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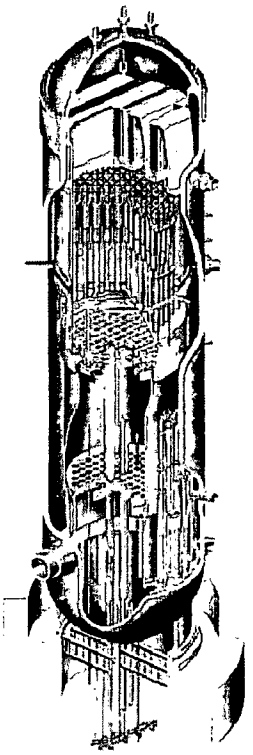
BWRVIP-181NP-A: BWR Vessel and Internals Project

Steam Dryer Repair Design Criteria



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BWRVIP-181NP-A: BWR Vessel and Internals Project

Steam Dryer Repair Design Criteria

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Final Report, Oct 2010

EPRI Project Manager
K. Wolfe

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ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

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NRC SAFETY EVALUATION

In accordance with an NRC request, the NRC Safety Evaluation immediately follows this page. Other NRC and BWRVIP correspondence on this subject are included in appendices.

Note: The changes proposed by the NRC in this Safety Evaluation as well those proposed by the BWRVIP in response to NRC Requests for Additional Information have been incorporated into the current version of the report (BWRVIP-181-A).

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION (SE) BY THE OFFICE OF NUCLEAR REACTOR REGULATION

BOILING WATER REACTOR (BWR) VESSEL AND INTERNALS PROJECT (BWRVIP)

TOPICAL REPORT (TR)-1013403 (BWRVIP-181): "BWR VESSEL AND INTERNALS PROJECT, STEAM DRYER REPAIR DESIGN CRITERIA" (TAC NO. MD8325)

BWRVIP

PROJECT NO. 704

1.0 INTRODUCTION

1.1 Background

Recent experience with steam dryers at operating BWRs, particularly those operating at extended power uprate (EPU) conditions associated with increased steam line flow velocities, has shown significant degradation in the dryer caused by acoustic resonance induced loads. Therefore, the BWRVIP embarked on an effort to develop TRs regarding steam dryers, such as inspection and flaw evaluation guidelines (BWRVIP-139) and repair design criteria, which is the focus of BWRVIP-181 "Steam Dryer Repair Design Criteria." As a result of inspections performed on steam dryers, repairs and modifications were required at some plants. In some cases, the observed damage was so extensive that replacement dryers were subsequently installed.

In order to address BWR vessel internal issues, the BWRVIP was formed in 1994 under a utility directed initiative. Under the guidance of the Repair Focus Group of the BWRVIP, this criteria document, BWRVIP-181 was developed. By letter dated December 19, 2007 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML0735511456), the BWRVIP submitted BWRVIP- 181 to the U.S. Nuclear Regulatory Commission (NRC) staff for review.

By letter dated September 10, 2008 (ADAMS Accession No. ML0823211543), the NRC staff sent a request for additional information (RAI) to the BWRVIP. By letter dated March 25, 2009 (ADAMS Accession No. ML0908901830), the BWRVIP submitted responses to the staff's RAIs.

1.2 Purpose and Applicability

The purpose of BWRVIP-181 is to provide general design guidance and acceptance criteria for temporary and permanent repairs of existing steam dryers or steam dryer components and/or replacement steam dryers. These criteria are intended to assist the BWR owners with guidelines and considerations in planning for the design of repairs/replacements of the steam

ENCLOSURE 1

dryers. The guidance provided in BWRVIP-181 is applicable to the repair of existing damage of steam dryers as well as to preemptive modifications to steam dryers in preparation for operation at higher power levels including EPU conditions. BWRVIP-181 is applicable to nuclear power plants that are designed as General Electric (GE) plant types BWR/2, BWR/3, BWR/4, BWR/5, and BWR/6. While the dryer inspection guidelines in BWRVIP-139 are still valid for routine inspections, the repair design criteria in BWRVIP-181 supersede any repair guidance in BWRVIP-139.

Repairs, replacement, and installation of mitigating devices such as Acoustic Side Branches (ASBs) and Acoustic Vibration Suppressors (AVSs) are some of the approaches discussed in BWRVIP-181 that address cracking and degradation issues associated with steam dryers. The design of repairs/replacements, as discussed in BWRVIP-181, will maintain the structural integrity of the component under normal operation as well as under postulated transient and design basis accident conditions.

2.0 SUMMARY OF THE TOPICAL REPORT

BWRVIP-181 addresses items such as: (1) steam dryer assembly configurations for various BWR plant types, (2) scope of repairs, (3) general design criteria and American Society of Mechanical Engineers (ASME) Code design guidance, (4) structural and design evaluation, and load combinations, (5) system evaluations, (6) materials, fabrication, and installation, (7) inspection and testing, (8) design basis documentation, and (9) general conceptual designs for repairs.

BWRVIP-181 provides general design guidance and acceptance criteria for temporary and permanent repairs of existing steam dryers or steam dryer components and/or replacement of the steam dryers. Steam dryers use commercially available modules of dryer vanes that are enclosed in a housing designed by GE, which 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 reactor pressure vessel (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. The normal operating water level is approximately at mid-height on the 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. 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 RPV through the steam outlet nozzles. Moisture is separated from the steam by vanes and the hooks that are attached to the vanes. The captured moisture flows downward by gravity to a collection trough that carries the flow of liquid 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.

GE BWR steam dryer technology has evolved over many years and several product lines. The addition of perforated plates in certain designs results in a more uniform velocity over the height of the vanes. BWRVIP-181 describes eleven BWR steam dryer designs. While the design of

various types of the steam dryers is similar, the main differences that impact the structural integrity of the steam dryer are the design of hoods (using square, slanted, or curved hood type), and the stiffening of the hoods (using gussets, inner braces, or tie rods).

BWR 2/3/4/5/6 steam dryers are welded assemblies constructed with stainless steel type 304 with 0.08-percent maximum carbon content. The material in the weld heat affected zone is likely to be sensitized. [

] 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. [

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The steam dryer does not perform a safety function and is not required to prevent or mitigate the consequences of accidents. However, 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. Table 6-1 of the BWRVIP-181 topical report provides recommended ASME design and fabrication guidance for use in steam dryer repair/replacement activities. The structural integrity is considered to be adequate if the degraded steam dryer in the cracked condition does not continue to experience significant crack propagation and if the safety consequences of any loose parts that may be generated have been previously analyzed and proven 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.

The BWRVIP-181 topical report provides design criteria for repairs/replacement of degraded steam dryer assemblies. Section 4 of the topical report categorizes repairs and replacements into three categories, namely Category A, B, and C which require different levels of evaluation and implementation.

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The repair design considers loads associated with normal operation, upset condition loads from anticipated operational occurrences, and emergency/faulted condition loads from design basis accidents.

The topical report addresses steam dryer assembly repairs caused by cracking from IGSCC and fatigue loading and discusses different options: such as (i) leaving the flaw in place, but structurally replacing the flawed area, or (ii) removal of the flaw by a qualified machining process with subsequent weld repair, if required.

The repairs should be such that they will not adversely impact the design performance of the steam dryer. When multiple repairs are performed on a steam dryer, evaluation for the interacting effect must also be performed.

3.0 STAFF EVALUATION

The staff has reviewed BWRVIP-181 regarding steam dryer repair design criteria from the design and structural adequacy perspective. The topical report provides general design guidance and acceptance criteria for temporary and permanent repairs of existing steam dryers or steam dryer components and/or replacement of the steam dryers. Based on a review of the topical report and the responses to the staff's RAIs provided by the BWRVIP, the staff finds that the steam dryer repair design criteria are useful in assisting the BWR owners with guidelines and considerations in planning for the design of repairs or replacements of steam dryers. The guidance provided in BWRVIP-181 is applicable to the repair of existing damage as well as to preemptive modifications to steam dryers in preparation for operation at higher power levels including EPU conditions. The topical report also provides some conceptual designs for repairs that were successfully utilized in the past and for use in current and future repairs. The staff finds the recommendations in the TR for steam dryer repairs reasonable because they are based on substantial past operating experience data. The staff finds that the topical report adequately addresses the appropriate analysis and design basis documentation requirements as applicable for the A, B, and C Categories for steam dryer repairs and replacements to ensure that the repairs will adequately meet the plant's current licensing basis. The staff also finds that the topical report adequately addressed the need for loose parts evaluation and adequately considered this as a key item with regards to steam dryer repairs.

Section 1 of the topical report provides an introduction to steam dryers and includes a table of BWR plant types and their corresponding plant names, and Section 2 contains definitions of the terms: replacement, repair, steam dryer assembly, and safety analysis report. The staff finds

the introduction acceptable because it includes a table that accurately associates the BWR plant type with the corresponding plant. The staff finds the definitions acceptable because the major terms such as repair, replacement, and steam dryer assembly are correctly defined.

The steam dryer assembly configuration and safety function are addressed in Section 3 of the topical report. The staff reviewed Section 3 of the topical report and requested additional information as discussed below.

In its response to the staff's request for clarification on steam flow velocities in Section 3.1.2 of the topical report, the BWRVIP proposed a revision to state that local regions in the dome near the nozzle entries might be continuously exposed to steam flow significantly in excess of 100 fps, and even higher velocities may be experienced under power uprate conditions. This is acceptable to the staff because the statement addresses the significance with respect to the steam velocity for local regions of the steam dryer and for EPU conditions.

In Section 3.2, the topical report states that the limiting design basis event for steam dryer structural integrity is the main steam line (MSL) break outside the containment. The staff requested the BWRVIP to address fluctuating pressure loads on the steam dryer induced by acoustic excitation in MSL safety relief valve stand pipes, as those could be severe based on the recent operating experience with steam dryer failures at EPU operation. The BWRVIP, in its response, proposed two changes to Section 3.2. These included the following: (1) clarification to a statement to read that the limiting event for steam dryer structural integrity is the MSL break outside containment from the allowable stress perspective, and (2) addition of a sentence to state that the acoustic loads have also been shown to be significant in certain cases, and the fluctuating pressure loads on the steam dryer induced by acoustic excitation in the main steam line safety relief valve inlet stand pipes have the potential to create an alternating stress that can exceed fatigue limits during normal operation. The staff agrees that these loads must be given consideration in the design of a repair. These changes to Section 3.2 of the topical report adequately address the staff's comment on the acoustic loads and therefore the staff finds the proposed changes acceptable.

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The staff reviewed Section 4 regarding the scope of repairs. The staff sought clarification on the replacement steam dryers that can be evaluated as Category A, if the decision to replace the steam dryers is for reasons other than an increase in loading. In its response, the BWRVIP proposed to add a sentence in Sections 4 and 7.4 of the topical report to reflect that the design shall include consideration of flow induced vibration (FIV) loads as in the case of a Category C dryer, if the dryer is expected to be subjected to increased loading due to EPU operation. Based on a review of the proposed clarification, as stated above, the staff considers this issue to be adequately addressed.

The design objectives, addressed in Section 5 of the topical report, were reviewed by the staff. The topical report initially did not address installation interference problems and damages during dryer replacements. The staff requested the BWRVIP address steam dryer repair design criteria to be used during installation to avoid interference problems and component damages during the installation of new steam dryers, as experienced during recent installations at some plants. In response, the BWRVIP agreed to revise the report by adding a paragraph to Section 5.8. The paragraph will state that industry experience has shown that total reliance on design drawings of original steam dryers and nearby reactor components for the design of a repair or replacement involves some risk. Modifications to the design dimensions may have been necessary to accommodate installation. In at least one instance, a newly-fabricated dryer was damaged during installation due to interference with existing reactor components. When possible, in-vessel measurements to verify that adequate installation clearances exist, for a given replacement dryer design, should be made during an outage of opportunity prior to fabrication of the replacement dryer. In the event that damage occurs during installation, its repair shall be treated as any other Category A, B or C repair (as appropriate to the dryer) and the applicable repair design criteria are to be applied in its entirety. The staff reviewed the proposed change to the topical report and finds it acceptable because it adequately addresses interference problems and repair design criteria that can be applied to the repair of any damages occurring during the installation of replacement dryers. Section 5 of the report also provides a discussion on loose parts consideration. The staff finds that the topical report adequately addresses the significance of loose parts as addressed in detail in the BWRVIP-06-A report.

Section 6 provides guidelines for compliance with the ASME Code, Section III, with respect to the design of repairs to, or the replacement of, steam dryers. This section provides, in sufficient detail, the general design criteria that are to be implemented for repair/replacement of Category A, B and C steam dryers. The staff specifically reviewed the non-destructive examination requirements specified in Section 6. The BWRVIP referenced the inspection requirements specified in ASME Code, Section III, Subsections NB/NC/ND. The staff noted that since the repair/replacement steam dryers are designed per ASME Code, Section III, Subsection NG, the inspection requirements specified in ASME Code, Section III, Subsection NG are relevant for the steam dryers. In this context, the staff requested that the BWRVIP confirm that the ASME Code, Section III, Subsection NG inspection requirements would be used in lieu of the ASME Code, Section III, Subsection NB/NC/ND inspection requirements. By letter dated March 25, 2009, the BWRVIP provided a response in which it stated that it would revise Table 6-1 to indicate that the inspection requirements specified in ASME Code, Section III, Subsection NG would be used for steam dryers. The staff accepted the BWRVIP's response because compliance with the inspection requirements specified in ASME Code Section III, Subsection NG is appropriate for the steam dryers and it would ensure adequate weld quality in steam dryer welds. With the aforementioned modification, the staff concluded that Table 6-1 provides an adequate summary of the selection of the materials, welding, inspections and design criteria.

Section 7 of the topical report provides a discussion on structural and design evaluation for Category A repairs, and Category B and C repairs and replacements along with the load combinations. The staff reviewed and requested additional information regarding the discussion on load combinations on Section 7. In response to the staff's comment regarding load combinations (Tables 7-1 and 7-2 in Section 7.3 of the topical report), pertaining to contribution of FIV loads from higher frequencies (above 33 Hz) due to turbulent flow excited acoustic resonances to steam dryer stresses, the BWRVIP agreed that higher frequency loads are often significant in dryer design. As a result, the BWRVIP developed a revised set of loads and load

combinations that appropriately consider high frequencies. The BWRVIP's response also included revised load combination tables, namely Table 7-1 that is applicable for Mark I plants, and Table 7-2 that is applicable for Mark II and Mark III plants. These revised tables show significant changes that appropriately represent the FIV loads included in the applicable load combinations associated with the normal, upset, emergency, and faulted service conditions. The staff finds the BWRVIP's response acceptable because the revised load combination tables properly include and consider FIV in the applicable load combinations for the various service conditions.

The staff reviewed Section 8 which briefly addresses leakage, pressure drop, flow distribution, and power uprate under system evaluation and the staff found this section acceptable because the significance of the potential for acoustic resonance loads in the main steam line and attachments was adequately highlighted based on past experience.

Section 9 addresses material selection, fabrication and installation requirements for the steam dryer components. The BWRVIP invokes the BWRVIP-84 report requirements, which were previously approved by the staff. This section provides details regarding the fabrication and installation requirements for steam dryers for which licensees are expected to comply. Since IGSCC is affected by the presence of crevices and cold work, this section adequately provides guidance with respect to controlling the crevices and surface conditions of the steam dryer components. In addition, welding requirements, including underwater welding (when required), and the ASME Code, Section IX weld qualification requirements are specified in this section. The staff's review found that this section provides sound guidelines for selection of materials and fabrication requirements for the steam dryers, and the licensee's compliance with these requirements is essential to ensure that adequate quality will be achieved for steam dryer components.

The staff sought clarification regarding Section 9.2.10, and requested examples of welds in the steam dryer that the have compressive residual stresses requiring no augmented examinations. In its response, the BWRVIP proposed to eliminate this caveat and revise the report to require augmented inspections, if solution annealing can not be performed. This is acceptable to the staff because the caveat on compressive stress will be eliminated.

Section 10 describes pre- and post–installation inspection requirements for repaired steam dryers (i.e., Categories A and B) which licensees must comply with to ensure that adequate quality will be achieved for the repair. This section, however, does not address the final inspection criteria for the repair/replacement welds. Therefore, the staff requested the BWRVIP confirm that the ASME Code, Section III, Subsection NG inspection requirements would be used. In a letter dated March 25, 2009, the BWRVIP provided a response in which it stated it would revise paragraph 10.2 to indicate that the scope and frequency of all inspections of Category A, B, and C steam dryers, which are repaired or fabricated to ASME Code, Section III, Subsection NG requirements shall be inspected in accordance with the Subsection NG criteria. The staff accepted the BWRVIP response because compliance with the inspection requirements, as specified in ASME Code Section III, Subsection NG for the steam dryers is consistent with the ASME Code requirements and, therefore, the staff finds that adequate weld quality will be achieved for the steam dryers.

The staff noted that Section 10 did not clearly identify the criteria regarding inspection frequency for Category A and B steam dryers. Therefore, the staff requested the BWRVIP confirm that the inspection frequency of Category A and B steam dryer welds shall be consistent with the intent of the BWRVIP-139, "BWR Vessel and Internals Project, Steam Dryer Inspection and Flaw Evaluation

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Guidelines." In its response dated March 25, 2009, the BWRVIP stated that for Category A and B steam dryers, the requirements regarding frequency of inspections, as specified in the BWRVIP-139 report shall be met. The staff found the BWRVIP's response acceptable because the inspection criterion in the BWRVIP-139 report were already approved by the staff and the criterion would ensure that adequate quality will be achieved for steam dryer welds.

Also, in Section 10, the BWRVIP stated that the pre and post-installation inspections for repaired Category C welds are specified by the designer. With respect to this issue, the staff requested the BWRVIP confirm whether: (1) the inspection criteria specified in ASME Code, Section III, Subsection NG apply for repaired Category C steam dryers and (2) the frequency of inspections for the repaired Category C steam dryers is consistent with the BWRVIP-139 report. In its response dated March 25, 2009, the BWRVIP stated Category C steam dryer repair welds would be inspected per the ASME Code, Section III, Subsection NG, after the repair was completed. However, the subsequent in-service examinations of the steam dryers would comply with the intent of the BWRVIP-139 report. The staff found the BWRVIP's response acceptable because the inspection criteria in the BWRVIP-139 report were already approved by the staff and the criteria would ensure adequate quality will be achieved for the steam dryer welds. Additionally, compliance with inspection criteria specified in the ASME Code, Section III, Subsection NG would ensure adequate quality will be achieved for Category C steam dryer welds.

In Section 11, the BWRVIP addressed the Quality Assurance (QA) program, which is acceptable to the staff because the design and fabrication of repairs are to be conducted under an augmented QA program meeting the intent of the design and fabrication requirements of 10 CFR Part 21 or 10 CFR Part 50, Appendix B, as the steam dryer is not a safety related component. Section 12 discusses adequately the design basis documentation requirements for Categories A, B, and C repairs. The staff found these design basis documentation requirements acceptable.

Section 13 presents general conceptual designs for steam dryer repairs. The topical report correctly notes that the restoration of the original safety margin may not be adequate, if operation at higher power levels, such as when EPU is anticipated. Common repairs mentioned in the topical report include stop drilling techniques to retard crack propagation, weld reinforcement, structural reinforcement, removal of cracked components if they are redundant and not serving any structural function, leaving benign flaws as-is, grinding out the fatigue crack, and re-welded to restore the design margin. Section 14 lists the applicable references cited in the body of the topical report.

The staff sought clarification regarding the applicability of the leave-as-is approach to IGSCC and/or certain fatigue cracks. In its response, the BWRVIP proposed to add a paragraph to Section 13.1.5 to explain leave-as-is flaws. The leave-as-is approach is most easily applied to flaws whose growth has been confirmed to have been arrested and/or are growing slowly due to IGSCC alone. Also, some relatively small flaws that are growing due to fatigue cracking may also be left in place, provided it can be demonstrated that the fatigue growth will not result in an unacceptable flaw size, before a subsequent inspection and re-characterization of the flaw can be performed. The proposed explanation by the BWRVIP, as described above, is acceptable to the staff because it adequately addresses the applicability of the leave-as-is approach to IGSCC as well as relatively small fatigue cracks with slow growth rates, not resulting in an unacceptable flaw size and not affecting the structural integrity of the dryer.

In response to the staff's request on acoustic load mitigation devices to eliminate load sources if they are significant, the BWRVIP proposed to include paragraphs briefly describing two devices,

namely, ASBs and AVSs in Section 13.2 of the topical report. The staff found the BWRVIP's proposed change acceptable because it adequately addresses the acoustic load mitigation devices.

Based on a review of the topical report and the responses to staff's request for additional information provided by the BWRVIP, the staff concludes that the steam dryer repair design criteria are useful in assisting the BWR owners with guidelines and considerations in planning for the design of repairs or replacements of the steam dryers. The staff finds the guidance provided in BWRVIP-181 to be applicable to the repair of existing damage as well as to preemptive modifications to steam dryers in preparation for operation at higher power levels, including EPUs. The staff finds the recommendations in the topical report for steam dryer repairs to be reasonable because they are based on substantial past operating experience data. The staff finds that the topical report adequately addresses the appropriate analysis and design basis documentation requirements for the Categories A, B, and C, steam dryer repairs/replacements to ensure that the repairs are safe in meeting the plant's current licensing basis. The staff also finds that the topical report adequately addresses the need for loose parts evaluation and considers this to be a key item for steam dryer repairs.

4.0 CONCLUSION

The staff has reviewed BWRVIP-181 that was transmitted to the NRC by the BWRVIP's letter dated December 19, 2007, and the additional information provided in the RAI responses, included in the BWRVIP's letter dated March 25, 2009, and finds that the topical report, as modified and clarified, is acceptable for providing guidance on the design criteria for steam dryer repairs/replacements, for the selection of the materials that are to be used for steam dryers, and for establishing fabrication, installation, and inspection requirements for steam dryers. Therefore, the staff has concluded that implementation of the guidelines in BWRVIP-181, as modified to incorporate the resolution of RAIs as discussed in this SE, shall be included in the "-A" version of this topical report and will provide an acceptable technical basis for the design criteria for use in the structural and design evaluation of steam dryer repairs and replacements, applied loads and load combinations, recommended ASME Code design guidance, fabrication and installation, and inspection of the steam dryers.

Principal Contributors: C. Basavaraju
G. Cheruvenki

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The following organizations, under contract to EPRI, prepared this report:

Electric Power Research Institute (EPRI)
3420 Hillview Avenue
Palo Alto, CA 94304

Principal Investigator
K. Wolfe

Structural Integrity Associates

Principal Investigators
M. Herrera
A. Giannuzzi.

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

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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. A previous version of this report was published as BWRVIP-181 (TR-1013403). This report (BWRVIP-181-A) incorporates changes proposed by the BWRVIP in response to U.S. Nuclear Regulatory Commission (NRC) Requests for Additional Information, recommendations in the NRC Safety Evaluation (SE) and other necessary revisions identified since the previous publication of the report. All changes except typographical errors are marked with margin bars. In accordance with a NRC request, the SE is included and the report number includes an "A" indicating the version of the report accepted by the NRC staff.

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

RECORD OF REVISIONS

Revision Number	Revisions
BWRVIP-181	Original Report (1013403)
BWRVIP-181-A	The report as originally published (1013403) was revised to incorporate changes proposed by the BWRVIP in responses to NRC Requests for Additional Information, recommendations in the NRC Safety Evaluation (SE), and other necessary revisions identified since the last issuance of the report. All changes, except corrections to typographical errors, are marked with margin bars. In accordance with a NRC request, the SE is included in the report and the report number includes an "A" indicating the version of the report accepted by the NRC staff. Non-essential format changes were made to comply with the current EPRI publication guidelines. Details of the revision can be found in Appendix C.

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 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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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. Average steam flow velocities through the dryer vanes at rated conditions are relatively modest: 2 to 4 feet per second (0.6-1.2 m/sec). However, local regions, near the steam outlet nozzles might be continuously exposed to steam flows significantly in excess of 100 feet per second (30 m/sec). Even higher velocities may be experienced during power uprate conditions. In addition, acoustic loading might be present at very high flow rates depending on plant specific parameters. Thus, there is concern for not only IGSCC, but also for fatigue due to flow-induced vibration. 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.

As described in Section 4, a detailed structural analysis is not required for Category A repairs. 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
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 [5], 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 [6], 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 13-1
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]

14
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. *BWRVIP-194: BWR Vessel and Internals Project, Methodologies for Demonstrating Steam Dryer Integrity for Power Uprate,"* EPRI Technical Report 1016578, October 2008.
5. *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.
6. ASME Section XI Code Case N-516-2, 2001 Edition.

A
NRC REQUEST FOR ADDITIONAL INFORMATION

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

September 10, 2008

Mr. Rick Libra
Exelon
Chairman, BWR Vessel and Internals Project
Electric Power Research Institute
3420 Hillview Avenue
Palo Alto, CA 94304-1395

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION (RAI) FOR ELECTRIC POWER RESEARCH INSTITUTE (EPRI) BOILING WATER REACTOR (BWR) VESSEL AND INTERNALS PROJECT (BWRVIP) TOPICAL REPORT (TR)-1013403, "BWRVIP-181: BWR VESSEL AND INTERNALS PROJECT, STEAM DRYER REPAIR DESIGN CRITERIA" (TAC NO. MD8325)

Dear Mr. Libra:

By letter dated December 19, 2007 (Agencywide Documents Access and Management System Accession No. ML073551145), the BWRVIP submitted to the U.S. Nuclear Regulatory Commission (NRC) staff for review TR-1013403, "BWRVIP-181: BWR Vessel and Internals Project, Steam Dryer Repair Design Criteria." Upon review of the provided information, the NRC staff determined that additional information is needed to complete the review. On September 8, 2008, Larry Steinert and I agreed that the NRC staff will receive your response to the RAI questions by December 15, 2008. If you have any questions regarding the enclosed RAI questions, please contact me at 301-415-8143.

Sincerely,

Vanice A. Perin

Vanice A. Perin, Project Manager
Special Projects Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 704

Enclosure: RAI questions

cc w/encl: See next page

BWRVIP

Project No. 704

cc:
Randy Stark, EPRI BWRVIP
Integration Manager
Raj Pathania, EPRI BWRVIP
Mitigation Manager
Ken Wolfe, EPRI BWRVIP
Repair Manager
Larry Steinert, EPRI BWRVIP
Electric Power Research Institute
3420 Hillview Ave.
Palo Alto, CA 94304
rstark@epri.com
rpathani@epri.com
kwolfe@contractor.epri.com
ldsteine@contractor.epri.com

Bob Geier, Technical Chairman
BWRVIP Assessment Committee
Exelon Corporation
Cornerstone II at Cantera
4300 Winfield Rd.
Warrenville, IL 60555
robert.geier@exeloncorp.com

Dennis Rickertsen, Technical Chairman
BWRVIP Mitigation Committee
Southern Nuclear Operating Co.
P. O. Box 1295 (M/S B234)
Birmingham, AL 35201-1295
ddricker@southernco.com

Paul J. Davison, Executive Chairman
BWRVIP Assessment Committee
PSEG Nuclear, LLC
Salem/Hope Creek Nuclear Station
11 Yubas Ave.
Burlington, NJ 08016
paul.davison@pseg.com

Denver Atwood, Chairman
BWRVIP Repair Focus Group
Southern Nuclear Operating Co.
Post Office Box 1295
40 Inverness Center Parkway
(M/S B031)
Birmingham, AL 35242-4809
dgatwood@southernco.com

Rich Ciemiewicz, Chairman
BWRVIP Inspection Focus Group
Exelon Corporation
200 Exelon Way, Suite 210 (M/S KSA 2-N)
Kennett Square, PA 19349
richard.ciemiewicz@exeloncorp.com

Charles J. Wirtz, Technical Chairman
BWRVIP Integration Committee
FirstEnergy Corp.
Perry Nuclear Power Plant
(M/S A250)
10 Center Road
Perry, OH 44081
cjwirtz@firstenergycorp.com

Oscar Limpias, Executive Chairman
BWRVIP Integration Committee
Entergy Nuclear Operations, Inc.
Echelon One
1340 Echelon Parkway.
Jackson, MS 39213-8202
olimpia@entergy.com

Joe Donahue
BWRVIP Vice Chairman
V. P., Nuclear Engineering & Services
Progress Energy, Inc.
410 S. Wilmington St. (M/S PEB6)
Raleigh, NC 27601-1849
joe.w.donahue@pgnmail.com

Richard Anderson
BWRVIP Executive Oversight Committee
Site Vice President
FPL Energy Duane Arnold
Duane Arnold Energy Center
3277 DAEC Road
Palo, IA 52324-9785
rich_anderson@fpl.com

Robert Carter, EPRI BWRVIP
Assessment Manager
Jeff Landrum, EPRI BWRVIP
Inspection Manager
EPRI NDE Center
P.O. Box 217097
1300 W. T. Harris Blvd.
Charlotte, NC 28221
bcarter@epri.com
jlandrum@epri.com

Dennis Madison, Executive Chairman
BWRVIP Mitigation Committee
Site Vice President
Southern Nuclear Operating Company
Edwin I. Hatch Nuclear Plant
US Hwy 1 N
Baxley, GA 31515-2010
drmadiso@southernco.com

REQUEST FOR ADDITIONAL INFORMATION (RAI)

BY THE OFFICE OF NUCLEAR REACTOR REGULATION

BOILING WATER REACTOR (BWR) VESSEL AND INTERNALS PROJECT (BWRVIP)

"BWRVIP-181: BWR VESSEL AND INTERNALS PROJECT,

STEAM DRYER REPAIR DESIGN CRITERIA"

TAC NO.MD8325

By letter dated December 19, 2007 (Agencywide Documents Access and Management System Accession No. ML073551145), the BWRVIP submitted the topical report (TR) Electric Power Research Institute (EPRI) Proprietary Report TR-1013403, November 2007, "BWRVIP-181: BWR Vessel and Internals Project, Steam Dryer Repair Design Criteria," for U.S. Nuclear Regulatory Commission (NRC) staff review and approval. The NRC staff has identified areas for which additional information is needed to complete the review. The RAIs are listed below and are divided into sections that are related to specific technical areas.

Section 1: Structural Issues

RAI-1: Section 1.1 Background, Section 13.1.7, Replacement: BWRVIP is requested to include a brief description of steam dryer cracking experienced at Quad Cities Units 1 and 2, and Dresden units 2 and 3 outlining the generic significance of the steam dryer failures, and replacements at Quad Cities, Dresden, and Susquehanna plants.

RAI-2:
(a) Figure 3-2, Section 3.1, Generic Physical Description, refers to Section A-A of Figure 2-1. There is no Figure 2-1. The BWRVIP is requested to correct this discrepancy.
(b) Section 9.2.6, Qualification of Critical Design Parameters and Processes: The BWRVIP is requested to clarify if EDM stands for Electrical Discharge Machining process.
(c) Section 9.2.10, Repairs to Material: BWRVIP states that augmented examinations are not required if it can be demonstrated that compressive residual stress exists for certain welds. Please provide examples for welds in the steam dryer that are always subjected to compressive stresses and do not require augmented examinations.

RAI-3: Section 3.1.2, Environment, states that local regions near the outlet nozzles might be continuously exposed to steam flows in excess of 100 feet per second (fps). However, maximum steam flow velocities can be much greater than 100 fps in some BWR plants during extended power uprate (EPU) operation. The NRC staff requests that the BWRVIP address this issue.

RAI-4: Section 3.2, Safety Design Basis, states that the limiting design basis event for steam dryer structural integrity is the main steam line (MSL) break outside the containment. However, the recent experience with steam dryer failures at EPU operation indicates that, fluctuating pressure loads on the steam dryer induced by acoustic excitation in MSL safety relief valve inlet

Enclosure

stand pipes could be very severe. The BWRVIP is requested to include a description to highlight this phenomenon.

RAI-5: Section 3.3, Event Analyses, general load cases to be considered for Category B repairs, and Category C replacements are addressed. No such information is provided for Category A repairs. The BWRVIP is requested to address or provide guidance on load cases to be considered for Category A repairs.

RAI-6: Section 4.1, Scope of Repairs: Category A repairs are described to be repairs to dryers that are operated at or near (<107 percent of) original rated power or those that have operated without damage for 2 cycles at higher power level. Clarify if the higher power level corresponds to EPU power level or not.

RAI-7: Section 5.1, Design Life: Provide clarification in this section about why there is no specific design life for Category A repairs.

RAI-8: Section 5.6, Loose Parts Considerations: The TR states that the acceptance of a repair that includes leaving a cracked component in place should not be comprised solely on the acceptance of a loose part. Provide guidance on what other considerations are important.

RAI-9: Section 6, General Design Criteria: BWRVIP-181 TR states that in certain circumstances, acoustic loads represent the most significant loads on the dryer and advises to use the best available industry information on acoustic loads when developing Category B or C designs. The TR should elaborate to consider all known bias errors and uncertainties in developing fluctuating pressure loads acting on the dryer, including instrument location and measurement uncertainties.

RAI-10: Section 7, Structural and Design Evaluation, Section 7.1.8, Flow Induced Vibration (FIV), Section 7.6, Flow Induced Vibration; Section 9.2.7, Peak Stresses and Strains: Under fatigue analysis including consideration of acoustic pressure loading, the BWRVIP TR should elaborate to state that a 100 percent margin shall be maintained for calculated alternating stress in steam dryer components for projected EPU conditions especially when the dryer pressure loading is estimated from MSL measurements due to many unknowns and uncertainties. In other words, the minimum alternating stress ratio, defined as the endurance limit for the material obtained from American Society of Mechanical Engineers (ASME) Section III fatigue curve divided by the maximum alternating stress in the dryer is maintained to be 2 or higher for EPU conditions. As stated in RAI-9 above, all known bias errors and uncertainties in developing fluctuating pressure loads acting on the dryer, including instrument location and measurement uncertainties are considered. In addition, the structural analysis of the dryer shall also consider mesh discretization error, frequency discretization error, and uncertainties associated with modeling simplifications.

RAI-11: Section 7.3, Load Combinations (Table 7-1, and Table 7-2): Note 8 on these tables states that the peak values of the FIV loads shall be included in this load combination (for normal and upset service conditions), if FIV contains significant energy at frequencies below 33 Hz. It is requested that the TR provide the basis for considering contribution from

frequencies below 33 Hz as the contribution of FIV loads from higher frequencies due to turbulent flow excited acoustic resonances to steam dryer stresses could be significant

RAI-12: Section 7.4, Analysis Methodology: The BWRVIP TR states that if the plant owner decides to replace the steam dryer for reasons other than an increase in loading on the dryer, the replacement dryer can be evaluated as Category A. It should be clarified that if EPU is planned, then consideration shall be given to FIV loads due to potential turbulent flow excited acoustic resonances under category C replacement

RAI-13: The BWRVIP-181, Steam Dryer Repair Design Criteria does not address repair and criteria to be used during fit up problems and damages done during the installation of new steam dryer as experienced by Quad Cities Unit 2 in 2006 and Susquehanna Unit 1 in 2008. The BWRVIP is requested to include a discussion on damages to lower ring and skirt plates of the new dryers during installation and measures to prevent future recurrences. Design criteria to repair such damages should also be addressed.

RAI-14: Section 13.2, Acoustic Load Mitigation: The TR states that an overall repair-replacement program might need to consider modification of the steam line to eliminate load sources if those are found to be significant. The BWRVIP is requested to briefly address load mitigation devices such as Acoustic Vibration Suppressors and Acoustic Side Branches.

RAI-15: Section 13, Conceptual Designs, Table 13-1, BWR Steam Dryer Information: The NRC staff requests the BWRVIP to enhance this table by adding MSL steam flow velocity, and MSL dimensions.

RAI-16: Section 13. 1.5 Leave As-Is: Provide clarification if this approach is applicable for IGSCC cracks and/or certain fatigue cracks as well.

Section 2: Components Issues

RAI-1: Table 6-1 of the BWRVIP-181 TR indicates that non-destructive examinations of Category A, B, and C repaired steam dryer components/welds shall be in accordance with the requirements specified in ASME Code, Section III, Subsections NG/NB/NC/ND. The applicable inspection requirements for the repaired steam dryer welds/components are specified in ASME Code, Section III, Subsection NG. Therefore, the NRC staff requests that the BWRVIP provide an explanation for referencing the inspection requirements of the ASME Code, Subsections NB/NC/ND for the repaired steam dryer welds/components. Paragraph 10.2 in Section 10.0 of the BWRVIP-181 TR states that the repair designer shall specify pre- and post-inspections of the repaired Category A and B steam dryer components/welds. The NRC staff requests that the BWRVIP confirm whether the inspection requirements specified in ASME Code, Section III, Subsection NG are applicable to the repaired Category A and B steam dryer welds/components and modify Paragraph 10.2 accordingly.

RAI-2: Section 10.0, Paragraph 10.2 states that the Category A and B repaired steam dryer welds/components will be inspected on a continuing periodic basis. The NRC staff requests that the BWRVIP confirm that the frequency of inspections for the Category A and B repaired

steam dryer welds/components are consistent with the intent of the BWRVIP-139 TR, "BWR Vessel Internal Project, Steam Dryer Inspection and Flaw Evaluation Guidelines," and modify Paragraph 10.2 accordingly.

RAI-3: Section 10.0, Paragraph 10.2 states that the repair designer shall specify pre- and post-inspections of the repaired Category C steam dryer components/welds. The NRC staff requests that the BWRVIP confirm whether: (1) the inspection requirements specified in ASME Code, Section III, Subsection NG are applicable to the repaired Category C steam dryer welds/components, and (2) the frequency of inspections for the Category C repaired steam dryer welds/components are consistent with the intent of the BWRVIP-139 TR. Paragraph 10.2 shall be modified according to the response to this RAI question for consistency.

B

BWRVIP RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

2009-117 BWR Vessel & Internals Project (BWRVIP)

March 25, 2009

Document Control Desk
U. S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852

Attention: Joseph Williams

Subject: Project No. 704 – BWRVIP Response to NRC Request for Additional Information on BWRVIP-181 Report

References:

1. Letter from V. Perin (NRC) to Rick Libra (BWRVIP Chairman), "Request for Additional Information for Electric Power Research Institute (EPRI) Boiling Water Reactor (BWR) Vessel and Internals Project (BWRVIP) Topical Report (TR) – 1013403, "BWRVIP-181: BWR Vessel and Internals Project, Steam Dryer Repair Design Criteria" (TAC NO. MD8325)," dated September 10, 2008.
2. Letter from Rick Libra (BWRVIP Chairman) to H. Cruz (NRC) "Project No. 704 – BWRVIP-181: BWR Vessel and Internals Project, Steam Dryer Repair Design Criteria," dated December 19, 2007.

Enclosed are five (5) copies of the BWRVIP response to the NRC Request for Additional Information (RAI) on the BWRVIP report entitled "BWRVIP-181: BWR Vessel and Internals Project, Steam Dryer Repair Design Criteria," that was transmitted to the BWRVIP by the Reference 1 letter identified above.

Please note that the enclosed response contains proprietary information. The response includes margin bars to indicate the proprietary information. This information is considered proprietary because it contains trade secrets. A letter requesting that the responses be withheld from public disclosure and an affidavit describing the basis for withholding this information are provided as Attachment 1.

Two (2) copies of a non-proprietary version of "BWRVIP Response to NRC Request for Additional Information on "BWRVIP-181: BWR Vessel and Internals Project, Steam Dryer Repair Design Criteria," are also enclosed. This non-proprietary version is identical to the enclosed proprietary response except that the proprietary information has been deleted and the words "Non-Proprietary" appear at the top of each page.

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BWRVIP 2009-117

If you have any questions on this subject, please contact Denver Atwood (Southern Nuclear, BWRVIP Repair Focus Group Chairman) by telephone at 205-992-7461.

Sincerely,

Rick Libra
Exelon Corporation
Chairman, BWR Vessel and Internals Project

c: BWRVIP Technical Chairmen
BWRVIP EPRI Task Managers

Non-Proprietary

BWRVIP Response to NRC Request for Additional Information on "BWRVIP-181: BWR Vessel and Internals Project, Steam Dryer Repair Design Criteria"

Each item from the NRC Request for Information (RAI) is repeated below verbatim followed by the BWRVIP response to that item.

Section 1: Structural Issues

RAI-1: Section 1.1 Background, Section 13.1.7, Replacement: BWRVIP is requested to include a brief description of steam dryer cracking experienced at Quad Cities Units 1 and 2, and Dresden units 2 and 3 outlining the generic significance of the steam dryer failures, and replacements at Quad Cities, Dresden, and Susquehanna plants.

BWRVIP Response to Section 1: Structural Issues RAI-1:

The BWRVIP notes that a comprehensive summary of the scope suggested by the staff is included in the Steam Dryer Inspection and Flaw Evaluation Guideline (BWRVIP-139) and proposes to include a reference to that discussion in Section 1.1 of the Repair Design Criteria. Inclusion of this type of background information is inconsistent with the format of all other BWRVIP Repair Design Criteria and is more typically found in BWRVIP Inspection and Flaw Evaluation Guidelines.

RAI-2: (a) Figure 3-2 of section 3.1, Generic Physical Description, refers to section A-A of Figure 2-1. There is no Figure 2-1. BWRVIP is requested to correct this discrepancy. (b) Section 9.2.6, Qualification of Critical Design Parameters and Processes: The BWRVIP is requested to clarify if EDM stands for Electrical Discharge Machining process. (c) Section 9.2.10, Repairs to Material: BWRVIP states that augmented examinations are not required if it can be demonstrated that compressive residual stress exists for certain welds. Please provide examples for welds in the steam dryer that are always subjected to compressive stresses and do not require augmented examinations.

BWRVIP Response to Section 1: Structural Issues RAI-2:

(a) The reference to Figure 2-1 in the title of Figure 3-2 will be deleted as suggested.
(b) The meaning of "EDM" will be clarified as suggested.
(c) Note that Section 9.2.10 applies to repair of defective *material* that is used to fabricate a repair (prior to installation), not to the steam dryer welds themselves. While no specific locations were envisioned for the application of this criterion, it could be applicable in certain instances where repair materials are used in such a way that they are always under a unidirectional heavy load. However, the BWRVIP proposes to eliminate the caveat and

Non-Proprietary

revise the report to require augmented inspections if solution annealing cannot be performed.

RAI-3: In section 3.1.2, Environment, states that local regions near the outlet nozzles might be continuously exposed to steam flows in excess of 100 feet per second (fps). However, maximum steam flow velocities can be much greater than 100 fps in some BWR plants during extended power uprate (EPU) operation. The staff requests that the BWRVIP address this issue.

BWRVIP Response to Section 1: Structural Issues RAI-3:

The BWRVIP agrees that 100 fps is not an upper limit velocity for all plants. However, quantification of these local velocities is not essential to the intent of Section 3.1.2 which is provided primarily as background information. In recognition of the potentially higher velocities, the BWRVIP proposes to revise the sentence to read "However, local regions in the dome near the nozzle entries might be continuously exposed to steam flows significantly in excess of 100 feet per second (fps). Even higher velocities may be experienced under power uprate conditions."

RAI-4: Section 3.2, Safety Design Basis, states that the limiting design basis event for steam dryer structural integrity is the main steam line (MSL) break outside the containment. However, the recent experience with steam dryer failures at EPU operation indicates that, fluctuating pressure loads on the steam dryer induced by acoustic excitation in MSL safety relief valve inlet stand pipes could be very severe. The BWRVIP is requested to include a description to highlight this phenomenon.

BWRVIP Response to Section 1: Structural Issues RAI-4:

The BWRVIP agrees that acoustic loads require special consideration. While main steam line loads may represent a limiting case from an allowable stress perspective, acoustic loads may be overall more significant due to the impact on fatigue crack initiation and propagation. In light of this, two changes to Section 3.2 are proposed. The first sentence of the third paragraph will be revised to read "From the perspective of allowable stress, the limiting event for steam dryer structural integrity is the main steam line break outside containment." In addition, the following sentences will be added at the end of Section 3.2: "Acoustic loads have also been shown to be significant in certain cases. The fluctuating pressure loads on the steam dryer induced by acoustic excitation in main steam line safety relief valve inlet stand pipes has the potential to create an alternating stress that can exceed fatigue limits during normal operation. These loads must be considered in design of a repair and are discussed further in Section 7.1.8." Note: Section 7.1.8 currently discusses acoustic loads from standpipes in the steam lines.

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RAI-5: Section 3.3, Event Analyses, general load cases to be considered for Category B repairs, and Category C replacements are addressed. No such information is provided for Category A repairs. The BWRVIP is requested to address or provide guidance on load cases to be considered for Category A repairs.

BWRVIP Response to Section 1: Structural Issues RAI-5:

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RAI-6: Section 4.1, Scope of Repairs: Category A repairs are described to be repairs to dryers that are operated at or near (<107% of) original rated power or those that have operated without damage for 2 cycles at higher power level. Clarify if the higher power level corresponds to EPU power level or not.

BWRVIP Response to Section 1: Structural Issues RAI-6:

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RAI-7: Section 5.1, Design Life: Provide clarification in this section about why there is no specific design life for Category A repairs.

BWRVIP Response to Section 1: Structural Issues RAI-7:

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RAI-8: Section 5.6, Loose Parts Considerations: The TR states that the acceptance of a repair that includes leaving a cracked component in place should not be comprised solely on the acceptance of a loose part. Provide guidance on what other considerations are important.

BWRVIP Response to Section 1: Structural Issues RAI-8:

There are two aspects to this request. The first involves the scope of the requirements that would need to be met to install a repair that leaves a cracked component in place. In this case, the scope is no different from any other repair: all requirements in the BWRVIP-181 report must be met.

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RAI-9: Section 6, General design Criteria: BWRVIP-181 TR states that in certain circumstances, acoustic loads represent the most significant loads on the dryer and advises to use the best available industry information on acoustic loads when developing Category B or C designs. The TR should elaborate to consider all known bias errors and uncertainties in developing fluctuating pressure loads acting on the dryer, including instrument location and measurement uncertainties.

BWRVIP Response to Section 1: Structural Issues RAI-9:

The BWRVIP agrees that inclusion of bias and uncertainty is important in establishing the magnitude of acoustic loads. However, a detailed discussion of errors associated with developing these loads is outside the scope of the Repair Design Criteria. It is proposed that the paragraph referenced by the NRC be revised as follows: "In certain instances, acoustic loads represent the most significant loads on the dryer. An approved methodology should be implemented to determine the magnitude of these loads for Category B and C repairs. The methodology should include consideration of all known bias and uncertainty

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errors in developing fluctuating pressure loads acting on the dryer. One methodology for establishing these acoustic loads is documented in the report *BWRVIP-194: BWR Vessel and Internals Project, Methodologies for Demonstrating Steam Dryer Integrity for Power Uprate.* Other methodologies are also acceptable.

RAI-10: Section 7, Structural and Design Evaluation, Section 7.1.8, Flow Induced Vibration (FIV), Section 7.6, Flow Induced Vibration; Section 9.2.7, Peak Stresses and Strains: Under fatigue analysis including consideration of acoustic pressure loading, the BWRVIP TR should elaborate to state that a 100 percent margin shall be maintained for calculated alternating stress in steam dryer components for projected EPU conditions especially when the dryer pressure loading is estimated from MSL measurements due to many unknowns and uncertainties. In other words, the minimum alternating stress ratio, defined as the endurance limit for the material obtained from American Society of Mechanical Engineers (ASME) Section III fatigue curve divided by the maximum alternating stress in the dryer is maintained to be 2 or higher for EPU conditions. As stated in RAI-9 above, all known bias errors and uncertainties in developing fluctuating pressure loads acting on the dryer, including instrument location and measurement uncertainties are considered. In addition, the structural analysis of the dryer shall also consider mesh discretization error, frequency discretization error, and uncertainties associated with modeling simplifications.

BWRVIP Response to Section 1: Structural Issues RAI-10:

The BWRVIP considers that documentation of steam dryer load definition methods, bias and uncertainties, and any additional margins are beyond the scope of this report. These issues are more appropriately addressed in documents that present and justify specific steam dryer load definition and stress evaluation methods e.g., "BWRVIP-194: BWR Vessel and Internals Project, Methodologies for Demonstrating Steam Dryer Integrity at Power Uprate".

RAI-11: Section 7.3, Load Combinations (Table 7-1, and Table 7-2): Note 8 on these tables states that the peak values of the FIV loads shall be included in this load combination (for normal and upset service conditions), if FIV contains significant energy at frequencies below 33 Hz. It is requested that the TR provide the basis for considering contribution from frequencies below 33 Hz. as the contribution of FIV loads from higher frequencies due to turbulent flow excited acoustic resonances to steam dryer stresses could be significant.

BWRVIP Response to Section 1: Structural Issues RAI-11:

The BWRVIP agrees that higher frequency loads are often significant in dryer design. In response to this concern, a revised set of loads and load combinations has been developed that appropriately considers high frequencies. These revised

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loads are consistent with the steam dryer evaluation methodology that has also been developed by the BWRVIP. The BWRVIP proposes to revise Section 7.3 as shown in Attachment 1 to this RAI Response.

RAI-12: Section 7.4, Analysis Methodology: The BWRVIP TR states that if the plant owner decides to replace the steam dryer for reasons other than an increase in loading on the dryer, the replacement dryer can be evaluated as Category A. It should be clarified that if EPU is planned, then consideration shall be given to FIV loads due to potential turbulent flow excited acoustic resonances under category C replacement.

BWRVIP Response to Section 1: Structural Issues RAI-12:

The BWRVIP agrees and proposes to add the following sentence to Section 7.4 and Section 4: "If it is anticipated that, at a future date, the dryer may be subjected to increased loading due to extended power uprate (EPU), the design shall include consideration of FIV loads as in the case of a Category C dryer."

RAI-13: The BWRVIP-181, Steam Dryer Repair Design Criteria does not address repair and criteria to be used during fit up problems and damages done during the installation of new steam dryer as experienced by Quad Cities-2 in 2006 and Susquehanna-1 in 2008. BWRVIP is requested to include a discussion on damages to lower ring and skirt plates of the new dryers during installation and measures to prevent future recurrences. Design criteria to repair such damages should also be addressed.

BWRVIP Response to Section 1: Structural Issues RAI-13:

The BWRVIP agrees that the RDC should address fit-up issues and proposes to add the following paragraph to Section 5.8 ("Installation"): "Industry experience has shown that total reliance on design drawings of original steam dryers and nearby reactor components for design of a repair or replacement involves some risk. Modification to the design dimensions may have been necessary to accommodate installation. In at least one instance, a newly-fabricated dryer was damaged during installation due to interference with existing reactor components. When possible, in-vessel measurements to verify that adequate installation clearances exist for a given replacement dryer design should be made during an outage of opportunity prior to fabrication of the replacement dryer. In the event that damage occurs during installation, its repair shall be treated as any other Category A, B or C repair (as appropriate to the dryer) and the Repair Design Criteria is applicable in its entirety."

RAI-14: Section 13.2, Acoustic Load Mitigation: The TR states that an overall repair-replacement program might need to consider modification of the steam line to eliminate load sources if those are found to be significant. BWRVIP is requested to briefly address

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load mitigation devices such as Acoustic Vibration Suppressors (AVS), and Acoustic Side Branches (ASB).

BWRVIP Response to Section 1: Structural Issues RAI-14:

The BWRVIP proposes to include the following paragraphs at the end of Section 13.2:

Methods for mitigating acoustic resonances in steam lines include installation of Acoustic Side Branches (ASBs) and/or Acoustic Vibration Suppressors (AVSs). Such resonances are often the result of a coupling of the standing waves in branch lines off the main steam line that accommodate pressure relief valves with vortex shedding pressure pulses produced by flow passing by the entrance to the stand pipe. By adding a side branch (ASB) of a certain length to the main branch line, the amplitude of the resonance can be reduced by shifting the standing wave frequency. A further reduction in amplitude is possible if the side branch is filled with a fine mesh that acts as a muffler and damps the resonance.

Another approach is to add a plug (ASV) to the main branch line effectively reducing its length to zero and thereby eliminating the potential for acoustic resonance.

RAI-15: Section 13, Conceptual Designs, Table 13-1, BWR Steam Dryer Information: The staff requests BWRVIP to enhance this table by adding MSL steam flow velocity, and MSL dimensions.

BWRVIP Response to Section 1: Structural Issues RAI-15:

While this information would be of interest, it is not readily available and is not required for steam dryer repair design. The BWRVIP proposes that no change be made to the table.

RAI-16: Section 13. 1.5 Leave As-Is: Provide clarification if this approach is applicable for IGSCC cracks and/or certain fatigue cracks as well.

BWRVIP Response to Section 1: Structural Issues RAI-16:

The BWRVIP proposes to add the following sentences to the end of Section 13.1.5: "The "leave-as-is" approach is most easily applied to flaws whose growth has been confirmed to have been arrested and/or are growing slowly due to IGSCC alone. However, relatively small flaws that are growing due to fatigue cracking may also be left in place provided it can be shown that the fatigue

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growth will not result in an unacceptable flaw size before a subsequent inspection and re-characterization of the flaw can be performed."

Section 2: Component Issues

RAI-1: Table 6-1 of the BWRVIP-181 TR indicates that non-destructive examinations of Category A, B and C repaired steam dryer components/welds shall be in accordance with the requirements specified in ASME Code, Section III, Subsections NG/NB/NC/ND. The applicable inspection requirements for the repaired steam dryer welds /components are specified in ASME Code, Section III, Subsection NG. Therefore, the staff requests that the BWRVIP provide an explanation for referencing the inspection requirements of the ASME Code, Subsections NB/NC/ND for the repaired steam dryer welds/components. Paragraph 10.2 in Section 10.0 of the BWRVIP-181 TR states that the repair designer shall specify pre- and post-inspections of the repaired Category A and B steam dryer components/welds. The NRC staff requests that the BWRVIP confirm whether the inspection requirements specified in ASME Code, Section III, Subsection NG are applicable to the repaired Category A and B steam dryer welds/components and modify Paragraph 10.2 accordingly.

BWRVIP Response to Section 2: Component Issues RAI-1:

The NRC is correct that inspections should be in accordance with Subsection NG and that the other Subsections are not applicable. The intent is to define inspections in accordance with Subsection NG for those dryers that are fabricated or modified using Subsection NG. Once the fabrication/construction examinations of Subsection NG are satisfactorily completed, Subsection NG is no longer applicable. All future inservice examinations will be in accordance with the intent of BWRVIP-139. The BWRVIP proposes to revise Table 6-1 to reference only Subsection NG for NDE and to add the following note: "Applicable to dryers that were fabricated in accordance with Subsection NG." In addition, the last sentence of Section 10.2 will be revised to state: "The scope and frequency of all inspections of category A, B and C dryers that are fabricated or modified using Subsection NG will meet the fabrication/construction examinations of Subsection NG. Once these examinations are satisfactorily completed, Subsection NG is no longer applicable. All future inservice examinations will be in accordance with the intent of BWRVIP-139. Note: the imposition of Subsection NG inspections on repair/replacement dryers at plants where the original dryer was not fabricated as a Code component in no way implies that the repair/replacement dryer shall be considered a Code component in the future. For repair/replacement dryers installed at plants where the original dryer was fabricated as a Code component, all original plant commitments remain intact."

In addition, for clarity the BWRVIP proposes to add the following paragraph after the third paragraph of Section 6 ("General Design Criteria"): "Note: imposition of

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Code requirements for the design of repair/replacement dryers at plants where the original dryer was not fabricated as a Code component in no way implies that the repair/replacement dryer shall be considered a Code component in the future. For repair/replacement dryers installed at plants where the original dryer was fabricated as a Code component, all original plant commitments remain intact."

RAI-2: Section 10.0, Paragraph 10.2 states that the Category A and B repaired steam dryer welds/components will be inspected on a continuing periodic basis. The NRC staff requests that the BWRVIP confirm that the frequency of inspections for the Category A and B repaired steam dryer welds/components are consistent with the intent of the BWRVIP-139 TR, "BWR Vessel Internal Project, Steam Dryer Inspection and Flaw Evaluation Guidelines," and modify Paragraph 10.2 accordingly.

BWRVIP Response to Section 2: Component Issues RAI-2:

As stated at the end of Section 10.2, all inspections shall be consistent with the intent of BWRVIP-139. For additional clarity, the BWRVIP proposes to modify the sentence as described in the response to RAI-1.

RAI-3: Section 10.0, Paragraph 10.2 states that the repair designer shall specify pre- and post-inspections of the repaired Category C steam dryer components/welds. The NRC staff requests that the BWRVIP confirm whether: (1) the inspection requirements specified in ASME Code, Section III, Subsection NG are applicable to the repaired Category C steam dryer welds/components, and (2) the frequency of inspections for the Category C repaired steam dryer welds/components are consistent with the intent of the BWRVIP-139 TR. Paragraph 10.2 shall be modified according to the response to this RAI question for consistency.

BWRVIP Response to Section 2: Component Issues RAI-3:

See response to RAI-1. Since Category C dryers would be fabricated in accordance with Subsection NG, the inspection requirements of NG would apply. Once the fabrication/construction examinations of Subsection NG are satisfactorily completed, Subsection NG is no longer applicable. All future inservice examinations will be in accordance the intent of BWRVIP-139. The revision to Section 10.2 proposed in response to RAI-1 will clarify these requirements.

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Attachment 1: Proposed Revision to Section 7.3

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RECORD OF REVISIONS

BWRVIP-181-A	Information from the following documents was used in preparing the changes included in this revision of the report: 1. "BWRVIP-181: BWR Vessel and Internals Project, Steam Dryer Repair Design Criteria," EPRI Technical Report 1013403, November 2007. 2. Letter from Vanice A. Perin (NRC) to Rick Libra (BWRVIP Chairman), "Request for Additional Information (RAI) for Electric Power Research Institute (EPRI) Boiling Water Reactor (BWR) Vessel and Internals Project (BWRVIP) Topical Report (TR) 1013403 "BWRVIP-181: BWR Vessel and Internals Project, Steam Dryer Repair Design Criteria" (TAC.NO MD8325)", dated September 10, 2008. (BWRVIP Correspondence File Number 2008-263). 3. Letter from Chuck Wirtz (BWRVIP Chairman) to Joseph Williams (NRC), "Project No. 704 – BWRVIP Response to NRC Request for Additional Information on BWRVIP-181 Report," dated March 25, 2009 (BWRVIP Correspondence File Number 2009-118). 4. Letter from Thomas Blount (NRC) to Rick Libra (BWRVIP Chairman), "Final Safety Evaluation for Electric Power Research Institute Boiling Water Reactor Vessel and Internals Project Topical report 1013403 "BWR Vessel and Internals Project, Steam Dryer Repair Design Criteria (BWRVIP-181)" (TAC.NO MD8325)", dated January 11, 2010 (BWRVIP Correspondence File Number 2010-025). Details of the revisions can be found in Table C-1.
END	

Table C-1
Revision details

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Delete reference to Figure 2-1 in title of Figure 3-2.	RAI Response (2009-118). Structural Issues RAI 2.	Reference deleted.
Clarify meaning of "EDM" in Section 9.2.6.	RAI Response (2009-118). Structural Issues RAI 2.	"EDM" clarified.
Delete caveat in Section 9.2.10 allowing augmented inspections to be eliminated if material can be shown to be in compressive stress state.	RAI Response (2009-118). Structural Issues RAI 2.	Section 9.2.10, 9.2.9 and 9.2.13 revised to require augmented inspections whenever solution annealing cannot be performed.
Section 3.1.2.: Clarify that steam velocities exceeding 100 fps in certain conditions.	RAI Response (2009-118). Structural Issues RAI 3.	Section 3.1.2 clarified.
Section 3.2: Clarify importance of acoustic loads.	RAI Response (2009-118). Structural Issues RAI 4.	Section 3.2 revised (2 plcs).
Section 3.3: Clarify load cases that are to be analyzed for Category A repairs.	RAI Response (2009-118). Structural Issues RAI 5.	Section 3.3 clarified to indicate that detailed structural analyses are not required for Category A repairs.
Section 4.1: Clarify loads that should be used if dryer operation at EPU is anticipated.	RAI Response (2009-118). Structural Issues RAI 12.	Section 4.1 clarified.
Section 5.1: Clarify why there is no specific design life for Category A repairs.	RAI Response (2009-118). Structural Issues RAI 7.	Section 5.1 clarified.
Section 6: Elaborate discussion of use of best available information in defining dryer loads.	RAI Response (2009-118). Structural Issues RAI 9.	Section 6 revised.
Section 7.3: Revise loads and load combinations.	RAI Response (2009-118). Structural Issues RAI 11.	Section 7.3 revised.
Section 7.4: Clarify loads that should be used if dryer operation at EPU is anticipated.	RAI Response (2009-118). Structural Issues RAI 12.	Section 7.4 clarified.
Provide guidance on repair of damage occurring during installation.	RAI Response (2009-118). Structural Issues RAI 13.	Section 5.8 revised.
Section 13.2: Discuss methods of load mitigation.	RAI Response (2009-118). Structural Issues RAI 14.	Section 13.2 revised.
Section 13.1.5: Clarify use of "leave as is" approach.	RAI Response (2009-118). Structural Issues RAI 16.	Section 13.1.5 clarified.
Clarify appropriate inspections to be performed.	RAI Response (2009-118). Component Issues RAI 1.	Sections 6 and 10.2 and Table 6-1 revised.
Clarify that periodic, ongoing inspections are to be performed in accordance with the intent of BWRVIP-139.	RAI Response (2009-118). Component Issues RAI 2.	Section 10.2 revised.
	Editorial	Table 6-1, "Underwater Welding" remarks clarified.
END		

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Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com