July 6, 2017

Docket Nos.: 52-025 52-026

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

Southern Nuclear Operating Company
Vogtle Electric Generating Plant Units 3 and 4
Request for Alternative:
Application of VT-1 Visual Examination Methodology for Preservice Inspection of the
Reactor Vessel Nozzle Inner Radius Sections (VEGP 3&4-PSI-ALT-07)

Ladies and Gentlemen:

Pursuant to 10 CFR 50.55a(z)(1), Southern Nuclear Operating Company (SNC) hereby requests NRC authorization to use an alternative to the requirements of Section XI, IWB-2500, of the ASME Boiler and Pressure Vessel (B&PV) Code, 2007 Edition through 2008 Addenda (code of record) for Vogtle Electric Generating Plant (VEGP) Units 3 and 4. The proposed request for alternative is applicable to preservice inspection (PSI) of reactor vessel nozzle inner radius sections listed in Section XI Table IWB-2500-1 Examination Category B-D, Item B3.100.

The details of the 10 CFR 50.55a(z)(1) request are contained in the enclosures to this letter. Approval is requested by March 30, 2018, to support preparation for and performance of the VEGP Unit 3 Section XI PSI of reactor vessel nozzle inner radius sections.

This letter contains no regulatory commitments. Should you have any questions, please contact Mr. Corey Thomas at (205) 992-5221.
I declare under penalty of perjury that the foregoing is true and correct. Executed on the 6th day of July 2017.

Respectfully submitted,

SOUTHERN NUCLEAR OPERATING COMPANY

[Signature]

Brian H. Whitley
Director, Regulatory Affairs
Southern Nuclear Operating Company

BHW/BCT/Iss

Enclosure 1: Proposed Alternative VEGP 3&4-PSI-ALT-07 in Accordance with 10 CFR 50.55a(z)(1) – Application of VT-1 Visual Examination Methodology for Preservice Inspection of the Reactor Vessel Nozzle Inner Radius Sections

Enclosure 2: Technical Basis for the Alternative Request on Preservice Inspection Requirements for Reactor Vessel Nozzle Inner Radius Sections
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Vogtle Electric Generating Plant (VEGP) Units 3 and 4

Proposed Alternative VEGP 3&4-PSI-ALT-07 in Accordance with 10 CFR 50.55a(z)(1) - Application of VT-1 Visual Examination Methodology for Preservice Inspection of the Reactor Vessel Nozzle Inner Radius Sections

(Enclosure 1 consists of 3 pages, not including this cover page.)
<table>
<thead>
<tr>
<th><strong>Plant Site-Unit:</strong></th>
<th>Vogtle Electric Generating Plant (VEGP) – Units 3 and 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interval-Interval Dates:</strong></td>
<td>Applies to Preservice Inspection (PSI)</td>
</tr>
<tr>
<td><strong>Requested Date for Approval:</strong></td>
<td>Approval is requested by March 30, 2018 to support the preparation for and performance of the VEGP Unit 3 Section XI PSI of reactor vessel nozzle inner radius sections.</td>
</tr>
<tr>
<td><strong>ASME Code Components Affected:</strong></td>
<td>The VEGP Units 3 and 4 Reactor Vessel design has two outlet nozzles, four inlet nozzles and two direct vessel injection (DVI) nozzles.</td>
</tr>
<tr>
<td><strong>Applicable Code Requirements:</strong></td>
<td>The preservice inspection (PSI) and inservice inspection (ISI) requirements for reactor vessel nozzle inner radius sections are defined in Table IWB-2500-1, Examination Category B-D, Item B3.100. The stated examination method is volumetric.</td>
</tr>
<tr>
<td><strong>Reason for Request:</strong></td>
<td>ASME Code Section XI Code Case N-648-1, as conditionally accepted in Regulatory Guide 1.147, Revision 17, allows licensees to perform a VT-1 visual examination in lieu of a UT examination as currently required in Table IWB-2500-1, Examination Category B-D, Item B3.100 during the Inservice Interval, and it is SNC’s intention to adopt this Code Case for future ISI. The proposed alternative is requested to align the Preservice inspection with the subsequent planned Inservice Inspections. This code case applies only for ISI and is used extensively in operating units.</td>
</tr>
</tbody>
</table>
Proposed Alternative:

SNC proposes to perform a VT-1 visual examination of the nozzle inner radius sections for the two outlet nozzles, the four inlet nozzles and the two DVI nozzles using a remote underwater visual examination process that will be comparable to the subsequent inservice inspections. This visual examination will be conducted in accordance with the ASME Code Section XI, 2007 Edition with the 2008 Addenda. The allowable flaw length criteria of Table IWB-3512-1 with the flaw aspect ratio \((a/l)\) limited to 0.5 shall be applied. This revised flaw acceptance criterion is consistent with the condition defined in Regulatory Guide 1.147 for Code Case N-648-1. These VT-1 visual examinations will satisfy the PSI requirements. In addition to these VT-1 visual examinations, a liquid penetrant (PT) surface examination will be performed at the plant site on the nozzle inner radius sections of the two outlet nozzles, the four inlet nozzles and the two DVI nozzles. The PT surface examination results will be evaluated in accordance with ASME Code Section III, NB-5350. The PT examinations will be performed prior to the VT-1 visual examinations. In addition to these VT-1 visual and PT surface examinations, manual UT examinations using two opposing circumferential beam directions will be conducted from the inner diameter (ID) surface and will cover the nozzle inner radius section examination volume of the two outlet nozzles, the four inlet nozzles and the two DVI nozzles as defined in ASME Code Section XI, Figure IWB-2500-7(b). These UT examinations will be conducted using dual focused 70-degree transmit-receive longitudinal wave transducers. The UT examination procedure requirements will be in accordance with ASME Code Section XI, Appendix III as supplemented by ASME Code Section XI, Appendix I Supplements 1 - 8, 10 and 11. However the notch depth in the calibration standard is to be with an \(a/t\) equal to 2.5% consistent with the ASME Code Section XI, Table IWB-3512-1 allowable planar flaw size at the inside corner region. The UT examinations will be performed prior to the VT-1 visual examinations and after the PT examinations.
**Basis for Use:**
The technical basis for this proposed alternative is included in Enclosure 2.

This proposed alternative provides an acceptable level of quality and safety in accordance with 10 CFR 50.55a(z)(1).

**Duration of Proposed Alternative:**
The duration of the proposed alternative is the ASME Section XI preservice inspections for both VEGP Unit 3 and VEGP Unit 4.

**References:**

**Status:**
Awaiting NRC authorization
Southern Nuclear Operating Company

ND-17-1121

Enclosure 2

Vogtle Electric Generating Plant (VEGP) Units 3 and 4

Technical Basis for the Alternative Request on Preservice Inspection Requirements for Reactor Vessel Nozzle Inner Radius Sections

(Enclosure 2 consists of 16 pages, not including this cover page.)
TECHNICAL BASIS FOR THE ALTERNATIVE REQUEST ON PRESERVICE INSPECTION REQUIREMENTS FOR REACTOR VESSEL NOZZLE INNER RADIUS SECTIONS

1.0 Introduction

ASME Code Section XI Code Case (CC) N-648-1 [1] allows for the use of a VT-1 visual examination in lieu of the volumetric examination requirement defined in ASME Code Section XI, Table IWB-2500-1, Examination Category B-D, Item No. B3.100 [2]. This code case is conditionally accepted by the NRC in Regulatory Guide 1.147 [3]. The condition is that the allowable flaw length criteria of ASME Code Section XI, Table IWB-3512-1 must be used with limiting assumptions on the flaw aspect ratio. CC N-648-1 applies only to inservice inspection (ISI).

The technical basis for CC N-648-1 is documented in a paper prepared for and presented at the ASME 2001 Pressure Vessels and Piping Conference [4]. The key arguments to justify elimination of the volumetric ISI requirements are good inspection history, a large flaw tolerance, and a risk argument concluding that there is negligible change in core damage frequency with the elimination of the inspection. The logic for the VT-1 visual examination is that service-induced flaw mechanisms (fatigue) will be associated with the inner diameter (ID) surface of the cladding and that the VT-1 examinations are sufficient to detect such mechanisms occurring at the ID surface well before the nozzle suffers degradation of its structural integrity.

It is proposed to extend the application of VT-1 visual examination to the preservice inspection (PSI) subject to the following requirements:

- The surface M-N shown in Figure IWB-2500-7 sketches (a) through (d) is examined using a surface examination method and shall meet the Section III fabrication acceptance standards at least once after the Construction Code hydrostatic test. The surface examination is performed prior to the preservice VT-1 visual examination.

- The volume O-P-Q-R shown in Figure IWB-2500-7 sketches (a) through (d) is examined using a manual volumetric examination method and shall meet the Section XI acceptance standards at least once after the Construction Code hydrostatic test.

- The appropriate surface is prepared in accordance with IWA-2200(b) for application of a future volumetric examination in accordance with Table IWB-2500-1, Examination Category B-D.
An evaluation that includes the following is performed:

- Review of the fabrication examination history for the nozzle inner radius region
- Verification that the nozzle of interest meets the requirements of Section III, Nonmandatory Appendix G.

This technical basis addresses a VT-1 visual examination approach that includes a deterministic fracture assessment similar to that performed as a basis for CC N-648-1, provides a description and justification of a preservice inspection process that addresses the requirements provided above, and will provide an acceptable level of quality and safety in accordance with 10 CFR 50.55a(z)(1).

2.0 PWR Nozzle Inner Radius Section Inspection History in Industry

The ASME Code Section XI 1971 Edition through the 2015 Edition requires volumetric examination of the reactor vessel inner radius section. The original requirement for an examination of this region was developed as a result of cracking in a non-nuclear vessel that occurred around the time when the ASME Code Section XI inspection requirements were being established [6].

Up until the implementation of ASME Code Section XI Code Case N-648-1 after 2001\(^1\), volumetric examinations of PWR reactor vessel nozzle inner radius sections were conducted as required by ASME Section XI using the ultrasonic test method. No recordable flaw indications were detected [6]. Subsequently, enhanced VT-1 visual examinations with a resolution capability of distinguishing a 1-mil wire or crack have been applied to PWR reactor vessel nozzle inner radius sections. Again, no recordable flaw indications have been detected.

3.0 Reactor Vessel Nozzle Inner Radius Section Design and Fabrication Inspection History

The reactor vessel and the reactor vessel nozzles are designed in accordance with the ASME Code Section III, Subsection NB [7]. The reactor vessel nozzles are fabricated of

\(^1\) Code Case N-648-1 was conditionally approved by the NRC in Regulatory Guide 1.147, Revision 13 issued in June 2003.
SA-508, Grade 3, Class 1 [27] ferritic steel forgings clad on the inner diameter surface with multiple layers of stainless steel cladding (Type 309L first layer and Type 308L subsequent layers). The AP1000® reactor vessel has two outlet nozzles, four inlet nozzles, and two direct vessel injection (DVI) nozzles. Figure 1 through Figure 3 show elevation view cross-sections of the three nozzle types, respectively.

Figure 1: AP1000® Reactor Vessel Outlet Nozzle – Elevation View Cross-Section
Figure 2: AP1000® Reactor Vessel Inlet Nozzle – Elevation View Cross-Section
In accordance with ASME Code Section III, NB-2540, the nozzle forgings are subject to magnetic particle examination over all external surfaces and accessible internal surfaces, and ultrasonic examination of the nozzle volume in accordance with the ASME Code Section V, Article 7 and Article 5, respectively [8]. The ultrasonic test requirements are enhanced by the Westinghouse material specification for SA-508 forging materials. Such enhancements include the implementation of Supplementary Requirement S2 of SA-508 [9] that requires the use of a higher sensitivity straight beam examination calibrated on 1/4-inch diameter flat-bottomed holes rather than the forging back surface, recording and investigating of angle beam indications equal to or exceeding 20% of the reference level rather than equal to or exceeding 50% of the reference level, and specifically identifying all recordable angle beam indications located near a surface (within 15% of the wall thickness) and/or all indications that display crack-like characteristics for separate disposition.

In accordance with ASME Code Section III, NB-5120 (d), the nozzle base metal surface is examined by the magnetic particle method prior to the deposition of the stainless steel
cladding using the acceptance standards of ASME Code Section III, NB-5340. After the cladding is deposited, the cladding surface is examined by liquid penetrant method using the acceptance standards of ASME Code Section III, NB-5350. The cladding is also subject to an ultrasonic examination for lack of bond as defined in the Westinghouse fabrication specification.

After completion of welding and the intermediate heat treatment but before the post-weld heat treatment, the ultrasonic test method is applied for the examination of the inlet, outlet and DVI nozzle inner radius section volumes as defined by ASME Code Section XI, Figure IWB-2500-7(b). The nozzle inner radius section volumes are shown in Figures 1 through 3. These examinations are conducted from the inside and outside diameter surfaces in accordance with the examination procedure requirements of ASME Code Section V, Article 4 and using the acceptance standards of ASME Code Section XI, IWB-3512. These are mandatory supplemental requirements defined in the Westinghouse fabrication specification.

After the vessel hydrostatic test, the Westinghouse fabrication specification requires a liquid penetrant examination of all internal vessel surfaces including the stainless steel cladding in the nozzle inner radius sections using the acceptance standards of ASME Code Section III, NB-5350. This specification also requires a repeat of the ultrasonic test method on the nozzle inner radius section volumes applied before the post-weld heat treatment including the examinations from the inner and outer diameter surfaces.

The examinations described above were applicable to the reactor vessel nozzles of Vogtle Units 3 and 4 and V.C. Summer Units 2 and 3.

For these four units, the post-hydrostatic test liquid penetrant examinations detected no relevant flaw indication of cracking or linear indication \([10, 11, 12, 13]\). A relevant indication is defined as being greater than 1/16-inch long.

For these four units, the post-hydrostatic test nozzle inner radius section ultrasonic examinations of the two outlet nozzles, four inlet nozzles and two DVI nozzles of each unit detected no recordable indications \([14, 15, 16, 17]\). The inner and outer diameter surface applied ultrasonic examinations consisted of the techniques defined in Table 1.
Table 1: Ultrasonic Test Techniques Applied in the Shop on the Inlet, Outlet and DVI Nozzle Inner Radius Sections Prior to the Vessel Post-Weld Heat Treatment and After the Hydrostatic Test

<table>
<thead>
<tr>
<th>Applied Surface</th>
<th>Test Angle(s)</th>
<th>Test Mode</th>
<th>Test Frequency</th>
<th>Reference Sensitivity</th>
<th>Nozzle Inner Surface Radius Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside</td>
<td>27°, 30°, 45°</td>
<td>Shear Wave</td>
<td>2.25 MHz</td>
<td>ID notch (2%T)</td>
<td>Inlet and Outlet Nozzles</td>
</tr>
<tr>
<td>Outside</td>
<td>13°, 22°</td>
<td>Shear Wave</td>
<td>2.25 MHz</td>
<td>ID notch (2%T)</td>
<td>DVI Nozzle</td>
</tr>
<tr>
<td>Inside</td>
<td>70°</td>
<td>Transmit-receive longitudinal wave</td>
<td>2 MHz</td>
<td>ID notch (2.5% a/t)</td>
<td>Inlet, Outlet and DVI Nozzles</td>
</tr>
</tbody>
</table>

Note 1: 0° transducer applied for the detection of laminar flaw indications that would limit or affect the interpretation of the angle beam examination results.
Note 2: Notch depth consistent with ASME Code Section XI, Table IWB-3512-1 for inside corner region.
Note 3: Examinations in two circumferential directions around nozzles.
Note 4: Examinations in four directions, two axial and two circumferential directions.

4.0 Section III, Appendix G Verification

The AP1000® reactor vessel was evaluated for its ability to protect against non-ductile failure in accordance with ASME Code Section III, Appendix G [18] requirements for postulated defects. The inlet nozzle, outlet nozzle and DVI nozzle regions were part of this linear elastic fracture mechanics (LEFM) evaluation. The fracture mechanics evaluation considered the Level A/B service condition, Level C/D service condition and Test Condition (at 70°F and at 110°F) design transients and mechanical loads.

The results demonstrate that the maximum $K_I$ values, resulting from the design transients and mechanical loads, meet the requirements of ASME Code Section III, Appendix G for the postulated flaw sizes. The AP1000® reactor vessel is in compliance with ASME Code Section III, Appendix G. To meet these requirements, flaw sizes smaller than one-quarter of the section thickness were assumed. For the reactor vessel nozzle inner radius regions, the smallest postulated flaw size was 0.16-inch at a hydrostatic test temperature of 70°F. Such a small postulated flaw was justified based on the manufacturing inspections described in Section 3.0 and the ultrasonic and visual examinations to be performed prior to service as described in Section 6.0.

5.0 Fracture Assessment

Reference [4] provides a basis to eliminate inservice volumetric examinations at the inner radius of reactor vessel nozzles for the operating reactor vessels in the US. The American Society of Mechanical Engineers (ASME) approved Code Case N-648-1 [1]
based on the results documented in [4]. At the time of publication of [1], the Code Case was only applicable to operating plants in the US. The fracture assessment results documented in this section support the technical basis for the AP1000® plant design. This includes calculation of the end of evaluation period flaw sizes for the AP1000® inlet, outlet and direct vessel injection (DVI) nozzles as well as fatigue crack growth analyses using the rules of ASME Section XI [2].

The allowable end of evaluation period flaw sizes (depths) for the AP1000® inlet, outlet, and DVI nozzles were determined using both linear elastic fracture mechanics (LEFM) and elastic plastic fracture mechanics (EPFM) methods. The LEFM flaw tolerance calculations were performed per ASME Section XI IWB-3600 and Appendix A, and the EPFM method followed the guidelines of Code Case N-749 [5]. Fatigue crack growth (FCG) analyses were also performed in order to determine the maximum initial flaw size that will not grow beyond the allowable end of evaluation period flaw size within the life of the plant (60 years) considering Level A/B/Test conditions. In addition, FCG analyses were also performed to determine the maximum initial flaw size for a 10 year period using LEFM only. In all cases the crack growth law for ferritic steels not susceptible to environmentally assisted cracking (EAC) given in Code Case N-643-2 [26] was used for the FCG calculations.

Table 2 shows the fracture assessment results for Level A/B/Test conditions for all three nozzle types using both LEFM and EPFM methods. The LEFM method is very conservative because it does not take into account the ductile behavior of the nozzle material, due to the lack of constraint present in this geometry. The EPFM results listed in Table 2 were produced using Code Case N-749 [5] and provide a more realistic fracture assessment considering the resistance to crack extension of the ductile nozzle material.

For the LEFM results, the DVI nozzle design produced the smallest end of evaluation period flaw size (0.358 inch), as well as the most limiting FCG result (0.326 inch) for a 60 year operating life. The results for ten years of operation show tolerance for slightly larger flaws and demonstrate the flaw sizes that might be of concern between inspection intervals based on conservative LEFM evaluations.

The EPFM evaluations demonstrate tolerance for much larger flaws, as shown in Table 2. The most limiting end of evaluation period flaw size is 4.5 inches for the DVI nozzle. However, the most limiting FCG result occurs for the outlet nozzle with a flaw depth of 3.088 inches. In all cases, tolerance for flaws over three inches in depth is demonstrated for 60 years of operation. Because the 60 year results demonstrate tolerance for such large flaws, it was not necessary to evaluate a 10 year period as was done for the LEFM cases.

The end of evaluation period flaw sizes for Level C/D conditions were also determined for each nozzle type using the LEFM method. As can be seen in Table 3, the Level C/D
flaw evaluation results are not limiting in comparison to the Level A/B/Test LEFM results reported in Table 2. For all cases listed in Table 3, the limiting flaw sizes are over 3 inches.

These initial flaw size results for 60 years are considered to be acceptable based on Section III flaw acceptance criteria prior to the components being placed into service. The largest permissible flaw length for magnetic partial examination per NB-2545 for forgings is 3/16 inch. The analyses were performed using the nozzle corner, quarter-circular stress intensity factor solution from API 579-1 [25] with the built-in assumed length-to-depth ratio of 2. Thus, the depth corresponding to a 3/16 (0.1875) inch flaw length would be 3/32 (0.094) inch. Additionally, the in-process and post-hydrostatic test UT examinations of the nozzle inner radius sections from the ID and OD surfaces (described in Section 3.0) detected no indications that may have appeared after cladding of the ID surface. Therefore, any flaw that would have been placed into service would have a depth less than the limiting flaw size reported in Table 2, even for the conservative LEFM cases.
Table 2: End of Evaluation Period Flaw Size and Fatigue Crack Growth Results for Inlet, Outlet and DVI Nozzles (Level A/B/Test Conditions)

<table>
<thead>
<tr>
<th>LEFM/EPFM</th>
<th>Component\Location</th>
<th>End of Evaluation Period Flaw Size (in)</th>
<th>FCG Results Period = 10 Years (in)</th>
<th>FCG Results Period = 60 Years (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEFM</td>
<td>Inlet Nozzle\Cut 5</td>
<td>1.034</td>
<td>0.946</td>
<td>0.663</td>
</tr>
<tr>
<td>LEFM</td>
<td>Inlet Nozzle\Cut 6</td>
<td>0.988</td>
<td>0.944</td>
<td>0.786</td>
</tr>
<tr>
<td>LEFM</td>
<td>Outlet Nozzle\Cut 5</td>
<td>1.151</td>
<td>1.066</td>
<td>0.793</td>
</tr>
<tr>
<td>LEFM</td>
<td>Outlet Nozzle\Cut 6</td>
<td>0.922</td>
<td>0.884</td>
<td>0.766</td>
</tr>
<tr>
<td>LEFM</td>
<td>DVI Nozzle\Cut 8</td>
<td>0.362</td>
<td>0.356</td>
<td>0.335</td>
</tr>
<tr>
<td>LEFM</td>
<td>DVI Nozzle\Cut 9</td>
<td>0.358</td>
<td>0.351</td>
<td>0.326</td>
</tr>
<tr>
<td>EPFM</td>
<td>Inlet Nozzle\Cut 5</td>
<td>7.0</td>
<td>N/A</td>
<td>4.542</td>
</tr>
<tr>
<td>EPFM</td>
<td>Inlet Nozzle\Cut 6</td>
<td>5.0</td>
<td>N/A</td>
<td>4.195</td>
</tr>
<tr>
<td>EPFM</td>
<td>Outlet Nozzle\Cut 5</td>
<td>6.0</td>
<td>N/A</td>
<td>3.595</td>
</tr>
<tr>
<td>EPFM</td>
<td>Outlet Nozzle\Cut 6</td>
<td>4.0</td>
<td>N/A</td>
<td>3.088</td>
</tr>
<tr>
<td>EPFM</td>
<td>DVI Nozzle\Cut 8</td>
<td>5.0</td>
<td>N/A</td>
<td>4.652</td>
</tr>
<tr>
<td>EPFM</td>
<td>DVI Nozzle\Cut 9</td>
<td>4.5</td>
<td>N/A</td>
<td>4.132</td>
</tr>
</tbody>
</table>

Table 3: End of Evaluation Period Flaw Size for Level C/D Conditions Using LEFM Method

<table>
<thead>
<tr>
<th>Nozzle/Cut</th>
<th>End of Evaluation Period Flaw Size (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet/5</td>
<td>7.200</td>
</tr>
<tr>
<td>Inlet/6</td>
<td>7.200</td>
</tr>
<tr>
<td>Outlet/5</td>
<td>9.480</td>
</tr>
<tr>
<td>Outlet/6</td>
<td>9.480</td>
</tr>
<tr>
<td>DVI/8</td>
<td>5.260</td>
</tr>
<tr>
<td>DVI/9</td>
<td>3.477</td>
</tr>
</tbody>
</table>

6.0 Preservice Inspection Process for Reactor Vessel Nozzle Inner Radius Sections

The ASME Code Section XI preservice inspection (PSI) of the nozzle inner radius sections for the two outlet nozzles, the four inlet nozzles and the two DVI nozzles will be done using a VT-1 visual examination method using an underwater camera system attached to a submersible. This process will be comparable to the subsequent inservice inspections. This visual examination will be conducted in accordance with the ASME
Code Section XI, 2007 Edition with the 2008 Addenda. The allowable flaw length criteria of ASME Code Section XI, Table IWB-3512-1 with a flaw aspect ratio \((a/l)\) of 0.5 will be applied for any detected flaw indication. This exception is consistent with the condition defined in NRC Regulatory Guide 1.147 for Code Case N-648-1. Table 4 provides the acceptance standards for the VT-1 visual examination specific to the AP1000® reactor vessel nozzle sections.

However, prior to the VT-1 visual examination PSI, liquid penetrant (PT) surface examinations will be performed at the plant site on the nozzle inner radius sections of the two outlet nozzles, the four inlet nozzles and the two DVI nozzles. The liquid penetrant examinations will be conducted in accordance with ASME Code Section XI, IWA-2222 using the ASME Code Section III, NB-5350 acceptance standards. This is a repeat of the surface examinations performed in the manufacturer’s shop as described in Section 3.0 after the Construction Code hydrostatic test. These repeat surface examinations are applied to ensure that no relevant surface-breaking flaws are present on the cladding surfaces prior to service. The PT examination report is to be included in the preservice inspection (PSI) documentation package.

After the PT examinations, manual ultrasonic examinations (UT) will be conducted at the plant site. These UT examinations will be applied from the inner diameter surface using two opposing circumferential beam directions around the nozzle inner radius sections of the two outlet nozzles, the four inlet nozzles and the two DVI nozzles. Dual focused 70-degree transmit-receive longitudinal wave transducers with acoustic focusing at or near the clad/base metal interface will be used to interrogate the nozzle inner radius section examination volume as defined in ASME Code Section XI, Figure IWB-2500-7(b) for radial-axial flaws (see Figures 1 through 3). The ultrasonic examination procedure requirements will be in accordance with ASME Code Section XI, Appendix III as supplemented by ASME Code Section XI, Appendix I Supplements 1 – 8, 10 and 11. These supplements are:

- Supplement 1 – Calibration Block Material and Thickness
- Supplement 2 – Calibration Blocks for Clad Welds or Components
- Supplement 3 – Calibration Blocks for Examination of Parts with Curved Surfaces
- Supplement 4 – Alternative Weld Calibration Block Design
- Supplement 5 – Electronic Simulators
- Supplement 6 – Pulse Repetition Rate
- Supplement 7 – Instrument Calibration
- Supplement 8 – Scan Overlap and Search Unit Oscillation
- Supplement 10 – Recording Criteria
- Supplement 11 – Geometric Indications
The reference sensitivity will be established on a radial-axial notch at the inside corner region with a depth equal to an ‘a/t’ of 2.5% consistent with the ASME Code Section XI, Table IWB-3512-1 allowable planar flaw size.

It is noted that dual focused 70-degree transmit-receive longitudinal wave transducers have proven to be effective at detecting near surface flaws initiating at the cladding surface or at the clad/base metal interface [19 – 24].

These ultrasonic examinations ensure that the appropriate surfaces have been prepared for application of future volumetric examinations in accordance with ASME Code Section XI, Table IWB-2500-1, and they provide a baseline volumetric examination of the nozzle inner radius section volumes. The UT examination report is to be included in the preservice inspection (PSI) report.

<table>
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<tr>
<td></td>
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<td>2.5</td>
<td>0.192</td>
<td>0.384</td>
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<tr>
<td></td>
<td>$t_n = 2.87$</td>
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<td>$t_s = 10.15$</td>
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</table>

Note 1: Thickness is the smallest of the three thicknesses shown in ASME Code Section XI, Figures IWB-2500-7(a) and 7(b) as defined by Table IWB-3512-2. The smallest component thickness is shown in bold print.

Note 2: Based on Reg. Guide 1.147, Rev. 17 condition to Code Case N-648-1 and approach defined in this technical basis; ‘a/l’ is the flaw depth / flaw length ratio.

Note 3: Based on ASME Code Section XI, Table IWB-3512-1 for Inside Corner Region; applicable for nominal wall thickness ranging from 2.5-inches or less to 12-inches; ‘a/t’ is the flaw depth / component thickness ratio. This table was defined in the Reg. Guide 1.147 condition on CC N-648-1 and is the same approach defined in this technical basis.

Note 4: Calculated as 2.5% of the smallest component thickness or 0.025 times the smallest component thickness.

Note 5: Calculated as ‘a’/0.5.

7.0 Conclusions

The following conclusions can be made:

1. The combination of the post-hydrostatic test surface (PT) examinations performed at the manufacturer’s facility and at the plant site ensures that fabrication flaws, particularly cracks and linear flaws, do not exist on the cladding inner diameter.
surface prior to implementing the VT-1 visual examination method. The ASME Code Section III, NB-5340 acceptance standards consider all cracks and linear flaws greater than 1/16-inch long to be unacceptable.

2. The combination of the post-hydrostatic test volumetric (UT) examinations performed at the manufacturer’s facility and at the plant site ensures that the appropriate surfaces have been prepared in accordance with ASME Code Section XI, IWA-2200(b) for application of future volumetric examinations. This is consistent with the Owner’s responsibility to provide adequate design and access provisions for periodic in-service inspection in compliance with ASME Code Section III, NCA-3220(r), ASME Code Section XI, IWA-1400(b) and IWA-1500, and 10 CFR 50.55a(g)(3)(i). The UT examinations performed at the plant site also provide for a baseline volumetric examination of the nozzle inner radius section volumes.

3. The fabrication examination history for the nozzle inner radius sections have been reviewed and documented. This examination history includes the required ASME Code Section III, NB-2500 and NB-5000 examinations of the forging material and cladding as supplemented by Westinghouse requirements for UT of the cladding for lack of bond, in-process and post-hydrostatic test UT examinations applied from the ID and OD surfaces for flaws in the base metal, and post-hydrostatic test PT examinations of the cladding surfaces for flaws on the ID surface. Such examinations support the maximum postulated flaw sizes used in the ASME Code Section III, Appendix G evaluation.

4. The nozzles meet the requirements of ASME Code Section III, Appendix G.

5. A deterministic fracture mechanics assessment has shown that the governing initial flaw size for the AP1000® inlet, outlet and DVI nozzles over a 10 year period consistent with the 10-year inspection interval is 0.351-inch deep within the underlying nozzle base metal, using very conservative LEFM methods. The limiting flaw size for a 60 year period is 0.326 inch, also using LEFM. More realistic EPFM results show that a flaw over 3 inches in depth can be tolerated for a 60 year plant life. The flaw depth to length aspect ratio consistent with the condition on Code Case N-648-1 in Regulatory Guide 1.147 is \( a/l = 0.5 \). Thus for a flaw depth \( a \) of 0.326-inch, the flaw length \( l \) is 0.652-inch for the base metal.

6. The governing initial flaw depth of 0.326-inch in the base metal (calculated for the DVI nozzle as indicated on Table 2) corresponds to a flaw length of 1.09-inches on the surface of the cladding given the nominal clad thickness of 0.22-inch, the total flaw depth \( a \) of 0.546-inch (0.326 + 0.22) and a 0.5 flaw depth to flaw length \( (a/l) \) aspect ratio. Table 4 indicates that for the VT-1 visual examination of the DVI nozzle
the allowable flaw length is 0.144-inch which is smaller than the governing initial flaw length of 1.09-inch given a 0.5 flaw depth to flaw length aspect ratio. A VT-1 visual examination finding exceeding this allowable acceptance standard would result in repair/replacement and reexamination, and regulatory review in accordance with ASME Code Section XI, IWB-3113 and IWB-3114 to ensure fitness for service.

8.0 References

1. ASME Boiler and Pressure Vessel Code, Case N-648-1: Alternative Requirements for Inner Radius Examinations of Class 1 Reactor Vessel Nozzles, Section XI, Division 1, approved September 7, 2001.


9. ASME/ASTM SA-508: Specification for Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings for Pressure Vessels (including S2: Ultrasonically Testing – Reference Block Calibration (for examining sections 24 in. [610mm] thick or less)).


15. Doosan Heavy Industries & Construction, U140107-017-002: UT Report for the Examination of Nozzle Inner Radius Regions (After Hydrostatic Test) for Vogtle Unit 4, January 2014.

16. Doosan Heavy Industries & Construction, U120907-022-002: UT Report for the Examination of Nozzle Inner Radius Regions (After Hydrostatic Test) for V.C Summer Unit 2, September 2012.

17. Doosan Heavy Industries & Construction, U150330-031-001: UT Report for the Examination of Nozzle Inner Radius Regions (After Hydrostatic Test) for V.C Summer Unit 3, April 2015.


27. VEGP 3&4 UFSAR Revision 6, Table 5.2-1