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May 20, 2019

10 CFR 50.55a

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

BRUNSWICK STEAM ELECTRIC PLANT, UNITS 1 AND 2, DOCKET NOS. 50-325, 50-324

CATAWBA NUCLEAR STATION, UNITS 1 AND 2, DOCKET NOS. 50-413, 50-414

MCGUIRE NUCLEAR STATION, UNITS 1 AND 2, DOCKET NOS. 50-369, 50-370

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3, DOCKET NOS. 50-269, 50-270, 50-287

H.B. ROBINSON STEAM ELECTRIC PLANT, UNIT 2, DOCKET NO. 50-261

SHEARON HARRIS NUCLEAR POWER PLANT, UNIT 1, DOCKET NO. 50-400

SUBJECT: Relief Request (19-GO-001) Proposed Alternative to use Encoded Phased Array Ultrasonic Examination in Lieu of Radiography for Welds in Ferritic or Austenitic Pipe Section XI, Division 1

Pursuant to 10 CFR 50.55a(z)(1), Duke Energy Carolinas, LLC and Duke Energy Progress, LLC (hereafter referred to collectively as Duke Energy) request NRC approval to implement a proposed alternative to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, “Rules for Inservice Inspection of Nuclear Power Plant Components.”

The ASME Boiler and Pressure Vessel Code, Section XI requires that ferritic and austenitic piping welds be examined using radiographic examination techniques to satisfy nondestructive examination requirements. Duke Energy requests NRC approval to use encoded phased array ultrasonic examination techniques as an alternative to radiographic examination. Duke Energy considers that the proposed alternative provides an acceptable level of quality and safety.

Enclosure 1 contains Relief Request 19-GO-001 associated with the use of encoded phased array ultrasonic examination techniques in lieu of radiography for ferritic and austenitic piping welds. The duration of the proposed alternative request is for the remainder of the current 10-year inservice inspection interval for each unit as described in Table 1 of Enclosure 1.

Duke Energy requests that this Relief Request receive review and approval by May 20, 2020.

If you have questions concerning this request, please contact Art Zaremba, Director - Fleet Licensing, at (980) 373-2062.

Sincerely,

Steve Snider
Vice President – Nuclear Engineering

Enclosure:

1. Relief Request 19-GO-001: Relief Request Associated with the Use of Encoded Phased Array Ultrasonic Examination Technique in Lieu of Radiography for Ferritic and Austenitic Piping Welds

cc : (all with Enclosure unless otherwise noted)

C. Haney, Regional Administrator USNRC Region II
J. D. Austin, USNRC Senior Resident Inspector – CNS
G. A. Hutto, USNRC Senior Resident Inspector - MNS
J. Zeiler, USNRC Senior Resident Inspector – HNP
J. Hammon, USNRC Senior Resident Inspector – RNP
G. Smith, USNRC Senior Resident Inspector - BNP
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M. C. Barillas, NRR Project Manager – HNP
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M. Mahoney, NRR Project Manager - CNS & MNS
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Enclosure 1

Duke Energy Carolinas, LLC

Duke Energy Progress, LLC

Relief Request 19-GO-001

Relief Requested in Accordance with 10 CFR 50.55a(z)(1)

Relief Request Associated with the Use of Encoded Phased Array Ultrasonic Examination Technique in Lieu of Radiography for Ferritic and Austenitic Piping Welds

1.0 ASME CODE COMPONENTS AFFECTED:

All American Society of Mechanical Engineers (ASME), Boiler & Pressure Vessel (BPV) Code, Section XI, ISI ferritic and austenitic piping welds requiring radiography during repair/replacement activities at plants identified in Table 1 of this request.

2.0 APPLICABLE CODE EDITION AND ADDENDA:

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

Table 1

Plant/Unit(s)	ISI Interval	ASME Section XI Code Edition/Addenda	Interval Start Date	Interval End date
Brunswick Steam Electric Plant Units 1 and 2	Fifth	2007 Edition, Through 2008 Addendum	05/11/2018	05/10/2028
Catawba Nuclear Station Units 1 and 2	Fourth	2007 Edition, Through 2008 Addendum	08/19/2015	12/06/2024 (Unit 1) 02/24/2026 (Unit 2)
H.B. Robinson Steam Electric Plant Unit 2	Fifth	2007 Edition, Through 2008 Addendum	07/21/2012	02/19/2023
McGuire Nuclear Station Units 1 and 2	Fourth	2007 Edition, Through 2008 Addendum	12/01/2011 (Unit 1) 07/15/2014 (Unit 2)	11/30/2021 (Unit 1) 12/14/2024 (Unit 2)
Oconee Nuclear Station Units 1, 2, and 3	Fifth	2007 Edition, Through 2008 Addendum	07/15/2014	07/15/2024
Shearon Harris Nuclear Power Plant Unit 1	Fourth	2007 Edition, Through 2008 Addendum	09/09/2017	09/08/2027

3.0 APPLICABLE CODE REQUIREMENTS:

IWA-4221 requires that items used for repair/replacement activities meet the applicable Owner's Requirements and Construction Code requirements when performing repair/replacement activities. IWA-4520 requires that welded joints made for installation of items be examined in accordance with the Construction Code identified in the Repair/Replacement Plan.

4.0 REASON FOR REQUEST:

Replacement of piping is periodically performed in support of the Flow Accelerated Corrosion (FAC) program as well as other repair and replacement activities. The use of encoded Phased Array Ultrasonic Examination Techniques (PAUT) in lieu of radiography (RT) to perform the required examinations of the replaced welds would eliminate the safety risk associated with performing RT, which includes the planned exposure and the potential for accidental personnel exposure to plant workers. PAUT also minimizes the impact on other outage activities normally involved with performing RT such as limited access to work.

In addition, encoded PAUT is equivalent or superior to the code-required RT examination for ASME ferritic and austenitic piping repair/replacement welds for detecting and sizing critical (planar) flaws, such as cracks and lack of fusion. PAUT provides sizing capabilities for both depth and length dimensions of the flaw, which are required to apply the acceptance criteria of the applicable code case. RT does not provide depth sizing capabilities.

Duke Energy requests approval of this proposed alternative for the remainder of the intervals identified in Section 2 above.

5.0 PROPOSED ALTERNATIVE AND BASIS FOR USE:

5.1 Proposed Alternative

Encoded PAUT is proposed in lieu of the Code-required RT examination for ASME ferritic and austenitic piping repair/replacement welds. Similar techniques are being used throughout the nuclear industry for examination of dissimilar metal welds and overlaid welds, as well as other applications including ASME B31.1 piping replacements. The capability of this alternative technique is comparable to the examination methods documented in the ASME Code Sections III, VIII, IX, and XI, and associated code cases (References 8.1, 8.3, 8.4, 8.5, 8.7, 8.8, 8.9, and 8.10) using ultrasonic examination techniques for weld acceptance. This proposed alternative request includes requirements that provide an acceptable level of quality and safety to satisfy the requirements of 10 CFR 50.55a(z)(l), by the use of encoded PAUT.

1. Limitations of Use
   a. Use of this alternative request is limited to welds made as part of a repair/replacement activity and is subject to review by the Authorized Inspection Agency.
   b. The ultrasonic examination shall be performed using encoded PAUT technology that produces an electronic record of the ultrasonic responses indexed to the probe position, permitting off-line analysis of ultrasonic data.
   c. Where component configuration does not allow for effective examination for transverse flaws, (e.g., pipe-to-valve, tapered weld transition, weld shrinkage, etc.) the use of non-encoded PAUT technology may be used for transverse flaws. The basis for the non-encoded examination shall be documented.
   d. The ultrasonic examination shall be performed with equipment, procedures, and personnel qualified by performance demonstration as described below.
   e. The qualification shall be applicable to the scope of the procedure, e.g., flaw detection or sizing (length or through-wall height), single or dual side access.
   f. The welds to be examined shall be conditioned such that the transducers properly couple with the scanning surface with no more than a 1/32 in. gap between the search unit and the scanning surface.
2. Examination Volume and Examination Coverage
   a. The examination volume shall include 100% of the weld volume and the weld-to-base-metal interface.
   b. Angle beam examination of the complete examination volume for fabrication flaws oriented parallel (circumferential flaws) to the weld joint shall be performed.
   c. Angle beam examination for fabrication flaws, oriented transverse (axial flaws) to the weld joint shall be performed to the extent practical. Scan restrictions that limit coverage shall be documented.
   d. A supplemental straight beam examination shall be performed on the volume of base metal through which the angle beams will travel to locate any reflectors that can limit the ability of the angle beam to examine the weld.
      1) Detected laminar reflectors that may limit the angle beam examination shall be recorded and evaluated for impact on examination coverage.

3. Acceptance Criteria
   a. All detected axial and circumferential flaws from paragraphs 5.1(2)(b) and 5.1(2)(c) shall be evaluated as planar flaws and compared to the preservice acceptance standards for volumetric examination in accordance with IWB-3000, IWC-3000 or IWD-3000, as applicable.
4. Evaluation of Flaws
   a. Analytical evaluation for acceptance of flaws in accordance with IWB-3600, IWC-3600 or IWD-3600 is permitted for flaws that exceed the applicable acceptance standards and are confirmed by surface or volumetric examination to be non-surface connected.
   b. Flaws exceeding the applicable acceptance standards and where analytical evaluation has not been performed for acceptance, shall be reduced to an acceptable size or removed and repaired, and the location of the repair shall be reexamined using the same ultrasonic qualified technique that detected the flaw.
5. The written ultrasonic examination procedure qualified by performance demonstration as described in paragraph 5.3 shall be used. The PAUT procedure shall:
   a. Contain a statement of scope that specifically defines the limits of procedure applicability (e.g., minimum and maximum thickness, minimum and maximum diameter, scanning access);
   b. Specify which parameters are considered essential variables, and a single value, a range of values or criteria for selecting each of the essential variables;
   c. List the examination equipment, including manufacturer and model or series;
   d. Define the scanning requirements; such as beam angles, scan patterns, beam direction, maximum scan speed, extent of scanning, and access;
   e. Contain a description of the calibration method (i.e., actions required to ensure that the sensitivity and accuracy of the signal amplitude and time outputs of the examination system, whether displayed, recorded, or automatically processed, are repeated from examination to examination);
   f. Describe the method and criteria for discrimination of indications (e.g., geometric indications versus indications of flaws and surface versus subsurface indications); and
   g. Describe the surface preparation requirements.

5.2 Performance Demonstration Specimens

Performance demonstration specimens shall conform to the following requirements.

1. The specimens shall be fabricated from ferritic or austenitic material, similar to the material being examined. Ferritic specimens shall be fabricated with the same inside surface cladding process, if applicable, with the following exceptions:
   a. Demonstration with shielded metal arc weld (SMAW) single-wire cladding is transferable to multiple-wire or strip-clad processes;
   b. Demonstration with multiple-wire or strip-clad process is considered equivalent but is not transferable to SMAW type cladding processes.
2. The demonstration specimens shall contain a weld representative of the joint to be ultrasonically examined, including the same welding processes.

3. The demonstration set shall include specimens not thicker than 0.1 in. more than the minimum thickness, nor thinner than 0.5 in. less than the maximum thickness for which the examination procedure is applicable.
4. The demonstration set shall include the minimum, within ½ inch of the nominal outside diameter (OD), and maximum pipe diameters for which the examination procedure is applicable.
5. If the procedure is applicable to piping of 24 in. OD or larger, the specimen set must include at least one specimen 24 in. OD or larger but need not include the maximum diameter.
6. The demonstration specimen scanning, and weld surfaces shall be representative of the surfaces to be examined.
7. The demonstration specimen set shall include geometric conditions that require discrimination from flaws (e.g., counterbore, weld root conditions, or weld crowns) and limited scanning surface conditions for single-side access, when applicable.
8. The demonstration specimens shall include both planar and volumetric fabrication flaws (e.g., lack of fusion, crack, incomplete penetration, slag inclusions) representative of the welding process or processes of the welds to be examined.
9. The flaws shall be distributed throughout the examination volume.
10. Specimens shall be divided into flawed and unflawed grading units as follows:
    a. Flawed grading units shall be the actual flaw length, plus a minimum of 0.25 in. on each end of the flaw. Unflawed grading units shall be at least 1 in.;
    b. The number of unflawed grading units shall be at least 1-1/2 times the number of flawed grading units.
11. Demonstration specimen set flaw distribution shall be as follows:
    a. For thickness greater than 0.50 in.:
        1) At least 20% of the flaws shall be distributed in the outer third of the specimen wall thickness
        2) At least 20% of the flaws shall be distributed in the middle third of the specimen wall thickness
        3) At least 40% of the flaws shall be distributed in the inner third of the specimen wall thickness
    b. For thickness 0.50 in. and less,
        1) At least 20% of the flaws shall be distributed in the outer half of the specimen wall thickness
        2) At least 40% of the flaws shall be distributed in the inner half of the specimen wall thickness
    c. For all thicknesses
        1) At least 30% of the flaws shall be classified as surface planar flaws in accordance with IWA-3310
        2) At least 40% of the flaws shall be classified as subsurface planar flaws in accordance with IWA-3320
        3) At least 50% of the flaws shall be planar flaws, such as lack of fusion, incomplete penetration, or cracks

4) At least 20% of the flaws shall be volumetric flaws, such as slag inclusions.

5) If applicable, at least two flaws, but no more than 30% of the flaws, shall be oriented perpendicular (axial) to the weld fusion line and the remaining flaws shall be circumferentially oriented.

d. For Demonstration of Single-Side-Access Capabilities,

1) At least 30% of the flaws shall be located on the far side of the weld centerline

2) At least 30% of the planar flaws shall be located on the near side of the weld centerline

3) The remaining flaws shall be distributed on either side of the weld

e. Through-Wall Height Flaws

1) The flaw through-wall heights shall be based on the applicable acceptance standards for volumetric examination in accordance with IWB-3400, IWC-3400 or IWD-3000, as applicable.

2) At least 30% of the flaws shall be classified as acceptable planar flaws, with the smallest flaws being at least 50% of the maximum allowable size based on the applicable a/ℓ aspect ratio for the flaw.

3) Additional smaller flaws may be included in the specimens to assist in establishing a detection threshold but shall not be counted as a missed detection if not detected.

4) At least 30% of the flaws shall be classified as unacceptable in accordance with the applicable acceptance standards.

12. Welding Fabrication Flaw Through-Wall Sizes

a. Welding fabrication flaws are typically confined to a height of a single weld pass.

b. Flaw through-wall height distribution shall range from approximately one to four weld pass thicknesses, based on the welding process used.

5.3 Procedure Performance Demonstration

1. The straight beam examination procedure, or the straight beam portion of the procedure, is required to be demonstrated in accordance with ASME Section V, Articles 1 and 4.

2. Ultrasonic examination procedures shall be qualified by performance demonstration in accordance with the following requirements.

a. The procedure demonstration specimen set shall include at least 30 flaws meeting the requirements of paragraph 5.2.

b. Procedure modifications or enhancements made to the procedure, based on the feedback process, shall be applied to all applicable specimens based on the scope of the changes.

c. The procedure demonstration specimen set shall be representative of the procedure scope and limitations (e.g., thickness range, diameter range, material, access, surface condition).

d. The demonstration set shall include specimens to represent the minimum and maximum diameter and thickness covered by the procedure. If the procedure spans a range of diameters and thicknesses, additional specimens shall be included in the set to demonstrate the effectiveness of the procedure throughout the entire range.

3. The procedure shall be qualified using either a blind or a non-blind demonstration.

a. The non-blind performance demonstration is used to assist in optimizing the examination procedure.

b. When applying the non-blind performance demonstration process, personnel have access to limited knowledge of specimen flaw information during the demonstration process.

c. The non-blind performance demonstration process consists of an initial demonstration without any flaw information, an assessment of the results and feedback on the performance provided to the qualifying candidate.

d. After an assessment of the initial demonstration results, limited flaw information may be shared as part of the feedback process to assist in enhancing the examination procedure to improve the procedure performance.

e. In order to maintain the integrity of the specimens for blind personnel demonstrations, only generalities of the flaw information may be provided.

5.4 Procedure Performance Demonstration Acceptance Criteria

1. Objective evidence of a flaw's detection, length and through-wall height sizing, in accordance with the procedure requirements, shall be provided to the Ultrasonic Level III or organization administering the performance demonstration.
2. Root Mean Square (RMS) error shall be calculated as follows:

$$\mathrm{RMS} = \left[\frac{\sum_{i=1}^{n} (m_i - t_i)^2}{n} \right]^{1/2}$$

where

m_i = measured flaw size
t_i = true flaw size
n = number of flaws measured

3. To be qualified for flaw detection,
   a. All flaws in the demonstration set that are not less than 50% of the maximum allowable size, based on the applicable a/ℓ aspect ratio for the flaw, shall be detected.
   b. In addition, when performing blind procedure demonstrations, no more than 20% of the non-flawed grading units may contain a false call. Any non-flaw condition (e.g., geometry) reported as a flaw shall be considered a false call.
4. To be qualified for flaw length sizing,
   a. The RMS error of the flaw lengths estimated by ultrasonics, as compared with the true lengths,
      1) Shall not exceed 0.25 in. for diameters of NPS 6.0 in. and smaller
      2) Shall not exceed 0.75 in. for diameters greater than NPS 6.0 in.

5. To be qualified for flaw through-wall height sizing,
   a. The RMS error of the flaw through-wall heights estimated by ultrasonics, as compared with the true through-wall heights, shall not exceed 0.125 in.
6. Essential variables may be changed during successive personnel performance demonstrations. Each examiner need not demonstrate qualification over the entire range of every essential variable.
7. Expansion of a procedure, demonstrated to include an additional material type (i.e. ferritic or austenitic) shall meet the following:
   a. The procedure expansion may be performed during successive personnel performance demonstrations, performed as described in paragraph 5.5(2), with the exception that all flaws must be detected.
   b. The examination technique is the same, e.g. wave modes, angles, V-path, access, etc. Any changes in essential variables as identified in ASME Section V, Article 4 shall require additional demonstration.
   c. The demonstration set must include the minimum and maximum diameter and thickness range of the new material being demonstrated.
   d. Personnel using the expanded procedure shall demonstrate the additional material type in accordance with paragraph 5.5.

5.5 Personnel Performance Demonstration

1. Ultrasonic examination personnel shall be qualified in accordance with IWA-2300.
2. In addition, examination personnel shall demonstrate their capability to detect and size flaws by performance demonstration using the qualified procedure in accordance with the following requirements.
   a. The personnel performance demonstration shall be conducted in a blind fashion (flaw information is not provided), except for personnel initially qualifying the procedure shall be qualified during the procedure qualification process.
   b. The demonstration specimen set shall contain at least 10 flaws and shall meet the flaw distribution requirements of paragraph 5.2, with the exception of paragraph 5.2(11)(c)(5).
   c. When applicable, at least one flaw, but no more than 20% of the flaws, shall be oriented perpendicular to the weld fusion line and the remaining flaws shall be circumferentially oriented.
3. Personnel performance demonstration acceptance criteria:
   a. To be qualified for flaw detection:
      1) At least 80% of the flaws in the demonstration set shall be detected
      2) No more than 20% of the grading units shall contain a false call
      3) Any non-flaw condition (e.g., geometry) reported as a flaw shall be considered a false call
   b. To be qualified for flaw length sizing, the RMS error of the flaw lengths estimated by ultrasonics, as compared with the true lengths, shall not exceed:
      1) 0.25 in. for NPS 6.0 in. and smaller
      2) 0.75 in. for diameters larger than NPS 6.0 in.

c. To be qualified for flaw through-wall height sizing, the RMS error of the flaw through-wall heights estimated by ultrasonics, as compared with the true through-wall heights, shall not exceed 0.125 in.

5.6 Review and Documentation

1. Duke Energy is responsible for reviewing the procedure and demonstration results to validate that the ranges of the essential variables in the procedure were included in the demonstration.
2. Documentation of the qualifications of procedures and personnel shall be maintained. Documentation shall include identification of personnel, NDE procedures, equipment and specimens used during qualification, and results of the performance demonstration.

5.7 Basis for Use

1. The basis for this proposed alternative is that encoded PAUT is equivalent or superior to RT for detecting and sizing critical (planar) flaws. In this regard, the basis for the proposed alternative was developed from numerous codes, code cases, associated industry experience, articles, and the results of RT and encoded PAUT examinations. Applicable ASME Section V and ASME B31.1 code cases not referenced in Section 8.0 have been annulled and incorporated into the code.
2. The examination procedure and personnel performing examinations are qualified using representative piping conditions and flaws that demonstrate the ability to detect and size flaws that are both acceptable and unacceptable to the defined acceptance standards.
3. The demonstrated ability of the examination procedure and personnel to appropriately detect and size flaws provides an acceptable level of quality and safety alternative as allowed by 10 CFR 50.55a(z)(l).

6.0 DURATION OF PROPOSED ALTERNATIVE:

This alternative is requested for the duration of the inservice inspection intervals listed in Table 1 of this request.

7.0 PRECEDENTS:

7.1 **ADAMS Accession Number ML18252A003. NRC approval dated September 17, 2018.** Millstone Power Station, Units 2 and 3; "Proposed Alternative Requests RR-04-27 and IR-3-38, Use of Encoded Phased Array Ultrasonic Examination Techniques in Lieu of Radiography," dated February 28, 2018 (ML18066A522).

7.2 **ADAMS Accession Number ML18236A236. NRC approval dated September 26, 2018.** Surry Power Station, Units 1 and 2; Proposed Alternative Requests S1-15-ISI-04 and S2-15-ISI-04, Use of Encoded Phased Array Ultrasonic Examination Techniques in Lieu of Radiography, dated April 11, 2018 (ML18108A123).

7.3 **ADAMS Accession Number ML18106B121. NRC approval dated April 25, 2018.** NextEra Energy for Relief No. FRR-01, Proposed Alternative for the Use of Encoded Phased Array Ultrasonic Techniques, dated July 24, 2017 (ML17208A058).

7.4 **ADAMS Accession Number ML13091A177. NRC approval dated April 12, 2013.** Palo Verde Nuclear Generating Station Relief Request 48, dated August 1, 2012 (ML12229A046).

7.5 **ADAMS Accession Number ML14091A973. NRC approval dated April 04, 2014.** Millstone Power Station Unit 2 Alternative Request RR-04-16, dated August 1, 2013 (ML13220A019).

7.6 **ADAMS Accession Number ML15257A005. NRC approval dated September 21, 2015.** Millstone Power Station Unit 2 Alternative Request RR-04-21, dated October 6, 2014 (ML14283A128).

7.7 **ADAMS Accession Number ML15257A005. NRC approval dated September 21, 2015.** Millstone Power Station Unit 3 Alternative Request IR-3-25, dated October 6, 2014 (ML14283A128).

7.8 **ADAMS Accession Number ML16363A089. NRC approval dated January 23, 2017.** Millstone Power Station Unit 2 Alternative Request RR-04-023, dated April 11, 2016 (ML16106A105).

7.9 **ADAMS Accession Number ML16363A089. NRC approval dated January 23, 2017.** Millstone Power Station Unit 3 Alternative Request IR-3-28, dated April 11, 2016 (ML16106A105).

7.10 **ADAMS Accession Number ML18019A195. NRC approval dated January 24, 2018.** Millstone Power Station, Units 2 and 3; North Anna Power Station, Units 1 and 2; and Surry Power Station, Units 1 and 2; "Proposed Alternative for the Use of Encoded Phased Array Ultrasonic Examination, 11 dated June 29, 2017 (ML17188A379).

7.11 **ADAMS Accession Number ML18187A149. NRC approval dated July 24, 2018.** South Texas Project, Units 1 and 2; 11 Proposed Alternative for the Use of Encoded Phased Array Ultrasonic Examination Techniques in Lieu of Radiography; Relief Request RR-ENG-3-22,11 dated December 12, 2017 (ML17346B279).

7.12 **ADAMS Accession Number ML17150A091. NRC approval dated June 05, 2017.** Exelon Generation Company, LLC, "Proposed Alternative for the Use of Encoded Phased Array Ultrasonic Examination Techniques In Lieu of Radiography," dated November 2, 2016 and amended by letter dated March 13, 2017 (ML16307A253 and ML17072A385 respectively).

8.0 REFERENCES:

8.1 ASME Section III Code Case N-659-3, “Use of Ultrasonic Examination in Lieu of Radiography for Weld Examination Section III, Division 1; Section III, Division 3,” dated October 12, 2017.

8.2 Pacific Northwest National Laboratory Report PNNL-19086, “Replacement of Radiography with Ultrasonics for the Nondestructive Inspection of Welds - Evaluation of Technical Gaps - An Interim Report,” dated April 2010.

8.3 ASME Section III, 1986 Edition, no Addenda [BNP, HNP, RNP], 1989 Edition, no Addenda [CNS, MNS, ONS].

8.4 ASME Section III, Code Case N-818-1, “Use of NDE and Fracture Mechanics for Acceptance of Full Penetration Butt Welds in Lieu of Weld Repair, Class 1 and 2 Section III, Division 1” dated August 20, 2014.

8.5 ASME Code Case 2235-13; “Use of Ultrasonic Examination in Lieu of Radiography Section I; Section XII,” dated July 9, 2014.

8.6 Journal of Pressure Vessel Technology, “Technical Basis for ASME Section VIII Code Case 2235 on Ultrasonic Examination of Welds in Lieu of Radiography;” Rana, Hedden, Cowfer and Boyce, Volume 123 dated August 2001.

8.7 ASME Section V, 2007/2008 Addenda and 2017 Edition.

8.8 ASME Section IX, 2017 Edition.

8.9 ASME Section XI, Code Case N-713, "Ultrasonic Examination in Lieu of Radiography," dated November 10, 2008.

8.10 ASME Section XI, Code Case N-831-1, "Ultrasonic Examination in Lieu of Radiography for Welds in Ferritic or Austenitic Pipe," dated July 25, 2018.

8.11 US NRC, NUREG/CR-7204, "Applying Ultrasonic Testing in Lieu of Radiography for Volumetric Examination of Carbon Steel Piping" (ADAMS Accession Number ML15253A674).

8.12 Technical Basis for Substituting Ultrasonic Testing for Radiographic Testing for New, Repaired, and Replacement Welds for ASME Section XI, Division 1, Stainless Steel Piping. EPRI, Palo Alto, CA; 2017. 3002010297.