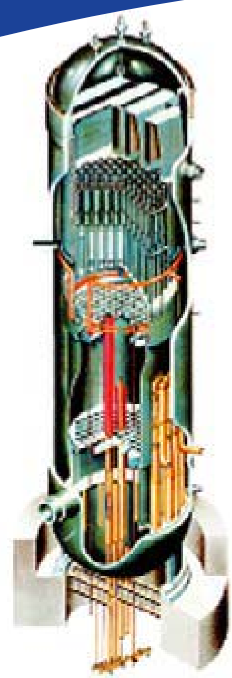
ELECTRIC POWER RESEARCH INSTITUTE

2016 TECHNICAL REPORT

TR-105696-R19 (BWRVIP-03NP) Revision 19: BWR Vessel and Internals Project

Reactor Pressure Vessel and Internals Examination Guidelines



TR-105696-R19 (BWRVIP-03NP) Revision 19: BWR Vessel and Internals Project

Reactor Pressure Vessel and Internals
Examination Guidelines

3002008095NP

Final Report, December 2016

EPRI Project Manager
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All or a portion of the requirements of the EPRI Nuclear Quality Assurance Program apply to this product.

YES NO

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ACKNOWLEDGMENTS

The Electric Power Research Institute (EPRI) prepared this report.

Principal Investigator
BWRVIP Inspection Focus Group

This report describes research sponsored by EPRI and its Boiling Water Reactor Vessel and Internals Project (BWRVIP) participating members.

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 following staff of the EPRI NDE Program are acknowledged for contributing to the completion of this document:

Mark Dennis
Bret Flesner
Bruce Greer
Jeff Landrum
Greg Selby
Paul Zayicek

This publication is a corporate document that should be cited in the literature in the following manner:

TR-105696-R19 (BWRVIP-03NP) Revision 19: BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines. EPRI, Palo Alto, CA: 2016. 3002008095NP.

PRODUCT DESCRIPTION

This report provides the boiling water reactor (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.

Background

In 1990, a visual examination of the core shroud of a Swiss 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 and 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.

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.

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.

Results

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.

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.

Keywords
BWRVIP
NDE
Internals
Inspection
Ultrasound
Vessel

Deliverable Number: 3002008095

Product Type: Technical Report

Product Title: TR-105696-R19 (BWRVIP-03NP) Revision 19: BWR Vessel and Internals Project Reactor Pressure Vessel and Internals Examination Guidelines

PRIMARY AUDIENCE: BWRVIP Program Owners

KEY RESEARCH QUESTION

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.

RESEARCH OVERVIEW

The Inspection Focus Group has developed guideline documents that 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.

KEY FINDINGS

- Extensive investigations and demonstrations of NDE techniques appropriate for inspection of BWR internals are provided.
- Design, fabrication, and inspection of a series of realistic mockups containing realistic simulations of degradation mechanisms are described.
- Evaluation factors, which are numerical values related to the uncertainties inherent in delivering and executing an NDE technique in a BWR, are provided.
- 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.

WHY THIS MATTERS

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.

HOW TO APPLY RESULTS

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.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- BWRVIP semi-annual meetings held each year in June and December

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PROGRAM: BWRVIP, 41.01.03

IMPLEMENTATION CATEGORY: Category 1

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PREFACE

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 that 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 19

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-R18 (BWRVIP-03) Revision 18: BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines* (EPRI Report 3002005571, December 2015).

Affected Section(s)	**Description of Change**
Figure 4.3.1.7-1	Updated figure showing mockup details
4.3.1.13	New section documenting a new NDE mockup
4.3.1.14	New section documenting a new NDE mockup
4.3.1.15	New section documenting new NDE mockups
Table 4.4.2-1	Updated to reflect new NDE technique demonstrations
4.4.86–4.4.94	New sections: new NDE technique demonstrations
Table 5.4-1	Updated to reflect new NDE demonstrations
5.4.62 and 5.4.63	New sections: new NDE technique demonstrations
Table 6.4.2-1	Updated to reflect new NDE demonstrations
6.4.68	New section: new NDE technique demonstration
Table 10.4-1	Updated to reflect new NDE demonstrations

10.4.28	New section: new NDE technique demonstration
14.5	New section for documenting UT technique demonstrations
14.5.2	New section: new NDE technique demonstration

HISTORY OF CHANGES TO THIS DOCUMENT REVISION 18

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-R17 (BWRVIP-03) Revision 17: BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines* (EPRI Report 3002003091, December 2014).

Affected Section(s)	**Description of Change**
Table 4.4.2-1	Updated to reflect new NDE technique demonstrations.
4.4.71 and 4.4.72	Revised to add search unit frequency.
4.4.79–4.4.85	New sections: new NDE technique demonstrations.
4.7.9	New section: new delivery tooling demonstration.
Table 5.4-1	Updated to reflect new NDE demonstrations.
5.4.59	Revised to reference a new delivery tool demonstration.
5.4.60 and 5.4.61	New sections: new NDE technique demonstrations.
5.6.5	New section: new delivery tooling demonstration.
7.4.4	New section: new NDE technique demonstration.
Table 12.4.1-1	Updated to reflect new NDE technique demonstration.
12.4.3	New section: new NDE technique demonstration.
Table 15.4.1-1	Updated to reflect new NDE technique demonstrations.
15.4.8–15.4.10	New sections: new NDE technique demonstrations.

HISTORY OF CHANGES TO THIS DOCUMENT REVISION 17

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-R16 (BWRVIP-03) Revision 16: BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines* (EPRI Report 3002000664, December 2013).

Affected Section(s)	**Description of Change**
4.3.1.7	Revised to show modifications to an existing shroud weld H1 mockup (BWRVIP-H1) that included adding core spray sparger brackets and associated flaws.
Table 4.4.2-1	Updated to include new NDE demonstrations.
4.4.75–4.4.78	New sections: new NDE technique demonstrations.
Table 5.4-1	Updated to include a new NDE demonstration.
5.4.59	New section: new NDE technique demonstration.
Table 6.4.2-1	Updated to include new NDE demonstrations.
6.4.37	Revised demonstration to clarify access.
6.4.65–6.4.67	New sections: new NDE technique demonstrations.
7.4.3	New section: new NDE technique demonstration.

Table 10.4-1	Updated to include new NDE demonstrations.
10.4.25–10.4.27	New sections: new NDE technique demonstrations.
14	Revised section to include discussion related to the inspection of instrument penetrations and to add new NDE mockups.

HISTORY OF CHANGES TO THIS DOCUMENT REVISION 16

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-R15 (BWRVIP-03) Revision 15: BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines* (EPRI Report 1025142, December 2012).

Affected Section(s)	**Description of Change**
Section 3.1	Revised to clarify guidance for flaw measurement accuracy of visual indications including treatment of NDE uncertainty as described in BWRVIP letter 2004-426, which was approved by the NRC on December 23, 2011 (reference: ADAMS accession numbers ML113550419 and ML113110505)
Table 4.4.2-1	Updated to reflect archival of NDE demonstrations.
4.4.23, 4.4.24, 4.4.33	Revised to reflect UT demonstrations that have been archived.
Table 5.4-1	Updated to reflect archival of NDE demonstrations.
5.4.12, 5.4.26	Revised to reflect UT demonstrations that have been archived.
Table 6.4.2-1	Updated to reflect archival of NDE demonstrations.
6.4.15, 6.4.16, 6.4.17, 6.4.23, 6.4.24	Revised to reflect UT demonstrations that have been archived.
8.4	Revised to add UT demonstration summary table.
8.4.5	New section: new NDE technique demonstration.
Table 10.4-1	Updated to reflect archival of NDE demonstrations.

10.4.4, 10.4.5, 10.4.6, 10.4.7	Revised to reflect UT demonstrations that have been archived.
12.4.1	New section for UT demonstration summary table.
12.4.2	New section: new NDE technique demonstration.

HISTORY OF CHANGES TO THIS DOCUMENT REVISION 15

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-R14 (BWRVIP-03) Revision 14: BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines* (EPRI Report 1022848, December 2011).

Affected Section(s)	Description of Change
1.4	Add nine-month implementation requirement.
4.3.1.12	New section documenting new NDE mockup.
Table 4.4.2-1	Updated to document new demonstrations.
4.4.69–4.4.74	New sections: new NDE technique demonstrations.
Table 5.4-1	Updated to document new demonstration.
5.4.58	New section: new NDE technique demonstration.
Table 6.4.2-1	Updated to document new demonstrations.
6.4.53–6.4.64	New sections: new NDE technique demonstrations.
12.3	New section documenting new NDE mockup.
Table 15.4.1-1	Updated to document new demonstrations.
15.4.4–15.4.7	New sections: new NDE technique demonstrations.

HISTORY OF CHANGES TO THIS DOCUMENT REVISION 14

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-R13 (BWRVIP-03) Revision 13: BWR Vessel and Internals Project, Reactor Pressure Vessel and Internals Examination Guidelines* (EPRI Report 1021007, December 2010).

Affected Section(s)	**Description of Change**
Table 4.4.2-1	Updated to document new demonstrations.
4.4.67–4.4.68	New sections: new NDE technique demonstrations.
Table 5.4-1	Added table for UT demonstration summary.
5.4.53–5.4.57	New sections: new NDE technique demonstrations.
6.3.1.6	New section documenting new NDE mockups.
10.3.6	New section documenting new NDE mockups.
Table 10.4-1	Added table for UT demonstration summary.
10.4.24	New section: new NDE technique demonstration.
13.3.2	New section documenting new NDE mockup.

HISTORY OF CHANGES TO THIS DOCUMENT REVISION 13

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-R12 (BWRVIP-03) Revision 12: Boiling Water Reactor Pressure Vessel and Internals Examination Guidelines* (EPRI Report 1019075, December 2009).

Affected Section(s)	**Description of Change**
	Deleted the Inspection Focus Group roster.
2.5, Para. 6.0	Clarified intent of performing cleaning assessments.
Table 4.4.2-1	Updated to document new demonstrations.
4.4.62–4.4.66	New sections: new NDE technique demonstrations.
5.4.50–5.4.52	New sections: new NDE technique demonstrations.
Table 6.4.2-1	Updated to document new demonstrations.
6.4.44–6.4.52	New sections: new NDE technique demonstrations.
7	Revised section to incorporate new inspection guidance for grid beams and to include new NDE mockups.
10.4.23	New section: new NDE technique demonstration.
10.6.5	New section: new delivery tool demonstration.
Table 15.4.1-1	Updated to document new demonstrations.
15.4.3	New section: new NDE technique demonstration.

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
xxxi	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).

Affected Section(s)	Description of Change
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).

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

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

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

Affected Section(s)	Description of Change
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*.

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

Affected Section(s)	Description of Change
1	Updated the Committee roster and Acknowledgments.
2.1 - 2.4	Changes to administrative procedures, made necessary by discontinuation ofreferenced 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.

CONTENTS

* 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

LIST OF TABLES

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 four technical committees and focus group:

- The Assessment Committee
- The Inspection 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 Inspection 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.”

A nine-month implementation schedule is applicable starting from the date that the report is published.

2
GENERAL PROCEDURES

Demonstration of inspection tooling and NDE techniques on realistic mockups is a central premise of the Inspection Committee's approach to assurance of effective internals NDE. These demonstrations must be performed, documented, and reported in a consistent and formal manner.

The following guideline documents are intended to provide objective, uniform demonstrations.

2.1 Guidelines for Use of BWRVIP Mockups

1.0 Purpose

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2.0 Reference

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3.0 Guidelines for Usage

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4.0 Guidelines for Use Prioritization

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2.2 Protocol for NDE Technique Demonstrations on BWRVIP Mockups

1.0 Purpose

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2.0 Responsibilities

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3.0 Prerequisites

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4.0 Demonstration Plan

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5.0 Demonstration Process

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6.0 Results Reporting and Documentation

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2.3 Guidelines for Determining NDE Technique Uncertainty

1.0 Purpose

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2.0 References

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3.0 Responsibilities

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4.0 Demonstration Process

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5.0 Documentation

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2.4 Guidelines for Determining Inspection Tool Positioning Uncertainty

1.0 Purpose

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2.0 References

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3.0 Responsibilities

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4.0 Guidelines for Uncertainty Measurements

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5.0 Demonstration Plan

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6.0 Demonstration Process

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7.0 Documentation

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

1.0 Purpose

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2.0 Scope

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3.0 Definitions

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4.0 Personnel Training/Experience

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5.0 Equipment Requirements

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6.0 Inspection Requirements

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7.0 Evaluation of Indications

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8.0 Documentation of Results

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Figure 2.5.8.1-1. System Setup

2.6 Generic Standards for Ultrasonic Examination of BWR Vessel Internal Components

1.0 Scope

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2.0 References

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3.0 Personnel

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4.0 Technique Demonstrations

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5.0 Equipment

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6.0 Calibration

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7.0 Examination

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8.0 Recording

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9.0 Evaluation

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10.0 Reporting

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

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

1.0 Scope

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2.0 References

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3.0 Personnel

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4.0 Technique Demonstration

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5.0 Equipment

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6.0 Calibration

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7.0 Examination

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8.0 Recording

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9.0 Evaluation

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10.0 Reporting

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3
DEMONSTRATION OF ACCURACY OF FLAW LENGTH MEASUREMENT BY VISUAL EXAMINATION

3.1 Summary

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Table 3.1-1. Flaw Evaluation Factors

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3.2 Demonstration

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3.2.1 Vendors

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3.2.2 Mockups

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3.2.3 Flaws

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3.2.4 Cameras

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3.2.5 Measurement Techniques

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3.3 Sizing Performance

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3.3.1 Estimation

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Table 3.3.1-1. Sizing Performance of Length Estimation Techniques

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3.3.2 Measurement by Ruler

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

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4
SHROUD

4.1 Summary

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

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4.2 Inspection Considerations

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4.3 Applicable Mockups

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4.3.1 Shroud Weld Mockups

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4.3.1.1 NDE Center's Original H3 Mockup

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4.3.1.2 Utility H3 and H4 Mockups

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

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

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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

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

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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

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

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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

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

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

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Figure 4.3.1.6-3. Shroud Ring Segment Weld

4.3.1.7 Shroud Mockup BWRVIP-H1: Shroud Weld H1

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Figure 4.3.1.7-2. Configuration of BWRVIP-H1-R1 Mockup (New Sparger Brackets Shown in Blue)

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Figure 4.3.1.7-3. Details for BWRVIP-H1-R1 Sparger Bracket Flaws

4.3.1.8 Shroud Mockup BWRVIP-SSC1: Shroud Scallops

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

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Figure 4.3.1.8-1. Mockup BWRVIP-SSC1

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

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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

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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

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

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

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

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

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

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

4.3.1.12 BWR/6 H3 Core Shroud Weld Mockups (BWRVIP-BWR6-H3-A and BWRVIP-BWR6-H3-B)

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Figure 4.3.1.12-1. Roll-Out View of Shroud Flange, Showing Bolt Hole and Alignment Pinhole Locations

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Figure 4.3.1.12-4-1-2. BWR/6 H3 Weld Configurations (Bolt Hole Cross Section Shown)

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Figure 4.3.1.12-3. BWR/6 H3 Core Shroud Mockups (Photograph)

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Figure 4.3.1.12-4. BWR/6 H3 Core Shroud Mockups (Photograph of Bolt Holes)

4.3.1.13 Core Shroud Mockup Containing “Atypical” or “Off-Axis” Flaws (BWRVIP-IASCC-1)

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Figure 4.3.1.13-1. BWRVIP-IASCC-1 Mockup (Photograph)

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Figure 4.3.1.13-2. BWRVIP-IASCC-1 Mockup Design

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Figure 4.3.1.13-3. BWRVIP-IASCC-1 Flaw Layout (Surface A)

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Figure 4.3.1.13-4. BWRVIP-IASCC-1 Flaw Layout (Surface B)

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Table 4.3.1.13-1. Specifications for the "A" Category Flaws

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Figure 4.3.1.13-5. Length and Depth Profile of Flaw A8 (End View)

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Figure 4.3.1.13-6. Side Profile of Flaw A8

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Figure 4.3.1.13-7. Methodology Used to Measure the Length of Category "A" Flaws

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Table 4.3.1.13-2. Details About "B" Category Flaws

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Figure 4.3.1.13-8. Arrangement of Flaw Segments That Make Up Flaw C1

Table 4.3.1.13-3. Flaw C1 Specifications

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Figure 4.3.1.13-9. Arrangement of Flaw Segments That Make Up Flaw C2

Table 4.3.1.13-4. Flaw C2 Specifications

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Figure 4.3.1.13-10. Arrangement of Flaw Segments That Make Up Flaw C3

Table 4.3.1.13-5. Flaw C3 Specifications

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Figure 4.3.1.13-11. Arrangement of Flaw Segments That Make Up Flaws C4 and C5

Table 4.3.13-6. Flaw C4 and C5 Specifications

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Figure 4.3.1.13-12. Arrangement of Flaw Segments That Make Up Flaws C6 and C7

Table 4.3.13-7. Flaw C6 and C7 Specifications

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4.3.1.14 Core Shroud Mockup with Remnant Attachments, Excavation Repairs, and Simulated SCC Flaws (BWRVIP-SHRD-REMNANT-1)

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Figure 4.3.1.14-1. BWRVIP-SHRD-REMNANT-1 Mockup Design (Prior to Attachment Removal)

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Figure 4.3.1.14-2. Final Configuration of the BWRVIP-SHRD-REMNANT-1 Mockup (After Attachment Removal)

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Figure 4.3.1.14-3. Example of Compressed EDM Notch (Photograph of Notch 3a)

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Figure 4.3.1.14-4. Flaw Layout of the BWRVIP-SHRD-REMNANT-1 Mockup

Table 4.3.1.14-1. Mockup Notch and Flaw As-Built Dimensions

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Figure 4.3.1.14-5. Cross Section of Flaw 7a

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Figure 4.3.1.14-6. Cross Section of Flaw 7b

4.3.1.15 BWR/2 Through BWR/5 H2 and H3 Core Shroud Weld Mockups BWRVIP-H3-BWR3-P, BWRVIP-H3-BWR4-F, and BWRVIP-H3-BWR5-P

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Figure 4.3.1.15-1. Photograph of BWRVIP-H3 Core Shroud Mockups Placed in Inspection Tank

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Figure 4.3.1.15-2. BWRVIP-H3-BWR4-F Mockup Configuration (TGSR Flaws Shown in Red, Cylinder Side Flaws Shown in Purple)

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Figure 4.3.1.15-3. BWRVIP-H3-BWR5-P Mockup Configuration (TGSR Flaws Shown in Red, Cylinder Side Flaws Shown in Purple)

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Figure 4.3.1.15-4. BWRVIP-H3-BWR4-P Mockup Configuration (TGSR Flaws Shown in Red)

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Table 4.3.1.15-1. As-Built Flaw Details

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Figure 4.3.1.15-5. Example of Through-Wall Extent Measurements of Flaws That Are Larger Than the Weld Fillet (Flaw H3K Shown)

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Figure 4.3.1.15-6. Example of Flaw Length Measurements When Flaw Is Larger Than Weld Fillet (Weld #1 of BWRVIP-H3-BWR4-F Mockup Shown)

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Figure 4.3.1.15-7. Example of Unflawed Remaining Ligament Measurement When Flaw Is Smaller Than the Weld Fillet (Flaw H3o Shown)

4.3.2 Special Purpose Mockups

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4.3.2.1 Surface Roughness

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Figure 4.3.2.1-1. Surface Roughness Mockup

4.3.2.2 Multiple Parallel Cracks

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

4.3.2.3 EDM Notches in Weld Toe

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4.4 UT Technique Demonstrations for Core Shroud Welds

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4.4.1 General Findings for UT

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4.4.1.1 Detection of Shallow Reflectors

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4.4.1.2 Detection of Skewed Reflectors

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4.4.1.3 Effect of Multiple Parallel Defects

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4.4.1.4 Effect of Roughness of Scanning Surface

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4.4.2 UT Demonstration Summary

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Table 4.4.2-1. UT Demonstration Summary

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Table 4.4.2-1. UT Demonstration Summary (continued)

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Table 4.4.2-1. UT Demonstration Summary (continued)

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Table 4.4.2-1. UT Demonstration Summary (continued)

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Table 4.4.2-1. UT Demonstration Summary (continued)

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Table 4.4.2-1. UT Demonstration Summary (continued)

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Table 4.4.2-1. UT Demonstration Summary (continued)

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4.4.3 UT Demonstration 1

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4.4.4 UT Demonstration 2

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4.4.5 UT Demonstration 3

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

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Figure 4.4.5-2. Principle of Operation of LLT Technique

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4.4.12 UT Demonstration 10

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4.4.15 UT Demonstration 13

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4.4.16 UT Demonstration 14

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4.4.18 UT Demonstration 16

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

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Table 4.4.18-2. Results of UT Demonstration 16

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4.4.19 UT Demonstration 17

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4.4.25 UT Demonstration 23

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4.4.26 UT Demonstration 24

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4.4.27 UT Demonstration 25

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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Figure 4.4.60-1. Vertical Ring Segment Weld Orientation

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Table 4.4.61-1. Focal Law Groups for Demonstration 59

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Figure 4.4.62-1. Scanning the H1 Weld from the Core Shroud Flange

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Figure 4.4.63-1. H5/H6A Looking Up and Looking Down Scan Configurations

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Figure 4.4.63-2. H4/H5 and Vertical Weld Scan Configuration

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Figure 4.4.64-1. H2 Examination Technique

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Figure 4.4.65-1. H3 Full-Vee Technique at Rear Scan Line Position

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Figure 4.4.65-2. H3 Full-Vee (Red) and High-Angle (Pink) Technique at Forward Scan Line Position

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Table 4.4.66-1. Crack Location and Orientation Categories in Mockup BWRVIP-H6OH

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Figure 4.4.66-1. H6OH Examination Technique

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Table 4.4.68-1. UT System Essential Variables

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Figure 4.4.68-1. Top View of Data Collected with the UltraVision 3.2/Dynaray System

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Figure 4.4.68-2. Top View of 2006 Data Collected with the TomoView/TomoScan-III System

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Figure 4.4.69-1. Probe Position on BWRVIP Mockup

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Figure 4.4.70-1. Mockups BWRVIP-A and BWRVIP-B (H1, H2, and H5/H6A Scan Surface)

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Figure 4.4.70-2. Mockups BWRVIP-A and BWRVIP-B (H3 and H6/H6B Scan Surface)

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Figure 4.4.70-3. Mockup BWRVIP-C (H4/H5 Flaws Connected to the Scan Surface)

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Figure 4.4.70-4. Mockup BWRVIP-C (H4/H5 Flaws Connected Opposite to the Scan Surface)

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Figure 4.4.71-1. Probe Positions on BWRVIP Mockup

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Figure 4.4.72-1. 25° to 55° Sector Scan Technique for H3 Weld Examination

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Figure 4.4.72-2. Creeping Wave (ODCR) Technique for H3 Weld Examination

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Figure 4.4.73-1. Core Plate Support Ring and Top Guide Support Ring Scan Locations

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Table 4.4.74-1. Crack Location and Orientation Categories in Mockup BWRVIP-H6OH

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Figure 4.4.74-1. H6OH Line Scan Examination Technique

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Figure 4.4.75-1. Mockup BWRVIP-C (H4/H5 and Vertical Welds; Flaws Connected to the Scan Surface)

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Figure 4.4.75-2. Mockup BWRVIP-C (H4/H5 and Vertical Welds; Flaws Connected Opposite to the Scan Surface)

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Table 4.4.75-1. Focal Laws for Line Scan Technique

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Table 4.4.75-2. Focal Laws for Raster Scan Technique

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Figure 4.4.76-1. Mockup BWRVIP-C (H4/H5 and Vertical Welds; Flaws Connected to the Scan Surface)

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Figure 4.4.76-2. Mockup BWRVIP-C (H4/H5 and Vertical Welds; Flaws Connected Opposite to the Scan Surface)

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Table 4.4.76-1. Focal Laws for Line Scan Technique

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Table 4.4.76-2. Focal Laws for Raster Scan Technique

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Figure 4.4.77-1. BWR/6 H3 Configuration Without Flange Extension Above the H3 Weld

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Figure 4.4.77-2. Demonstrated Scan Line Positions

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Figure 4.4.77-3. OD Looking Down D-Scan Images Showing Unflawed Region (Left) and Outside Surface Flaw A8 (Right)

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Figure 4.4.77-4. OD Looking Down D-Scan Images Showing Unflawed Region (Left) and Inside Surface Flaw A6 (Right)

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Figure 4.4.77-5. OD Looking Down B- and C-Scan Images Showing Shadowing of Geometric Response (Top) and Low-Amplitude Flaw Responses (Bottom)

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Figure 4.4.77-6. ID Looking Down B- and Sector-Scan Images Showing Shadowing of Geometric Response (Left) and A14 Flaw Response (Right)

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Figure 4.4.77-7. ID Looking Down Examination Data Showing Near-Side and Far-Side OD Flaw Responses

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Figure 4.4.78-1. BWR/6 H3 Configuration with Flange Extension Above the H3 Weld

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Figure 4.4.78-2. Inside Surface (Left) and Outside Surface (Right) Scan Line Positions

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Figure 4.4.78-3. Looking Down Ultrasonic Data Display from Unflawed Region of BWRVIP-B Mockup (Probe Located on Outside Surface)

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Figure 4.4.78-4. Looking Down Ultrasonic Data Display from Flaw B7 in Mockup BWRVIP-B (Probe Located on Outside Surface)

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Figure 4.4.78-5. Looking Down Ultrasonic Data Display from Unflawed Region of BWRVIP-B Mockup (Probe Located on Inside Surface)

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Figure 4.4.78-6. Looking Down Ultrasonic Data Display from Flaw B5 in Mockup BWRVIP-B (Probe Located on Inside Surface)

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Figure 4.4.79-1. BWR/6 H3 Configuration with Flange Extension Above the H3 Weld

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Figure 4.4.79-2. Inside Surface (Left) and Outside Surface (Right) Scan Line Positions

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Figure 4.4.79-3. Example of Inside Surface Looking Down Examination Data (Red Boxes Indicate the Location of the Seven Outside Surface Flaws)

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Figure 4.4.79-4. Example of Outside Surface Looking Down Examination Data (Red Boxes Indicate the Location of the Seven Inside Surface Flaws)

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Figure 4.4.79-5. Values Used to Determine Flaw Depth When Scanning from the Outside Surface (Mockup Flaw B4 Shown)

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Figure 4.4.79-6. Values Used to Determine Flaw Depth When Scanning from the Inside Surface (Mockup Flaw B8 Shown)

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Figure 4.4.80-1. Ultrasonic Data Display of ID Looking Up Scan of the BWRVIP-BWR/6-H3-B Mockup

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Figure 4.4.80-2. Ultrasonic Data Display of OD Looking Up Scan of the BWRVIP-BWR/6-H3-B Mockup

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Figure 4.4.81-1. Probe Positions on BWRVIP Mockup

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Figure 4.4.81-2. Example of H2 Looking Up Examination Data (Mockup Weld #1 Shown)

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Figure 4.4.81-3. Response of Flaw 1-2b Using the H3 Looking Down Focal Laws

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Figure 4.4.82-1. 25° to 55° Sector Scan Technique for H3 Weld Examination

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Figure 4.4.82-2. 80° Creeping Wave (ODCR) Technique for H3 Weld Examination

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Figure 4.4.82-3. Full-Vee Shear Wave Examination Data Obtained on Weld #2 of the BWRVIP-H2/H3 Mockup (ID Flaw Detection Only)

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Figure 4.4.82-4. Full-Vee Shear Wave Examination Data Obtained on Weld #2 of the BWRVIP-H2/H3 Mockup (OD Flaw Detection Only)

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Figure 4.4.82-5. 80° ODCR Examination Data Obtained on Weld #2 of the BWRVIP-H2/H3 Mockup (OD Flaw Detection Only)

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Figure 4.4.82-6. Example of Qualitative Depth Sizing Assessment of Deep Flaws (Dark Blue Indication on the Left Side of the Upper Two Panes Is 2.5-Inch-Deep Flaw 2-2a)

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Figure 4.4.83-1. BWRVIP-A and BWRVIP-B from the H1 Looking Up, H2 Looking Down, and H5/(H6a) Looking Down Scan Surface (Near-Side Flaws Shown)

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Figure 4.4.83-2. BWRVIP-A and BWRVIP-B from the H3 Looking Up and H6/(H6b) Looking Up Scan Surface (Near-Side Flaws Shown)

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Figure 4.4.83-3. BWRVIP-C from the H4/(H5) and Vertical Weld Scan Surfaces When Flaws Are Located on the Opposite Surface from Which Scanning Was Performed

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Figure 4.4.83-4. BWRVIP-C from the H4/(H5) and Vertical Weld Scan Surfaces When Flaws Are Located on the Same Surface from Which Scanning Was Performed

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Figure 4.4.83-5. Ultrasonic Examination Data from BWRVIP-C with Six Inside-Surface-Connected Flaws Located on the Near Side of the Weld Joint

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Figure 4.4.83-6. Ultrasonic Examination Data from BWRVIP-C with Six Outside-Surface-Connected Flaws Located on the Near Side of the Weld Joint

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Figure 4.4.83-7. Remaining Ligament Reported for Ring-Side Flaws

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Figure 4.4.84-1. Scan Surfaces for BWRVIP-A (Left) and BWRVIP-B (Right) Mockups

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Figure 4.4.84-2. Ultrasonic Examination Data Obtained on BWRVIP-A

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Figure 4.4.84-3. Ultrasonic Examination Data Obtained on BWRVIP-B

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Figure 4.4.84-4. Remaining Ligament Reported for Inside-Surface-Initiating Ring-Side Flaws

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Table 4.4.85-1. Crack Location and Orientation Categories in Mockup BWRVIP-H6OH

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Figure 4.4.85-1. Probe Position During the Detection Scan

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Figure 4.4.85-2. Probe Position During the Sizing Scan

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Figure 4.4.85-3. Remaining Ligament Reported for Horizontal Flaw

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Figure 4.4.86-1. Plate-Side Coverage Plots for 20° to 85° Longitudinal Beam Angles

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Figure 4.4.86-2. Plate-Side Coverage Plots for 30° to 70° Shear Beam Angles

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Figure 4.4.86-3. Plate-Side Coverage Plots for 30° to 50° Full-Vee Path Shear Beam Angles

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Figure 4.4.86-4. BWRVIP-A and BWRVIP-B from the H1 Looking Up, H2 Looking Down, and H5/(H6a) Looking Down Scan Surface (Near-Side Flaws Shown)

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Figure 4.4.86-5. BWRVIP-A and BWRVIP-B from the H3 Looking Up and H6/(H6b) Looking Up Scan Surface (Near-Side Flaws Shown)

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Figure 4.4.86-6. BWRVIP-C from the H4/(H5) and Vertical Weld Scan Surfaces When Flaws Are Located on the Opposite Surface From Which Scanning Was Performed

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Figure 4.4.86-7. BWRVIP-C from the H4/(H5) and Vertical Weld Scan Surfaces When Flaws Are Located on the Same Surface from Which Scanning Was Performed

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Figure 4.4.86-8. Longitudinal Wave Response from BWRVIP-C with Six Outside Surface-Connected Flaws Located on the Near Side of the Weld Joint

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Figure 4.4.86-9. Shear Wave Full-Vee Path Response from BWRVIP-C with Six Outside Surface-Connected Flaws Located on the Near Side of the Weld Joint

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Figure 4.4.86-10. Remaining Ligament Reported for Ring-Side Flaws

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Figure 4.4.87-1. Scan Surfaces for BWRVIP-A (Left) and BWRVIP-B (Right) Mockups

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Table 4.4.87-1. Core Shroud Focusing Conventions from the Ring Side

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Figure 4.4.87-2. Ring-Side Coverage Plots for 20° to 85° Longitudinal Beam Angles

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Figure 4.4.87-3. Ring-Side Coverage Plots for 30° to 70° Shear Beam Angles

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Figure 4.4.87-4. Longitudinal Wave Response Obtained on BWRVIP-A

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Figure 4.4.87-5. Shear Wave Response Obtained on BWRVIP-A

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Figure 4.4.87-6. Longitudinal Wave Response Obtained on BWRVIP-B

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Figure 4.4.87-7. Shear Wave Response Obtained on BWRVIP-B

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Figure 4.4.87-8. Longitudinal Wave Response Obtained on BWRVIP-A from Two Scan Lines

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Figure 4.4.87-9. Longitudinal Wave Response Obtained on BWRVIP-B from Two Scan Lines

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Figure 4.4.87-10. Remaining Ligament Reported for Inside Surface-Initiating Ring-Side Flaws

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Table 4.4.88-1. Demonstrated Azimuthal Arrays

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Figure 4.4.88-1. Example of Initial Scan Pattern and Probe Orientations

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Figure 4.4.88-2. Example of a Supplemental Scan (Same Probe Orientations as Initial Scan)

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Figure 4.4.88-3. Example of a Supplemental Scan (End-Effector Rotated for Opposing Beam Orientations)

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Figure 4.4.88-4. Looking Counterclockwise Probe Orientation (Flaw C1; 40° Inspection Angle with -10° Skew)

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Figure 4.4.88-5. Looking Down Probe Orientation (Flaw C1; 35° Inspection Angle with +20° Skew)

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Figure 4.4.88-6. Volumetric Merge of Looking Down and Looking Counterclockwise Probe Orientation Data

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Figure 4.4.88-7. Provided Length Measurements for Flaw C5 (Applies to ID and OD Surface)

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Figure 4.4.88-8. Example of Reported Flaw Length

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Figure 4.4.88-9. Ultrasonic Examination Data from BWRVIP Remnant Attachment Mockup

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Figure 4.4.88-10. Ultrasonic Examination Data from 0.01-Inch to 0.05-Inch Deep Notches (Side View)

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Figure 4.4.89-1. BWR/6 H3 Configuration Without Flange Extension Above the H3 Weld

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Figure 4.4.89-2. Scan Line Positions (Looking Down on Left, Looking Up on Right)

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Figure 4.4.89-3. Example of Outside Surface Looking Down Examination Data (Red Boxes Indicate the Location of the Detected Near-Side Flaws)

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Figure 4.4.89-4. Values Used to Determine Flaw Depth When Scanning from the Outside Surface (Mockup Flaws A8 and A9 Shown)

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Figure 4.4.89-5. Ultrasonic Data Display of OD Looking Up Scan of the BWRVIP-BWR/6-H3-A Mockup (Software Gates Positioned to Isolate Near-Side Flaws)

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Figure 4.4.89-6. Ultrasonic Data Display of OD Looking Up Scan of the BWRVIP-BWR/6-H3-A Mockup (Software Gates Positioned to Isolate Far-Side Flaws)

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Figure 4.4.90-1. Plate-Side Coverage Plots for 20° to 85° Longitudinal Beam Angles

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Figure 4.4.90-2. Plate-Side Coverage Plots for 30° to 70° Shear Beam Angles

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Figure 4.4.90-3. Plate-Side Coverage Plots for 30° to 50° Full-Vee Path Shear Beam Angles

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Figure 4.4.90-4. BWRVIP-A and BWRVIP-B from the H1 Looking Up, H2 Looking Down, and H5/(H6a) Looking Down Scan Surface (Near-Side Flaws Shown)

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Figure 4.4.90-5. BWRVIP-A and BWRVIP-B from the H3 Looking Up and H6/(H6b) Looking Up Scan Surface (Near-Side Flaws Shown)

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Figure 4.4.90-6. BWRVIP-C from the H4/(H5) and Vertical Weld Scan Surfaces When Flaws Are Located on the Opposite Surface from Which Scanning Was Performed

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Figure 4.4.90-7. BWRVIP-C from the H4/(H5) and Vertical Weld Scan Surfaces When Flaws Are Located on the Same Surface from Which Scanning Was Performed

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Figure 4.4.90-8. Longitudinal Wave Response from BWRVIP-C with Six Outside Surface-Connected Flaws Located on the Near Side of the Weld Join

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Figure 4.4.90-9. Shear Wave Full-Vee Path Response from BWRVIP-C with Six Outside Surface-Connected Flaws Located on the Near Side of the Weld Joint

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Figure 4.4.90-10. Remaining Ligament Reported for Ring-Side Flaws

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Figure 4.4.91-1. Scan Surfaces for BWRVIP-A (Left) and BWRVIP-B (Right) Mockups

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Figure 4.4.91-2. Longitudinal Wave Response Obtained on BWRVIP-A

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Figure 44.4.91-3. Shear Wave Response Obtained on BWRVIP-A

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Figure 4.4.91-4. Longitudinal Wave Response Obtained on BWRVIP-B

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Figure 4.4.91-5. Shear Wave Response Obtained on BWRVIP-B

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Figure 4.4.91-6. Longitudinal Wave Response Obtained on BWRVIP-A from Two Scan Lines

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Figure 4.4.91-7. Longitudinal Wave Response Obtained on BWRVIP-B from Two Scan Lines

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Figure 4.4.91-8. Remaining Ligament Reported for Inside Surface-Initiating Ring-Side Flaws

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Figure 4.4.92-1. Demonstrated Probe Location and Sector Scan (H1 Flaw Locations and Orientations Shown in Red)

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Figure 4.4.92-2. Ultrasonic Examination Data Display of Expected Geometric Reflectors (Unflawed Location)

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Figure 4.4.92-3. H1 Weld Ultrasonic Examination Data Display (Top View) Compared with Flaw “Truth” Information

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Figure 4.4.92-4. Ultrasonic Examination Data Display Showing Geometric Lug Indication and H1 Flaw Response

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Figure 4.4.92-5. Ultrasonic Examination Data Display Showing Sparger Bracket Locations and Flaws (Top View)

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Figure 4.4.93-1. Scan Line Positions and Sector Scan Arrays (BWRVIP Mockup Configuration Shown)

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Figure 4.4.93-2. Ultrasonic Response (Side View) Obtained from Outside Surface-Initiating Flaw (Flaw H3i Shown)

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Figure 4.4.93-3. Ultrasonic Response (Side View) Obtained from Inside Surface-Initiating Flaw (Flaw H2a Shown)

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Figure 4.4.93-4. Reported Length Measurements for Inside Surface Flaws That Are Larger Than the Weld Fillet

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Figure 4.4.94-1. Scan Line Positions and Sector Scan Arrays (BWRVIP Mockup Configuration Shown)

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Figure 4.4.94-2. Flaw Responses with Software Gates Positioned to Isolate Flaw H3d (Yellow Indication Box)

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Figure 4.4.94-3. Interrogation of the Outside Surface HAZ of the 3-Inch-Thick TGSR Mockup Configuration

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Figure 4.4.94-4. 40° Shear Wave Examination Data Showing H3t Flaw Response

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Figure 4.4.94-5. Reported Length and Depth Measurements for Inside Surface Flaws That Are Larger Than the Weld Fillet

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Figure 4.4.94-6. Proper Positioning of the Weld Configuration Overlay for Depth Sizing

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Figure 4.4.94-7. Ultrasonic Flaw Depth Sizing of Flaw H3n (Flaw Tip Responses Originate from Actual Tip Locations)

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Figure 4.4.94-8. Ultrasonic Flaw Depth Sizing of Flaw H3s (Flaw Tips Detected Only Using Sound Beams That Had First Reflected Off Inside Surface of TGS)

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Figure 4.4.94-9. Reported Remaining Ligament of Outside Surface Flaws with Through-Wall Extents That Are Smaller Than the Weld Fillet Dimension

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4.5 VT Technique Demonstrations for Core Shroud Welds

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4.5.1 VT General Findings

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4.5.1.1 Training

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4.5.2 VT Demonstration 1

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Table 4.5.2-1. Data and Analysis from Shroud VT Demonstration 1

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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

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4.6.1 ET General Findings

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Figure 4.6.1-1. Cross-Wound ET Probe

4.6.1.1 Detection of Skewed Reflectors

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4.6.1.2 Effect of Scanning on a Rough Surface

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

4.6.1.3 Scan Pattern

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4.6.2 ET Demonstration 1

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4.6.2.1 Crack Length Measurement

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4.6.2.2 Optimum Parameters for ET Imaging

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

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

4.6.3 ET Demonstration 2

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4.6.4 ET Demonstration 3

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4.6.4.1 Data Acquisition

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4.6.4.2 Data Evaluation

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4.6.5 ET Demonstration 4

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4.6.6 ET Demonstration 5

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Figure 4.6.6-1. Eddy Current Surface Probe

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

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

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Figure 4.6.6-4. Shroud Mockup Containing Rough Weld Surface

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

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4.7 Delivery System Demonstrations for Core Shroud Welds

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4.7.1 Delivery System Demonstration 1

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4.7.2 Delivery System Demonstration 2

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4.7.3 Delivery System Demonstration 3

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4.7.4 Delivery System Demonstration 4

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Table 4.7.4-1. Evaluation Factors for Carousel Scanner

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4.7.5 Delivery System Demonstration 5

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4.7.6 Delivery System Demonstration 6

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4.7.7 Delivery System Demonstration 7

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4.7.7.1 Flaw Length Measurement Within a Single Scan

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4.7.7.2 Flaw Length Measurement Using More Than One Scan

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4.7.8 Delivery System Demonstration 8

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Table 4.7.8-1. Evaluation Factors for TS[2]

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4.7.8.1 Horizontal Welds

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4.7.8.2 Vertical Welds

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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)

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

4.7.9 Delivery System Demonstration 9

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4.7.9.1 Global Position Uncertainty

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4.7.9.2 Flaw Length Measurement Uncertainty

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4.8 References

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

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

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

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

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

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

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

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

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

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Figure 4.3.1.12-5. Flaw Details for BWRVIP-BWR6-H3-A (Flaws 1 Through 4)

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Figure 4.3.1.12-6. Flaw Details for BWRVIP-BWR6-H3-A (Flaws 5 Through 11)

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Figure 4.3.1.12-7. Flaw Details for BWRVIP-BWR6-H3-A (Flaws 12 Through 16)

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Figure 4.3.1.12-8. Flaw Details for BWRVIP-BWR6-H3-B (Flaws 1 Through 5)

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Figure 4.3.1.12-9. Flaw Details for BWRVIP-BWR6-H3-B (Flaws 6 Through 11)

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Figure 4.3.1.12-10. Flaw Details for BWRVIP-BWR6-H3-B (Flaws 12 Through 16)

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Figure 4.3.1.15-8. BWRVIP-H3-BWR4-F Mockup Drawing (General Configuration)

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Figure 4.3.1.15-9. BWRVIP-H3-BWR4-F Mockup Drawing (Weld #1 Flaws)

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Figure 4.3.1.15-10. BWRVIP-H3-BWR4-F Mockup Drawing (Weld #2 Flaws)

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Figure 4.3.1.15-11. BWRVIP-H3-BWR4-P Mockup Drawing (General Configuration)

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Figure 4.3.1.15-12. BWRVIP-H3-BWR4-P Mockup Drawing (H3 Weld Flaws)

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Figure 4.3.1.15-13. BWRVIP-H3-BWR4-P Mockup Drawing (H2 Weld Flaws)

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Figure 4.3.1.15-14. BWRVIP-H3-BWR5-P Mockup Drawing (General Configuration)

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Figure 4.3.1.15-15. BWRVIP-H3-BWR5-P Mockup Drawing (Weld #1 Flaws)

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Figure 4.3.1.15-16. BWRVIP-H3-BWR5-P Mockup Drawing (Weld #2 Flaws)

5
SHROUD SUPPORT

5.1 Summary

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5.2 Inspection Considerations

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5.2.1 Chicago Bridge & Iron/CBI Nuclear Shroud Supports

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

5.2.2 Babcock & Wilcox Shroud Supports

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5.2.3 Combustion Engineering Shroud Supports

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5.2.3.1 Gusset Supports

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Figure 5.2.3.1-1. CE Shroud Support Configuration

5.2.3.2 Cone Skirt Support

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

5.2.3.3 Heavy Steel Baffle Plate

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Figure 5.2.3.3-1. Hatch Unit 2 Shroud Support Configuration

5.2.4 Inspection Access

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5.3 Applicable Mockups

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5.3.1 Shroud Support Mockup BWRVIP-D: Weld H7

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

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

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

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

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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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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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

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

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

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

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

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

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

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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

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

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Figure 5.3.4-1. Shroud Support Mockup BWRVIP-P

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

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5.3.5 Shroud Support Mockups BWRVIP-B2SS1 and BWRVIP-B2SS2

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Figure 5.3.5-1. Mockup BWRVIP-B2SS1

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Figure 5.3.5-2. Mockup BWRVIP-B2SS2

5.4 UT Technique Demonstrations for Core Shroud Support Welds

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Table 5.4-1. UT Demonstration Summary

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Table 5.4-1. UT Demonstration Summary (continued)

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Table 5.4-1. UT Demonstration Summary (continued)

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Table 5.4-1. UT Demonstration Summary (continued)

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Table 5.4-1. UT Demonstration Summary (continued)

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Table 5.4-1. UT Demonstration Summary (continued)

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5.4.1 General Findings for UT

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5.4.1.1 Effect of Alloy 82/182 Weld Material

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

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5.4.2 UT Demonstration 1

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5.4.3 UT Demonstration 2

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5.4.4 UT Demonstration 3

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5.4.5 UT Demonstration 4

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5.4.6 UT Demonstration 5

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

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Table 5.4.6-2. Results of UT Demonstration 5

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5.4.7 UT Demonstration 6

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5.4.8 UT Demonstration 7

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5.4.9 UT Demonstration 8

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5.4.10 UT Demonstration 9

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5.4.11 UT Demonstration 10

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5.4.12 UT Demonstration 11

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5.4.13 UT Demonstration 12

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5.4.14 UT Demonstration 13

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5.4.15 UT Demonstration 14

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5.4.16 UT Demonstration 15

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5.4.17 UT Demonstration 16

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5.4.18 UT Demonstration 17

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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

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

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5.4.20 UT Demonstration 19

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5.4.21 UT Demonstration 20

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5.4.22 UT Demonstration 21

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5.4.23 UT Demonstration 22

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5.4.24 UT Demonstration 23

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5.4.25 UT Demonstration 24

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5.4.26 UT Demonstration 25

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5.4.27 UT Demonstration 26

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5.4.28 UT Demonstration 27

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

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Figure 5.4.28-2. Geometry for Inspection of Weld H8

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Figure 5.4.28-3. Coverage for Inspection of Weld H8

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

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5.4.30 UT Demonstration 29

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

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Figure 5.4.30-2. Geometry for Inspection of Weld H8

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Figure 5.4.30-3. Coverage for Inspection of Weld H8

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

5.4.31 UT Demonstration 30

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

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

5.4.32 UT Demonstration 31

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5.4.33 UT Demonstration 32

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5.4.34 UT Demonstration 33

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5.4.35 UT Demonstration 34

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5.4.36 UT Demonstration 35

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Figure 5.4.36-1. Geometry for Inspection of Weld H8

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Figure 5.4.36-2. Coverage for Inspection of Weld H8

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

5.4.37 UT Demonstration 36

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5.4.38 UT Demonstration 37

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5.4.39 UT Demonstration 38

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

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5.4.41 UT Demonstration 40

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5.4.42 UT Demonstration 41

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5.4.43 UT Demonstration 42

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5.4.44 UT Demonstration 43

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5.4.45 UT Demonstration 44

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5.4.46 UT Demonstration 45

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5.4.47 UT Demonstration 46

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Figure 5.4.47-1. Scan Line Positions

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

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

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

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5.4.48 UT Demonstration 47

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

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Figure 5.4.48-2. Coverage for Inspection of Weld H8

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

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

5.4.49 UT Demonstration 48

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

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

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5.4.50 UT Demonstration 49

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Table 5.4.50-1. Demonstrated Search Unit Angles and Beam Orientations

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Figure 5.4.50-1. Reported Flaw Depth for Circumferential Flaws Oriented Perpendicular to the Scan Surface (Measurements Made Along the Ultrasound Axis)

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Figure 5.4.50-2. Reported Flaw Depth for Circumferential Flaws Oriented Parallel to the Scan Surface (Measurements Made Along the Ultrasound Axis)

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Figure 5.4.50-3. Reported Flaw Depth for Circumferential Flaws Oriented Parallel to the Scan Surface (Measurements Made Along the Scan Axis)

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Figure 5.4.50-4. Reported Flaw Depth for Axial Flaws (Measurements Made Along the Ultrasound Axis)

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Figure 5.4.50-5. Reported Flaw Depth for Axial Flaws (Measurements Made Along the Scan Axis)

Table 5.4.50-2. Reported Length Sizing Errors

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Table 5.4.50-3. Reported Depth Sizing Errors

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5.4.51 UT Demonstration 50

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Figure 5.4.51-1. BWRVIP-P NDE Mockup (Scan and Index Orientations)

5.4.52 UT Demonstration 51

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Figure 5.4.52-1. H7 Scan Configuration

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5.4.53 UT Demonstration 52

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Table 5.4.53-1. Demonstrated Focal Law Parameters and Resolutions

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Figure 5.4.53-1. Axial Beam Direction Scan for H8 Weld

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Figure 5.4.53-2. Circumferential Beam Direction Scan for H8 Weld

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Table 5.4.53-2. Demonstrated Parameters for Volumetric Merge

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5.4.54 UT Demonstration 53

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Table 5.4.54-1. Demonstrated Focal Law Parameters and Resolutions

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Figure 5.4.54-1. Axial Beam Direction Scan for H9 Weld (Side View)

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Figure 5.4.54-2. Circumferential Beam Direction Scan for H9 Weld (Top View)

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Table 5.4.54-2. Demonstrated Parameters for Volumetric Merge

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Figure 5.4.56-1. Axial Flaw Located in the H9 Weld and Attachment Pad. (Axial flaw detection in this area was possible.)

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Figure 5.4.56-2. Axial Flaw Located in H9 Weld and Shroud Support Plate. (Axial flaw detection in this area was unreliable.)

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Figure 5.4.56-3. Reported RPV Extent (Flaw Depth Reported Along the Ultrasound Depth Axis)

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Figure 5.4.56-4. Reported Shroud Support Plate Extent (Flaw Depth Based on Axial Distance Measurements)

5.4.57 UT Demonstration 56

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Figure 5.4.57-1. H12 Flaw Depth Measurements

5.4.58 UT Demonstration 57

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5.4.59 UT Demonstration 58

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Figure 5.4.59-1. Probe Positions for Axial Scan Lines

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Figure 5.4.59-2. Probe Positions for Circumferential Scan Lines

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Figure 5.4.59-3. Reported Circumferential Flaw Depth (Flaw Depth Reported Along the Ultrasound Axis Using Data Acquired During the Axial Scan Examination Shown in Figure 5.4.59-1)

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Figure 5.4.59-4. Reported Circumferential Flaw Depth (Flaw Depth Measured From the Electronic Sector Scan Sweep During the Axial Scans Shown in Figure 5.4.59-1)

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Figure 5.4.59-5. Reported Axial Flaw Horizontal Depth (Flaw Depth Reported Along the Ultrasound Axis Using Data Acquired During the Circumferential Scan Shown in Figure 5.4.59-2)

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Figure 5.4.59-6. Estimated Axial Flaw Vertical Depth (Flaw Depth Estimated Using the 0.5-inch Incremental Scan Line Positions in Scans Performed Between the Two Elevations Shown in Figure 5.4.59-2)

5.4.60 UT Demonstration 59

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Figure 5.4.60-1. H7 Weld Configuration with Weld Buildup Layer Present (3-D CAD Section View)

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Table 5.4.60-1. Tabulated Detection Results

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Table 5.4.60-2. Flaw Evaluation Factors for Flaws Located on the Near Side and/or Within the Weld Material

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Table 5.4.60-3. Flaw Evaluation Factors for Flaws Located on the Far Side of the H7 Weld

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5.4.61 UT Demonstration 60

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Figure 5.4.61-1. Looking Down Ultrasonic Examination Data from BWRVIP-D Mockup

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Figure 5.4.61-2. Looking Down Ultrasonic Examination Data from BWRVIP-D2 Mockup

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Figure 5.4.61-3. Inside Surface Flaw Depth Sizing Error If Correction Is Not Used

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Figure 5.4.61-4. Outside Surface Flaw Depth Sizing Error If Correction Is Not Used

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Table 5.4.62-1. H7 Focal Law Groups

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Figure 5.4.62-1. Shroud Support Cylinder Side Coverage Plots for 20° to 85° Longitudinal Beam Angles

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Figure 5.4.62-2. Shroud Support Cylinder Side Coverage Plots for 30° to 70° Shear Beam Angles

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Figure 5.4.62-3. Shroud Support Cylinder Side Coverage Plots for 30° to 50° Full Vee-Path Shear Beam Angles

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Figure 5.4.62-4. Looking Down Ultrasonic Examination Data from BWRVIP-D Mockup

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Figure 5.4.62-5. Looking Down Ultrasonic Examination Data from BWRVIP-D2 (Weld 1)

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Figure 5.4.62-6. Mismatch Measurement Using High-Angle Longitudinal Waves

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5.4.63 UT Demonstration 62

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Table 5.4.63-1. H7 Focal Law Groups

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Figure 5.4.63-1. Shroud Support Cylinder Side Coverage Plots for 20° to 85° Longitudinal Beam Angles

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Figure 5.4.63-2. Shroud Support Cylinder Side Coverage Plots for 30° to 70° Shear Beam Angles

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Figure 5.4.63-3. Shroud Support Cylinder Side Coverage Plots for 30° to 50° Full Vee-Path Shear Beam Angles

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Figure 5.4.63-4. Looking Down Ultrasonic Examination Data from BWRVIP-D Mockup

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Figure 5.4.63-5. Looking Down Ultrasonic Examination Data from BWRVIP-D2 (Weld 1)

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Figure 5.4.63-6. Mismatch Measurement Using High-Angle Longitudinal Waves

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5.5 ET Technique Demonstrations for Core Shroud Support Welds

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5.5.1 General Findings for ET

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5.5.2 ET Demonstration 1

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5.6 Delivery System Demonstrations for Core Shroud Support Welds

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5.6.1 Delivery System Demonstration 1

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5.6.2 Delivery System Demonstration 2

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5.6.3 Delivery System Demonstration 3

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5.6.4 Delivery System Demonstration 4

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5.6.5 Delivery System Demonstration 5

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Figure 5.6.5-1. Example of H9 Weld Location Scan

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Figure 5.6.5-2. Example of Looking Down Examination Data from UT Demonstration 58 (Manually Encoded)

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Figure 5.6.5-3. Example of Looking Down Examination Data Collected During AMPSS Tooling Demonstration

6
CORE SPRAY PIPING AND SPARGER

6.1 Summary

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6.2 Inspection Considerations

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

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

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

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Figure 6.2-4. Typical Core Spray Sparger

6.2.1 Downcomer Sleeve

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6.2.2 Tee Box Assembly

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6.2.3 Shroud Connection Region

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6.3 Applicable Mockups

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6.3.1 Core Spray Mockups

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6.3.1.1 Downcomer Sleeve Joint Mockup (BWRVIP-J)

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

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

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

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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)

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

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

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

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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)

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

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

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

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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)

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

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

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

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

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

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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-P4-1r, BWRVIP-P4-2r, and BWRVIP-P4-3)

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

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

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

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Figure 6.3.1.6-4. Flaw Details of BWRVIP-P4-3

6.4 UT Technique Demonstrations for Core Spray Welds

6.4.1 General Findings for UT

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6.4.1.1 Detection and Sizing of Flaws Parallel to the Weld

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6.4.1.2 Detection of Flaws Transverse to the Weld

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6.4.1.3 Effect of Roughness of Scanning Surface

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6.4.2 UT Demonstration Summary

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Table 6.4.2-1. UT Demonstration Summary

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Table 6.4.2-1. UT Demonstration Summary (continued)

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Table 6.4.2-1. UT Demonstration Summary (continued)

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6.4.3 UT Demonstration 1

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6.4.4 UT Demonstration 2

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6.4.5 UT Demonstration 3

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6.4.6 UT Demonstration 4

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6.4.7 UT Demonstration 5

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6.4.8 UT Demonstration 6

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6.4.9 UT Demonstration 7

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6.4.10 UT Demonstration 8

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6.4.11 UT Demonstration 9

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6.4.12 UT Demonstration 10

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6.4.13 UT Demonstration 11

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6.4.14 UT Demonstration 12

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6.4.15 UT Demonstration 13

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6.4.16 UT Demonstration 14

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6.4.17 UT Demonstration 15

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6.4.18 UT Demonstration 16

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6.4.19 UT Demonstration 17

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6.4.20 UT Demonstration 18

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6.4.21 UT Demonstration 19

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6.4.22 UT Demonstration 20

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6.4.23 UT Demonstration 21

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6.4.24 UT Demonstration 22

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6.4.25 UT Demonstration 23

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6.4.26 UT Demonstration 24

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6.4.27 UT Demonstration 25

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6.4.28 UT Demonstration 26

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6.4.29 UT Demonstration 27

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6.4.30 UT Demonstration 28

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6.4.31 UT Demonstration 29

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6.4.32 UT Demonstration 30

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

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

6.4.33 UT Demonstration 31

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6.4.34 UT Demonstration 32

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6.4.35 UT Demonstration 33

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

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6.4.37 UT Demonstration 35

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6.4.38 UT Demonstration 36

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6.4.40 UT Demonstration 38

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6.4.41 UT Demonstration 39

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6.4.42 UT Demonstration 40

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6.4.43 UT Demonstration 41

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6.4.44 UT Demonstration 42

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Figure 6.4.44-1. Array Probe Positioning on T-Box

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6.4.45 UT Demonstration 43

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Figure 6.4.45-1. Array Probe Positioning for Scanning from the Cover Plate Side

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Figure 6.4.46-1. 45° and 50° Examination Angles

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Figure 6.4.46-2. 0° Skew Examination

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Figure 6.4.46-3. Supplemental ±10° Skew Examination

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Figure 6.4.46-4. Primary 360° Scan (Blue) and Supplemental Scan (Green)

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Figure 6.4.47-1. 1/2-Vee Technique for ID Flaws (Pipe Side)

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Figure 6.4.47-2. Full-Vee Technique for OD Flaws (Pipe Side)

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Figure 6.4.47-3. Probe Position for Elbow-Side Scanning (P4d Weld Shown)

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6.4.48 UT Demonstration 46

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Figure 6.4.48-1. 45° and 50° Examination Angles from Riser Pipe Side (P5 Shown)

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Figure 6.4.48-2. 45° Examination Angles from Sliding Sleeve Side (P5 Shown)

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Figure 6.4.48-3. 45° Examination Angle from Outer Sleeve Side (P7 Shown)

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6.4.49 UT Demonstration 47

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Figure 6.4.49-1. Direction of Sound Beams

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6.4.50 UT Demonstration 48

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Figure 6.4.50-1. Direction of Sound Beams

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6.4.51 UT Demonstration 49

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Figure 6.4.51-1. BWR/2 P8 Weld Examination

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Figure 6.4.51-2. BWR/2 P9 Weld Examination

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6.4.52 UT Demonstration 50

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6.4.53 UT Demonstration 51

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Figure 6.4.53-1. Scan Surface for P1 Weld Examination

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Figure 6.4.54-1. Scan Surface for P2 Weld Examination

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6.4.55 UT Demonstration 53

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6.4.56 UT Demonstration 54

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6.4.57 UT Demonstration 55

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6.4.58 UT Demonstration 56

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6.4.59 UT Demonstration 57

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6.4.60 UT Demonstration 58

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6.4.61 UT Demonstration 59

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6.4.62 UT Demonstration 60

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6.4.63 UT Demonstration 61

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6.4.64 UT Demonstration 62

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6.4.65 UT Demonstration 63

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Figure 6.4.65-1. Example of the Original Demonstration Data (Zetec μTomoScan Instrument)

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Figure 6.4.65-2. Example of the Equivalency Demonstration Data (Zetec Z-Scan UT Instrument)

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6.4.66 UT Demonstration 64

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6.4.67 UT Demonstration 65

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Figure 6.4.67-1. C-Scan Display Showing the Four Different Engagement Responses in Mockup BWRVIP-J

6.4.68 UT Demonstration 66

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Figure 6.4.68-1. Comparing Flaw Detection of Clearly Detected Flaws Versus Flaws Located Near Transducer Standing Wave Response

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6A
INVESTIGATION OF CORE SPRAY INTERNAL PIPING OVERLAY INSPECTION

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6A.1 Materials

6A.1.1 Probes

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6A.1.2 Ultrasonic Instrument

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6A.1.3 Mockups

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

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

6A.2 Surface Condition

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6A.3 Examination Results

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6A.4 Conclusions

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6A.5 References

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7
TOP GUIDE

7.1 Summary

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7.2 Inspection Considerations

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Figure 7.2-1 Grid Beam Regions to Be Inspected for BWR/2-5 Designs

7.2.1 Aligner Pin Assemblies

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Figure 7.2.1-1. Typical Vertical Aligner Pin Assembly

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Figure 7.2.1-2. Aligner Pin Assembly Variations

7.2.2 Hold-Down Assemblies

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Figure 7.2.2-1. Hold-Down Assembly

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Figure 7.2.2-2. Hold-Down Assembly

7.2.3 Wedges

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Figure 7.2.3-1. Lateral Restraint Brackets and Wedges

7.2.4 BWR/6 Hold-Down Studs

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Figure 7.2.4-1. Hold-Down Assembly

7.2.5 Rim-to-Bottom Plate Weld

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

7.2.6 Grid Beams

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Figure 7.2.6-1. Typical 0.36-Inch Wide Top Guide Grid Structure

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Figure 7.2.6-2. Typical 0.55-Inch Wide Top Guide Grid Structure

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Figure 7.2.6-3. Typical BWR/6 Top Guide Grid Structure

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Figure 7.2.6-4. Photograph of BWR/2 Grid Beam Cracking Observed During Metallurgic Evaluation

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Figure 7.2.6-5. Mid-Span Flaw in Upper Grid Beam

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Figure 7.2.6-6. Intersecting Slot Flaw in Upper Grid Beam

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Figure 7.2.6-7. Mid-Span Flaw in Lower Grid Beam

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Figure 7.2.6-8. Flaw Located at Incore Instrumentation Notch Location of Lower Grid Beam

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Figure 7.2.6-9. Intersecting Slot Flaw in Lower Grid Beam

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Figure 7.2.6-10. Flaw Emanating from Poison Notch

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Figure 7.2.6-11. Configuration of Top Guide Grid, Fuel Channels, and Control Blades

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Figure 7.2.6-12. Phased Array Sector Scan Techniques for Top Guide Grid Beam Examinations

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7.3 Applicable Mockups

7.3.1 Top Guide Grid Mockup BWRVIP-I

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

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

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

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

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

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

7.3.2 Top Guide Grid Mockups BWRVIP-TG1-x Through BWRVIP-TG13-x Series

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Table 7.3.2-1. BWRVIP Top Guide Grid Beam Mockups

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Table 7.3.2-1. BWRVIP Top Guide Grid Beam Mockups (continued)

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7.4 UT Technique Demonstrations for Top Guide Components

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7.4.1 General Findings for UT

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7.4.1.1 Grid Beams

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7.4.2 UT Demonstration 1

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7.4.3 UT Demonstration 2

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Figure 7.4.3-1. Example of CAD-Generated Drawing Overlaid on Examination Data Display

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Figure 7.4.3-2. Example of Flaws That Initiate from Geometric Reflectors

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7.4.4 UT Demonstration 3

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Figure 7.4.4-1. Probe Arrangement and Inspection Angles

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Figure 7.4.4-2. Assembled BWR/2 Top Guide Mockup (with Welded Stiffener Bar Shown)

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Figure 7.4.4-3. Example of Examination Data

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Figure 7.3.2-1. BWRVIP-TG1-x and BWRVIP-TG2-x Flaw Details

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Figure 7.3.2-2. BWRVIP-TG3-x and BWRVIP-TG4-x Flaw Details

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Figure 7.3.2-3. BWRVIP-TG5-x and BWRVIP-TG6-x Flaw Details

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Figure 7.3.2-4. BWRVIP-TG7-x Flaw Details

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Figure 7.3.2-5. BWRVIP-TG8-x and BWRVIP-TG9-x Flaw Details

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Figure 7.3.2-6. BWRVIP-TG10-x and BWRVIP-TG11-x Flaw Details

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Figure 7.3.2-7. BWRVIP-TG12-x and BWRVIP-TG13-x Flaw Details

8
CORE PLATE

8.1 Summary

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8.2 Inspection Considerations

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8.2.1 Rim Hold-Down Bolt Locations

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8.3 Applicable Mockups

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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

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Table 8.4-1. UT Demonstration Summary

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8.4.1 UT Demonstration 1

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8.4.2 UT Demonstration 2

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8.4.3 UT Demonstration 3

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8.4.4 UT Demonstration 4

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8.4.5 UT Demonstration 5

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Figure 8.4.5-1 BWRVIP-B Mockup Configuration (with Bolt Installed)

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Figure 8.4.5-2 BWRVIP-H6OH Mockup Configuration (with Bolt Installed)

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9 LPCI COUPLING

9.1 Summary

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9.2 Inspection Considerations

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9.3 Applicable Mockups

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9.4 UT Technique Demonstrations for LPCI Coupling Welds

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10
JET PUMP ASSEMBLY

10.1 Summary

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10.2 Inspection Considerations

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10.3 Applicable Mockups

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10.3.1 Mockup BWRVIP-U

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10.3.2 Mockup BWRVIP-V

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10.3.3 Mockups BWRVIP-Z3 and BWRVIP-Z3R

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10.3.4 Mockup BWRVIP-Z4

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10.3.5 Jet Pump Beam Mockups

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Figure 10.3.5-1. EPRI Jet Pump Beam Mockup A

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

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Figure 10.3.5-3. EPRI Jet Pump Beam Mockup C

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

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

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

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

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

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

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

10.3.6 Riser Brace Mockups BWRVIP-RB-1 and BWRVIP-RB-2

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Figure 10.3.6-1. BWRVIP-RB-1 and BWRVIP-RB-2 Mockups (Photograph)

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Figure 10.3.6-2. Flaw Layout and Electrode Profiles

Table 10.3.6-1. Flaw Table for BWRVIP-RB-1 and BWRVIP-RB-2

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10.4 UT Technique Demonstrations

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Table 10.4-1. UT Demonstration Summary

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Table 10.4-1. UT Demonstration Summary (continued)

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10.4.1 General Findings for UT

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10.4.2 UT Demonstration 1

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10.4.4 UT Demonstration 3

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10.4.5 UT Demonstration 4

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10.4.6 UT Demonstration 5

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10.4.7 UT Demonstration 6

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10.4.8 UT Demonstration 7

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10.4.9 UT Demonstration 8

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10.4.10 UT Demonstration 9

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10.4.11 UT Demonstration 10

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10.4.12 UT Demonstration 11

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10.4.13 UT Demonstration 12

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10.4.14 UT Demonstration 13

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10.4.15 UT Demonstration 14

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Table 10.4.15-1. Examination Sequence

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

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Figure 10.4.16-2. Demonstration for Weld AD-1

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Figure 10.4.16-3. Demonstration for Weld AD-2

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Figure 10.4.16-4. Demonstration for Weld DF-3

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10.4.18 UT Demonstration 17

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10.4.19 UT Demonstration 18

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

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

10.4.20 UT Demonstration 19

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10.4.21 UT Demonstration 20

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10.4.22 UT Demonstration 21

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

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

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Figure 10.4.23-1. Azimuthal Focal Laws (Technique 2 Shown on AD-1 Weld Configuration)

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Figure 10.4.23-2. Linear Focal Laws (Shown on AD-1 Weld Configuration)

Table 10.4.23-1. Demonstrated Parameters for Technique 1

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Table 10.4.23-2. Demonstrated Parameters for Technique 2

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Figure 10.4.24-1. Area BB-2 and BB-3 Examination Technique

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Figure 10.4.24-2. Jet Pump Beam Taper-to-Radius Transition Mockups

10.4.25 UT Demonstration 24

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Figure 10.4.25-1. Lateral and Raster Scan Techniques (Including Focal Laws)

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Figure 10.4.25-2. Reported Versus Actual Length Measurements

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10.4.26 UT Demonstration 25

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Table 10.4.26-1. Scan Surface and Probe Orientation for RS-1 Weld Locations

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Table 10.4.26-2. Scan Surface and Probe Orientation for RS-2 Weld Locations

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Table 10.4.26-3. Scan Surface and Probe Orientation for RS-3 Weld Locations

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Figure 10.4.26-1. Actual Ultrasonic Beam Path for Flaw Depth Sizing (Outside Surface of Elbow Affects Refracted Angle, Inside Surface of Elbow Affects Reflected Angle)

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Figure 10.4.26-2. Assumed Geometry for Reporting Flaw Depth (Does Not Account for Elbow Curvature / Assumes Flat and Parallel Surfaces)

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10.4.28 UT Demonstration 27

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Figure 10.4.28-1. Refracted and Skew Angles

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Figure 10.4.28-2. Scan Pattern and Examination Angles

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Figure 10.4.28-3. Example of Flaw Detection (BWRVIP-RB-1 Mockup, Location of Flaws 1 Through 6)

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**Figure 10.4.28-4
Example of 3-D Segment Cursor Placement When Measuring Flaw Length**

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10.5 ET Technique Demonstrations

10.5.1 ET Demonstration 1

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10.5.2 ET Demonstration 2

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10.6 Delivery System Demonstrations

10.6.1 Delivery System Demonstration 1

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10.6.2 Delivery System Demonstration 2

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10.6.3 Delivery System Demonstration 3

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10.6.4 Delivery System Demonstration 4

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10.6.5 Delivery System Demonstration 5

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

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

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

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

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

11
STANDBY LIQUID CONTROL

11.1 Summary

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11.2 Inspection Considerations

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11.2.1 Nozzle-to-Vessel Weld

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11.2.2 Penetration-to-Vessel Weld

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11.2.3 Nozzle-to-Safe-End Weld

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11.2.4 Penetration-to-Safe-End Extension Weld

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11.3 Applicable Mockups

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11.3.1 Mockup BWRVIP-X1

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11.3.2 Mockup BWRVIP-X2

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11.3.3 Mockup BWRVIP-Y3

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11.3.4 Mockup BWRVIP-Y4

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11.3.5 Mockup BWRVIP-Y5

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11.4 UT Technique Demonstrations for SLC Components

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11.4.1 General Findings for UT

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11.4.2 UT Demonstration 1

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11.4.3 UT Demonstration 2

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

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

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

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

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

12
VESSEL ATTACHMENTS

12.1 Summary

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12.2 Inspection Considerations

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12.3 Applicable Mockups

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12.3.1 Steam Dryer Support Lug Attachment Weld

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12.3.1.1 BWRVIP-SDL1 (Steam Dryer Support Lug Mockup)

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Figure 12.3.1.1-1. BWRVIP-SDL-1 Mockup (Photograph)

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Figure 12.3.1.1-2. "Set-in" Lug Configuration (Cross-Sectional View)

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Figure 12.3.1.1-3. Flaws in Lugs A, B, and C

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Figure 12.3.1.1-4. Flaws in Lugs D, E, and F

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Figure 12.3.1.1-5. Typical Fabrication Flaws in Close Proximity to Flaw F1

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Figure 12.3.1.1-6. Repaired Lack-of-Fusion Flaw

12.4 UT Technique Demonstrations for Vessel Attachment Welds

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12.4.1 UT Demonstration Summary

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Table 12.4.1-1 UT Demonstration Summary

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12.4.2 UT Demonstration 1

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Figure 12.4.2-1. Probe Position and Scan Distance on the BWRVIP Mockup

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Figure 12.4.2-2. Focal Law Calculator Image Showing All Three Sets of Sector Scans

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Figure 12.4.2-3. Length Measurements for Flaws with Orientations Similar to the Orientations of A-1, B-1, B-2, D-1, and D-2

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Figure 12.4.2-4. Depth Measurements for Flaws with Orientations Similar to the Orientations of A-1, B-1, B-2, D-1, and D-2

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Figure 12.4.2-5. Length and Depth Measurements for Flaws with Orientations Similar to the Orientation of C-2

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Figure 12.4.2-6. Length and Depth Measurements for Flaws with Orientations Similar to the Orientation of A-2 (Note That Flaw Extents Are Measured from the Edge of the Lug and Not from the Flaw Initiating Point in the Weld)

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12.4.3 UT Demonstration 2

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Figure 12.4.3-1. Ultrasonic Display with the Probe Positioned at the Location of the Lug, in a Looking Up Beam Orientation (No Flaws Present)

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Figure 12.4.3-2. Ultrasonic Display with the Probe Positioned at the Location of the Lug, in a Looking Counterclockwise Beam Orientation (No Flaws Present)

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Figure 12.4.3-3. Reported Axial Length and Circumferential Length (Horizontal Flaws)

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Figure 12.4.3-4. Reported Flaw Depth (Measured Along the Ultrasound Axis, from the Clad To RPV Base Metal Interface)

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13
LOWER PLENUM

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13.1 Summary

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13.2 Inspection Considerations

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13.3 Applicable Mockups

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13.3.1 BWRVIP-CRDH1

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

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

13.3.2 BWRVIP-CRDH2

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Table 13.3.2-1. Specifications of Applicable Flaws for BWRVIP-CRDH2

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Figure 13.3.2-1. BWRVIP-CRDH2 Mockup (Photograph)

13.4 UT Technique Demonstrations for Lower Plenum Welds

13.4.1 UT Demonstration 1

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14
INSTRUMENT PENETRATIONS

14.1 Summary

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14.2 Configurations

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Figure 14.2-1. Example of Instrument Penetration (Partial Penetration J-Groove Weld Configuration)

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Figure 14.2-2. Example of Instrument Penetration (Full-Penetration Welded Low-Alloy Steel Nozzle Configuration)

14.3 Inspection Considerations

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14.3.1 Inspection Considerations for Partial Penetration J-Groove Welds

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Figure 14.3.1-1. BWR/6-Style Instrument Penetration That Contains the Low-Alloy Weld Pad

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14.3.2 Inspection Considerations for the Penetration Tube Material

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14.4 Applicable Mockups

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14.4.1 Mockup BWRVIP-IP-1

14.4.1.1 BWRVIP-IP-1 Configuration

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Figure 14.4.1.1-1. BWRVIP-IP-1 Instrumentation Penetration Mockup (OD Surface)

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Figure 14.4.1.1-2. BWRVIP-IP-1 Instrumentation Penetration Mockup (ID Surface)

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Figure 14.4.1.1-3. Penetration #1 Configuration (Nominal Dimensions)

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Figure 14.4.1.1-4. Penetration #2 Configuration (Nominal Dimensions)

14.4.1.2 Penetration Tube Flaws

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Table 14.4.1.2-1. 10 CFR 50.55a Requirements for PWR Reactor Vessel Head Specimens Versus BWRVIP Mockup Design Inputs

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Table 14.4.1.2-1. (continued) 10 CFR 50.55a Requirements for PWR Reactor Vessel Head Specimens Versus BWRVIP Mockup Design Inputs

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Figure 14.4.1.2-1. Penetration #1 Flaw Details (Nominal Design Intent)

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Figure 14.4.1.2-2. Penetration #2 Flaw Details (Nominal Design Intent)

Table 14.4.1.2-2. As-Built Flaw Details (Penetration Tube Flaws)

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14.4.1.3 J-Groove Weld Flaws

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Figure 14.4.1.3-1. As-Built Details of J-Groove Weld Flaw 1a

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Figure 14.4.1.3-2. As-Built Details of J-Groove Weld Flaw 1b

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Figure 14.4.1.3-3. As-Built Details of J-Groove Weld Flaw 1c

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Figure 14.4.1.3-4. As-Built Details of J-Groove Weld Flaw 2a

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Figure 14.4.1.3-5. As-Built Details of J-Groove Weld Flaw 2b

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Figure 14.4.1.3-6. As-Built Details of J-Groove Weld Flaw 2c

14.4.1.4 Simulated Erosion

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Figure 14.4.1.4-1. Simulated Erosion Path Ground into Penetration #1 Bore Hole (Photograph)

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Figure 14.4.1.4-2. Simulated Erosion Path Ground into Penetration #1 Bore Hole (CAD Roll-Out Drawing)

14.5 UT Technique Demonstrations for Instrument Penetrations

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14.5.1 UT Demonstration Summary

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Table 14.5.1-1. UT Demonstration Summary

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14.5.2 UT Demonstration 1

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Figure 14.5.2-1. Probe Orientation for Radial Scan (Probe Positioned for Detection of Circumferential Flaw 1c)

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Figure 14.5.2-2. Probe Orientation for Clockwise Circumferential Scan (Radial Flaw 1b)

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Figure 14.5.2-3. Probe Orientation for Counterclockwise Circumferential Scan (Radial Flaw 1b)

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Figure 14.5.2-4. Obtained Ultrasonic Response from Circumferential Flaw (Flaw 1c in BWRVIP-IP-1)

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Figure 14.5.2-5. Obtained Ultrasonic Response from Radial Flaw (Flaw 2c in BWRVIP-IP-1)

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15
ACCESS HOLE COVERS

15.1 Summary

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Figure 15.1-1. Access Hole Cover

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15.2 Inspection Considerations

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

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

15.2.1 Thin Access Hole Covers

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

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15.2.2 Intermediate Thickness Access Hole Covers

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

15.2.3 Thick Access Hole Covers

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

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

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

15.2.5 Non-Creviced Single Access Hole Cover Design

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Figure 15.2.5-1. BWR/6 Single Oval Design

15.3 Applicable Mockups

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15.3.1 Access Hole Cover Mockups

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15.3.1.1 BWRVIP-AHC1

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

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

15.3.1.2 BWRVIP-AHC2

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

15.3.1.3 BWRVIP-AHC3 and BWRVIP-AHC4

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

15.3.1.4 BWRVIP-AHC5

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

15.3.1.5 BWRVIP-AHC6

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

15.4 UT Technique Demonstrations for Access Hole Covers

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15.4.1 UT Demonstration Summary

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Table 15.4.1-1. UT Demonstration Summary

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15.4.2 UT Demonstration 1

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

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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

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15.4.3 UT Demonstration 2

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15.4.4 UT Demonstration 3

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Table 15.4.4-1. Demonstrated Scan and Index Variables

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15.4.5 UT Demonstration 4

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Figure 15.4.5-1. Demonstrated Immersion Technique (1-inch Water Path)

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Table 15.4.5-1. Demonstrated Scan and Index Variables

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15.4.6 UT Demonstration 5

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Table 15.4.6-1. Demonstrated Scan and Index Variables

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15.4.7 UT Demonstration 6

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Figure 15.4.7-1. Demonstrated Immersion Technique (1-inch Water Path)

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Table 15.4.7-1. Demonstrated Scan and Index Variables

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15.4.8 UT Demonstration 7

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Figure 15.4.8-1. BWRVIP-AHC-2 Looking Out Examination Data Prior to Performing Geometric Echo Removal

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Figure 15.4.8-2. BWRVIP-AHC-2 Looking Out Examination Data After Performing Geometric Echo Removal

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Figure 15.4.8-3. BWRVIP-AHC-2 Looking In Examination Data Prior to Performing Geometric Echo Removal

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Figure 15.4.8-4. BWRVIP-AHC-2 Looking Out Examination Data Without Performing Geometric Echo Removal

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Figure 15.4.8-5. BWRVIP-AHC-2 Looking Counterclockwise Examination Data Without Performing Geometric Echo Removal

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Figure 15.4.8-6. Correction Factor Used for BWRVIP Mockups When Measuring Flaw Through-Wall Extent from the SSP Side (Upper Surface Flaw Shown)

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15.4.9 UT Demonstration 8

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Figure 15.4.9-1. BWRVIP-AHC3 Looking Out Examination Data Prior to Performing Geometric Echo Removal

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Figure 15.4.9-2. BWRVIP-AHC3 Looking Out Examination Data After Performing Geometric Echo Removal

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Figure 15.4.9-3. BWRVIP-AHC3 Looking In Examination Data Prior to Performing Geometric Echo Removal

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Figure 15.4.9-4. BWRVIP-AHC3 Looking In Examination Data After Performing Geometric Echo Removal

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Figure 15.4.9-5. BWRVIP-AHC3 Looking Clockwise Examination Data (Lower Surface Flaw Shown)

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Figure 15.4.9-6. BWRVIP-AHC3 Looking Clockwise Examination Data (Upper Surface Flaws Shown)

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Figure 15.4.9-7. Correction Factor Used for BWRVIP Mockups When Measuring Flaw Through-Wall Extent from the AHC Side (Lower Surface Flaw Shown)

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15.4.10 UT Demonstration 9

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Figure 15.4.10-1. Top View of the "Intermediate" Access Hole Cover Configuration

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Figure 15.4.10-2. Cross-Sectional View of the "Intermediate" Access Hole Cover Configuration

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Figure 15.4.10-3. Looking Out Scan Line Positions and Sector Scan Parameters

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Figure 15.4.10-4. Looking Out Beam Intensity Simulation at the First and Second Scan Line Positions

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Figure 15.4.10-5. Looking In Scan Line Positions and Sector Scan Parameters

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Figure 15.4.10-6. Looking In Beam Intensity Simulation at the First and Second Scan Line Positions

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Table 15.4.10-1. "Most conservative" Values Selected from UT Demonstrations 7 and 8

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Table 15.4.10-2. RMS and Flaw Evaluation Factors Calculated by Combining and Normalizing the Values in UT Demonstrations 7 and 8 to Percent of AHC Thickness

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Figure 15.4.10-7. Correction Factor Used for "Thin" BWRVIP Mockups When Measuring Flaw Through-Wall Extent from the SSP Side (Upper Surface Flaw Shown)

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15.5 References

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Figure 15.3.1.1-3. Configuration Drawing of BWRVIP-AHC1

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

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

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

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

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

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Figure 15.3.1.2-2. Configuration Drawing for BWRVIP-AHC2

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

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

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

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Figure 15.3.1.3-2. Configuration Drawing of BWRVIP-AHC3

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

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Figure 15.3.1.3-4. Configuration Drawing of BWRVIP-AHC4

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

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

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

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

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

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

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Figure 15.3.1.5-2. Configuration Drawing of BWRVIP-AHC6

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

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

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