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BWRVIP-181NP: BWR Vessel and Internals Project

Steam Dryer Repair Design Criteria

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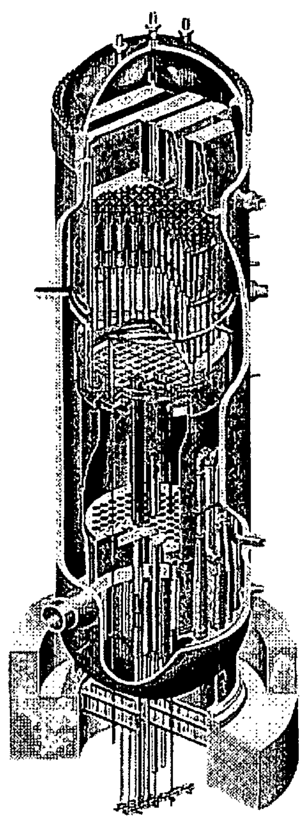

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Steam Dryer Repair Design Criteria

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Final Report, November 2007

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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 provides design guidance for the repair or replacement of steam dryers.

Background

Recent experience at several BWRs, particularly those operating at extended power uprate (EPU) conditions with high steam flow velocities, have shown significant degradation in the steam dryer caused by acoustic loads. In response to this issue, General Electric and the BWRVIP developed BWRVIP-139, *Steam Dryer Inspection and Flaw Evaluation Guidelines* (EPRI report 1011463). In addition to this inspection guidance, generic criteria are needed for the design of repairs to address observed or anticipated steam dryer degradation.

Objective

To provide general design guidance and acceptance criteria for permanent and temporary repair or replacement of steam dryers and/or steam dryer components.

Approach

The project team assembled the key attributes that need to be considered in designing modifications to or total replacement of a steam dryer. Items discussed include: design objectives; structural evaluation; system evaluation; materials, fabrication, and installation considerations; and, required inspection and testing.

Results

The document provides general design acceptance criteria for the repair and replacement of steam dryers. Repairs or replacements 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 that are important in planning steam dryer repair or replacement. They will assist BWR owners in designing repairs or replacements that maintain the structural integrity and system functionality of the steam dryer. Regulatory acceptance of these generic criteria will significantly reduce the utility effort required to obtain approval for plant-specific repairs or total steam dryer replacement.

Keywords
Boiling Water Reactor
Steam Dryer
Flow-Induced Vibration
Fatigue
Stress Corrosion Cracking
BWR Vessel and Internals

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 under the guidance of the Repair Focus Group of the BWRVIP.

This document provides the general design acceptance criteria for permanent or temporary repair or replacement of steam dryers. It is provided to assist BWR owners in designing repairs or replacements which maintain the structural integrity and system functionality of the steam dryer 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 a steam dryer is the only viable method for resolving cracking. Due to variations in the material, fabrication, environment and as-found condition of individual components, and depending upon which component is degraded, repair is only one of several options that are available. Replacement of the steam dryer is another option, and is discussed in detail in this document. The action to be taken for individual plants will be determined by the plant licensee.

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1 INTRODUCTION

1.1 Background

The Boiling Water Reactor and Internals Project (BWRVIP) has developed a series of Repair Design Criteria that provide guidance for repair of certain reactor internals components. This report documents criteria for the repair or replacement of steam dryers. Recent experience with the steam dryers at operating BWRs, particularly those operating at Extended Power Uprate (EPU) conditions with high steam line flow velocities, have shown significant degradation in the dryer caused by acoustic resonance induced loads. In response to this issue, GE and the BWRVIP developed an inspection and flaw evaluation guideline for the steam dryer, BWRVIP-139 [1]. As a result of the inspections performed, repairs and modifications have been required at some plants. In some cases, the observed damage has been sufficiently extensive that replacement dryers have been installed.

In conjunction with the inspection and flaw evaluation guidelines, a repair design criteria is outlined here for cases in which repair or replacement of the steam dryer or steam dryer components is warranted. Note that this repair design criteria supersedes any repair guidance provided in BWRVIP-139. However, BWRVIP-139 is still valid for routine inspection criteria.

1.2 Purpose

The purpose of this document is to provide general design guidance and acceptance criteria for permanent and temporary repair of existing steam dryers or steam dryer components and for the design of replacement steam dryers. The guidance is applicable to the repair of existing damage as well as to performing preemptive modifications to steam dryers in preparation for operation at higher power levels, e.g., EPU. It is expected that individual licensees and vendors will adhere to these criteria in the application of plant specific repair and replacement activities.

The issuance of this document is not intended to imply that repair or replacement of steam dryers or steam dryer components is the only viable approach to resolution of the cracking/degradation issue.

1.3 Scope

This document is applicable to General Electric BWR/2-6 plants. Table 1-1 shows the plant configurations that were specifically evaluated in preparing this Guideline. Configuration and material information included in the guideline is based on the best information available. Plants are advised to confirm the accuracy of this information when designing repairs or replacements.

Table 1-1
Plant Configurations Evaluated

Plant Type	Plant Name
BWR/2	Oyster Creek, Nine Mile Point 1
BWR/3	Millstone, Pilgrim, Monticello, Quad Cities 1, 2, Dresden 2, 3, Santa Maria de Garoña, KKM, 1 Fukushima 1
BWR/4	Vermont Yankee, Fermi 2, Hope Creek 1, Limerick 1, 2, Susquehanna 1, 2, Browns Ferry 1, 2, 3, Peach Bottom 2, 3, Brunswick 1, 2, Hatch 1,2, Cooper, 1 Fukushima 2, Fitzpatrick, Duane Arnold, Chinshan 1, 2
BWR/5	LaSalle 1,2, Laguna Verde 1,2, Nine Mile Point 2, Columbia
BWR/6	Perry 1, Grand Gulf 1, River Bend, Clinton 1, Cofrentes, Kuo Sheng 1 & 2, KKL

1.4 Implementation Guidelines

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

2 DEFINITIONS

2.1 Replacement

Replacement as used in the context of this document constitutes removal of a steam dryer assembly and installation of a completely new steam dryer assembly.

2.2 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 or addresses the structural and functional integrity of the steam dryer assembly. In performing repairs, flaws are sometimes left in place. Weld buildup/repair, without removal of the defect, as well as removal of flaws by a qualified machining process, including hole drilling of crack tips, are also considered repairs in the context of this document. Repairs may also include removal of flaws by underwater grinding. The repairs can be temporary, i.e. designed for a specified amount of time, e.g. months of operation, or permanent, i.e., designed for the remaining plant operating term.

Repairs also include preemptive modifications in preparation for operation at higher power levels, e.g., EPU.

2.3 Steam Dryer Assembly

Steam Dryer Assembly is used in the context of this document to mean the entire steam dryer including the vane modules, attached support structure, and all internal components. The steam dryer support attachments which are welded to the RPV are covered under a separate repair design criteria.

2.4 Safety Analysis Report

Safety Analysis Report (SAR) is used throughout this design criteria to refer to the current licensing document for the plant (e.g., FSAR, UFSAR, etc.).

3
STEAM DRYER ASSEMBLY CONFIGURATION AND SAFETY FUNCTION

3.1 Generic Physical Description

A typical GE BWR steam dryer, with its flow paths, is shown in Figure 3-1. Wet steam flows upward from the steam separators into an inlet header, horizontally through the perforated plates (if applicable) and dryer vanes, vertically in an outlet header and into the RPV dome. Steam then exits the reactor pressure vessel (RPV) through steam outlet nozzles. Moisture (liquid) is separated from the steam by the vane surface and the hooks attached to the vanes (see Figure 3-2 and Figure 3-3). The captured moisture flows downward under the force of gravity to a collection trough that carries the liquid flow to drain pipes and vertical drain channels. The liquid flows by gravity through the vertical drain channels to the lower end of the skirt where the flow exits below normal water level.

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Figure 3-1
Typical BWR Steam Dryer Flow Path and Terminology [1]

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Figure 3-2
Horizontal Section (Section A-A of Figure 2-1) Through Typical BWR Steam Dryer Vane Modules (Dryer Units) (Note: Tie Rod Nuts Differ Between BWR 4/5 and BWR 6 as Shown) [1]. Lower Figure Shows Example of One Cam Nut Design

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Figure 3-3
Typical BWR 4/5/6 Steam Dryer Vane Module (Dryer Unit) Requirements [1]

Steam dryers use commercially available modules of dryer vanes that are enclosed in a designed housing to make up the steam dryer assembly. The modules or subassemblies of dryer vanes, called dryer units, are arranged in parallel rows called banks. Four to six banks are used depending on the vessel size. Dryer banks are attached to an upper support ring, which is supported by four to six steam dryer support brackets that are welded attachments to the RPV. The steam dryer assembly does not physically connect to the shroud head and steam separator assembly and it has no direct connection with the core support or shroud. A cylindrical skirt attaches to the upper support ring and projects downward forming a water seal around the array of steam separators. Normal operating water level is approximately mid-height on the steam dryer skirt. During refueling the steam dryer is supported from the floor of the equipment pool by the lower support ring that is located at the bottom edge of the skirt. Dryers are installed and removed from the RPV using the reactor building crane. A steam separator and dryer strongback, which attaches to four steam dryer lifting rod eyes, is used for lifting the dryer. Guide rods in the RPV are used to aid dryer installation and removal. BWR steam dryers typically have upper and lower guides that interface with the guide rods.

GE BWR steam dryer technology has evolved over many years and several product lines.

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Figure 3-4
Evolution of Steam Dryers and Dryer Hood Designs Types (Some Later BWR-4s Also had Curved Hoods) [1]

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Figure 3-5
213-BWR/2 Dryer Cross-Section [1]

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Figure 3-6
251-BWR/3 Dryer Isometric [1]

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Figure 3-7
251-BWR/3 Bank Details [1]

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Figure 3-8
158-BWR/4 Steam Dryer With RPV (Dimensions in MM) [1]

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Figure 3-9
205-BWR/3/4 Steam Dryer Assembly [1]

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Figure 3-10
188-BWR/3 Dryer in RPV [1]

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Figure 3-11
224-BWR/3 Dryer Cross-Section [1]

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**Figure 3-12
BWR/4 Slanted Hood Steam Dryer [1]**

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Figure 3-13
218-BWR/4 Dryer Installed in RPV [1]

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Figure 3-14
183-BWR/4 Dryer Installed In RPV [1]

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Figure 3-15
251-BWR/4 Dryer Installed In RPV [1]

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**Figure 3-16
BWR/4/5/6 Curved Hood Steam Dryer [1]**

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Figure 3-17
251 BWR/4/5 Dryer Installed in RPV [1]

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**Figure 3-18
218 BWR/4 Dryer Installed in RPV [1]**

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Figure 3-19
218-BWR/6 Dryer Installed In RPV [1]

3.1.1 Materials and Construction

BWR 2/3/4/5/6 steam dryers are welded assemblies constructed from Type 304 stainless steel. The Type 304 stainless steel used in BWR 2/3/4/5/6 steam dryers was generally purchased with a maximum carbon content specification of 0.08% (standard ASTM composition). Therefore, weld heat affected zone material is likely to be sensitized. Temporary attachments might have also been welded to the dryer during fabrication and could have resulted in unexpected weld sensitized material. Steam dryer parts such as support rings and drain channels were frequently

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3.1.2 Environment

Most of the steam dryer is located in the steam space but the lower half of the skirt is below normal water level. These environments are highly oxidizing. Condensation of moisture on these steam dryer surfaces represents the primary concern for IGSCC.

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The design basis steam line break accident environment includes higher than normal two-phase flow through the dryer flow path as well as bypass flow through the annulus between the dryer skirt and the inside of the RPV. Hold down features (including lifting rods and lugs in the RPV head) are used to restrain the dryer assembly during steam line break blow down conditions. At each refueling outage the steam dryer must be lifted out of the vessel and stored in the equipment pool. SIL 558 [2] discusses the potential for damage during installation and removal of the dryer assembly from the RPV. A lower support ring at the bottom of the skirt supports the dryer assembly from the floor of the equipment pool during refueling.

3.2 Safety Design Bases

The steam dryer does not perform a safety function and is not required to prevent or mitigate the consequences of accidents. The steam dryer contributes to the thermal efficiency, and thus power output of the plant by removing moisture (liquid) from the flow as it passes through the steam dryer assembly. Although the steam dryer is not a safety related component, it is designed to withstand design basis events. For a potentially degraded steam dryer, the structural integrity is considered to be adequate if the steam dryer in the cracked condition, does not continue to experience significant crack propagation and the safety consequences of any loose parts that may be generated have been previously analyzed to be acceptable. The ability to shut down the reactor (control rod insertion), provide adequate core cooling, and the ability to isolate the main steam lines must be assured even when a credible loose part is postulated.

Although not contained in the scope of this report, the RPV steam dryer support brackets are subjected to loading from the steam dryer assembly. The RPV steam dryer support brackets are connected to the RPV, which is part of the primary pressure boundary. Loading on the support brackets and vessel must be assured to be within acceptable levels such that ASME Code Section III stress limits in the RPV are met. Repair requirements for support brackets are covered by the Attachment Weld Repair Design Criteria, BWRVIP-52-A [3].

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3.3 Event Analyses

As previously stated, the purpose of this document is to provide general design criteria for repairs and replacement of degraded steam dryer assembly. Accordingly, various events and operational conditions must be considered to ensure that the repair does not inhibit the ability of the steam dryer assembly to maintain structural integrity and operational functions.

As described in detail later in this report, the level of evaluation required for a repair/replacement design will depend upon the circumstances of the repair or replacement. Steam dryer repairs and replacements are categorized in Section 4 depending on power level and whether a repair or replacement is being performed. Each Category requires a different level of evaluation.

For Category B repairs and Category C replacements (defined in Section 4), the following general load cases shall be considered.

3.3.1 Normal Operation

The repair design should consider loads existing during periods of reactor startup, shutdown, and power operation. This includes dead weight of the steam dryer assembly, differential pressure, and thermal-hydraulic loads (including flow induced vibration (FIV)).

3.3.2 Anticipated Operational Occurrence (Upset Conditions)

Loads due to anticipated operational occurrences which have the potential to increase steam dryer assembly loads above normal operation should be considered. Typical events include: maximum system pressure, recirculation flow control failure (maximum demand), loss of feedwater with feedwater restart without feedwater heating, and inadvertent activation of a safety relief valve. Also, the combination of normal loads plus operating basis earthquake (OBE) loads is an upset event. System testing conditions shall also be considered upset conditions. Turbine stop valve (TSV) loads are very important, as these loads led to deformation in a BWR/5, which resulted in subsequent re-sizing of hood plates.

3.3.3 Design Basis Accidents (Emergency/Faulted Conditions)

Loads associated with a design basis earthquake in conjunction with a steam line or recirculation line break shall be considered as required by the design basis for the plant. All components of these loads should be considered. For the steam dryer, the main steam line loads bound those for the recirculation line break.

3.3.4 Loading Combinations

For replacement steam dryers and dryers being repaired due to degradation caused by EPU operation or plants with plans to go to EPU, all loads, including seismic and LOCA events, shall be combined in accordance with specific plant SAR requirements.

4 SCOPE OF REPAIRS

4.1 Scope of Repairs

The design criteria in this document apply to the repair of all of the steam dryer assembly components. The criteria also apply to replacement steam dryers. The scope does not include the RPV steam dryer support brackets or RPV shell.

The steam dryer assembly repairs may address cracking due to IGSCC or fatigue loading by a number of options.

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Repair and replacements can be classified into separate categories requiring different levels of evaluation and implementation. The classification of steam dryer repairs and replacements are separated using the operating condition of the plant.

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For purposes of this Repair Design Criteria, repairs and replacements are categorized into three categories; Category A, B and C.

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5
DESIGN OBJECTIVES

5.1 Design Life

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5.2 Safety Design Bases

For Category B and C, the repair or replacement shall be designed such that the safety bases described in Section 3.2 of this document, the plant SAR and technical specifications are met. For Category A repairs the repair returns the dryer to or similar to the original design.

5.3 Safety Analysis Events

Safety analysis event scenarios described in individual plant SARs remain valid and unaltered by the criteria contained in this document.

5.4 Structural Integrity

All repairs must address the causal factors of the observed cracking and assure that no loose parts will occur. For Category B and C, the repair or replacement shall be designed to provide structural integrity for all specified loading conditions.

Thermal-hydraulic loads, including flow-induced loads (with acoustic loads, if applicable), acting on the steam dryer assembly for normal, upset, emergency and faulted conditions in addition to seismic loads shall be considered for Category B and C. The pressure differences used for these events shall be consistent with, or bound, the current plant licensing basis documents.

The level of evaluation required depends on the steam dryer repair or replacement category (A, B or C) and is explained in Sections 6 through 12.

5.5 Retained Flaws

For Category B repairs, where an existing steam dryer weld or component is being structurally reinforced but not physically replaced, the repair design and analysis shall consider the impact of postulated crack growth from any existing flaws, including the potential for creating loose parts.

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5.6 Loose Parts Considerations

For Category A and B, repair hardware shall be designed to minimize the potential for loose parts inside the vessel during installation of the repair and during reactor operation.

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5.7 Physical Interfaces With Other Reactor Internals

The repaired configuration shall interface properly with other reactor internal components to ensure that all components continue to function as intended. Clearance with all internal features shall be evaluated to assure that there is sufficient clearance for the planned installation of the repairs.

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5.8 Installation

A robust design and ALARA are most important in performing the dryer repair or replacement. Thus, minimizing in-vessel critical path time is also an important issue.

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5.9 Steam Dryer Performance and Leakage

The repair shall minimize leakage from the steam dryer flow path during normal and upset conditions.

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5.10 Design Verification

For each repair, all of the applicable requirements related to loose parts, vibration analysis, inspection, etc. shall be evaluated and satisfied to ensure that the as-installed hardware configuration is consistent with the design and analysis assumptions.

5.11 Multiple Repairs

In cases where multiple repairs are performed on a steam dryer, the potential adverse affect of interaction among the repairs must be evaluated.

6
GENERAL DESIGN CRITERIA

As stated in Section 3.2, the steam dryer does not perform a safety function and is not required to prevent or mitigate the consequences of accidents. The steam dryer contributes to the thermal efficiency, and thus power output of the plant by removing moisture (liquid) from the flow as it passes through the steam dryer assembly. Although the steam dryer is not a safety related component, any repair to the steam dryer must be designed to operate without the generation of loose parts, including withstanding design basis events.

Paragraph NG-1122 of Section III, Subsection NG of the ASME Code classifies the steam dryer as an internal structure. The steam dryer does not contribute to the support of the core support structure even under faulted conditions.

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Table 6-1 below provides a summary of the recommended ASME design and fabrication guidance for use in steam dryer repair/replacement activities.

Table 6-1
Summary of ASME Code Design Guidance*

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7 STRUCTURAL AND DESIGN EVALUATION

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Following is a discussion of the loads that may be applicable to the steam dryer. Some of these loads may not be significant for a particular plant. Non-significant loads may be eliminated from consideration if justified on a plant-specific basis.

7.1 Load Definitions–Applied Loads

The applied loads on the reactor internals consist of the following; deadweight, differential pressure, hydraulic loads, seismic inertia, LOCA phenomena, TSV closure, SRV opening, loads due to flow induced vibration and thermal and pressure anchor displacements. Based on recent steam dryer degradation at a few plants operating at EPU levels with high steam line velocities, flow induced vibration loads on the dryer caused by acoustic resonance in the steam lines and connections must also be addressed, if present. A general discussion of these loads with some specific applications to the steam dryer follows below.

7.1.1 Applicability of Hydrodynamic Loads

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7.1.2 Deadweight (DW)

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7.1.3 Hydraulic Loads (F)

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7.1.4 Differential Pressure (DP)

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7.1.5 Seismic Inertia

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7.1.6 Seismic Anchor Displacements

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7.1.7 Safety Relief Valve Opening (SRV)

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7.1.8 Flow Induced Vibration (FIV)

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7.1.9 Thermal and Pressure Anchor Displacement (D)

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7.1.10 Turbine Stop Valve (TSV)

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7.1.11 Main Steam Line Break (MSLB)

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7.2 Service Level Conditions

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7.2.1 Service Level A (Normal Operating Conditions)

Service Level A loads should include the combination of all sustained loads that are anticipated during normal plant/system operation. These include deadweight of all supported components, differential pressures, and thermal-hydraulic loads (including FIV).

7.2.2 Service Level B (Upset Conditions)

Service Level B loads include loads due to anticipated operational occurrences that have the potential to increase the loads acting on the reactor internals components above those experienced during normal operation. Typical events include normal operation loads plus system operating transients (SOT). The SOTs shown on the RPV thermal cycle diagram do not induce significant stress on the dryer. The combination of normal loads plus OBE loads is considered an upset event.

7.2.3 Service Level C (Emergency Conditions)

Service Level C loads include the combination of all sustained normal operation loads in conjunction with loads from the design basis pipe break (DBPB). The DBPB includes all postulated pipe breaks other than a LOCA, MSLB, or feedwater pipe break. These include postulated pipe breaks in Class 1 branch lines that result in the loss of reactor coolant at a rate less than or equal to the capability of the reactor coolant makeup system.

7.2.4 Service Level D (Faulted Conditions)

Service Level D loads include the combination of all sustained loads in conjunction with several combinations of design basis events. These combinations include the DBPB, MSLB/feedwater pipe break, or LOCA and the SSE (where applicable per the plant specific design basis). All components of these loads should be considered.

7.3 Load Combinations

The load combinations used in the evaluation should be consistent with the requirements of the plant SAR or related licensing basis documentation. Typically, Section 3.9 of the SAR contains the necessary information on loads including, for some plants, hydrodynamic loads (i.e., "new loads") and/or AP loads. However, dryer loads are not typically included in the SAR. In the event that adequate definition of load combinations is not contained in the plant licensing basis documentation, the following load combinations may be used. In any case, the loads utilized in the design must be verified for consistency with the SAR.

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7.3.1 Mark I Plants

For the purposes of providing a general guideline in the event that load combinations are not specified in the SAR, the set of load combinations shown in Table 7-1 may be used.

Table 7-1
Load Combinations for Mark I Plants

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7.3.2 Mark II and III Plants

For Mark II and III plants, the method for load combination was specified at the time that the loads caused by hydrodynamic events were defined and labeled "new loads". A set of load combinations, in lieu of plant specific documentation, is shown in Table 7-2.

Table 7-2
Load Combinations for Mark II & III Plants

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Table 7-3
Load Term Definitions for Tables 7-1 and 7-2

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7.4 Analysis Methodology

The methodology used in determining the appropriate stresses shall be selected by the owner and the adequacy of the methodology must be demonstrated depending on the category (A, B or C). The selection of the methodology is most important with regard to the dynamic loads. In some cases a static analysis can be used, with appropriate factors to account for dynamic effects. Other methods that could also be used are response spectrum or time history methods.

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7.5 Allowable Stresses

For Category B and C repairs and replacements, the allowable stresses under the above loading combinations should be consistent with the current plant SAR. Unless otherwise specified, the following allowables apply:

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7.6 Flow Induced Vibration

For Category B and C, the repair or replacement shall be designed to address the potential for vibration, and to keep vibration to a minimum.

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7.7 Impact on Existing Internal Components

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7.8 Radiation Effects on Repair Design

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7.9 Analysis Codes

All thermal-hydraulic, acoustic and structural computer codes utilized in the design analysis for all categories shall be appropriately validated.

New or improved calculation methods may be utilized by the designer. For these techniques, appropriate benchmark information to demonstrate that the method is conservative and bounding for the application, shall be provided.

7.10 Thermal Codes

The design and analysis of Category B and C repairs and replacements shall consider the operating conditions and events specified on the RPV and nozzle thermal cycle diagrams or equivalent source.

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7.11 Corrosion Allowance

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8 SYSTEM EVALUATION

8.1 Leakage

Leakage from a steam dryer is defined as steam flow that does not pass through the intended flow path. For example, steam passing through a crack in a cover plate without passing through the dryer vanes would be considered leakage. Leakage from the steam dryer assembly is not a safety related issue, but can be an important economic issue. Excessive leakage can potentially reduce the power output of the plant. Leakage is also an important factor in monitoring steam dryer performance.

An increase in leakage during operation, as measured by moisture carryover, can be an indication that degradation of the steam dryer assembly has occurred and that the potential for a loose part has increased. Section 10.3 provides the recommendation regarding moisture carryover monitoring, which is discussed in more detail in the BWRVIP-139 (Section 7 of Reference 1).

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8.2 Internal Steam Dryer Pressure Drop

The head loss through the steam dryer assembly is dependent on the flow rate. Hydraulic analysis shall be performed to reconcile any significant increase in the total pressure drop for rated system flow through the repaired steam dryer assembly with the system capability.

8.3 Impact to Flow Distribution

The design of the repair for the steam dryer assembly shall not adversely affect the normal flow of steam or restrict the flow of steam in any way that would affect the normal balance of flow through the RPV. The design of the steam dryer repair shall not adversely affect flow to the main steam line.

8.4 Emergency Operating Procedure (EOP) Calculations

Inputs to the EOP calculations, such as bulk steel residual heat capacity shall be addressed based on replacement hardware mass.

8.5 Power Uprate

For those units currently undergoing a power uprate program, the resulting increased loadings must be considered in the Category B repair design.

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9
MATERIALS, FABRICATION AND INSTALLATION

9.1 Materials, Fabrication and Welding

Materials, fabrication and welding shall be in accordance with the current version of BWRVIP-84 [4], as a minimum. While the dryer is not safety related, recent industry experience would indicate that the stringent requirements of BWRVIP-84 are appropriate. Steam dryer vanes are specifically addressed in Section 9.3.

For replacement dryers (Category C), the additional provisions to those presented in BWRVIP-84 are included in this section.

Where augmented requirements are needed, such as for underwater welding or surface conditioning when solution heat treatment is impractical, the requirements are identified in this report.

9.2 Materials, Fabrication and Installation Requirements

9.2.1 Crevices

A crevice is a narrow region between two reactor internal surfaces, into or through which there is limited flow of reactor coolant. The crevices of greatest concern are those that involve contact between any material and the weld heat affected zone of existing 300 series stainless steel internals components, and those that involve contact between any material and any Alloy 600 material or associated weld metal.

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9.2.2 Pre-Installation As Built Inspection

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9.2.3 Post-Installation As-Built Inspection

For all categories, the designer shall specify the as-built inspections required for the entire repair or replacement, commensurate with design basis considerations and Code requirements.

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9.2.4 Installation Cleanliness

For all categories, the design shall minimize the in-vessel debris generation.

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9.2.5 ALARA

For all categories, the design should utilize construction and installation techniques that minimize the radiation exposure to the workers using ALARA practices in all steps.

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9.2.6 Qualification of Critical Design Parameters and Process

For all categories, critical design parameters shall be identified and shall be qualified and documented to ensure that the parameters meet the design basis.

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9.2.7 Peak Stresses and Strains

For all repaired components, and for all replacements, control of peak stresses in discontinuity regions is vital.

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9.2.8 Surface Roughness

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9.2.9 Welding

Since Category A and B steam dryers are contaminated, welded repairs are generally performed underwater. To maintain high quality and to assure that the repairs meet the original strength requirements, the welding processes must meet ASME Section IX requirements. Code Case N-516-2 [5], as approved by the NRC and as incorporated into Section XI and referenced by BWRVIP-84, provides the guidance for underwater welding.

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9.2.10 Repairs to Material

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9.2.11 Cold Work

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9.2.12 Forming and Bending

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9.2.13 Augmented NDE Requirements

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9.3 Steam Dryer Vanes

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10
INSPECTION AND TESTING

10.1 Inspection Access

The Category A and B repairs will be typically inspected outside the RPV and thus are not likely to cause problems with inspection access of other RPV components. Regardless, the repair design shall be such that inspection of reactor internals, reactor vessel, ECCS components and repair hardware is not impaired.

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10.2 Pre and Post Installation Inspection

For Category A and B, the repair designer shall specify pre- and post-installation inspections of the repair (including future periodic inspections) commensurate with the nature of the design and the specified design life.

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10.3 Testing

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11
QUALITY ASSURANCE PROGRAM

The steam dryer is not a safety related component as defined in 10CFR50.2. As such, the provisions of 10CFR21 or Appendix B are not required. However, the design and fabrication of repairs should be conducted under an augmented QA program that meets the intent of the design and fabrication requirements of Appendix B and which is consistent with the current licensing basis for the plant.

12
DESIGN BASIS DOCUMENTATION

For Category A repairs, documentation of the disposition should as a minimum include review and approval of the disposition by qualified personnel in the areas of materials, fabrication, inspection and stress analysis. The requirements of Section 11 of this document must also be met.

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13 CONCEPTUAL DESIGNS

This section presents some general conceptual designs for repairs that have been applied in the past and that might be considered in the future. Application of other types of repairs are not limited by what is presented in this section as the repair design depends significantly on geometry, loading and available time to design and implement the repair. Note that some of the information presented here has been extracted (and, in some cases modified) from BWRVIP-139. The repair design requirements presented in this document supersede those contained in BWRVIP-139.

Table 13-1 presents information regarding many of the options identified in this section, and provides additional information regarding the status of inspections. In addition this table describes the current plans for many plants that are considering increase in power levels in the future.

13.1 Example Conceptual Designs/Options

Typically, the intent has been to repair such that as a minimum, the original safety margins are restored. Restoration of original safety margins is acceptable if the cause of cracking was not the result of a deficiency in the original design. For example, high stress concentration locations or loads that were not included in the original design represent a potential deficiency. Restoration of original safety margins might not be sufficient if there are anticipated changes in system operation such as operation at EPU levels. Some of the common repairs/dispositions that have been implemented include the following.

13.1.1 Stop Drilling

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Table 13-1
BWR Steam Dryer Information

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Table 13-1
BWR Steam Dryer Information (Continued)

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Table 13-1
BWR Steam Dryer Information (Continued)

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13.1.2 Weld Reinforcement/Enhancement

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13.1.3 Added Structural Reinforcement

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13.1.4 Removal of Cracked Components

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13.1.5 Leave As-Is

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13.1.6 Grinding and Rewelding

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13.1.7 Replacement

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13.2 Acoustic Load Mitigation

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13.3 BWR Steam Dryer Cracking and Repair Experience

The BWRVIP Steam Dryer Inspection and Evaluation Guidelines [1] provides detailed information regarding cracking in steam dryer assemblies based on general plant histories as well as a survey of BWRs conducted in 2003. In 2006, a survey was taken of BWR plants requesting information on cracking in steam dryers as well as a description of any repairs. Table 13-1 presents a summary of the survey responses. As can be seen in Table 13-1, and in BWRVIP-139, many of the options in Section 13.1 have been implemented. Also, many plants are considering increase in power levels in the future. It is possible that these plants might need to implement preemptive modification for the higher power and related loads.

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13.4 Example Repair Configurations

Figures 13-1 through 13-5 provide schematics of a few of the Category B modifications/repairs made to steam dryers. Repairs can be generalized into 2 categories, 1) those made to restore a degraded condition, and 2) those made to enhance the dryer design.

Figure 13-1 shows an example of a repair made to a dryer that experienced significant degradation on the outer hoods nearest the main steam line nozzles.

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Figure 13-2 shows a preemptive modification made for power uprate conditions. The application of the gusset changes the dynamic characteristics in order to withstand the power uprate loads. The gusset strengthens the vertical outer hood and also changes the dynamic response of the outer hood.

Figure 13-3 through 13-5 show examples of modifications made to resolve local high stress locations by enhancing the joint design, increasing weld size or including reinforcement. In these cases, special care was taken to assure that new/different high stress locations are not created.

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Figure 13-1
251-BWR/3 Outer Bank Modifications

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Figure 13-2
Brunswick 1 Outer Bank Hood Gusset

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Figure 13-3
BWR/4/5 Outer Hood Modification

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Figure 13-4
Reinforcement Strip of the Middle Bank

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**Figure 13-5
251 BWR/4/5 Steam Dryer Modification [1]**

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REFERENCES

1. *BWRVIP-139: BWR Vessel and Internals Project, Steam Dryer Inspection and Flaw Evaluation Guidelines, April 2005*, EPRI Technical Report 1011463.
2. *Steam Dryer Damage Prevention,* General Electric Service Information Letter 558, dated April 22, 1993.
3. *BWRVIP-52-A: BWR Vessel and Internals Project, Shroud Support and Vessel Bracket Repair Design Criteria*. September 2005. EPRI Technical Report 1012119.
4. *BWR Vessel and Internals Project, Guidelines for Selection and Use of Materials for Repairs to BWR Internal Components (BWRVIP-84).* EPRI Report 1000248. October 2000.
5. ASME Section XI Code Case N-516-2, 2001 Edition.

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