EPRI

BWR Vessel and Internals Project Instrument Penetration Repair Design Criteria (BWRVIP-57NP)

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REPORT SUMMARY

The Boiling Water Reactor Vessel and Internals Project (BWRVIP), formed in June, 1994, is an association of utilities focused exclusively on BWR vessel and internals issues. This BWRVIP report documents criteria which can be used to design a repair for Instrument Penetrations in a BWR.

BACKGROUND:

In the event that significant degradation is observed in a BWR Instrument Penetration, repair may be required. Utilities need criteria which can be used in the development of designs for those repairs.

OBJECTIVE:

To compile the appropriate repair design criteria into a document which can be used by utility personnel performing the design and which could be submitted to appropriate regulatory agencies for approval of the generic design process.

APPROACH:

The contractor assembled a draft document which discussed all elements which need to be considered in designing a repair. Items discussed include: design objectives; structural evaluation; system evaluation; materials, fabrication and installation consideration; and, required inspection and testing. The resulting draft was reviewed in depth by BWRVIP utility representatives as well as third party contractors. The final report incorporates comments received during those reviews.

RESULTS:

The document provides general design acceptance criteria for the repair of an Instrument Penetration. Repairs designed to meet these criteria will maintain the structural integrity of the component under normal operation as well as under postulated transient and design basis accident conditions.

EPRI PERSPECTIVE:

The criteria listed in the report define a standard set of considerations which are important in designing a repair. It is intended that these criteria will be submitted to the USNRC, and possibily non-US regulators, for their approval. Regulatory acceptance of these generic criteria will significantly reduce the utility effort required to obtain approval for plant-specific repairs.

TR-108721NP

Key Words
Boiling Water Reactor
Repair
Stress Corrosion Cracking
Vessel and Internals
Instrument Penetration

BWR Vessel and Internals Project

Instrument Penetration Repair Design Criteria (BWRVIP-57NP)

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GE Nuclear Energy

BWRVIP Repair Committee

Prepared for
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Executive Summary

The Boiling Water Reactor Vessel and Internals Project (BWRVIP) was formed in June 1994 as a utility-directed initiative to address BWR vessel and internals issues. This criteria document was developed by the Repair Technical Subcommittee of the BWRVIP.

This document provides the general design acceptance criteria for temporary and permanent repair of BWR vessel instrument penetrations. It is provided to assist BWR owners in designing repairs which maintain the structural integrity of the instrument penetrations during normal operation and under postulated transient and design basis accident conditions for the remaining plant life or other service life as specified by the plant owner.

Issuance of this document is not intended to imply that repair of the instrument penetrations is the only viable method for resolving cracking in this component. Due to variation in the material, fabrication, environment and as-found condition of the individual instrument penetrations, repair is only one of several options that are available. The action to be taken for individual plants will be determined by the plant licensee.

1. INTRODUCTION

1.1 Background

Recently, the BWRVIP prepared a safety assessment of BWR internals [1] as a follow-on to the activities completed on shroud cracking. As documented in this safety assessment, extensive degradation can be tolerated in the reactor vessel instrument penetrations. The BWRVIP have also prepared generic inspection and evaluation guidelines [2] to assure the continued safety function integrity of the reactor vessel instrument penetrations. There have been at least two reports of cracking in BWR reactor vessel instrument penetrations. To prepare for potential repairs, the BWRVIP have prepared this repair criteria for the reactor vessel instrument penetrations.

1.2 Purpose

The purpose of this document is to provide general design guidance and acceptance criteria for permanent and temporary repair of cracked or leaking BWR vessel instrument penetrations.

The issuance of this document is not intended to imply that a repair of reactor vessel instrument penetrations is the only viable disposition of such cracking/degradation.

1.3 Scope

This document is applicable to General Electric BWR/2 through BWR/6 plants which plan to implement repairs to reactor vessel water level instrument penetrations. The scope of this repair design criteria includes the reactor vessel instrument penetration nozzle, the nozzle safe end, the nozzle to vessel shell weld and where applicable the coupling which was manufactured as a part of the reactor vessel.

2. DEFINITIONS

Repair	Repair as used in the context of this document is a broad term that applies to actions taken to design, analyze, fabricate and install hardware that restores the structural and functional integrity of the reactor vessel instrument penetration. Weld repair is considered within this definition. Reducing an indication to an acceptable size is also within the definition of repair. Weld overlay, without removal of the defect, is another repair in the context of this criteria.

3. INSTRUMENT PENETRATION CONFIGURATIONS AND SAFETY FUNCTIONS

3.1 General Physical Description

This section describes the functions and various configurations of BWR vessel instrument penetrations. The guidelines of this report are generic in nature. Efforts have been taken to identify the various configurations, differences in materials, etc. between different plant types. However, it is the responsibility of the BWRVIP member utilities to verify their specific plant configurations for applicability with respect to the descriptions, materials, figures and tables included in this document.

Instrument penetrations (or nozzles) are located in the reactor vessel cylindrical shell at various elevations (Figure 1) and are welded to the reactor vessel. Reactor vessel instrumentation utilizes these penetrations to determine vessel water level based on differential pressure between variable leg taps from penetrations in the liquid region of the core shroud annulus and penetrations in the steam region which provide a constant reference.

3.1.1 Instrument Penetration Configurations

The configurations of instrument penetrations vary with BWR type and RPV vendor. Figures 2 through 7 provide typical configurations for the instrument penetrations (or nozzles). Table 1 provides the plant-specific cross-reference to these figures and information on the materials used in the instrument penetrations.

In most designs, the penetration is connected to the vessel wall with a partial penetration weld made on the inside of the vessel (Figures 2 through 5 and Figure 7). In those cases, an air gap exists between the penetration and vessel, behind the vessel shell-to-penetration weld. In a few cases, the instrument lines connect to vessel nozzles which are in turn connected to the vessel with full penetration welds (Figure 6).

The main differences between configurations are in the penetrations and extensions attached to the penetrations.

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Table 1 - Configuration and Material Summary for Instrumentation Penetrations

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3.1.2 Attached Piping

Typical BWR water level instrument drywell piping is of a one inch nominal size. Most early BWR vessel water level penetrations or nozzles provided a safe end outside diameter corresponding to nominal 2 inch pipe, and a 2-inch by 1-inch reducing socket weld fitting (not supplied with the vessel) was used to interface with the drywell piping. In later BWRs the vessel instrument penetrations were typically supplied with the safe end or the penetration itself machined as an integral 2-inch female socket, in which case a 2-inch by 1-inch reducing socket weld fitting (not supplied with the vessel) was used to interface with the drywell piping.

3.2 Safety Design Bases

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Table 2 - Typical Water Level Trip Functions

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3.3 Event Analyses

The purpose of this document is to provide general design criteria for repairs of instrument penetrations. Accordingly, various events and operational conditions must be considered to ensure that the repair does not inhibit the ability of the instrument penetrations to perform their basic safety functions. The following general load cases shall be considered in design of the proposed repair.

3.3.1 Normal Operation

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3.3.2 Anticipated Operational Occurrences (Upset Conditions)

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3.3.3 Design Basis Accidents (Emergency/Faulted Conditions)

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3.3.4 Loading Combinations

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4. SCOPE OF REPAIRS

The instrument penetration repairs primarily address cracking and or leaking in IGSCC susceptible stainless steel and nickel-chrome-iron alloy components. Susceptible instrument penetration welds and materials are discussed in Reference 2. This repair criteria applies to the instrument penetration (or low alloy nozzle forging), penetration (or nozzle forging) to vessel shell weld, the penetration (or nozzle) safe end and the socket weld fittings used to attach drywell piping.

5. DESIGN OBJECTIVES

5.1 Design Life

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5.2 Safety Design Bases

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5.3 Safety Analysis Events

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5.4 Structural Integrity

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5.5 Retained Flaw(s)

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7.2 Service Level Conditions

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7.3 Load Combinations

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7.3.1 Mark I Plants

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7.3.2 Mark II and III Plants

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7.4 Allowable Stresses

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7.5 Radiation Effects on Repair Design

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7.6 Analysis Codes

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7.7 Thermal Cycles

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7.8 Corrosion Allowance

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Table 3: Load Combinations for Mark I Plants

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Table 4: Load Combinations for Mark II and Mark III Plants

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Table 5: Load Term Definitions for Tables 3 and 4

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10.2 Pre and Post Installation Inspection

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10.3 System Pressure Test

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11. QUALITY ASSURANCE PROGRAM

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12. Documentation

The following documentation shall be prepared and maintained as permanent records:

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13. REFERENCES

[1] EPRI Report TR-105707, "BWR Vessel and Internals Project, Safety Assessment of BWR Reactor Internals," (BWRVIP-06), October 1995.

[2] EPRI Report TR-108695,"BWR Vessel and Internals Project, Instrument Penetrations Inspection and Flaw Evaluation Guidelines," (BWRVIP-49), March 1998.

[3] EPRI Document 84-MG-18, "Nuclear Grade Stainless Steel Procurement, Manufacturing and Fabrication Guidelines", Rev. 2, January 1986

[4] EPRI Document NP-7032, Material Specification for Alloy X-750 for Use in LWR Internal Components, Revision 1

[5] Code Case N-516, "Underwater Welding Section XI, Division", Approved August 9, 1993

[6] EPRI Report TR-106712, "BWR Vessel and Internals Project- Roll/Expansion Repair of Control Rod Drive and In-Core Instrument Penetrations in BWR Vessels," (BWRVIP-17), November, 1996

[7] Code Case N-504-1, "Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping, Section XI, Division 1

14. FIGURES

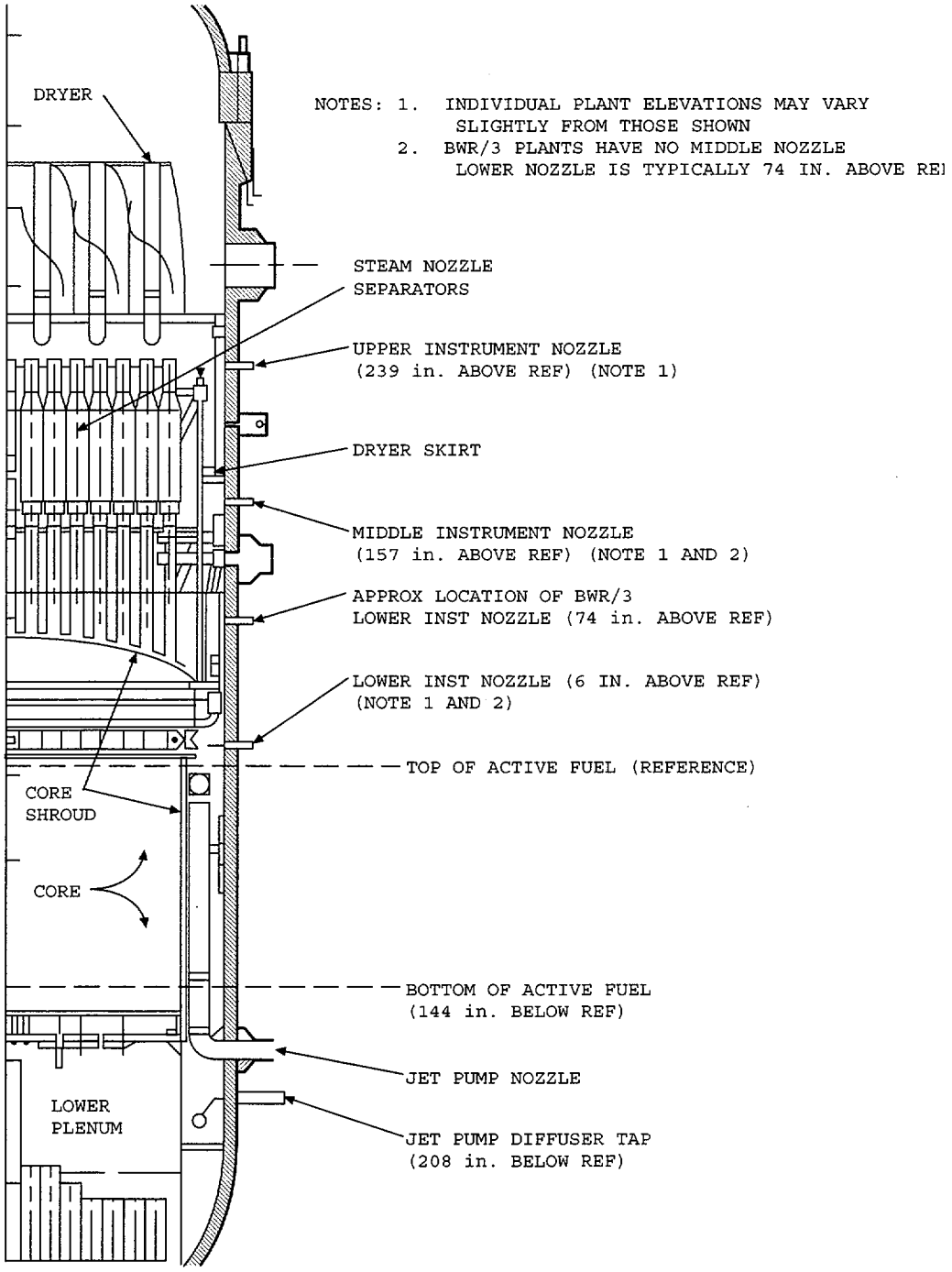

Figure 1: Location of Water Level Instrument Penetrations

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Figure 2: Alloy 600 Penetration With 304 Extension

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Figure 3: Carbon Steel Penetration

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Figure 4: Alloy 600 Penetration With Carbon Steel Extension

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Figure 5: 304 Stainless Penetration

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Figure 6: Low Alloy Nozzle With 304 Stainless Safe End

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Figure 7: 304 Stainless Penetration With 308/309 Penetration Weld

APPENDIX A: REPAIR CONCEPTS

A.1 Repair Experience

At least two previous repairs have been performed on BWR vessel instrumentation penetrations. In both these cases an initial or temporary repair was performed and then a permanent repair was implemented, or prepared for later implementation.

A.1.1 A Specific BWR/3 Repair

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A.1.2 A Specific BWR/4 Repair

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A.2 J-groove Penetration Attachment Repair Concept

There are no know failures or repairs of the vessel J-groove attachment welds for operating BWR instrument penetrations. However, as these welds generally use the IGSCC susceptible Alloy 182 weld material, this is a likely location for a crack which

may eventually result in a leak. The upper levels of instrument penetrations are located above the top of the shroud. Thus it is possible to partially drain the vessel, decontaminate and use temporary shielding in order to have direct access for all but the lowest level of instrument penetrations.

A.2.1 Roll Expansion

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A.2.2 Welded Repairs

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Figure 8: Temporary BWR/3 Repair

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Figure 9: Concept for Instrument Penetration Safe End Permanent Repair

Target:
Nuclear Power

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