From: Edwards, Nicole D <Nicole.Edwards@duke-energy.com>
Sent: Friday, April 23, 2021 2:14 PM
To: Cotton, Karen
Cc: Zaremba, Arthur H.; Sigmon, Chet Austin
Subject: [External_Sender] CNS RR RA-21-0133
Attachments: RA-21-0133 for submittal.pdf

Karen,

The attached relief request was just submitted electronically. The ADAMS accession number is ML21113A215.
Art will be giving you a call to discuss a possible time for verbal approval.

Thank you
Nicole

Nicole Edwards
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Hearing Identifier: NRR_DRMA
Email Number: 1148

Mail Envelope Properties (BN7PR03MB3698EF13E852C85BAEB0B177DB459)

Subject: [External_Sender] CNS RR RA-21-0133
Sent Date: 4/23/2021 2:13:49 PM
Received Date: 4/23/2021 2:14:14 PM
From: Edwards, Nicole D

Created By: Nicole.Edwards@duke-energy.com

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"Zaremba, Arthur H." <Arthur.Zaremba@duke-energy.com>
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Tracking Status: None
"Cotton, Karen" <Karen.Cotton@nrc.gov>
Tracking Status: None

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Files	Size	Date & Time
MESSAGE	379	4/23/2021 2:14:14 PM
RA-21-0133 for submittal.pdf	763916	

Options
Priority: Normal
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:

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10 CFR 50.55a

Serial: RA-21-0133
April 23, 2021

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Catawba Nuclear Station, Unit No. 2
Renewed Facility Operating License No. NPF-52
Docket No. 50-414

SUBJECT: Proposed Alternative to Use Reactor Vessel Head Penetration Embedded Flaw Repair Method

Ladies and Gentlemen:

During the Catawba Nuclear Station (CNS) Unit 2 refueling outage 24 (C2R24), supplemental eddy current testing was performed in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section XI and its associated Code Case N-729-6, due to suspect volumetric ultrasonic leak path (UTLP) for Reactor Vessel Closure Head (RVCH) penetration #74. Non-Destructive Examination (NDE) of the J-groove weld surface was performed on April 20, 2021 and identified a relevant indication that requires repair. Repair of the weld will be performed and completed prior to return of CNS Unit 2 to service.

Pursuant to 10 CFR 50.55a(z)(1), Duke Energy Carolinas, LLC. (Duke Energy) requests NRC approval of a proposed alternative to the ASME Code repair/replace requirements, on the basis that the proposed alternative provides an acceptable level of quality and safety.

The relief request is provided as the Enclosure to this letter. A qualitative fracture mechanics assessment of the embedded flaw repair is provided as Attachment 1 to verify the repair for one cycle. To support critical path for C2R24, verbal approval is requested by April 25, 2021 to support plant startup.

Should you have any questions concerning this letter and its enclosure, please contact Art Zaremba, Director – Nuclear Fleet Licensing at (980) 373-2062.

Sincerely,

Tom Simril

Tom Simril
Vice President, Catawba Nuclear Station

Enclosure: Proposed Alternative to Use Reactor Vessel Head Penetration Embedded Flaw Repair Method

Attachment: 1. Fracture Mechanics Assessment of Embedded Flaw Repair Acceptability for Catawba Unit 2

cc:

L. Dudes, USNRC, Region II Regional Administrator
K. Cotton, USNRC NRR Project Manager for CNS
J. Austin, USNRC Senior Resident Inspector for CNS

Enclosure

Proposed Alternative to Use Reactor Vessel Head Penetration Embedded Flaw Repair Method
(9 pages plus the cover)

1.0 ASME CODE COMPONENT(S) AFFECTED:

Component: Reactor Pressure Vessel (RPV) Head Penetration #74

Code Class: 1

Examination Category: ASME Code Case N-729-6 (Reference 8.1)

Item Number: B4.20

2.0 APPLICABLE CODE EDITION AND ADDENDA:

The applicable Edition and Addenda of the ASME Code, Section XI (Reference 8.2) is identified in Table 1.

Table 1

Plant/Unit(s)	ISI Interval	ASME Section XI Code Edition/Addenda	Interval Start Date	Interval End Date[1]
Catawba Nuclear Station Unit 2 (CNS2)	Fourth	2007 Edition, Through 2008 Addenda	08/19/2015	02/24/2026

Notes:

1. The Interval End Date is subject to change in accordance with IWA-2430(c)(1).

Examinations of the Reactor Vessel Closure Head (RVCH) penetrations are performed in accordance with 10 CFR 50.55a(g)(6)(ii)(D), which specifies the use of ASME Code Case N-729-6, with conditions.

The RPV Construction Code is ASME Section III, 1971 Edition through Winter 1972 Addenda (Reference 8.3).

The Construction Code applicable to the repair of weld defects on the RVCH at CNS2 is the 1989 Edition of ASME Section III (Reference 8.4).

3.0 APPLICABLE CODE REQUIREMENT:

IWA-4000 of ASME Section XI contains requirements for the removal of defects from and welded repairs performed on ASME components. The specific Code requirements for which use of the proposed alternative is being requested are as follows:

ASME Section XI, IWA-4421 states:

Defects shall be removed or mitigated in accordance with the following requirements:

(a) Defect removal by mechanical processing shall be in accordance with IWA-4462.

(b) Defect removal by thermal methods shall be in accordance with IWA-4461.

(c) Defect removal or mitigation by welding or brazing shall be in accordance with IWA-4411.

(d) Defect removal or mitigation by modification shall be in accordance with IWA-4340.

- Note that the use of the "Mitigation of Defects by Modification" provisions of IWA-4340 is prohibited per 10 CFR 50.55a(b)(2)(xxv)(A).

For the removal or mitigation of defects by welding, ASME Section XI, IWA-4411 states, in part:

Welding, brazing, fabrication, and installation shall be performed in accordance with the Owner's Requirements and, except as modified below, in accordance with the Construction Code of the item.

(a) Later editions and addenda of the Construction Code, or a later different Construction Code, either in its entirety or portions thereof, and Code Cases may be used provided the substitution is as listed in IWA-4221(c). Filler metal requirements shall be reconciled, as required, in accordance with IWA-4224.

The Construction Code that will be used for performing defect removal and repair of welds on the RVCH at CNS2 is the 1989 Edition of ASME Section III. Requirements applicable to repair of weld defects are specified in NB-4450 as follows:

- NB-4451, which provides general requirements for removal of weld metal defects, states:

  Defects in weld metal detected by the examinations required by NB-5000, or by the tests of NB-6000, shall be eliminated and repaired when necessary.

- NB-4452, which provides requirements for eliminating weld surface defects without welding states:

  Weld metal surface defects may be removed by grinding or machining, and need not be repaired by welding, provided that the requirements of (a) through (c) below are met.

  (a) The remaining thickness of the section is not reduced below that required by NB-3000.

  (b) The depression, after defect elimination, is blended uniformly into the surrounding surface.

  (c) The area is examined by a magnetic particle or liquid penetrant method in accordance with NB-5110 after blending and meets the acceptance standards of NB-5300 to ensure that the defect has been removed or reduced to an imperfection of acceptable limit. Defects detected by visual or volumetric method and located on the interior surface need only be reexamined by the method which initially detected the defect when the interior surface is inaccessible for surface examination.

- NB-4453.1, which provides requirements for repairing weld defects with welding, states:

  Defects may be removed by mechanical means or by thermal gouging processes. The area prepared for repair shall be examined by a liquid penetrant or magnetic particle method in accordance with NB-5110, and meet the acceptance standards of NB-5340 or NB-5350. This examination is not required where defect elimination removes the full *thickness of the weld and where the backside of the weld joint is not accessible for removal of examination materials.*

4.0 REASON FOR REQUEST:

Catawba is presently in refueling outage C2R24 and has performed a volumetric examination of the RVCH penetrations in accordance with ASME Code Case N-729-6 (Item No. B4.20) as mandated and conditioned by 10CFR50.55a(g)(6)(ii)(D). While performing the volumetric ultrasonic leak path (UTLP) assessment of nozzle #74, a change in backwall reflectivity between the penetration OD and RVCH was discovered which was not present in prior UTLP data from 2007 and 2013 (Reference 8.5). Eddy current testing (ECT) surface examination was performed on the full circumference of the J-groove weld surface which confirmed a relevant indication in the weld on the low hill side of the nozzle (Reference 8.6). Liquid penetrant (PT) surface examination was then performed which confirmed the indication was surface breaking (Reference 8.7). A bare metal visual examination of the complete RVCH was performed with no head penetration leakage detected.

The location of the relevant indication was determined from the PT examination to be on the weld surface 0.8" counter-clockwise from the lowest point on the downhill side of the weld (looking up) and 0.6" above the toe of the weld (Reference 8.7). The indication is described in the ECT Indication Notification Report (INR) (Reference 8.6) to be "a relevant single circumferential linear indication". The indication is described in the PT INR to be a "rounded liquid penetrant indication 1/16 inch in diameter". The ECT and PT surface examinations identified the relevant indication at the same position on the weld. As a result of the change in backwall reflectivity observed during the UTLP assessment and the relevant indication detected by both supplemental surface examination methods (ECT and PT), repair of the J-groove weld will be required during the current refueling outage. See Figure 1 for a representative illustration of the location of the surface indication.

Due to the relevant indication described above, a weld repair of the penetration #74 J-groove weld is necessary. As an alternative to the defect removal and weld repair provisions of ASME Section XI, IWA-4000 and ASME Section III, NB-4450, Duke Energy proposes to repair the subject J-groove weld using the embedded flaw repair process as described in WCAP-15987-P-A (Reference 8.8). Verbal approval requested by April 25, 2021 to support plant startup.

5.0 PROPOSED ALTERNATIVE AND BASIS FOR USE:

Pursuant to 10 CFR 50.55a(z)(1), Duke Energy proposes to repair the J-groove weld of RVCH penetration #74 using an embedded flaw repair process as an alternative to the defect removal and weld repair provisions of ASME Section XI, IWA-4000 and ASME Section III, NB-4450. The proposed embedded flaw repair process is described in WCAP-15987-P-A and was approved by the NRC in Reference 8.9. This proposed alternative is requested for one cycle of operation. A one-cycle justification letter is provided in Attachment 1 which includes the technical basis for operation during cycle 25 (Attachment 1). A site-specific fracture mechanics analysis will be performed during cycle 25 to justify a longer period of operation for the repair, in which additional relief will be requested.

Basis for Use:

Duke Energy's review concludes that the proposed embedded flaw repair process based on WCAP-15987-P-A provides an acceptable level of quality and safety. In the Safety Evaluation Report for

WCAP-15987-P-A, the NRC documented the same conclusion subject to their specified conditions and limitations (Reference 8.9). Consistent with WCAP-15987-P-A methodology, the following repair requirements will be met.

5.1 J-Groove Weld Repair Methodology

Consistent with WCAP-15987-P-A methodology, the following repair requirements are proposed for RVCH penetration OD and J-groove weld repairs

A. The interface boundary between the J-groove weld and stainless steel cladding will be located to positively identify the weld clad interface to ensure that all of the Alloy 82/182 material of the J-groove weld is seal welded during the repair.

B. Prior to the application of the Alloy 52 or 52M seal weld repair on the RPV clad surface, at least three beads (one layer) of ER309L stainless steel buffer will be installed on the clad surface at least 0.5 inches beyond the interface of the clad and J-groove weld metal 360 degrees around. These weld passes serve to isolate subsequent ERNiCrFe-7A weld passes from contaminants in the cladding.

C. The J-groove weld will be completely covered by at least three (3) layers of Alloy 52 or 52M deposited 360° around the nozzle and over the ER309L stainless steel buffer. It will extend at least 0.5 inches beyond the stainless steel cladding interface after deposition of the ER309L buffer layer.

D. Additionally, the seal weld will extend onto and encompass the outside diameter of the penetration tube Alloy 600 material by at least one-half inch. The seal weld on the Alloy 600 tube will consist of at least 2 layers of Alloy 52 or 52M weld metal.

Excavation or partial excavation of J-groove weld flaws is not required. Between each weld layer applied, light grinding of the weld surface will be performed to eliminate detrimental deposits and promote weld quality. See Figure 2 for additional details.

5.2 Nondestructive Examinations Requirements

In lieu of the examination requirements identified for J-groove welds in the NRC staff safety evaluation of WCAP-15987-P-A, non-destructive examination (NDE), including preservice and inservice, of the completed seal weld repair will be performed as specified below.

Repair Location	Flaw Orientation	Repair Method	Repair NDE	ISI NDE
J-groove weld	Circumferential	Seal Weld	UT and Surface (Notes 1 and 2)	UT and Surface (Notes 1 and 2)

(1) Preservice and Inservice Inspection to be consistent with 10 CFR 50.55a(g)(6)(ii)(D), which requires implementation of Code Case N-729-6 with conditions; or NRC-approved alternatives to these specified conditions.

a. Ultrasonic (UT) personnel and procedures are qualified in accordance with 10 CFR 50.55a(g)(6)(ii)(D), which requires implementation of Code Case N-729-6 with conditions.

b. UT reinspection frequency of the nozzle tube shall be at least once every 36 months of operating time.

c. Surface reinspection frequency shall be as defined below.

(2) Surface examination of the embedded flaw repair (EFR) shall be performed to ensure the repair satisfies ASME Section III, NB-5350 acceptance standards. The frequency of examination shall be as follows:

a. Perform surface examination during the first and second refueling outage after installation or repair of the EFR.

b. When the examination results in 2.a above verify acceptable results then re-inspection of the EFR will be continued at a frequency of every other refueling outage. If these examinations identify unacceptable results that require flaw removal, flaw reduction to acceptable dimensions, or welded repair, the requirements of 2.a above shall be applied during the next refueling outage.

A. Note 2 permits a reinspection frequency of every other cycle when the surface examination results of the EFR are verified to be acceptable for two consecutive cycles after the original installation or repair of the EFR. Westinghouse Report LTR-PSDR-TAM-14-005, Revision 3 (Reference 8.10) provides the technical bases for reducing surface examination requirements for J-groove weld repairs. This technical justification includes a detailed review of PT examination history, review of potential causes of PT indications in EFRs, and the use of crack resistant alloys in the EFR. The EFR is a robust design that is resistant to PWSCC. EFR installation, examination, and operational history indicate that the EFR performs acceptably. With inspection of the EFR every other cycle of operation, the nozzles are adequately monitored for degradation by ultrasonic examination methods similar to the nozzles without EFR repairs.

B. The proposed inservice examination requirements assure that the EFR repaired nozzles are adequately monitored through a combination of volumetric and surface examinations throughout the life of the installation at a frequency approved by the NRC, thus ensuring the EFR repaired nozzles will continue to perform their required function.

5.3 Technical Basis for Proposed Alternative

A. The proposed alternative seeks to embed and isolate the Alloy 600 RVCH penetration J-groove weld and any identified flaws with a non-structural, corrosion resistant seal weld (overlay).

B. WCAP-15987-P-A considers the embedded flaw repair a permanent repair technique. PWSCC flaws are unable to propagate if they remain isolated from the primary system water environment. Alloy 52/52M is considered highly resistant to PWSCC and is intended to preclude new PWSCC flaw initiation and growth through the overlay to prevent the primary coolant environment from interacting with the susceptible material. Structural integrity of the affected J- groove weld will be maintained by the remaining unflawed portion of the weld. The resistance of Alloy 52/52M weld metal to PWSCC has been demonstrated by laboratory tests and operating experience in replacement steam generators.

C. WCAP-15987-P-A states that the small overlay thickness contributes to low residual stresses produced by the embedded flaw technique. This implies that no new flaws will initiate and grow in the area adjacent to the repair weld. There are no other known mechanisms for significant flaw propagation in the reactor vessel closure head and penetration tube region since cyclic loading is negligible. Section 3.2 of the Safety Evaluation for WCAP-15987-P-A highlights this conclusion and its basis which is provided in WCAP-13998, Revision 1 (Reference 8.11).

D. The thermal expansion properties of Alloy 52 or 52M weld metal are not specified in the ASME Code. The properties of the equivalent base metal (Alloy 690) should be used. For Alloy 690, the thermal expansion coefficient at 600 degrees Fahrenheit (F) is 8.2E-6 in/in/degree F as found in Section II part D. A five percent difference in coefficient of thermal expansion exists between Alloy 690 and the Alloy 600 base material which has a coefficient of thermal expansion of 7.8 E-6 in/in/degree F. This small difference in thermal expansion will produce a compressive stress on the Alloy 600 J-groove weld. The benefit of the compressive stress effect has been accounted for in the residual stress measurements reported in the technical basis for the embedded flaw repair, as noted in the WCAP-15987-P-A.

E. Westinghouse letter LTR-SDA-21-027, Fracture Mechanics Assessment of Embedded Flaw Repair Acceptability for Catawba Unit 2, provides a technical basis for returning the Reactor Pressure Vessel to service with the embedded flaw repair of penetration #74 J-groove weld (Attachment 1). The technical basis includes discussion of the operating experience with embedded flaw repairs within the PWR fleet using WCAP-15987-P-A and ASME Section XI flaw analysis. The letter also discusses the applicability and conservatism of the historical analyses relative to the Catawba Unit 2 repair. The Westinghouse evaluation provides a technical basis for one additional cycle of operation.

Duke Energy's review concludes that the proposed embedded flaw repair of the RVCH penetration #74 J-groove weld is a technically sound alternative to performing an ASME Section XI Code repair in accordance with IWA-4000 and ASME Section III, NB-4450. The embedded flaw weld repair isolates the PWSCC susceptible Alloy 82/182 J-groove weld from the primary water environment by deposition of a 360-degree overlay consisting of Alloy 52 or 52M weld metal. The repair will be examined by both surface and UT examination methods as described in Section 5.2. Because Alloy 52/52M welds are considered highly resistant to PWSCC, a new PWSCC flaw should not initiate and grow through the Alloy 52/52M seal weld to reconnect the primary water environment with the embedded flaw. Furthermore, the existing flaw in the J-groove weld can no longer grow by PWSCC since the weld is isolated from the reactor coolant environment. Additional technical justification is provided in Section 5.3. In conclusion, Duke Energy believes that this proposed alternative provides an acceptable level of quality and safety as required by 10 CFR 50.55a(z)(1).

6.0 DURATION OF PROPOSED ALTERNATIVE:

The proposed alternative is for one cycle of operation until the completion of Cycle 25 (Fall 2022).

7.0 PRECEDENTS:

7.1 **ADAMS Accession Number ML18227A733. NRC approval dated August 27, 2018.** Beaver Valley, Unit No. 2 – Request for Relief from the Requirements of the ASME Code (EPID L-2018-LLR-0026).

7.2 **ADAMS Accession Number ML18142A431. NRC approval dated May 31, 2018.** Indian Point Nuclear Generating Unit No. 2 – Safety Evaluation for Relief Request IP2-ISI-RR-06 Regarding Approval of Alternative to use Embedded Weld Repair (EPID L-2018-LLR-0050).

7.3 **ADAMS Accession Number ML17062A428. NRC approval dated March 6, 2017.** Byron Station, Unit Nos. 1 and 2 – Request for Relief from the Requirements of the ASME Code (CAC NOS. MF8282 and MF8283).

7.4 **ADAMS Accession Number ML14107A332. NRC approval dated April 30, 2014.** Virgil C. Summer Nuclear Station, Unit 1 – Alternative Request Weld Repair for Reactor Vessel Upper Head Penetrations (TAC NO. MF3546).

7.5 **ADAMS Accession Number ML080280033. NRC approval dated February 14, 2008.** Indian Point Nuclear Generating Unit No. 2 – Relief Request (RR) No. RR-07 on Embedded Flaw Weld Repair (TAC NO. MD4702).

8.0 REFERENCES:

8.1 ASME Code Case N-729-6, “Alternative Examination Requirements for PWR Reactor Vessel Upper Heads with Nozzles Having Pressure-Retaining Partial-Penetration Welds,” Section XI, Division 1, American Society of Mechanical Engineers, New York, Approved March 3, 2016.

8.2 ASME Boiler and Pressure Vessel Code, Section XI, “Rules for Inservice Inspection of Nuclear Power Plant Components,” 2007 Edition with the 2008 Addenda.

8.3 ASME Boiler and Pressure Vessel Code, Section III, “Rules for Construction of Nuclear Facility Components,” 1971 Edition through Winter 1972 Addenda.

8.4 ASME Boiler and Pressure Vessel Code, Section III, “Rules for Construction of Nuclear Facility Components,” 1989 Edition.

8.5 RVCH ISI INR C2R24-001 Rev 3, “Catawba Unit 2 (C2R24) Reactor Vessel Closure Head Penetration In-Service Inspection Indication Notification Report, Reactor Vessel Closure Head, Penetration ID: 74, Change in back-wall reflectivity (UTLP),” dated April 20, 2021.

8.6 RVCH ECT INR C2R24-001 Rev 2, “Catawba Unit 2 (C2R24) Reactor Vessel Closure Head Penetration In-Service Inspection Indication Notification Report, Reactor Vessel Closure Head, Penetration ID: 74, CRDM Nozzle to RVCH Shell Weld Surface,” dated April 21, 2021.

8.7 RVCH PT INR C2R24-001 Rev 0, "Catawba Unit 2 (C2R24) Reactor Vessel Closure Head Penetration In-Service Inspection PT Indication Notification Report, Reactor Vessel Closure Head, Penetration ID: 74," dated April 22, 2021.

8.8 Westinghouse Topical Report, WCAP-15987-P, Revision 2-P-A, "Technical Basis for the Embedded Flaw Process for Repair of Reactor Vessel Head Penetrations," dated December 2003.

8.9 Letter from H. N. Berkow (U.S. NRC) to H. A. Sepp (Westinghouse Electric Company), "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)," dated July 3, 2003, ADAMS Accession Number ML031840237.

8.10 LTR-PSDR- TAM-14-005-NP, Revision 3, "Technical Basis for Optimization or Elimination of Liquid Penetrant Exams for the Embedded Flaw Repair," May 2015.

8.11 WCAP-13998, Revision 1, "RV Closure Head Penetration Tube ID Weld Overlay Repair," November 1995.

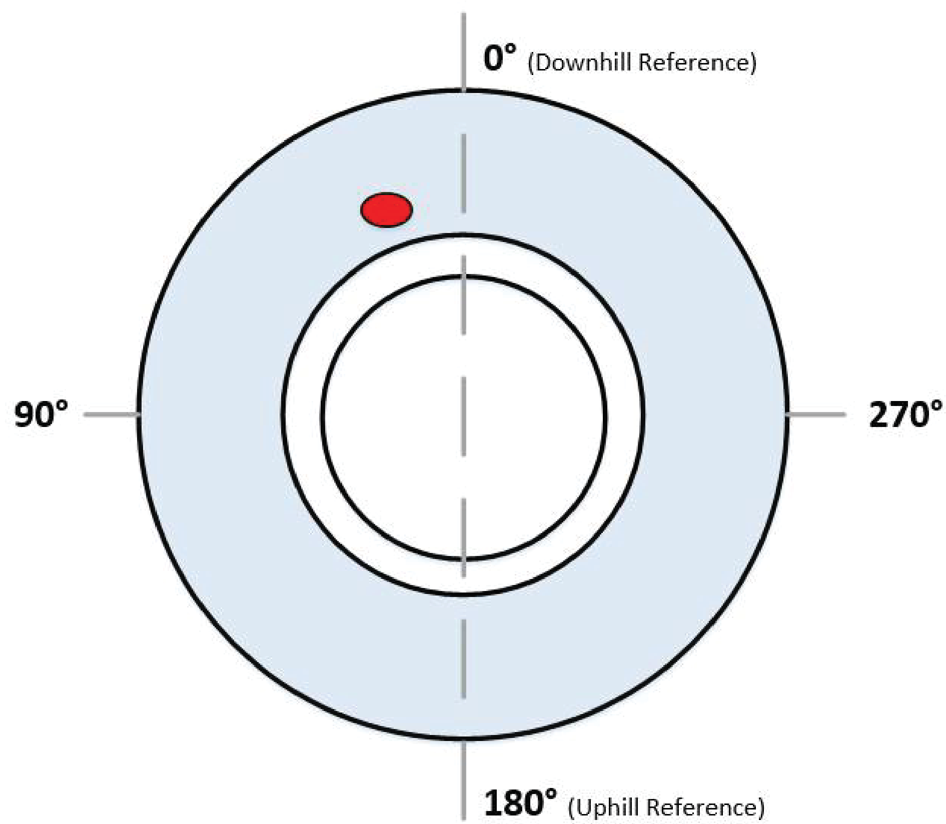

Figure 1: Location of Weld Surface Indication (Representative)

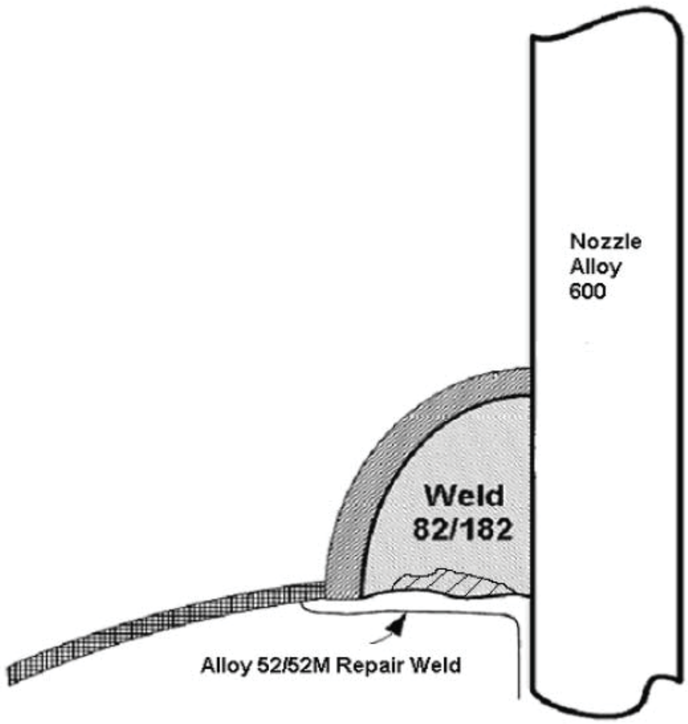

Figure 2: Repair of J-groove Weld

Attachment 1

Fracture Mechanics Assessment of Embedded Flaw Repair Acceptability for Catawba Unit 2
(6 pages plus the cover)

Westinghouse Non-Proprietary Class 3

LTR-SDA-21-027 Revision 0

Fracture Mechanics Assessment of Embedded Flaw Repair Acceptability for Catawba Unit 2

April 2021

Author: Stephen Marlette*, RV/CV Design and Analysis

Verifier: Anees Udyawar*, RV/CV Design and Analysis

Reviewer: Dave Barton*, WWM Engineering

Stephan L. Abbott*, RV/CV Design and Analysis

Manager: Lynn Patterson*, RV/CV Design and Analysis

*Electronically approved records are authenticated in the electronic document management system.

Background on Embedded Flaw Repair

During the Spring 2021 outage, as a part of the ultrasonic examination (UT) for the inservice inspection at Catawba Nuclear Station Unit 2 (CNS2), a leak path indication was found in the reactor vessel head Penetration No. 74 J-groove weld. Subsequent, manual eddy current testing (ET) examination revealed a single circumferential linear indication on the surface of the J-groove weld approximately 0.8” from the downhill side counter-clockwise looking up and 0.5” from the toe of the weld.

Therefore, the use of the Westinghouse embedded flaw repair process for Penetration No. 74 at Catawba Unit 2 is appropriate and is consistent with repairs performed for numerous other plants with similar as-found indications in the J-groove weld. The embedded flaw repair process involves depositing weld material, which is Primary Water Stress Corrosion Cracking (PWSCC) resistant, over the entire surface of the J-groove weld on the penetration nozzle of interest, as well as over the outside surface of the nozzle tube as shown in Figure 1. At least three weld layers of Alloy 52/52M repair weld material are deposited (360° full circumference) covering the wetted surface of the penetration nozzle J-groove weld including 0.5 inch past the J-groove weld buttering and stainless steel cladding interface. At least two weld layers of A52/52M are deposited on the outside surface of the head penetration nozzle below the J-groove weld. Since the Alloy 52/52M repair weld material is PWSCC resistant, the detected indications in the attachment weld of the head penetration nozzle of interest is then isolated from the primary water environment and is no longer susceptible to PWSCC.

Since 2001, Westinghouse has completed approximately 55 embedded flaw repairs (EFR) for indications on the J-groove weld or the outside surface of the penetration nozzle. After each embedded flaw repair was implemented, each repair has been inspected by PT in subsequent outages. To date, no PT examination has shown evidence of PWSCC in the embedded flaw repair deposits. Thus, the lack of any further PWSCC related cracking after the implementation of the EFR demonstrates the overall acceptable inservice performance of this particular repair method.

The embedded flaw repair methodology is based on extensive analytical work completed by the Westinghouse Owners Group (currently the Pressurized Water Reactor Owners Group (PWROG)), and a large collection of test data obtained under the sponsorship of Westinghouse, Babcock & Wilcox (B&W) and the former Combustion Engineering Owners groups (CEOG), as well as the Electric Power Research Institute (EPRI). The technical basis of the embedded flaw repair process is documented in WCAP-15987-P Revision 2-P-A [1] and has been reviewed and accepted by the Nuclear Regulatory Commission (NRC) in the United States. In the NRC Safety Evaluation Report that was incorporated in WCAP-15987-P Revision 2-P-A, the NRC staff concluded that the embedded flaw repair process described in WCAP-15987-P provides an acceptable level of quality and safety. The staff also concluded that WCAP-15987-P is acceptable for referencing in licensing applications.

Embedded Flaw Repair Assessment

With the implementation of the embedded flaw repair process at Catawba Unit 2, PWSCC is mitigated and no longer a credible crack growth mechanism. Fatigue is the only remaining credible crack growth mechanism. While normal steady state operating stresses are the primary driving forces for crack growth due to PWSCC, the through-wall stresses resulting from plant operating thermal and pressure transients are the driving forces for fatigue crack growth. The pressure and thermal transients in the closure head region are typically very mild as indicated by the low fatigue usage factors in that region. The CNS2 fatigue usage at the J-groove weld is approximately 0.3 considering conservative operational basis earthquake (OBE) loads with postulated cycles over 60 years of operation. As a result, fatigue crack growth is expected to be negligible, especially for the short time duration of 18 months between inspections.

The previous analyses performed for embedded flaw repairs have demonstrated a design life greater than 10 years considering very conservative postulated flaws. Since the UT technology cannot characterize the flaw shape in the attachment weld, the fracture mechanics evaluations that have been performed assuming a hypothetical flaw that extends radially over the entire attachment weld cross-section. Thus, the historical evaluations have always bounded any actual flaws that may have been present within the attachment weld. The methodology and guidance for the fracture mechanics evaluation used in the embedded flaw repair evaluations are based on the NRC accepted WCAP-15987 Rev 2-P-A, Appendix C.3 [1].

The fatigue crack growth of the postulated J-groove weld flaw considers growth through the weld repair (about 3/16 inch thick) and also through the reactor vessel head. This fatigue crack growth assessment is performed as part of the fracture mechanics evaluation to demonstrate the integrity of the repair layer. Due to the relative thickness of the seal weld compared to the RV head, crack growth analysis results through the repair weld have always been the limiting case; however, the analysis also considers fatigue crack growth through the reactor vessel head as well. Based on the fatigue crack growth results for other four loop plants, with similar vessel head penetration configuration, any assumed postulated flaw in the attachment weld will take a period longer than 10 years to grow through the repair layer. Fatigue crack growth through the reactor vessel head, for postulated flaws in the attachment weld, is much slower and provides more than 40 years of operating life. Fatigue crack growth evaluations of postulated flaws in the Alloy 600 tube (although no base metal indications were detected at Penetration No. 74 at Catawba Unit 2) have also been performed and have produced insignificant growth of postulated flaws. Any initial postulated axial or circumferential flaws (on the order of 20% of the tube wall thickness) embedded in the Alloy 600 tube after the repair would not reach 75% of the wall thickness (ASME Section XI allowable [2]) in less than 10 years. Thus, these previous fracture mechanics evaluations demonstrate that a postulated flaw size encompassing the attachment weld shape or postulated flaws in the Alloy 600 tube are acceptable for duration of at least 10 years based on ASME Section XI flaw evaluation rules.

The above mentioned fracture mechanics evaluations consider through-wall time history transient and welding residual stresses based on the outermost reactor vessel head penetration nozzle, and is based on a detailed three-dimensional elastic-plastic finite element analysis. The outermost penetration nozzle through-wall stresses are the highest, most conservative, and therefore bound the embedded flaw repair analysis of any of the penetration nozzles. For Catawba Unit 2 the indication was found on one of the outermost penetrations (Penetration 74), which is similar to bounding location analyzed in previous analyses for other four loop plants. In addition, several of the previous reactor vessel head repairs analyzed were four loop Westinghouse plants similar in construction to Catawba Unit 2, with similar design basis transients. Thus, the fracture mechanics results determined for a typical plant with an indication on the outermost penetration bound the indication found on Penetration No. 74 for Catawba Unit 2.

Catawba Unit 2 is requesting operation for one fuel cycle (18 months) with the embedded flaw repair at Penetration No. 74. As mentioned above, plant specific analysis experiences for plants with embedded flaw repairs show that the integrity of the embedded flaw repair and acceptability of the flaws in the repaired penetration nozzles were demonstrated for 10 years or more of plant operation. Examinations performed at these plants in subsequent refueling outages after the repair, have shown no evidence of any crack growth or new cracks in the repaired penetration nozzles of interest. Thus, the 10 year or more service life justified by analysis has remained valid after each inspection, extending the operation duration to another 10 years for the repair.

The flaw detected in Catawba Unit 2 is typical of those detected in the head penetration nozzle attachment weld that is subjected to PWSCC. Plant specific technical basis evaluations have been performed for a number of plants in the United States that have flaws similar to Catawba Unit 2, which have been repaired using the embedded flaw repair process. These technical basis evaluations have been submitted, reviewed and accepted by the NRC and have, in each case, confirmed that the embedded flaw repair process meets the acceptable level of quality and safety. In addition, the NRC Staff has previously accepted the use of the WCAP-15987-P, Revision 2-P-A repair method without a site specific analyses on a one-cycle-of-operation (i.e. 24 months) basis based on the successful operating history of embedded flaw repairs [3, 4]. It should be noted that a detailed fracture mechanics analysis was performed after the refueling outage for the plant identified in [3, 4] to demonstrate continued long-term operation of the plant with the embedded flaw repair.

Conclusion of Embedded Flaw Repair Acceptability Assessment

Based on actual plant operating experiences with similar embedded flaw repairs performed for more than 50 penetration nozzles across the US fleet, it is concluded that the Westinghouse Embedded Flaw Repair methodology can be successfully used to repair the as-found flaw detected at Catawba Unit 2 penetration nozzle attachment weld. The basis for this conclusion has been demonstrated through numerous ASME Section XI analyses reviewed and accepted by the NRC, as well as inspection results since 2001 that have shown no additional flaw growth of any kind after the repairs. The success of the embedded flaw repair is attributed to the PWSCC resistant weld metal used to cover the susceptible region of the head penetrations and the negligible fatigue crack growth rate within the closure head region. Catawba Unit 2 Penetration No. 74 is an outermost penetration on the reactor vessel head and is similar to analyzed outer penetration locations previously justified for more than ten years of operation with an embedded flaw repair. Furthermore, the previous fracture mechanics evaluations for the embedded flaw repair performed in accordance with the NRC approved WCAP-15987 Revision 2-P-A [1] report have demonstrated that a postulated flaw size encompassing the attachment weld shape are acceptable for duration of at least 10 years based on ASME Section XI flaw evaluation rules. The embedded flaw repair proposed for Catawba Unit 2 Penetration No. 74 is considered bounded by previous analyses and therefore the structural integrity of the closure head and the penetration are maintained for at least one fuel cycle of operation (18 months).

References

1. Westinghouse WCAP-15987-P, Revision 2-P-A, "Technical Basis for the Embedded Flaw Process for Repair of Reactor Vessel Head Penetrations," December 2003. (Westinghouse Proprietary Class 2). NRC Safety Evaluation Report, Accession No. ML031840237.

2. ASME Boiler & Pressure Vessel Code, 2007 Edition with 2008 Addenda, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components.

3. NRC Verbal Authorization ML18099A373, Verbal Authorization by the Office of Nuclear Reactor Regulation for Relief Request IP2-ISI-RR-06 Alternate Repair of a Reactor Vessel Head Penetration Nozzle Entergy Nuclear Operations, Inc. Indian Point Unit 2 Docket NO. 50-247, April 9, 2018.

4. U. S. NRC, "Indian Point Nuclear Generating Unit No. 2 – Safety Evaluation for Relief Request IP2-ISI-RR-06 Regarding Approval of Alternative to Use Embedded Weld Repair (EPID L-2018-LLR-0050)." May 31, 2018. (NRC Accession No. ML18142A431).

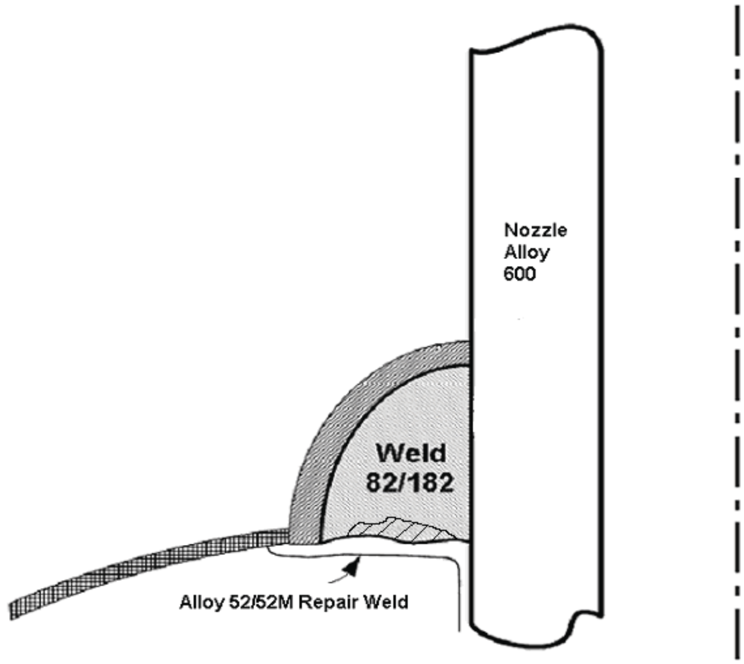

Figure 1 Schematic of Typical Repair Configuration for the Surface Flaw in the J-groove Weld