuration**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.2-2. Typical BWR/3-5 Core Spray Piping Configuration**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.2-3. Typical BWR/6 Core Spray Piping Configuration**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.2-4. Typical Core Spray Sparger**

**6.2.1 Downcomer Sleeve**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**6.2.2 Tee Box Assembly**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.2.3 Shroud Connection Region

[[

**Content Deleted -  
EPRI Proprietary Information**

### 6.3 Applicable Mockups

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

#### 6.3.1 Core Spray Mockups

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

6.3.1.1 Downcomer Sleeve Joint Mockup (BWRVIP-J)

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.1-1. Mockup BWRVIP-J: Downcomer Slip Joint**



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.1-2. Downcomer Sleeve Mockup (BWRVIP-J)**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.1-3. Mockup BWRVIP-J: Downcomer Slip Joint: Configuration**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.1-4. Mockup BWRVIP-J: Downcomer Slip Joint: Flaw Details**

6.3.1.2 BWR/2 Shroud Penetration Mockup (BWRVIP-K)

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.2-1. BWRVIP-K Mockup: Shroud Penetration (BWR/2)**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.2-2. BWR/2 Shroud Penetration Mockup (BWRVIP-K)**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.2-3. Mockup BWRVIP-K: BWR/2 Shroud Penetration: Configuration**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.2-4. Mockup BWRVIP-K: BWR/2 Shroud Penetration: Flaw Details**



6.3.1.3 BWR/3-5 Shroud Penetration Mockup (BWRVIP-L)

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.3-1. BWRVIP-L Mockup: Shroud Penetration (BWR/3-5)**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.3-2. BWR/3-5 Shroud Penetration Mockup (BWRVIP-L)**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.3-3. Mockup BWRVIP-L: BWR/3-5 Shroud Penetration: Configuration**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.3-4. Mockup BWRVIP-L: BWR/3-5 Shroud Penetration: Flaw Details**

6.3.1.4 BWR/3-5 Core Spray Header Tee Box Mockups (BWRVIP-M and -N)

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

6.3.1.5 BWR/6 Core Spray Pipe Coupling Assembly Mockup (BWRVIP-CS6)

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.4-1. BWRVIP-M Mockup: Header Tee Box**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.4-2. BWR/3-5 Core Spray Header Tee Box Mockup (BWRVIP-M)**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.4-3. Mockup BWRVIP-M: BWR/3-5 Header Tee Box: Configuration**



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.4-4. Mockup BWRVIP-M: BWR/3-5 Header Tee Box: Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.5-1. BWR/6 Core Spray Pipe Coupling Assembly Mockup BWRVIP-CS6: Weld Configuration and Flaw Details**

6.3.1.6 BWR/3-6 P4a, P4b, and P4c Pipe-to-Elbow Mockups (BWRVIP-P4-1 and BWRVIP-P4-2)

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.6-1. Photograph of BWRVIP-P4-1 and BWRVIP-P4-2**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.6-2. Flaw Details of BWRVIP-P4-1**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.3.1.6-3. Flaw Details of BWRVIP-P4-2**

## 6.4 UT Technique Demonstrations for Core Spray Welds

### 6.4.1 General Findings for UT

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 6.4.1.1 Detection and Sizing of Flaws Parallel to the Weld

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 6.4.1.2 Detection of Flaws Transverse to the Weld

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 6.4.1.3 Effect of Roughness of Scanning Surface

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**6.4.2 UT Demonstration Summary**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 6.4.2-1. UT Demonstration Summary**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 6.4.2-1. UT Demonstration Summary (continued)**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



### 6.4.3 UT Demonstration 1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 6.4.4 UT Demonstration 2

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.5 UT Demonstration 3

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **6.4.6 UT Demonstration 4**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.7 UT Demonstration 5

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.8 UT Demonstration 6

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.9 UT Demonstration 7

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.10 UT Demonstration 8

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.11 UT Demonstration 9

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.12 UT Demonstration 10

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.13 UT Demonstration 11

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**6.4.14 UT Demonstration 12**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



### **6.4.15 UT Demonstration 13**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.16 UT Demonstration 14

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.17 UT Demonstration 15

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **6.4.18 UT Demonstration 16**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.19 UT Demonstration 17

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**6.4.20 UT Demonstration 18**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.21 UT Demonstration 19

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.22 UT Demonstration 20

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.23 UT Demonstration 21

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **6.4.24 UT Demonstration 22**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.25 UT Demonstration 23

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **6.4.26 UT Demonstration 24**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.27 UT Demonstration 25

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



**6.4.28 UT Demonstration 26**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.29 UT Demonstration 27

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.30 UT Demonstration 28

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.31 UT Demonstration 29

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.32 UT Demonstration 30

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.4.32-1. Correspondence of Flaws in Mockup BWRVIP-J to the Inspection Configuration of BWR/2 Weld P8**



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.4.32-2. Inability to Detect OD Pipe-Side Flaws Using the Single-stroke Scan Technique**

### 6.4.33 UT Demonstration 31

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.34 UT Demonstration 32

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.35 UT Demonstration 33

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6.4.35-1. Detection Paths for Flaws in Mockup BWRVIP-K**

### **6.4.36 UT Demonstration 34**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6.4.37 UT Demonstration 35

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **6.4.38 UT Demonstration 36**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



**6.4.39 UT Demonstration 37**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 6.4.40 UT Demonstration 38

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 6.4.41 UT Demonstration 39

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 6.4.42 UT Demonstration 40

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **6.4.43 UT Demonstration 41**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



# 6A

## INVESTIGATION OF CORE SPRAY INTERNAL PIPING OVERLAY INSPECTION

---

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6A.1 Materials

#### 6A.1.1 Probes

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6A.1.2 Ultrasonic Instrument

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 6A.1.3 Mockups

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6A.1.3-1. Mockup BWRVIP-CSRA: Weld Overlay Repair with Cracks Propagating from Existing Throughwall Defects: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 6A.1.3-2. Mockup BWRVIP-CSRC: Weld Overlay Repair with Sidewall Lack of Fusion:  
Configuration and Flaw Details**

## 6A.2 Surface Condition

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 6A.3 Examination Results

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **6A.4 Conclusions**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **6A.5 References**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

# 7

## TOP GUIDE

---

### 7.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## **7.2 Inspection Considerations**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **7.2.1 Aligner Pin Assemblies**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.2.1-1. Typical Vertical Aligner Pin Assembly**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.2.1-2. Aligner Pin Assembly Variations**

### **7.2.2 Hold-Down Assemblies**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.2.2-1. Hold-Down Assembly**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.2.2-2. Hold-Down Assembly**

### **7.2.3 Wedges**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.2.3-1. Lateral Restraint Brackets and Wedges**

### 7.2.4 BWR/6 Hold-Down Studs

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

Figure 7.2.4-1. Hold-Down Assembly

### 7.2.5 Rim-to-Bottom Plate Weld

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.2.5-1. Rim-to-Bottom Plate Weld**

### **7.2.6 Grid Beams**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.2.6-1. Configuration of Top Guide Grid, Fuel Channels, and Control Blades**

### **7.3 Applicable Mockups**

#### **7.3.1 Top Guide Grid Mockup BWRVIP-I**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.3.1-1. Configuration of Top Guide Grid Mockup BWRVIP-I**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.3.1-2. Top Guide Grid Mockup BWRVIP-I, Plate BWRVIP-I-A: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.3.1-3. Top Guide Grid Mockup BWRVIP-I, Plate BWRVIP-I-B: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.3.1-4. Top Guide Grid Mockup BWRVIP-I, Plate BWRVIP-I-C: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.3.1-5. Top Guide Grid Mockup BWRVIP-I, Plate BWRVIP-I-D: Configuration and Flaw Details**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 7.3.1-6. Top Guide Grid Mockup BWRVIP-I, Plate BWRVIP-I-E: Configuration and Flaw Details**

## **7.4 UT Technique Demonstrations for Top Guide Components**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **7.4.1 General Findings for UT**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

7.4.1.1 Grid Beams

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 7.4.2 UT Demonstration 1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



# 8

## CORE PLATE

---

### 8.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 8.2 Inspection Considerations

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 8.2.1 Rim Hold-Down Bolt Locations

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **8.3 Applicable Mockups**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 8.3-1. EDM Notches in Upper and Lower Threaded Regions of Core Plate Bolt Mockup**

## 8.4 UT Technique Demonstrations for Core Plate Rim Hold-Down Bolts

### 8.4.1 UT Demonstration 1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 8.4.2 UT Demonstration 2

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 8.4.3 UT Demonstration 3

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 8.4.4 UT Demonstration 4

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



# 9

## LPCI COUPLING

---

### 9.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 9.2 Inspection Considerations

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 9.3 Applicable Mockups

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 9.4 UT Technique Demonstrations for LPCI Coupling Welds

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

# 10

## JET PUMP ASSEMBLY

---

### 10.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 10.2 Inspection Considerations

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**10.3 Applicable Mockups**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**10.3.1 Mockup BWRVIP-U**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**10.3.2 Mockup BWRVIP-V**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**10.3.3 Mockups BWRVIP-Z3 and BWRVIP-Z3R**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**10.3.4 Mockup BWRVIP-Z4**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **10.3.5 Jet Pump Beam Mockups**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.3.5-1. EPRI Jet Pump Beam Mockup A**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.3.5-2. EPRI Jet Pump Beam Mockup B (No Flaws)**



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.3.5-3. EPRI Jet Pump Beam Mockup C**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.3.5-4. Jet Pump Beam Mockup BWRVIP-G2JPB1**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.3.5-5. Jet Pump Beam Mockup BWRVIP-G2JPB2-R1**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.3.5-6. Jet Pump Beam Mockup BWRVIP-G2JPB3**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.3.5-7. Jet Pump Beam Mockup BWRVIP-G2JPB4**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.3.5-8. Jet Pump Beam Taper-to-Radius Transition Mockups (Perspective Drawing)**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.3.5-9. Jet Pump Beam Taper-to-Radius Transition Mockups (Photo)**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.3.5-10. Jet Pump Beam Taper-to-Radius Transition Mockups (Side View Drawing)**

## **10.4 UT Technique Demonstrations**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **10.4.1 General Findings for UT**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 10.4.2 UT Demonstration 1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



### 10.4.3 UT Demonstration 2

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **10.4.4 UT Demonstration 3**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 10.4.5 UT Demonstration 4

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 10.4.6 UT Demonstration 5

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 10.4.7 UT Demonstration 6

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 10.4.8 UT Demonstration 7

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **10.4.9 UT Demonstration 8**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



### 10.4.10 UT Demonstration 9

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**10.4.11 UT Demonstration 10**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**10.4.12 UT Demonstration 11**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**10.4.13 UT Demonstration 12**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**10.4.14 UT Demonstration 13**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



**10.4.15 UT Demonstration 14**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 10.4.15-1. Examination Sequence**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**10.4.16 UT Demonstration 15**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.4.16-1. LaSalle 1, Fermi Jet Pump Adapter Configuration**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.4.16-2. Demonstration for Weld AD-1**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.4.16-3. Demonslation for Weld AD-2**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.4.16-4. Demonstration for Weld DF-3**

**10.4.17 UT Demonstration 16**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**10.4.18 UT Demonstration 17**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



**10.4.19 UT Demonstration 18**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.4.19-1. Area BB-2 and BB-3 Examination Technique**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.4.19-2. Jet Pump Beam Taper-to-Radius Transition Mockups**

**10.4.20 UT Demonstration 19**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**10.4.21 UT Demonstration 20**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



**10.4.22 UT Demonstration 21**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.4.22-1. Fermi-2 and LaSalle-1 (“U-Shaped”) Curved Adapter Configuration**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.4.22-2. Fermi-2 and LaSalle-1 DF-3 Weld Inspection Location**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 10.5 ET Technique Demonstrations

### 10.5.1 ET Demonstration 1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 10.5.2 ET Demonstration 2

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 10.6 Delivery System Demonstrations

### 10.6.1 Delivery System Demonstration 1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 10.6.2 Delivery System Demonstration 2

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



### 10.6.3 Delivery System Demonstration 3

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **10.6.4 Delivery System Demonstration 4**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

“This page has been intentionally left blank”

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 10.3.1-1. Jet Pump Riser Mockup BWRVIP-U: Configuration and Flaw Details**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 10.3.2-1. Jet Pump Riser Mockup BWRVIP-V: Configuration and Flaw Details**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 10.3.3-1. Jet Pump Mixer Mockup BWRVIP-Z3: Configuration and Flaw Details**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 10.3.4-1. Jet Pump Mixer Mockup BWRVIP-Z4: Configuration**



[[

**Content Deleted -  
EPRI Proprietary Information**

Figure 10.3.4-2. Jet Pump Mixer Mockup BWRVIP-Z4: Flaw Details

]] TS



"This page has been intentionally left blank"



# 11

## STANDBY LIQUID CONTROL

---

### 11.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## **11.2 Inspection Considerations**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **11.2.1 Nozzle-to-Vessel Weld**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **11.2.2 Penetration-to-Vessel Weld**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **11.2.3 Nozzle-to-Safe-End Weld**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### **11.2.4 Penetration-to-Safe-End Extension Weld**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 11.3 Applicable Mockups

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 11.3.1 Mockup BWRVIP-X1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 11.3.2 Mockup BWRVIP-X2

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 11.3.3 Mockup BWRVIP-Y3

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 11.3.4 Mockup BWRVIP-Y4

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### 11.3.5 Mockup BWRVIP-Y5

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 11.4 UT Technique Demonstrations for SLC Components

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 11.4.1 General Findings for UT

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 11.4.2 UT Demonstration 1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**11.4.3 UT Demonstration 2**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 11.3.1-1. SLC Nozzle Mockup BWRVIP-X1: Configuration and Flaw Details**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 11.3.2-1. SLC Nozzle Mockup BWRVIP-X2: Configuration and Flaw Details**



[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 11.3.3-1. SLC Penetration Mockup BWRVIP-Y3: Configuration and Flaw Details**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 11.3.4-1. SLC Penetration Mockup BWRVIP-Y4: Configuration and Flaw Details**



[[

**Content Deleted -  
EPRI Proprietary Information**

Figure 11.3.5-1. SLC Penetration Mockup BWRVIP-Y5: Configuration and Flaw Details

]] TS

"This page has been intentionally left blank"



# 12

## VESSEL ATTACHMENTS

---

### 12.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 12.2 Inspection Considerations

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 12.3 Applicable Mockups

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 12.4 UT Technique Demonstrations for Vessel Attachment Welds

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

# 13

## LOWER PLENUM

---

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 13.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 13.2 Inspection Considerations

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 13.3 Applicable Mockups

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 13.3.1 BWRVIP-CRDH1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 13.3.1-1. Specifications of Applicable Flaws for BWRVIP-CRDH1**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 13.3.1-1. BWRVIP-CRDH1 Mockup (Photograph)**

## 13.4 UT Technique Demonstrations for Lower Plenum Welds

### 13.4.1 UT Demonstration 1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRi Proprietary Information**

]] TS

# 14

## INSTRUMENT PENETRATIONS

---

### 14.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 14.2 Inspection Considerations

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

# 15

## ACCESS HOLE COVERS

---

### 15.1 Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.1-1. Access Hole Cover**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 15.2 Inspection Considerations

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.2-1. Examples of Shroud Support Plate Side Ultrasonic Examination Techniques**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.2-2. Retrofit Top Hat Access Hole Cover Configuration**

### **15.2.1 Thin Access Hole Covers**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.2.1-1. Thin AHC and Conventional Shroud Support Plate with Ledge**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**15.2.2 Intermediate Thickness Access Hole Covers**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.2.2-1. Intermediate Thickness Access Hole Cover and Conventional Shroud Support Plate Without Ledge**

### 15.2.3 Thick Access Hole Covers

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.2.3-1. Thick Access Hole Cover and Conventional Shroud Support Plate with Ledge**

]] TS

### 15.2.4 Non-Creviced Retrofit Design for Some BWR/4 and BWR/5 Plants

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.2.4-1. Retrofit Design for Some BWR/4 and BWR/5 Plants**

]] TS

**15.2.5 Non-Creviced Single Access Hole Cover Design**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.2.5-1. BWR/6 Single Oval Design**

### **15.3 Applicable Mockups**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

#### **15.3.1 Access Hole Cover Mockups**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

15.3.1.1 BWRVIP-AHC1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.3.1.1-1. BWRVIP-AHC1 Mockup (Photograph)**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.3.1.1-2. Bottom Side of BWRVIP-AHC1 Mockup (Photograph)**

15.3.1.2 BWRVIP-AHC2

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.3.1.2-1. BWRVIP-AHC2 Mockup (Photograph)**

15.3.1.3 BWRVIP-AHC3 and BWRVIP-AHC4

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.3.1.3-1. BWRVIP-AHC3 and BWRVIP-AHC4 (Photograph)**

15.3.1.4 BWRVIP-AHC5

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.3.1.4-1. BWRVIP-AHC5 Mockup (Photograph)**

]] TS

15.3.1.5 BWRVIP-AHC6

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.3.1.5-1. BWRVIP-AHC6 Mockup (Photograph)**

]] TS

## 15.4 UT Technique Demonstrations for Access Hole Covers

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 15.4.1 UT Demonstration Summary

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Table 15.4.1-1. UT Demonstration Summary**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

### 15.4.2 UT Demonstration 1

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.4.2-1. Surface Distance Required for Azimuthal (Sector) Scan**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.4.2-2. Surface Distance Required for Linear Scans (Electronic Raster)**

**Table 15.4.2-1. Demonstrated Examination Groups and Scan/Index Resolutions**

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

## 15.5 References

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS



[[

Content Deleted -  
EPRI Proprietary Information

Figure 15.3.1.1-3. Configuration Drawing of BWRVIP-AHC1

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.3.1.1-4. Partial Top View of BWRVIP-AHC1 (1 of 2)**



[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.3.1.1-5. Partial Top View of BWRVIP-AHC1 (2 of 2)**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.3.1.1-6. BWRVIP-AHC1 (Flaws 1a Through 1e)**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.3.1.1-7. BWRVIP-AHC1 (Flaws 1f Through 1i)**

]] TS

[[

Content Deleted -  
EPRI Proprietary Information

]] TS

Figure 15.3.1.1-8. BWRVIP-AHC1 (Flaws 1j Through 1n)



[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.3.1.2-2. Configuration Drawing for BWRVIP-AHC2**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

Figure 15.3.1.2-3. BWRVIP-AHC2 Flaw Drawings (Flaws 2a Through 2d)





[[

**Content Deleted -  
EPRI Proprietary Information**

Figure 15.3.1.2-4. BWRVIP-AHC2 Flaw Drawings (Flaws 2e Through 2h)

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.3.1.2-5. BWRVIP-AHC2 Flaw Drawings (Flaws 2i Through 2l)**



[[

**Content Deleted -  
EPRI Proprietary Information**

Figure 15.3.1.3-2. Configuration Drawing of BWRVIP-AHC3

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.3.1.3-3. Flaw Detail Drawing of BWRVIP-AHC3**



[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.3.1.3-4. Configuration Drawing of BWRVIP-AHC4**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.3.1.3-5. Flaw Detail Drawing of BWRVIP-AHC4**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.3.1.4-2. BWRVIP-AHC5 (Flaw Table and Configuration Dimensions)**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.3.1.4-3. BWRVIP-AHC5 (Ring-to-Cover Weld Flaw Locations)**





[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

Figure 15.3.1.4-4. BWRVIP-AHC5 (Ring-to-Cover Weld Flaw Details)

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.3.1.4-5. BWRVIP-AHC5 (Adapter Ring-to-Ring Weld Flaw Locations)**



[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.3.1.4-6. BWRVIP-AHC5 (Adapter Ring-to-Ring Weld Flaw Details)**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.3.1.5-2. Configuration Drawing of BWRVIP-AHC6**

]] TS



[[

**Content Deleted -  
EPRI Proprietary Information**

**Figure 15.3.1.5-3. Flaw Detail Drawing for BWRVIP-AHC6 (Flaws 6a Through 6d)**

]] TS

[[

**Content Deleted -  
EPRI Proprietary Information**

]] TS

**Figure 15.3.1.5-4. Flaw Detail Drawings for BWRVIP-AHC6 (Flaws 6e Through 6h)**



## Export Control Restrictions

Access to and use of EPRI Intellectual Property is granted with the specific understanding and requirement that responsibility for ensuring full compliance with all applicable U.S. and foreign export laws and regulations is being undertaken by you and your company. This includes an obligation to ensure that any individual receiving access hereunder who is not a U.S. citizen or permanent U.S. resident is permitted access under applicable U.S. and foreign export laws and regulations. In the event you are uncertain whether you or your company may lawfully obtain access to this EPRI Intellectual Property, you acknowledge that it is your obligation to consult with your company's legal counsel to determine whether this access is lawful. Although EPRI may make available on a case-by-case basis an informal assessment of the applicable U.S. export classification for specific EPRI Intellectual Property, you and your company acknowledge that this assessment is solely for informational purposes and not for reliance purposes. You and your company acknowledge that it is still the obligation of you and your company to make your own assessment of the applicable U.S. export classification and ensure compliance accordingly. You and your company understand and acknowledge your obligations to make a prompt report to EPRI and the appropriate authorities regarding any access to or use of EPRI Intellectual Property hereunder that may be in violation of applicable U.S. or foreign export laws or regulations.

**The Electric Power Research Institute (EPRI)**, with major locations in Palo Alto, California; Charlotte, North Carolina; and Knoxville, Tennessee, was established in 1973 as an independent, nonprofit center for public interest energy and environmental research. EPRI brings together members, participants, the Institute's scientists and engineers, and other leading experts to work collaboratively on solutions to the challenges of electric power. These solutions span nearly every area of electricity generation, delivery, and use, including health, safety, and environment. EPRI's members represent over 90% of the electricity generated in the United States. International participation represents nearly 15% of EPRI's total research, development, and demonstration program.

Together...Shaping the Future of Electricity

### **Program:**

BWRVIP

© 2010 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER...SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute, Inc.

♻️ Printed on recycled paper in the United States of America

1019075NP

### **Electric Power Research Institute**

3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA  
800.313.3774 • 650.855.2121 • [askepri@epri.com](mailto:askepri@epri.com) • [www.epri.com](http://www.epri.com)