July 3, 2003

Mr. Henry A. Sepp, Manager
Regulatory and Licensing Engineering
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

SUBJECT: ACCEPTANCE FOR REFERENCING – TOPICAL REPORT WCAP-15987-P, REVISION 2, "TECHNICAL BASIS FOR THE EMBEDDED FLAW PROCESS FOR REPAIR OF REACTOR VESSEL HEAD PENETRATIONS," (TAC NO. MB8997)

Dear Mr. Sepp:

By letters dated December 13, 2001, August 29, 2002, November 13, 2002, and May 16, 2003, Westinghouse Electric Company (Westinghouse) introduced and submitted licensing Topical Report (TR) WCAP-15987-P, Revision 2, "Technical Basis for the Embedded Flaw Process for Repair of Reactor Vessel Head Penetrations," to the NRC for review and approval. The TR proposed a process for embedding flaws found in reactor pressure vessel (RPV) head penetration nozzles and adjoining j-groove weld metal as an alternative to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) requirements. Specifically, the process would embed primary water stress corrosion cracks found in Alloy 600 RPV head penetration nozzles and j-groove welds under a non-structural seal weld.

The staff has completed its review of the subject TR. The TR is acceptable for referencing in licensing applications as an alternative to the 1989 Edition of Section III of the ASME Code, NB-4453.1 to the extent specified and under the limitations delineated in the TR and in the associated NRC safety evaluation (SE), which is enclosed. The SE defines the basis for acceptance of the TR. Licensees may reference this SE when requesting an alternative pursuant to 10 CFR 50.55a(a)(3)(i).

Pursuant to 10 CFR 2.790, we have determined that the enclosed SE does not contain proprietary information. However, we will delay placing the SE in the public document room for ten working days from the date of this letter to provide you with the opportunity to comment on the proprietary aspects only. If you believe that any information in the enclosure is proprietary, please identify such information line by line and define the basis pursuant to the criteria of 10 CFR 2.790.

We do not intend to repeat our review of the matters described in the subject TR, and found acceptable, when the TR appears as a reference in license applications, except to ensure that the material presented applies to the specific plant involved. Our acceptance applies only to matters approved in the TR.

In accordance with the guidance provided on the NRC website, we request that Westinghouse publish an accepted version within three months of receipt of this letter. The accepted version shall incorporate (1) this letter and the enclosed SE between the title page and the abstract,

(2) all requests for additional information from the staff and all associated responses, and (3) a "-A" (designating "accepted") following the report identification symbol.

Should our criteria or regulations change so that our conclusions as to the acceptability of the report are invalidated, Westinghouse and/or the licensees referencing the TR will be expected to revise and resubmit their respective documentation, or submit justification for the continued applicability of the TR without revision of their respective documentation.

Sincerely,

**/RA/**

Herbert N. Berkow, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 700

Enclosure: Safety Evaluation

cc w/encl:
Mr. Gordon Bischoff, Project Manager
Westinghouse Owners Group
Westinghouse Electric Company
Mail Stop ECE 5-16
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Pittsburgh, PA 15230-0355

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

WESTINGHOUSE ELECTRIC COMPANY

TOPICAL REPORT WCAP-15987-P, REVISION 2,

"ALTERNATIVE REPAIR TECHNIQUE FOR

REACTOR VESSEL HEAD PENETRATIONS AND ADJOINING WELDS"

PROJECT NO. 700

## 1.0 INTRODUCTION AND BACKGROUND

On August 2, 2001, Westinghouse Electric Company (Westinghouse) made a presentation entitled, "Vessel Penetration Repair via Embedded Flaw," in a public meeting at the NRC offices in Rockville, Maryland. The presentation proposed an alternative to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code) repair concept for primary water stress corrosion cracking (PWSCC) of reactor pressure vessel (RPV) head penetration nozzles and the j-groove weld attaching the vessel head penetration (VHP) nozzles to the RPV head. By letter dated December 13, 2001, Westinghouse submitted Topical Report (TR) LTR-NRC-01-41, "ASME Section XI Inservice Inspection Program Relief Requests - Alternative Repair Technique," containing the repair concept for the staff's review. On June 13, 2002, the staff e-mailed a request for additional information (RAI) to Westinghouse. On August 29, 2002, Westinghouse responded (LTR-NRC-02-45, "Submittal of Reference Documents on CRDM Nozzle Examinations.") to the staff's RAI. On October 9, 2002, Westinghouse made a presentation supporting its TR entitled, "The Embedded Flaw Process for Repair of Reactor Vessel Head Penetrations," in a public meeting at the NRC offices in Rockville, Maryland. On November 13, 2002, the staff participated in a conference call with Westinghouse pertaining to clarifications of the TR. Based on the conference call, Westinghouse resubmitted its request as clarified in TR WCAP-15987-P, "Technical Basis for the Embedded Flaw Process for Repair of Reactor Vessel Head Penetrations," December 2002. In a followup telecon on April 29, 2003, the staff questioned the analytical references. Westinghouse addressed the staff's concerns and resubmitted the TR as WCAP-15987-P, Revision 2, (the TR). The TR proposed using a generic repair technique as an alternative for the ASME Code repair requirements. Specifically, the proposal seeks to embed PWSCC found in Alloy 600 VHP nozzles or Alloy 600 filler material under a non-structural Alloy 690 weld overlay or seal weld.[1]

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[1]Alloy 600 is ASME Code, Section II, Part B, Alloy N06600 (i.e., SB-166, SB-167, and SB-168) and associated filler metal (i.e., Part C, SFA-5.11 and SFA-5.14). Alloy 600 filler metal is known as Inco (Alloy) 82 and 182. Alloy 690 is ASME Code, Section II, Part B, Alloy N06690 (i.e., SB-166, SB-167, and SB-168) and associated filler metal (i.e., Part C, SFA-5.11 and SFA 5.14). Alloy 690 filler metal is known as Inco (Alloy) 52 and 152.

Since 1986, PWSCC has been identified in VHP nozzles made from Alloy 600 material. The cracks were located axially in the nozzles and were determined to be manageable from a safety aspect. The determination was based on a slow crack growth rate in Alloy 600 material and its high fracture toughness; thus, any cracks or evidence of cracks should be detectable before jeopardizing the pressure boundary's safety function. The staff determined that these axial cracks were not an immediate safety concern and notified licensees through Information Notice (IN) 90-10, "Primary Water Stress Corrosion Cracking (PWSCC) of Inconel 600," dated February 23, 1990. An update on the status of PWSCC in VHP nozzles was provided to licensees in Generic Letter (GL) 97-01, "Degradation of Control Rod Drive Mechanism Nozzle and Other Vessel Closure Head Penetration," issued April 1, 1997. In addition to axially oriented PWSCC, GL 97-01 identified an incident of circumferential intergranular attack (IGA) at a facility in Spain. The IGA was in the j-groove welds connecting the VHP nozzles to the RPV head. The cause for this IGA was attributed to cation resin that inadvertently entered the reactor cooling system.

In 2001, leakage from circumferential cracks in Alloy 600 control rod drive mechanism (CRDM) VHP nozzles was identified at two pressurized water reactors (PWRs). The NRC alerted licensees to the existence of CRDM nozzle circumferential cracks in NRC Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles," dated August 3, 2001. The bulletin required licensees to provide a written response on the structural integrity of their VHP nozzles (which includes the CRDM nozzles), the extent of VHP nozzle leakage and cracking, inspection and results, corrective action to satisfy applicable regulatory requirements, and the basis that future inspections will ensure compliance with the applicable regulatory requirements. In 2002, circumferential cracks were found in CRDM nozzles at Crystal River Nuclear Station, Unit 3 and Davis-Besse Nuclear Power Station, Unit 1.

While repairing a CRDM nozzle at Davis-Besse, the licensee discovered a large cavity in the RPV head surrounding a VHP nozzle. The discovery prompted the NRC to issue Bulletin 2002-01, "Reactor Pressure Vessel Head Degradation and Reactor Coolant Pressure Boundary Integrity," dated March 18, 2002. The bulletin requested that licensees provide information on the extent to which they could conclude that their respective plants(s) did not have RPV head degradation like that experienced at Davis-Besse.

As a result of staff concerns related to the adequacy of current ASME Code inspection requirements for assuring the integrity of VHP nozzles and j-groove welds joining the VHP nozzles to the RPV, the staff issued Bulletin 2002-02, "Reactor Pressure Vessel Head Penetration Nozzle Inspection Programs," on August 9, 2002. The bulletin notified PWR licensees that ASME Code-required visual examinations for leakage from VHP nozzles and j-groove welds may need supplemental volumetric and surface examination to demonstrate compliance with applicable regulations and that inspection methods and frequencies should be reliable and effective.

On February 11, 2003, the staff issued Order EA-03-009 entitled, "Issuance of Order Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads at Pressurized Water Reactors." The Order requires specific inspection methods and inspection frequencies of RPV head penetrations and j-groove welds. Prompted by the bulletins and the Order, PWR licensees are examining VHP nozzles and adjoining j-groove welds for PWSCC. In the event that PWSCC is found, licensees may choose to reestablish the leak tightness of the Inconel 600 material with the Westinghouse proposed seal weld repair process discussed herein.

## 2.0 REGULATORY EVALUATION

The proposed seal weld repair process is based on, and compared to, the requirements of the 1989 Edition of ASME Section XI. ASME Section XI, 1989 Edition, Paragraph IWA-4120 states, in part, that "Repairs shall be performed in accordance with the Owner's Design specification and the original Construction Code of the component or system. Later editions and addenda of the Construction Code or of Section III, either in their entirety or portions thereof, and Code Cases may be used." Licensees choosing to use other editions and addenda of the ASME Code must reconcile the Code requirements to those of the 1989 Edition of ASME Code.

Section III, Subparagraph NB-4453.1, requires the removal of defects and requires liquid penetrant or magnetic particle examinations of the repair excavation with acceptance criteria in accordance with NB-5340 (NB-5342 for magnetic particle testing (MT) acceptance standards) or NB-5350 (NB-5352 for liquid penetrant testing (PT) acceptance standards). These paragraphs state that any cracks or linear indications are unacceptable.

## 3.0 TECHNICAL EVALUATION

The staff reviewed the TR by analyzing the reasonableness of assumptions and by independent analysis to confirm results. The staff's review evaluated the special features of the repair, analysis of stresses and crack growth, stress location, corrosion, operating experience of material, effectiveness of nondestructive examination (NDE) methods and the application of the embedded flaw technique.

### 3.1 Special Repair Features

In lieu of IWA-4310 and associated Code-requirements necessary for verifying complete removal of PWSCC, Westinghouse developed a less intrusive alternative repair for VHP nozzles and adjoining j-groove welds. The repair entails embedding PWSCC under a minimum of three layers of weld material. The welding will use a welding process with controlled heat input parameters. The proposed embedded flaw repair is designed to isolate PWSCC susceptible Alloy 600 weld material from primary water, which should arrest any further crack growth. The isolation is accomplished by applying thin layers of Alloy 690 weld material over austenitic material (Alloy 600 or stainless steel). The selection of Alloy 690 for the repair was based on laboratory testing and 10 years of field experience in RPV and steam generator environments. The repair is applicable for VHP nozzles designed by Westinghouse or Combustion Engineering.

### 3.2 Analysis of Stresses and Crack Growth

The TR states that the residual stresses produced by the embedded flaw technique have been measured and found to be relatively low because of the small thickness of the weld as documented in WCAP-13998, "RV Closure Head Penetration Tube ID Weld Overlay Repair," March 1994. That also implies that no new PWSCC cracks will grow in the area adjacent to the repair weld. The TR goes on to relate that there are no other known mechanisms for significant crack propagation in this region because the cyclic fatigue loading is considered negligible. The cumulative usage factor (CUF) in the upper head region was calculated to be typically less than 0.2 in the ASME Code reactor vessel design report, as well as in various aging management review reports such as, WCAP-15269, Rev. 1, "Aging Management Review and Time Limited Aging Analysis for the North Anna Units 1 and 2 Reactor Pressure Vessels," September 2001.

The evaluation methodology assumes that an axial or circumferential crack has been detected in (1) a penetration nozzle inside diameter (ID), (2) an axial crack in the J-groove attachment weld or (3) an axial crack in the penetration outside diameter (OD) (below the J-groove weld). In the first and third cases, the allowable flaw (crack) size for surface flaws envelops that for embedded flaws of comparable size. To determine allowable flaw sizes for those embedded flaws, ASME Code, Section XI, IWB-3600 safety factors and limit load methodology is used. The results are presented in the Appendix C figures of the TR. However, the allowable flaw sizes were adjusted to account for fatigue crack growth of the repaired flaws as a result of the fatigue crack growth analysis described in Appendix C of the TR.

For the case of an axial crack in the j-groove attachment weld, it is assumed that the crack extends radially over the entire attachment weld cross-section since currently available NDE technology cannot characterize the depth of the crack. With the embedded flaw repair, the only mechanism for sub-critical crack growth is fatigue. The allowable flaw size is adjusted for the predicted fatigue crack growth to obtain the maximum allowable flaw size that can be repaired in the j-groove weld using the embedded repair technique. The allowable crack size is based on analyses employing both linear elastic fracture mechanics analysis and elastic plastic fracture mechanics analysis in accordance with established methods in the ASME Code, Section XI. The predicted fatigue crack growth is subtracted from the allowable crack sizes calculated to result in maximum allowable crack sizes as a function of crack shape.

### 3.3 Stress Locations

As stated above, the TR considered residual stresses produced by the proposed repair as being low. The first layer fuses the Alloy 690 material to the Alloy 600 base material. Because of shrinkage differences, the Alloy 600 material cools in compression and the Alloy 690 material cools in tension. Subsequent layers provide stress relief of the preceding layers. The net effect is a relatively low level of residual stresses at the Alloy 600/690 interface located below three or more layers of Alloy 690 weld material.

An area of concern is where the last layer of Alloy 690 material is in contact with Alloy 600 material. This condition exists for welded inlay and seal weld repairs. The concern is that the higher shrinkage of Alloy 690 material will result in larger stresses at the Alloy 600 interface. For repairs from the inside diameter of an Alloy 600 tube, the last layer of Alloy 690 weld material does not receive the benefit of a stress relief and is tied at both ends to Alloy 600 base material. The shrinkage difference at the connection joining the two alloys can produce large tensile stresses. The same condition exists for repairs involving Alloy 690 and stainless steel material, such as with seal weld repairs made on the outside VHP nozzle surface or an adjoining j-groove weld.

## 3.4 Corrosion Experience

PWSCC was found in mill annealed Alloy 600 CRDM nozzles, mill annealed Alloy 600 wrought tubing and machined tubing from bar stock, as-welded Alloy 600 butter, and as-welded Alloy 600 partial penetration welds. The time necessary for PWSCC to initiate and grow in mill annealed Alloy 600 tubing is sufficiently known for making predictions. The time for PWSCC to initiate and grow in as-welded Alloy 600 welds is not known; however, operating experience shows that a flaw, once initiated, can grow through the weld in less than one operating cycle. Apparently, growth of PWSCC in Alloy 600 material is strongly influenced by its thermal processing.

The susceptibility of Alloy 600 to stress corrosion cracking has been known since the early 1980s. In 1982, Inco Research and Development Center, the laboratory that developed Alloy 600 and Alloy 690, published results (Reference 1) that showed Alloy 690 weld materials were more resistant to intergranular stress corrosion cracking than Alloy 600 weld materials. In April 1993, weld material closely matching Alloy 690 was added to the ASME Code with the publishing of Code Cases 2142 and 2143. The staff reviewed these two code cases and determined that they were acceptable alternatives for Alloy 600 weld material (Reference 2). A recent study (Reference 3) provided corrosion comparisons of stress-relieved Alloy 600, as-welded Alloy 600, as-welded Alloy 690, and (undefined heat treatment) Alloy 690 weld metals and Alloy 690 base metal. For the constant extension rate tests (CERT) performed at $1 \times 10^{-6}$(second $^{-1}$), none of the tested material exhibited stress corrosion cracks in PWR primary water or chloride faulted primary water. When the CERT speed was reduced two orders of magnitude, both stress relieved and as-welded Alloy 600 exhibited cracks.

The field and test data show that as-welded Alloy 600 weld metal and Alloy 600 base metal are prone to PWSCC. Field and test data show that as-welded Alloy 690 weld and Alloy 690 base metal are more resistant to PWCSS than Alloy 600 material. Also, field data from North Anna Unit 2 show that PWSCC is confined to the Alloy 600 weld side of a stainless steel (clad) Alloy 600 j-groove weld interface. The limited data is insufficient for formulating conclusions on PWSCC located in the weld interface regions. Therefore, based on the limited data and field experience with Alloy 690 seal welds to Alloy 600 or stainless steel (clad) weld material, the weld interface should be periodically examined.

## 3.5 Effectiveness of Nondestructive Examination

ASME Section XI, IWA-4310 states that defects shall be removed or reduced in size in accordance with IWA-4000. Cracks reduced to an acceptable size must be verifiable. In the TR, PWSCC detection and characterization was based on LTR-SMT-01-74, "Ultrasonic Testing of CRDM Penetration Tubes for the Detection of Outer Surface Circumferential Cracking: Technical Justification and Qualification Information," December 13, 2001. On August 29, 2002, LTR-SMT-01-74 was updated with technical justification contained in WDI-TJ-007-02-P, "Demonstration of Volumetric Ultrasonic Inspection of CRDM Nozzles Using the Open Housing Scanner for ANO-2," May 30, 2002; and WDI-TJ-002-02, Rev. 1, "Technical Justification for Eddy Current Testing of J Groove Welds at CRDM Penetrations Using Procedure ISI-ET-001, Rev. 0, Eddy Current Inspection of J-groove Welds in Vessel Head Penetrations," August 27, 2002. Using a combination of ultrasonic testing (UT) and eddy current testing (ET) techniques, Westinghouse successfully demonstrated detection and length sizing of axial and circumferential PWSCC flaws located on the OD and ID surfaces of the CRDM nozzles.

WDI-TJ-007-02-P includes mechanized ultrasonic time-of-flight diffraction (TOFD) criteria which should be effective in clean, small grained, homogeneous material such as CRDM nozzles; however, the data presented was inconclusive for supporting depth sizing of PWSCC. In the absence of demonstrated depth sizing capabilities in the CRDM, PWSCC flaws cannot be repaired to an acceptable flaw depth, determined to be within IWB-3500 or IWB-3600 or determined not to exceed the NRC flaw evaluation guidelines. Therefore, flaws must be completely removed, assumed through-wall, or depth sized with a UT technique successfully demonstrated for this application.

For CRDM nozzle ID initiated PWSCC adjacent to and above the j-groove weld, the proposed repair is to cover the crack on the ID with a non-structural Alloy 690 seal weld. The welding process produces a microstructure that is conducive to UT examination. Where access is available, UT examinations can and should be used to validate weld integrity. In a previously approved application for the embedded flaw technique at North Anna Unit 1 (Reference 4), the finished weld was to be applied on the inside surface of the CRDM nozzle and examined with UT and liquid PT or UT and ET; the examination was in accordance with the requirements contained in Code Case N-504-1, "Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping."

For CRDM nozzle OD and ID initiated PWSCC below the j-groove weld, the repair must satisfy the NRC flaw evaluation guidelines (Reference 5). For the segment of the VHP nozzle extending below the j-groove weld, a repair need only be a seal weld to prevent continued PWSCC degradation and to prevent pieces from separating from the CRDM nozzle. Therefore, as a minimum, a finished weld repair to the VHP nozzle extending below the j-groove weld (either ID or OD) need only receive a surface examination. The surface examination must satisfy the acceptance requirements of NB-5342 or NB-5352. If ET is used, the liquid PT acceptance criteria must be applied.

The UT techniques used by Westinghouse have not demonstrated detection and characterization capability of PWSCC in the j-groove weld region from the CRDM nozzle ID. Also, the UT technique has not demonstrated examination capabilities from the j-groove weld surface. However, there are indications that UT inspections from the ID of the VHP nozzle may be capable of detecting flaws in that portion of the j-groove weld adjacent to the VHP nozzle, and UT inspections from the accessible surface of the j-groove weld may be capable of detecting flaws at and near the weld surface. If access is available, seal welds applied to j-groove welds must be periodically examined with demonstrated UT examinations. The importance of monitoring the repair with UT is to determine if the embedded flaw has changed or new flaws were generated within the repaired region. The detection of changes to the original flaw(s) or of new flaw(s) beneath or in the seal weld repair invalidates the adequacy of the repair. The NRC must be notified of changes in flaw(s) or finding new flaw(s) in the j-groove weld beneath a seal weld repair or in the seal weld repair.

Alloy 690 seal welds have acoustic responses similar to stainless steel weld overlays which are performed with qualified personnel and procedures in accordance with ASME Section XI, Appendix VIII, Supplement 11 requirements. Furthermore, Supplement 11 inspection volume is the same as that specified in Code Case 504-1, which consists of the weld overlay and 25 percent of the base metal. In this case, the base metal may consist of weld material beneath the seal weld. Although the seal weld is a non-structural weld, monitoring it like a weld overlay is prudent to validate the assumptions that a crack which has been sealed from the primary water environment is benign.

3.6 Applying the Embedded Flaw Technique

Licensees which utilize the approach of the TR must follow the NRC flaw evaluation guidelines for maximum allowable flaw dimensions. For flaw dimensions not addressed in the NRC flaw evaluation guideline, the staff will disposition them on a case-by-case basis.

3.6.1 <u>VHP Nozzles</u>

The staff reviewed the embedded flaw technique as a function of crack orientation and location. The use of this technique on axially oriented PWSCC that originated from the inside surface of the VHP nozzle was previously reviewed for North Anna Unit 1 and determined to be acceptable. This TR includes axially oriented PWSCC extending 75 percent through-wall from the ID at and above the j-groove weld. The UT technique used to characterize these flaws must be demonstrated for this application.

The adequacy of embedding a through-wall flaw is not assured, unless both ends of the flaw are sealed off from the primary water source. The need to isolate the embedded flaw from all liquid sources is necessary because of the limited capability of UT to validate VHP nozzle integrity after the repair. The complexities associated with UT examinations performed from the ID, through the seal weld, to find changes occurring at the OD has not been demonstrated. The capability of detecting flaws on the VHP nozzle OD through a seal weld repair on the ID must be demonstrated prior to performing the repair.

Axial ID flaws found in the VHP nozzles below the j-groove weld may be repaired regardless of depth as long as it can be demonstrated that the upper extremity of the flaw will not reach the bottom of the weld during the period of service prior to the next inspection. The crack growth rate (CGR) in Appendix C of the TR shall be used to ensure that an axial crack in the VHP nozzle will not reach the j-groove weld. A circumferential OD flaw below the j-groove weld is acceptable provided its length does not exceed 75 percent of the VHP nozzle circumference. However, intersecting axial and circumferential flaws below the j-groove weld must be removed or repaired due to a concern for loose parts. The embedded flaw repair technique may be applied to OD axial or circumferential cracks below the j-groove weld because they are located away from the pressure boundary, and the proposed repair of sealing the crack with Alloy 690 weld material would isolate the crack from the environment.

3.6.2 <u>J-groove Welds</u>

Currently, there are no reliable volumetric methods for characterizing the depth of an existing crack, nor are there CGR data for Alloy 600 weld material exposed to primary water chemistry. Based on current examination capabilities, a potential leakage path through the j-groove weld is only verifiable with surface examinations. Any PWSCC detected on the surface of the j-groove weld must be considered through-weld for leakage and structural integrity evaluation. The embedded flaw repair may be used provided the entire Alloy 600 weld material exposed to primary water and any material adjacent to the j-groove weld with the potential for cracks propagating into the j-groove weld is sealed with a minimum of three layers of Alloy 690 weld material. The seal weld must extend beyond the Alloy 600 weld material by at least ½ inch. For inservice inspection (ISI), the seal weld surface contour limits application of UT techniques to what is accessible. Therefore, verification of the repair integrity must include a surface examination. Consistent with the requirement of NRC Order EA-03-009 which was sent to all PWR licensees, repaired penetration and j-groove welds are subject to reinspection every refueling outage.

### 3.7 Disclaimer

This safety evaluation does not address the acceptability of WPS 3-43/52-TB MC-GTAW-N638 for temper bead weld repairs or PQRs 695, 694A, and 707 for weld procedure qualification, nor did the staff review and evaluate Westinghouse WCAP-15987-P, Revision 2, Appendix B. These items will be the subject of a separate safety evaluation.

## 4.0 CONCLUSIONS

Based on the above evaluation, the staff has determined that seal weld repairs of circumferential and axial cracks in the VHP nozzle ID at or above the j-groove weld, in the VHP nozzle ID and OD below the j-groove weld, and in the j-groove weld, subject to the conditions listed in the table in Section 5.0 of this safety evaluation, will provide an acceptable level of safety and quality. Therefore, licensees may reference this safety evaluation and the associated TR as a proposed alternative to the 1989 Edition of Section III to ASME Code, NB-4453.1 for the repair of VHP nozzles and adjoining j-groove welds.

## 5.0 CONDITIONS AND LIMITATIONS

1. Licensees must follow the NRC flaw evaluation guidelines (Reference 5).

2. The crack growth rate is not applicable to Alloy 600 or Alloy 690 weld material, i.e., Alloy 52, 82, 152, and 182 filler material.

3. The NDE requirements listed in the Table below must be implemented for examinations of repairs made using the embedded flaw process.

| Repair Location | Flaw Orientation | Repair Weld | Repair NDE | ISI NDE of the repair, Note 2 |
|---|---|---|---|---|
| VHP Nozzle ID | Axial | Seal | UT and Surface | UT or Surface |
| VHP Nozzle ID | Circumferential | Note 1 | Note 1 | Note 1 |
| VHP Nozzle OD above j-groove weld | Axial or Circumferential | Note 1 | Note 1 | Note 1 |
| VHP Nozzle OD below j-groove weld | Axial or Circumferential | Seal | UT or Surface | UT or Surface |
| j-groove weld | Axial | Seal | UT and Surface, Note 3 | UT and Surface, Note 3 |
| j-groove weld | Circumferential | Seal | UT and Surface, Note 3 | UT and Surface, Note 3 |

Notes:
1. Repairs must be reviewed and approved separately by the NRC.
2. Inspection consistent with the NRC Order EA-03-009 dated February 11, 2003 and any subsequent changes.
3. Inspect with personnel and procedures qualified with UT performance-based criteria. Examine the accessible portion of the repaired region. The UT coverage plus surface coverage must equal 100 percent.

6.0 REFERENCES


1. J. R. Crum and R. C. Scarberry, "Corrosion Testing of Inconel Alloy 690 for PWR Steam Generators," Journal of Materials for Energy Systems, Vol. 4, No. 3, December 1982.

2. D. B. Matthews (NRC) letter to G. Grier (Duke Power Company), "Request to Use Alternative Weld Materials in the Fabrication and Installation of Replacement Steam Generators for McGuire Nuclear Station, Units 1 and 2, and Catawba Nuclear Station, Unit 1," July 20, 1993.

3. M. J. Psaila-Dombrowski, et. al., "Evaluation of Weld Metals 82, 152, 52 and Alloy 690 Stress Corrosion Cracking and Corrosion Fatigue Susceptibility," Proceedings, Eighth International Symposium on Environmental Degradation of Materials in Nuclear Power Systems - Water Reactors, pp. 412-421, August 1997.

4. D. B. Matthews (NRC) letter to J. P. O’Hanlon (Virginia Electric), "North Anna Unit 1 - Use of an Alternative Repair Technique for Reactor Vessel Head Penetrations," February 5, 1996.

5. R. J. Barrett (NRC) letter to A. Marion (Nuclear Energy Institute), "Flaw Evaluation Guidelines," April 11, 2003.

Principal Contributor: D.G. Naujock

Date: July 3, 2003