

Southern Nuclear Operating Company

ND-21-0070

Enclosure 8

Vogle Electric Generating Plant (VEGP) Units 3 and 4

**Revision to Westinghouse Non-Proprietary Technical Description of the Flaw Tolerance
Evaluation Conducted on the Subject Weldolet Branch Connections (Non-Proprietary)**

(VEGP 3&4-PSI//ISI-ALT-15R1)

(This Enclosure consists of 15 pages, including this cover page)

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LTR-SDA-20-096-NP, Revision 2

Flaw Tolerance Evaluation to Assess Lack of Inspection Coverage of AP1000 14 x 4 Stainless Steel Weldolets to Pipe Welds

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Record of Revisions

Rev	Date	Revision Description
1	See EDMS	This document provides the non-proprietary information from LTR-SDA-20-096-P Revision 1.
2	See PRIME	In response to NRC comments, Revision 2 adds discussion to the Fatigue Crack Growth section of the report to clarify the comparison between the weldolet location and pipe to valve transition weld in APP-GW-GLR-178 (Reference 4), in regards to the thermal transient severity at these two locations.

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Forward

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Introduction

The AP1000 Class 1 14x4 weldolet-to-pipe welds do not allow for essentially 100% of the required examination volume coverage as defined in ASME Section XI, IWA-2200 (c) due to geometry restrictions imposed by the configuration. Qualified ultrasonic testing (UT) examination coverage will be approximately 64% of the examination volume, as identified within the Non-destructive Examination (NDE) report (Reference 1). Therefore, to justify the lack of examination coverage for these particular locations, a fracture mechanics assessment is provided in this report to demonstrate that the weldolet to pipe weld location is flaw tolerant by demonstrating that a postulated flaw in the required examination region does not grow to the maximum allowable end-of-evaluation period flaw size within the life of the plant per ASME Section XI (Reference 2).

The flaw tolerance evaluation performed for the 14x4 weldolet to pipe weld []^{a,c,e} is based on the piping loads, material properties, dimensions, along with consideration of transient loadings and cycles. The weldolet to piping weld considered the actual profile of the weldolet with the appropriate weld dimensions and configuration. An illustration of the weldolet weld profile is shown in Figures 1 and 2 based on UT NDE of the Circumferential and Axial Scans, respectively. These figures also show the potential missed area within the inner 33% of the wall thickness where the required 100% inspection coverage is not achievable. [

] ^{a,c,e}.

Therefore, per ASME Section XI Appendix C flaw evaluation guidelines, the maximum allowable end-of-evaluation axial and circumferential flaw size acceptable for the life of the plant will be determined. Then it will be demonstrated that any potential flaws in the missed inspection coverage area will not reach the maximum end of evaluation period flaw size for the life of the plant.

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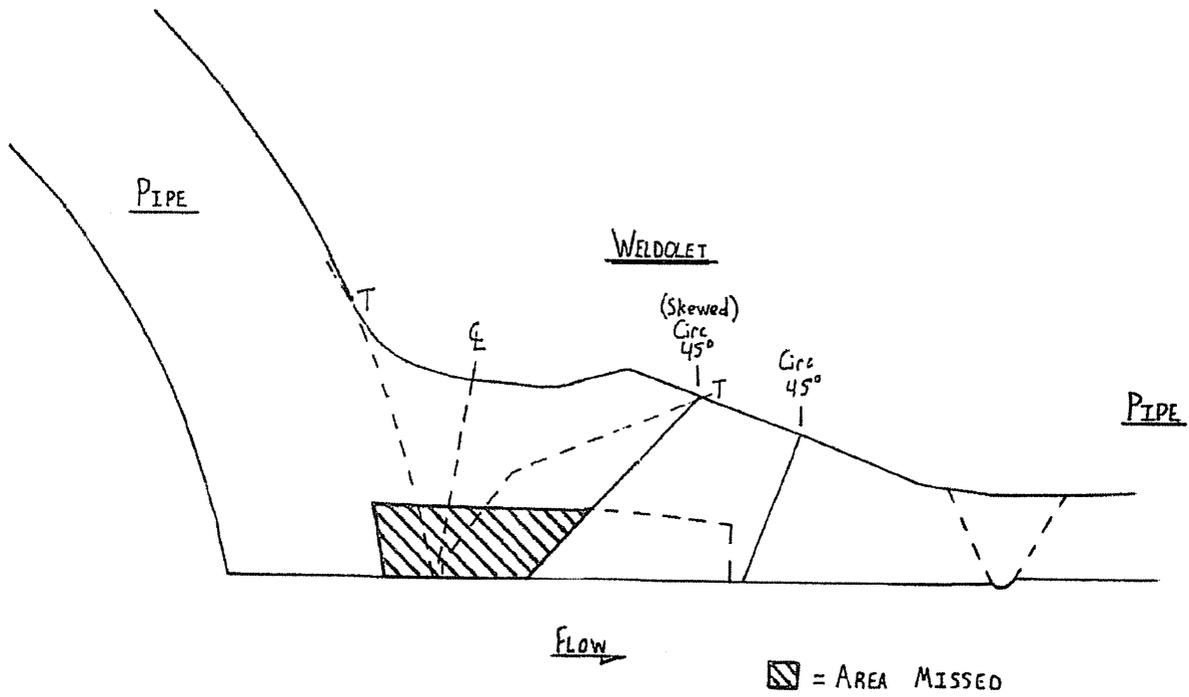


Figure 1: Configuration of Circumferential Scan on Weldolet to Pipe Weld Location

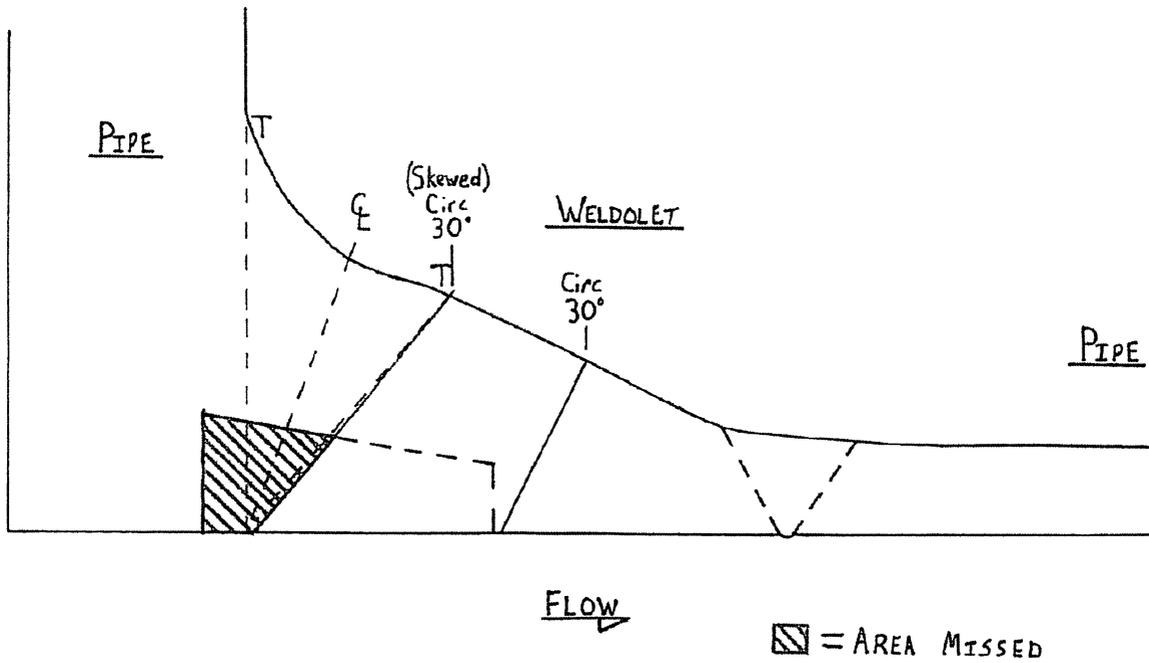


Figure 2: Configuration of Axial Scan on Weldolet to Pipe Weld Location

Flaw Tolerance Evaluation Methodology

The weldolet to pipe weld location is evaluated based on the guidelines in paragraph IWB-3640 and Appendix C of the 2007 Edition with 2008 Addenda ASME Section XI code (Reference 2).

The maximum allowable end-of-evaluation period flaw size is calculated at the stainless steel weldolet location for a postulated inside surface axial and circumferential flaw using the guidance of ASME Section XI Appendix C-5000. Note that the weld is fabricated per the Gas Tungsten Arc Weld (GTAW) process; thus, the procedures based on Appendix C-5000 limit load methodology is appropriate. The evaluations of inside surface flaws are considered herein, because the required examination for this weldolet to pipe weld location is of the inner one-third thickness of the wall. Furthermore, the evaluation of postulated inside surface flaws conservatively bounds evaluations for embedded flaws as the limit load and crack growth rate methodologies for inside surface flaws are more limiting than embedded flaws.

The primary crack growth mechanism considered for postulated flaws in the stainless steel weldolet to pipe weld location is Fatigue Crack Growth (FCG). Crack growth due to Primary Water Stress Corrosion Crack (PWSCC) growth does not need to be investigated since the base metal (stainless steel weldolet) and stainless steel weld material have a very low susceptibility to stress corrosion cracking due to the lack of oxygen in a PWR (Pressurized Water Reactor) environment. The FCG for the weldolet assessment is based on a comparison to the FCG evaluation documented within APP-GW-GLR-178 (Reference 4) for a similar pipe weld location. The goal of the flaw tolerance evaluation is to demonstrate that the maximum allowable end-of-evaluation flaw sizes are sufficiently large as compared to the missed coverage area of the weldolet, and any missed flaws within the inspection zone will not grow to the maximum end-of-evaluation period flaw sizes for the life of the plant.

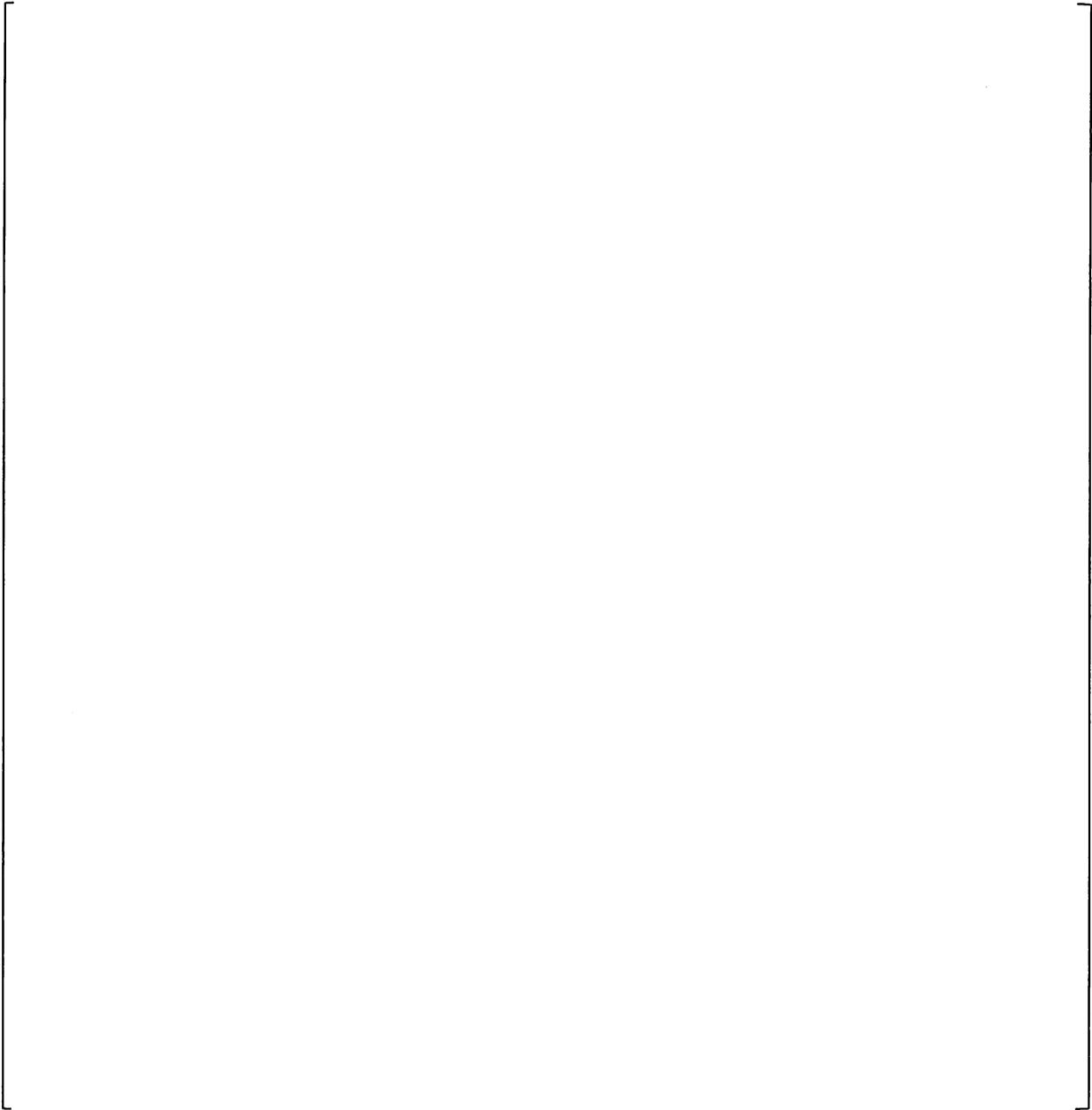
Maximum Allowable End-of-Evaluation Period Flaw Sizes

The calculation of the maximum allowable end-of-evaluation period flaw sizes for stainless steel base metals and stainless steel welds are based on the guidelines from paragraph IWB-3640 and Appendix C of ASME Section XI (Reference 2). These guidelines were used to determine the maximum allowable end-of-evaluation period flaw size for axial and circumferential flaw configurations per Appendix C-5000.

The maximum end-of-evaluation period flaw sizes determined for both axial and circumferential flaws have incorporated the limiting material properties based on ASME Section II Code values (Reference 3), plant specific loadings and geometry. Loadings under normal, upset, test, emergency and faulted conditions were considered with the applicable safety factors for the corresponding service conditions required in the ASME Code Section XI. For circumferential flaws, axial stress due to the pressure, deadweight, seismic, and pipe break loads were considered in the evaluation. As for the axial flaws, hoop stress resulting from pressure loading was used.

The dimensions and operating parameters for the weldolet to piping weld location are shown in Table 1. The weldolet to pipe weld axial membrane and bending stresses and hoop pressure stresses are given in Table 2. Total stresses with the appropriate stress indices were used within this evaluation since the weld occurs at a branch connection and the loadings from the run piping, and the branch piping need to be accounted for in the total stress. The piping stresses are based on all the applicable loads and moments from various Service Levels as described in Table 3.

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The maximum allowable end-of-evaluation period flow sizes are determined based on the limiting of the base metals and weld material flow strength values (average of the yield and ultimate strengths) at the temperatures applicable to loading conditions. The material properties at the weldolet to pipe weld location are conservatively based on ASME Section II (Reference 3), in lieu of using the CMTR (Certified Material Test Report) properties. [

]^{a,c,e}. The weld material is considered to have stronger material properties values than the base metals.

The weldolet to pipe welds are constructed from GTAW (gas tungsten arc weld). Thus, the maximum end-of-evaluation flow sizes will be based on the tabular solution guidance of ASME Section XI Appendix C-5310 and C-5410. The calculated maximum allowable end-of-evaluation period flow sizes for the weldolet to pipe weld location are shown in Table 4 (where a_f is the maximum allowable end-of-evaluation flow depth, and t = wall thickness).

From the results in Table 4, it is concluded that the maximum allowable end of evaluation flow size of the weldolet to pipe weld has a large flow tolerance. The second step in this process involves consideration of fatigue crack growth analyses which will determine the final flow size after 60 years of plant operation for any missed flaws in the inspection zones at the weldolet. The 60 year final flow size can be compared to the maximum allowable end-of-evaluation flow size in Table 4 to determine the structural integrity of this location.

Table 4: Maximum Allowable End-of-Evaluation Period Flow Size

Postulated Flaw Configuration	Maximum End-of-Evaluation Period Flow Size (a_f/t)
Axial Flaw	0.71
Circumferential Flaw	0.75

Fatigue Crack Growth Analysis

Fatigue crack growth for the weldolet location is assessed by comparing the evaluation performed in APP-GW-GLR-178 (Reference 4) to the weldolet location. Both the weldolet and the valve transition weld locations in Reference 4 are stainless steel weld material, with potential inspection zones that may contain missed hypothetical flaws exposed to the PWR water environment. The transient events and cycles (Table 5), loadings combinations (Table 6), and welding residual stress are considered to be the same between the weldolet and the pipe weld location in APP-GW-GLR-178 (Reference 4), since both locations are in the same piping lines which have consistent loading events and similar geometrical properties. However, there are some differences between these two locations. [

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[

]a,c,e

For a given flaw size, the range in fatigue crack growth stress intensity factors (ΔK_I) is directly proportional to the range in transient stresses. A higher stress intensity factor range results in a faster fatigue crack growth. Therefore, it is conservative to consider that the range in stress intensity factors at the weldolet will be the same as the valve transition weld location evaluated in APP-GW-GLR-178. As a result, it is conservatively assumed that the crack growth calculated within APP-GW-GLR-178 will bound the weldolet locations.

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The fatigue crack growth evaluation in APP-GW-GLR-178 shows that the crack growth is less than 3% of the initial flaw size for 60 years of plant life (i.e. negligible) which is the maximum for both axial and circumferential flaw sizes. Based on the above discussion, the amount of fatigue

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crack growth (i.e. less than 3% growth over 60 years) from APP-GW-GLR-178 can also be considered to be applicable to the weldolet evaluation. The crack growth for the weldolet assessment is thus considered to be approximately 3% over 60 years (i.e. the same for the weldolet as compared to the pipe weld in APP-GW-GLR-178).

As shown in Table 7 the maximum allowable end-of-evaluation axial and circumferential flaw sizes (a/t) are determined to be 0.71 and 0.75, respectively. The initial potential axial and circumferential flaw sizes are considered to grow to 34% of the wall thickness after 60 years. This final flaw size is far less than the maximum allowable end-of-evaluation flaw size. Therefore, any potential axial or circumferential flaws in the missed inspection coverage zones with depths of 33% of the wall thickness along with the missed inspection volume length will not grow to the maximum end of evaluation flaw per ASME Section XI over the life of the plant. Therefore, it is demonstrated the weldolet locations are flaw tolerant and there is no concern for the structural integrity of this location.

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Table 6: Service Condition Required Loadings

Service Condition	Required Loadings
Normal (Level A)	Normal Condition Transients + External Normal/Upset Loads
Upset (Level B)	Upset Condition Transients + External Normal/Upset Loads
Emergency (Level C)	Emergency Condition Transients + External Emergency Loads
Faulted (Level D)	Faulted Condition Transients + External Faulted Loads
Test	Test Condition Pressures + External Loads

Table 7: Flaw Tolerance of Inspection Zone in Weldolet to Stainless Steel Pipe Weld Location

Postulated Flaw Configuration	Maximum Potential Inspection Zone Flaw Size (1/3 of wall thickness) (a/t)	60 year FCG Final Flaw Size (a_p/t)	Maximum Allowable End of Evaluation Flaw Size (a_f/t)
Axial Surface Flaw	0.33	0.34	0.71
Circumferential Surface Flaw	0.33	0.34	0.75

Note: a_p = final potential flaw depth, a_f = ASME Code Maximum Allowable flaw depth, t = thickness, a = non-inspectable depth

Summary and Conclusions

A flaw tolerance evaluation was completed for the AP1000 14x4 stainless steel weldolet to pipe weld location since the weld cannot be fully volumetrically examined because of the geometric restraints of the configuration. The weld is required to have the inner third (33%) of the wall thickness volumetrically examined per ASME Code Section XI (Reference 2) Figure IWB-2500-10. The goal of this flaw tolerance assessment is to demonstrate that a large postulated axial or circumferential flaw at the weldolet to pipe weld region encompassing the missed examination region will not grow to the maximum end-of-evaluation flaw size for the design life of the plant (60 years).

The weldolet to pipe weld location was evaluated per the guidelines in paragraph IWB-3640 of ASME Section XI and Appendix C-5000 (Reference 2). Postulated inside surface axial and circumferential flaws were evaluated at the weldolet to pipe weld locations. AP1000® specific geometry, pipe loadings, design transients, and ASME Section II material properties (Reference 3) were considered in the maximum end-of-evaluation period flaws and the fatigue crack growth analysis. The flaw tolerance evaluation incorporated the limiting ASME code material properties based on the base metals. The welding process is GTAW (gas tungsten arc welding) for the welds.

As shown in Table 7, the maximum allowable end-of-evaluation flaw size (a/t) is 0.71 for an axial flaw and 0.75 for a circumferential flaw. It is demonstrated that any potential flaw in the required inner one-third wall thickness examination region would not grow to the maximum allowable end-of-evaluation flaw size in 60 years (design life); as a result, there is acceptable structural integrity margin for the weldolet to pipe location.

References

1. NDE report reference
 - a. Westinghouse UT Examination Report 20-004102, Summary # 114500, Pipe to 14x4" Weldolet, SV3-RCS-PLW-01C-SW3. UT of Austenitic Pipe Welds IAW with PDI-UT-2. Work Order: SV3-ISI-WRP-010. Jason Nahory, Richard Fuller, 9/13/2020
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2. ASME Code Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," 2007 Edition with 2008 Addenda.
3. ASME Code Section II, "Part D – Properties," 1998 Edition with 2000 Addenda.
4. APP-GW-GLR-178, Revision 0, "AP1000 PSI Inspectability of Stainless Steel Valve to Pipe Welds" (Westinghouse Proprietary).
5. APP-PL02-Z0-101, Revision 5, "AP1000 Class 1 Piping and Non-Class 1 Extension Design Specification." (Westinghouse Proprietary).
6. APP-RCS-M1-001, Revision 5, "Reactor Coolant System Design Transients." (Westinghouse Proprietary).