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CCEC-26-002

January 29, 2026

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

Christopher M. Crane Clean Energy Center
Renewed Facility License No. DPR-50
NRC Docket No. 50-289

Subject: Response to Request for Additional Information by the Office of Nuclear Reactor Regulation to support Review of TMI-1/Crane (Cycle 22) Steam Generator Inspection Report

References:

1. Letter from Trevor Orth (Constellation Energy Generation, LLC) to U.S. Nuclear Regulatory Commission, “TMI-1 Steam Generator Inspection Report for End of Cycle 22” dated December 19, 2024 (ML24355A09)

2. E-Mail from Brent Ballard (U.S. Nuclear Regulatory Commission) to Dennis Moore (Constellation Energy Generation, LLC) “Christopher M. Crane Clean Energy Center - Final RAI for S[team] G[enerator] Tube Inspection Report (EPID-L-2024-LRO-0064)” dated November 19, 2025 (ML25325A059)

On September 20, 2024, Constellation Energy Generation, LLC (CEG) announced its intent to restore Three Mile Island Nuclear Station, Unit 1 (TMI-1) to safe and reliable commercial power operation. In anticipation of the restart announcement, CEG completed an examination of the TMI-1 steam generator tubing in Spring 2024. This was the first examination of the steam generator tubing since the plant shutdown in September 2019, at the End of Cycle 22.

By letter dated December 19, 2024, (Reference 1) Constellation Energy Generation, LLC (CEG) submitted the Three Mile Island Unit 1, Steam Generator Tube Inspection Report. By E-Mail dated November 19, 2025, (Reference 2) the NRC identified areas where additional information was necessary to complete the review.

The attachment to this letter contains the NRC's request for additional information immediately followed by CEG's response.

There are no new or revised regulatory commitments contained in this letter.

If you have any questions, please contact Mr. Christian Williams, at 732-281-9104.

Respectfully,

Moore, Dennis M

Digitally signed by Moore, Dennis M
Date: 2026.01.28 15:41:33 -05'00'

Dennis M. Moore
Senior Manager Licensing
Constellation Energy Generation, LLC

Attachment: Response to Request for Additional Information with Enclosure

cc: w/ Attachment

NRC Regional Administrator, Region I
NRC Director, NRR – DORL
NRC Deputy Director, NRR – DORL
NRC Project Manager, NRR – DORL – Christopher M. Crane Clean Energy Center
NRC Project Manager, NMSS – Christopher M. Crane Clean Energy Center
Director, Bureau of Radiation Protection - PA Department of Environmental Resources
Chairman, Board of County Commissioners of Dauphin County
Chairman, Board of Supervisors of Londonderry Township

Attachment 1

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
BY THE OFFICE OF NUCLEAR REACTOR REGULATION
TMI-1/CRANE (CYCLE 22) STEAM GENERATOR INSPECTION REPORT
CONSTELLATION ENERGY GENERATION, LLC
CHRISTOPHER M. CRANE CLEAN ENERGY CENTER
DOCKET NO. 05000289
ISSUE DATE: 11/18/2025

Background

On September 20, 2024, Constellation Energy Generation, LLC (CEG) announced its intent to restore Three Mile Island Nuclear Station, Unit 1 (TMI-1) to commercial power operation. In anticipation of the restart announcement, CEG completed an examination of the TMI-1 steam generator (SG) tubing in Spring 2024. This was the first examination of the steam generator tubing since the plant shutdown in September 2019, at the end of Cycle 2.

By letter dated December 19, 2024, (Reference 1) Constellation Energy Generation, LLC (CEG) submitted the TMI-1, Steam Generator Tube Inspection Report. By E-Mail dated November 19, 2025, (Reference 2) the NRC identified areas where additional information was necessary to complete the review.

This attachment contains the NRC's request for additional information immediately followed by CEG's response. The enclosure to this attachment is the requested Condition Monitoring and Operational Assessment (CMOA).

It should be noted that on May 13, 2025, the Nuclear Regulatory Commission (NRC) issued Amendment No. 306 (ML25100A006) changing the name of the facility to the Christopher M. Crane Clean Energy Center.

Regulatory Basis

All pressurized water reactors have Technical Specifications (TS) according to § 50.36 of Title 10 of the *Code of Federal Regulations* (10 CFR) that include a SG Program with specific criteria for the structural and leakage integrity, repair, and inspection of SG tubes. The TMI-1 TS Section 6.9.6, in effect at the time of shutdown, required that a report be submitted within 180 days after the reactor coolant temperature exceeds 200 F, following completion of an inspection of the SGs. In addition, the TS in effect at the time of shutdown required that a SG Program be established and implemented to ensure SG tube integrity is maintained.

Question 1

Submit a copy of the final steam generator Condition Monitoring and Operational Assessment (CMOA) document from the May 2024 steam generator (SG) tube inspection. If a final CMOA is not available, please provide a copy of the preliminary CMOA and discuss when the final CMOA will be available.

Response

Included, as an enclosure to this attachment, is a copy of the final steam generator Condition Monitoring and Operational Assessment (CMOA) document from the May 2024 steam generator (SG) tube inspection.

Question 2

Based on the inspection report, secondary side visual inspections were focused on the top of tubesheet region. Please discuss whether or not there is a potential for high humidity inside the steam generators during the extended shutdown period to have resulted in formation of oxides (i.e. corrosion of the alloy steel) on the secondary side that could:

a) Cause the tube support plate (TSP)-to-shroud locking issue in SG B to become more severe, resulting in greater tube wear than has been experienced in previous outages.

b) Cause an issue with TSP-to-shroud locking in SG A that has not previously been observed.

Response

The steam generator support material is SA 240 Type 410M stainless steel, with Eight (8) SA-516 Grade 60 carbon steel alignment wedges, welded to the shroud ID, and equally spaced circumferentially around each TSP between the support and the shroud. The only source of corrosion material as it relates to locking issues would be from these wedges. Based on the very slight amounts of discoloration/rust seen on the shroud from visual inspection from the top of tubesheet level (Figure 6-3 from the Condition Monitoring and Operational Assessment of TMI-1 Steam Generators 2024 Inspection, Framatome Document 51-9378840-000), any contribution of corrosion from the small contact area of the wedges against the support plate is expected to be minimal and would break free from heat up expansion forces. As a result, any corrosion on the wedge to tubesheet interface is expected to have a negligible impact on TSP wear concerns in both steam generators.

Question 3

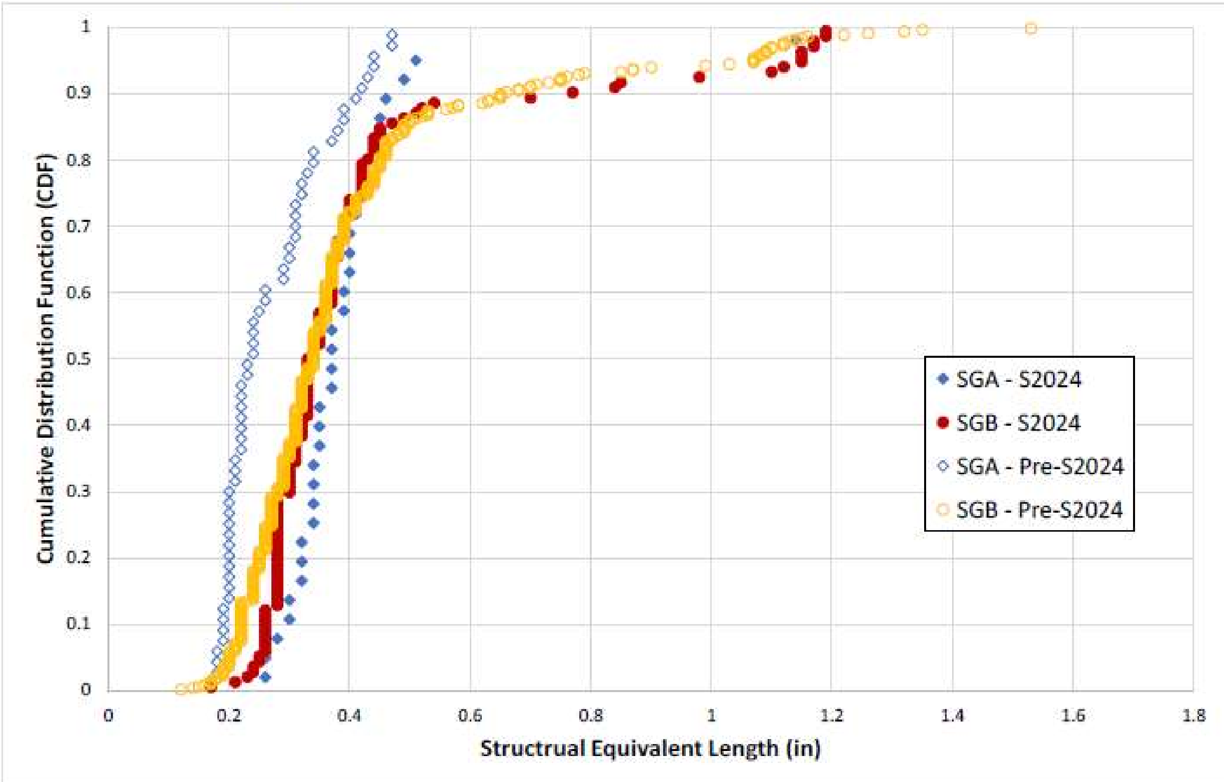
During the most recent operating cycle, two wear indications at broached tube supports in SG B grew from non-detectable to greater than 40 percent through-wall in one cycle. The deepest indication, sized as 47 percent through-wall, has a distinctly tapered wear shape. Discuss if other deep wear scar[s] that exhibited high growth from the previous inspection had flat wear or tapered wear. In addition, discuss how these higher growth indications are considered in the operational assessment for wear at broached support plates.

Response

TSP wear flaws greater than or equal to 30% through wall depth (TWD), measured with the bobbin probe, were structurally profiled to establish the number of flat vs. tapered wear flaws and to determine if wear was occurring on multiple lands. The majority of the broached TSP wear indications had tapered flaw shapes, with the largest growth from a repeat indication also tapered The deepest single flaw, SG B, R4-T1 at 12S, had a distinctly tapered profile resulting in a maximum depth of 45%TW and structurally equivalent depth of 38.7% as sized with Array. The figure below (Figure 4-3 taken from the 2024 CMOA) shows a distribution of structural lengths for the deepest flaws for both SGs. The population is tightly grouped up to approximately 0.5” in length, indicative of tapered wear, with flaws greater than 0.5” in length being flat or nearly flat.

It is noted that the flaws with the largest growth in 1R22 (2017) and largest depth from Array had tapered flaws (Tubes R5-T11 at 11S, R5-T14 at 11S, and R17-T74 at 11S). The largest new flaw and largest depth from bobbin in 1R22 (2017) were flat (Tubes R105-T3 at 14S and Tube R105-C4 at 15S).

Figure 4-3: TMI Distribution of Structural Lengths – Both SGs



When considering the operational assessment for SG B, support wear continues to be notably different inside vs outside a tube bundle radius of 48", therefore the bundle was treated as separate zones. In past analyses three zones were used: "Inner Bundle", "Broken Ring" and "W-axis" zones, since a large fraction of the tubes in the "W-axis" zone are now plugged, wear growth rates and new flaw depths were sufficiently similar such that combining the "Broken Ring" and "W-axis" into one "Outer Ring" zone simplified calculations while maintaining conservatism.

The broken ring and W-Prime zones of SG B showed attenuation in 95th percentile values, while the averages in these zones increased. In the inner bundle of SG B, the average and upper 95th percentile growth rates increased slightly. These values are shown below in Table 7-2 and Table 7-3 taken from the 2024 CMOA.

Table 7-2: Comparison of SG A Broached Bobbin TSP Wear Growth Rates at 1R21 and 2024

Region	1R20 to 1R21 (%TW/EFPY)		1R21 to 2024 (%TW/EFPY)	
	Average	Upper 95th	Average	Upper 95th
SG A (entire population)	0.53	3.17	0.36	1.89

Table 7-3: Comparison of SG B Broached Bobbin TSP Wear Growth Rates at 1R22 and 2024

Region	1R21 to 1R22 (%TW/EFPY)		1R22 to 2024 (%TW/EFPY)	
	Average	Upper 95th	Average	Upper 95th
SG B (Broken Ring)	1.10	5.06	0.784	3.627
SG B (W-Prime)	0.73	7.30	2.625	6.218
SG B (Inner Bundle)	0.20	2.25	0.414	2.591

Independent, fully probabilistic operational assessment models were used for broached TSP wear in each SG. Predictions were made for a single cycle of 2.0 EFPY. The predictions for SG B are illustrated in Table 7-7 below taken from the 2024 CMOA. The predictions are made by zone based on 400 probabilistic trials of all flaws returned to service and picking the highest value. The results for SG B bound SG A. This methodology used to predict the number of new flaws greatly overestimates the number of flaws and is expected to continue to be conservative. New flaws are predicted to initiate following a similar depth distribution to what was observed in 2024 as seen in the example for the outer ring zone in Figure 7-13 below.

Table 7-7: SG B Maximum Flaw Depth Predictions after 2.0 EFPY

Parameter	Outer Ring	Inner Bundle
Repeat	68%TW	47%TW
New	37%TW	26%TW

Question 4

Were any deleterious species detected in the secondary side water/sludge samples taken from the steam generator during the extended shutdown? If so, please discuss any actions that are being taken to monitor or mitigate any effects on SG tube degradation. In addition, please discuss the primary side environment the steam generator tubes were exposed to [during] the extended shutdown and if any adverse conditions (e.g., impurities, low pH) were detected that could affect the steam generator tubes.

Response

Samples were collected from the following locations prior to the start of inspection activities in May of 2024.

- The RCS samples were obtained from the ‘A’ and ‘B’ cold leg drains
- The ‘A’ SG secondary did not have enough water remaining in the as found condition to obtain a sample.
- A single secondary side sample was obtained from the ‘B’ SG feedwater drain during the draining of an estimated 7000 gallons of water. Subsequent visual inspections concluded that this equated to approximately 8 inches of water on the secondary side tubesheet.

Attachment 1

A summary of the sample results are as follows:

Parameter	'A' RCS	'B' RCS	'B' feedwater
Conductivity	671 (uhmo)	262 (umho)	40.4 (umho)
pH	2.85	3.27	7.72
Copper	<0.050	<0.050	<0.050
Sodium	<0.063	<0.063	<0.063
Lead	<0.063	<0.063	<0.063
Silicon	0.140	0.179	0.127
Bromide	<0.10	<0.10	<0.10
Chloride	0.20	0.19	<0.10
Fluoride	0.50	0.52	<0.50
Sulfate	0.50	0.33	0.14

All values are in ppm. The reporting limit for copper is 0.050 ppm, sodium, lead and silicon is 0.063 ppm.

During the 2024 SG inspections all water was drained from the secondary side of the steam generators, and a dry layup was implemented post inspection removing moisture that is required to sustain corrosion. As discussed in the Condition Monitoring and Operational Assessment from the 2024 inspection, no degraded conditions existed. Since the SG inspections were completed, the secondary side has been maintained in a dry layup condition per the EPRI Secondary Water Chemistry Guidelines. Prior to operation, per EPRI guidelines, CEG intends to fill and drain the secondary side of the SGs to reduce / remove the remaining residual deleterious species. Although there were deleterious species identified in both secondary and primary water, the environment was exempt from elevated temperature and/or pressure that is necessary to initiate degradation. With the absence of elevated temperature and pressure, there is reasonable assurance that the deleterious species identified would not cause any degradation other than those mechanisms already identified.

The Primary water samples obtained at the beginning of the 2024 SG inspections identified adverse conditions as discussed in the summary table above. However, the amount of water present was not enough to completely fill the channel head and reach the SG tubes, therefore the tubes were never directly exposed to these conditions. Visual inspections of the lower primary channel head and the cold leg loops showed no signs of degradation, which is as expected given the corrosion resistant cladding and piping materials.

REFERENCES:

1. Letter from Trevor Orth (Constellation Energy Generation, LLC) to U.S. Nuclear Regulatory Commission, “TMI-1 Steam Generator Inspection Report for End of Cycle 22” dated December 19, 2024 (ML24355A09)

2. E-Mail from Brent Ballard (U.S. Nuclear Regulatory Commission) to Dennis Moore (Constellation Energy Generation, LLC) “Christopher M. Crane Clean Energy Center - Final RAI for SG Tube Inspection Report (EPID-L-2024-LRO-0064)” dated November 19, 2025 (ML25325A09)

ENCLOSURE: Condition Monitoring and Operational Assessment of TMI-1 Steam Generators 2024 Inspection framatome

Framatome Inc.

Engineering Information Record

Document No.: 51 - 9378840 - 001

Condition Monitoring and Operational Assessment of TMI-1 Steam Generators 2024 Inspection

Export Classification	**US EC:** ☒ N ☐ Part 810 ☐ EAR	**ECCN:** N/A

Condition Monitoring and Operational Assessment of TMI-1 Steam Generators 2024 Inspection

Safety Related? ☒ YES ☐ NO

Does this document establish design or technical requirements? ☐ YES ☒ NO

Does this document contain assumptions requiring verification? ☐ YES ☒ NO

Does this document contain Customer Required Format? ☐ YES ☒ NO

Signature Block

Name and Title	Signature and Date	Role	Scope/Comments
Victor Newman Advisory Engineer	[signature] 1/27/26	LP	All
Craig Kelley Supervisory Engineer	Craig Kelley 1/27/2026	LR	All
Wayne Belden Technical Manager, SG Performance Engineering	[signature] 1/27/26	A	All
Mary Addario Project Manager	M. Addario 1/27/26	A	Use of Customer References

Role Definitions:

P/R/A designates Preparer (P), Reviewer (R), Approver (A);
LP/LR designates Lead Preparer (LP), Lead Reviewer (LR);
M designates Mentor (M);
PM designates Project Manager (PM)

Record of Revision

Revision No.	Pages/Sections/ Paragraphs Changed	Brief Description / Change Authorization
000	All	Original Issue
001	Cover page	Released as non-proprietary

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1.0 PURPOSE AND SCOPE

In accordance with the EPRI Steam Generator Integrity Assessment Guidelines [1] a condition monitoring (CM) assessment shall be performed at the conclusion of each steam generator eddy current examination. This process is defined as "backward-looking," since its purpose is to confirm that adequate steam generator (SG) integrity was maintained during the last cycle of operation. It involves an evaluation of the "as-found" conditions of the steam generator relative to established performance criteria for structural and accident induced leakage integrity. The performance criteria are defined in NEI 97-06 [2] and plant technical specifications [3] and summarized in Section 3.3. The 2024 inspection requirements are identified in the degradation assessment (DA) [4]. Eddy current inspection results are provided to Tube Integrity Engineering (TIE) via the Framatome Data Management System (FDMS). The eddy current exam was performed in accordance with the EPRI Steam Generator Examination Guidelines [5].

Additionally, utilities are to perform an operational assessment (OA) to assure that steam generator tubing will meet all performance criteria over the upcoming inspection cycle(s). This OA evaluates postulated steam generator tube degradation over the inspection interval. Postulated degradation is based on the results of SG inspections, known existing modes of degradation, and known modes of degradation in similar plants. The CM and OA calculations are performed in accordance with the EPRI Steam Generator Degradation Specific Management Flaw Handbook [6].

This evaluation is for the Three Mile Island Unit 1 (TMI-1) steam generators, which are Reactor Coolant System components, performed during the 2024 Health Assessment which includes operating time for cycle 22. This report provides documentation that applicable CM performance criteria were met during the 2024 examination and the OA provides reasonable assurance that the performance criteria will not be exceeded for an operating period of 2.0 EFPY.

2.0 ASSUMPTIONS

There are no assumptions requiring verification.

3.0 SG DESIGN AND BACKGROUND

3.1 Design Information

The TMI-1 replacement steam generators are Framatome Enhanced Once-Through Steam Generators (EOTSGs) [7] which are vertically mounted once-through heat exchangers with a counter-flow design. The EOTSGs have 15,597 Alloy 690 thermally treated tubes (690 TT), 0.625" nominal outer diameter (OD) with a 0.0368" wall thickness. The two steam generators are designated SG A and SG B.

The tubes are supported by 15 stainless steel tube support plates (TSPs), which are 1.18" thick and have trefoil broached holes. The uppermost TSP (15S) has 1740 drilled holes for the tubes at the outer periphery of the tube bundle for control of steam flow. The TSPs are supported by tie rods, which control the spacing between the TSPs and are spread evenly around the tube bundle in four concentric rings. The two inner most ring tie rods in each of the upper spans have a nominal diameter of 0.625" while the tie rods in the remaining spans have a nominal diameter of 0.787". There are no tie rods in the uppermost tube span between the 15th TSP and the upper tubesheet (UTS).

All tubes were inserted, tack-rolled, welded, and hydraulically expanded into the lower tubesheet while the opposite end of the tube (at the upper tubesheet) was "free" (unattached). The hydraulic expansion includes the full-thickness of the lower tubesheet (24"). Once the tube attachment was finalized for all tubes at the lower tubesheet, the tubes at the upper tubesheet were tack-rolled and welded. The final tube installation step was the full-length hydraulic expansion into the upper tubesheet.

3.2 Operating History

The operating cycle lengths since SG replacement are identified in the 1R22 DA [4] the 1R22 CMOA Input Transmittal Report [8] and summarized in Table 3-1. Cycle 22 is the fifth operating cycle with the replacement SGs, beginning in November, 2017 and including shutdown on September 18, 2019.

Table 3-1: TMI-1 Operating Cycles since Steam Generator Replacement

Cycle	End of Cycle Outage Designation	Outage/Inspection Date	Cycle EFPY	Notes	Cumulative SG EFPY	Reference
Cycle 17	1R18	Oct 2009	N/A	EOTSGs Installed		[4]
Cycle 18	1R19	Nov 2011	1.72	1st ISI	1.72	[4]
Cycle 19	1R20	Nov 2013	1.88	2nd ISI	3.60	[4]
Cycle 20	1R21	Nov 2015	1.89	3rd ISI	5.49	[4]
Cycle 21	1R22	Sep 2017	1.78	4th ISI	7.26	[4]
Cycle 22	1D23	May 2024	1.93	SG Health Inspection	9.20	[4]

3.3 Performance Criteria

The performance criteria, provided in NEI-97-06 and TMI-1 Technical Specification Requirements [3] are as follows:

- *Structural Integrity Performance Criterion*: All in-service steam generator tubes shall retain structural integrity over the full range of normal operating conditions (including startup, operation in the power range, hot standby, and cool down) and all anticipated transients included in the design specification and design basis accidents. This includes retaining a safety factor of 3.0 against burst under normal steady state full power operation primary-to-secondary pressure differential and a safety factor of 1.4 against burst applied to the design basis accident primary-to-secondary pressure differentials. Apart from the above requirements, additional loading conditions associated with the design basis accidents, or combination of accidents in accordance with the design and licensing basis, shall also be evaluated to determine if the associated loads contribute significantly to burst or collapse. In the assessment of tube integrity, those loads that do significantly affect burst or collapse shall be determined and assessed in combination with the loads due to pressure with a safety factor of 1.2 on the combined primary loads and 1.0 on axial secondary loads.
- *Accident Induced Leakage Performance Criterion*: The primary to secondary accident induced leakage rate for the limiting design basis accident, other than a steam generator tube rupture, shall not exceed the leakage rate assumed in the accident analysis in terms of total leakage rate for all steam generators and leakage rate for an individual steam generator. The accident induced leakage for all types of degradation is not to exceed 1.0 gpm per steam generator and allowable leakage for accident conditions is conservatively considered at 650°F.

- *Operational Leakage Performance Criterion*: The RCS operational primary-to-secondary leakage through any one steam generator shall be limited to 150 gallons per day (gpd).

4.0 2024 INSPECTION SUMMARY

The 2024 Inspection work scope included the following inspection activities for TMI-1 steam generators. These inspection activities are further defined in the DA.

4.1 PRIMARY SIDE INSPECTIONS

Primary side inspections consisted of examinations performed by eddy current testing (ECT), visual inspections of all installed tube plugs, visual inspection of the channel head and tubesheet cladding and a visual inspection down the cold leg nozzles of SG A, due to the fact that the SG A primary (upper) manway cover had been removed for some time [4].

ECT Inspections are summarized in Figure 4-1 and Table 4-1 based on criteria defined in the DA and ECT Inspection Plan [9]. Overall, there were no new manufacturing indications detected (i.e. BLG, DNG, MBM), no foreign object wear or potential loose parts (PLPs) identified. The existing degradation mechanisms of TSP wear (broached and drilled locations) and tube-to-tube wear (TTW) continued to be identified. Proximity indications to a tie rod (PTR) were identified for the first time at TMI-1 (12 indications in SG B) which were confirmed to be associated with tie rod bowing of 6 tie rods in the uppermost span. More detailed discussion is provided in the following sections.

Figure 4-1: Final ECT Inspection Status

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Three Mile Island Nuclear Power Station
Spring 2024 - Unit 1 SG ECT Inspection
Status Report

				SG 1A			
Examination	**Leg**	**Probe**	**Extent**	**Planned**	**Acquired**	**Resolved**	**% Complete**
Bobbin Exam							
Full Length Bobbin	Outlet	510HS	UTELTE	15589	15589	15589	100.00%
Array Exam							
Periphery Array	Outlet	510XP	01SLTE	898	898	898	100.00%
SSI Foreign Object Items	Outles	510XP	01SLTE	33	33	33	100.00%
Special Interest							
Array SI	Outlet	510XP	UTELTE	124	124	124	100.00%
PlusPoint SI	Outlet	520PP	Various	0	0	0	0.00%
Plug Visual							
Upper leg	Inlet		UTEUTE	8	8	8	100.00%
Lower leg	Outlet		LTELTE	8	8	8	100.00%
Total Inspections				**16644**	**16644**	**16644**	**100.00%**

				SG 1B			
Examination	**Leg**	**Probe**	**Extent**	**Planned**	**Acquired**	**Resolved**	**% Complete**
Bobbin Exam							
Full Length Bobbin	Outlet	510HS	UTELTE	15350	15350	15350	100.00%
Array Exam							
Periphery Array	Outlet	510XP	01SLTE	792	792	792	100.00%
SSI Foreign Object Items	Outlet	510XP	01SLTE	12	12	12	100.00%
Tie Rod Bounding	Outlet	510XP	UTELTE	24	24	24	100.00%
Special Interest							
Array SI	Outlet	510XP	UTELTE	411	411	411	100.00%
PlusPoint SI	Outlet	520PP	Various	0	0	0	0.00%
Plug Visual							
Upper leg	Inlet		UTEUTE	247	247	247	100.00%
Lower leg	Outlet		LTELTE	247	247	247	100.00%
Total Inspections				**16589**	**16589**	**16589**	**100.00%**

Table 4-1: Spring 2024 ECT Inspection Summary

Type	Extent	Scope	Condition or Degradation Mechanism Assessed
Bobbin Coil (1)	Full Length Lower Tube End (LTE) to Upper Tube End (UTE)	100% in-service tubes	Wear at TSPs
			TTW
			Dents/Dings
			Possible wear due to foreign objects (object not identified)
			Proximity to tubes or tie rods due to tie rod bowing
Array X-probe (Array) (1)	Lower Tubesheet (LTS) to 1st TSP (01S)	2 tube-deep periphery	Potential foreign objects and potential wear due to foreign objects
	Special Interest (SI) for analysis – Tubes with new and prior TSP and TTW Wear	• All bobbin drilled TSP wear indications • All affected tubes and 1-tube bounding of tubes of foreign objects identified by visual inspections (see Table 6-1) • Tubes with bobbin proximity to a tie rod (PTR) in SG B that indicates tie rod bowing including all tubes surrounding the 6 affected tie rods at the elevation of proximity (15th span of SG B only) • New bobbin TSP %TWD Indications >= 20% • Bobbin TSP %TWD Indications >= 25% • Select tubes full length to allow for future deposit mapping evaluation of TSP broach blockage [9]	• TSP Wear • Tube-to-tube wear (TTW) • Tie rod wear (TRW) - (none found) • Potential Corrosion Mechanisms – (none found) Foreign Objects/Foreign Object Wear – (none found)
	Line-by-Line (LxL) Sizing	Select TSP wear (e.g., >=30% bobbin, multiple lands, flat, deep, etc.)	TSP Wear

Notes:
1. All bobbin and array probes were run through the deposit standard [25]

Table 4-2: Summary of Spring 2024 ECT Indications

Probe	Indication Code (3)	SG A	SG B
Bobbin	ADS	1	0
	BLG	4	16
	DNG	0	3
	DSS	0	5
	INF	1	0
	INR	24	45
	MBM	10	25
	NQS	0	7
	PTR	0	12
	SLG	321	130
	TWD (1)	5363	7524
Array	NDF (2)	1	16
	WAR	113	442

Notes:

1. All bobbin TWD indications include broached TSP wear, drilled TSP wear, and tube-to-tube wear (TTW).
2. All Array NDF indications are for drilled TSP wear indications identified by bobbin.
3. Definition of Abbreviations:

ADS	Absolute Drift Signal (NDF in history with no change)	NQS	Non-Quantifiable Signal (NDF in history with no change)
BLG	Bulge	PTR	Proximity to Tie Rod
DNG	Ding	SLG	Sludge Height
DSS	Distorted Support Signal (NDF in history with no change)	TWD	Through-Wall Degradation
INF	Indication not Found	NDF	No Degradation Found
INR	Indication not Reportable	WAR	Confirmed Wear
MBM	Manufacturing Burnish Mark	-	-

4.1.1 Primary side Visual Inspections

Primary side visual inspections performed in 2024 are summarized below.

- Tube Plug Visual inspections on 100% installed tube plugs
- Channel head and tubesheet cladding visual inspection
- Visual inspection down both cold legs of SG A & SG B

All plug inspection results were nominal. No degradation or abnormalities were noted during plug inspections.

4.1.2 Tube Wear at Broached TSP Intersections

Mechanical wear at broached TSP intersections is the predominant degradation mechanism at TMI-1. Broached TSP wear was detected and sized with the bobbin probe. In accordance with special interest examination criteria (see Table 4-1) certain bobbin wear indications were also inspected with an array probe to obtain additional information on structural depth and length and flaw morphology.

There were 5,243 broached TSP wear indications in SG A and 7,188 in SG B identified in the 2024 inspection. The majority of these indications are located at or above the 8th TSP. The deepest indications were primarily located at the 10th through the 14th TSPs. The deepest indication (SG B tube R4 T1 at 12S) had a maximum depth of 47%TWD as measured with the bobbin coil. A summary of broached flaw results is provided in Table 4-3. It is notable that while there are a large number of flaws in each SG, only a small fraction are of any significant depth, with fewer than 89 flaws in SG A (~1.7% of the flaw population) and 301 in SG B (~4.2% of the flaw population) greater than 24%TW in depth.

In order to ensure that flaws identified as "new" were properly categorized, analysts were instructed to look in historical data any time a broached TSP wear flaw detected by bobbin equal to or greater than the reporting threshold of 10%TWD was identified as "new" (meaning not reported in 1R22). A total of 354 and 475 newly-reported bobbin indications, in SG A and SG B respectively, had signals present in prior inspection data (1R21 or 1R22) that could be sized. Analysts recorded the historical "lookup" value in the UTIL 1 field of the inspection database. The largest newly reported flaws without a "lookup" value in history (i.e., actual newly initiated flaw since las inspection) was a 24%TW in SG A (R28-T7 at 10S) and a 46%TW in SG B (R6-T1 at 12S)

TSP wear flaws greater than or equal to 30%TWD, as determined by the bobbin probe, were structurally profiled to establish the number of flat vs. tapered wear flaws and to determine if wear was occurring on multiple lands. The majority of the broached TSP wear indications had tapered flaw shapes. The deepest single flaw, SG B, R1-T4 at 12S, had a distinctly tapered profile. Figure 4-2 shows the structural profile of the wear flaw in SG B, R4-T1 at 12S. Figure 4-3 shows a distribution of structural lengths for the deepest flaws for both SGs. The population is tightly grouped up to approximately 0.5" in length, indicative of tapered wear, with flaws greater than 0.5" in length being flat or nearly flat. The profile results of all flat flaws identified in the Spring 2024 inspection are listed in Table 4-4.

Tubesheet maps and depth distribution of all broached flaws are provided in and Figure 4-4 through Figure 4-8.

Distributions of growth rates illustrate that, overall, broached TSP wear growth rates are attenuating over time. Figure 4-9 and Figure 4-10 illustrate the historical growth rate distributions and their attenuation for the entire population in each SG. As illustrated in Figure 4-11 and Figure 4-12, the Operational Assessment zones defined prior to 1R21 [14] also show attenuation of growth rates in the individual zones in SG B.

Growth rates in SG A are much lower than SG B, which permits the SG A OA to conservatively be treated probabilistically as one population without impacting tube plugging. Note that when SG A is divided into the same OA zones as SG B, it becomes evident that growth rate patterns are consistent with respect to these zones in both SGs. That is, the inner bundle tubes have the lowest growth rates, the W-axis periphery tubes having the highest growth rates, and the rest of the periphery (i.e., referred to as the "broken ring") in the middle.

A total of 42 tubes (7 in SG A, 35 in SG B) were plugged for wear at broached TSPs during the Spring 2024 inspection.

Table 4-3: Broached TSP Wear Summary for 2024 Inspection

	SG A	SG B
Total Number of In-Service Tubes After 2024 Inspection	15,582	15,315
Number of Broached TSP Wear Indications	5,243	7,188
Number of Tubes with Broached TSP Wear	3,718	4,047
Average Depth of Broached TSP Wear (%TW)	11.08	13.04
Maximum Depth of Broached TSP Wear (%TW)	46	47
Number of Broached TSP Wear Indications ≥40%TW	3	8
Number of Broached TSP Wear Indications ≥30%TW	32	107
Number of Broached TSP Wear Indications ≥25%TW	89	301
Number of Tubes w/ Broached TSP Wear ≥40%TW	3	8
Average Growth Rate for Repeat Wear Indications (%TW/EFPY) (1)	0.36	0.77
Upper 95th Percentile Growth Rate for Repeat TSP Wear (%TW/EFPY) (1)	1.89	3.63
Maximum Growth Rate for Repeat Broached TSP Wear (%TW/EFPY) (1)	7.55	19.17
Number of Newly-Reported Indications (2)	657	692
Number of Actual New Indications (2)	303	217
Average Depth for Newly-Reported Indications (%TW) (2)	12.69	12.97
Maximum Depth for Newly-Reported Indications (%TW) (2)	37	46
Maximum Depth for Actual new Indications (%TW) (2)	24	46
Number of Tubes Plugged due to Broached TSP Wear	7	35
Maximum Depth Returned to Service (%TW)	38	39

Notes:

1. Growth rate statistics are for the entire SG bundle. For SG A the max growth rate was in the broken ring, while for SG B the max growth rate was in the W-Axis.
2. Newly reported indications include all flaws that were not reported in the prior inspections at 1R21 (SG A) or 1R22 (SG B) which prompted a review of prior outage Bobbin data. Newly reported flaws with no signal present in prior outage data can be considered an actual new flaw that initiated after the SG was last inspected.

Figure 4-2: Deepest Flaw Broached TSP Wear in Tube R4 T1 12S Profile

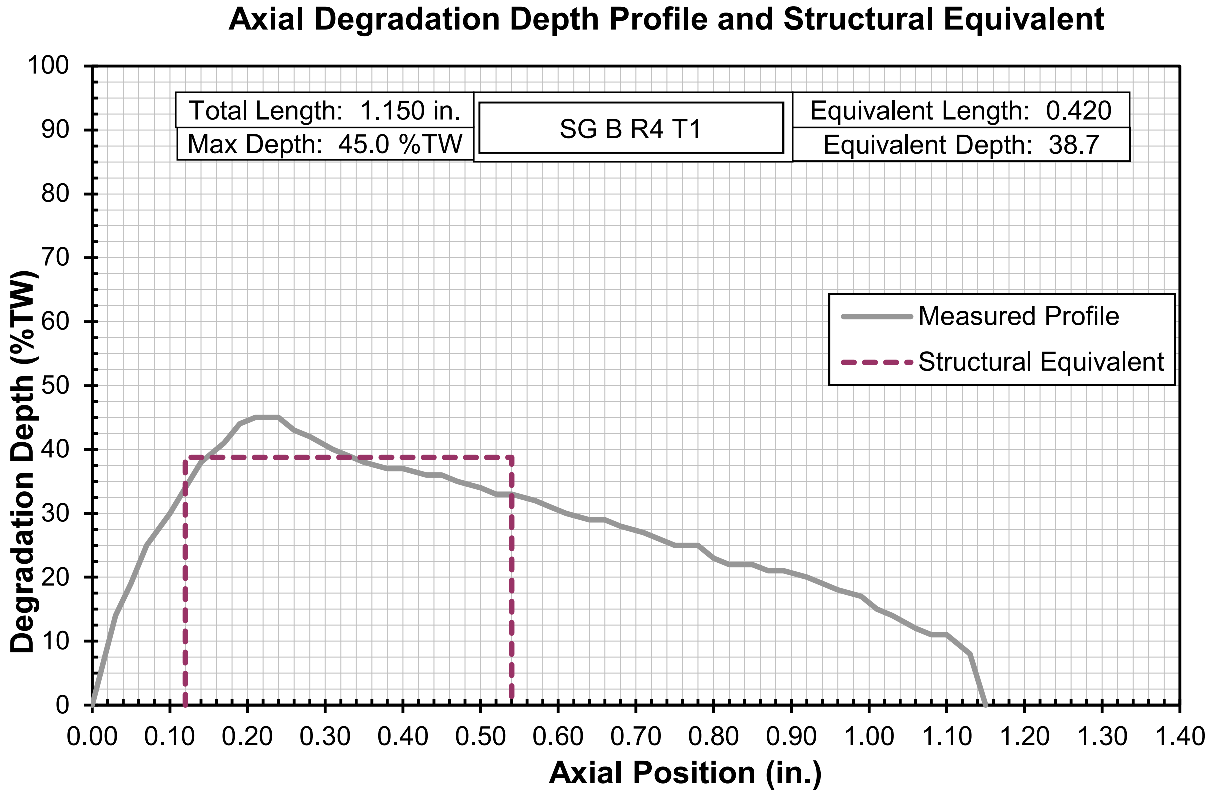


Figure 4-3: TMI Distribution of Structural Lengths – Both SGs

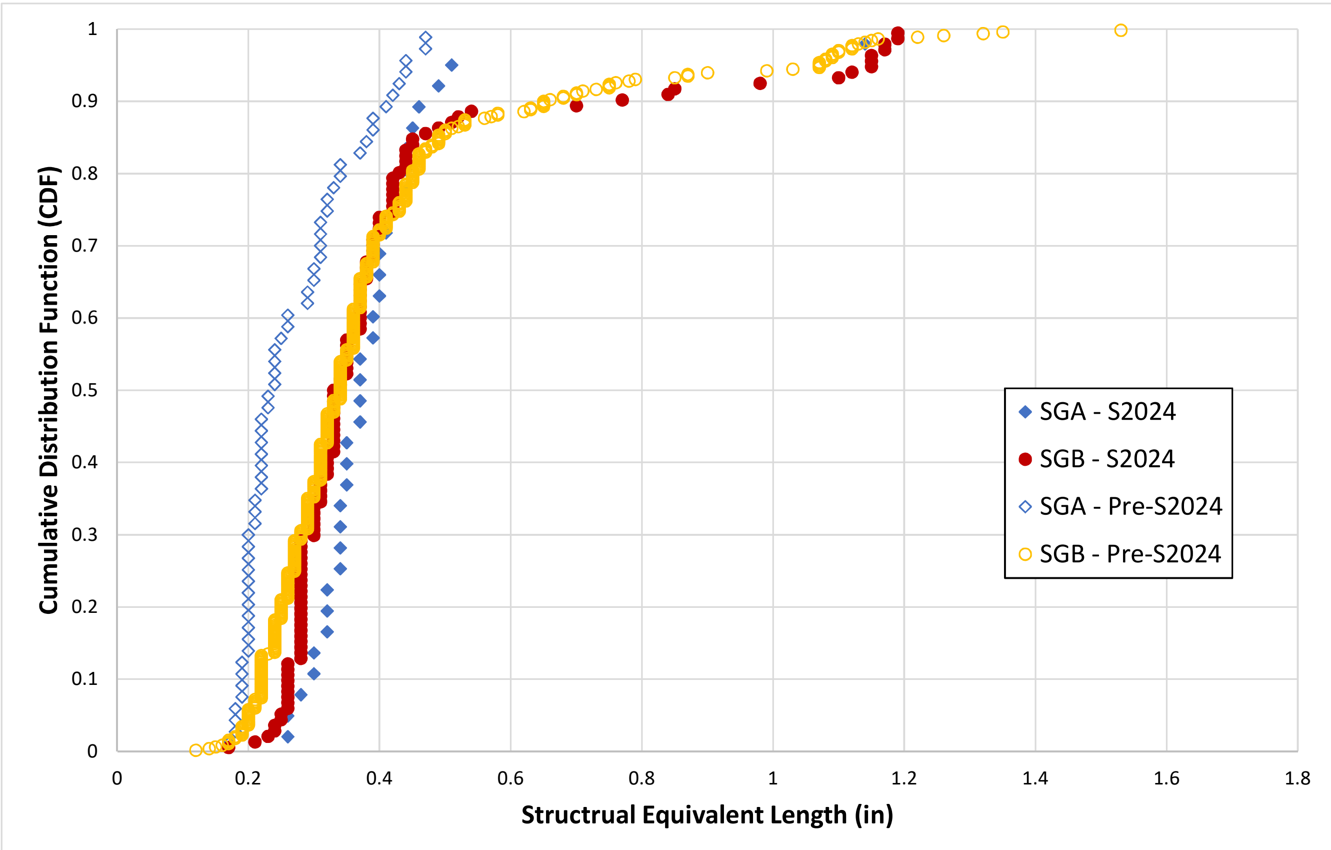


Table 4-4: Properties of Flat Broached TSP Wear Flaws from 2024 Profiles

SG	Row	Tube	Elev (TSP)	Flaw[(1)]	NDE Length (in.)	Max Array Depth (%TW)	Structural Length (in.)	Structural Depth (%TW)	2024 Bobbin Depth (%TW)	1R21/22 Bobbin Depth (%TW)	Struct/Max Depth ratio	Struct/ NDE length ratio	Status
A	117	1	12S	-	1.49	43	1.14	39.84	37	9	0.93	0.77	Plugged
B	5	6	11S	Flaw2	1.28	20	0.51	17.44	16	15	0.87	0.40	Plugged
B	7	17	15S	-	1.40	35	0.77	31.45	32	19	0.90	0.55	In-Service
B	8	2	14	-	1.38	40	1.10	36.34	39	31	0.91	0.80	plugged
B	8	2	14S	Flaw2	1.28	21	0.54	18.69	39	31	0.89	0.42	Plugged
B	8	3	13S	-	1.42	30	0.84	24.80	30	29	0.83	0.59	In-Service
B	8	3	13	Flaw2	1.31	17	1.17	13.58	30	29	0.80	0.89	in service
B	8	3	14	-	1.42	36	1.12	32.04	33	32	0.89	0.79	in service
B	8	53	14S	Flaw2	1.35	38	0.70	33.56	35	29	0.88	0.52	In-Service
B	13	73	13S	-	1.48	34	0.85	29.05	32	29	0.85	0.57	In-Service
B	46	6	15	Flaw2	1.29	24	0.98	20.56	31	31	0.86	0.76	in service
B	100	4	15S	-	1.36	29	0.52	26.48	35	31	0.91	0.38	In-Service
B	100	4	15	Flaw2	1.35	26	1.19	22.49	35	31	0.87	0.88	in service
B	101	5	5	-	1.33	21	1.17	17.98	33	32	0.86	0.88	in service
B	101	5	14	Flaw2	1.38	34	1.15	29.13	33	32	0.86	0.83	in service
B	102	4	14	-	1.27	19	1.19	15.34	27	25	0.81	0.94	in service
B	102	4	14	Flaw2	1.38	30	1.15	27.39	27	26	0.91	0.83	in service
B	102	4	15	-	1.35	26	1.15	24.19	31	27	0.93	0.85	in service

Notes:

1. The array probe is able to identify multiple flaws at the same support elevation and through the profiling process a "Flaw2" designator is given to the 2nd flaw profiled. For example, at SGB R5-T6 there were two flaws identified with "Flaw2" having a flat profile.

Figure 4-4: 2024 Inspection Map of Tubes with Broached TSP Wear Indications – SG A

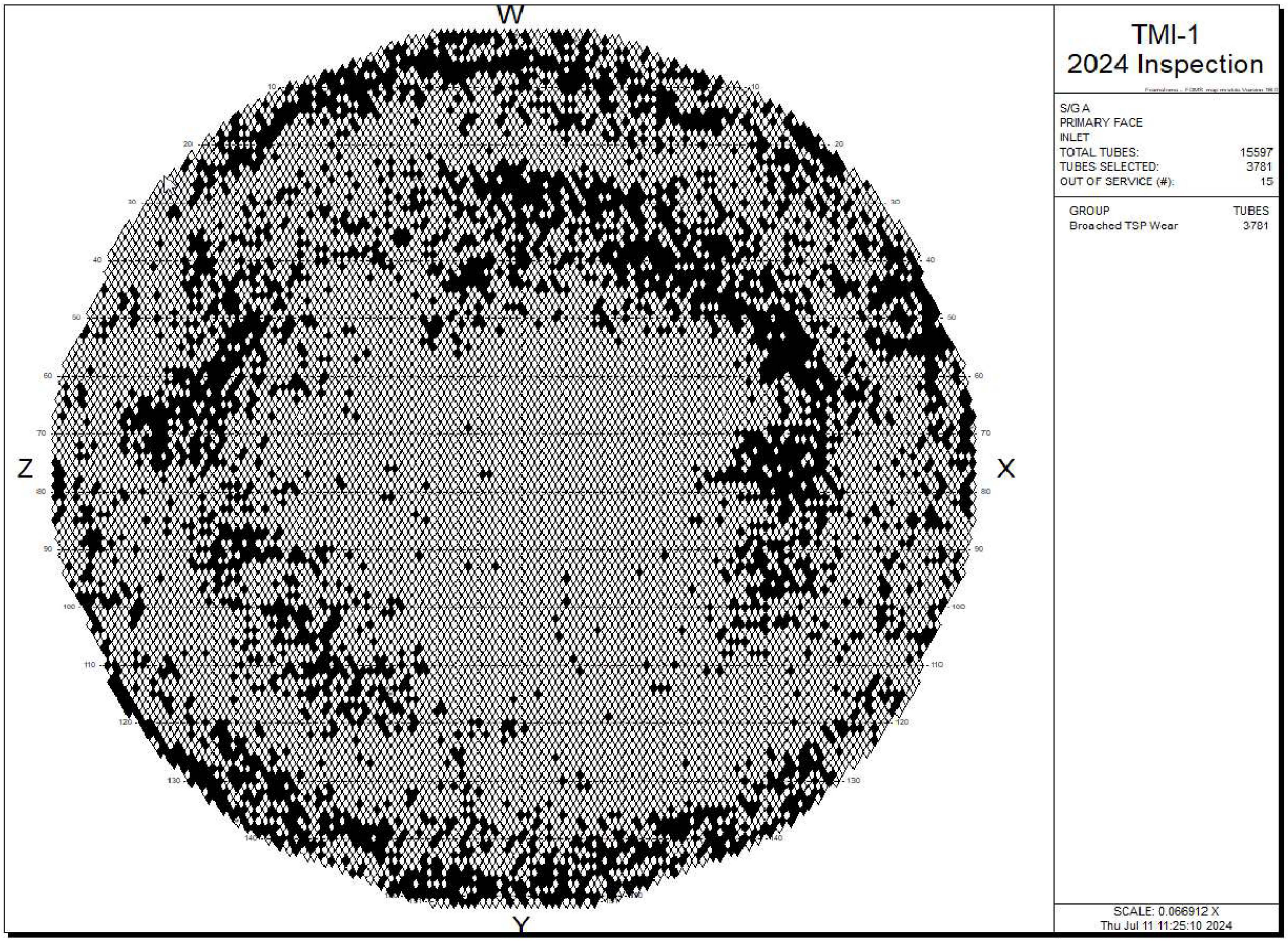


Figure 4-5: 2024 Inspection Map of Tubes with Broached TSP Wear Indications – SG B

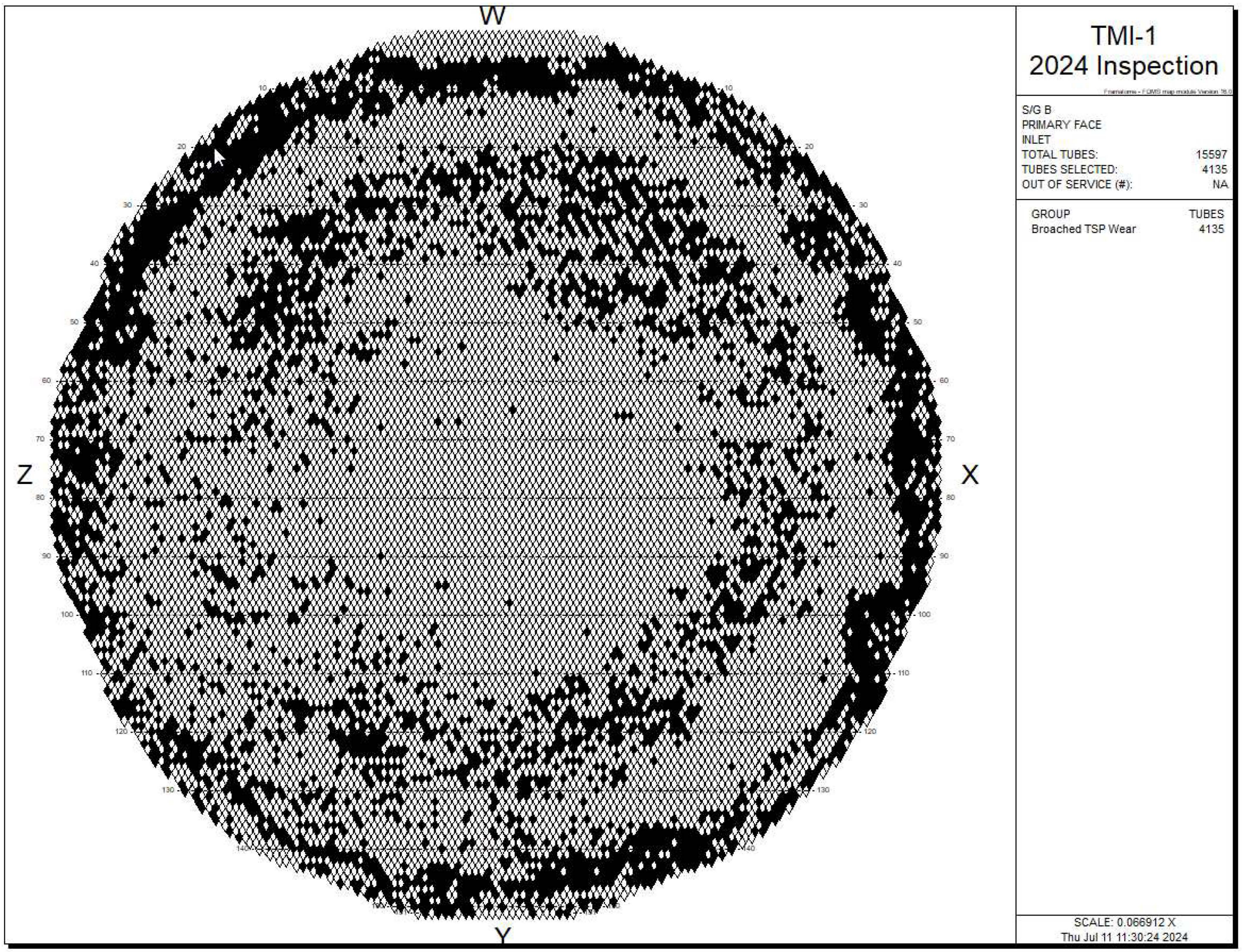
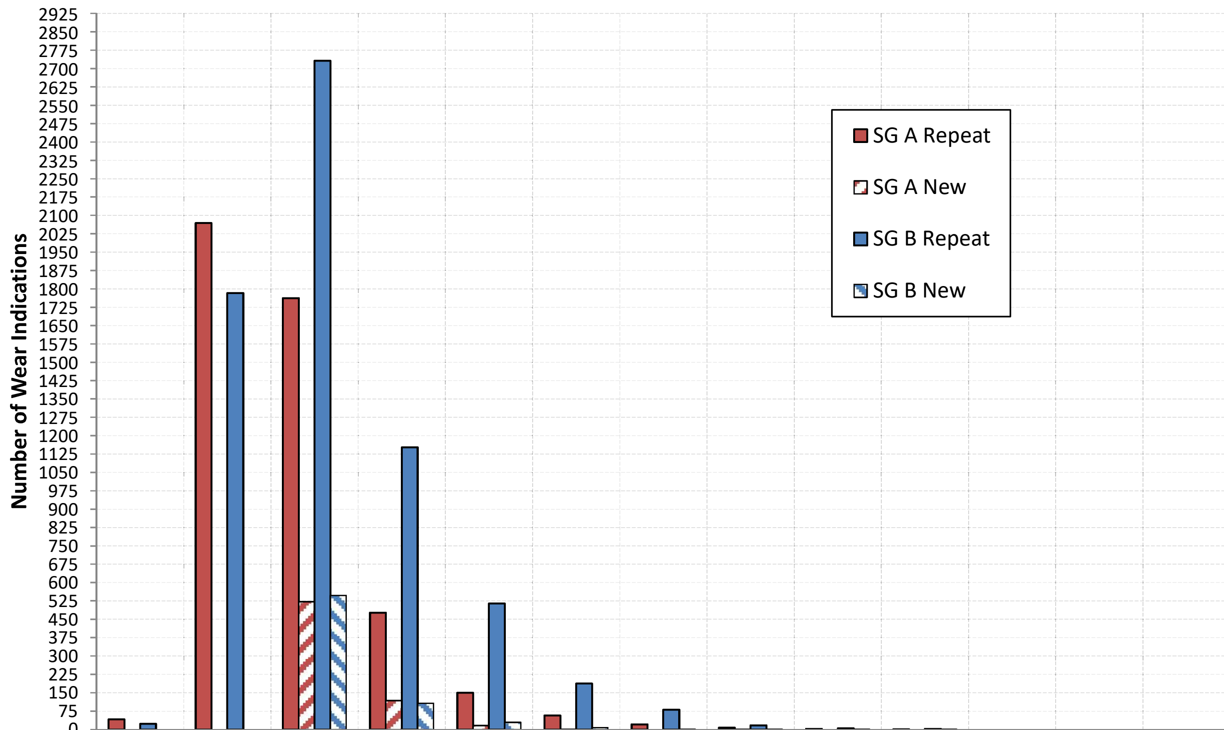


Figure 4-6: 2024 Inspection Broached TSP Wear Bobbin Depth Distributions – Both SGs



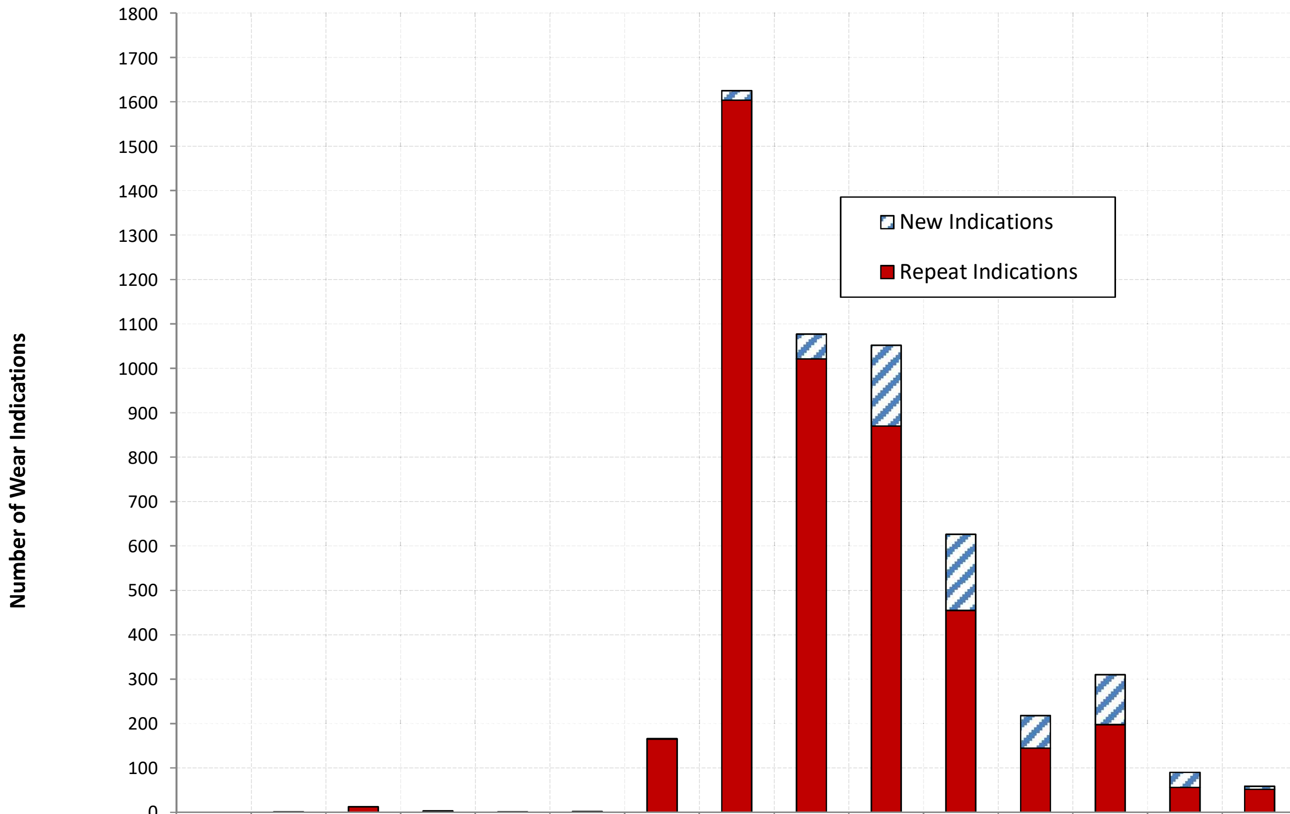
	<5	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	>=60
SG A Repeat	41	2069	1762	477	150	56	21	7	2	1	0	0	0
SG A New	0	0	521	118	16	1	0	1	0	0	0	0	0
SG B Repeat	23	1783	2732	1153	515	187	80	17	4	2	0	0	0
SG B New	0	0	547	106	28	7	1	1	1	1	0	0	0

Depth Bin (%TW)

Notes for Figure 4-6:

1. The reporting threshold for new flaws at the 2024 inspection was increased from 6%TW to 10%TW.

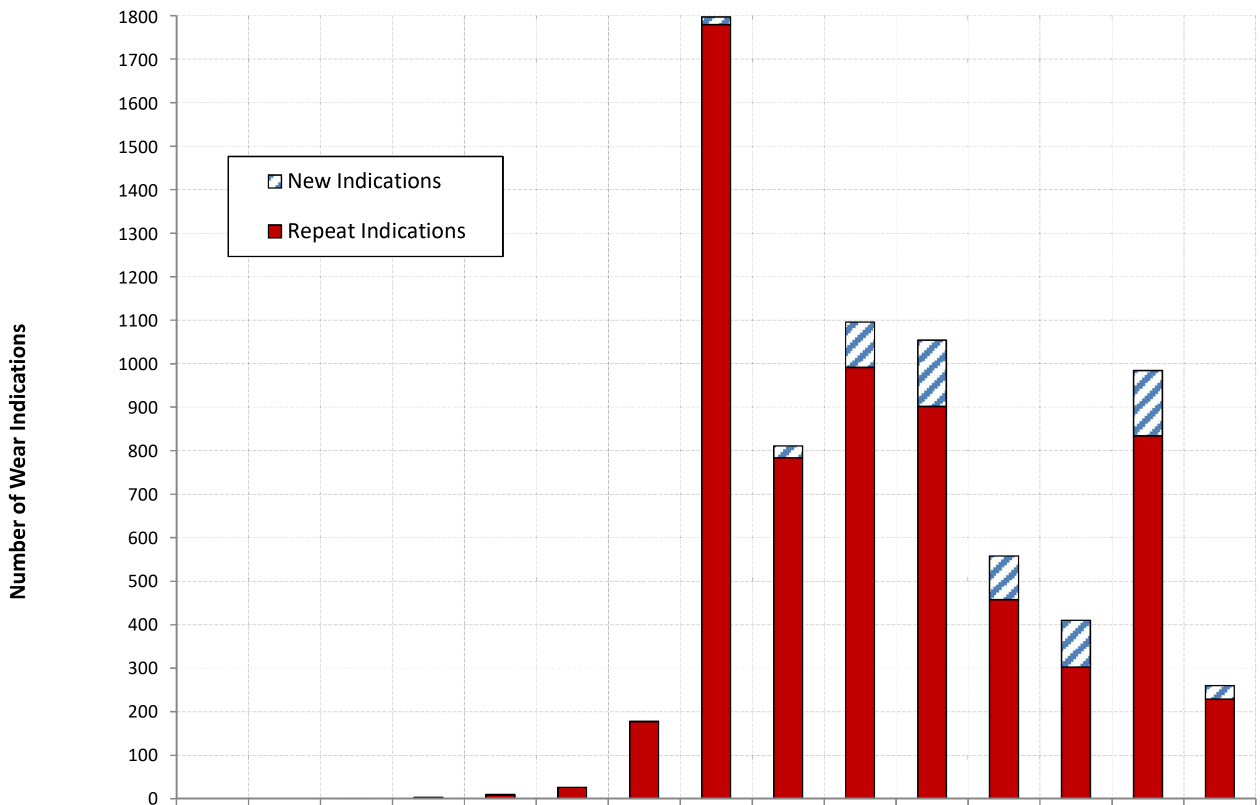
Figure 4-7: 2024 Inspection Broached TSP Wear Distributions by TSP Location – SG A



	01S	02S	03S	04S	05S	06S	07S	08S	09S	10S	11S	12S	13S	14S	15S
New Indications	0	0	0	0	0	0	1	21	56	182	171	73	112	34	7
Repeat Indications	0	1	13	3	1	2	165	1604	1021	870	455	145	198	56	52

Tube Support Plate Location

Figure 4-8: 2024 Inspection Broached TSP Wear Distributions by TSP Location – SG B



	01S	02S	03S	04S	05S	06S	07S	08S	09S	10S	11S	12S	13S	14S	15S
New Indications	0	0	0	0	2	0	1	18	27	104	152	100	107	150	31
Repeat Indications	0	0	1	3	8	26	177	1779	784	992	902	458	303	834	229

Tube Support Plate Location

Figure 4-9: SG A Historical Broached TSP Wear Growth Rates (Entire SG)

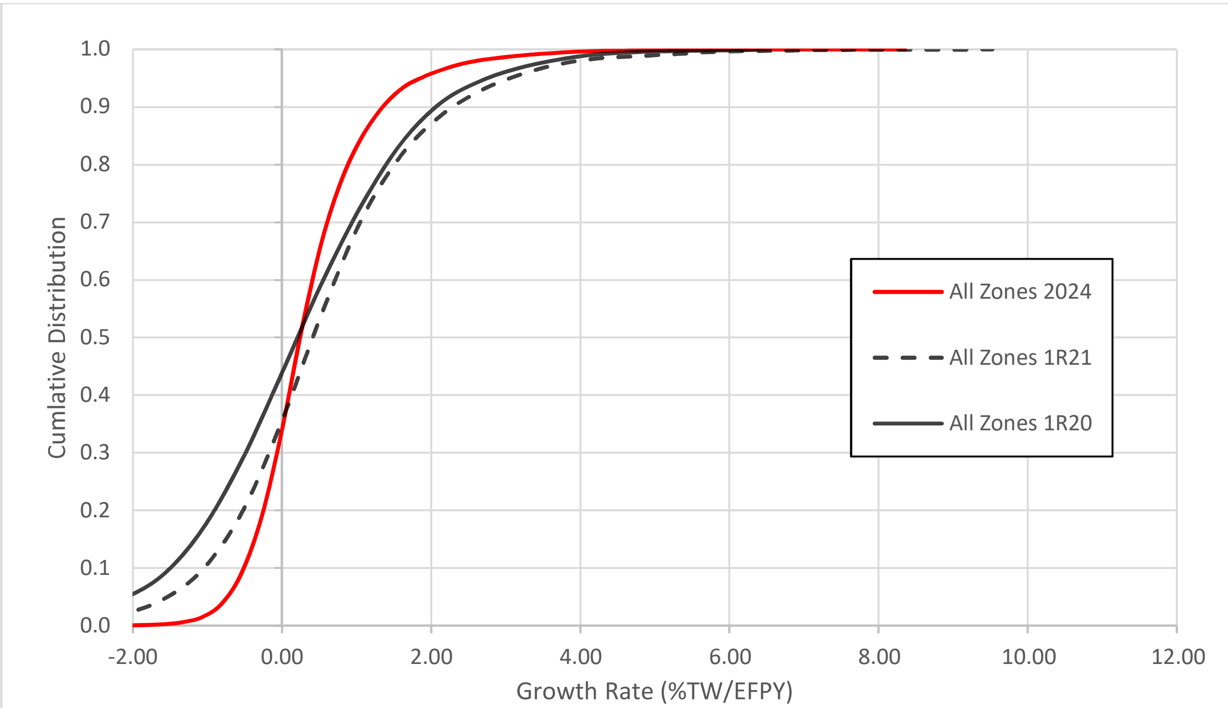


Figure 4-10: SG B Historical Broached TSP Wear Growth Rates

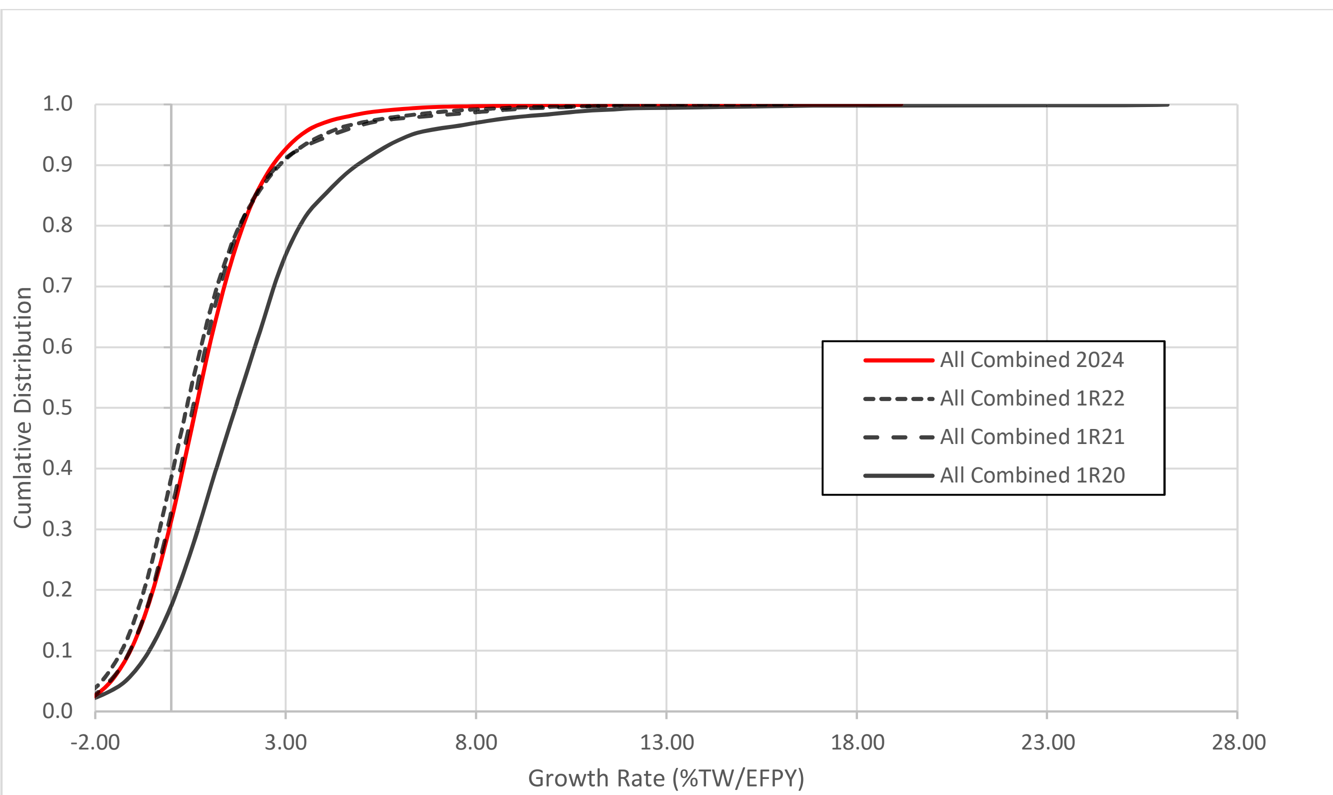


Figure 4-11: SG B Historical Broached TSP Wear Growth Rates for Inner Bundle

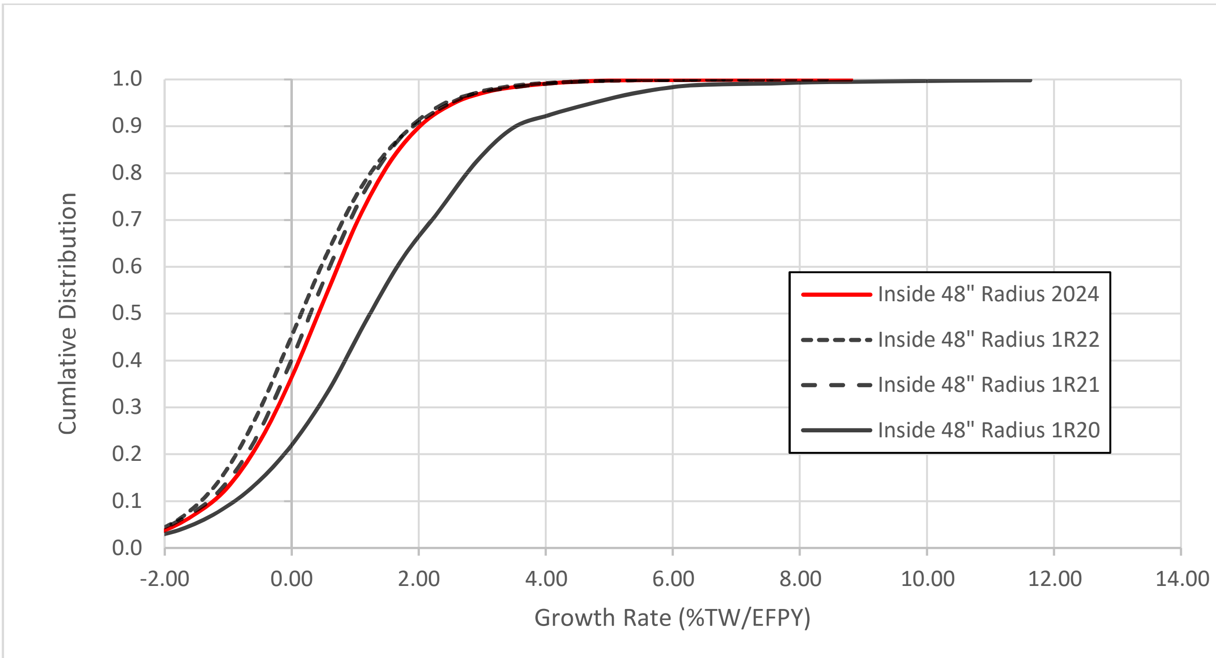


Figure 4-12: SG B Historical Broached TSP Wear Growth Rates Broken Ring Zone

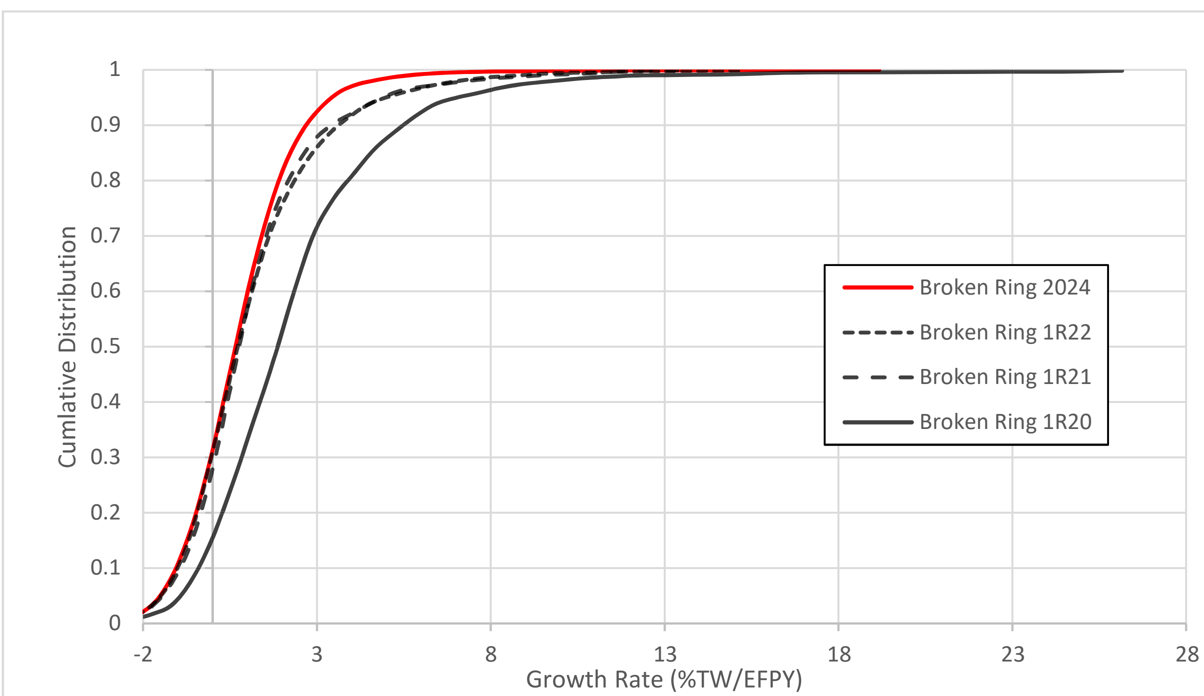


Figure 4-13: SG B Historical Broached TSP Wear Growth Rates W Zone

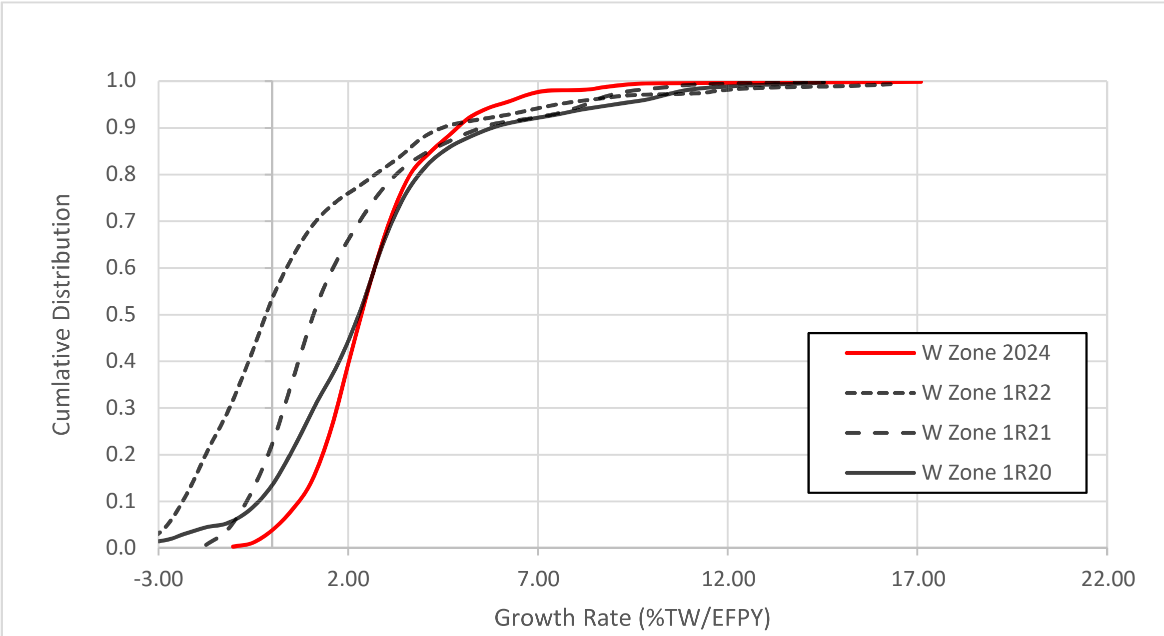
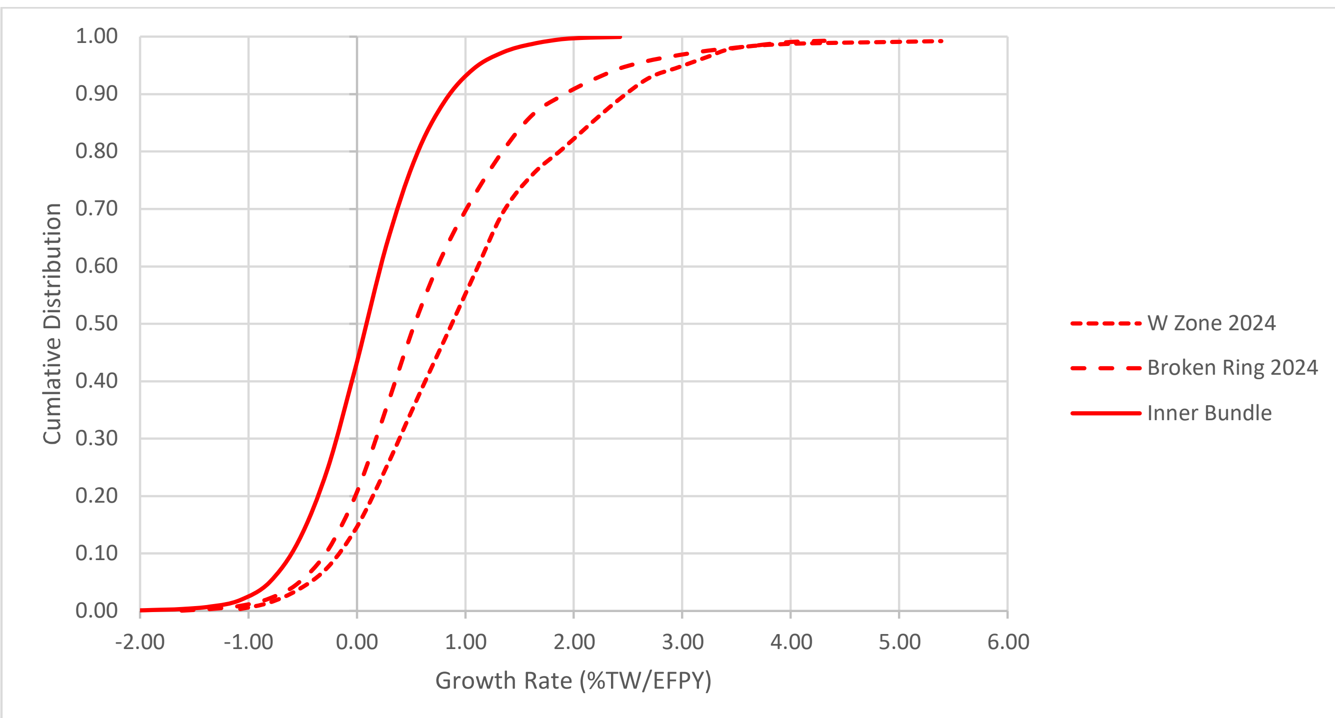


Figure 4-14: SG A Broached TSP Wear Growth Rates by OA Zone



4.1.3 Tube Wear at Drilled TSP Intersections

All drilled support locations are located at the 15th support plate and the Spring 2024 inspection was the first time that drilled TSP wear, was depth-sized with bobbin. Previously, all sizing was done via supplementary exam with the rotating coil probe. The bobbin probe identified 58 flaws (9 in SG A and 49 in SG B), with follow up array inspections confirming 41 indications (8 in SG A, 33 in SG B). The largest flaw drilled support wear detected at the 15th support was tube R145-T7 in SG B and was sized by bobbin at 36%TWD in 2024. The same flaw was identified as Indication Not Reportable (INR) in 1R22 and applying the 2024 sizing to the bobbin signal from the 1R22 data results in a depth of 21%TWD. Of all the flaws confirmed with array, only two had no prior signal in the historical bobbin data with the maximum depth of 16%TW (SG A R2-T17 and R11-T1). None of the drilled TSP wear flaws required plugging; however, SGB tube R145-T7 was plugged for broached TSP wear at the 14th TSP. A summary of drilled TSP wear is provided in Table 4-5, with a complete list of all drilled TSP wear indications provided in in Table 4-6. Figure 4-15 is a tubesheet map showing the locations of drilled TSP wear indications in both SGs.

There were no tubes were plugged for wear at drilled TSP intersections during the Spring 2024 inspection.

Table 4-5: Drilled TSP Wear Statistics

	SG A	SG B
Number of Bobbin Indications	9	49
Number of Array Indications	8	33
Number of New Indications	8	20
Maximum Bobbin Depth (%TW)	19	36
Maximum Array Depth (%TW)	19	26
Maximum New Array Depth (%TW)(1)	16	N/A
Maximum Circumferential Extent (degrees) (2)	130	221
Maximum PDA(2)	4.37	8.74
Average Growth Rate (%TW/EFPY) (3)	1.58	1.09
95th Percentile Growth Rate (%TW/EFPY) (3)	2.96	4.82
Maximum Growth Rate (%TW/EFPY) (3)	2.96	7.77
Number of Tubes Plugged due to Drilled TSP Wear	0	0

Notes:

1. The maximum new Array depth is for confirmed TSP wear that has no signal present in the 1R21 (SG A) or 1R22 (SG B) bobbin data when performing lookups. For SG B, all confirmed wear had a signal present in 1R22.
2. The maximum circumferential extent and PDA are both identified with the same flaws in each SG, R7-T49 for SG A and R103-T4 for SG B.
3. All growth rates are based on the Spring 2024 bobbin depths and the lookups from 1R21 (SG A) and 1R22 (SG B).

Table 4-6: TMI 2024 Inspection Drilled TSP Wear

SG	Row	Tube	Elev	Offset	R21/R22 Results Note 1	R21/R22 Bobbin Lookup Note 2	S2024 Bobbin Depth (%TW)	Bobbin Growth Rate (%TW/EFPY) Note 2	R21/R22 +Point Depth (%TW)	S2024 Array Results Note 1	S2024 Array Depth (%TW) Note 3	Axial Ext (in) Note 4	Circ. Ext (deg) Note 5	PDA Note 5
A	1	11	15S	0.26	DSI/NDF	8	19	2.96	N/A	WAR	17	0.31	104.0	3.65
A	1	15	15S	0.18	NDD	4	11	1.89	N/A	WAR	14	0.31	104.0	2.96
A	1	16	15S	0.26	DSI/NDF	11	11	0.00	N/A	WAR	13	0.31	104.0	2.71
A	1	17	15S	0.2	NDD	7	18	2.96	N/A	WAR	16	0.33	130.0	4.19
A	2	17	15S	0.2	NDD	-	12	N/A	N/A	WAR	16	0.31	91.0	2.93
A	6	46	15S	0.18	NDD	11	17	1.62	N/A	WAR	19	0.29	104.0	3.83
A	7	49	15S	0.14	DSI/NDF	8	14	1.62	N/A	WAR	16	0.38	130.0	4.37
A	10	6	15S	0.21	DSI/NDF	8	8	0.00	N/A	NDF	N/A	N/A	N/A	N/A
A	11	1	15S	0.18	NDD	-	11	N/A	N/A	WAR	14	0.25	78.0	2.06
B	5	3	15S	-0.85	NDD	5	12	3.63	N/A	NDF	N/A	N/A	N/A	N/A
B	5	4	15S	-0.8	DSI/NDF	11	13	1.04	N/A	WAR	14	0.25	117.0	3.29
B	5	33	15S	-0.89	NDD	12	10	-1.04	N/A	WAR	14	0.27	104.0	2.93
B	5	34	15S	-0.98	DSI/NDF	15	15	0.00	N/A	WAR	14	0.25	91.0	2.78
B	6	37	15S	-0.97	NDD	11	11	0.00	N/A	WAR	13	0.27	91.0	2.38
B	7	2	15S	-0.89	DSI/NDF	18	20	1.04	N/A	WAR	16	0.27	143.0	4.88
B	7	48	15S	-0.82	NDD	13	18	2.59	N/A	WAR	15	0.31	130.0	4.26
B	8	5	15S	0.26	DSI/WAR	18	16	-1.04	17	WAR	18	0.38	143.0	5.13
B	8	6	15S	0.25	DSI/WAR	19	21	1.04	18	WAR	16	0.36	143.0	4.88
B	8	8	15S	0.21	DSS	17	20	1.55	N/A	WAR	16	0.29	117.0	3.94
B	8	47	15S	0.21	INR	8	18	5.18	N/A	WAR	17	0.31	104.0	3.61
B	9	3	15S	-0.71	DSS	21	17	-2.07	N/A	WAR	16	0.33	117.0	4.41
B	9	6	15S	0.23	DSS	12	12	0.00	N/A	WAR	14	0.29	117.0	3.36
B	9	7	15S	0.19	NDD	13	14	0.52	N/A	WAR	16	0.36	104.0	3.65

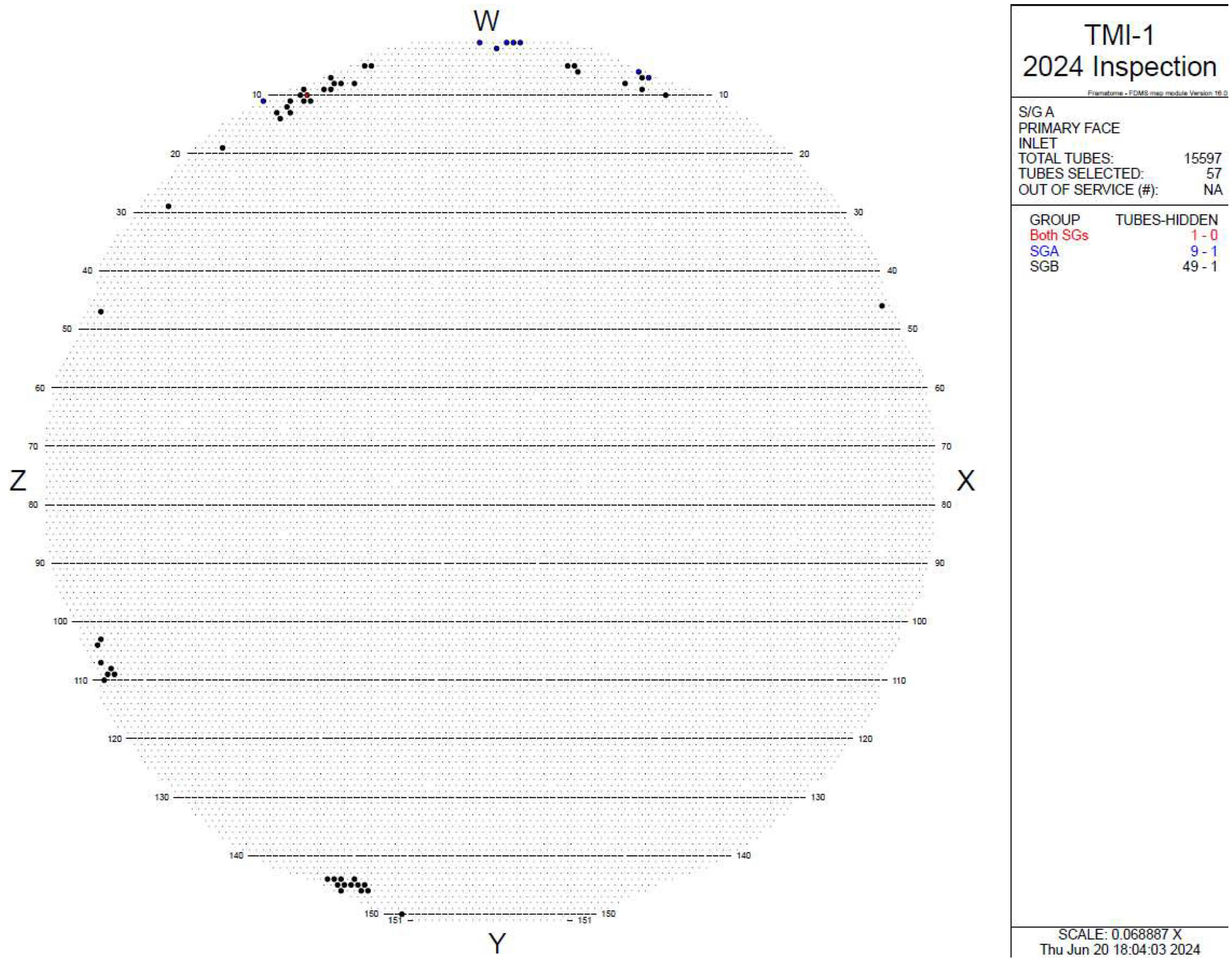
SG	Row	Tube	Elev	Offset	R21/R22 Results Note 1	R21/R22 Bobbin Lookup Note 2	S2024 Bobbin Depth (%TW)	Bobbin Growth Rate (%TW/EFPY) Note 2	R21/R22 +Point Depth (%TW)	S2024 Array Results Note 1	S2024 Array Depth (%TW) Note 3	Axial Ext (in) Note 4	Circ. Ext (deg) Note 5	PDA Note 5
B	9	53	15S	-0.91	DSS	9	10	0.52	N/A	NDF	N/A	N/A	N/A	N/A
B	10	5	15S	0.28	DSS	12	9	-1.55	N/A	NDF	N/A	N/A	N/A	N/A
B	10	6	15S	0.2	DSI/WAR	20	20	0.00	18	WAR	16	0.31	130.0	4.37
B	10	59	15S	-0.89	DSS	13	18	2.59	N/A	WAR	16	0.33	117.0	3.79
B	11	5	15S	-0.76	DSI/NDF	20	17	-1.55	N/A	WAR	15	0.31	117.0	3.68
B	11	7	15S	-0.75	DSS	15	16	0.52	N/A	NDF	N/A	N/A	N/A	N/A
B	11	8	15S	0.21	DSI/WAR	20	19	-0.52	18	WAR	18	0.38	117.0	4.62
B	12	6	15S	-0.76	DSS	21	24	1.55	N/A	WAR	17	0.33	130.0	4.84
B	13	6	15S	0.28	DSS	12	10	-1.04	N/A	NDF	N/A	N/A	N/A	N/A
B	13	8	15S	0.28	DSI/WAR	12	11	-0.52	18	WAR	16	0.33	117.0	4.01
B	14	8	15S	-0.76	DSS	13	17	2.07	N/A	WAR	13	0.27	130.0	3.61
B	19	5	15S	-0.71	DSI/NDF	12	13	0.52	N/A	NDF	N/A	N/A	N/A	N/A
B	29	5	15S	-0.67	NDD	8	16	4.15	N/A	NDF	N/A	N/A	N/A	N/A
B	46	118	15S	0.35	DSI/WAR	19	17	-1.04	28	WAR	13	0.32	78.0	1.95
B	47	3	15S	-0.65	DSS	16	19	1.55	N/A	NDF	N/A	N/A	N/A	N/A
B	103	4	15S	0.33	INR	17	23	3.11	N/A	WAR	18	0.33	221.0	8.74
B	104	3	15S	0.38	DSI/NDF	10	11	0.52	N/A	NDF	N/A	N/A	N/A	N/A
B	107	2	15S	0.44	DSI/NDF	13	18	2.59	N/A	NDF	N/A	N/A	N/A	N/A
B	108	3	15S	0.36	DSI/WAR	31	28	-1.55	22	WAR	23	0.29	182.0	8.38
B	109	2	15S	0.39	DSS	18	21	1.55	N/A	WAR	21	0.42	143.0	6.46
B	109	3	15S	0.35	INR	13	17	2.07	N/A	NDF	N/A	N/A	N/A	N/A
B	110	2	15S	0.44	NDD	9	17	4.15	N/A	NDF	N/A	N/A	N/A	N/A
B	144	4	15S	0.3	DSI/NDF	10	8	-1.04	N/A	NDF	N/A	N/A	N/A	N/A
B	144	5	15S	0.22	DSIWAR	16	15	-0.52	17	WAR	20	0.47	130.0	5.45
B	144	6	15S	0.16	DSI/WAR	21	27	3.11	21	WAR	23	0.36	143.0	6.72
B	144	8	15S	0.2	DSI/WAR	9	14	2.59	11	WAR	16	0.36	104.0	3.83
B	145	3	15S	0.25	DSS	10	12	1.04	N/A	NDF	N/A	N/A	N/A	N/A

SG	Row	Tube	Elev	Offset	R21/R22 Results Note 1	R21/R22 Bobbin Lookup Note 2	S2024 Bobbin Depth (%TW)	Bobbin Growth Rate (%TW/EFPY) Note 2	R21/R22 +Point Depth (%TW)	S2024 Array Results Note 1	S2024 Array Depth (%TW) Note 3	Axial Ext (in) Note 4	Circ. Ext (deg) Note 5	PDA Note 5
B	145	4	15S	0.25	DSS	21	20	-0.52	N/A	WAR	22	0.38	130.0	6.21
B	145	5	15S	0.25	DSS	10	12	1.04	N/A	NDF	N/A	N/A	N/A	N/A
B	145	6	15S	0.22	DSI/WAR	13	24	5.70	16	WAR	19	0.36	156.0	6.21
B	145	7	15S	0.18	INR	21	36	7.77	N/A	WAR	26	0.49	156.0	8.63
B	146	2	15S	0.25	DSI/WAR	21	19	-1.04	10	WAR	19	0.31	104.0	4.26
B	146	5	15S	0.22	DSI/NDF	10	14	2.07	N/A	WAR	17	0.31	117.0	4.44
B	146	6	15S	0.21	NDD	-	10	N/A	N/A	NDF	N/A	N/A	N/A	N/A
B	150	3	15S	0.2	DSI/WAR	11	11	0.00	14	WAR	16	0.31	78.0	2.53

Notes:

1. 1R21 and 1R22 and Spring 2024 results are as follows
   DSS = Distorted Support Signal by Bobbin (NDF in history with no change)
   DSI = Distorted Support Indication by Bobbin
   DSI = Distorted Support Indication by Bobbin
   NDD = No Detectable Degradation by Bobbin
   NDF = No Degradation Found by +Point™ or Array
   WAR = Wear confirmed by +Point™ or Array
2. All Spring 2024 bobbin depths had lookups performed on 1R21 or 1R22 bobbin data. Any signal that was present was sized using ETSS 96042.1 and was used to determine a bobbin growth rate.
3. The Spring 2024 Array depth is the maximum from the line-by-line profile using ETSS 11956.3.
4. The axial extent is from the single line Array WAR measurement.
5. The circumferential extent and Percent Degraded Area (PDA) were determined using the EPRI Draw Program [28] based on the line-by-line profile measurements with approximately 13° between measurements.

Figure 4-15: TMI 2024 Inspection Drilled TSP Wear Map – Both SGs



4.1.4 Tube-to-Tube Wear

During the 2024 inspection, there were 398 indications of tube-to-tube wear (TTW) identified with the bobbin probe (111 in SG A and 287 in SG B). All of these indications were relatively shallow with the deepest measuring 20% TWD with a fixed-curve bobbin sizing technique. Tube-to-tube wear has been reported and sized by bobbin, array and +Point™ since its initial discovery, with array and +Point™ capable of distinguishing multiple wear flaws at the same axial location. Because the bobbin technique tends to conservatively oversize TTW, particularly when multiple wear flaws exist at the same axial location, and because this degradation mechanism has not challenged the OAs for any of the OTSGs it has been identified in, it is the primary probe used for sizing.

Table 4-7 and Figure 4-16 through Figure 4-20 provide additional information and illustrate that the growth rate has attenuated since first being identified, to a point where it is fairly stagnant compared to the prior inspection. The deepest TTW indications reported in 2024 were 20% TWD in both SGs with maximum growth rates approximately 1.0 and 2.0 %TW/EFPY in SG A and SG B, respectively.

No new TTW was identified adjacent to any tie rod locations and with all repeat indications having been confirmed as TTW during prior inspections, tie-rod wear (TRW) is not existing in either of the TMI-1 SGs as of the Spring 2024 inspection.

No tubes were plugged for TTW during the Spring 2024 inspection.

Table 4-7: Tube-to-Tube Wear Summary for 2024 Inspection

	SG A	SG B
Total Number of In-Service Tubes After 2024 Inspection	15582	15315
Number of TTW Indications	111	287
Number of Tubes with TTW	111	280
Average Depth of TTW (%TW)	9.64	9.68
Maximum Depth of TTW (%TW)	20	20
Number of TTW Indications ≥15%TW	3	3
Number of TTW Indications ≥10%TW	28	81
Average Growth Rate for Repeat TTW Indications (%TW/EFPY)	0.197	-0.02
Upper 95th Percentile Growth Rate for Repeat TTW (%TW/EFPY)	0.809	1.04
Maximum Growth Rate for Repeat TTW (%TW/EFPY)	1.078	2.07
Number of Newly-Reported Indications	0	2
Average Depth for New Indications (%TW)	NA	9
Maximum Depth for New Indications (%TW)	NA	9
Number of Tubes Plugged due to TTW	0	0

Notes:
1. All sizing and growth rates are based on bobbin probe results.

Figure 4-16: 2024 Inspection Tubes with Tube-to-Tube Wear Indications – SG A

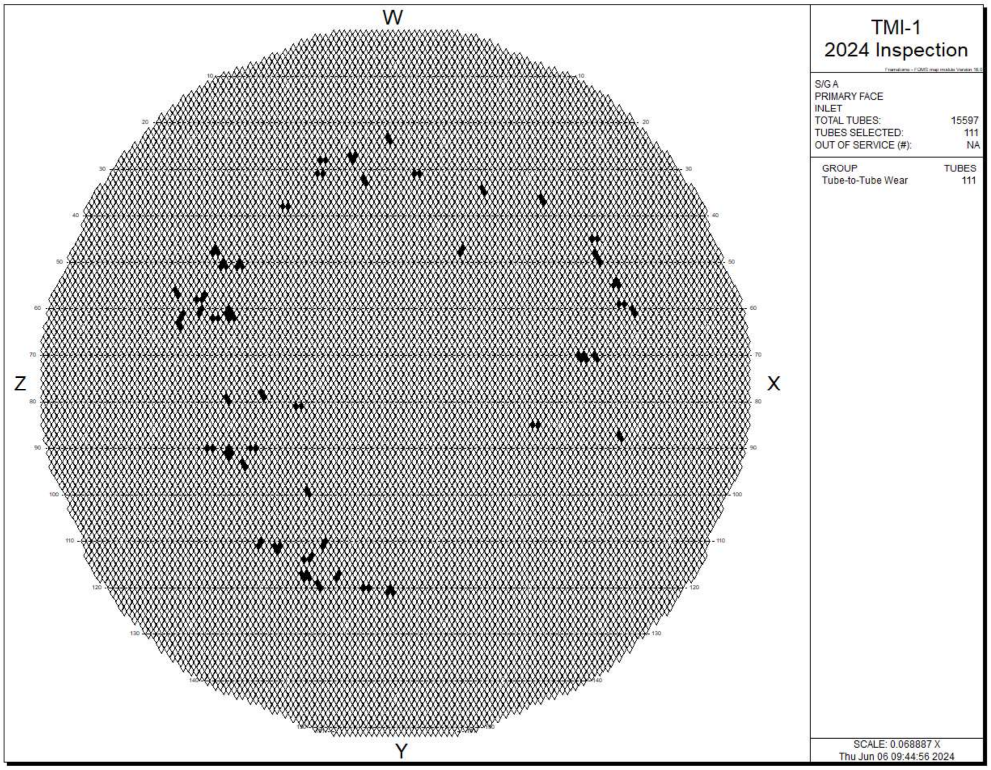


Figure 4-17: 2024 Inspection Tubes with Tube-to-Tube Wear Indications – SG B

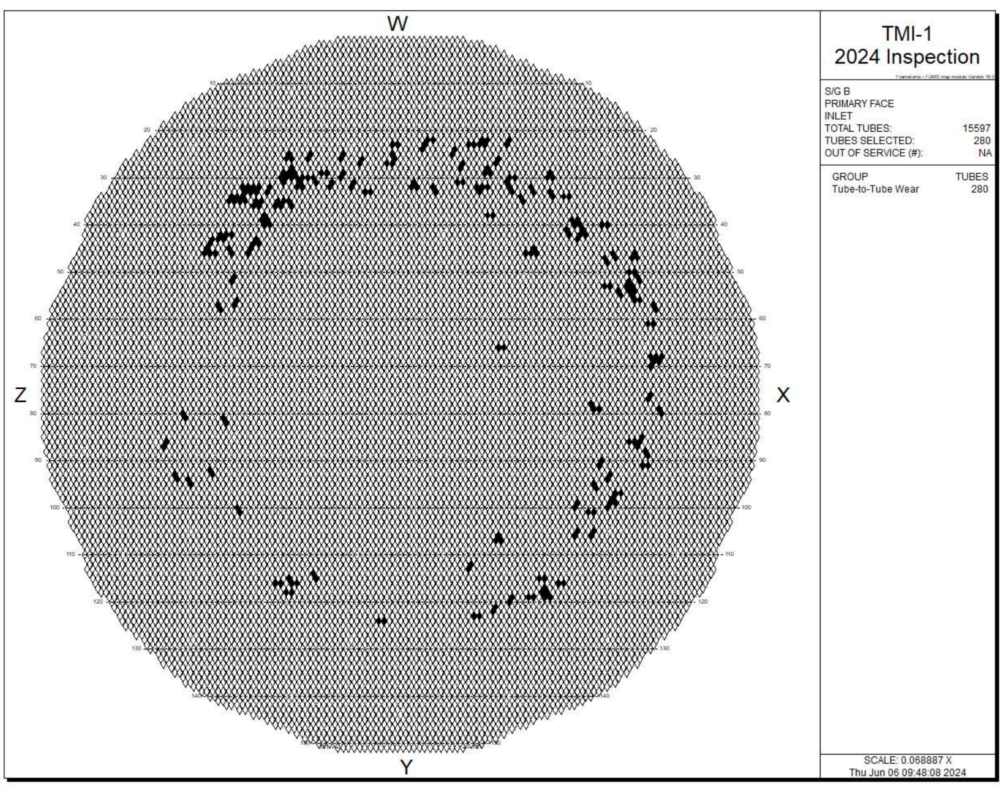
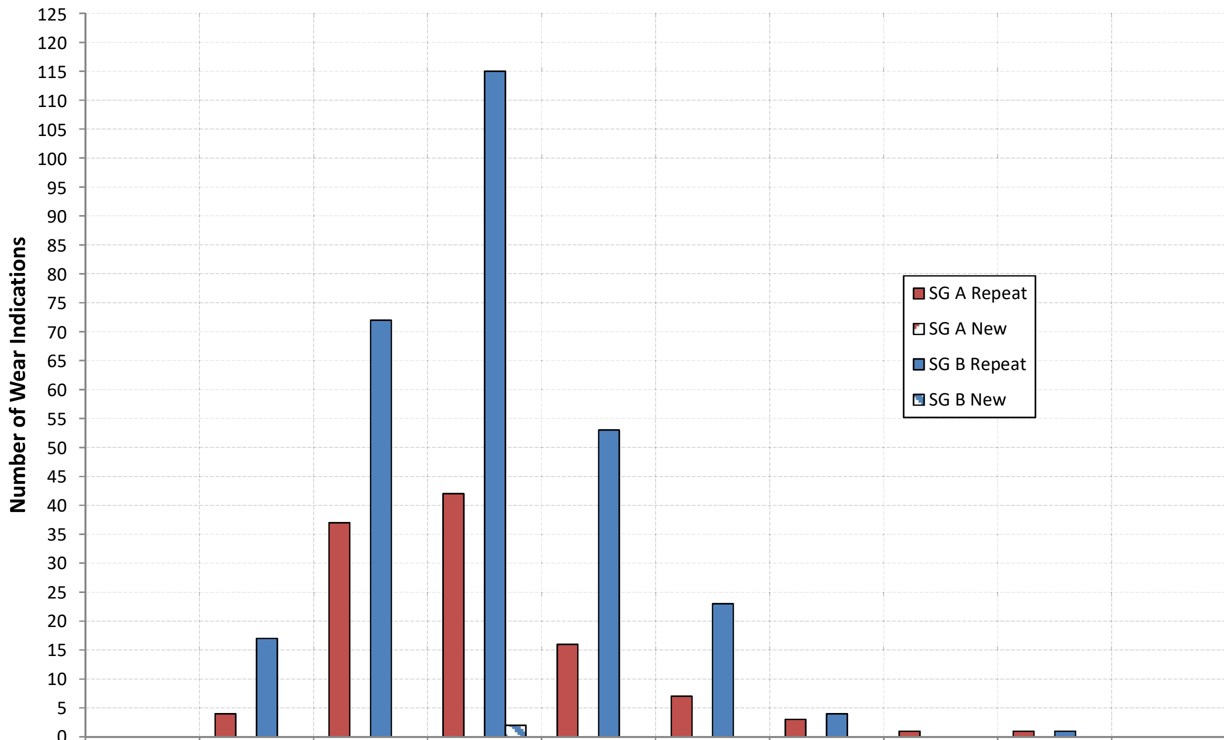


Figure 4-18: 2024 Inspection Tube-to-Tube Wear Depth Distributions – Both SGs



	<=4	5 to 6	7 to 8	9 to 10	11 to 12	13 to 14	15 to 16	17 to 18	19 to 20	>20
SG A Repeat	0	4	37	42	16	7	3	1	1	0
SG A New	0	0	0	0	0	0	0	0	0	0
SG B Repeat	0	17	72	115	53	23	4	0	1	0
SG B New	0	0	0	2	0	0	0	0	0	0

TTW Depth (%TW)

Notes for Figure 4-18:

1. The reporting threshold for new flaws at the 2024 inspection was increased from 5%TW to 10%TW.

Figure 4-19: 2024 Inspection Tube-to-Tube Wear Growth Distributions – SG A

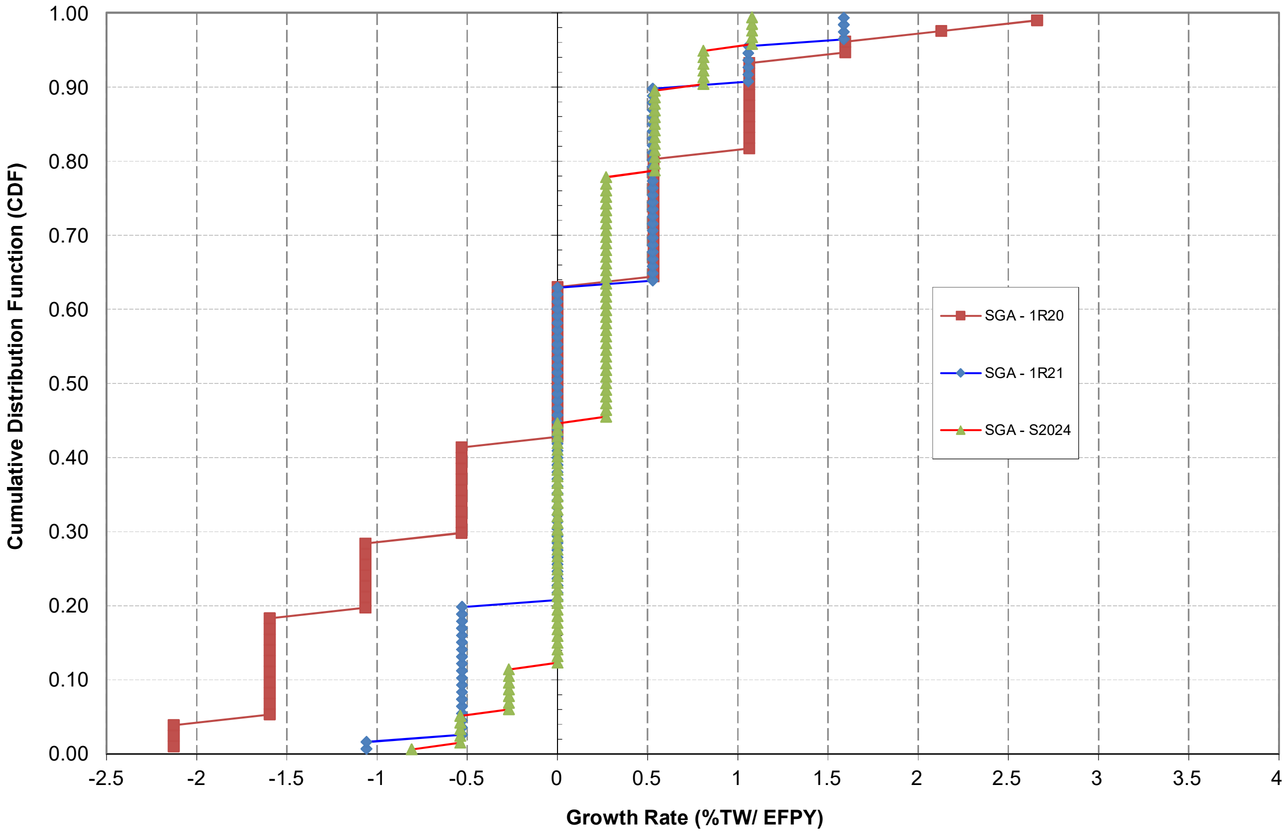
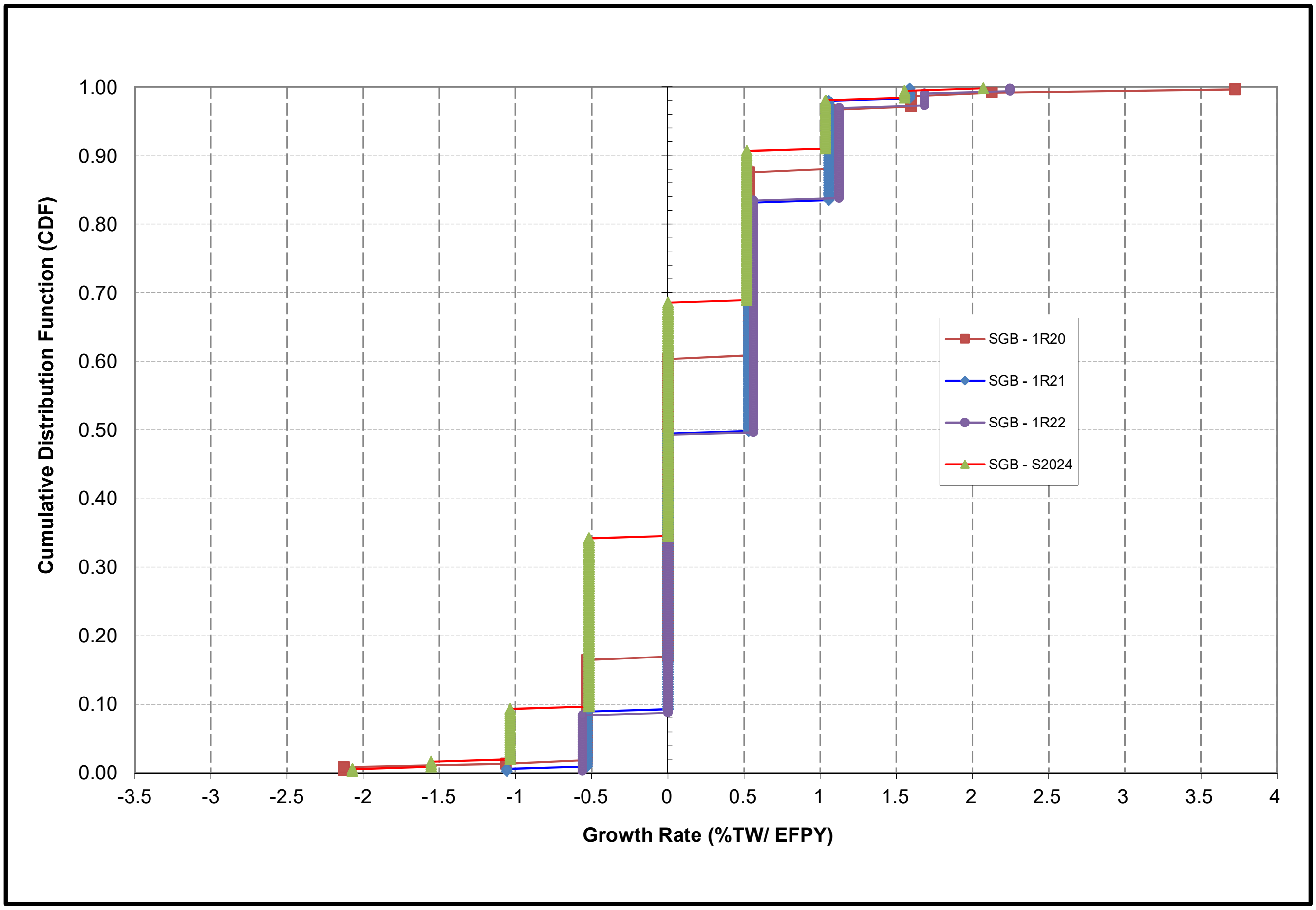


Figure 4-20: 2024 Inspection Tube-to-Tube Wear Growth Distributions – SG B



4.1.5 Tie Rod Bowing

Twelve tubes in SG B were identified as having proximity signals adjacent to tie rod locations (PTR). The locations are shown in Figure 4-21. No tubes in SG A exhibited proximity signals of any kind.

All proximity indications occurred "inboard" of tie rod locations (i.e. toward the center of the SG relative to the associated tie rod) from approximately 22 to 25 inches above the 14th TSP. Tubes on the opposite side of these tie rods (i.e. toward the periphery relative to the associated tie rod) showed signals indicating that the tie rod had moved away from those tubes. This strongly indicates that the six tie rods in question were subject to bowing. No signals were identified as indicative of contact between a tie rod and a tube. Tie rod bowing is a known phenomenon and has been identified in two other operating OTSG units, one of which, ANO-1, is an EOTSG design similar to TMI-1.

The models developed in response to the original discovery of tie rod bowing in ANO-1 shows that the bowing takes place after a heat up/cool down cycle due to binding of the tube support plates against the surrounding structures during thermal contraction. Relative movement of the shroud to TSP, combined with binding between the two, places a compressive load on the tie rods. Consequently, models indicate that the bowing is at its maximum in the cold condition and minimized at operating temperature. For ANO-1, tie rod bowing is primarily in the 1st span where the tie rod diameter is smaller at 0.625", but some minor amounts of bowing had bene detected in the upper spans where the tie rod diameter is larger at 0.787". During the manufacture of the TMI-1 SGs, the tie rods in the 1st span were made to match the upper span diameter of 0.787" as a means to mitigate potential for tie rod bowing.

One of the potential causes for tie rod bowing in a non-EOTSG SG [26] is that deposit buildup in the broached holes could increase locking of the tubes to the TSPs causing downward forces on the tie rods as the tubes pull down on the TSPs during cooling. A complete deposit mapping study, including review of full-length array data, could provide additional information in understanding potential contributing causes behind tie rod bowing at TMI.

The Framatome developed methods using a gap calibration standard to measure tie rod displacement with ECT [22] confirmed that none of the tubes are in contact with an adjacent bowed tie rod. Additionally, assuming that the current bowed magnitude has occurred over at least 5 cooldowns since the SGs have been installed, any projected bow over the course of an additional heat-up and cooldown cycle (HU/CD) will be within the 0.2" elastic range as determined from testing of the tie rods [23]. Therefore, there is no potential for contact with an in-service tube during operation. See Table 4-8 for a summary of the Tie Rod Proximity (PTR) indications and calculated tie rod bow. A representative calculation is provided in Figure 4-22.

A concern associated with tie rod bowing is the potential for a tie rod to come into contact with an in-service tube, or for a tube in contact with a tie rod to be pushed into contact with another in-service tube during operation. While conservative wear rates are estimated for both tie rod-to-tube and for tube-to-tube contact [27], the strategy has historically been to preventatively plug any tubes that have potential for contact during operation with either a tie rod or another tube displaced by tie rod bowing. Note that tie-rod wear (TRW) was identified during a recent ANO-1 inspection but was determined not to be from tie rod bowing and therefore the affected tubes were left in-service due to having historical signals present confirming small wear rates [27]. During the TMI-1 2024 inspection, no new tube-to-tube wear was identified adjacent to any tie rod locations. As such it is not presently feasible that wear on a tube caused by tie rod contact could have been mis-identified as TTW.

Proximity and contact signals related to tie rod bowing are detected by the same bobbin technique used for the full-length exam normally performed on 100% of the tubes. Recurring or new proximity indications will be detected in this way in future inspections and the status of existing or new indications can be tracked and any progression of tie rod displacement can be monitored, with remedial actions taken as appropriate.

No tubes were plugged as a result of tie rod bowing.

Figure 4-21: Tie Rod Proximity Indications in SG B

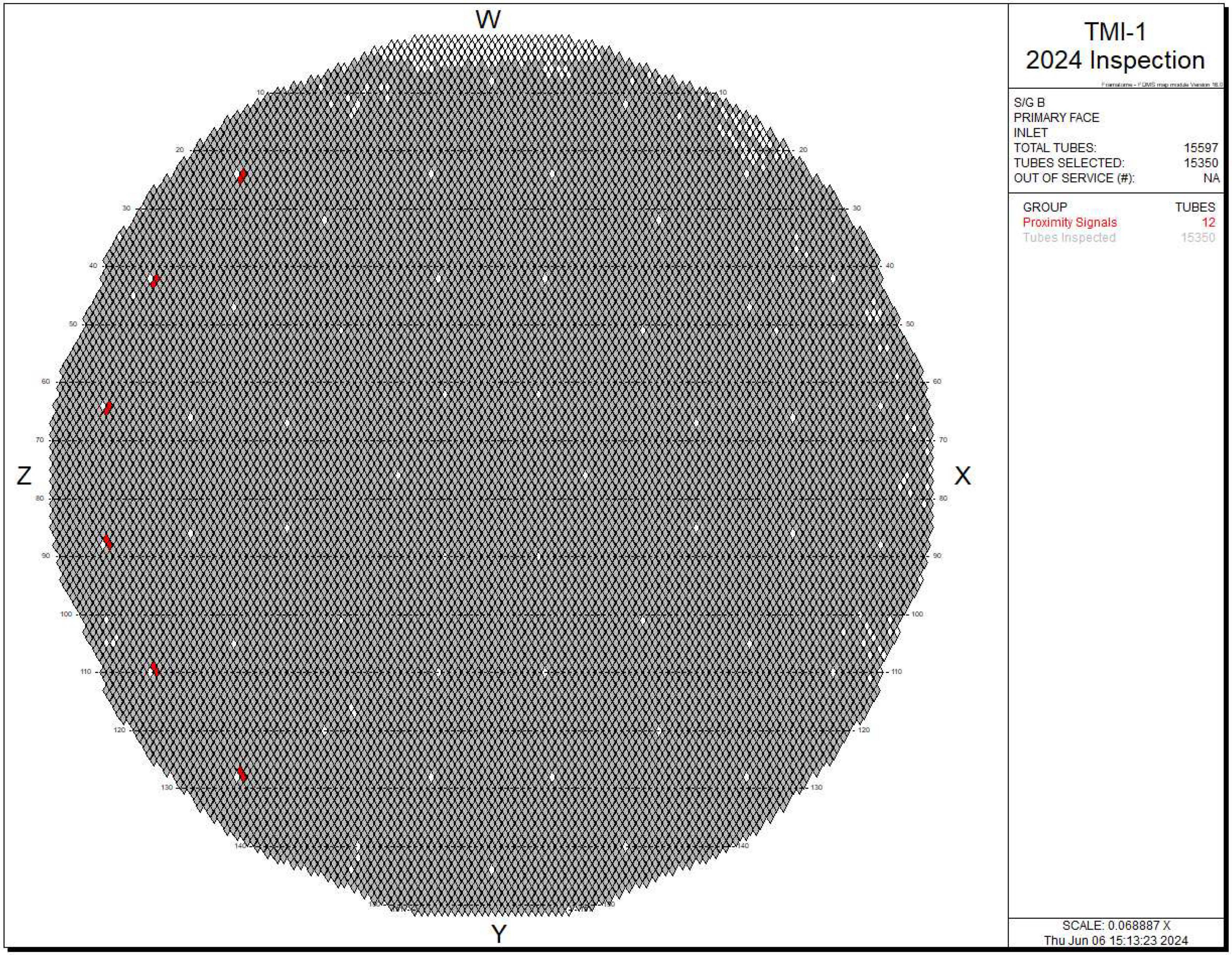


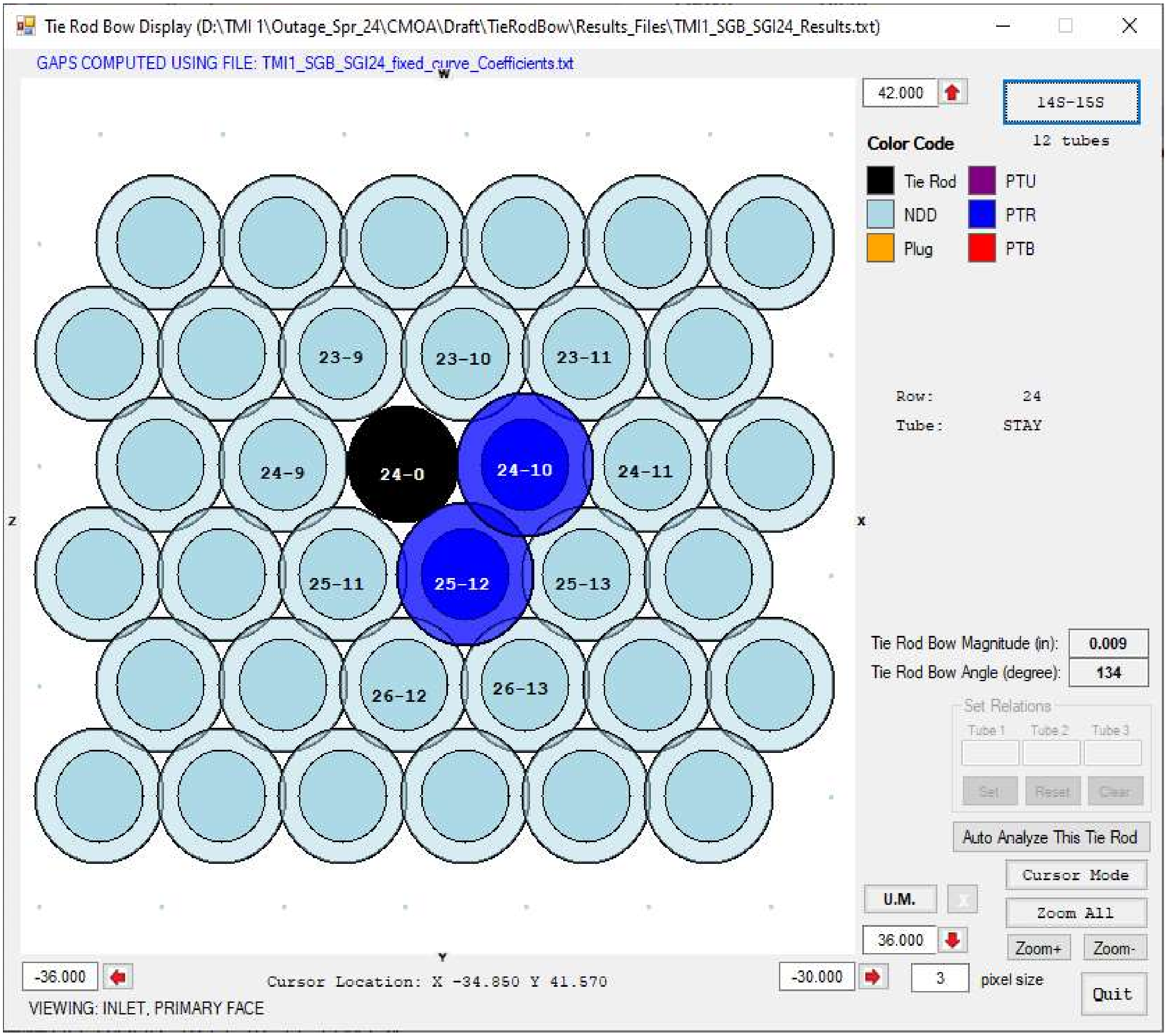
Table 4-8: TMI-1 2024 Tie Rod Gap Measurements

SG	Row	Tube	Elev	Offset (in)	Ind	Volts	Deg	Chan	Util1 (Volts)	Proximity (in)	Associated Tie Rod Bow (in)(1)	Elastic range [22]
B	24	10	14S	24.92	PTR	0.17	319	P14	0.14	0.175	0.009	Yes
B	25	12	14S	24.59	PTR	0.15	346	P14	0.15	0.178		Yes
B	42	8	14S	22	PTR	0.57	214	P14	0.76	0.060	0.110	Yes
B	43	8	14S	23.6	PTR	0.33	237	P14	0.41	0.107		Yes
B	64	8	14S	24.44	PTR	0.61	205	P14	0.81	0.055	0.127	Yes
B	65	8	14S	22.86	PTR	0.51	217	P14	0.7	0.068		Yes
B	87	8	14S	22.39	PTR	0.30	199	P14	0.28	0.125	0.084	Yes
B	88	8	14S	24.79	PTR	0.40	219	P14	0.59	0.085		Yes
B	109	8	14S	22.39	PTR	0.26	237	P14	0.28	0.131	0.058	Yes
B	110	8	14S	24.14	PTR	0.33	223	P14	0.35	0.113		Yes
B	127	12	14S	23.43	PTR	0.22	232	P14	0.34	0.130	0.042	Yes
B	128	10	14S	22.93	PTR	0.26	203	P14	0.25	0.135		Yes

Notes:

1. The tie rod bow is conservatively calculated by subtracting the proximity from the maximum possible tie rod displacement of 0.204” for a tie rod to contact the adjacent tube. For example, the tie rod adjacent to tubes R64-T8 and R65-T8 had the smallest proximity of 0.055”, resulting in a maximum possible tie rod bow of 0.149”.

Figure 4-22: Representative Tie Rod Bow Calculation



4.2 Secondary Side Inspections

In response to the extended shutdown with a lack of a managed layup on the secondary side, visual inspections were performed in the secondary side of both SGs [29, 33]. This was the first time since the preservice inspection that the secondary side of these SGs was inspected.

- Top of tubesheet inspections were performed in both steam generators. This included general views of the tubesheet to the shell annulus region, tube to tubesheet interfaces looking inward approximately 10 tubes deep into the bundle around the entire periphery of the SGs.
- An inspection was performed of the entire anulus trough region.
- An inspection was performed looking up at the orifice plate around the entire periphery. Views included orifice plate hardware and other supports/structures in the area above the top of tubesheet.

A small number of foreign objects were identified. All were either removed or dispositioned as acceptable to remain in place as discussed in Section [6.0].

4.3 Comparison to Previous Operational Assessment

The previous OAs [21, 34] included deterministic and probabilistic analyses for all detected mechanisms (tube-to-TSP wear and tube-to-tube wear). This section compares the projections from the last OA for each SG to the as-found conditions during the 2024 inspection.

Table 4-9 provides a summary of the projected versus as-found comparison. The quantities and depths of TSP wear and TTW are bounded by predictions in the previous OAs with the exception of the largest depths for new broached flaws in SGA and the inner bundle for SGB. These locations are generally benign in comparison to the more controlling periphery (W-zone and Broken ring) of SGB which had larger new flaws bounded by the OA.

Table 4-9: SG A Comparison to Previous Operational Assessment

Parameter	1R21 OA Prediction [21]	2024 Actual
Cycle Length	3.73	3.71
Repeat Flaw Broached TSP Wear Max Depth (%TW)	71.3(1)	46
New Flaw Broached TSP Wear Max Depth (%TW)	35.25(1)	37(2)
Number of new Broached TSP Flaws	4,440	657(3)
Drilled TSP Wear Max Depth (%TW)	40.7	19
TTW Max Depth (%TW)	39.7	20

Notes:

1. Broached TSP wear was evaluated probabilistically, and the max repeat and new depths projected are an upper 95th value of all max depths from 400 Monte Carlo simulations.
2. The largest new flaw was 37%TW and next biggest flaw was 27%TW.
3. The reporting threshold for new flaws was raised from 6 to 10%TW for the 2024 inspection.

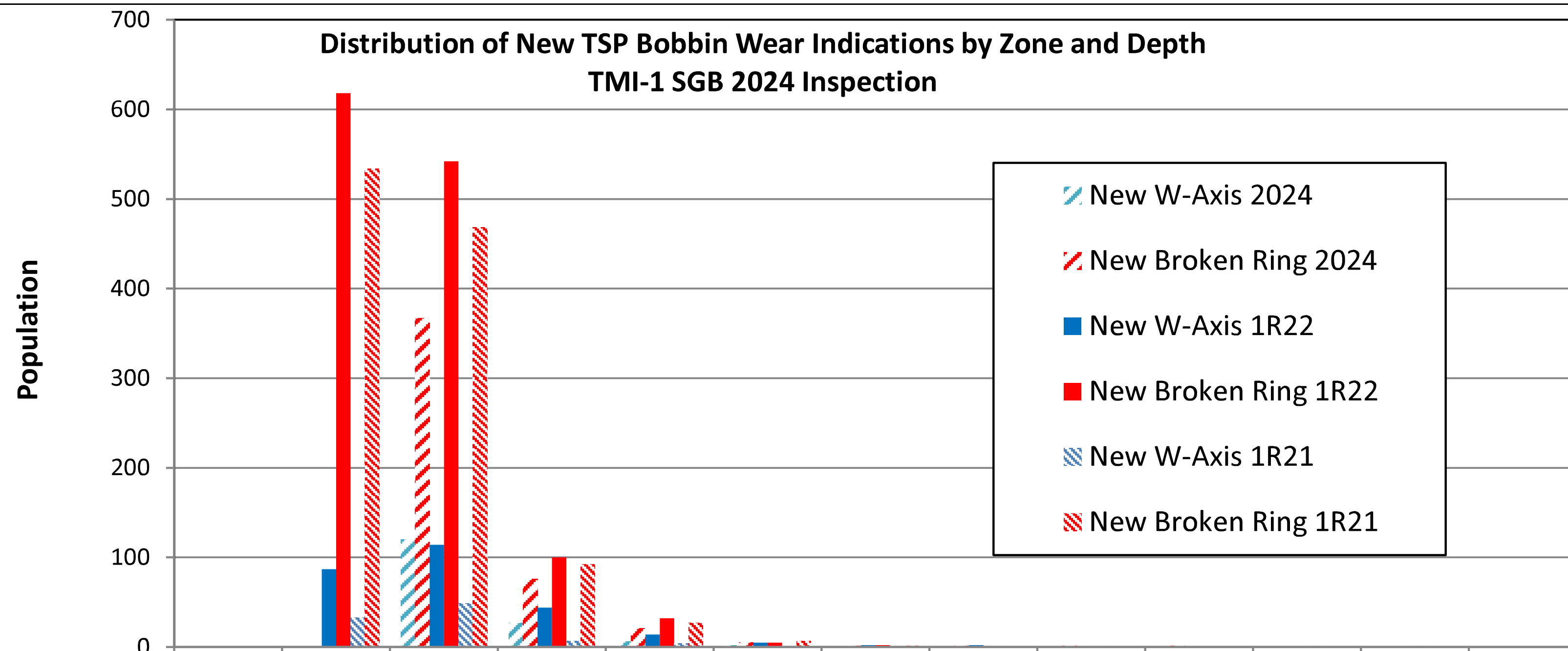
Table 4-10: SG B Comparison to Previous Operational Assessment

Zone	Parameter	1R22 OA Prediction [34]	2024 Actual
	Cycle Length	2.0	1.93
W-Axis	Repeat Flaw Broached TSP Wear Max Depth (%TW)	65(1)	47
	New Flaw Broached TSP Wear Max Depth (%TW)	35(1)	27
	Number of new Broached TSP Flaws	536	155(3)
Broken Ring	Repeat Flaw Broached TSP Wear Max Depth (%TW)	70(1)	47
	New Flaw Broached TSP Wear Max Depth (%TW)	49(1)	46
	Number of new Broached TSP Flaws	1628	473(3)
Inner Bundle	Repeat Flaw Broached TSP Wear Max Depth (%TW)	50(1)	32
	New Flaw Broached TSP Wear Max Depth (%TW)	16(2)	23(2)
	Number of new Broached TSP Flaws	740	64(3)
N/A	Drilled TSP Wear Max Depth (%TW)	39.2	36
N/A	TTW Max Depth (%TW)	23.5	20

Notes:

1. Broached TSP wear was evaluated probabilistically, and the max repeat and new depths projected for W-axis and Broken Ring are an upper 95th value of all max depths from 100 Monte Carlo simulations. The depth for inner bundle is a maximum of all 100 simulations.
2. The largest new depth for the inner bundle was not predicted; however, the maximum possible depth of new flaws was 16%TW based on the input distribution. A total of 2 new flaws in 2024 were larger than 16%TW, a 23%TW and a 17%TW flaw.
3. The reporting threshold for new flaws was raised from 6 to 10%TW for the 2024 inspection with a comparison for each zone to the prior two inspections shown in Figure 4-23.

Figure 4-23: Depth Distributions of New Bobbin Indications by Zone – SG B



	<5	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	>=60
New W-Axis 2024	0	0	120	27	6	2	0	0	0	0	0	0	0
New Broken Ring 2024	0	0	367	76	21	5	1	1	1	1	0	0	0
New W-Axis 1R22	0	87	114	44	14	5	2	2	0	0	0	0	0
New Broken Ring 1R22	0	618	542	100	32	5	2	1	1	0	1	1	0
New W-Axis 1R21	0	33	49	7	4	0	0	0	0	0	0	0	0
New Broken Ring 1R21	0	534	468	92	27	[illegible]	1	0	0	0	0	0	0

Notes for Figure 4-23:

1. The reporting threshold for new flaws at the 2024 inspection was increased from 6%TW to 10%TW.

4.4 Noise Monitoring

In accordance with Revision 8 of the EPRI Examination Guidelines the noise associated with the regions of interest (ROIs) for freespan wear and TSP wear at broached and drilled supports was measured. Figure 4-24 shows that a typical ETSS noise distribution ("baseline noise"). Due to the differing eddy current response at TSP centers and edges, two separate noise groups were created for TSP wear, one for the center of the support and the other for the edges. Noise at all ROIs was measured and compared to the upper limit developed in the DA. Drilled support edge noise was most limiting, but inspection data never approached the upper limit as show in Figure 4-25.

Figure 4-24: SG B Probability of Detection of Baseline Limiting Noise Distribution

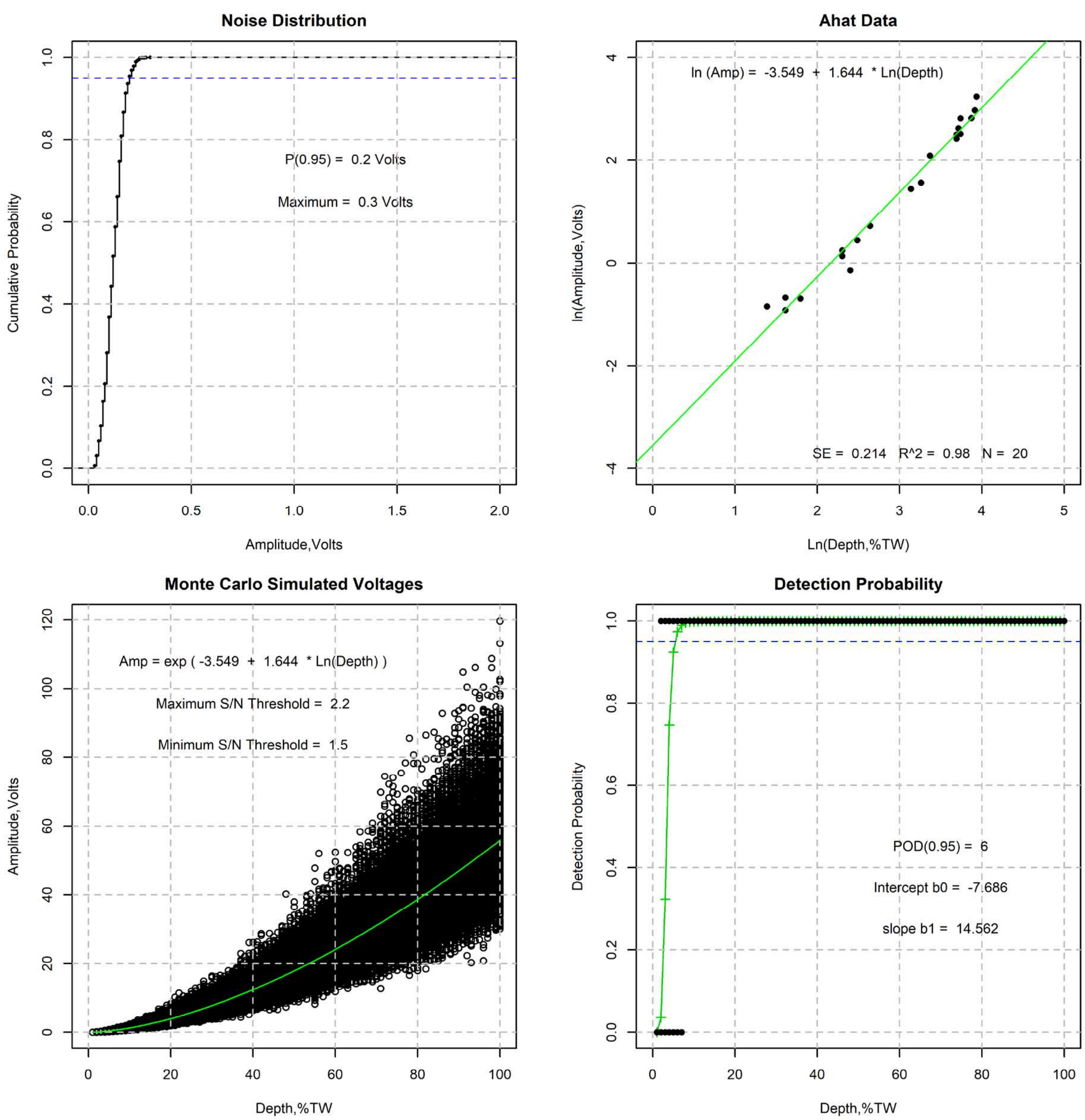
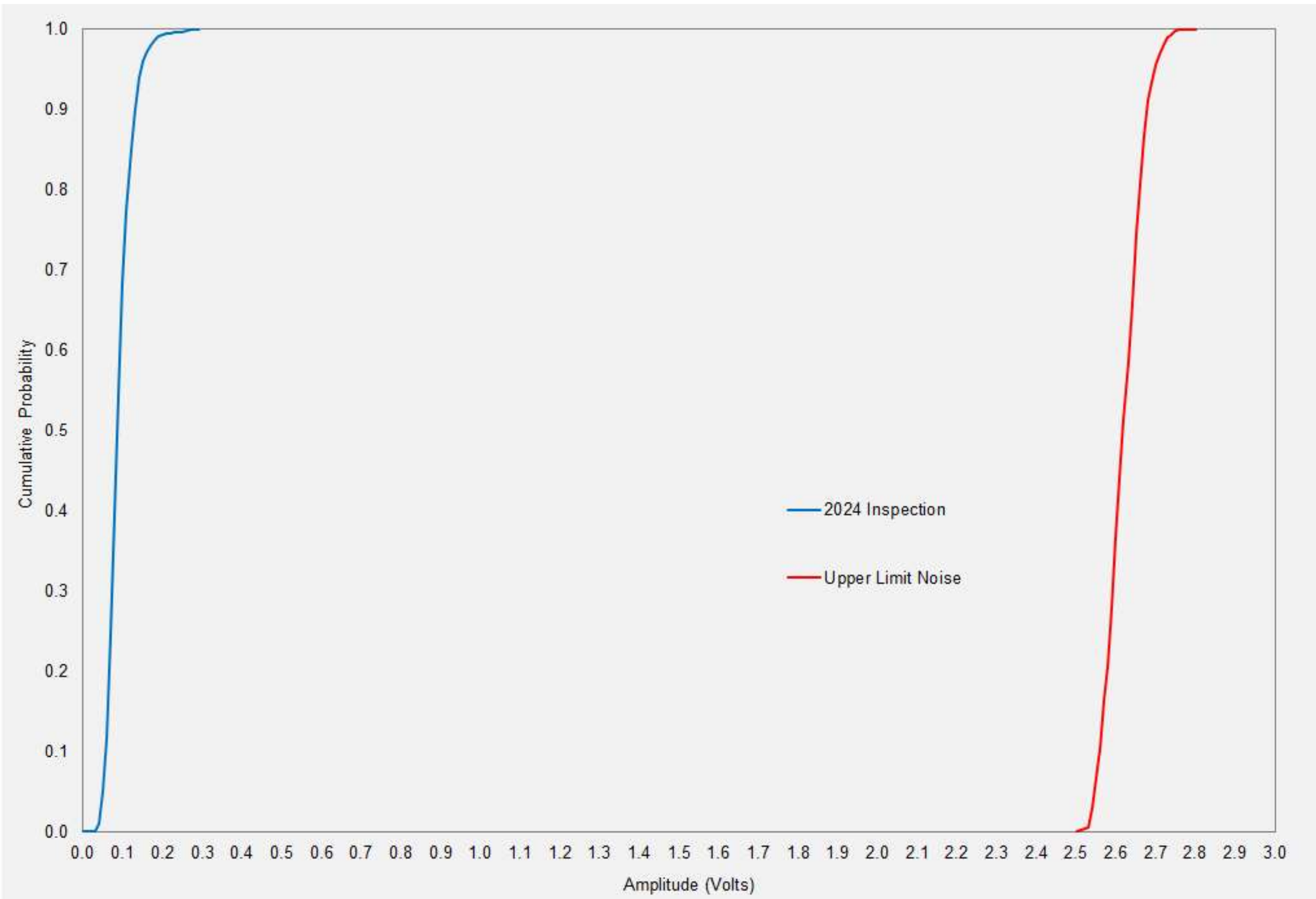


Figure 4-25: SG B Drilled TSP Edge ECT Noise Vs. Upper Limit



4.5 As-Found Condition Reports

In the course of as-found examinations, three relevant condition reports (CRs) were initiated in response to conditions identified, CR 2024-1333, CR 2024-1448, and CR-2024-1630. Additionally, three CRs were initiated related to issues with threaded fasteners as listed in Table 4-11 for tracking purposes.

Table 4-11: TMI-1 2024 SG Threaded Fastener CRs

Framatome CR Number	Condition
CR-2024-1356	SG B2 studs stuck in secondary side hand hole
CR-2024-1380	SG B as found damaged studs
CR-2024-1364	SG B studs stuck on upper primary insp port

4.5.1 CR 2024-1333

Since the SG A upper manway cover had been removed for an extended period of time during shutdown (to serve as an RCS vent path), a visual inspection was performed down both cold legs to ensure no foreign material had entered via the upper manway opening, fallen through tube(s) and down the cold legs. The video inspection revealed no foreign objects and no abnormal conditions.

While performing the visual inspection of SG B lower head, dark areas were noted on the inside diameter of the left nozzle. Review of closeout video from 1R22 in 2017 revealed the same areas, unchanged. The areas showed no evidence of material loss or degradation and are believed to be highly-polished areas left over from fabrication that reflect more light away from the camera and as a result, appear darker than the surrounding area. Framatome CR 2024-1333 and Constellation AR 04779302 were initiated to document and track these. See Figure 4-26.

Figure 4-26: CR 2024-1333: SG B Cold Leg Nozzle Blemishes as seen in 2017 (l) and 2024 (r)

4.5.2 CR 2024-1448

While performing a preliminary review of the TTS on the Upper Channel head of SG A, in the region below the Primary Handhole (also referred to as Inspection Port) a localized area of discoloration was seen. The localized discoloration started from the handhole along the ID of the channel head and down onto the tubesheet (~R60-90T1-10). Near R78 T01 and R76 T01 along the periphery region of the tubesheet a more localized anomaly was visible, covering an area of approx. 1" long x 2" wide. Based on the actions prescribed in the CR (i.e., scraping the area with a putty knife blade on a pole) the material on the tubesheet was identified as boron and condensation that dripped down from the primary handhole. No further actions are required based on the action taken. See Figure 4-27.

Figure 4-27: CR 2024-1448: Suspect Foreign Material in SG A Upper Head

4.5.3 CR 2024-1630

CR 2024-1630 was initiated to document the identification of Tie Rod Bowing. This is discussed fully in section [4.1.5]. The overall conclusion is that it not unreasonable for tie rod bowing to occur at TMI-1 and that the magnitude of the tie rod bowing at TMI-1 is not expected to result in tie rod to tube contact over the projected 1-cycle of operation assuming 2 cooldowns per cycle. Similar to ANO-1, tie rod bowing is expected to be managed by regular inspection intervals as determined by an operational assessment.

5.0 CONDITION MONITORING

The observed degradation in the TMI-1 SGs identified during the Spring 2024 Inspection was evaluated to determine if structural and leakage integrity requirements were maintained. The evaluation was consistent with NEI 97-06 and the applicable EPRI Guidelines [1] [5] [6]. The degradation was shown not to present challenges performance criteria under normal operating or postulated accident conditions.

5.1 INPUTS FOR CM EVALUATION

For most of the degradation detected at TMI-1, the limiting structural integrity performance criterion is three times the normal operating pressure differential (NOPD). This is due to the fact that most of the wear indications are predominantly axial in nature and are located at broached TSP lands, which limit the circumferential extent of the indications. However, axial extents were not measured for all flaws. Hence, confirmation of the predominantly axial nature of the flaws was not obtained. Therefore, each degradation mechanism was also evaluated as circumferentially oriented degradation. For circumferentially oriented degradation, the limiting load is the axial load imposed by the difference in thermal expansion between the tubes and the shell under Large Break Loss-of-Coolant Accident (LBLOCA) conditions with a maximum pressure of 3605 psid (1.4x2575 psid) [10, 11]

Per the Degradation Assessment, the 95th percentile value for normal operating pressure differential over Cycle 21 was 1275 psid. The 3ΔP value used for CM evaluations was 3825 psid (3x1275 psid).

Table 5-1 provides a summary of the pressure differential inputs discussed above and the material properties used in the CM evaluations. The material properties were obtained from Reference [10]

Table 5-1: Pressure Differential and Material Property Inputs for CM Evaluation

Parameter	Value
Normal Operating Pressure Differential (NOPD)	1275 psid [8]
3 * NOPD	3825 psid
Steam Line Break Accident Pressure Differential	2575 psid [8]
1.4 * Accident Pressure Differential	3605 psid
Material Properties at Operating Temperature (Yield + Ultimate)	115.6 ksi [10]
Std Deviation of (Yield + Ultimate)	2.4485 ksi [10]

Four different sizing techniques were used in the assessment of the as-found conditions [4] which are listed in. Table 5-2 All these techniques were validated for use at TMI via Reference [24].

Table 5-2: NDE Sizing Parameters Used for CM Evaluations

Parameter	ETSS 96043.4 (Rev. 1; Bobbin)	ETSS 96042.1 (Rev. 4; Bobbin)	ETSS 13091.1 (Rev 0, Bobbin)	ETSS 11956.3 (Rev. 3; Array)
Scope	Detection and sizing of broached TSP wear	Detection and sizing of drilled TSP wear	Detection and sizing of TTW	Sizing and profiling of broached and drilled TSP wear
Slope	1.01	1.05	.94	1.03
Intercept	2.03	-1.15	1.24	-1.22
Technique Standard Error of Regression	3.86	3.21	1.57	2.42

5.2 Structural Integrity

Using the inputs from Section 5.1, all indications of tube degradation were evaluated against the conservative structural integrity criterion of 3,825 psid for 3ΔP per [4] for axially-oriented volumetric flaws as well as the LBLOCA loading for circumferentially oriented flaws. The condition monitoring limit curves at 3ΔP conditions were developed using the Flaw Handbook Calculator [12] The allowed flaw sizes for the axial tensile loads under LBLOCA conditions were taken from Reference [11].

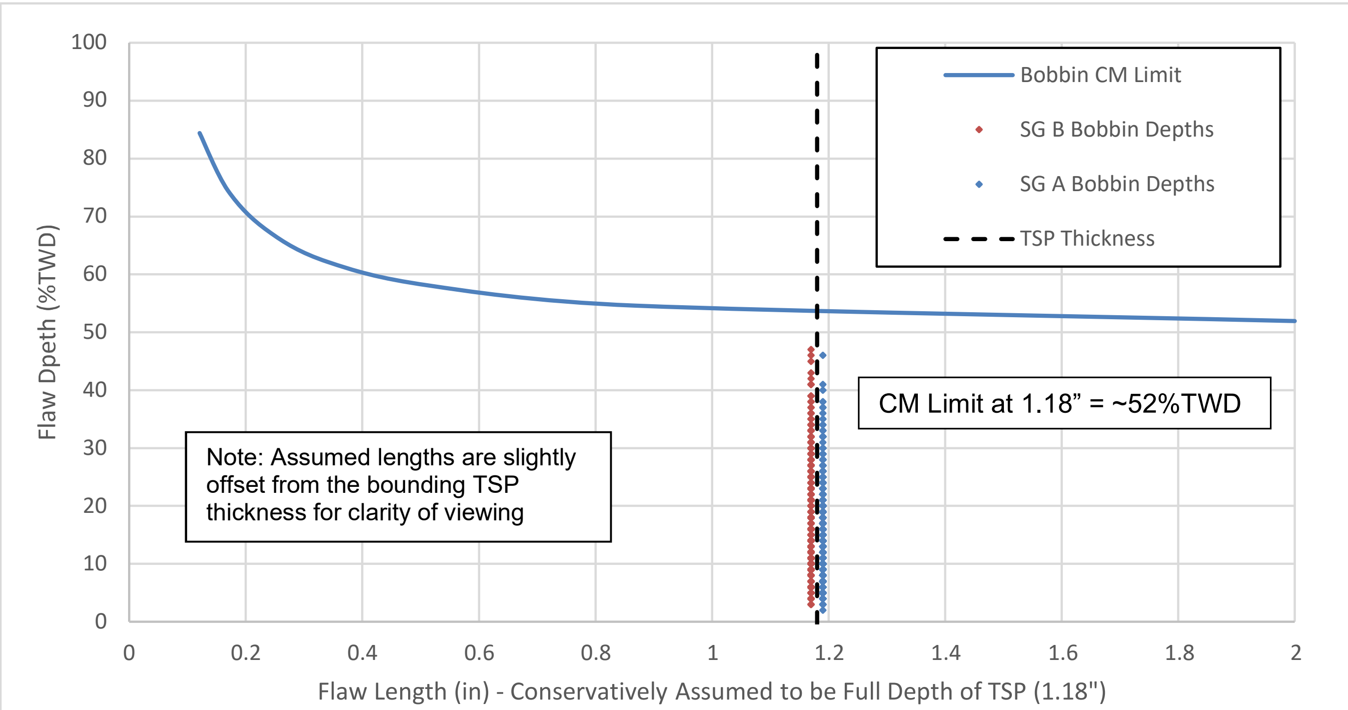
5.2.1 Wear at Broached TSP Intersections

A total of 5,243 and 7,188 bobbin probe indications of tube wear at the broached tube support plates were reported in SG A and SG B, respectively during the 2024 inspection. Using a bounding flaw structural length equal to the entire thickness of the TSPs (1.18"), all indications met the structural integrity performance criteria by analysis based on bobbin sizing (ETSS 96043.4 Rev. 1). The largest flaw detected by bobbin was in SG B tube R4 T1 at 12S at 47%. Since the largest flaw, as sized by bobbin, was shown by analysis to meet the bobbin CM limit, all broached TSP wear flaws therefore also met structural integrity performance criteria by analysis.

Figure 5-1 shows the CM limit as a function of length and depth for the bobbin coil (ETSS 96043.4) technique. As shown, the CM limit for an indication with a structural length of 1.18" is ~54%TWD by bobbin. All TSP wear indications sized by bobbin fell below that limit and passed condition monitoring analytically. In-situ pressure testing was not required for broached TSP wear and was not performed.

Large Break Loss-of-Coolant Accident (LBLOCA) conditions were also considered during the CM evaluation. For LBLOCA events, the limiting load is the axial load created by the large tube-to-shell temperature differential that develops as the tubes cool faster than the shell. Per [11] structural integrity is satisfied with 100%TWD wear indications at two lands of the support plate. Since none of the detected indications approached 100%TW, structural integrity under postulated LBLOCA conditions is satisfied.

Figure 5-1: Broached TSP Wear Depths vs Bobbin CM Limit (ETSS 96043.1 Rev. 2)



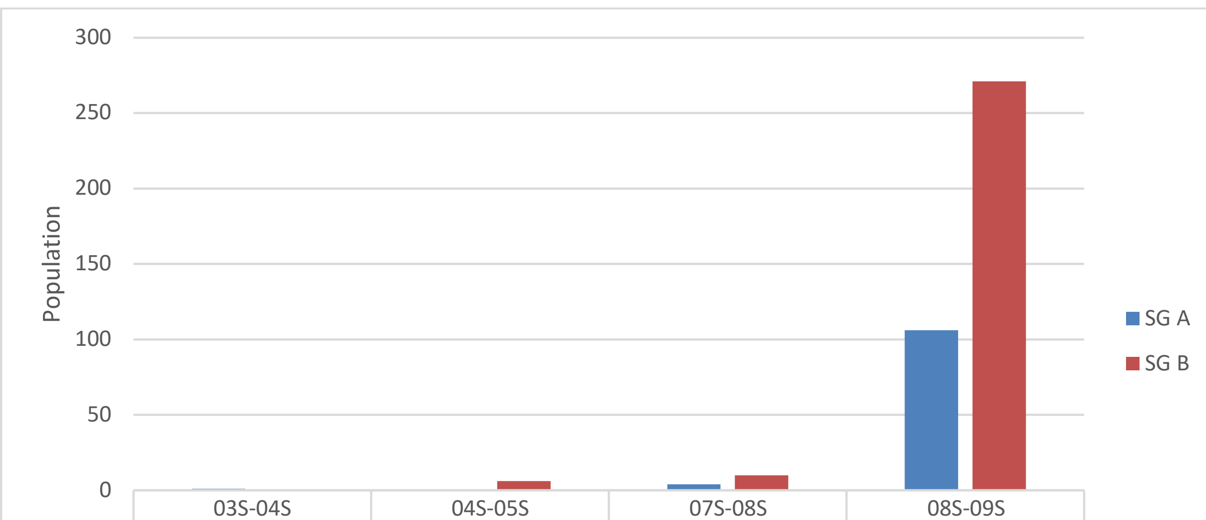
5.2.2 Tube-to-Tube Wear

A total of 111 and 288 indications of tube-to-tube wear (TTW) were reported in SG A and SG B, respectively, during the 2024 inspection. Bobbin ETSS 13091.1 has used for detection and sizing of TTW since 1R21.

Figure 5-2 illustrates that the majority of TTW indications in both SG A and SG B were located between the 8th and the 9th TSPs. The freespan length between the 8th - 9th and 4th - 5th TSPs is 37.82” between the edges of the two TSPs. The freespan length between the edges of the 3rd - 4th and 7th - 8th TSPs is 38.82” [7]. Therefore, a bounding structural length of 39” for all TTW flaws was used in the CM evaluation. The NDE lengths of these indications were not measured in 1R21 or 1R22 because of the slowly-changing nature of TTW and the fact that the longest flaw measured in 1R20 was less than 8.2” long. Therefore, using a structural length of 39” (i.e., assuming a completely flat wear shape along the entire TSP span) is extremely conservative. Using this bounding structural length, all indications of tube-to-tube wear met the structural integrity performance criteria with ample margin.

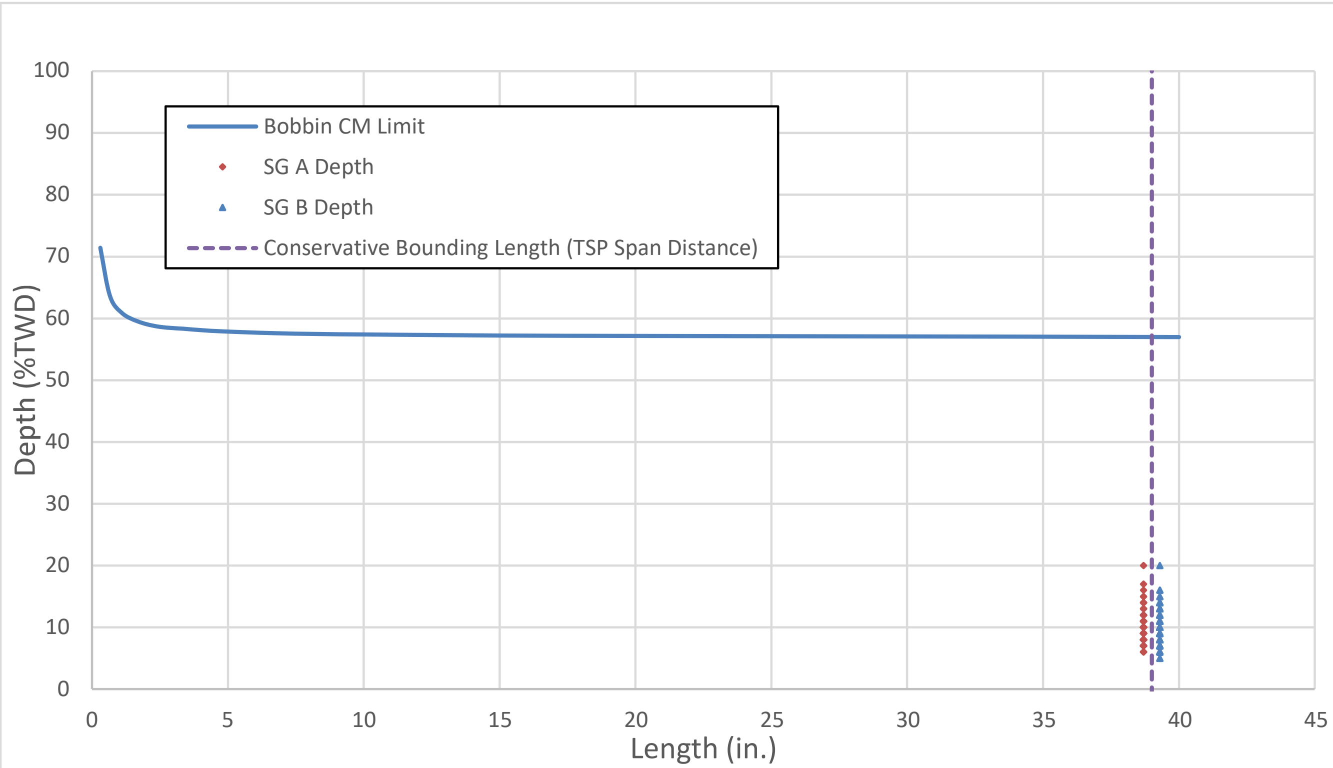
Figure 5-3 shows the CM limits as a function of length and depth for the bobbin coil TTW technique. As shown in the figures, the CM limit for an indication with a bounding structural length of 39” is approximately 56%TW. Since the deepest NDE depths were 20%TW (R70-T100 in SGA, andR22-T63 in SGB) all tube-to-tube wear indications passed condition monitoring analytically. In-situ pressure testing was not required for TTW and was not performed.

Figure 5-2: Distribution of TTW by Support Span



	03S-04S	04S-05S	07S-08S	08S-09S
SG A	1	0	4	106
SG B	0	6	10	271

Figure 5-3: 2024 Tube-Tube Wear and CM Limit



Axial loading acting on the circumferential extent of the wear scar was also considered and is not limiting.

Large Break Loss of Coolant Accident (LBLOCA) conditions were also considered during the CM evaluation. For LBLOCA events, the limiting load is the axial load created by the large tube-to-shell temperature differential that develops as the tubes cool faster than the shell. Per Reference [11] structural integrity is satisfied with 100%TWD wear indications with a total circumferential extent of 107 degrees. Converting this to a Percent Degraded Area (PDA) gives a PDA of 29.7.

During the 1R19 inspection, all of the tube-to-tube wear indications were measured for circumferential extent. The 1R19 flaws generally had circumferential extents of 50 to 70 degrees. During 1R20, there was one tube with four tube-to-tube wear flaws in the same span. These indications had a combined circumferential extent of 147 degrees. Based on the allowable PDA of 29.7, an allowable depth of 59.4%TW is obtained for a postulated bounding 180-degree circumferential extent (29.7 PDA x 360 / 180). Since none of the measured TTW depths in 1R22 approached this value, structural integrity under postulated LBLOCA conditions is satisfied.

5.2.3 Wear at 15S Drilled Locations

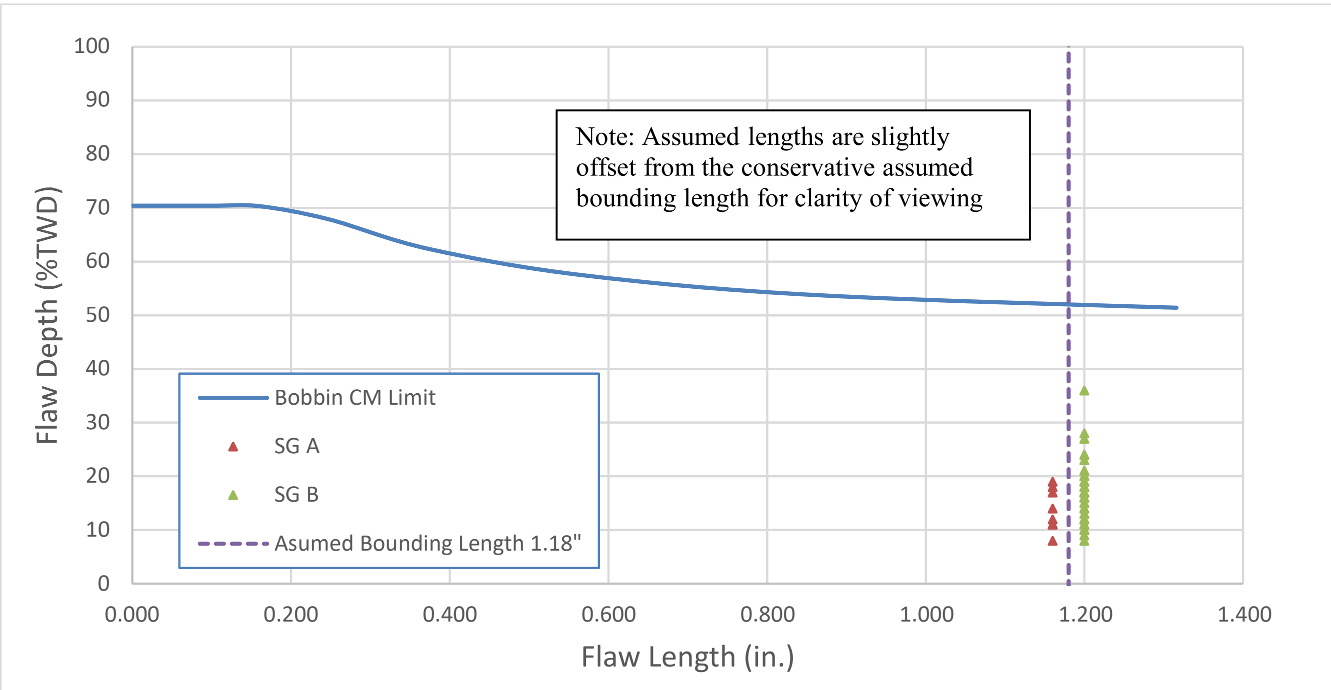
As the Spring 2024 inspection is the first where bobbin was used for sizing in addition to detection of TSP wear, all bobbin wear indications were also inspected with Array for confirmation and sizing.

A total of 58 drilled TSP wear indications were identified by bobbin (9 in SG A, 49 in SG B), with array confirming wear at only 41 locations (8 in SG A, 33 in SG B) as summarized in Table 4-6

The deepest indication detected (SG B R145-T7) had a measured depth of 36%TWD by bobbin, well below the CM limit of 53%TWD for a 360 degree, uniform thinning flaw with a length of 1.2" as shown in Figure 5-4. This is bounding the largest axial length measured by array of 0.49".

Measured circumferential extents varied from 0.42 to 1.12 inches with the max PDA of any drilled TSP flaw of 8.74 PDA, satisfying the 29.7 PDA LBLOCA acceptance criterion 10]. Since none of the indications approached this depth, the LBLOCA criterion is also met for this mechanism.

Figure 5-4: Bobbin CM Limit Plot for Drilled TSP Wear



5.3 Leakage Integrity

Per Reference 1, the onset of pop-through leakage for axially oriented volumetric indications with limited circumferential extent is coincident with burst. Therefore, since all indications met the structural integrity requirements, leakage integrity at the lower steam line break pressure differential of 2575 psid is also satisfied.

The above statement is only true if the indication has an axial extent greater than or equal to 0.25". Volumetric flaws of limited axial extent should also be evaluated as circumferential cracks for leakage integrity. Since length measurements were not obtained for all TSP wear indications, some of these indications could have axial extents less than 0.25". Although the indications with these very short lengths would typically be shallow, the onset of pop-through leakage was also considered based on the circumferential extents and depths of the flaws. For circumferential degradation, the axial loads associated with a LBLOCA accident is the limiting condition. Per Reference [11] the onset of pop-through leakage under the limiting LBLOCA axial load would occur at about 78%TWD over the width of a single land. Since none of the indications detected at the broached TSP locations approached this depth, leakage integrity under the limiting LBLOCA conditions is satisfied for the broached TSP wear indications.

For tube-to-tube wear and drilled TSP wear, the circumferential extents are not limited by the geometry of the support structure as in the case of broached TSP wear. Therefore, depth limits were determined as a function of circumferential extent. As identified in Table 4-6, the maximum circumferential extent for drilled TSP wear was 221 degrees. For tube-to-tube wear, the limiting tube the last time an array coil was used for sizing in 1R20, had four indications and a combined circumferential extent of 147 degrees. Therefore, a conservative circumferential extent of 180 degrees was used for the analysis to bound all cases. Per Reference [11] the allowable pop-through depth for a conservative 180-degree flaw is 55%TW. Since none of the indications approached this depth, leakage integrity under the limiting LBLOCA conditions is satisfied for drilled TSP wear and tube-to-tube wear.

5.4 Primary Side Visuals

All visual examinations of the tube plugs were performed in accordance with EPRI guidelines [1, 5]. During this time the channel heads (hot and cold leg in each SG) were also inspected for degradation in accordance with Framatome procedures [30, 31]. No degradation or conditions adverse to quality were observed and no primary-to-secondary leakage was detected during the previous operating cycle. A few discolorations were observed which upon further investigation were confirmed as variations in reflective surfaces as well as boron and condensation as discussed in Section [4.5]. Therefore, there is reasonable assurance that the installed tube plugs and SG components are operating within the design qualifications.

6.0 SECONDARY SIDE ASSESSMENT

From 1R19 to 1R22 the secondary side of the steam generators was not opened or inspected. By design Framatome EOTSGs have a lower susceptibility to foreign material intrusion as compared to Recirculating SGs, having 6-foot risers off the feed rings and 3/16" diameter holes on the strainer/spray plate portion of the feedwater nozzles opening into the SG. Additionally, the TMI SGs have no history of ECT potential loose part (PLP) indications.

Given that the TMI SGs had not been in a managed layup since shutdown in 2019 and that rigorous FME controls were not in place, a thorough inspection for potential foreign object intrusion as well as potential degradation of the secondary side components was performed [29]. Findings are summarized in this section but are extensively detailed in the SSI Final Report [33].

6.1 Scope

The following scope was performed in both SGs.

- Visual inspections at the top-of-tubesheet (TTS) including general views of the tubesheet to the shell annulus region, and tube-to-tubesheet interfaces looking inward a minimum of 5 tubes deep into the bundle around the entire periphery of the SGs.
- Visual inspection of the entire anulus trough region.
- Visual inspections looking up at the orifice plate around the entire periphery. Views included orifice plate hardware and other supports/structures in the area above the TTS.
- Foreign Object Search and Retrieval (FOSAR) of potential foreign objects as summarized in Section 6.3.
- All bobbin and array probes were run through a deposit standard [25] that would allow mapping of tube deposits the outer surface of the tubes and within the broached support locations.

6.2 Visual Inspections

Inspections did not identify any unusual findings. Both SGs were drained of any remaining water before inspection. SG A had a minimal amount, filling the secondary side less than 1” deep, while SG B had enough to fill the secondary side approximately 12” deep. After draining, a thin layer of reddish oxidation products was visible on the tubesheets and the bottom of the tubes in both SGs as shown in Figure 6-1 and Figure 6-2.

No abnormalities were identified during visual inspections looking upward at the orifice plate and other nearby structures. with an example shown in Figure 6-3.

Figure 6-1: TMI-1 SG A Secondary Side As-Found View

Figure 6-2: TMI-1 SG B Secondary Side As-Found View

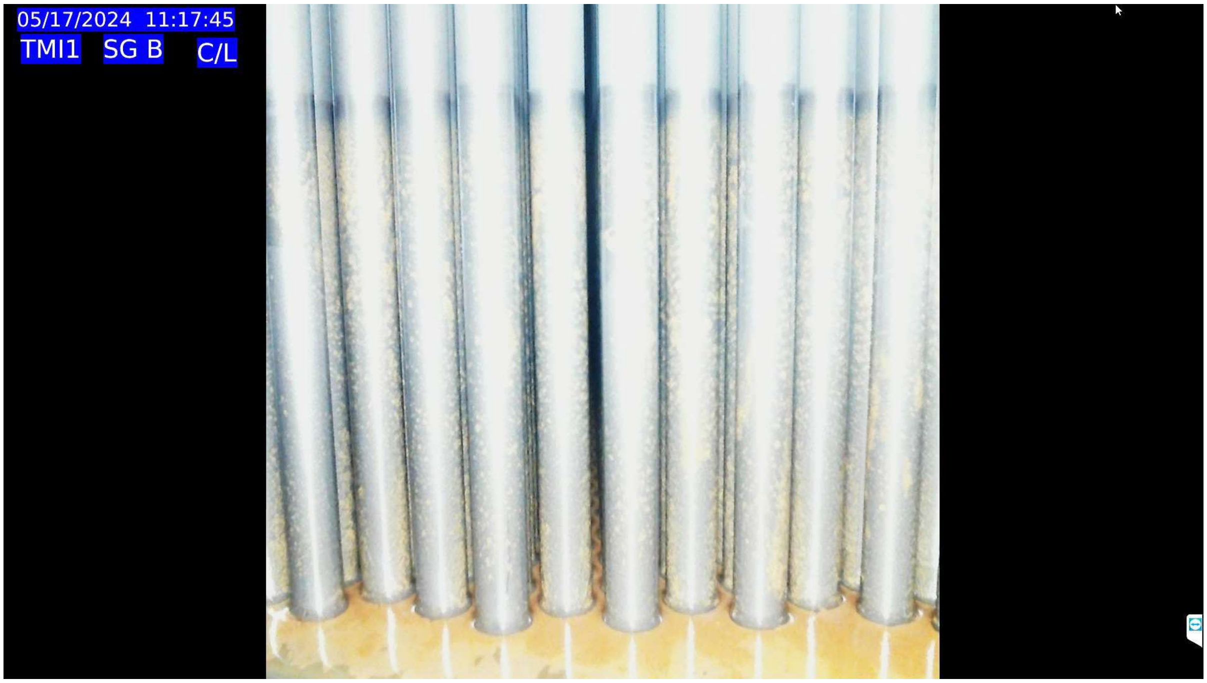


Figure 6-3: TMI-1 2024 Secondary Side Inspection – Upward View at Orifice Plate

6.3 Foreign objects

While there were no ECT PLP indications identified during the Spring 2024 inspection, a minimal number of objects were identified during the tubesheet visual examination and entered into Framatome's Foreign Object Tracking System (FOTS) as summarized in Table 6-1 . All objects that posed a potential threat to SG integrity were removed. The remaining objects that were left in place without requiring affected tubes to be plugged are justified based on their composition and lack potential to threaten SG integrity. All foreign objects are evaluated per Constellation ER-AA-2006 included in Appendix C.

Table 6-1: TMI-1 2024 Foreign Objects Identified

SG	FOTS Item	Description	Location	Affected Tubes (Row-Tube)	Removed	Spring 2024 Inspection Results
A	2	Tubesheet Stain	LTS[2] +0.00	23-39	No	Upon retrieval attempts, verified that the image seen was a Tubesheet stain. ECT is NDD with bobbin and array.
A	3	Machine Curl 0.8" x 0.2" x 0.1"	LTS +0.00	N/A (annulus)	Yes	Located in annulus trough, item was identified as a machine curl and removed from the SG. ECT is NDD with bobbin and array.
A	4	Metallic Object 1.0" x 0.13" x 0.1"	LTS +0.00	112-12 113-13 114-12	Yes	Item identified as a metallic strip and removed from the SG. ECT is NDD with bobbin and array.
A	5	Deposit Flake	LTS +0.00	148-13 147-15 146-16 146-17 147-14	No	Item was identified as a deposit flake and broke into multiple pieces when pushed on by the camera. ECT is NDD with bobbin and array.
A	6	Graphoil flake	LTS +0.00	145-19 145-20 144-21	No	Item identified as a small piece of graphoil, with pieces breaking apart during retrieval attempts. ECT is NDD with bobbin and array.
A	7	Hair-Like Metallic Strand	LTS +0.00	21-35 21-36	Yes	Item identified as a hair-like strand and removed from the SG. ECT is NDD with bobbin and array.
B	3	Graphoil	LTS +0.00	15-53 15-52 14-51	Yes	Item identified as graphoil and removed from the SG. ECT is NDD with bobbin and array.
B	4	Soft material	LTS +0.00	79-124 80-124	No	Item broke apart upon during retrieval attempts. ECT is NDD with bobbin and array.
B	5	Graphoil	LTS +0.00	96-110 95-110 96-109	No	Item identified as graphoil and broke apart during retrieval attempt. ECT is NDD with bobbin and array.

SG	FOTS Item	Description	Location	Affected Tubes (Row-Tube)	Removed	Spring 2024 Inspection Results
B	6	Graphoil	LTS +0.50	101-101 100-104 101-100	No	Item identified as graphoil and broke apart during retrieval. ECT is NDD with bobbin and array.
B	7	Graphoil	LTS +0.00	109-23 109-24 108-24	Yes	Item identified as graphoil and retrieved from the SG. ECT is NDD with bobbin and array.
B	8	Hair-Like Metallic Strand	LTS +0.00	133-48 132-48 133-47	No	Very small hair like metallic strand. Object was irretrievable as one end was embedded in a hard sludge collar and the was too small for the tool to maintain a grip on the strand. Due to the small size and length the object is not considered to have potential to cause wear on the tube and was left in place. ECT is NDD with bobbin and array.
B	9	Graphoil	LTS +0.00	136-63 135-65 135-64	No	Item identified as graphoil and broke part during retrieval. ECT is NDD with bobbin and array.

Notes:
1. Foreign objects are evaluated per Constellation ER-AA-2006 included in Appendix C.
2. Lower Tube Sheet

6.4 Deposit Mapping

Deposit mapping of the SGs can be performed using the bobbin ECT data which can provide estimates of the total deposit loading as well as identify elevations the deposit is accumulating and tube locations with potential blockage of the broached support plates. Broach blockage can be a concern as it could alter the secondary side fluid flow or lock a tube against the support plate, influencing wear rates of the tubes. An example of the bobbin mapping is shown in Figure 6-4 for SG B using the Spring 2024 data. For TMI-1 the deposit accumulates primarily between the 4th and 11th support plates in a conical shape typical of OTSGs.

Full length array ECT data can be used to identify the number of broaches that are blocked as well as the severity of the blockage. An example of the array mapping is shown in Figure 6-5 for SG B R48-T7 at the 3rd support plate, which has no deposit accumulation, and the 7th support plate which has deposit buildup on the lower edge and broaches which are either partially or fully blocked with deposit.

From preliminary review of the data, the largest concentration of deposits for TMI-1 are at the 7th support plate with broached holes of the small sample acquired with array showing partially or fully blocked supports. Currently only one replacement OTSG in the industry has performed chemical cleaning to address broached blockage concerns after approximately 9 years of operation. It is recommended that TMI perform a full deposit mapping analysis to quantify the amount of deposit currently within the SGs, the severity of broach blockage, and trend the rate of accumulation in comparison to other OTSGs.

Figure 6-4: Example Bobbin Deposit Mapping – SG B 2024 Results

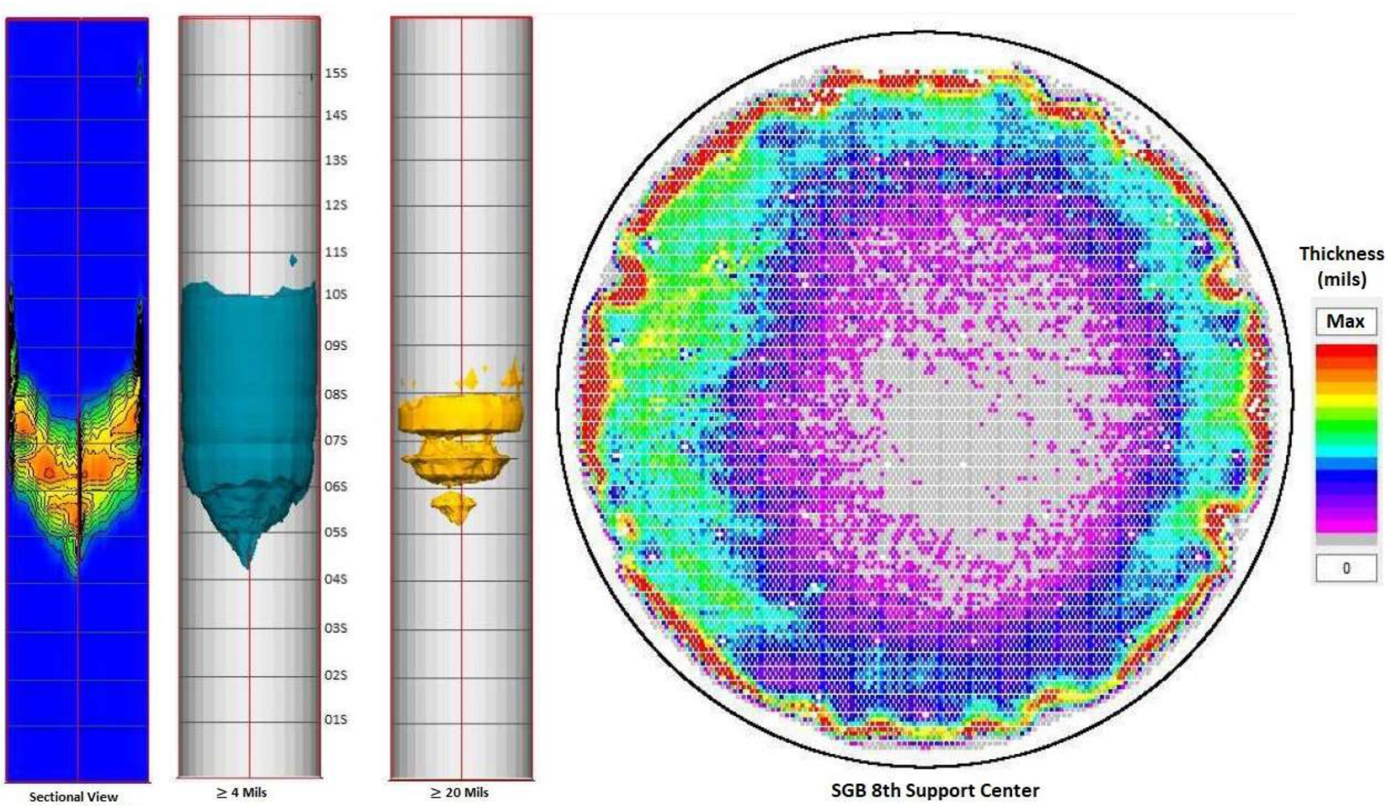
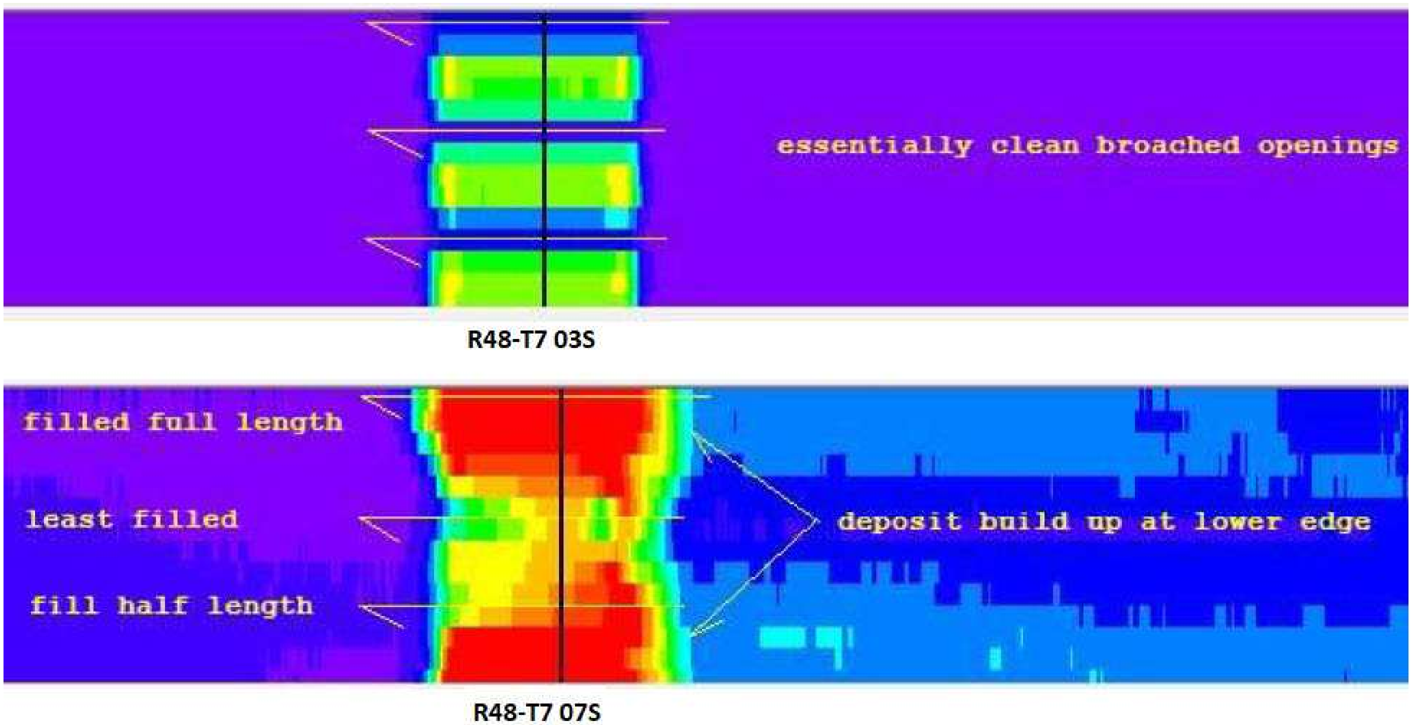


Figure 6-5: Example Array Deposit Mapping – SG B R48-T7 at 3rd and 7th Supports



7.0 OPERATIONAL ASSESSMENT

The only observed form of degradation in the TMI-1 SGs at the Spring 2024 inspection was wear. This occurred primarily at broached TSP intersections, and to a lesser extent at drilled TSP intersections and tube-to-tube wear (TTW) at mid-span elevations. Operational Assessment calculations for both SGs are presented in this section based on a hypothetical projected one-cycle operating period not to exceed 2.0 EFPY which bounds the maximum TMI-1 cycle length of 1.93 EFPY [4].

7.1 BROACHED TSP WEAR PROBABILISTIC MODEL

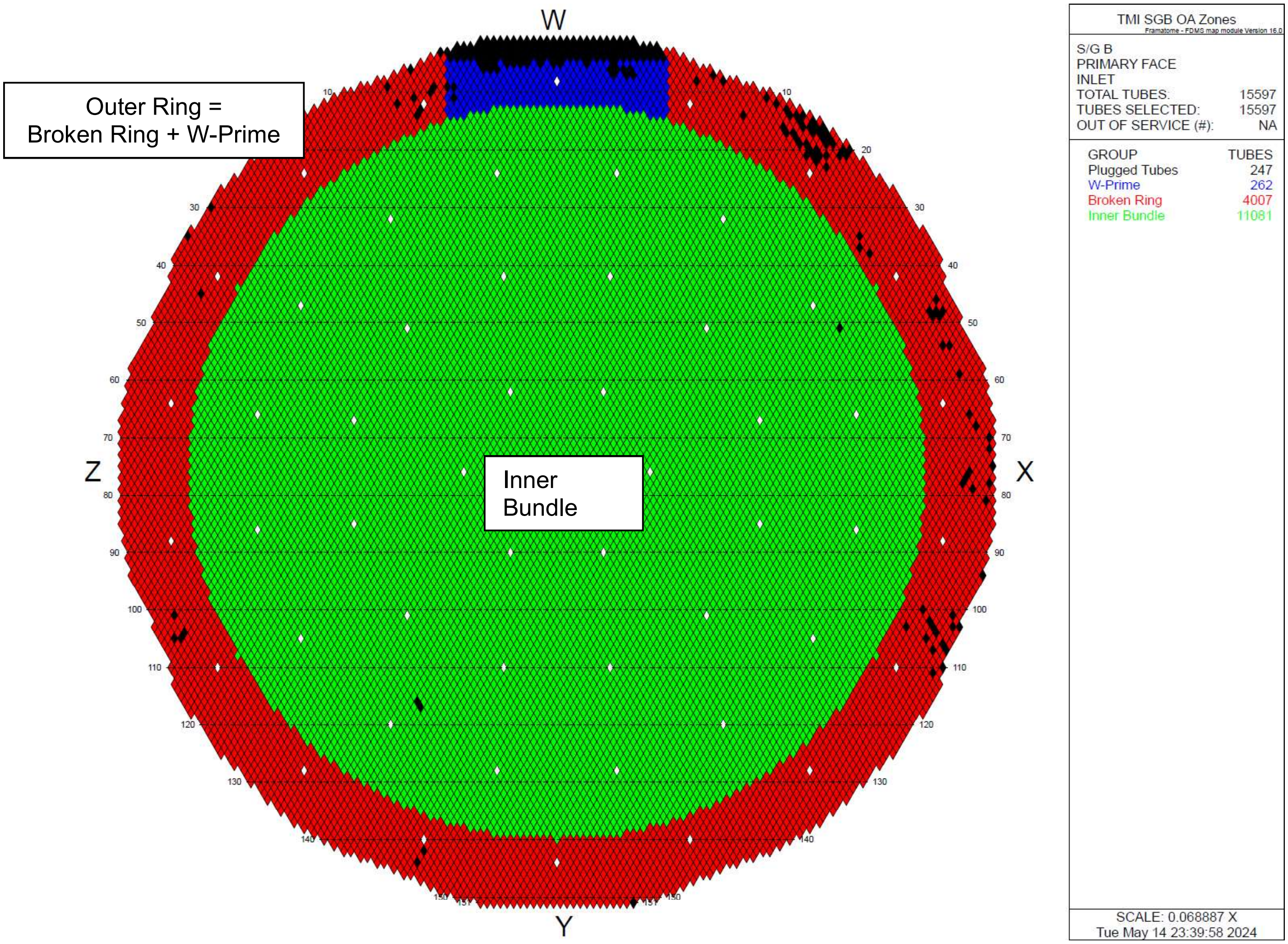
Broached TSP wear was evaluated using a fully-probabilistic full bundle approach. The full bundle approach considers each wear scar returned to service together with the development of new wear scars projected over the upcoming operating cycle. A Framatome Mathcad Monte Carlo model [13] was used to perform the fully probabilistic full bundle evaluation. The full bundle program starts with beginning of cycle (BOC) depths for the return to service (RTS) and new wear indication populations. Each population is subsequently corrected for NDE uncertainty, material property uncertainty, and burst equation uncertainty. Afterwards, each wear depth (repeat and new) is grown, by sampling from a growth rate distribution, followed by adjustments for structural length and depth. The output of the full bundle model is the probability that a wear indication of a given depth (EOC depth) will not burst when a 3ΔP pressure is applied. The probability that all wear indications (repeat and new) survive is the product of the individual probabilities of survival of each wear indication.

The full bundle evaluation for SG A treated the bundle as one population. For SG B, because behavior continues to be notably different inside or outside a radius of 48", the bundle was treated as separate zones. In past analyses three zones were used: "Inner Bundle", "Broken Ring" and "W-axis" zones [14, 21, 34]; and with a large fraction of the tubes in the "W-axis" zone are now plugged wear growth rates and new flaw depths were sufficiently similar that combining the "Broken Ring" and "W-axis" into one "Outer Ring" zone simplified calculations while maintaining conservatism. The zones used in 2024 for SG B are illustrated in the tubesheet map presented in Figure 7-1. When the full bundle model is applied across multiple zones (i.e., a multi-zone OA), the overall bundle probability of survival (POS) is equal to the product of each zone-specific POS and must be at least 95% at 50% confidence [1].

In summary, for the 2024 inspection, the following two zones are used:

- Inner Bundle Zone: all tubes at radius < 48 inches.
- Outer Ring Zone: all tubes at radius >48 inches
    - This combines the "Broken Ring" and "W-axis" zones from prior OAs [14, 21, 34]
- Note that no tubes lie exactly on the 48" radius as tubes have a radius that are either greater than or less 48".

Figure 7-1: SG B Zones Used for Operational Assessment

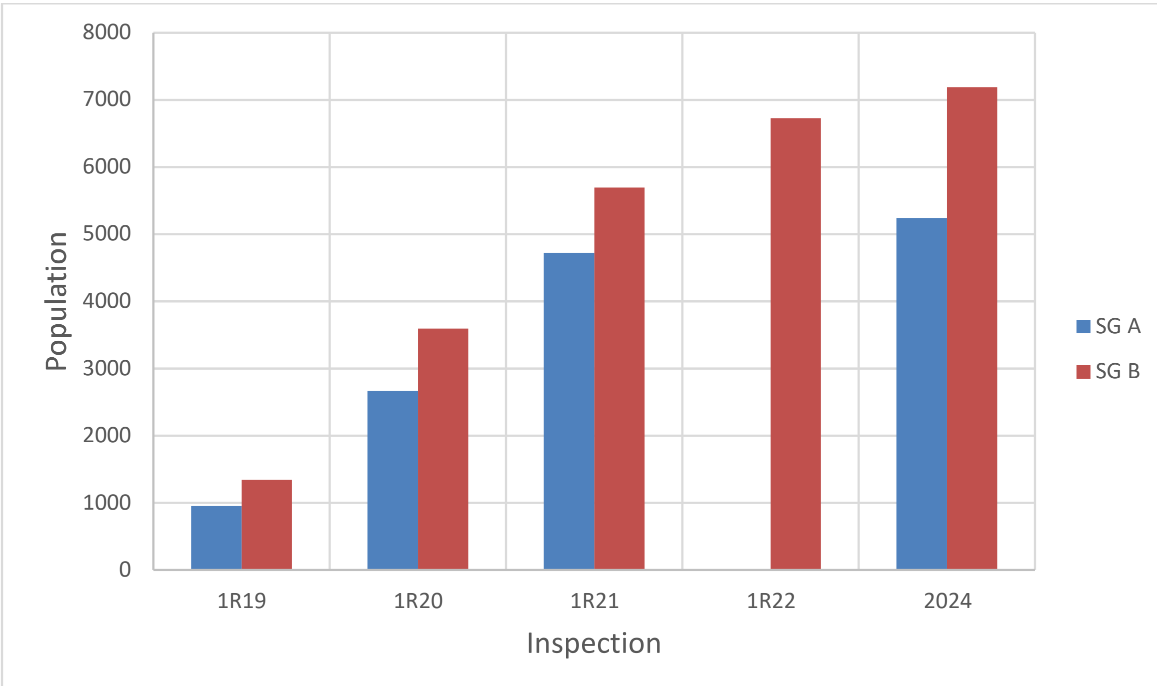


7.2 Broached TSP Wear OA

During the 2024 outage, 5,243 and 7,188 broached TSP wear indications were detected in SG A and SG B, respectively. Table 4-3 contains a complete breakdown of details. Figure 7-2 and Figure 7-3 show that the total number of reported wear flaws increased at a lower rate than the past as illustrated in Figure 7-4. The larger difference in new flaws reported in the Spring 2024 inspection is primarily due to increasing the reporting threshold of newly reported flaws from 6% to 10%. SG A ran nearly 4 EFPY, or roughly twice as long as SG B, since the last inspection, and the fact that the largest new wear flaw is slightly higher than 1R21 indicates little change in the upward trend in SG A. In all likelihood the largest new flaw in SG A would have decreased in 2024 had SG A run for one cycle prior to an inspection. Figure 7-4 shows maximum depths reported by bobbin. The noticeable increase in SG A is again attributable to operating two fuel cycles since the last inspection. Figure 7-5 shows a mild upward trend in average flaw depth, which is to be expected as the population of flaws age. Figure 7-6 illustrates how the

95th percentile and upper tail of the SG B wear growth has decreased, although the maximum growth rate has increased slightly every inspection since 1R21.

Figure 7-2: Total Broached TSP Wear Indications

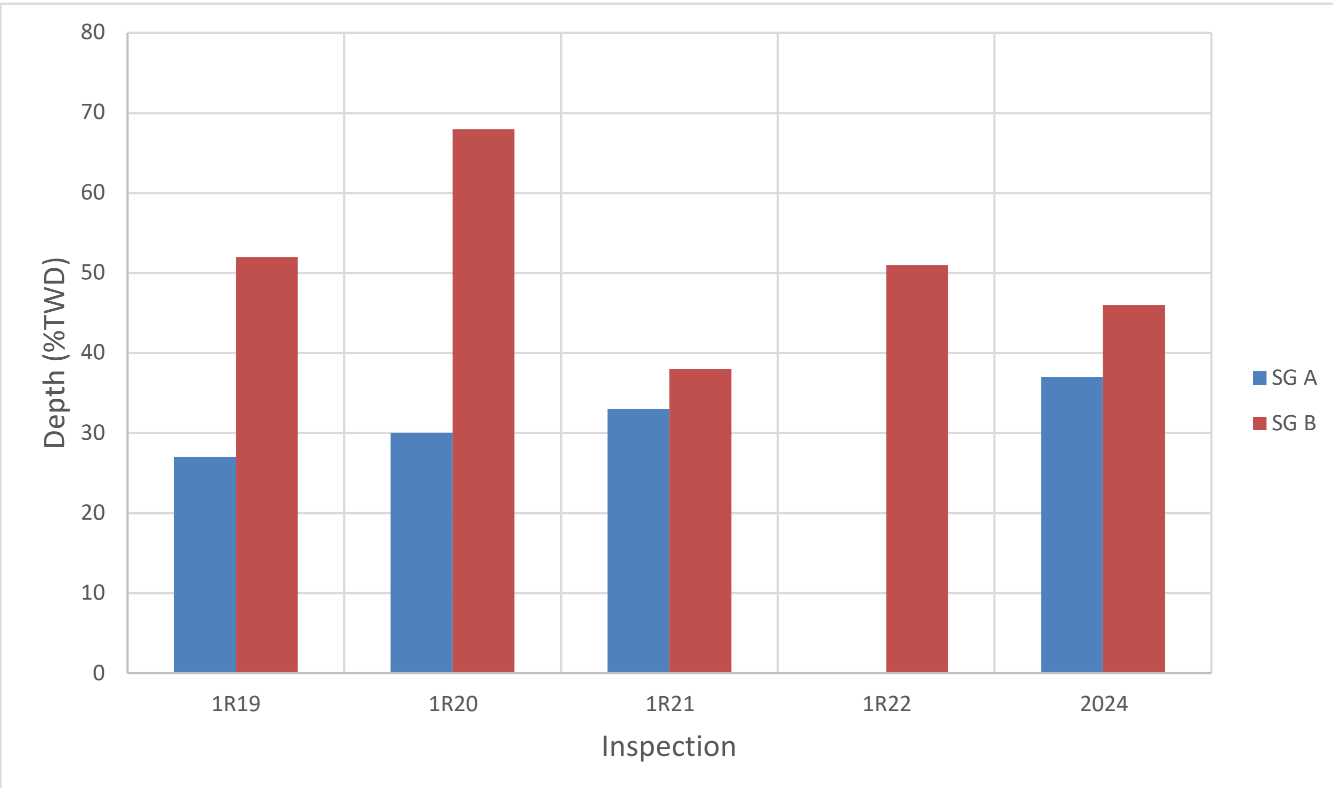


Note: SG A was not inspected in 1R22

Figure 7-3: Number of New Broached TSP Wear Indications

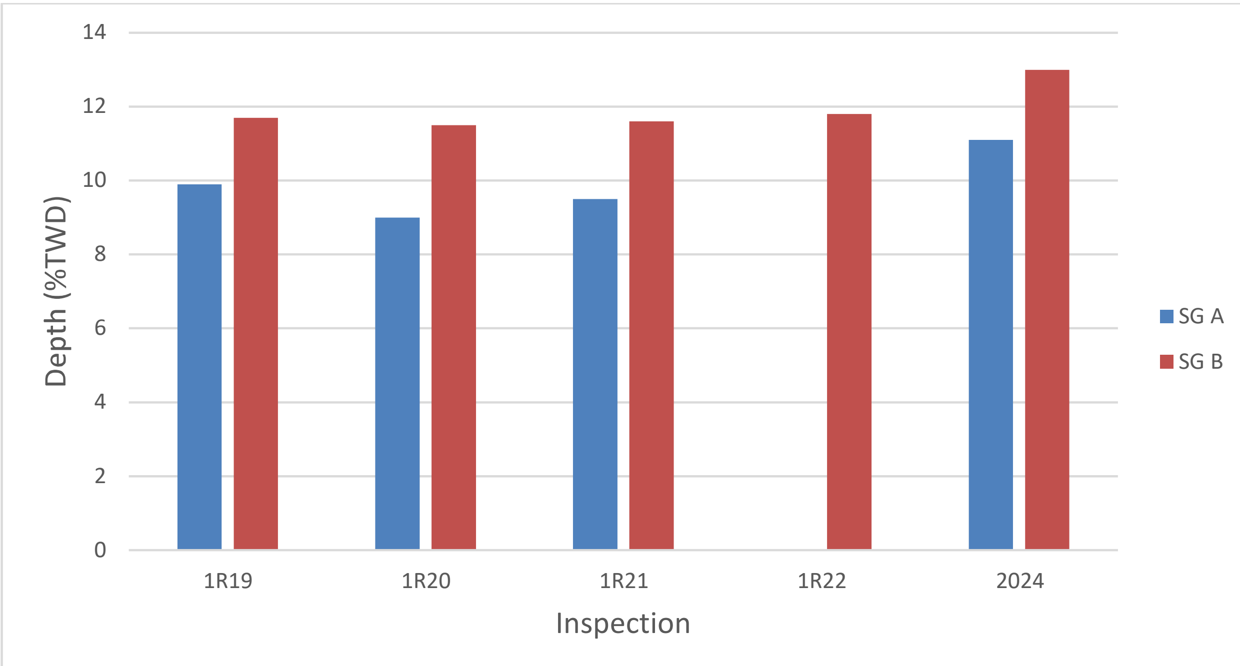
Note: SG A was not inspected in 1R22

Figure 7-4: Largest New Broached TSP Wear Bobbin Depth



Note: SG A was not inspected in 1R22

Figure 7-5: Average Broached TSP Wear Depth



Note: SG A was not inspected in 1R22

Figure 7-6: SG B Broached TSP Wear Growth 1R20 to 1R22, Bobbin Values

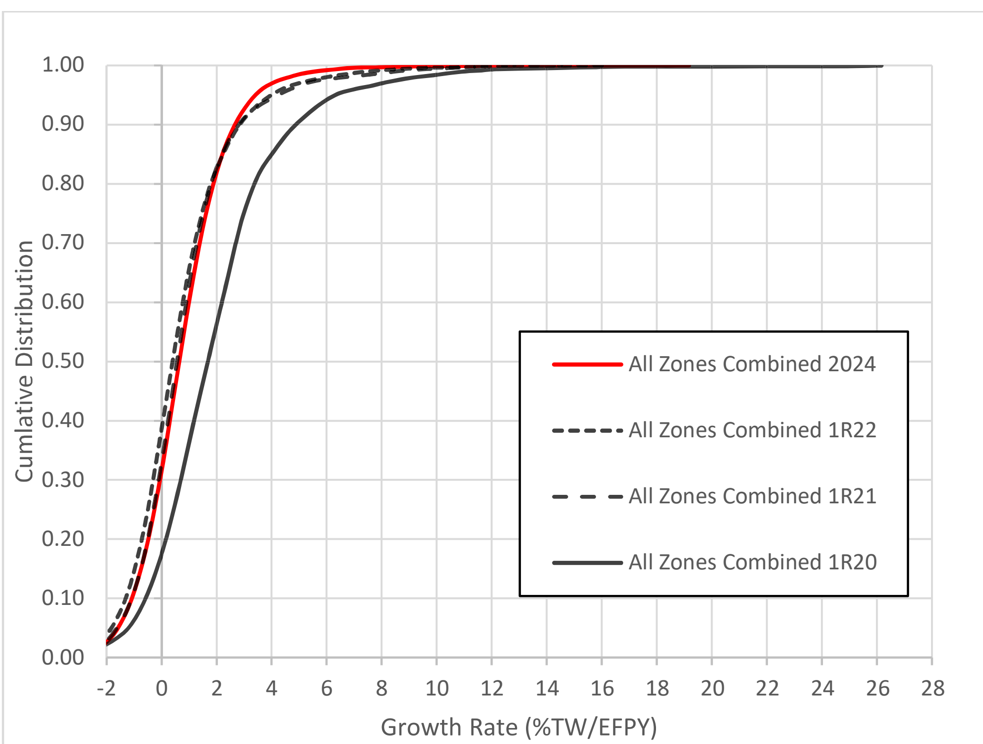
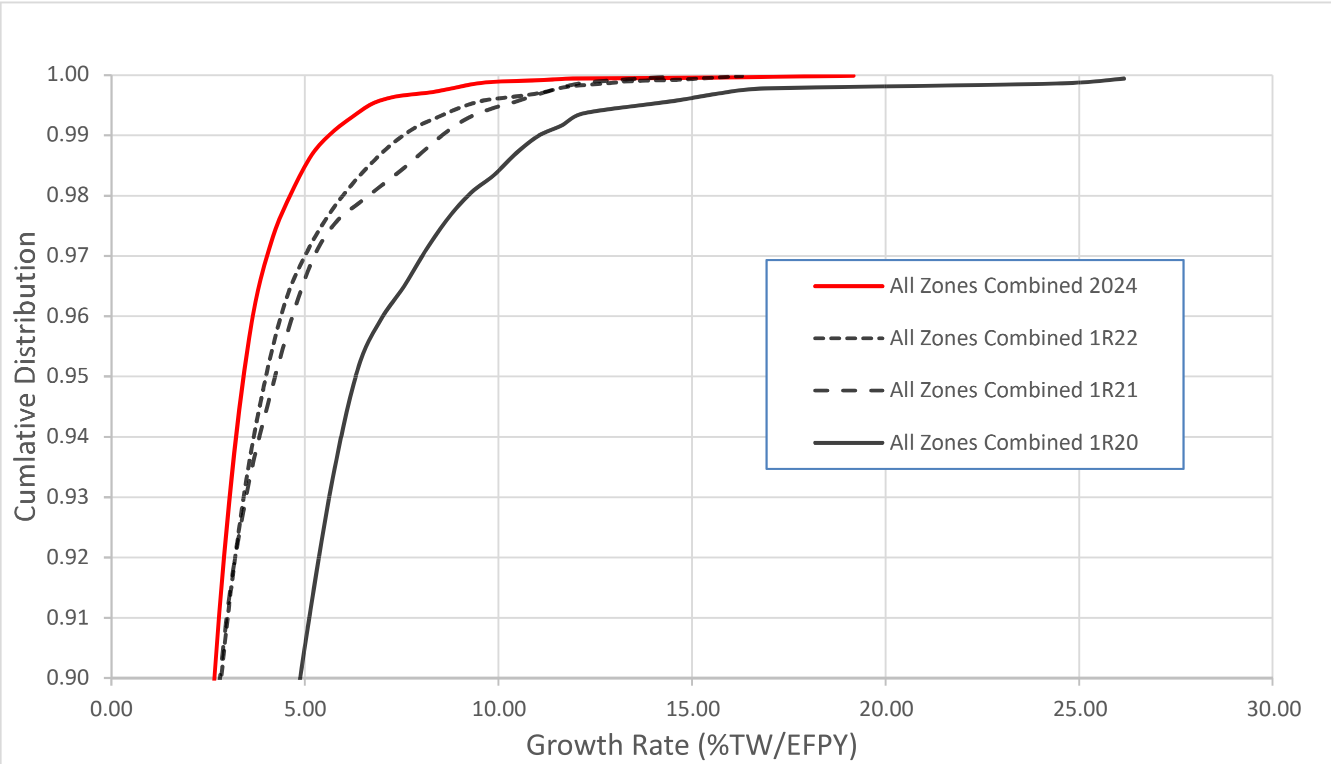


Figure 7-7: SG B Broached TSP Wear Growth 1R20 to 1R22, Upper Tail, Bobbin Values



7.2.1 Inputs for Probabilistic OA for Broached TSP Wear

The full bundle evaluation requires inputs for flaw depths, shapes, length, growth rates and initiation rates (new flaws). These inputs are discussed below. Inputs pertaining to material properties, pressure differentials, and tubing dimensions are also required and previously addressed earlier in this document. Table 7-1 provides a summary of the full bundle model inputs.

Table 7-1: Summary of Inputs for Probabilistic OA

Parameter	SG B 1-cycle	SG A 1-Cycle
Mean of the sum of yield and ultimate strengths at temperature	114,800 psi	
Standard deviation of the sum of yield and ultimate strengths at temperature	2,448.5 psi	
3 X Normal Operating Pressure Differential	3,830 psid NOTE: Conservatively 5 PSI higher than CM input in Table 5-1 to accommodate the possibility of higher pressure in the future	
Tubing wall thickness	0.0368 inch	
Tubing outer diameter	0.625 inch	
Flaw Parameters	Distributed Properties of profiles from the Spring 2024 Inspection (See Figure 7-15)	Fixed Properties bounding profiles from all inspections (See Figure 7-16)
Growth Rates	Sampled from Bounding Kunin fit (See Figure 7-10, Figure 7-12)	Sampled from Bounding Kunin fit (See Figure 7-8)
ETSS Technique	96043.4 Rev 1	
ETSS NDE depth sizing parameters	Slope = 1.01 Intercept = 2.03 Standard Error = 3.86	
New Indications	Weibull projection based on historical flaws (See Table 7-5) Depth distribution from bounding Kunin fit (See Figure 7-9Figure 7-11)	
Assumed operating cycle length	2.0 EFPY	

Figure 7-8 SG A Broached TSP Wear Growth Rates and Kunin Fit for OA Calculation

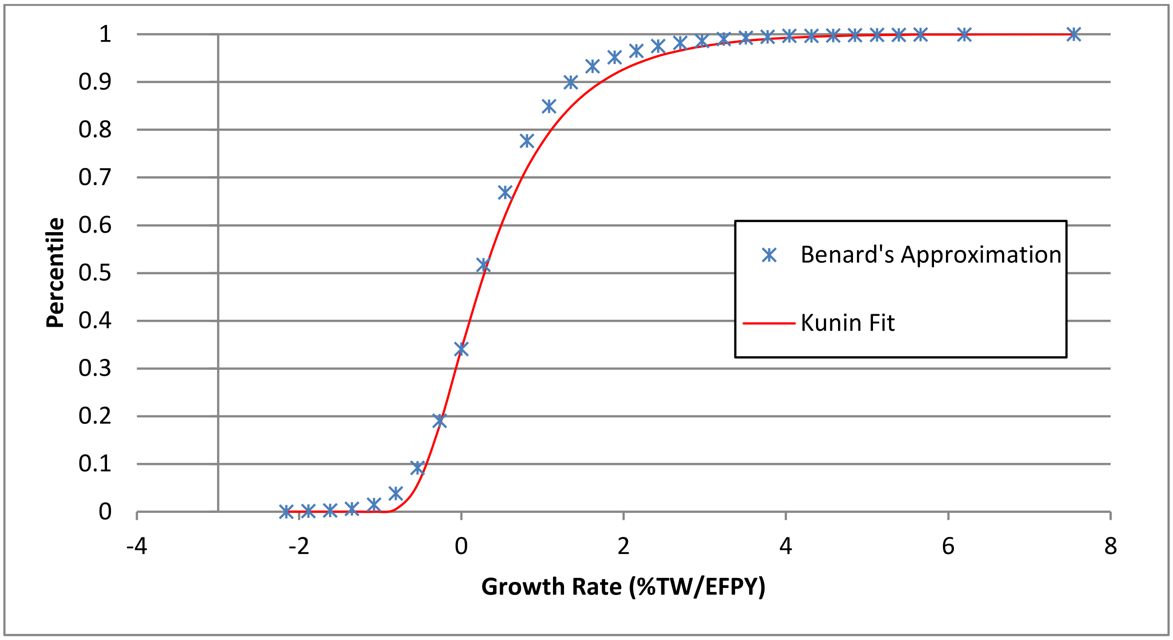


Figure 7-9: SG A Broached TSP Wear New Flaw Depths and Kunin Fit for OA Calculation

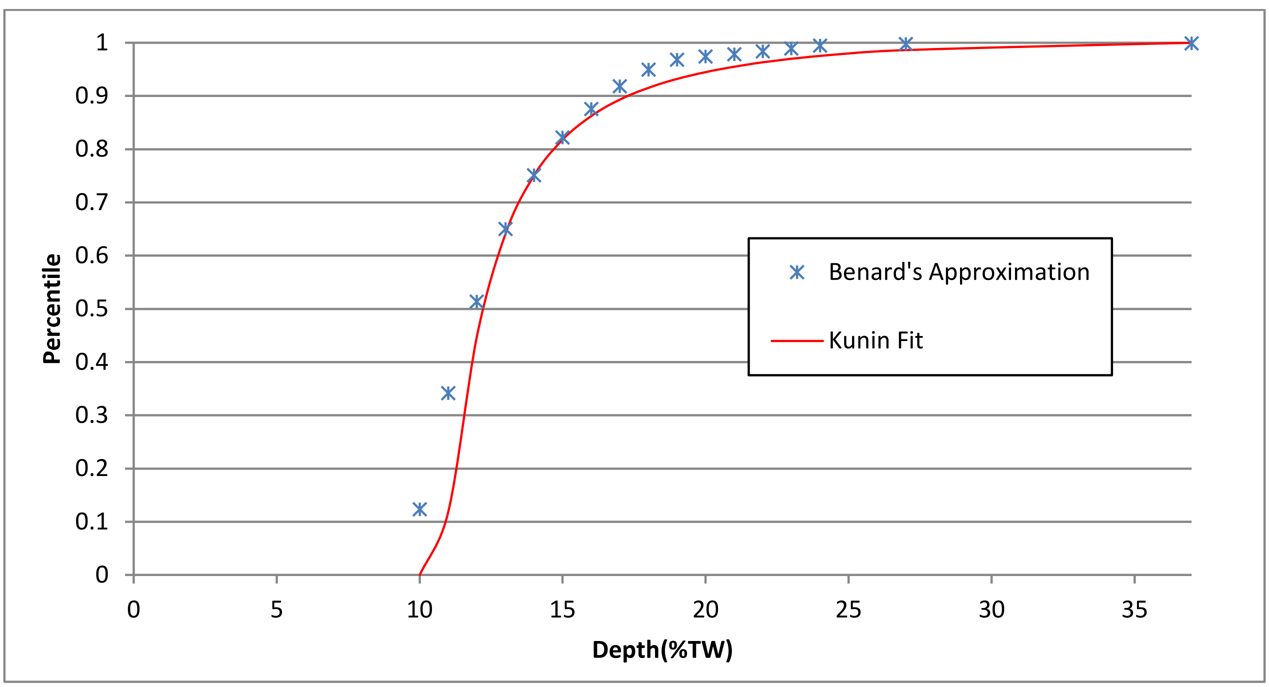


Figure 7-10: SG B Inner Broached TSP Wear Growth Rates and Kunin Fit for OA Calculation

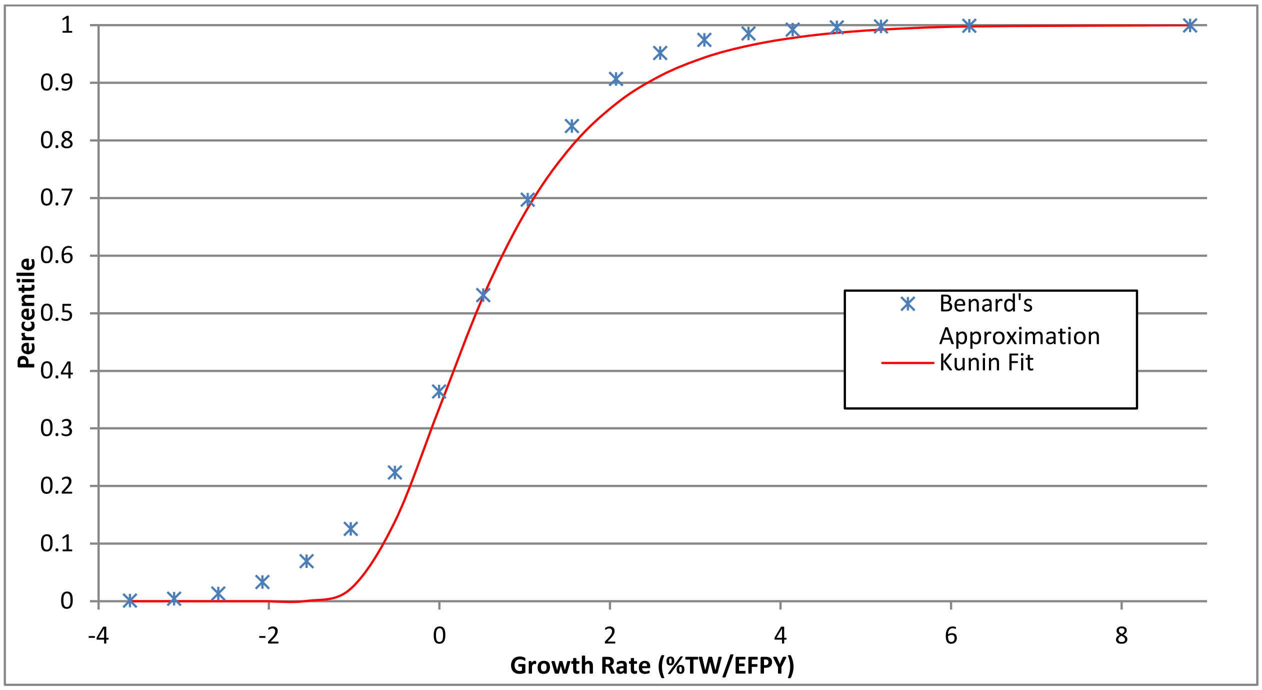


Figure 7-11: SG B Inner Broached TSP Wear New Flaw Depths and Kunin Fit for OA Calculation

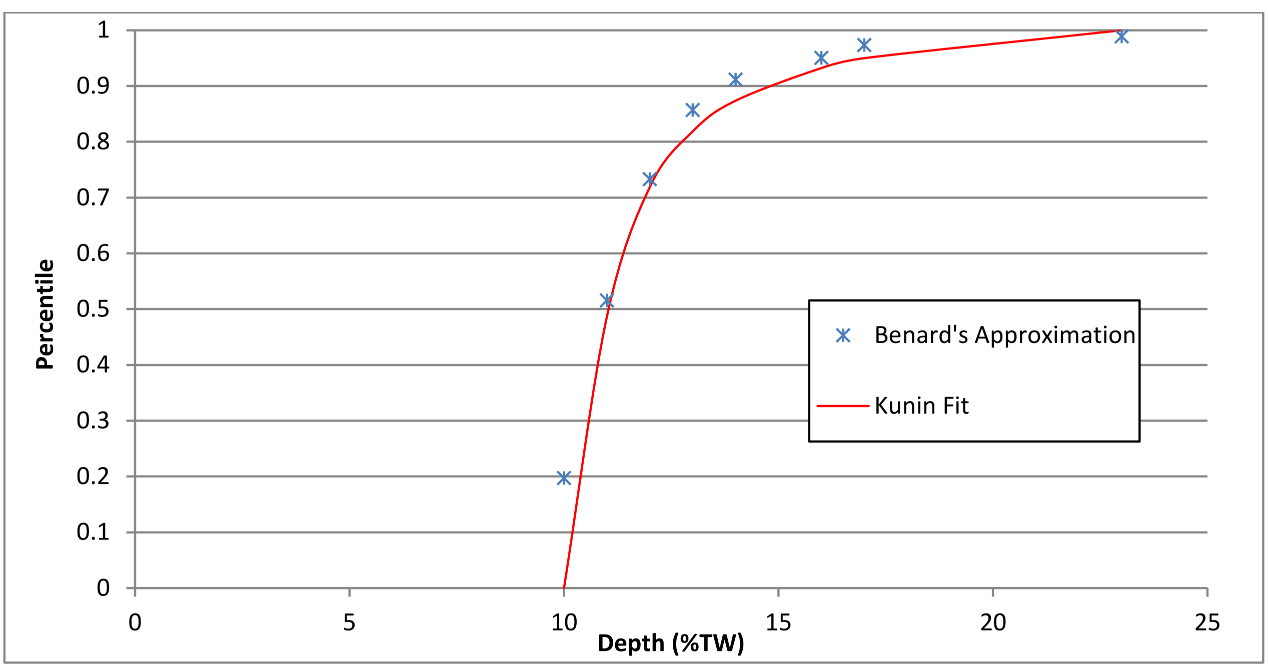


Figure 7-12: SG B Outer Ring TSP Wear Growth Rates and Kunin Fit for OA Calculation

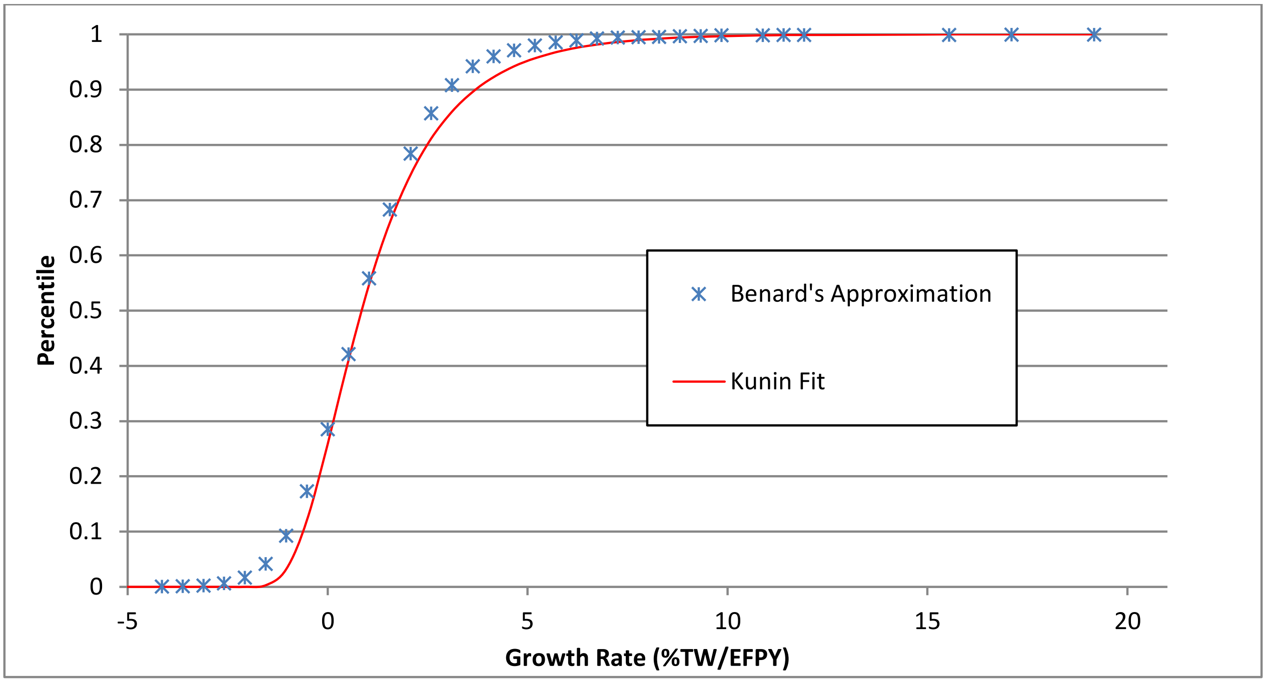
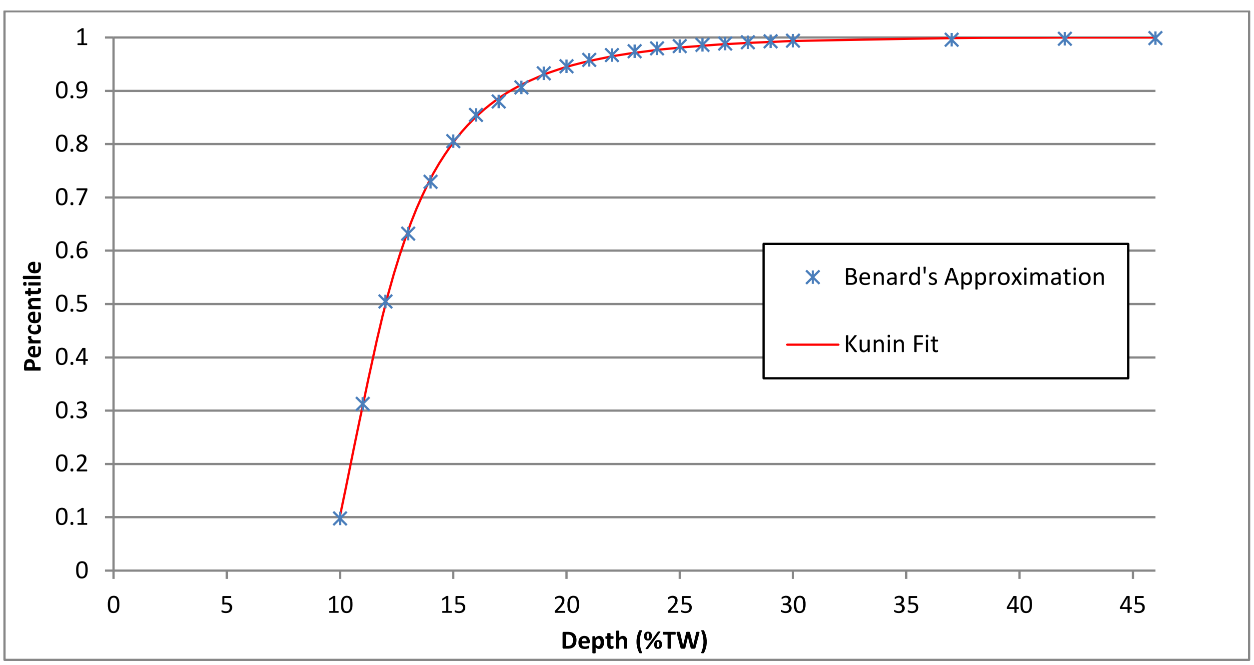


Figure 7-13: SG B Outer Ring Broached TSP Wear New Flaw Depths and Kunin Fit for OA Calculation



Flaw Depths Returned to Service

During the 2024 Inspection, 7 tubes were plugged in SG A and 35 tubes were plugged in SG B. Three (3) tubes were plugged in SG A based on indications at or above the Tech Spec limit of 40%TW. Eight (8) tubes were plugged in SG B based on indications at or above the Tech Spec limit of 40%TW. Probabilistic modeling supports a plugging limit of 40% TW and deeper, with 27 additional tubes plugged based on high growth rates in order to support operational assessment. Section 8.0 provides additional information on plugging and stabilization. In the course of plugging tubes based on flaw depths that met the plugging criteria, numerous smaller flaws in the same tubes were also removed from service. The largest flaws returned to service are a 38%TW in SG A (R133-T2 at 12S) and a 39% TW in SG B (R84-T128 at 10S).

Structural Depth to Max Depth Ratio

Figure 7-14 provides a generic example of a typical wear scar profile and its structural equivalent model. That is, there is a flaw with a rectangular-shaped profiled flaw that has equivalent structural properties (i.e., burst pressure) as the original flaw profile. As all flaws are input into the model as a singular maximum bobbin depth, the probabilistic model essentially evaluates all flaws as their structural equivalence by applying a structural depth to maximum depth ratio (SD:MD) and a structural length to each flaw as sampled from a distribution of profiles for each SG. This same methodology was applied to a representative statistical sample of wear scars using the line-by-line sizing data for both SGs as represented in Figure 7-15 and Figure 7-16 which are the SD:MD ratio plotted vs. the structural length for both SG B and SG A inspection data.

Figure 7-14: Wear Scar Profile and its Structural Equivalent

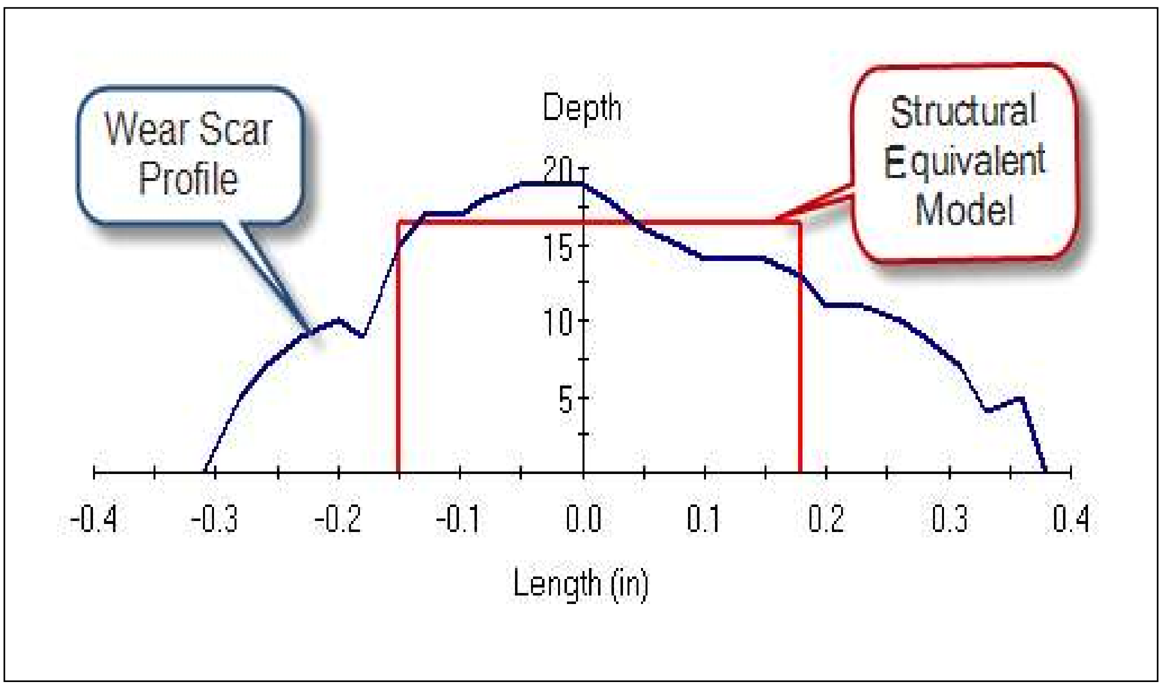


Figure 7-15: 2024 Inspection Broached TSP Wear Flaw Outer Ring Profile Parameters – SG B

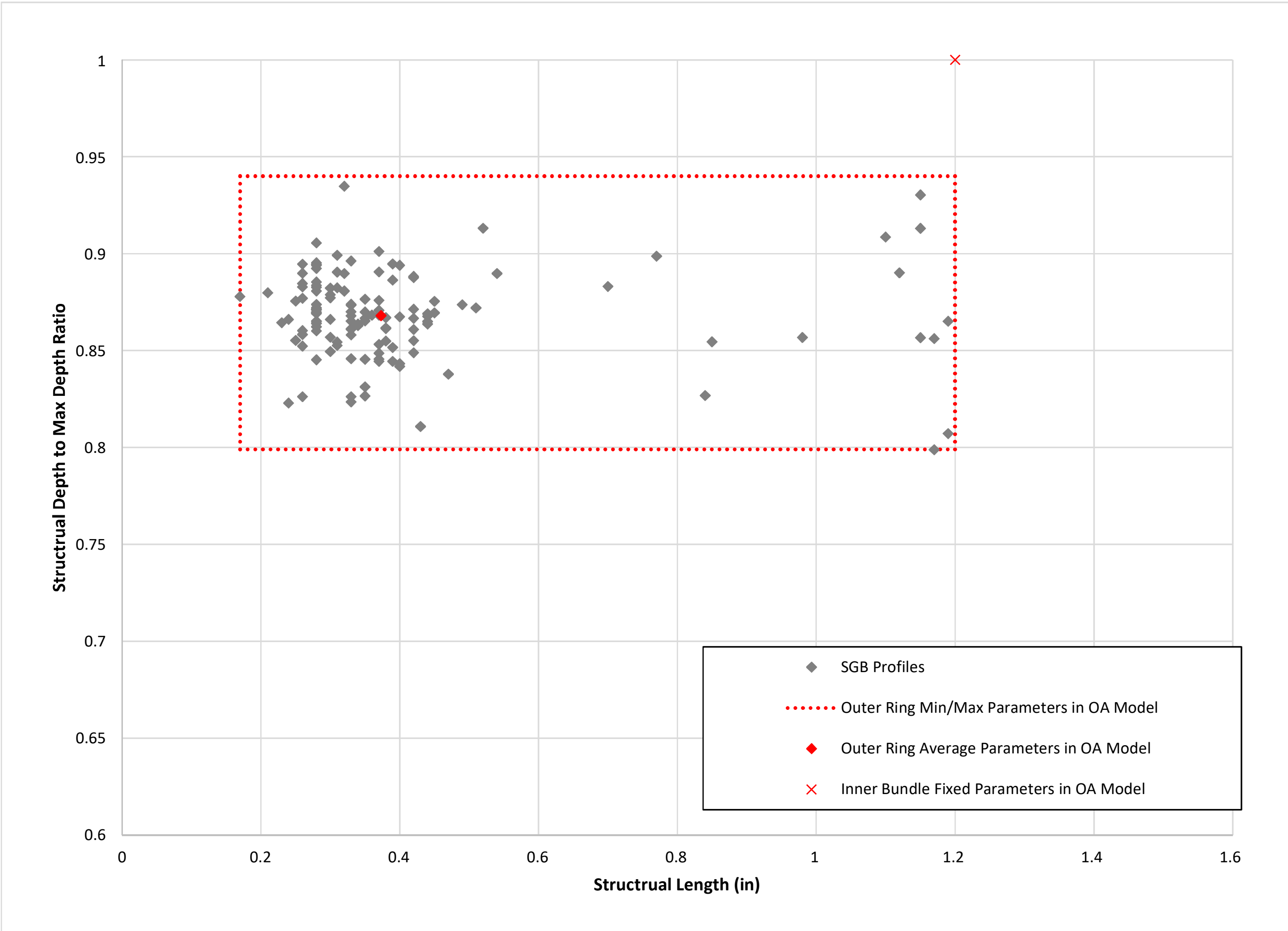
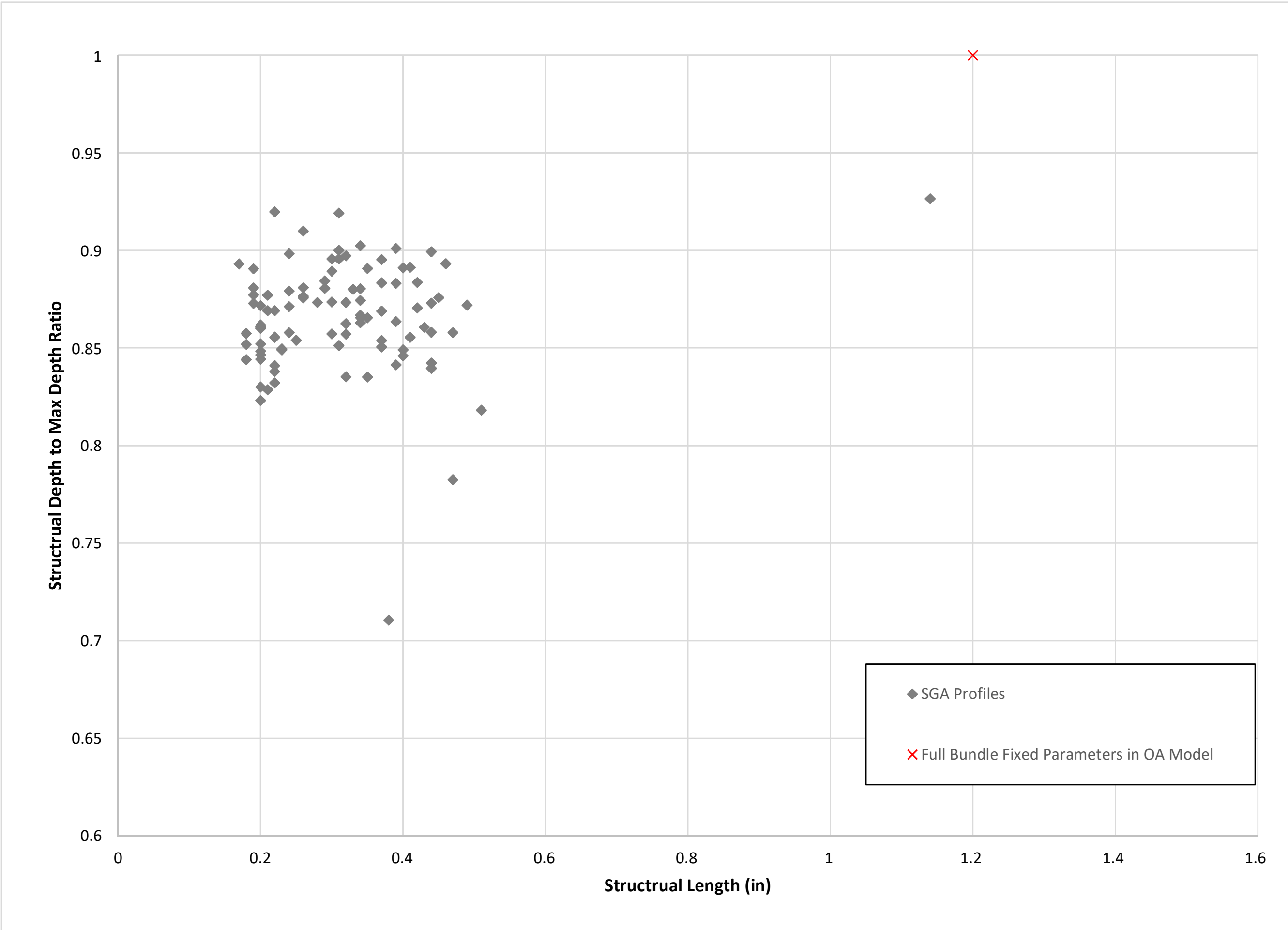


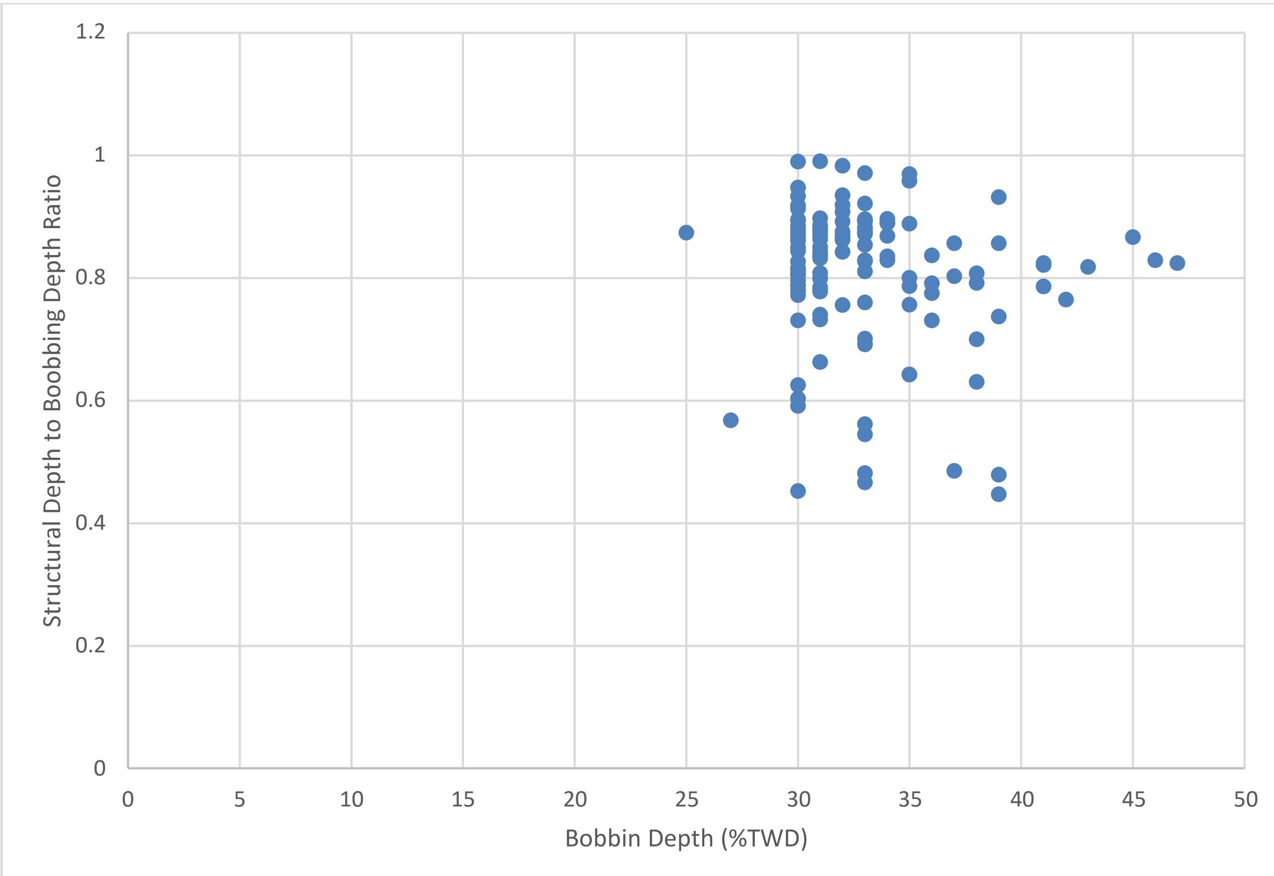
Figure 7-16: 1R19 to 2024 Inspection Broached TSP Wear Flaw Profile Parameters – SG A



During the 2024 Inspection, structural lengths and depths were obtained from 103 tubes/129 indications of broached TSP wear in SG B line-by-line sizing the array coil results. The selection of indications for profiling was based on a combination of factors including maximum depth and whether the indications could potentially have a flat profile.

Because the bobbin coil was used as the technique of record to size TSP wear, the metric of interest for creating length and depth distributions is how the structural depths relate to the depths reported by bobbin. Figure 7-17 shows how the ratio of structural depth to bobbin depth changes as bobbin depth increases. Because flaws less than 30%TWD do not present a challenge to tube integrity, depth sizing distributions were based on the flaws sized by bobbin 30%TWD and deeper.

Figure 7-17: SG B TSP Wear Depth Ratio Vs. Bobbin Depth

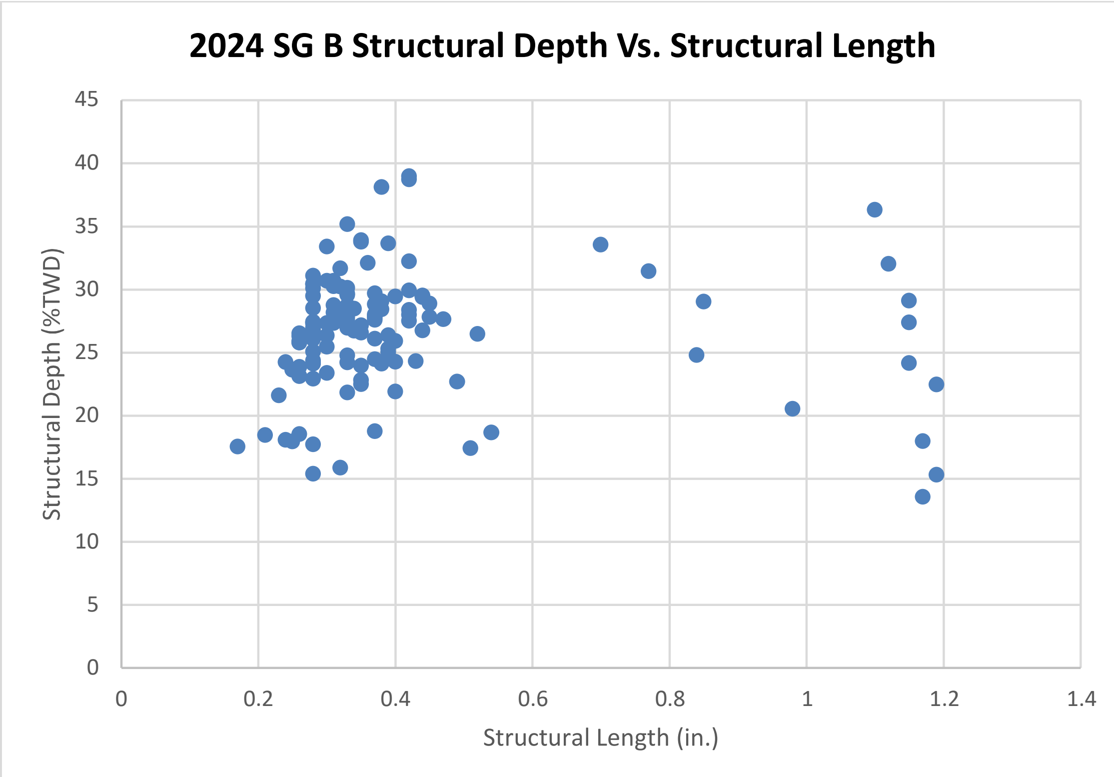


The Framatome full bundle model [13] provides the user with the option to model structural parameters as either fixed or variable. The fixed option assigns a single bounding value to the structural parameters for all Monte Carlo cycles. The distributed variable option samples from a representative distribution of structural parameters to produce a range of structural values. Historically, owing to minimal wear initiation and growth rates and shallow depths, SG A has been modeled using conservative bounding fixed values. For SG B, the "inner bundle" zone was conservatively modeled with fixed values while the more aggressive, deeper wear in the "outer ring" zone used distributed properties.

Structural Length

Structural lengths followed the same pattern as that of structural depth ratios. Namely, that structural depth does not appear to be correlated to structural length as shown in Figure 7-18.

Figure 7-18: 2024 Inspection Broached TSP Wear Distribution of Structural Lengths – SG B



<u>Growth Rates</u>

Growth rates were calculated for all repeat flaws reported in the 2024 inspection (i.e. flaws that had been previously reported such that growth rates could be calculated). When considering the tube bundle as a whole and when comparing the growth rates, the growth rates showed slight attenuation in SG A. There was attenuation in 95th percentile values in the broken ring and W-Prime zones of SG B, while the averages in these zones increased. In the inner bundle of SG B, the average and upper 95th percentile growth rates increased slightly. These values are presented in Table 7-2 and Table 7-3.

Table 7-2: Comparison of SG A Broached Bobbin TSP Wear Growth Rates at 1R21 and 2024

Region	1R20 to 1R21 (%TW/EFPY)		1R21 to 2024 (%TW/EFPY)	
	Average	Upper 95th	Average	Upper 95th
SG A (entire population)	0.53	3.17	0.36	1.89

Table 7-3: Comparison of SG B Broached Bobbin TSP Wear Growth Rates at 1R22 and 2024

Region	1R21 to 1R22 (%TW/EFPY)		1R22 to 2024 (%TW/EFPY)	
	Average	Upper 95th	Average	Upper 95th
SG B (Broken Ring)	1.10	5.06	0.784	3.627
SG B (W-Prime)	0.73	7.30	2.625	6.218
SG B (Inner Bundle)	0.20	2.25	0.414	2.591

In addition to repeat indication growth rates, average bobbin depths associated with new indications are also of interest. As illustrated in Table 7-4, the average bobbin depths of newly-reported indications has remained approximately constant in both SGs since replacement.

Table 7-4: New Broached Bobbin TSP Wear Indication Average Depths

Steam Generator	1R19 (%TW)	1R20 (%TW)	1R21 (%TW)	1R22 (%TW)	2024 (%TW)
SG A	9.93	8.23	8.77	NA(1)	12.69 (2)
SG B	11.67	10.0	9.80	10.45	12.97 (2)

Notes:
1. SG A was not inspected during 1R22.
2. The reporting threshold for new flaws was increased from 6%TW to 10%TW in the Spring 2024 inspection. This results in a slightly higher average in both SGs.

Initiation and Depth Distribution of New Indications

From the 1R22 OA, a total of 2,914 new wear indications were predicted for SG B. These indications were broken down by each of the two OA zones. The results reported in 2024 showed all zones and the bundle as a whole had fewer new indications than projected in 1R22. The prediction for number of new flaws in 2024 (referred to in the 1R22 OA [21] as "1R23") is based on a conservative projection of the recent and historical trends in new flaw initiation for each zone. Table 7-5 lists the quantity of new indications (at each cumulative EFPY value) for each OA zone.

Predictions for the two zones are based on a combination of extrapolation of trends and judgement which produced the values shown in the last row of Table 7-5.

Table 7-5: New Indications Reported by Outage

Cumulative EFPY	SG B (Outer Ring)	SG B (Inner Bundle)	SG A (Full Bundle)
1.72, 1R19	673	449	952
3.60, 1R20	1126	1164	1739
5.49, 1R21	1249	1063	2057
7.27, 1R22	1570	333	NA (1)
9.2, CY 2024	631	61	666
Projected at 11.2 EFPY	750	1550	1583

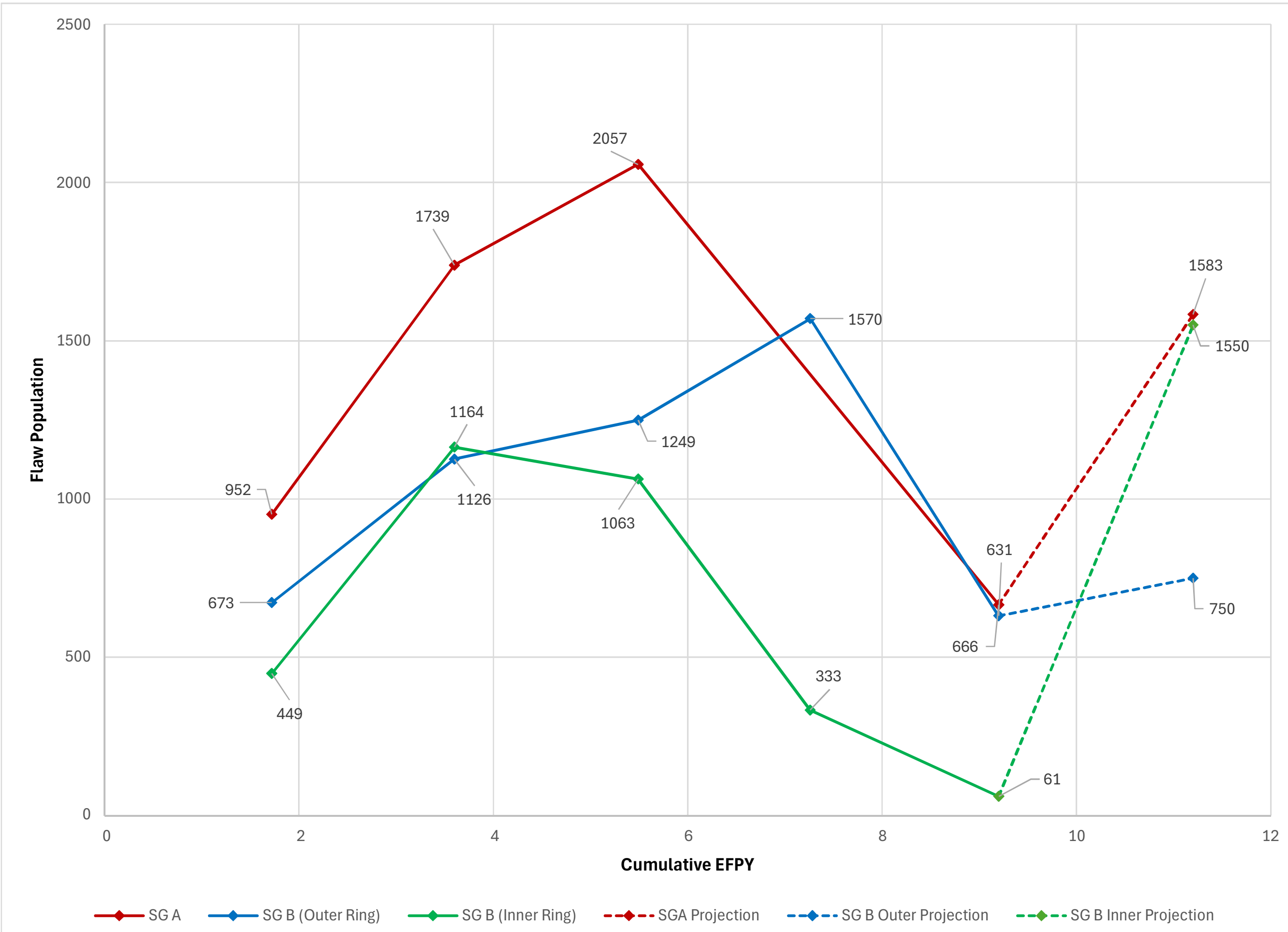
Notes:

1. SG A was not inspected in 1R22

As confirmed in Section 4.3, the methodology implemented in the model to predict the number of new flaws greatly overestimates the number of flaws and is expected to continue to be conservative.

New flaws are predicted to initiate following a similar depth distribution to what was observed in 2024. The maximum depth new indication was sized with bobbin at 47%W, which does not challenge tube integrity.

Figure 7-19: TMI New Broached TSP Wear Flaws vs Cumulative EFPY



7.2.2 Results of Probabilistic OA for Broached TSP Wear

Independent, fully-probabilistic operational assessment models were evaluated for each SG. In 1R20 through 1R22, three zones were used for probabilistic modeling in SGB: "W-Axis", "Broken Ring", and "Inner Bundle". The reduction in tube count in the W-Pime zone because of plugging, a decrease in certain growth rates (namely, 95^{th} percentile) and the location of the single highest growth rate tube in the "Broken Ring" made it reasonable to combine the "W-Axis" and "Broken Ring" zones into one "Outer Ring" zone for the 2024 OA. The Inner Bundle zone remained unchanged. As such, the probabilistic models created for the 2024 OA use two zones: "Inner Bundle" and "Outer Ring". The delineation is tubes outside 48" radius are in the outer ring and inside 48" radius are in the inner bundle. Use of the 48" radius is consistent with the past. SGA was not seperated into different zones and does not have a large number of tubes in the W-axis plugged.

The probability that the tube bundle will meet a minimum burst pressure of 3ΔP is the product of all the probabilities of each existing, postulated new, and postulated undetected wear indication within the tube bundle meeting 3ΔP and is termed the Probability of Survival (POS). These probabilities of meeting 3ΔP for broached TSP wear are listed in Table 7-6 for SG B.

As shown in Table 7-6, the projected structural integrity probabilities of survival for both SGs exceed the required 0.95 probability. These results compounded with use of a conservative 2.0 EFPY duration serve to demonstrate with reasonable assurance that the structural performance criteria will not be challenged for 2.0 EFPY of operation.

Table 7-6: SG B POS for Broached TSP Wear at 1R23

<table>
<tr><th></th><th>SG A POS Result
2 EFPY Run Time</th><th>SG B POS Result
2 EFPY Run Time</th><th>Minimum Required</th></tr>
<tr><td>Outer Ring</td><td rowspan="2">0.982
(one population)</td><td>0.9813</td><td>>=0.95</td></tr>
<tr><td>Inner Bundle</td><td>0.9878</td><td>>=0.95</td></tr>
<tr><td>Product (1)</td><td>NA</td><td>0.969 (2)</td><td>>=0.95</td></tr>
<tr><td colspan="4">Notes:
1. Each POS must be >=0.95 and the product of all POS combined must be >=0.95
2. Value truncated at the third decimal place for conservatism</td></tr>
</table>

7.2.3 Broached TSP Wear Predictions for Future Inspection

Predictions for broached TSP wear indications were performed using the probabilistic full bundle model. Predictions were made for a single cycle of 2.0 EFPY. The predictions for SG B are illustrated in Table 7-7. The predictions are made by zone based on 400 probabilistic trials of all flaws returned to service and picking the highest value. The results for SG B bound SG A.

Table 7-7: SG B Maximum Flaw Depth Predictions after 2.0 EFPY

Parameter	Outer Ring	Inner Bundle
Repeat	68%TW	47%TW
New	37%TW	26%TW

7.2.4 Leakage OA for Broached TSP Wear

As discussed earlier, most wear indications will leak and break at essentially the same pressure. Therefore, leakage integrity at a much lower faulted pressure differential of 2575 psi is also demonstrated. The above statement is only true if the indication has an axial extent greater than or equal to 0.25 inches. Volumetric flaws of limited axial extent should also be evaluated as circumferential cracks for leakage integrity. Since length measurements were not obtained for all TSP wear indications, some of these indications could have axial extents less than 0.25 inches. Although the indications with these very short lengths would typically be shallow, the onset of pop-through leakage was also considered based on the circumferential extents and depths of the flaws. For circumferential degradation, the axial loads associated with a LBLOCA accident is the limiting condition. MSLB, Small Break LOCA (SBLOCA) and Large Break LOCA (LBLOCA) have all been evaluated and with regard to the tube axial loads applied to circumferential flaws, LBLOCA is limiting [10, 11]. Per Reference [11] the onset of pop-through leakage under the limiting LBLOCA axial load would occur at about 78%TWD over the width of a single land. Since the projected maximum depth is 68%TWD (Table 7-7), there is reasonable assurance that leakage integrity under the limiting LBLOCA conditions will continue to be met for broached TSP wear.

7.2.5 LBLOCA Considerations for OA Structural Integrity of Broached TSP Wear

Large Break Loss-of-Coolant Accident (LBLOCA) conditions were also considered during the OA evaluation for broached TSP wear. For LBLOCA events, the limiting load is the axial load created by the large tube-to-shell temperature differential that develops as the tubes cool faster than the shell. Per Reference [11] structural integrity is satisfied with 100%TWD wear indications at two lands of the support plate. Since no indications approaching 100% TWD are predicted in the probabilistic analysis, structural integrity under postulated LBLOCA conditions is satisfied for broached TSP wear.

7.3 Drilled TSP Wear OA

Wear at the drilled TSP intersections is likely to have the structural characteristics of a circumferential flaw. MSLB, Small Break LOCA (SBLOCA) and Large Break LOCA (LBLOCA) have all been evaluated and with regard to the tube axial loads applied to circumferential flaws, and LBLOCA was found to be limiting [10, 11]. Thus for all cases where flaws are of a geometry that results in circumferential structural behavior, the limiting case uses LBLOCA loads.

The population of drilled TSP wear flaws is small and is addressed with deterministic methods as shown below.

For circumferentially-oriented degradation under LBLOCA conditions, the structural variable for drilled wear is Percent Degraded Area (PDA) which is a function of both flaw depth and circumferential extent, in addition to conservatively assuming the flaw is the full axial extent of the TSP.

7.3.1 Structural Integrity for Drilled TSP Wear

Nine (9) and 49 indications of wear at drilled TSP holes were reported SG A and SG B, respectively, and no tubes were plugged for drilled TSP wear. All indications in SG A were returned to service and three indications in SG B were in tubes plugged for additional wear on the tubes at broached TSP intersections. Using a conservative deterministic approach, a projected real depth (RD) after a postulated 2.0 EFPY of operation is calculated using the bobbin probe technique, Appendix I ETSS 96042.1 rev 4, and shown to be less than allowable structural limit of 50.1%TWD at 3,830 psid. The structural limit was conservatively determined using the methodology defined by the EPRI Flaw Handbook Calculator for 360° Uniform Thinning over a length of 1.18”.

Both SGs are evaluated for one cycle (2.0 EFPY) using the largest flaw returned to service and the maximum observed growth rate for repeat indications from the Spring 2024 inspection results.

$$\boldsymbol{RD} = \underbrace{\mathbf{1.05} * (\boldsymbol{NDE\%\ TWD}) - \mathbf{1.15}}_{\text{Correction of max drilled TSP wear returned to service using ETSS I 96042.1 Rev 4 linear regression}} + \underbrace{(\mathbf{3.21})(\mathbf{1.645})}_{\text{Upper 95}^{\text{th}}\text{ percentile NDE uncertainty}} + \underbrace{\boldsymbol{Growth} * \boldsymbol{EFPY}}_{\text{Max measured growth rate adjusted for projected cycle length}} = \%\,\boldsymbol{TWD}$$

Where:

RD = Projected end-of-cycle Real Depth at 1R23

NDE%TWD = maximum 2024 drilled TSP wear returned to service = 28 %TW (SG B R108-T3)

Growth rate = Maximum repeat growth rate from Table 4-5: 7.77 %TW/EFPY

EFPY = Evaluated inspection interval = 2.0 EFPY

$$\boldsymbol{RD} = \mathbf{1.05} * (\mathbf{28}) - \mathbf{1.15} + (\mathbf{3.21})(\mathbf{1.645}) + \mathbf{7.77} * \mathbf{2.0} = \mathbf{49.1}\%\,\boldsymbol{TW}$$

The projected end-of-cycle real depth of 49.1%TW is less than the structural limit of 50.1%TW for a flaw length of 1.18”.

The above discussion is valid if the degradation is treated as axially-oriented volumetric degradation. Since the circumferential extent of wear at drilled TSPs is not limited by the width of the TSP lands, it is also evaluated as circumferentially oriented degradation under LBLOCA conditions. Per Reference 16, the bounding PDA is 29.7. Therefore, considering the projected end-of-cycle depth of 49.1%TW and a circumferential extent of 200°, which bounds the current circumferential extent of the flaw of 182°, results in a calculated PDA of 27.28 (49.1*200/360). This is less than the allowable EOC PDA of 29.7 demonstrating that structural integrity for LBLOCA is satisfied for drilled TSP wear.

7.3.2 Leakage Integrity for Drilled TSP Wear

As discussed earlier, axially oriented volumetric wear indications will leak and break at essentially the same pressure. Therefore, leakage integrity at a much lower faulted pressure differential of 2575 psi is also demonstrated for axially oriented wear indications.

Drilled TSP wear indications, however, must also be evaluated as circumferentially oriented indications for pop-through leakage under LBLOCA conditions. Per Framatome LBLOCA analysis [11] a 49%TWD indication of 360-degree extent should not experience ligament pop-thru. The maximum projected depth at after 2.0 EFPY (for SG B) of 49%TWD is equal to this limit, but the flaw would need to be 360 degrees in circumferential extent. The largest circumferential extent reported in 2024 was 221 degrees, which includes probe look-ahead. Drilled TSP wear occurs preferentially in one direction. There is no reasonable case for the circumferential extent to reach 360 degrees. Therefore, leakage integrity under LBLOCA conditions is also satisfied.

7.4 Tube-to-Tube Wear (TTW) OA

There were 111 TTW flaws in SG A and 287 TTW flaws in SG B identified during the Spring 2024 inspection. No tubes were plugged for TTW and none of the tubes that were plugged contained any TTW indications, therefore all TTW flaws were returned to service. While a larger quantity than drilled TSP wear, due to the smaller growth rates the TTW OA is performed similarly using a deterministic approach.

7.4.1 Structural Integrity for TTW

Using a conservative deterministic approach, a projected real depth (RD) after 2.0 EFPY is calculated using the bobbin probe technique ETSS 13091.1 and shown to be less than allowable structural limit of 54.5%TWD at the bounding length of 39". The structural limit is conservatively determined using the methodology defined by the EPRI Flaw Handbook Calculator for 360° Uniform Thinning over a finite length.

.

$$\boldsymbol{RD = \underbrace{0.94 * (NDE\%\,TWD) + 1.24}_{\text{Correction of max TTW returned to service using ETSS 13901.1 linear}} + \underbrace{(1.57)(1.645)}_{\text{Upper 95th percentile NDE uncertainty}} + \underbrace{Growth * EFPY}_{\text{Max growth rate adjusted for projected cycle length}} = 26.8\%\,TWD}$$

Where:

RD = Projected end-of-cycle Real Depth after 2.0 EFPY
NDE%TWD = maximum 2024 SG B TTW returned to service = 20%TWD [Table 4-7]
Growth = maximum growth = 2.07%TW/EFPY [Table 4-7]
EFPY = Evaluated inspection interval = 2.0 EFPY

$$\boldsymbol{RD = 0.94 * (28) + 1.24 + (1.57)(1.645) + 2.07 * 2.0 = 26.8\%\,TW}$$

The projected end-of-cycle real depth of 26.8%TW is less than the structural limit of 54.5%TW for a flaw length of 39.0”. The above discussion is valid if the degradation is treated as axially-oriented volumetric degradation. Since some tubes have multiple indications in the same plane, these indications also need to be evaluated based on the depth and circumferential extent of the indications under LBLOCA conditions. Per Reference [11] the bounding PDA is 29.7. Therefore, considering a maximum EOC indication of 26.8%TWD over 180 degrees equates to a PDA of 13.1. This is less than the allowable EOC PDA of 29.7 demonstrating that structural integrity for LBLOCA is satisfied for TTW.

7.4.2 Leakage Integrity for TTW

As discussed earlier, axially oriented volumetric wear indications will leak and break at essentially the same pressure. Therefore, leakage integrity at a much lower faulted pressure differential of 2575 psi is also demonstrated for axially oriented wear indications.

Tube-to-tube wear indications, however, must also be evaluated as circumferentially oriented indications for pop-through leakage under LBLOCA conditions. For a conservative 180-degree indication, the allowable real pop-through depth under LBLOCA conditions is 55%TW. Since the bounding projected real depth of 26.8%TWD is below the allowable depth, leakage integrity under LBLOCA conditions is also satisfied.

8.0 TUBE PLUGGING AND STABILIZATION

A total of tubes seven (7) tubes in SG A and 35 tubes in SG B were stabilized and plugged during the 2024 inspection using Alloy 690 mechanical rolled plugs [15]. All tubes plugged in 2024 were stabilized full-length (nominal 654.375" stabilizer length), from the upper tube end using EOTSG stabilizers qualified for all tube locations for the entire life of the plant [16].

Table 8-1 summarizes the total plugged tubes at each inspection and compares to the EOTSG design plugging limit of 5% from safety analysis. Table 8-2 summarizes the number of technical specification and preventative plugging performed in each SG during 2024. Copies of the final plugging lists are provided in Appendix A and B.

In SG A there were three (3) tubes that met Tech Spec plugging criteria of >=40%TWD, all for broached TSP wear. In SG B there were eight (8) tubes that met Tech Spec plugging criteria, all for broached TSP wear. Additional tubes in SG A and SG B were preventatively plugged based on individual flaw growth rates and deterministic projections assuming no attenuation in growth rates.

The TMI-1 EOTSGs have additional localized plugging criteria, with updated criteria for SG B after the extensive plugging campaign during the 1R21 inspection [32, 35]. SG A satisfies all localized plugging criteria while SG B has locations which do not satisfy the updated localized plugging criteria and will therefore need further evaluations. However, it is noted that primary purpose of these limits is to reduce risk of damage to in-service tubes adjacent to clusters of plugged tubes that would result from moisture droplet impingement, does not directly impact plant safety analyses or licensing basis, and does not impact short term operability of the SGs.

As an additional comparison to operating experience of US OTSG experience, Figure 8-1 provides the cumulative tube plugging for the TMI-1 SGs alongside all 10 operational OTSGs (5 OTSG Units) as of the Spring 2024 inspection.

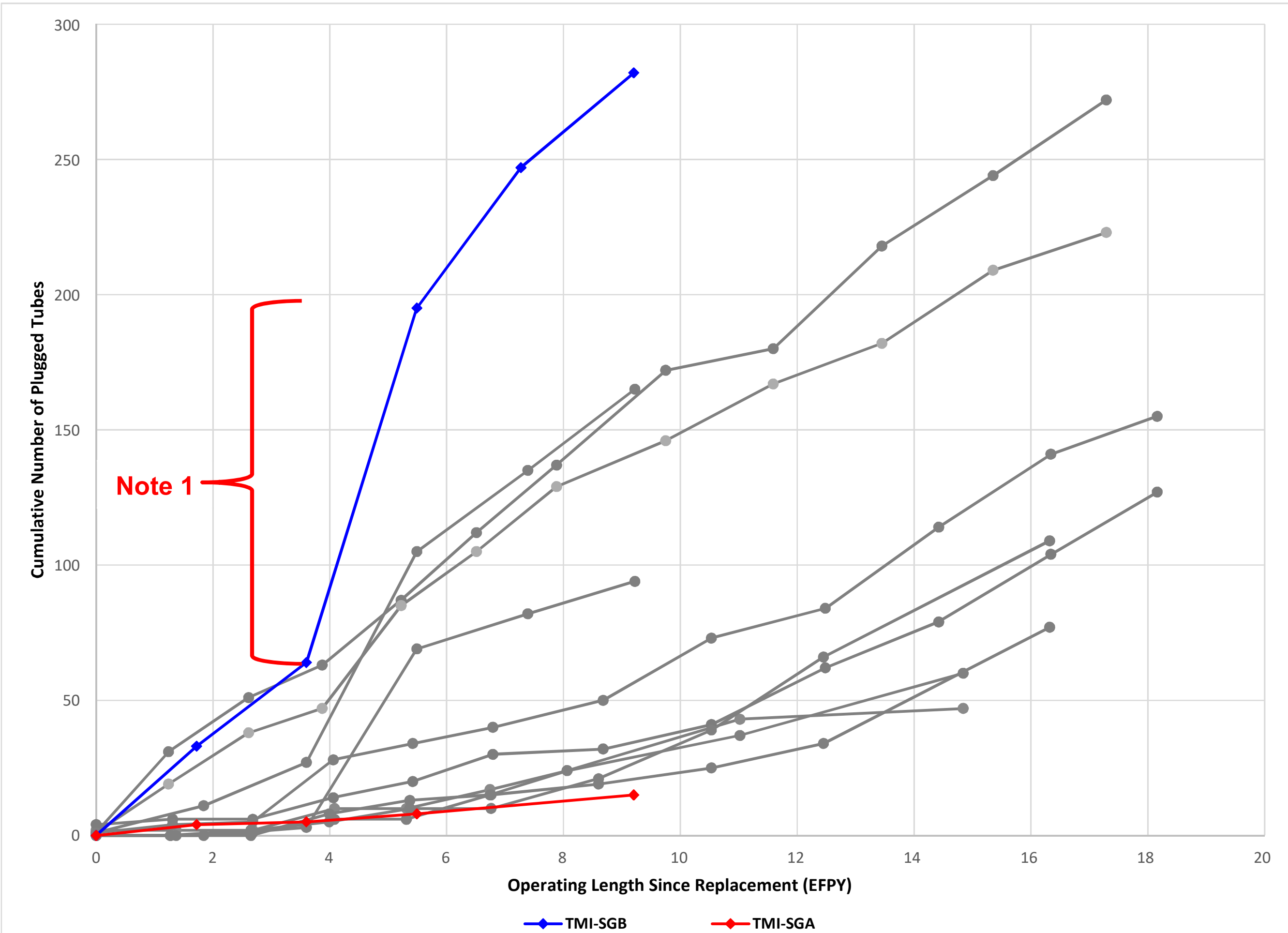
Table 8-1: TMI-1 Tube Plugging History

Outage	SG A Plug History				SG B Plug History				Total Plugged
	TSP Wear	TTW	Other	SG A Total Plugged	TSP Wear	TTW	Other	SG B Total Plugged	
PSI	0	0	0	0	0	0	0	0	0
1R19	0	4	0	4	30	3	0	33	37
1R20	1	0	0	1	31	0	0	31	32
1R21	3	0	0	3	131	0	0	131	134
1R22	No inspection or plugging				52	0	0	52	52
2024	7	0	0	7	35	0	0	35	42
Total (Tubes)	11	4	0	15	279	3	0	282	297
Total (%)	0.10%				1.81%				0.95%
Limit (%)	5.0%				5.0%				5.0%
Limit (Tubes)	779 of 15597				779 of 15597				1558 of 31194

Table 8-2: 2024 Plugged Tubes

	SG A	SG B
Technical Specification ≥40% TWD	3	8
Preventative Plugging	4	27

Figure 8-1: Cumulative Tube Plugging of all US OTSGs as of Spring 2024



Notes for Figure 8-1:

1. The large number of tubes plugged in SGB is primarily attributed to the preventative plugging of 86 W-axis tubes in 1R21, only 18 of which contained flaws ≥40%TW.

9.0 COMPUTER FILES

This section summarizes the computer files used to tabulate the ECT data from FDMS, generate the CM and OA plots, and input files used for the full bundle probabilistic models used in this document. All files are listed in Table 9-1

All files are located in the following ColdStor directory:

\cold\General-Access\51\51-9378840-000\official

Table 9-1: Computer Files

File	File type	Description	Modified Date / Time
2024 CMOA Wear	zip	Outage files for evaluating TSP wear including Full Bundle Probabilistic Input and Output files	11/08/24 01:37 PM
2024 TieRodBow Files	zip	TieRodBow software files to calculate bow magnitudes	11/08/24 01:51 PM
BWXT Structural Dimension Calculator TMI_R19-R22_FINAL	xlsm	TSP Wear structural profile calculations from R19-R22	06/23/24 05:19 PM
BWXT Structural Dimension Calculator TMI_S2024_FINAL	xlsm	TSP Wear structural profile calculations from 2024 inspection	06/04/24 01:24 PM
TMI_LxL_Plots_2011-2024	zip	TSP Wear structural profile plots from R19 to Spring 2024 inspection (2011-2024)	11/08/24 11:46 AM
TMI_S2024_Broach TSP Wear	xlsx	Broached TSP Wear data from Spring 2024 inspection	10/16/24 05:53 PM
TMI_S2024_Drilled TSP Wear	xlsx	Drilled TSP Wear data from Spring 2024 inspection	07/16/24 12:56 AM
TMI_S2024_LxL Summary	xlsx	Summary of TSP Wear profile data through Spring 2024 inspection	06/23/24 05:19 PM
TMI_S2024_SGA_EPRI Circ Crack Draw	xls	SGA Drilled TSP wear PDA calculations using EPRI Circ Draw Program	06/04/24 08:54 AM
TMI_S2024_SGB_EPRI Circ Crack Draw	xls	SGB Drilled TSP wear PDA calculations using EPRI Circ Draw Program	06/04/24 08:56 AM
TMI_S2024_Tie Rod Proximity_R1	xlsx	TMI tie rod proximity indications, bow limits, and conservative projections	07/16/24 06:10 PM
TMI_S2024_TTW	xlsx	TTW data from Spring 2024 inspection	06/24/24 02:00 AM

10.0 RESULTS AND CONCLUSIONS

During the 2024 Inspection at TMI Unit 1, eddy current inspections of the steam generator tubing were performed on all in-service tubes. The degradation mechanisms detected were tube support wear at drilled and broached TSPs and tube-to-tube wear. No new degradation mechanisms were detected in 2024 . The condition of tie rod bowing was newly identified for a small number of tie rods and determined to be acceptable for two cooldowns. All indications detected met condition monitoring criteria analytically and therefore no indications required in situ pressure testing, and no in situ pressure testing was performed. Populations and limiting flaw depths in 2024 were compared to the predictions of the previous Operational Assessments and were within expectations based on the predictions of the previous OAs. It is concluded that the CM performance criteria were met in 2024 and that the conclusions of the prior OA were validated.

Based on the inspection results, a total of 42 tubes were removed from service via plugging. Eleven (11) of these tubes required plugging due to flaw depths meeting or exceeding the Tech Spec plugging limit of >=40%TWD. All other tubes were plugged to gain margin in the operational assessment or due to their susceptibility to high growth rates based on flaw depths, growth rates, flaw count, and/or tube location within the bundle. The total number of tubes plugged are less than the plugging limit of 5% set by safety analysis; however, SG B exceeds the localized plugging criteria in several locations established in an updated assessment following 1R21 and will require additional evaluations. Note that exceeding the localized limit does not provide any short term operability concerns as discussed in Section 8.0.

An operational assessment was performed for all detected degradation mechanisms. Deterministic analyses were performed for wear at drilled TSP intersections and tube-to-tube wear. Both SGs were satisfactorily evaluated for 2.0 EFPY for tube-to-tube wear and wear at drilled TSPs.

A fully probabilistic assessment was performed for both SGs for broached TSP wear. SG A was evaluated as a single population and SG B was evaluated using multi-zone approach using two distinct populations separated by SG tube bundle radius as discussed previously. Evaluations addressed 2.0 EFPY of operation before the next inspection. The POS for both SGs for 2.0 EFPY of operation was greater than the required 0.95

In addition to the eddy current testing, visual inspections were also performed on previously installed plugs, channel head, tubesheet cladding. These inspections showed no anomalies indicative of degradation. Also, no PLP indications or evidence of foreign object wear were identified.

Due to the extended shutdown and lack of managed layup, Secondary Side Inspections (SSI) were conducted in both SGs as specified in the Degradation Assessment. An Array probe exam on the periphery outer 2 tubes did not identify any potential loose part (PLP) indications, foreign objects (FOs) or wear indications suggestive of foreign object wear.

The operational assessment provides reasonable assurance that the performance criteria will be satisfied for operation of up to 2.0 EFPY for tube degradation and 2 cooldowns for tie rod bowing.

11.0 REFERENCES

References identified with an (*) are maintained within Constellation Records System and are not retrievable from Framatome Records Management. These are acceptable references per Framatome Administrative Procedure 0402-01, Attachment 7. See page 2 for Project Manager Approval of customer references.

1. EPRI Report 3002020909, "Steam Generator Management Program: Steam Generator Integrity Assessment Guidelines Revision 5, December 2021
2. Nuclear Energy Institute Document 97-06, Revision 3, "Steam Generator Program Guidelines"
3. * Constellation TMI-1 Plant Technical Specification (TS), 3.1.6.3 Primary to Secondary Leakage, 4.19 Steam Generator (SG) Tube Integrity, 6.19 Steam Generator (SG) Program as of Amendment 279 (not presently in force)
4. Framatome Document 51-9377447-001 "TMI-1 Steam Generator Degradation Assessment – Spring 2024 Inspection"
5. EPRI Report 3002007572, "Pressurized Water Reactor Steam Generator Examination Guidelines: Revision 8", June 2016 (Includes Interim Guidance SGMP-19-01 incorporated April 2019 and Interim Guidance SGMP-21-02 Incorporated September 2021)
6. EPRI Report 3002005426 "Steam Generator Management Program: Steam Generator Degradation Specific Management Flaw Handbook, Revision 2" October 2015
7. Framatome Document 01-9072689-004 "Operation and Maintenance Manual for TMI Enhanced Once Through Steam Generators"
8. * Constellation Technical Evaluation 02614810-02, T1R22 Condition Monitoring/Operational Assessment Report Inputs: Normal Operating Pressure Differential (NOPD) and Cycle Effective Full Power Days (EFPDs)"
9. Framatome Document 51-9369464-000, "Three Mile Island Unit 1 SG ECT Inspection Plan – Spring 2024"
10. Framatome Document 32-9075183-005, "TMI NEI 97-06 Degraded Tube Analysis".
11. Framatome Document 51-9124284-003, "LBLOCA – EOTSG Degraded Tube Assessment"
12. Framatome Document 51-9125055-001, "EPRI Flaw Handbook Calculator Software Validation"
13. Framatome Document 32-9104082-003, MathCad Implementation of SG Full Probabilistic Operational Assessment
14. Framatome Document 51-9198846-000, TMI Multi-Zone OA Preparation Pre-1R21
15. Framatome Document 33-9079472-003, "Design Report for Alloy-690 Mechanical Roll Plug for TMI-1 EOTSG"
16. Framatome Document 51-9208510-000, "Input for 50.59 Evaluation for Stabilization of EOTSG Tubes at TMI-1"
17. Framatome Document 51-9172263-003, "Justification for Deviating from the Recommendations Provided in the TMI-1 EOTSG Stabilization Criteria"
18. * Exelon ECR 11-00543-000, "Alternate OTSG Tube Stabilizer"

19. Framatome Document 51-9069932-004, "TMI-1 EOTSG Tube Bundle Stabilization Criteria"
20. Framatome Document 51-9248876-000, "Justification for Deviating from Recommendation Provided in the EOTSG Stabilization Criteria during RFO 1R21.
21. Framatome Document 51-9276958-002, "Condition Monitoring and Final Operational Assessment of TMI-1 Steam Generators at 1R22".
22. Framatome Document 51-9094580-004, "Measuring the Gap between Tubes and Tie Rods with the Bobbin Coil Eddy Current Method"
23. Framatome Document 51-9191328-000, "EOTSG Upper Span Tie Rod Bow Test Results"
24. Framatome Document 51-9378314-000 "Site Validation of EPRI Qualified Eddy Current Techniques for Three Mile Island Unit 1 Spring 2024"
25. Framatome Drawing 02-8091860-B-000, ".625 by .036 Deposit Mapping Reference Standard As-Built Drawing" (Davis Besse)
26. Framatome Document 51- 9371514-000, "Davis Besse Steam Generator Degradation Assessment for 1R23 (Spring 2024)
27. Framatome Document 51-9265639-000, "ANO-1 Condition Monitoring and Operational Assessment for 1R26"
28. EPRI Product ID 1011803, "Flaw Profile Tool (FPT) Version 1.0", November 2005
29. Framatome Document 03-9378317-000, "Secondary Side Visual Inspection Plan and Procedure for Constellation, TMI Spring 2024"
30. Framatome Document 03-1246524-019, "Instructions for Plug Inspection"
31. Framatome Document 03-9203864-007, "Steam Generator Channel Head Visual Inspection Level 3 – Information Use"
32. Framatome Document 32-9060181-001, "TMI-1 EOTSG Localized Tube Plugging Limits"
33. Framatome Document 51-9379379-000, "Three Mile Island Unit 1 May 2024 Secondary Side Top of Tubesheet Visual Inspection Report"
34. Framatome Document 51-9198849-003, "Condition Monitoring and Final Operational Assessment of TMI-1 Steam Generators at 1R21"
35. Framatome Document 32-9240245-001, "TMI-1 EOTSG B Localized Tube Plugging Limits Analysis"

APPENDIX A: SG A PLUGGING LIST

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Three Mile Island Unit 1 - 2024 - S/G 1A

PLUG LIST (Rev. 0)

S/G	Row	Col	Hot Leg	Cold Leg	Reason for Tube Repair	Tube Qty.	Stab	Rev.
TMI1AR	7	20	ROLLSTAB	ROLLED	TWD @ 10S-0.76	1	YES	0
TMI1AR					TBP @ 10S-0.76			0
TMI1AR	7	21	ROLLSTAB	ROLLED	PTP @ 10S-0.73	2	YES	0
TMI1AR	10	3	ROLLSTAB	ROLLED	TWD @ 10S-0.57	3	YES	0
TMI1AR					TBP @ 10S-0.57			0
TMI1AR	15	7	ROLLSTAB	ROLLED	PTP @ 10S-0.69	4	YES	0
TMI1AR	117	1	ROLLSTAB	ROLLED	PTP @ 12S-0.78	5	YES	0
TMI1AR	138	20	ROLLSTAB	ROLLED	PTP @ 10S-0.73	6	YES	0
TMI1AR	142	4	ROLLSTAB	ROLLED	TWD @ 12S-0.71	7	YES	0
TMI1AR					TBP @ 12S-0.71			0
					Totals:	7	7	

Notes (Rev. 0):

1. All tubes shall be stablized from the upper tube end using stabilizer part number 8066927-001 (nominal 654.375" stabilizer length)
2. The upper tube ends shall be pllugged using part number 1196122-002 (OTSG Stabilizer Rolled Plug)
3. The lower tube ends shall be plugged using part number 1222118-005 (OTSG Threaded Rolled Plug Assembly)
4. The tubes on the above list have been reviewed for skip rolls, over expansions, dents, bulges and additional indications that could interfere with plug or stabilizer installation. No such anomalies or indications were detected that would interfere with installation of the plugs or stabilizers.
5. The indications in the tubes on the above list have been screened against the in-situ pressure test screeninng criteria. No tubes require in-situ pressure test.
6. Tubes on the above list have been selected based on the following plugging criteria: TWD=>40% and PTP (preventative tube plug)

Approvals:

[signature] 5/31/24 1806
Framatome Tube Integrity

[signature] Victor Newman 05/31/2024 18:00
Framatome Data Management

[signature] 5-31-2024 17:55
Framatome Lead Level III

Mike Bodak 5/31/24
Utility Steam Generator Engineer Mike Bodak

[signature] 5/31/24
Utility Project Manager Christopher Donovan

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APPENDIX B: SG B PLUGGING LIST

framatome Three Mile Island Unit 1 - 2024 - S/G 1B

PLUG LIST (Rev. 0)

S/G	Row	Col	Hot Leg	Cold Leg	Reason for Tube Repair	Tube Qty.	Stab	Rev.
TMI1BR	4	1	ROLLSTAB	ROLLED	TWD @ 12S-0.71	1	YES	0
TMI1BR					TBP @ 12S-0.71			0
TMI1BR	4	3	ROLLSTAB	ROLLED	PTP @ 12S-0.73	2	YES	0
TMI1BR	5	5	ROLLSTAB	ROLLED	PTP @ 11S-0.71	3	YES	0
TMI1BR	5	6	ROLLSTAB	ROLLED	PTP @ 11S-0.71	4	YES	0
TMI1BR	5	7	ROLLSTAB	ROLLED	TWD @ 11S-0.66	5	YES	0
TMI1BR					TBP @ 11S-0.66			0
TMI1BR	5	8	ROLLSTAB	ROLLED	PTP @ 11S-0.73	6	YES	0
TMI1BR	5	20	ROLLSTAB	ROLLED	PTP @ 11S-0.75	7	YES	0
TMI1BR	5	24	ROLLSTAB	ROLLED	PTP @ 12S-0.77	8	YES	0
TMI1BR	5	40	ROLLSTAB	ROLLED	PTP @ 12S-0.68	9	YES	0
TMI1BR	6	1	ROLLSTAB	ROLLED	TWD @ 12S-0.65	10	YES	0
TMI1BR					TBP @ 12S-0.65			0
TMI1BR	6	4	ROLLSTAB	ROLLED	PTP @ 12S-0.73	11	YES	0
TMI1BR	6	28	ROLLSTAB	ROLLED	PTP @ 11S-0.76	12	YES	0
TMI1BR	6	36	ROLLSTAB	ROLLED	PTP @ 12S+0.28	13	YES	0
TMI1BR	6	44	ROLLSTAB	ROLLED	PTP @ 12S-0.74	14	YES	0
TMI1BR	7	5	ROLLSTAB	ROLLED	PTP @ 12S+0.32	15	YES	0
TMI1BR	7	14	ROLLSTAB	ROLLED	PTP @ 11S-0.78	16	YES	0
TMI1BR	7	16	ROLLSTAB	ROLLED	PTP @ 11S-0.73	17	YES	0
TMI1BR	8	2	ROLLSTAB	ROLLED	PTP @ 14S+0.14	18	YES	0
TMI1BR	9	3	ROLLSTAB	ROLLED	TWD @ 12S-0.71	19	YES	0
TMI1BR					TBP @ 12S-0.71			0
TMI1BR	9	4	ROLLSTAB	ROLLED	PTP @ 12S+0.27	20	YES	0
TMI1BR	12	1	ROLLSTAB	ROLLED	PTP @ 12S-0.71	21	YES	0
TMI1BR	15	75	ROLLSTAB	ROLLED	PTP @ 12S+0.32	22	YES	0
TMI1BR	18	82	ROLLSTAB	ROLLED	PTP @ 11S-0.69	23	YES	0
TMI1BR	19	83	ROLLSTAB	ROLLED	PTP @ 11S+0.37	24	YES	0
TMI1BR	20	81	ROLLSTAB	ROLLED	TWD @ 11S+0.34	25	YES	0
TMI1BR					TBP @ 11S+0.34			0
TMI1BR	21	82	ROLLSTAB	ROLLED	PTP @ 11S+0.34	26	YES	0

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Three Mile Island Unit 1 - 2024 - S/G 1B
PLUG LIST (Rev. 0)

S/G	Row	Col	Hot Leg	Cold Leg	Reason for Tube Repair	Tube Qty.	Stab	Rev.
TMI1BR	56	123	ROLLSTAB	ROLLED	PTP @ 11S+0.38	27	YES	0
TMI1BR	80	126	ROLLSTAB	ROLLED	PTP @ 10S-0.75	28	YES	0
TMI1BR	80	128	ROLLSTAB	ROLLED	TWD @ 10S-0.68	29	YES	0
TMI1BR					TBP @ 10S-0.68			0
TMI1BR	81	128	ROLLSTAB	ROLLED	TWD @ 10S-0.62	30	YES	0
TMI1BR					TBP @ 10S-0.62			0
TMI1BR	83	128	ROLLSTAB	ROLLED	PTP @ 10S-0.73	31	YES	0
TMI1BR	87	128	ROLLSTAB	ROLLED	PTP @ 10S-0.71	32	YES	0
TMI1BR	96	1	ROLLSTAB	ROLLED	PTP @ 13S-0.71	33	YES	0
TMI1BR	145	6	ROLLSTAB	ROLLED	PTP @ 14S-0.81	34	YES	0
TMI1BR	145	7	ROLLSTAB	ROLLED	TWD @ 14S-0.66	35	YES	0
TMI1BR					TBP @ 14S-0.66			0
					Totals:	35	35	

Notes (Rev. 0):

1. All tubes shall be stabilized from the upper tube end using stabilizer part number 8066927-001 (nominal 654.375" stabilizer length)
2. The upper tube ends shall be plugged using part number 1196122-002 (OTSG Stabilizer Rolled Plug)
3. The lower tube ends shall be plugged using part number 1222118-005 (OTSG Threaded Rolled Plug Assembly)
4. The tubes on the above list have been reviewed for skip rolls, over expansions, dents, bulges and additional indications that could interfere with plug or stabilizer installation. No such anomalies or indications were detected that would interfere with installation of the plugs or stabilizers.
5. The indications in the tubes on the above list have been screened against the in-situ pressure test screening criteria. No tubes require in-situ pressure test.
6. Tubes on the above list have been selected based on the following plugging criteria: TWD=>40% and PTP (preventative tube plug)

Approvals:

[signature] 6/1/24
Framatome Tube Integrity
VICTOR NEWMAN 1817 hrs

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Utility Project Manager
Scott A. Kvasnicka

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APPENDIX C: ASSESSMENT OF POTENTIAL IMPACT TO PLANT SYSTEMS AND COMPONENTS

ER-AA-2006 Criteria	Assessment of Potential Impact
Flow blockage (piping, valves, etc.)	The foreign objects left in the steam generators are of a sufficiently small size that inter-tube flow blockage is not considered a potential problem structurally or from a performance standpoint. Should the objects become detached from their present location, they will likely move to a lower velocity region on the top-of-tubesheet surface.
Mechanical interference (active components, valve, pumps, etc.)	There are no moving parts in the secondary side of the SGs. The foreign objects left in the steam generators are not considered to have the potential to interfere with the mechanics of the tube bundle and tube supports due to their small size. The only way for these objects to exit the top of tubesheet region of the SG is through the blowdown system, the objects are of a size and material that they do not have the potential to cause mechanical interference in this system.
Corrosion or adverse chemical reaction	Most foreign objects, including those that may not have been detected, are made of metallic materials which are compatible with the Alloy 690 tubing and the carbon steel and stainless steel components of the steam generators, or gasket material that is approved for contact with the secondary side.
Mechanical damage (wear, fretting, deformation, breaking, etc.)	The foreign objects left in the steam generators are considered benign based on their location, size, and physical characteristics, and are not capable of causing significant mechanical damage or the affected tubes are no longer in service. Note that no tubes are presently plugged due to foreign object contact/proximity.
Other potential impact scenarios, such as pump impeller interaction, valve seating interaction, instrument line breakage, etc.)	The small size and mass of parts left in the steam generators would prevent them from affecting structural components and welds in the steam generators or any components downstream of the steam generators.
Potential for similar debris being elsewhere in the system, the possibility that similar material may still be continuing to be generated, and the impact that this debris may have if transported to other components (e.g., FWH)	Low Potential. The two main types of new objects found were deposits (sludge rocks and tube scale) and flexitallic gasket pieces. Sludge deposits are benign and characteristically remain in the SGs. Most of the gasket pieces are believed to have been generated during removal of the bolted closures within the secondary systems over multiple cycles. Other foreign material may be transported to the steam generator. Steam generator replacement activities often produce foreign material like the machine curl that was removed. Due to the configuration of the SGs, objects transported to the SGs are not likely to leave the SGs.
Cumulative effects considering previously lost parts	There were no previously-identified lost parts/foreign objects. Objects identified in 2024 are being tracked and will be evaluated for re-inspection at the next opportunity.