Tennessee Valley Authority, 1101 Market Street, Chattanooga, Tennessee 37402

CNL-20-078

October 13, 2020

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U.S. Nuclear Regulatory Commission
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Watts Bar Nuclear Plant Unit 1
Facility Operating License No. NPF-90
NRC Docket No. 50-390

Subject: **Supplement to Application to Revise Watts Bar Nuclear Plant (WBN), Unit 1 Technical Specifications for Steam Generator Tube Inspection Frequency and to Adopt TSTF-510, "Revision to Steam Generator Program Inspection Frequencies and Tube Sample Selection," (WBN-390-TS-20-012) (EPID L-2020-LLA-0161)**

References:

1. TVA letter to NRC, CNL-20-053, “Application to Revise Watts Bar Nuclear Plant (WBN), Unit 1 Technical Specifications for Steam Generator Tube Inspection Frequency and to Adopt TSTF-510, "Revision to Steam Generator Program Inspection Frequencies and Tube Sample Selection," (WBN-390-TS-20-012),” dated July 17, 2020 (ML20199M346)

2. TVA letter to NRC, CNL-20-076, “Response to Request for Additional Information Regarding Application to Revise Sequoyah Nuclear Plant (SQN) Unit 1 Technical Specifications for Steam Generator Tube Inspection Frequency (SQN-TS-20-01) (EPID L-2020-LLA-0030),” dated September 23, 2020 (ML20267A525)

In Reference 1, Tennessee Valley Authority (TVA) submitted a request for an amendment to Facility Operating License No. NPF-90 for the Watts Bar Nuclear Plant (WBN), Unit 1. The proposed license amendment request (LAR) revises WBN, Unit 1 Technical Specifications (TS) 5.7.2.12, “Steam Generator (SG) Program,” and WBN Unit, 1 TS 5.9.9, “Steam Generator Tube Inspection Report,” to reflect a proposed change to the required SG tube inspection frequency from every 72 effective full power months (EFPM) to every 96 EFPM.

Based on information requested by the Nuclear Regulatory Commission (NRC) in Reference 2, TVA is supplementing Reference 1 as follows:

- To assist the NRC in their review of the LAR, Enclosure 1 to this submittal contains Westinghouse Document, SG-SGMP-17-9, Revision 1, "Watts Bar U1R14 Steam Generator Condition Monitoring and Operational Assessment."
- TVA is revising the proposed change to WBN Unit 1 TS 5.7.2.12.d.2 as follows: "After the first refueling outage following SG installation, inspect each SG at least every 96 effective full power months. Tube inspections shall be performed using equivalent to or better than array probe technology. For regions where a tube inspection with array probe technology is not possible (such as due to dimensional constraints or tube specific conditions), the tube inspection techniques applied shall be capable of detecting all forms of existing and potential degradation in that region." Enclosure 2 to this submittal contains a revised mark-up to the proposed change to WBN Unit 1 TS 5.7.2.12.d.2 and Enclosure 3 to this submittal contains the re-typed WBN Unit 1 TS 5.7.2.12.d.2 to show the proposed change. Enclosures 2 and 3 supersede the corresponding information provided in Enclosures 3 and 4 to Reference 1.

This letter does not change the no significant hazard considerations nor the environmental considerations contained in Reference 1. Additionally, in accordance with 10 CFR 50.91(b)(1), TVA is sending a copy of this letter and the enclosures to the Tennessee Department of Environment and Conservation.

There are no new regulatory commitments associated with this submittal. If you have any questions about this proposed change, please contact Gordon R. Williams, Senior Manager, Fleet Licensing (Acting) at (423) 751-2687.

I declare under penalty of perjury that the foregoing is true and correct. Executed on this 13th day of October 2020.

Respectfully,

James Barstow

James Barstow
Vice President, Nuclear Regulatory Affairs & Support Services

Enclosures

cc: See Page 3

Enclosures:

1. Westinghouse Document, SG-SGMP-17-9, Revision 1
2. Revised TS Changes (Mark-Ups) for WBN Unit 1
3. Revised TS Changes (Final Typed) for WBN Unit 1

cc (Enclosures):

NRC Regional Administrator – Region II
NRC Project Manager – Watts Bar Nuclear Plant
NRC Senior Resident Inspector – Watts Bar Nuclear Plant
Director, Division of Radiological Health – Tennessee State Department of Environment and Conservation

Enclosure 1

Westinghouse Document, SG-SGMP-17-9, Revision 1

SG-SGMP-17-9 **November 2019**
Revision 1

Watts Bar U1R14 Steam Generator Condition Monitoring and Operational Assessment

SG-SGMP-17-9
Revision 1

Watts Bar U1R14 Steam Generator Condition Monitoring and Operational Assessment

Prepared for:
Tennessee Valley Authority

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**** Electronically Approved Records are Authenticated in the Electronic Document Management System***

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Record of Revisions

Revision	Date	Description
0a	April 2017	Preliminary for Tennessee Valley Authority review and comment.
0	April 4, 2017	Incorporated review comments from TVA. Issued to the Watts Bar site in preparation for Mode 4 return to power.
1	See EDMS	Inspection interval investigated. *(Note: Change bars are used in the left margins where substantial or technical changes occurred. Change bars are not used for editorial changes such as formatting changes and minor non-technical corrections.)*

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Executive Summary

The Watts Bar U1R14 Replacement Steam Generator (RSG) inspection conducted after cumulative service equivalent to approximately 9.29 effective full power years (EFPY). The service duration from the previous U1R11 RSG eddy current inspection was 4.07 EFPY. No SG primary-to-secondary tube leakage was reported during this operating interval. At Watts Bar U1R14, approximately 100.5 effective full power months (EFPM) of the 144 EFPM in the first sequential period have been accrued and U1R14 is the last planned inspection in this sequential period. Based on the U1R14 steam generator (SG) eddy current and visual inspection data, there are two existing degradation mechanisms in the Watts Bar Unit 1 RSGs. The existing degradation mechanisms are:

- Mechanical Wear at U-bend Support Structures
- Mechanical Wear at Horizontal Advanced Tube Support Grids (ATSGs)

No tubes have exhibited degradation exceeding the tube integrity criteria given in the Degradation Assessment (DA) for the U1R14 outage (Reference 3). No tubes required in situ pressure testing to support the Condition Monitoring (CM) assessment based on the DA and Electric Power Research Institute (EPRI) In Situ Pressure Test Guidelines (Reference 6). A summary of the number of plugged tubes in the Watts Bar Unit 1 RSGs following U1R14 is provided below.

SG	# Tubes	# Plugged	% Plugging
1	5,128	3	0.06%
2	5,128	5	0.10%
3	5,128	7	0.14%
4	5,128	14	0.27%
Total	20,512	29	0.14%

A final operational assessment (OA) has been performed considering the indications detected and degradation growth rates observed. Development of degradation growth rates for U-bend support structure and advanced tube support grid (ATSG) tube wear indications has been based on historical eddy current data comparisons made by the lead eddy current data analyst. These growth rates were then used to project degradation that could be encountered within the 95th percentile and 50% confidence limits.

This revision (Revision 1) of the OA report includes the results of a study to determine if the steam generators could be operated for more than the three cycles (4.5 EFPY), between inspections without violation of the performance criteria, that was determined in Revision 0. Additional calculations were performed on the growth projection of the flaws observed during U1R14 and it was determined that the SGs could be operated for 5 cycles (7.5 EFPY) before the SG performance criteria for burst was not met at 95% probability and 50% confidence levels. Table 3-4 is a summary of results from the foreign object search and retrieval (FOSAR) inspections. An independent evaluation (Reference 7) was performed to determine how foreign objects in the steam generators would affect integrity; continued steam generator operation with the current foreign objects known to be present in the secondary side will not adversely affect steam generator tube integrity for at least five operating cycles or 7.5 EFPY. See Section 4.0 for more details. The current plant Technical Specifications do not allow for inspection intervals greater than three cycles for plants with SG tubes composed of Alloy 690 material and an approved license amendment would be required to operate longer than three cycles before inspection.

1.0 Introduction

This condition monitoring and operational assessment (CMOA) has been developed for the Tennessee Valley Authority (TVA) following the Watts Bar Unit 1 14th Refueling Outage (U1R14) RSG tube in-service inspection and assessment conducted in the spring of 2017. The assessments have been performed to meet the requirements and intent of NEI 97-06 Revision 3 (Reference 2). In preparation for the inspection, and to assure that the inspection adequately supports the CM and final OA evaluations required by NEI 97-06, the licensee documented the inspection scope together with the qualification of the applied nondestructive examination (NDE) techniques (References 3 and 9, and Attachment 7). This process provides assurance that the NDE techniques are appropriate for detection and measurement and to support development of degradation growth rates, repair criteria, and integrity limits for the degradation mechanisms assessed.

Based on the results obtained from the Watts Bar U1R14 inspections, a condition monitoring assessment was performed on a defect-specific basis, by demonstrating compliance with integrity criteria through comparison of reported NDE measurements with calculated structural pressure or leakage integrity limits. The indication sizing by NDE was compared to the defect-specific condition monitoring criteria specified in the degradation assessment which are repeated in Attachment 2. All indications detected in this inspection were below the integrity limits and therefore met the condition monitoring requirements provided. A final OA has been performed considering the indications detected during U1R14 and degradation growth rates. The final OA concludes that steam generator tube structural and leakage integrity will be maintained for five cycles (7.5 EFPY).

The industry has developed guidelines for SG assessment and TVA has developed a long-term strategic plan to meet or exceed the industry guidelines. The Watts Bar U1R14 SG inspections have been led by the following industry guidelines and SG integrity programs:

- EPRI Steam Generator Integrity Assessment Guidelines (Reference 5)
- EPRI PWR Steam Generator Examination Guidelines (Reference 1)
- EPRI Steam Generator In Situ Pressure Test Guidelines (Reference 6)
- 1-SI-68-907 Watts Bar Nuclear Plant Unit 1 Surveillance Instruction for Steam Generator Tubing In-service Inspection and Augmented Inspections (Reference 8)

This document was prepared in accordance with the Westinghouse Quality Management System (QMS).

2.0 Watts Bar U1R14 Primary Side Inspection Program

2.1 Base Scope Inspection Plan

The inspection program, as required by the EPRI PWR SG Examination Guidelines (Reference 1), addressed the existing and potential degradation mechanisms for the Watts Bar Unit 1 RSGs. The defined scope implemented during U1R14 included the following:

- 100% combination bobbin and array probe inspection of all open tubes in all four SGs full length and tube Rows 1 through 4 to the first support from the hot leg (HL) and the cold leg (CL). The remaining portions of the tubes in Rows 1 through 4 were inspected with either a singular bobbin or array probe where necessary due to dimensional clearance restrictions.
- 100% array probe examination of dents ≥ 2 volts in the straight lengths and U-bends of all SGs. This included all dents previously identified and any additional identified during the inspections.
- **+POINT™**[1] probe Special Interest inspections of tube locations with non-resolved bobbin and/or array probe signals and any unresolved possible loose parts (PLPs) from the base scope inspection program in both the HL and CL to characterize the underlying condition. *No such examinations were necessary.*
- 100% visual inspection of all installed tube plugs from the primary side on both the HL and CL.
- Visual inspection in all SGs of channel head primary side HL and CL in accordance with Westinghouse letter NSAL-12-1 (Reference 15) inclusive of the entire divider plate-to-channel head weld and all visible clad surfaces.

The Watts Bar U1R14 SG inspection plan met or exceeded the requirements of the Reference 1 EPRI Examination Guidelines and was aligned with the Reference 8 TVA Watts Bar SG Surveillance Instructions. The Watts Bar U1R14 eddy current inspection scope as implemented during the outage is shown in Attachment 1.

2.2 Inspection Expansion

There was no nondestructive examination (NDE) inspection scope expansion required during Watts Bar U1R14 (Reference 1).

2.3 Inspection Results

Table 2-1 presents a filtered summary of the tube NDE indication results based on data relevant to evaluating tube integrity. The files listed below the table were generated by the Westinghouse **STMax™** eddy current results data management system and used to create the table.

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[1] *+POINT is a trademark or registered trademark of Zetec, Inc. Other names may be trademarks of their respective owners.*

[2] *STMax is a trademark of Westinghouse Electric Company LLC, its affiliates and/or its subsidiaries in the United States of America and may be registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited. Other names may be trademarks of their respective owners.*

Table 2-1: Watts Bar U1R14 SG Eddy Current Inspection – Final Indication Summary					
Indications	**Condition**	**SG 1**	**SG 2**	**SG 3**	**SG 4**
ADS	Absolute Drift Signal	137	158	37	117
BLG	Tubesheet Bulge	2	0	0	0
DEP	Deposit Signal	4	0	0	0
DFS	Distorted Freespan Signal	22	56	77	74
DNG	Ding at Support or Freespan	29	24	28	11
DSS	Distorted Support Signal	1	0	1	0
DTS	Distorted Tubesheet Signal	0	0	0	0
LPS	Possible Loose Part Signal Cleared by Visual Inspection	0	0	0	1
MBM	Manufacturing Burnish Mark	9	15	0	6
PCT	Volumetric % Through-wall	87	150	106	135
PRX	Tube Proximity Signal	6	6	8	8
WAR	Wear Array Probe	87	150	106	135

- **SG 1:** SG1_ENGINEERING_DUMP_FINAL.XLS
- **SG 2:** SG2_ENGINEERING_DUMP_FINAL.XLS
- **SG 3:** SG3_ENGINEERING_DUMP_FINAL.XLS
- **SG 4:** SG4_ENGINEERING_DUMP_FINAL.XLS

2.4 Tube Plugging and Stabilization

There were no tubes required to be plugged during the Watts Bar U1R14 RSG in-service inspection.

3.0 Condition Monitoring

Condition monitoring is the assessment performed on observed indications of tube degradation to confirm that the SG Integrity Performance Criteria embodied in the CM limits have not been violated. It is essentially a backward-looking evaluation. This is contrasted with the OA, which seeks to determine whether the tube integrity performance criteria will be exceeded during subsequent operation of the SGs until the next inspection. The CM limits, derived from the structural limits in accordance with the EPRI SG Integrity Assessment Guidelines (Reference 5) and the SG Degradation Specific Management Flaw Handbook (Reference 4), are provided in the outage DA (Reference 3) and echoed in Attachment 2. Discussion of the indications in relation to CM requirements is provided in the following subsections.

3.1 Existing Degradation Mechanisms

The EPRI PWR SG Examination Guidelines (Reference 1) requires that the existing degradation mechanisms identified in the DA be subject to appropriate inspection programs to comply with the plant Technical Specifications. This section addresses the existing SG degradation mechanisms for Watts Bar U1R14 and the indications identified.

3.1.1 Mechanical Wear at U-bend Support Structures

Wear at U-bend support structures is an existing degradation mechanism in the Watts Bar Unit 1 RSGs. This mechanism occurs due to tube interaction with the U-bend support structures resulting from flow-induced vibration (FIV) in the upper tube bundle. The mechanical wear process is related to the tightness of the upper bundle assembly as expressed in the distribution of tube to U-bend support structure gaps. In general, at plants with similar support structures, U-bend support structure wear indications do not represent a challenge to structural or leakage integrity standards between inspections. Indications of U-bend support structure wear may require plugging should observed indication depths exceed the plant SG Technical Specification plugging criterion of 40% through-wall (TW). Plugging may also be required in order to support extended operating intervals between inspections.

Figure 3-1 is a histogram showing the distribution of %TW indications for all four RSGs combined where 59 indications were detected in total. Attachment 3 provides the full listing of tube locations and eddy current signal character for U-bend support structure wear indications detected during Watts Bar U1R14. The tables display the eddy current signal parameters for the U1R14 bobbin inspection and the corresponding percent through-wall (%TW) degradation as compared to the U1R11 or U1R8 result where available. A graphical display of the spatial distribution of the U-bend support structure wear indications is also provided in Attachment 3 Figure A3-1. A representative depiction of the eddy current response from the Array probe for the U-bend wear indications is provided in Figure A3-4.

The bobbin probe sizing of the largest U-bend support structure wear indication observed during U1R14 was measured at 27% TW in SG3 Tube R81C56 at VS4+0.89 inch. The U1R11 OA projection was made assuming duration of 8.6 EFPY between inspection (Reference 12). Using the actual operating interval between inspections of 4.07 EFPY, the worst-case projected U-bend support structure wear indication would have been 42%TW at the U1R14 inspection. Therefore, the growth rate projection methods applied in the prior OA are validated. Further, an average change of 3.39%TW/EFPY and standard deviation of 2.04%TW/EFPY is observed in the limiting SG for growth with a normally distributed population of growth rate data points. Therefore, a reasonable and conservative growth rate projection for U-bend support structure wear can be developed in support of the OA.

Based on the inspection data for this mechanism in comparison to the limits identified in Attachment 2, structural integrity requirements have been met at the U1R14 inspection. Regarding U-bend support structure wear locations, satisfaction of structural integrity implies satisfaction of leakage integrity at accident conditions since steam line break accident condition pressure differential for pop-through is much

smaller than $3\Delta P_{NO}$ for pressure-only loading of volumetric flaws. Therefore, CM has been satisfied for degradation associated with U-bend support structure wear indications at the Watts Bar U1R14 inspection.

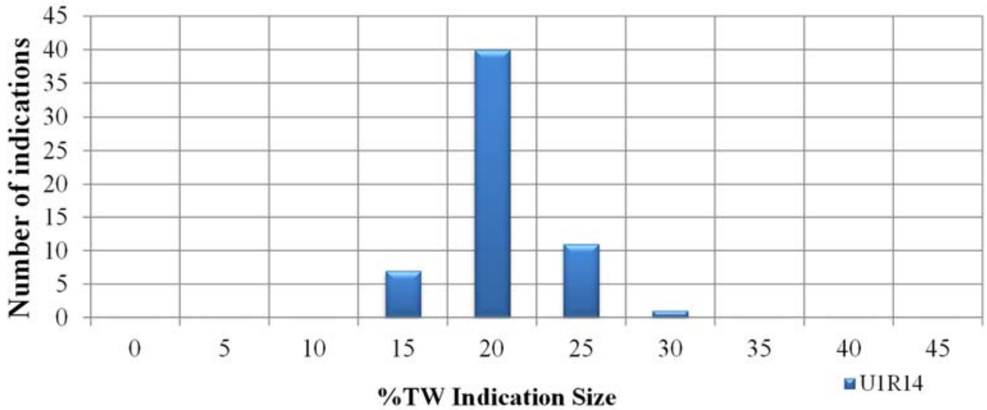

Figure 3-1: **Watts Bar U1R14 U-bend Support Structure Wear Indications - All SGs**

3.1.2 Mechanical Wear at Horizontal ATSGs

Wear at horizontal advanced tube support grids (ATSGs) is an existing degradation mechanism in the Watts Bar Unit 1 RSGs. Flow-induced vibration leading to wear at the ATSGs is governed primarily by thermal hydraulic characteristics and the sizes of the tube-to-support gaps. This suggests that wear rates are subject to steam generator specific conditions and will vary between plants and between steam generators at a specific plant. This has been the primary source of tube degradation leading up to the Watts Bar U1R14 inspection. Industry operating experience reviews indicate that plants with similar horizontal tube support designs have also identified ongoing wear at relatively low levels.

Figure 3-2 contains histograms showing the distribution of %TW indications between all four RSGs. Attachment 4 Table A4-1 through Table A4-4 provides the full listing tube locations and eddy current signal character for advanced tube support grid (ATSG) wear indications detected during Watts Bar U1R14. The tables also display the eddy current signal parameters for the U1R14 bobbin inspection and the corresponding %TW degradation as compared to the U1R11 or U1R8 result where available. A graphical display of the distribution of the ATSG wear indications is also provided for each of the RSGs in Attachment 4 Figure A4-1 through Figure A4-4. A representative depiction of the eddy current response from the Array probe for the ATSG wear indications is provided in Figure A4-8.

The bobbin probe sizing of the largest ATSG wear indication observed during U1R14 was measured at 37%TW which occurred in SG2 Tube R88C95 at C03-1.04 inches. The U1R11 OA projection was made assuming duration of 8.6 EFPY between inspection (Reference 12). Using the actual operating interval between inspections of 4.07 EFPY the worst-case projected U-bend support structure wear indication would have been 42%TW at the U1R14 inspection. Therefore, the growth rate projection methods applied in the prior OA are validated. An average change of 2.58%TW/EFPY and standard deviation of 1.86%TW/EFPY is observed for the indications across all four RSGs. Therefore, a reasonable and conservative growth rate projection for ATSG wear can be developed in support of the OA.

Based on the inspection data for this mechanism in comparison to the limits identified in Attachment 2, structural integrity requirements have been met at the U1R14 inspection. Regarding ATSG wear locations, satisfaction of structural integrity implies satisfaction of leakage integrity at accident conditions since steam line break accident condition pressure differential for pop-through is much smaller than $3\Delta P_{NO}$ for pressure-only loading of volumetric flaws. Therefore, CM has been satisfied for degradation associated with horizontal ATSG wear indications at the Watts Bar U1R14 inspection.

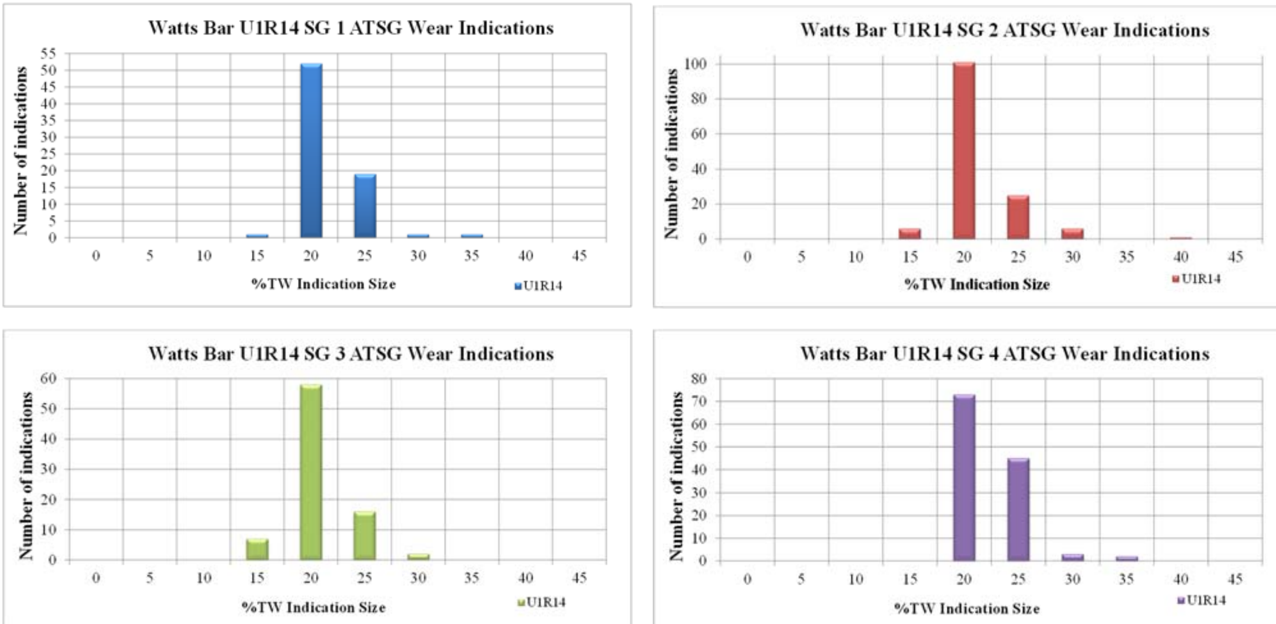

Figure 3-2: **Watts Bar U1R14 ATSG Wear Indication Distributions - All SGs**

3.2 Potential Degradation Mechanisms

The EPRI Pressurized Water Reactor (PWR) SG Examination Guidelines (Reference 1) require that the potential degradation mechanisms identified in the DA be subject to appropriate inspection programs to comply with the plant Technical Specifications. This section addresses the potential degradation mechanisms listed in the Reference 3 degradation assessment for Watts Bar U1R14.

3.2.1 Mechanical Wear Due to Foreign Objects

Although foreign objects have been observed in the Watts Bar Unit 1 RSGs at previous inspections, no tube degradation associated with the presence of these objects has been identified to date. The Array probe was utilized to supplement the detection of foreign objects and foreign object wear during U1R14. During the entirety of the Watts Bar U1R14 eddy current inspections there was only one signal corresponding to a new possible loose part (PLP) which is listed in Table 3-1. There was no tube wall degradation detected by eddy current coincident with this PLP indication. The location was visually inspected from the secondary side and no foreign object or contributing deposit condition was observed. Therefore, the indication was subsequently changed to a resolved loose part indication (LPS) based on the visual examination.

Table 3-1: Watts Bar U1R14 Loose Part Indications (PLP/LPS)

SG	Row	Col	Volts	Deg	Ind	Chn	Locn	Inch1	BegT	EndT	PDia	PType	Cal
4	3	12	2.95	97	PLP/LPS	152	CTS	0.02	VS3	CTE	0.61	ZYAXH	58

Visual inspections performed from the SG secondary side did identify a variety of small foreign objects, some of which were removed from the SGs. Those that remain have been evaluated for continued operation in Reference 7. During the FOSAR, there were no visible signs that any of the objects had caused tube wear due to interaction with adjacent tubes. The tube wear potential of the objects known to remain resident on the SG secondary side is evaluated as part of the OA.

3.2.2 Tube-to-Tube Contact Wear

Tube-to-tube wear can occur due to the interaction that occurs when two or more tubes come in contact with each other. This form of tube degradation would occur in the tube bundle straight sections generally near the mid-span between two subsequent tube support structures. However, it can also occur in the U-bend region

where unanticipated secondary side fluid flow characteristics create the conditions that would lead to tube reciprocating motions and interaction.

Indications of tube-to-tube proximity can be traced back to the baseline eddy current inspection of the Watts Bar Unit 1 RSGs. Low level indications of proximity (PRX), all measuring less than 1.0 volt, were detected during the U1R14 inspections. The listing and a mapping of these indications is shown in Attachment 5, Table A5-1. As tube-to-tube proximity alone is not a degradation mechanism, it is a condition which could potentially lead to tube interaction with one another. As such, each PRX indication was reviewed through the eddy current data analysis process for an associated volumetric wear indication. The eddy current results database was also reviewed for adjacent signals which may be indicative of tube-to-tube wear such that they are flagged for further diagnostic testing. No indications of tube-to-tube contact wear were detected through eddy current data analysis or review of the results database during the Watts Bar U1R14 inspections.

3.3 Resolution for Classification of Indications

Indications reported with flaw-like characteristics in the Watts Bar Unit 1 RSGs may include those initially reported as distortions of preexisting signals such as absolute drift indications (ADI/ADS), tube support indications (DSI/DSS), distorted tubesheet signals (DTI/DTS) and manufacturing burnish marks (MBI, MBM). The character of I-code signals is further determined by data history review, lead analyst review, or by follow-up examination with alternate NDE techniques. Those indications with a three letter code ending with an "I" are compared to historical data and are changed to an "S" if they have not changed within normal technique variations. The resolution of indications from Watts Bar U1R14 is summarized in Table 3-2 below.

Table 3-2: Watts Bar U1R14 Resolution for Classification of Indications

SG	Absolute Drift Signals (ADI/ADS)	Distorted Support Signals (DSI/DSS)	Distorted Tubesheet Signals (DFI/DFS)	Mfg. Burnish Marks (MBI/MBM)
1	0 / 137	0 / 1	0 / 22	0 / 9
2	0 / 158	0 / 0	0 / 0	0 / 15
3	0 / 37	0 / 1	0 / 77	0 / 0
4	0 / 117	0 / 0	0 / 74	0 / 6

A number of the ADS indications in the Watts Bar RSGs are residual effects from the RSG tube thermal treatment process. The distorted support and tubesheet bobbin signals from the U1R14 inspection have all been cleared by either review of the corresponding Array probe data or data history review. Finally, an MBM is most typically a burnishing relic created by the tube manufacturer to buff out surface blemishes. All of these eddy current indications have been cleared through the NDE analysis process as being free from tube degradation.

3.4 SG Channel Head Primary Side Bowl and Tube Plug Visual Inspections

Visual inspections have been performed of the SG channel head bowl in the vicinity of the drain line in all SGs during Watts Bar U1R14. These inspections are performed based on industry operating experience and guideline requirements discussed in the Reference 3 degradation assessment. Visual inspections of the SG hot leg and cold leg divider plate, inclusive of the entire divider plate-to-channel head weld and all visible clad surfaces, were performed in accordance with Westinghouse NSAL-12-1 (Reference 15). This inspection was performed using the SG manway channel head bowl cameras. Satisfactory inspection results were observed in all SGs with no indications of cladding surface degradation (Reference 11).

All previously installed tube plugs were also inspected from the primary side in all four of the Watts Bar Unit 1 RSGs using the cameras mounted to the eddy current robots. The inspection results were satisfactory

and showed no indication of tube plug leakage or failure. Inspection of the channel head bowl and all installed tube plugs is planned to be performed again during Watts Bar U1R17 in all RSGs at the subsequent inspection.

3.5 Secondary Side Activities

3.5.1 Top of Tubesheet Cleaning

A top of tubesheet deposit cleaning process was performed in all four SGs during Watts Bar U1R14. There are two main purposes of the cleaning process. The first is to remove hardened deposits that preferentially form at the top of the tubesheet and the second is to force and filter out any loose parts or foreign objects that have migrated to the SG secondary side during operation. The mass of deposit material and debris removed by the top of tubesheet cleaning process is summarized in Table 3-3 below.

Table 3-3: Watts Bar U1R14 SG Tubesheet Deposit Removal	
SG 1	8.5 lbs
SG 2	7.5 lbs
SG 3	9.5 lbs
SG 4	7.0 lbs
All SGs	32.5 lbs

Periodic views of the in-line grit tank screen were also performed throughout the tubesheet cleaning process. These confirmed that the process was successful at removing foreign objects and material from the RSG secondary side in addition to the hardened sludge deposits.

3.5.2 Top of Tubesheet FOSAR

A secondary side tubesheet FOSAR has been performed in all four SGs during Watts Bar U1R14 following a top of tubesheet cleaning. Sludge, scale, foreign objects, and other deposit accumulations at the top of the tubesheet may have been removed as part of the tubesheet sludge lancing process prior to FOSAR inspection of each SG. The FOSAR inspections included visual examination of tube bundle periphery tubes from both the annulus and tubelane on both the hot and cold legs and through the no tube lane. A limited top of tubesheet in-bundle visual inspection was also performed in each SG for the purpose of assessing the level of hardened deposit buildup in the kidney region. Table 3-4 is a summary of the final results from the FOSAR inspections.

Table 3-4: Watts Bar U1R14 SG FOSAR Summary

SG	Identified	Retrieved	Remaining
1	2	0	2
2	1	0	1
3	1	0	1
4	8	6	2
All SGs	12	6	6

During Watts Bar U1R14, a total of six foreign objects were removed from the top of the tubesheet. The majority of the foreign objects retrieved were small pieces of metal, wires and bristles. There were no indications of a significant or ongoing breakdown of foreign material exclusion processes. Any foreign objects not able to be retrieved were mapped and an engineering evaluation performed in Reference 7 to justify continued operation with the objects present on the SG secondary side.

3.6 Condition Monitoring Conclusions

Based on the inspection data, no tubes exhibited degradation that required in situ pressure testing to demonstrate structural and leakage integrity. There was no reported primary-to-secondary leakage prior to the end of the Watts Bar Unit 1 RSG inspection interval. No secondary side tube degradation attributable to

foreign objects has been identified from the FOSAR and visual inspections. No indications of U-bend support structure or horizontal ATSG wear were found to be in excess of the CM limits. The SG performance criteria for operating leakage and structural integrity were satisfied for the preceding Watts Bar Unit 1 RSG inspection interval.

4.0 Operational Assessment

NEI 97-06 (Reference 2) requires that an operational assessment be performed to determine if existing degradation mechanisms observed in a steam generator will continue to meet tube structural and leakage integrity performance criteria until the next inspection. An operational assessment of each existing tube degradation mechanism identified during Watts Bar U1R14 along with the foreign objects that remain on the secondary side is provided in the following sections.

4.1 Mechanical Wear at U-bend Support Structures

The two approaches that are used to project future wear depths are based on a constant progression of either the maximum depth of the wear or the volume of material worn away. Revision 0 of this report (Reference 17) utilized the depth-based approach. This approach is retained in this revision for comparison, and is described in Sections 4.1.1, 4.1.2 and 4.3. The volume based wear approach, new to Revision 1, is described in Section 4.1.4.

4.1.1 Degradation Growth Rates

Based on application of conservative U-bend support structure wear growth rates, the condition of the Watts Bar Unit 1 RSG tubes has been analyzed with respect to continued operability until the end of Cycle 19 without exceeding the limits for structural and leakage integrity. Upon completion of the combination bobbin and Array probe data program, the growth rates have been determined by comparative analysis of the U-bend support structure wear sites.

In order to determine growth rates, a data history review was performed by the lead eddy current analyst for all U-bend support structure wear indications measuring 20%TW or greater and a sampling of indications below this threshold. The purpose was to determine whether a measurable precursor signal was present but unreported in the prior inspection and the associated growth rate for use on the OA projections. The growth rates are determined given an operating duration of 4.07 EFPY from U1R11 to U1R14 and normalizing to a %TW/EFPY basis. The results of the comparative analysis with the purpose of developing a representative growth rate are shown in Attachment 3 Table A3-1. The cumulative frequency distribution (CDF) of growth rates for all SGs combined using the Benard's median rank fraction method (Reference 5) is shown in Figure A3-2 and is confirmed to be slightly conservative in comparison to the fit of a normal distribution. A summary of growth rates for the U-bend support structure wear indications in all four SGs is summarized in Table 4-1 below.

Table 4-1: Watts Bar U1R14 U-bend Support Structure Wear Growth Comparison

Outage	SG	Number of Indications	Max Indication (%TW)	Average Growth (%TW/EFPY)[1]	Standard Deviation (%TW/EFPY)[1]	Upper 95th Percentile (%TW/EFPY)[2]
U1R14	1	13	21	4.52	0.54	5.41
	2	11	24	1.97	2.11	5.44
	3	23	27	3.86	1.98	7.11
	4	12	23	2.87	2.24	6.56
	All	59	27	3.39	2.04	6.74

Note 1: Considering growth rates based on history review for indications 20%TW and greater and a sampling of those less than 20%TW.
Note 2: Based on a normally distributed growth rate population.

As an evaluation of conservatism in the approach to determining growth rates, all U-bend support wear indications <20%TW where no history review was performed were set to a non-degraded condition (0%TW) at the U1R11 inspection and assumed to grow to the measured depth at U1R14. The resulting 95th percentile growth rates were reduced from the approach where only growth rates associated with indications greater than 20%TW and those where a history review was performed were considered. A review was also performed of growth rates on a SG-specific basis and no single SG showed U-bend wear indication growth rates uncharacteristic of the others. Therefore, application of the growth rate data points associated with

wear indications of greater than 20%TW and only a sampling of those less for all SGs is an appropriate and conservative measure.

4.1.2 Operational Assessment – Deterministic (Depth-Based) Approach

An Operational Assessment for U-bend support structure wear using a deterministic, depth-based approach is first considered for a period of three cycles.

The Examination Technique Specification Sheet (ETSS) 96004.1, Revision 13, is the bobbin technique used to size U-bend support structure wear. As a result, the associated sizing equation (y = 0.98x + 2.89 and S_{yx} = 4.19%) is appropriate for the character of U-bend support structure wear indications that have been detected. This technique is part of the Appendix H ETSS library in the Reference 1 guidelines and, therefore, the standard error of the regression (S_{yx}) for the ETSS 96004.1 sizing equation to be applied for tube integrity must be multiplied by 1.645 to represent the 95% probability/50% confidence allowance and then multiplied by 1.12 to include analyst uncertainty. Thus, the projected wear depth of the largest indication at U1R17, using the largest indication and growth rate from Table 4-1, is calculated as follows:

<u>Projected U1R17 U-bend Support Structure Wear Measured with ETSS 96004.1 Revision 13</u>
%TW at U1R17 = [Corrected U1R14 Measurement]+[Growth]+[Total NDE Error]
%TW at U1R17 = [(0.98 x 27%) + 2.89%]+[7.11%/EFPY x 4.5 EFPY]+[1.12(1.645 x 4.19%)] = 69.06%TW

The table in Attachment 2 notes that the CM limit is 51%TW for a 2.5 inch long flaw. A deterministic, depth-based projection does not meet the CM criterion after three cycles of operation. Therefore, a Monte Carlo OA approach is considered.

4.1.3 Operational Assessment – Monte Carlo (Depth-Based) Approach

The Westinghouse configured software Single Flaw Model (SFM) Version 2.2 has been used for the OA projection using the inputs discussed previously and material properties from the Reference 3 DA. The associated software runs are attached to this document in the Westinghouse Electronic Document Management System (EDMS) and the configuration control is documented in Reference 10. With this software, the burst pressure of projected flaws is determined through the Monte Carlo simulation method described in Reference 5 and compared against the structural and leakage integrity performance criteria. The OA projection considers 95th percentile and 50% confidence level contributions from depth, relation, material and growth in the reduction in tube burst pressure due to degradation.

The largest indication returning to service following Watts Bar U1R14 measures 27% TW and 0.4 inch long in SG 3 R81C56 which will remain in service for an assumed 4.5 EFPY between inspections. This projection uses a Normal distribution with a mean of 3.86 and standard deviation of 1.98 to represent the growth rate function in the simulation and a bounding length growth rate of 0.1 inch/EFPY (or 0.4 inch/4.07 EFPY). The resulting projected flaw has a burst pressure of 4,028 psi (58% TW and 0.85 inch long) which is in excess of the 3,798 psi structural integrity performance criterion. A capture of the SFM software inputs and output is provided in Figure A3-3. Since the largest indication returning to service is greater than the 95th percentile detection threshold for bobbin inspection (see Figure A6-3), this conclusion also applies to the assumed undetected indications of U-bend support structure wear.

Using SFM, it was determined that this same, largest indication could remain in service for as long as 4.9 EFPY between inspections without the resulting projected flaw burst pressure falling below the 3,798 psi structural integrity performance criterion.

For pressure-only loading of volumetric flaws, satisfaction of the structural integrity implies satisfaction of leakage integrity at accident conditions since steam line break accident condition pressure differential for pop-through is much smaller than $3\Delta P_{NO}$.

The maximum inspection interval that can be established using the depth-based Monte Carlo approach in SFM is three cycles. Therefore, the volume-based wear approach as discussed in the next section, is applied

4.1.4 Use of Volume Based Wear Approach

The Westinghouse software W-VOL (Reference 16) was utilized to further evaluate an inspection interval that can be considered by TVA should a Technical Specification amendment permit extension of the inspection intervals beyond the current licensing basis limits for Alloy 690 plants. The W-VOL code applies a volume-based approach towards calculating wear over time. This method can project a flaw growth that is based on the applicable work function that actually occurs with the mechanical wear experienced in the SGs, and thus removes excess conservativism when calculated using wear depth methods. Ultimately, this method can demonstrate an increased operational assessment interval in which the SG performance criteria is maintained for a flaw distribution set.

Benchmarking is performed to define the plant-specific performance parameters for application of the volume predictive model. Benchmarking allows the program to assess flaws that do not have prior history without having to make the excessively conservative assumption that they initiated from 0%TW at a prior inspection. For the U-bend support structures at Watts Bar Unit 1, the amount of wear depth data that was available from U1R8 and U1R11 was insufficient to perform benchmarking for individual SGs; however, when the data from all four SGs was combined benchmarking parameters could be derived. The benchmark calculation regression lines for U-bend support structure wear are shown below in Figure 4-1. Figure 4-1 presents plots of reported versus predicted depths for each SG. The figure shows a regression line (green line) with a slope of 0.22; a slope less than unity (red line) indicates a conservative condition for application of the benchmark parameters. Table 4-4 summarizes the regression parameters that were determined by benchmarking.

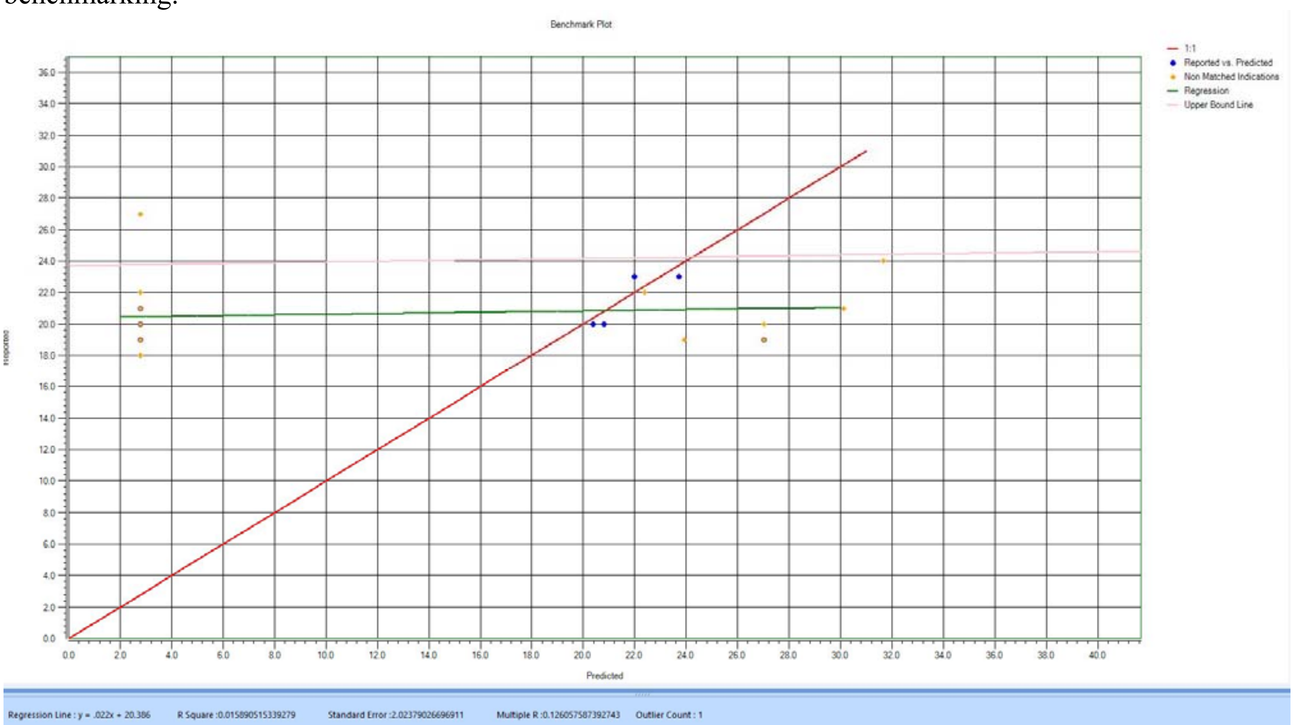

Figure 4-1: WVOL Benchmark Calculation Regression Lines for U-bend Support Structure Wear

The data used as input to W-VOL are the measured wear depths from the U1R14 inspection, and the eddy current lookup depths for these flaws from the U1R8 and U1R11 inspections. The program is able to establish flaw growth for the flaws based on the growth experienced between U1R11 and U1R14 in terms of the volume-removed method. The results are summarized in Table 4-2.

Table 4-2: 95/50 Burst Pressures from W-VOL Cases for U-Bend Structural Support Wear							
SG	Beginning of Growth Period	End of Growth Period	Growth EFPY	Max R14 Indication Remaining In-Service (%TW)	Projection EFPY	Largest Projected Flaw (including NDE Uncertainty) (%TW)	95/50 Burst Pressure (psi)
1	R11	R14	4.07	21	7.5	48.4	4833
2	R11	R14	4.07	24	7.5	50.5	4682
3	R11	R14	4.07	27	7.5	60.6	3807
4	R11	R14	4.07	23	7.5	50.5	4602

The flaw population in all SGs meets the performance criteria of 3798 psi at 95% probability and 50% confidence levels for 5 cycles (7.5 EFPY) of operation for mechanical wear at U-bend support structures.

4.2 Mechanical Wear at Horizontal ATSGs

The two approaches that are used to project future wear depths are based on a constant progression of either the maximum depth of the wear or the volume of material worn away. Revision 0 of this report (Reference 17) utilized the depth-based approach. This approach is retained in this revision for comparison, and is described in Sections 4.2.1, 4.2.2 and 4.3. The volume based wear approach, new to Revision 1, is described in Section 4.2.4.

4.2.1 Degradation Growth Rates

Based on application of conservative horizontal ATSG wear growth rates, the condition of the Watts Bar Unit 1 RSG tubes has been analyzed with respect to continued operability without exceeding the limits for structural and leakage integrity. Upon completion of the bobbin and Array probe data program, the growth rates have been determined by comparative analysis of the ATSG wear sites.

In order to determine growth rates, a data history review was performed by the lead eddy current analyst for each new horizontal ATSG wear indication measuring 20%TW or greater and a sampling of indications below this threshold. The purpose was to determine whether a measurable precursor signal was present but unreported in the prior inspection and the associated growth rate for use on the OA projections. The growth rates are determined given an operating duration of 4.07 EFPY from U1R11 to U1R14 and normalizing to a %TW/EFPY basis. The results of the comparative analysis for the purpose of developing a representative growth rate are shown in Attachment 4, Tables A4-1 through A4-4. The cumulative frequency distribution (CDF) of growth rates for each individual SG using the Benard's median rank fraction method (Reference 5) is shown in Figure A4-5 and is confirmed to be slightly conservative in comparison to the fit of a normal distribution. A mapped depiction of horizontal ATSG growth rates is provided in Figure A4-6. A summary of growth rates for the horizontal ATSG support structure wear indications in all four SGs is summarized below in Table 4-3.

Table 4-3: Watts Bar U1R14 Horizontal ATSG Wear Growth Comparison						
Outage	SG	Number of Indications	Max Indication (%TW)	Average Growth (%TW/EFPY)[1]	Standard Deviation (%TW/EFPY)[1]	Upper 95th Percentile (%TW/EFPY)[2]
U1R14	1	74	33	2.08	1.52	4.58
	2	139	37	1.93	1.46	4.33
	3	83	26	2.42	1.83	5.43
	4	123	34	2.58	1.86	5.64
	All	419	37	1.97	1.85	5.09

Note 1: Considering growth rates based on history review for indications 20%TW and greater and a sampling of those less than 20%TW.
Note 2: Assuming a normally distributed growth rate population.

As an evaluation of conservatism in the approach to determining growth rates, all horizontal ATSG support wear indications <20%TW where no history review was performed were set to a non-degraded condition (0%TW) at the U1R11 inspection and assumed to grow to the measured depth at U1R14. The resulting 95th percentile growth rates for all four SGs were reduced from the approach where only growth rates associated with indications greater than 20%TW and those where a history review was performed were considered. A review was also performed of growth rates on an SG-specific basis and no single SG showed horizontal ATSG wear indication growth rates uncharacteristic of the others. Therefore, application of the growth rate data points associated with wear indications of greater than 20%TW and only a sampling of those less for all SGs is an appropriate and conservative measure.

4.2.2 Operational Assessment – Deterministic (Depth-Based) Approach

An Operational Assessment for horizontal ATSG wear using a deterministic, depth-based approach is first considered for a period of three cycles.

The Examination Technique Specification Sheet (ETSS) 96004.1, Revision 13, is the bobbin technique used to size horizontal ATSG wear. As a result, the associated sizing equation ($y = 0.98x + 2.89$ and $S_{yx} = 4.19\%$) is appropriate for the character of horizontal ATSG wear indications that have been detected. This technique is part of the Appendix H ETSS library in the Reference 1 guidelines and, therefore, the standard error of the regression (S_{yx}) for the ETSS 96004.1 sizing equation to be applied for tube integrity must be multiplied by 1.645 to represent the 95% probability/50% confidence allowance and then multiplied by 1.12 to include analyst uncertainty. Thus, the projected wear depth of the largest indication at U1R17, using the largest indication and growth rate from Table 4-3, is calculated as follows:

<u>Projected U1R17 Horizontal ATSG Wear Measured with ETSS 96004.1 Revision 13</u>
%TW at U1R17 = [Corrected U1R14 Measurement]+[Growth]+[Total NDE Error]
%TW at U1R17 = [(0.98 x 37%) + 2.89%]+[5.64%/EFPY x 4.5 EFPY]+[1.12(1.645 x 4.19%)] = 72.25%TW

The table in Attachment 2 notes that the CM limit is 52%TW for a 2.0 inch long flaw. A deterministic, depth-based projection does not meet the CM criterion after three cycles of operation. Therefore, a Monte Carlo OA approach is considered.

4.2.3 Operational Assessment – Monte Carlo (Depth-Based) Approach

The Westinghouse configured software Single Flaw Model (SFM) Version 2.2 has been used for the OA projection using the inputs discussed previously and material properties from the Reference 3 DA. The associated software runs are attached to this document in the Westinghouse EDMS and the configuration control is documented in Reference 10. With this software, the burst pressure of projected flaws is determined through the Monte Carlo simulation method described in Reference 5 and compared against the structural and leakage integrity performance criteria. The OA projection considers 95th percentile and 50% confidence level contributions from depth, relation, material and growth in the reduction in tube burst pressure due to degradation.

The largest indication returning to service following Watts Bar U1R14 measures 37% TW and 0.39 inch long in SG2 Tube R88C95 at C03 and will be in service for an assumed 4.5 EFPY. This projection uses a normal distribution with a mean of 1.97 and standard deviation of 1.85 to represent the growth rate function in the simulation and a bounding length growth rate of 0.1 inch/EFPY (or 0.39 inch/4.07 EFPY). The resulting projected flaw has a burst pressure of 3,988 psi (59% TW and 0.85 inch long) which is in excess of the 3,798 psi structural integrity performance criterion. A capture of the SFM software inputs and output is provided in Figure A4-7. Since the largest indication returning to service is much greater than the 95th percentile detection threshold for bobbin inspection (see Figure A6-3), this conclusion also applies to the assumed undetected indications of horizontal ATSG wear.

Using SFM, it was determined that this same, largest indication could remain in service for as long as 4.93 EFPY between inspections without the resulting projected flaw burst pressure falling below the 3,798 psi structural integrity performance criterion.

For pressure-only loading of volumetric flaws, satisfaction of the structural integrity implies satisfaction of leakage integrity at accident conditions since steam line break accident condition pressure differential for pop-through is much smaller than $3\Delta P_{NO}$.

The maximum inspection interval that can be established using the depth-based Monte Carlo approach in SFM is three cycles. Therefore, the volume-based wear approach as discussed in the next section, is applied

4.2.4 Use of Volume-Based Wear Approach

The Westinghouse software W-VOL (Reference 16) was utilized to gain additional margin in terms of inspection interval that can be considered by TVA should a Technical Specification amendment permit extension of the inspection intervals beyond the current licensing basis limits for Alloy 690 plants. The W-VOL code applies a volume-based approach towards calculating wear over time. The method models a reduced volume removal rate over time due to less surface contact duration between the wear-initiating support structure and the tube. Therefore, this method can project a flaw growth that is based on the applicable work function that actually occurs with the mechanical wear experienced in the SGs, and thus removes excess conservativism when calculated using wear depth methods. Ultimately, this method can demonstrate an increased operational assessment interval in which the SG performance criteria is maintained for a flaw distribution set.

Benchmarking is performed to define the plant-specific performance parameters for application of the volume predictive model. Benchmarking allows the program to assess flaws that do not have prior history without having to make the excessively conservative assumption that they initiated from 0%TW at a prior inspection. Table 4-4 provides a summary of the benchmark parameters that were calculated by the W-VOL program. All slopes are less than unity; a slope less than unity indicates a conservative condition for application of the benchmark parameters.

Table 4-4: Summary of Benchmark Parameters

Location	SG	Slope	Intercept	Standard Error
ATSG	1	0.095	19.496	2.557
ATSG	2	0.179	17.412	3.777
ATSG	3	0.096	18.096	2.565
ATSG	4	0.07	20.348	2.687
U-bend	All	0.022	20.386	2.024

The data used as input to W-VOL are the measured wear depths from the U1R14 inspection, and the eddy current look-up depths for these flaws from the U1R8 and U1R11 inspections. The program is able to establish flaw growth for the flaws based on the growth experienced between U1R11 and U1R14 in terms of the volume-removed method.

The Watts Bar ATSG wear flaws have been observed to be primarily tapered wear, as opposed to flat (or uniform depth) wear. To distinguish flat wear from tapered wear it is necessary to review terrain map graphics from rotating probe inspections, such as that shown in Figure A4-8. In the volume-based approach the type of wear is important because at a given maximum depth flat wear will result in a greater volume of material that has worn away than tapered wear with the same maximum depth. It is conservative to assume that ATSG wear is flat wear.

If it is assumed that all ATSG wear is flat wear, the W-VOL model only projects 5.4 EFPY of operation before burst pressure and probability of burst criteria are exceeded. A review of the data showed that two wear indications that were left in service are the cause of the limitation in the projection:

- SG2-R88C95-C03 was 37%TW at U1R14 and 21%TW at U1R11
- SG4-R94C37-C03 was 34%TW at U1R14 and 16%TW at U1R11

These indications are relatively deep and have relatively large growth rates for extended projections of operation. Graphics for both of these indications were reviewed and it was shown that both indications are tapered wear. When it is modelled that these two indications are tapered wear, and it is assumed that all other ATSG wear is flat wear, the W-VOL model projects 7.5 EFPY (5 cycles) of operation before tube integrity criteria are exceeded. The SG2-R88C95-C03 indication is the controlling indication, even as tapered wear, and prevents a projection of six cycles.

The results are summarized in Table 4-5.

Table 4-5: 95/50 Burst Pressures from W-VOL Cases for Wear at Horizontal ATSGs

SG	Beginning of Growth Period	End of Growth Period	Growth EFPY	Max R14 Indication Remaining In-Service (%TW)	Projection EFPY	Largest Projected Flaw (including NDE Uncertainty) (%TW)	95/50 Burst Pressure (psi)
1	R11	R14	4.07	33	7.5	59.9	3918
2	R11	R14	4.07	37	7.5	59.8	4070
3	R11	R14	4.07	26	7.5	51.1	4523
4	R11	R14	4.07	34	7.5	56.6	4064

The flaw population in all SGs meets the performance criteria of 3798 psi at 95% probability and 50% confidence levels for five cycles (7.5 EFPY) of operation for mechanical wear at horizontal ATSGs.

4.3 U-bend Support Structure and Horizontal ATSG Wear – Fully Probabilistic Method

A fully probabilistic model has been developed for the Watts Bar Unit 1 U-bend support structure and horizontal ATSG degradation mechanisms as a confirmation of the conservatism involved with the Monte Carlo OA methods. This modeling entails the development of four different aspects including an Ahat function to represent analysis detection, site-specific eddy current data noise measurements in the regions of interest, a model assisted probability of detection (MAPOD) regression, and associated inputs to the full bundle model software. These three aspects are discussed below along with the results.

4.3.1 Ahat Development

The process of Ahat modeling is a form of regression analysis in which a structural variable such as length or depth is used as the independent variable while signal amplitude (voltage) is used as the dependent variable. With Ahat modeling, a continuous probability of detection (POD) function is directly calculated avoiding the need for fitting a model to binary hit and miss data which has been conventional with ETSS development until recently. In preparation for accurately sizing wear during the Watts Bar U1R14 inspection, TVA developed an eddy current wear calibration curve based on the tapered wear flaws standards of EPRI ETSS 27091. Data was collected on the actual EPRI wear standards, which has the same tube material and size as the Watts Bar Unit 1 RSGs, using the same collection process to be used during the inspection. Through this process, sufficient data points were generated to create an Ahat function relating maximum vertical voltage (Vvm) versus depth to the tapered wear flaw geometry which closely matches the degradation observed at Watts Bar Unit 1 (see Attachment 6 Figure A6-1).

4.3.2 Site Specific Noise Measurements

The second required input is the noise in terms of voltage amplitude within the region of interest. The Westinghouse auto analysis software program Real Time Auto Analysis (RTAA) collected Vvm noise

measurements at the U-bend support structures and horizontal ATSGs in every tube tested in all four RSGs. As this is an incredibly large volume of noise data, only one calibration group was selected in each of the four RSGs to represent the remainder of the tube bundle. The noise measurements were taken from the calibration group with the majority of the indications of tube degradation for each RSG. These were Cal 22 for SG1, Cal 36 for SG2, Cal 26 for SG3, and Cal 14 for SG4. The combined noise distributions for the diagonal bars, vertical straps and ATSGs are provided in Figure A6-2. Although noise measurements were taken at the center, leading edge and trailing edge of each support structure, only the edge noise measurements were used as this is where the degradation has been found to initiate at Watts Bar Unit 1.

4.3.3 Model Assisted Probability of Detection

A POD model is a functional measure of the ability of a Non-Destructive Examination (NDE) system to detect degradation and is one of the essential inputs to an OA. The POD is used to estimate degradation remaining in service after an eddy current program scope is performed. The POD associated with each eddy current detection technique is a standard part of the EPRI ETSS development process. However, industry experience has shown that eddy current noise can affect POD. The United States Nuclear Regulatory Commission (USNRC) has also requested that future POD developments consider the potential effects of noise on the detection of degradation. As a result, EPRI and the industry have adopted a model assisted probability of detection (MAPOD) method that incorporates both the ETSS data set with the site-specific noise data in order to develop a site-specific POD for a particular type of degradation. The EPRI software MAPOD has been developed for this purpose (Reference 14). Recent EPRI guideline updates have also incorporated considerations for noise measurements and POD development.

The MAPOD simulation software developed for industry wide application by EPRI was used to generate the site-specific POD for Watts Bar Unit 1. Three different MAPOD runs were made corresponding to the edges of the diagonal bars, vertical straps and the ATSGs. An analyst reporting threshold of 1.5 to 2.0 Signal to Noise (S/N) was applied as discussed in the MAPOD User's Manual (Reference 14). The POD regressions determined from the four MAPOD software runs are summarized in Table 4-6 below:

Table 4-6: Watts Bar U1R14 Model Assisted Probability of Detection Results

Noise Measurement Data Set	No. of Noise Measurements	Function Fit Type	Slope	Intercept	POD(95)
Diagonal Bars	1,791	Log-Logistic	4.633	-3.34	22%TW
Vertical Straps	2,755		3.991	-0.101	6%TW
Horizontal ATSGs	8,387		-2.086	-4.467	13%TW

Figure A6-3 provides the graphical representations of the POD regressions for each support type. Although these regressions show 95th percentile detection at degradation levels that are quite low, it is notable that the POD (95) associated with the diagonal bar noise measurements is not quite as good as those for the vertical strap and the ATSG intersections.

4.3.4 Fully Probabilistic Operational Assessment

The fully probabilistic or 'full bundle' operational assessment method entails accounting for non-detected flaws resulting from limitations of the applied NDE technique such as the POD and projecting the degradation forward in SG operating time. The full bundle method considers all relevant sources of error and uncertainty to evaluate whether the structural and leakage integrity requirements will be met with a probability of 95% at 50% confidence levels. The Westinghouse configured software Full Bundle Model (FBM) Version 2.0 has been used to evaluate these requirements. The FBM configuration control software release letter is documented in Reference 13 and the program input/output files are attached to this report in EDMS. The initial inputs to the fully probabilistic model, including tube geometry, material properties, normal operating, accident pressures and leakage limits are from the Reference 3 degradation assessment. The fully probabilistic models of U-bend support structure and horizontal ATSG wear developed for Watts Bar Unit 1 is discussed below.

The return to service depth distribution of U-bend support flaws was established by fitting a LogNormal distribution with a mean of 2.88, standard deviation of 0.135, upper and lower truncations of 12%TW and 27%TW to the population of 59 total flaws returned to service. Growth of U-bend flaws was modeled by a Beta distribution with an alpha of 0.746, a beta of 0.790, upper and lower bounds of 0%TW/EFPY and 7%TW/EFPY. All flaws returned to service were set assumed to be 2.5 inches in length with no potential for growth. The postulated undetected population of flaws was estimated by processing a uniform flaw distribution through the POD function using the 'uniform and forward' feature of the FBM software. This process simulates a non-detected flaw distribution based on the input POD curve and maximum assumed non-detected flaw depth. The maximum assumed non-detected flaw was very conservatively selected to be 30%TW and all non-detected flaws were again assumed to be 2.5 inches in length. A total of 35 undetected flaws were used in the simulation.

The return to service depth distribution of horizontal ATSG flaws was established by fitting a LogNormal distribution with a mean of 2.92, standard deviation of 0.136, upper and lower truncations of 8%TW and 37%TW to the limiting population of 139 total flaws returned to service in SG2. Growth of horizontal ATSG flaws was assumed to be a constant of 5.9%TW/EFPY which was the largest single growth rate observed. All flaws returned to service were set assumed to be 2.0 inches in length with no potential for growth. The postulated undetected population of flaws was estimated by processing a uniform flaw distribution through the POD function using the 'uniform and forward' feature of the FBM software. This process simulates a non-detected flaw distribution based on the input POD curve and maximum assumed non-detected flaw depth. The maximum assumed non-detected flaw was very conservatively selected to be 25%TW and all undetected flaws were again assumed to be 2.0 inches in length. A total of 40 undetected flaws were used in the simulation.

Although the Watts Bar flaws have been observed to be primarily tapered, flat wear was assumed in the model and no flaw geometry factor was applied. No flaw initiates were modeled as experience has shown the burst probability of wear mechanisms to be dominated by the flaws returned to service.

The Westinghouse FBM software ran a total of 500,000 Monte Carlo simulations in each case to develop the cumulative probability distribution (CPD) for structural burst and leakage. The industry wide SG tube integrity performance criteria are less than 5% cumulative probability of burst and leakage greater than that assumed in the limiting accident analysis. The results of the depth-based fully probabilistic model for 4.5 EFPY and 4.74 EFPY of operation between inspections are shown in Table 4-7 below and screen captures of the outputs are provided in Figure A6-4. The FBM software runs are attached to this letter in EDMS.

Table 4-7: Watts Bar U1R14 Fully Probabilistic Operational Assessment Results

Case	EFPY	Description	Probability of Burst	Probability of Leakage	Tube Integrity Criteria Satisfied?	Leak Rate at 5% Probability (gpm)
1	4.5	U-bend Support Structure	0.04%	0%	Yes	0.0
2		Horizontal ATSG	1.66%	0%	Yes	0.0
3	4.74	U-bend Support Structure	0.14%	0%	Yes	0.0
4		Horizontal ATSG	4.82%	0%	Yes	0.0

The cumulative probability of structural burst and leakage is determined after 4.5 EFPY and 4.74 EFPY of operation for each of the depth-based scenarios described. The results of each of these depth-based cases show that structural and leakage integrity is projected to be maintained for 4.74 EFPY. In comparison, the volume-based approaches discussed in Sections 4.1.4 and 4.2.4 demonstrated acceptable operation for 7.5 EFPY.

4.4 SG Secondary Side Foreign Objects

During Watts Bar U1R14 there was one signal corresponding to a new PLP in SG4 R3C12 at the top of the tubesheet on the cold leg side. The location was visually inspected from the secondary side and no foreign object or contributing deposit condition was observed. There was no tube degradation detected by eddy current or visual inspection coincident with this PLP indication. As a result, no degradation is anticipated as a result of the PLP indication in the upcoming 7.5 EFPY estimated operating interval.

For the objects known to be remaining in the SG secondary side following Watts Bar U1R14, the analysis performed in Reference 7 establishes that at least five cycles or 7.5 EFPY of operating time would accrue before the object with the greatest potential to cause tube wear degradation could potentially exceed the tube structural limit. Furthermore, for tube wear to approach $3\Delta P$ burst dimensions, the depth must exceed the structural limit for the degraded tube length. The actual axial flaw lengths for the remaining foreign objects are expected to be much less than those applied in the Reference 7 foreign object wear evaluation.

For pressure-only loading of volumetric flaws, satisfaction of the structural integrity implies satisfaction of leakage integrity at accident conditions since steam line break accident condition pressure differential for pop-through is much smaller than $3\Delta P_{NO}$. Therefore, it is projected that there will be no challenge to the Watts Bar Unit 1 SG structural and leakage integrity performance criteria relative to this degradation mechanism before the Watts Bar U1R19 eddy current inspections.

4.5 Operational Assessment Conclusions

An operational assessment is performed to assess whether degradation mechanisms observed in a plant will continue to meet the SG tube structural and leakage integrity performance criteria at the end of the upcoming inspection interval. Based on application of conservative U-bend support structure and horizontal ATSG wear growth rates, the condition of the Watts Bar Unit 1 RSG tubes has been analyzed with respect to continued operability of the SGs until the end of Cycle 19 without exceeding the SG tube integrity performance criteria. The growth rates were determined by comparative analysis of U-bend support structure and horizontal ATSG wear sites for all SGs. Based on conservative wear rate analysis applied to the retained foreign objects observed, there is no challenge to tube integrity in the upcoming five operating cycles until eddy current is performed again in U1R19. The operational assessment projections show that conditions exceeding the SG integrity performance criteria will not occur in any of the four SGs at Watts Bar Unit 1 during the five-cycle inspection interval from U1R14 to U1R19.

5.0 References

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11. Watts Bar Unit 1 SG Channel Head Primary Examination Reports, April 2017. (*Attached to this document in EDMS*)
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17. Westinghouse Report SG-SGMP-17-9, Revision 0, "Watts Bar U1R14 Steam Generator Condition Monitoring and Operational Assessment," April 2017.

Attachment 1 – Watts Bar U1R14 As-Implemented SG Inspection Scope

WATTS BAR 1
U1R14
S/G INSPECTION STATUS

Base Scope Exam Programs

S/G	Exam Type	Exams Programmed	Exams Acquired	Outstanding Retests	Analyzed & Complete	% Acquired	% Complete	Tubes Acquired Since Last Report
1	.610 HL Array VS3-HTE	5125	5125	0	5125	100.00%	100.00%	103
1	.610 CL Array VS3-CTE	5125	5125	0	5125	100.00%	100.00%	22
1	.590 HL/CL Bobbin (Ubend Region)	127	127	0	127	100.00%	100.00%	127
1	Total Tests SG 1 Base Scope Programs	10377	10377	0	10377	100.00%	100.00%	252
2	.610 HL Array VS3-HTE	5123	5123	0	5123	100.00%	100.00%	0
2	.610 CL Array VS3-CTE	5123	5123	0	5123	100.00%	100.00%	0
2	.590 HL/CL Bobbin (Ubend Region)	127	127	0	127	100.00%	100.00%	93
2	Total Tests SG 2 Base Scope Programs	10373	10373	0	10373	100.00%	100.00%	93
3	.610 HL Array VS3-HTE	5121	5121	0	5121	100.00%	100.00%	0
3	.610 CL Array VS3-CTE	5121	5121	0	5121	100.00%	100.00%	254
3	.590 HL/CL Bobbin (Ubend Region)	127	127	0	127	100.00%	100.00%	127
3	Total Tests SG 3 Base Scope Programs	10369	10369	0	10369	100.00%	100.00%	381
4	.610 HL Array VS3-HTE	5114	5114	0	5114	100.00%	100.00%	0
4	.610 CL Array VS3-CTE	5114	5114	0	5114	100.00%	100.00%	28
4	.590 HL/CL Bobbin (Ubend Region)	127	127	0	127	100.00%	100.00%	0
4	Total Tests SG 4 Base Scope Programs	10355	10355	0	10355	100.00%	100.00%	28
ALL	Combined Total All Tests Base Scope Programs	41474	41474	0	41474	100.00%	100.00%	

Diagnostic Exams for Bobbin/Array Indications (Special Interest Additional Scope)

S/G	Exam Type	Exams Programmed	Exams Acquired	Outstanding Retests	Analyzed & Complete	% Acquired	% Complete	Tubes Acquired Since Last Report
1	.590 HL/CL G3/G4 Ghent Probe SI	0	0	0	0	0.00%	0.00%	0
1	.610 HL/CL 3C-RPC Straight Section SI	0	0	0	0	0.00%	0.00%	0
1	.610 HL/CL 3C-Mag Bias SI	0	0	0	0	0.00%	0.00%	0
1	.580 HL/CL UB-RPC SI	0	0	0	0	0.00%	0.00%	0
1	.610 HL/CL Array SI	0	0	0	0	0.00%	0.00%	0
1	Total Tests Special Interest Programs	0	0	0	0	0.00%	0.00%	0
2	.590 HL/CL G3/G4 Ghent Probe SI	0	0	0	0	0.00%	0.00%	0
2	.610 HL/CL 3C-RPC Straight Section SI	0	0	0	0	0.00%	0.00%	0
2	.610 HL/CL 3C-Mag Bias SI	0	0	0	0	0.00%	0.00%	0
2	.580 HL/CL UB-RPC SI	0	0	0	0	0.00%	0.00%	0
2	.610 HL/CL Array SI	0	0	0	0	0.00%	0.00%	0
2	Total Tests Special Interest Programs	0	0	0	0	0.00%	0.00%	0
3	.590 HL/CL G3/G4 Ghent Probe SI	0	0	0	0	0.00%	0.00%	0
3	.610 HL/CL 3C-RPC Straight Section SI	0	0	0	0	0.00%	0.00%	0
3	.610 HL/CL 3C-Mag Bias SI	0	0	0	0	0.00%	0.00%	0
3	.580 HL/CL UB-RPC SI	0	0	0	0	0.00%	0.00%	0
3	.610 HL/CL Array SI	0	0	0	0	0.00%	0.00%	0
3	Total Tests Special Interest Programs	0	0	0	0	0.00%	0.00%	0
4	.590 HL/CL G3/G4 Ghent Probe SI	0	0	0	0	0.00%	0.00%	0
4	.610 HL/CL 3C-RPC Straight Section SI	0	0	0	0	0.00%	0.00%	0
4	.610 HL/CL 3C-Mag Bias SI	0	0	0	0	0.00%	0.00%	0
4	.580 HL/CL UB-RPC SI	0	0	0	0	0.00%	0.00%	0
4	.610 HL/CL Array SI	0	0	0	0	0.00%	0.00%	0
4	Total Tests Special Interest Programs	0	0	0	0	0.00%	0.00%	0
ALL	Combined Total All Special Interest Programs	0	0	0	0	0.00%	0.00%	

WATTS BAR 1
U1R14
S/G INSPECTION STATUS

S/G	Inspection Summary Combined Total All Tests and All Programs	Exams Programmed	Exams Acquired	Outstanding Retests	Analyzed & Complete	% Acquired	% Complete
1	Total Tests; Base and Diagnostic Tests	10377	10377	0	10377	100.00%	100.00%
2	Total Tests; Base and Diagnostic Tests	10373	10373	0	10373	100.00%	100.00%
3	Total Tests; Base and Diagnostic Tests	10369	10369	0	10369	100.00%	100.00%
4	Total Tests; Base and Diagnostic Tests	10355	10355	0	10355	100.00%	100.00%
	Combined Total All Tests and All Programs	41474	41474	0	41474	100.00%	100.00%

NOTE: Exams evaluated are counted when through the resolution process.

Additional Information

Repair Distribution	S/G 1	S/G 2	S/G 3	S/G 4	Total
OD Circumferential	0	0	0	0	0
OD Axial	0	0	0	0	0
ID Axial	0	0	0	0	0
ID Circumferential	0	0	0	0	0
Wear	0	0	0	0	0
LPI/Wear	0	0	0	0	0
Confirmed Tubes to be Plugged					
Repair Candidate (=>40%; Array/RPC I-Codes)	0	0	0	0	0
Preventative / Customer Decision Tube to Plug	0	0	0	0	0
Total New Plugged Tubes	0	0	0	0	0
Total Prior Plugged Tubes	3	5	7	14	29
Total Committed Plugged Tubes	3	5	7	14	29

EC Testing Summary		Hot Leg	Cold leg		Hot Leg	Cold leg
S/G 1	ECT Start Time	3/31/17 10:46 AM	3/31/17 8:40 AM	ECT Completed Time	4/3/17 2:10 PM	4/3/17 2:10 PM
S/G 2	ECT Start Time	3/31/17 2:34 AM	3/31/17 1:46 AM	ECT Completed Time	4/3/17 4:20 PM	4/3/17 4:20 PM
S/G 3	ECT Start Time	3/31/17 12:06 AM	3/31/17 12:04 AM	ECT Completed Time	4/3/17 4:20 PM	4/3/17 4:20 PM
S/G 4	ECT Start Time	3/31/17 8:30 AM	3/31/17 8:50 AM	ECT Completed Time	4/3/17 2:22 PM	4/3/17 2:22 PM

Current Inspection Status	Hot Leg	Cold leg	Problems Encountered Last 24 Hours
S/G 1	Complete	Complete	S/G 1
S/G 2	Complete	Complete	S/G 2
S/G 3	Complete	Complete	S/G 3
S/G 4	Complete	Complete	S/G 4

Inspection Notes:

Due to difficulties in acquiring Full Length Array data, the program has been changed to acquiring data from VS3 through the tube ends in each Steam Generator leg.

Modified Row 1 and 2 Ubend Array program to include Bobbin of the Ubend Region.

Attachment 2 – Watts Bar U1R14 SG Tube Structural and Condition Monitoring Limits

Degradation Mechanism	Plugging	Structural Limit	Condition Monitoring Limit
Existing			
Wear at U-bend Support Structures	40% TW	62% TW for 2.5 inch	51% TW for 2.5” 96004.1 Revision 13
Wear at Horizontal ATSGs	40% TW	63% TW for 2.0 inch	52% TW for 2.0” 96004.1 Revision 13
Potential			
Wear due to Foreign Objects	40% TW	64% TW for 1.5 inch	44% TW for 1.5” 21998.1 Revision 4
Tube-to-Tube Contact Wear	40% TW	63% TW for 2.0 inch	55% TW for 2.0” 27905.2 Revision 2
Diagnostic			
Pitting in the Sludge Pile Region	Plug on Detection	78% TW for 0.3 inch	57% TW for 0.3” 21998.1 Revision 4

Note: The structural and condition monitoring limits identified in this table are from the Reference 3 Degradation Assessment.

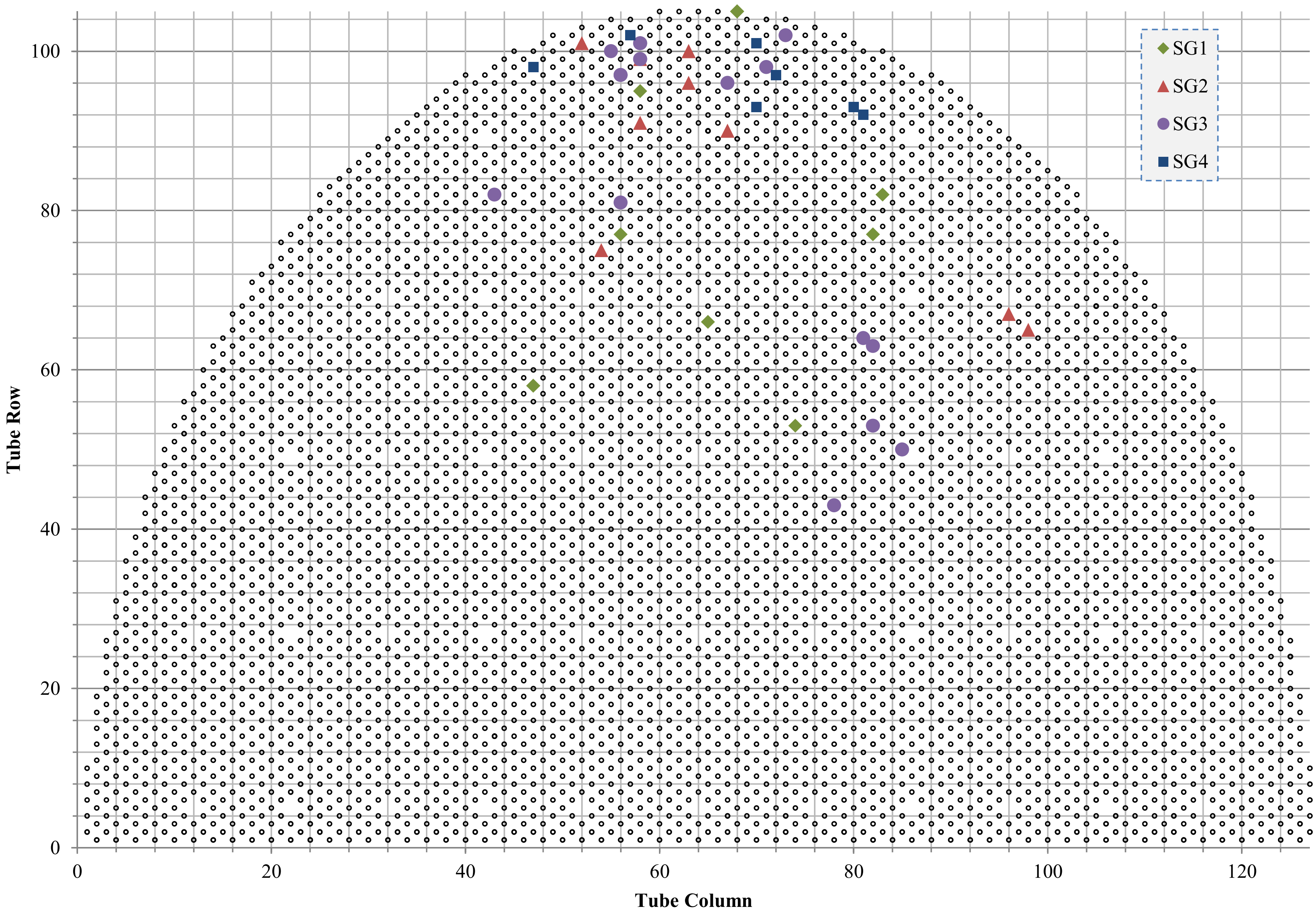
Attachment 3 – Watts Bar U1R14 U-bend Support Structure Wear Indications

Table A3-1: Watts Bar U1R14 U-bend Support Structure Wear Indications – All SGs

SG	Row	Col	Locn	Inch1	Ind	Per 2017[1] (%TW)	Per 2012[1] (%TW)	Delta (%TW/EFPY)
1	53	74	VS4	-1.15	PCT	15		
1	58	47	VS3	1.29	PCT	16		
1	58	47	VS3	-0.96	PCT	16		
1	66	65	VS4	0.86	PCT	19	0	4.7
1	77	56	VS3	-0.91	PCT	18		
1	77	82	VS3	-1.12	PCT	17		
1	82	83	VS4	-1.01	PCT	18		
1	95	58	VS2	-0.61	PCT	15		
1	105	68	DS2	0.62	PCT	21	0	5.2
1	105	68	VS2	-0.03	PCT	19	0	4.7
1	105	68	VS2	-0.72	PCT	18	0	4.4
1	105	68	VS4	-1.03	PCT	17		
1	105	68	DS2	-0.23	PCT	15	0	3.7
2	65	98	VS2	1.24	PCT	17		
2	67	96	VS2	1.05	PCT	14		
2	75	54	VS4	0.86	PCT	22	13	2.2
2	90	67	VS4	-0.76	PCT	18		
2	90	67	VS2	-0.85	PCT	12		
2	91	58	VS2	0.8	PCT	20	15	1.2
2	96	63	VS3	-0.64	PCT	22	0	5.4
2	99	58	VS4	0.8	PCT	18		
2	100	63	VS2	-0.75	PCT	24	19	1.2
2	100	63	VS2	0.55	PCT	18	19	-0.2
2	101	52	VS1	-0.93	PCT	13		
3	24	69	DS4	-0.03	PCT	23	0	5.7
3	43	78	VS3	-1.2	PCT	16		
3	50	85	VS3	-0.38	PCT	20	0	4.9
3	53	82	VS3	-0.12	PCT	19	0	4.7
3	63	82	VS3	1.35	PCT	17		
3	64	81	VS3	1.82	PCT	17		
3	81	56	VS4	0.89	PCT	27	0	6.6
3	82	43	VS2	-0.95	PCT	18		
3	96	67	VS2	-0.78	PCT	16		
3	97	56	VS3	0.74	PCT	20	0	4.9
3	97	56	VS3	1.21	PCT	19	0	4.7
3	97	64	DS3	-0.83	PCT	19	14	1.2
3	98	71	VS4	0.73	PCT	20	16	1.0
3	99	50	DS3	0.82	PCT	18		
3	99	58	VS4	0.96	PCT	21	0	5.2
3	99	58	VS4	0.03	PCT	17	0	4.2
3	100	55	VS2	-0.75	PCT	20	16	1.0
3	100	63	DS3	0.8	PCT	17		
3	100	67	DS3	0.75	PCT	18		
3	101	58	DS2	-0.8	PCT	21	18	0.7
3	101	58	VS4	0.84	PCT	19	0	4.7
3	101	58	VS3	-0.31	PCT	17		
3	102	73	VS1	-0.91	PCT	19	0	4.7
4	92	81	VS2	0.9	PCT	23	17	1.5
4	93	70	VS2	0.92	PCT	19	16	0.7
4	93	70	VS2	0.06	PCT	18	16	0.5
4	93	70	VS2	-0.82	PCT	18	16	0.5
4	93	80	VS2	0.96	PCT	21	0	5.2
4	93	80	VS2	0.2	PCT	17	0	4.2
4	96	83	DS2	-0.83	PCT	20	0	4.9
4	97	72	VS3	-0.24	PCT	18		
4	98	47	VS2	0.82	PCT	15		
4	101	70	VS3	0.61	PCT	19	16	0.7
4	102	57	VS3	-1.14	PCT	22	0	5.4
4	102	57	DS2	-0.76	PCT	21	0	5.2

Note 1: Determined either from production data results or lead analyst review of raw eddy current data history.

Figure A3-5: Watts Bar U1R14 U-bend Support Structure Wear Indications in All SGs – Tubesheet Map



Note: A small number of tube locations have multiple wear indications. Therefore, some data points are plotted on top of each other on this map.

Figure A3-6: Watts Bar U1R14 U-bend Wear Growth Cumulative Frequency Distribution – All SGs

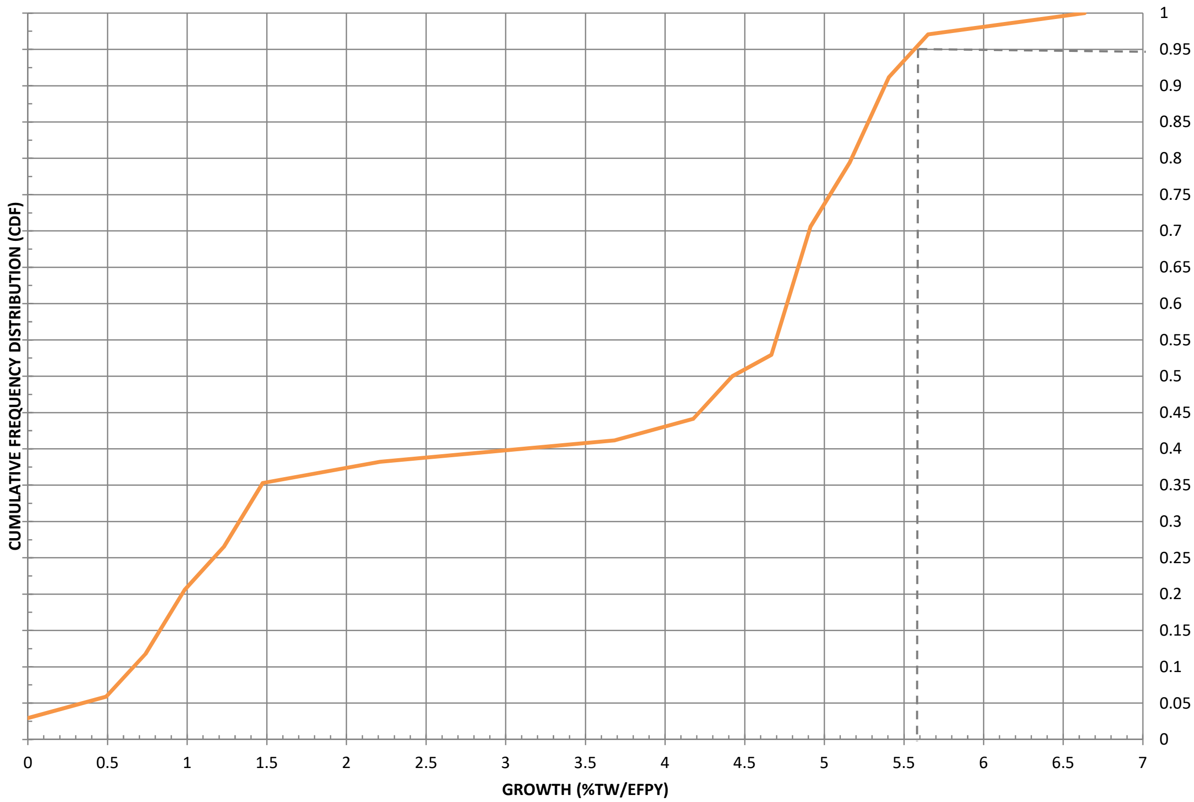


Figure A3-7: Watts Bar U1R14 U-bend Support Structure Wear - Monte Carlo Simulation

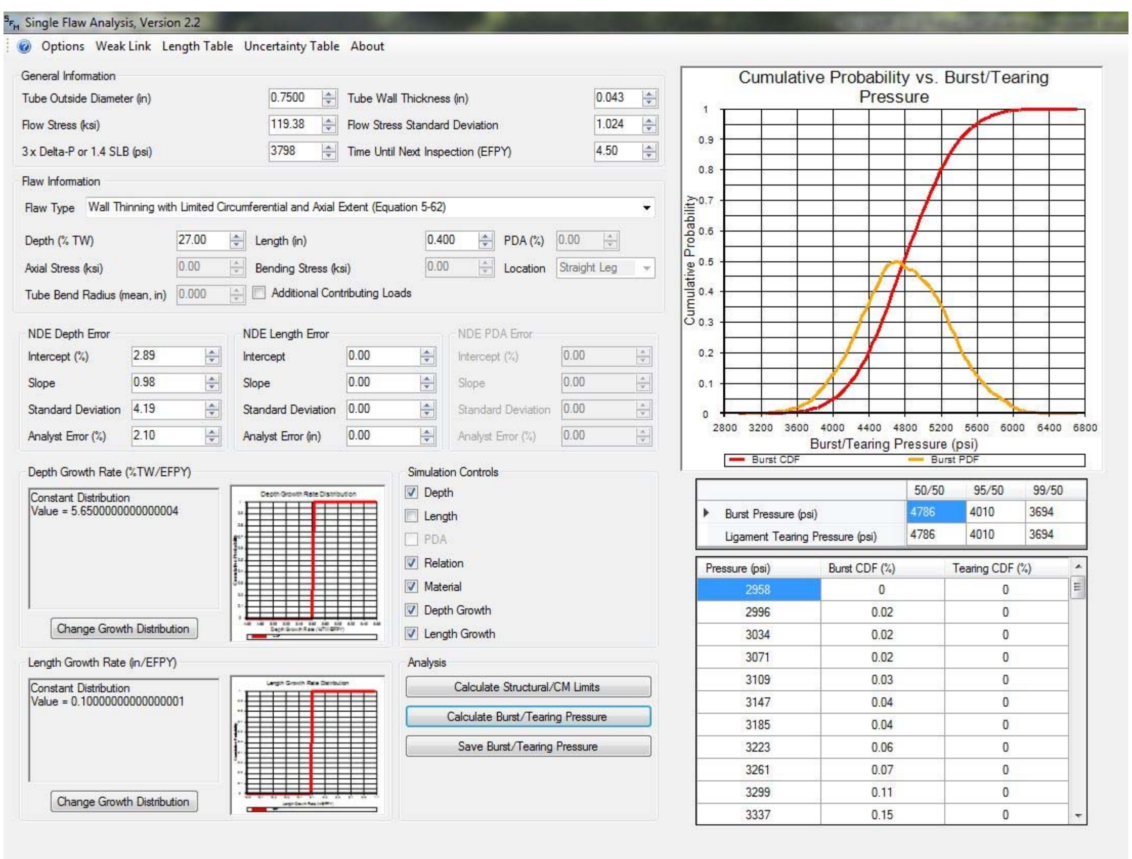
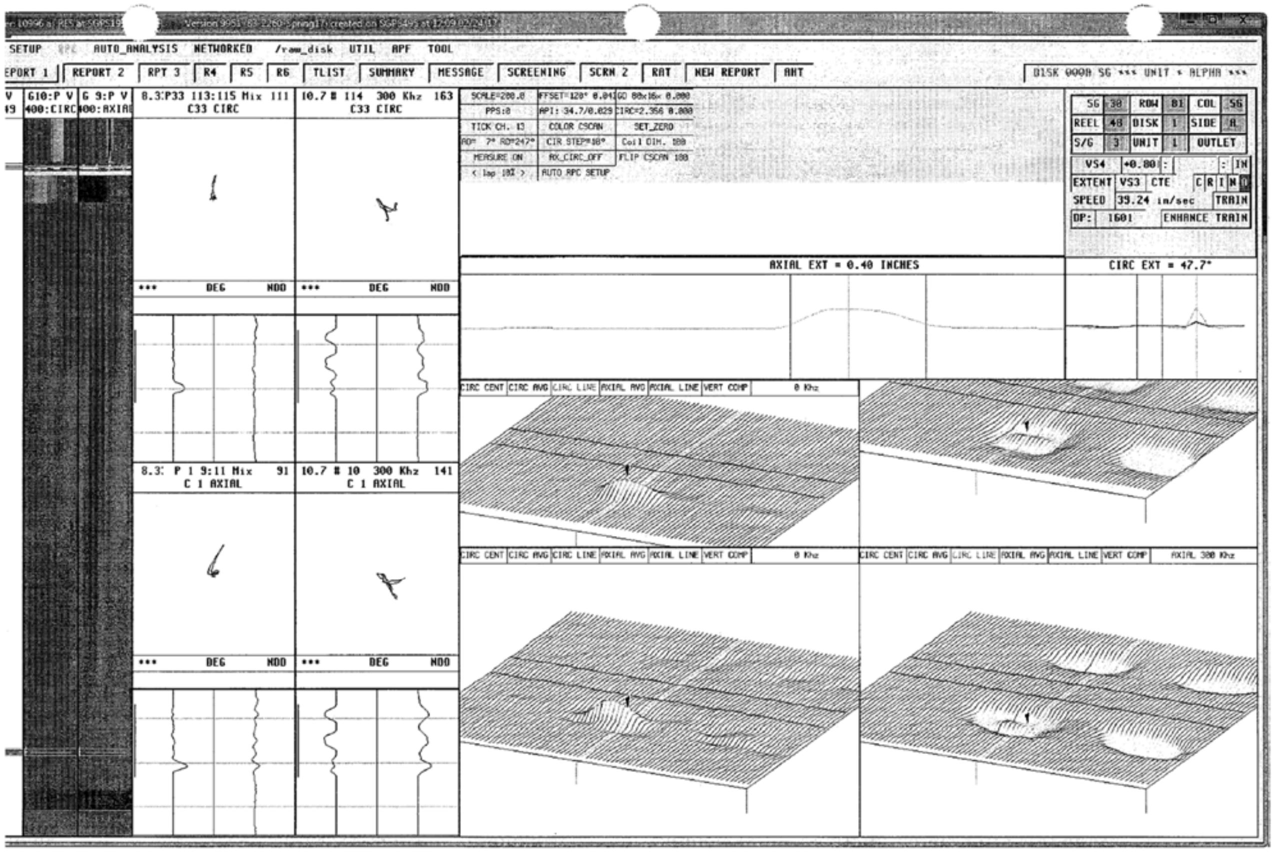


Figure A3-8: **Watts Bar U1R14 U-bend Support Wear Indication – SG3 R81C56 VS4 Array Graphic 2017**



Attachment 4 – Watts Bar U1R14 ATSG Wear Indications

Table A4-1: Watts Bar U1R14 ATSG Wear Indications – SG1

SG	Row	Col	Locn	Inch1	Ind	Per 2017[1] (%TW)	Per 2012[1] (%TW)	Delta (%TW/EFPY)
1	1	48	H04	-1.06	PCT	18		
1	1	48	H07	0.19	PCT	17		
1	1	116	C04	-0.88	PCT	18		
1	7	64	H09	0.66	PCT	19		
1	7	88	H06	-0.97	PCT	22	0	5.4
1	7	102	H08	0.63	PCT	18		
1	8	99	H09	-1.06	PCT	19		
1	8	127	C05	-0.67	PCT	17		
1	9	100	C10	-0.87	PCT	19		
1	9	100	C11	0.76	PCT	18		
1	9	104	H07	-0.92	PCT	22	18	1.0
1	18	103	H07	-0.92	PCT	20	0	4.9
1	23	84	C11	0.78	PCT	19		
1	26	123	C06	-0.7	PCT	19		
1	27	124	C06	-0.84	PCT	20	0	4.9
1	28	45	C11	0.67	PCT	19		
1	29	124	C06	0.77	PCT	20	20	0.0
1	29	124	C05	-0.9	PCT	17		
1	34	123	C05	-0.87	PCT	19		
1	59	112	C06	-0.67	PCT	17		
1	60	115	C05	-0.67	PCT	18		
1	67	112	C06	0.83	PCT	19		
1	68	111	C06	0.75	PCT	18		
1	71	110	C06	0.81	PCT	19		
1	76	107	C06	0.62	PCT	22	17	1.2
1	77	106	C06	0.72	PCT	18		
1	79	104	C03	-0.84	PCT	17		
1	82	103	C04	-0.74	PCT	15		
1	83	26	C03	0.73	PCT	19	16	0.7
1	83	102	C03	-0.76	PCT	19		
1	83	102	C06	0.67	PCT	17		
1	84	99	C04	0.75	PCT	22	16	1.5
1	84	99	C03	-0.76	PCT	19		
1	84	99	C07	1	PCT	18		
1	85	30	C03	0.73	PCT	21	17	1.0
1	85	94	C03	-1	PCT	18		
1	85	98	C04	0.81	PCT	18		
1	85	100	C03	-0.79	PCT	27	19	2.0
1	86	97	C04	0.56	PCT	17		
1	86	99	C03	-0.9	PCT	18		
1	87	30	C02	0.73	PCT	21	17	1.0
1	87	96	C04	-0.87	PCT	19		
1	87	98	C03	0.76	PCT	21	16	1.2
1	88	31	C03	0.78	PCT	17	0	4.2
1	88	95	C03	-0.87	PCT	22	16	1.5
1	88	97	C03	0.78	PCT	21	15	1.5
1	89	94	C04	0.73	PCT	18		
1	89	96	C03	-0.79	PCT	33	18	3.7
1	90	93	C03	-0.75	PCT	20	14	1.5
1	90	95	C04	0.59	PCT	22	15	1.7
1	90	95	C03	-0.78	PCT	21	0	5.2
1	91	90	C04	-0.98	PCT	19		
1	91	92	C03	-0.9	PCT	19		
1	91	94	C06	0.64	PCT	20	0	4.9
1	92	91	C03	-0.9	PCT	18		
1	92	93	C03	-0.79	PCT	24	16	2.0
1	95	88	C03	0.75	PCT	22	15	1.7
1	96	89	C03	-0.93	PCT	18		
1	97	84	C07	0.78	PCT	21	18	0.7
1	97	84	C03	-0.79	PCT	20	15	1.2
1	98	85	C05	-0.92	PCT	22	16	1.5
1	98	85	C03	0.73	PCT	20	15	1.2

SG	Row	Col	Locn	Inch1	Ind	Per 2017[1] (%TW)	Per 2012[1] (%TW)	Delta (%TW/EFPY)
1	100	83	C05	-0.95	PCT	23	15	2.0
1	100	83	C03	0.75	PCT	22	13	2.2
1	101	66	C03	0.78	PCT	17		
1	101	78	C03	-0.95	PCT	20	15	1.2
1	102	71	C03	-0.81	PCT	17		
1	102	71	C04	-1	PCT	16		
1	102	79	C03	0.73	PCT	23	15	2.0
1	103	54	C03	0.95	PCT	18		
1	103	74	C03	0.95	PCT	18		
1	104	63	C03	0.78	PCT	18		
1	105	64	C05	-0.92	PCT	22	18	1.0
1	105	64	C03	0.75	PCT	20	16	1.0

Note 1: Determined either from production data results or lead analyst review of raw eddy current data history.

Table A4-2: Watts Bar U1R14 ATSG Wear Indications – SG2

SG	Row	Col	Locn	Inch1	Ind	Per 2017[1] (%TW)	Per 2012[1] (%TW)	Per 2008[1] (%TW)	Delta (%TW/EFPY)
2	1	42	H04	-0.8	PCT	16			
2	1	44	H08	-0.91	PCT	16			
2	1	44	H04	-0.86	PCT	13			
2	1	48	H04	0.91	PCT	17			
2	1	70	H05	-0.95	PCT	16			
2	1	74	H04	-0.6	PCT	18			
2	2	31	H06	-0.99	PCT	19			
2	2	41	H07	-0.94	PCT	17			
2	2	53	H05	-0.72	PCT	16			
2	2	69	H04	-0.94	PCT	17			
2	2	73	H04	-0.88	PCT	16			
2	2	101	H06	0.86	PCT	17			
2	6	1	C03	0.81	PCT	17			
2	8	1	C03	0.56	PCT	18			
2	8	77	H08	-0.98	PCT	25		9	1.9
2	8	77	H07	-1.01	PCT	21		6	1.8
2	8	127	C04	0.82	PCT	22	17		1.2
2	8	127	C03	0.76	PCT	21	0		5.2
2	10	127	C03	0.75	PCT	21	12		2.2
2	14	123	C03	0.92	PCT	17			
2	18	73	H07	-1.04	PCT	19			
2	19	124	C05	-0.93	PCT	18			
2	19	124	C03	0.76	PCT	17			
2	19	126	C03	0.79	PCT	17			
2	20	123	C03	0.86	PCT	18			
2	21	122	C09	-1.04	PCT	20	15		1.2
2	22	123	C03	0.73	PCT	30	16		3.4
2	22	123	C07	0.76	PCT	23	15		2.0
2	22	123	C07	-0.92	PCT	23	15		2.0
2	22	123	C05	0.64	PCT	18			
2	22	123	C06	-1.07	PCT	18			
2	22	125	C03	0.7	PCT	18			
2	22	125	C06	0.73	PCT	18			
2	23	44	C12	0.67	PCT	20	0		4.9
2	23	48	C12	-0.84	PCT	17			
2	23	122	C03	0.76	PCT	22	16		1.5
2	25	28	C12	-0.79	PCT	13	0		3.2
2	25	122	C03	0.76	PCT	23	12		2.7
2	26	123	C03	0.65	PCT	21	16		1.2
2	26	123	C04	0.64	PCT	19			
2	26	123	C03	-0.95	PCT	18	16		0.5
2	26	125	C03	0.7	PCT	18			
2	27	4	C06	-1.04	PCT	15	10		1.2
2	27	124	C03	0.81	PCT	21	0		5.2
2	27	124	C05	-0.98	PCT	19			
2	28	119	C06	-0.82	PCT	21	17		1.0

SG	Row	Col	Locn	Inch1	Ind	Per 2017[1] (%TW)	Per 2012[1] (%TW)	Per 2008[1] (%TW)	Delta (%TW/EFPY)
2	28	123	C03	0.78	PCT	26	16		2.5
2	30	7	C06	0.76	PCT	16	14		0.5
2	30	123	C06	0.84	PCT	27	22		1.2
2	30	123	C07	-0.86	PCT	27	20		1.7
2	30	123	C03	0.73	PCT	26	10		3.9
2	30	123	C05	-0.89	PCT	23	19		1.0
2	30	123	C06	-0.84	PCT	20	22		-0.5
2	30	123	C04	0.65	PCT	18			
2	31	54	C12	-1.03	PCT	22	15		1.7
2	32	121	C03	0.73	PCT	19			
2	32	121	C05	-0.93	PCT	18			
2	33	122	C03	-0.9	PCT	19			
2	33	122	C04	0.73	PCT	18			
2	33	122	C07	0.53	PCT	18			
2	36	7	C06	-0.84	PCT	18	15		0.7
2	36	121	C03	-0.92	PCT	20	15		1.2
2	37	8	C03	0.75	PCT	18	12		1.5
2	38	7	C03	0.94	PCT	16			
2	39	8	C07	-1.07	PCT	15	15		0.0
2	47	10	C03	0.88	PCT	19	11		2.0
2	50	9	C04	-0.9	PCT	19	14		1.2
2	51	118	C03	-0.98	PCT	18			
2	53	118	C03	-0.89	PCT	21	15		1.5
2	59	114	C04	0.62	PCT	15			
2	60	115	C03	-0.96	PCT	19			
2	60	115	C06	-1.12	PCT	19			
2	60	115	C07	-1.01	PCT	17			
2	62	15	C05	0.67	PCT	19	9		2.5
2	62	15	C04	-1.03	PCT	17	10		1.7
2	62	113	C07	-0.98	PCT	25	18		1.7
2	62	113	C03	-0.95	PCT	18			
2	62	113	C04	0.62	PCT	18			
2	63	114	C03	-1.04	PCT	17			
2	63	114	C06	0.64	PCT	15			
2	64	113	C03	-0.87	PCT	17			
2	71	110	C05	0.65	PCT	16			
2	72	109	C03	-1.2	PCT	20	0		4.9
2	76	107	C03	0.65	PCT	16			
2	77	104	C03	-0.76	PCT	19			
2	77	104	C04	-1.01	PCT	18			
2	78	105	C03	-0.82	PCT	18			
2	79	104	C03	-1.04	PCT	18			
2	79	104	C04	-0.96	PCT	17			
2	80	103	C06	-0.95	PCT	19			
2	83	100	C04	0.54	PCT	20	0		4.9
2	85	100	C06	-0.99	PCT	21	16		1.2
2	85	100	C04	0.65	PCT	19			
2	85	100	C07	-1.22	PCT	18			
2	86	97	C04	0.89	PCT	18			
2	86	97	C03	0.68	PCT	17			
2	86	99	C04	0.7	PCT	22	0		5.4
2	87	30	C03	0.74	PCT	18	14		1.0
2	87	32	C06	-1.72	PCT	19	13		1.5
2	87	94	C04	0.73	PCT	20	12		2.0
2	87	98	C06	-0.95	PCT	30	19		2.7
2	87	98	C03	-0.95	PCT	23	16		1.7
2	87	98	C04	0.67	PCT	19			
2	88	95	C03	-1.04	PCT	37	21		3.9
2	88	95	C03	0.53	PCT	16	21		-1.2
2	88	95	C06	0.78	PCT	16			
2	89	32	C03	-0.94	PCT	19	16		0.7
2	89	32	C03	0.82	PCT	16	16		0.0
2	89	94	C03	-0.98	PCT	25	15		2.5
2	89	96	C06	-1.04	PCT	17			
2	90	95	C04	0.73	PCT	23	13		2.5

SG	Row	Col	Locn	Inch1	Ind	Per 2017[1] (%TW)	Per 2012[1] (%TW)	Per 2008[1] (%TW)	Delta (%TW/EFPY)
2	90	95	C07	-0.95	PCT	18			
2	91	94	C03	-0.92	PCT	25	15		2.5
2	92	35	C04	-0.86	PCT	17	15		0.5
2	92	35	C03	-0.92	PCT	16	15		0.2
2	92	93	C07	-0.87	PCT	19			
2	92	93	C04	0.73	PCT	18			
2	92	93	C06	-0.88	PCT	18			
2	95	82	C03	-1.15	PCT	17			
2	96	85	C06	0.89	PCT	19			
2	96	85	C07	-1.06	PCT	17			
2	96	87	C03	-0.82	PCT	18			
2	97	86	C03	-1.12	PCT	19			
2	97	88	C03	-0.96	PCT	20	13		1.7
2	98	43	C05	0.71	PCT	20	18		0.5
2	98	79	C03	-1.12	PCT	19			
2	98	83	C03	-1.18	PCT	18			
2	99	84	C02	0.62	PCT	16			
2	100	81	C04	0.78	PCT	23	18		1.2
2	101	78	C03	-1.15	PCT	20	15		1.2
2	101	80	C03	-1.2	PCT	20	15		1.2
2	103	62	C03	0.92	PCT	17			
2	103	66	C05	0.67	PCT	22	14		2.0
2	103	74	C03	-1.15	PCT	19			
2	104	61	C06	-0.9	PCT	16			
2	104	69	C05	0.7	PCT	19			
2	105	66	C03	0.72	PCT	23	16		1.7
2	105	66	C05	0.67	PCT	17			
2	105	68	C03	0.75	PCT	20	0		4.9

Note 1: Determined either from production data results or lead analyst review of raw eddy current data history.

Table A4-3: Watts Bar U1R14 ATSG Wear Indications – SG3

SG	Row	Col	Locn	Inch1	Ind	Per 2017[1] (%TW)	Per 2012[1] (%TW)	Delta (%TW/EFPY)
3	1	72	H04	-0.88	PCT	15		
3	1	72	H05	-0.96	PCT	14		
3	1	72	H04	0.91	PCT	13		
3	1	78	H04	-0.91	PCT	20	15	1.2
3	1	86	H04	-0.85	PCT	15		
3	7	2	C03	0.83	PCT	16		
3	9	106	C06	-0.78	PCT	18		
3	10	1	C03	0.72	PCT	23	16	1.7
3	10	1	C05	-0.92	PCT	17		
3	13	4	C03	0.75	PCT	18		
3	14	51	H10	0.68	PCT	18		
3	14	51	C11	-1.06	PCT	17		
3	14	81	H06	-0.9	PCT	18		
3	15	2	C04	-0.97	PCT	20	0	4.9
3	15	2	C03	0.83	PCT	17		
3	15	4	C06	-0.91	PCT	19	15	1.0
3	17	102	C12	-1.06	PCT	20	19	0.2
3	17	102	C12	0.66	PCT	18	19	-0.2
3	18	53	C12	-0.89	PCT	17		
3	19	2	C04	-0.98	PCT	23	18	1.2
3	20	61	C10	-0.98	PCT	19	0	4.7
3	23	124	C06	0.69	PCT	23	21	0.5
3	24	3	C05	0.8	PCT	18		
3	26	5	C03	-0.8	PCT	18		
3	28	119	C12	-0.86	PCT	18		
3	32	5	C03	-0.89	PCT	18		
3	34	5	C03	-1	PCT	20	0	4.9
3	53	118	C06	0.69	PCT	16	0	3.9
3	59	14	C03	-1.03	PCT	21	16	1.2
3	61	114	C06	0.83	PCT	26	15	2.7
3	61	114	C06	-0.75	PCT	17	15	0.5

SG	Row	Col	Locn	Inch1	Ind	Per 2017[1] (%TW)	Per 2012[1] (%TW)	Delta (%TW/EFPY)
3	64	17	C03	-0.89	PCT	16		
3	64	111	C04	-0.77	PCT	18	12	1.5
3	64	111	C07	-1	PCT	14	12	0.5
3	65	18	C03	-0.98	PCT	18		
3	67	112	C06	-1.11	PCT	16	16	0.0
3	68	19	C03	0.63	PCT	18		
3	71	104	C03	0.87	PCT	17	0	4.2
3	76	107	C04	0.75	PCT	21	16	1.2
3	76	107	C06	0.8	PCT	20	16	1.0
3	77	22	C03	0.72	PCT	16		
3	79	24	C03	0.75	PCT	18		
3	82	25	C03	0.69	PCT	16		
3	82	27	C03	0.67	PCT	16		
3	83	26	C03	0.95	PCT	15		
3	84	29	C03	0.72	PCT	20	0	4.9
3	84	95	C05	0.91	PCT	16	0	3.9
3	84	99	C03	-0.92	PCT	17	0	4.2
3	85	28	C03	0.75	PCT	21	14	1.7
3	85	96	C03	0.8	PCT	18	0	4.4
3	85	98	C02	-0.94	PCT	22	17	1.2
3	86	31	C03	0.66	PCT	17		
3	86	95	C03	0.71	PCT	20	0	4.9
3	86	97	C02	-0.82	PCT	22	20	0.5
3	86	99	C05	0.74	PCT	22	0	5.4
3	86	99	C02	-0.85	PCT	21	16	1.2
3	86	99	C04	0.62	PCT	18	17	0.2
3	86	99	C03	-0.89	PCT	17	0	4.2
3	89	32	C03	0.69	PCT	18		
3	89	96	C03	-0.92	PCT	22	16	1.5
3	90	33	C03	0.66	PCT	21	0	5.2
3	90	93	C04	-0.97	PCT	15	12	0.7
3	90	95	C04	-0.85	PCT	18	0	4.4
3	90	95	C03	-0.8	PCT	17	16	0.2
3	91	34	C03	-0.92	PCT	25	19	1.5
3	92	35	C03	-0.98	PCT	25	17	2.0
3	92	91	C03	-0.83	PCT	19	0	4.7
3	92	91	C05	-0.95	PCT	16	14	0.5
3	92	93	C04	-0.98	PCT	17	0	4.2
3	93	36	C03	-0.89	PCT	18		
3	93	36	C04	0.69	PCT	18		
3	93	90	C03	0.8	PCT	19	0	4.7
3	94	37	C06	-0.92	PCT	19	14	1.2
3	94	41	C07	-1.12	PCT	21	19	0.5
3	94	89	C03	-0.92	PCT	18	0	4.4
3	95	38	C02	-0.77	PCT	19	9	2.5
3	95	38	C04	0.69	PCT	17		
3	96	85	C06	0.79	PCT	19	10	2.2
3	97	40	C04	0.72	PCT	16		
3	97	42	C04	0.69	PCT	26	18	2.0
3	97	42	C06	0.86	PCT	16		
3	100	75	C03	0.72	PCT	18		
3	101	68	C03	0.8	PCT	21	0	5.2

Note 1: Determined either from production data results or lead analyst review of raw eddy current data history.

Table A4-4: Watts Bar U1R14 ATSG Wear Indications – SG4

SG	Row	Col	Locn	Inch1	Ind	Per 2017[1] (%TW)	Per 2012[1] (%TW)	Delta (%TW/EFPY)
4	3	42	C11	-0.96	PCT	23	0	5.7
4	3	42	C12	-1.09	PCT	19		
4	6	37	C11	-1.01	PCT	17		
4	6	73	H07	-0.87	PCT	21	0	5.2
4	6	127	C03	0.76	PCT	23	15	2.0
4	9	40	C11	-0.96	PCT	17		

SG	Row	Col	Locn	Inch1	Ind	Per 2017[1] (%TW)	Per 2012[1] (%TW)	Delta (%TW/EFPY)
4	9	42	H06	0.62	PCT	24	0	5.9
4	9	42	H07	0.72	PCT	17		
4	10	41	C09	-0.87	PCT	19		
4	10	61	H07	-1.12	PCT	18		
4	12	71	H06	-0.86	PCT	22	0	5.4
4	12	71	H07	-1.23	PCT	22	0	5.4
4	13	78	C10	0.64	PCT	31	17	3.4
4	14	3	C04	0.69	PCT	20	15	1.2
4	18	63	C12	0.61	PCT	23	0	5.7
4	18	63	C11	0.64	PCT	21	0	5.2
4	22	123	C03	-1.1	PCT	18		
4	23	124	C03	-0.88	PCT	21	19	0.5
4	23	124	C06	-0.84	PCT	21	21	0.0
4	24	91	H06	-0.22	PCT	19		
4	24	125	C03	0.87	PCT	24	13	2.7
4	24	125	C06	0.75	PCT	18		
4	25	62	C11	0.67	PCT	20	16	1.0
4	26	35	C12	-0.92	PCT	17		
4	26	123	C04	0.76	PCT	21	17	1.0
4	26	123	C08	-0.93	PCT	19		
4	26	123	C03	-0.9	PCT	18		
4	27	124	C03	-0.93	PCT	23	21	0.5
4	28	123	C04	-0.87	PCT	20	13	1.7
4	30	5	C05	-0.78	PCT	18		
4	31	124	C03	-0.93	PCT	20	19	0.2
4	32	5	C02	0.76	PCT	17		
4	32	7	C02	0.82	PCT	20	0	4.9
4	32	7	C03	0.73	PCT	18		
4	33	8	C03	0.94	PCT	18		
4	35	122	C03	0.97	PCT	20	17	0.7
4	43	8	C04	0.98	PCT	19		
4	44	9	C06	-0.7	PCT	18		
4	44	121	C03	1	PCT	22	16	1.5
4	45	8	C03	-0.82	PCT	18		
4	49	110	C12	-0.48	PCT	18		
4	50	87	H01	-1.22	PCT	19		
4	53	118	C02	-0.87	PCT	21	19	0.5
4	60	115	C07	0.9	PCT	18		
4	63	114	C06	-1.11	PCT	21	22	-0.2
4	65	112	C05	-0.84	PCT	19		
4	71	108	C06	0.73	PCT	16		
4	77	104	C03	0.71	PCT	26	16	2.5
4	78	103	C03	0.8	PCT	18		
4	83	98	C03	0.71	PCT	18		
4	83	98	C04	-0.9	PCT	16		
4	83	100	C03	0.72	PCT	20	0	4.9
4	84	97	C04	-0.94	PCT	20	18	0.5
4	84	97	C03	0.74	PCT	19		
4	84	101	C04	-0.94	PCT	22	16	1.5
4	84	101	C03	0.71	PCT	21	16	1.2
4	84	101	C02	0.68	PCT	20	12	2.0
4	84	101	C06	-0.91	PCT	18		
4	85	28	C03	-0.86	PCT	22	0	5.4
4	85	94	C03	-0.84	PCT	20	15	1.2
4	85	96	C04	-0.95	PCT	18		
4	85	100	C04	-0.86	PCT	20	15	1.2
4	87	92	C04	0.78	PCT	19		
4	87	96	C03	-0.89	PCT	24	16	2.0
4	87	96	C05	-0.72	PCT	19		
4	87	98	C04	-0.89	PCT	20	18	0.5
4	88	31	C03	-0.95	PCT	22	13	2.2
4	88	95	C03	-0.75	PCT	17		
4	89	94	C05	0.66	PCT	17		
4	89	96	C03	-0.89	PCT	23	17	1.5
4	89	96	C05	0.71	PCT	18		

SG	Row	Col	Locn	Inch1	Ind	Per 2017[1] (%TW)	Per 2012[1] (%TW)	Delta (%TW/EFPY)
4	90	35	C03	-1.18	PCT	19	0	4.7
4	90	39	C04	0.88	PCT	17		
4	90	91	C04	-0.92	PCT	18		
4	91	34	C03	-0.89	PCT	24	17	1.7
4	91	34	C05	0.74	PCT	20	0	4.9
4	91	36	C04	0.71	PCT	22	14	2.0
4	91	36	C03	-1.2	PCT	21	11	2.5
4	91	38	C03	-0.92	PCT	22	0	5.4
4	91	92	C04	-0.8	PCT	20	16	1.0
4	91	94	C03	0.71	PCT	23	19	1.0
4	92	37	C03	-0.86	PCT	25	14	2.7
4	92	91	C03	0.65	PCT	17		
4	92	93	C03	0.74	PCT	20	0	4.9
4	93	36	C03	-0.74	PCT	22	13	2.2
4	93	36	C05	0.68	PCT	21	19	0.5
4	94	37	C03	-1.17	PCT	34	16	4.4
4	94	39	C03	-0.86	PCT	22	10	2.9
4	94	39	C07	-0.92	PCT	18	11	1.7
4	94	41	C03	-0.92	PCT	23	15	2.0
4	95	40	C05	0.71	PCT	19	0	4.7
4	95	40	C06	-1.03	PCT	18	17	0.2
4	95	42	C03	-0.83	PCT	26	17	2.2
4	95	86	C03	0.68	PCT	24	16	2.0
4	96	41	C03	0.71	PCT	22	0	5.4
4	96	41	C05	-0.98	PCT	19	17	0.5
4	96	43	C03	-0.95	PCT	19		
4	96	45	C03	-0.92	PCT	21	16	1.2
4	96	81	C03	0.92	PCT	18		
4	97	42	C05	-0.97	PCT	22	17	1.2
4	97	78	C03	0.81	PCT	21	0	5.2
4	97	86	C03	0.74	PCT	25	19	1.5
4	97	88	C03	0.8	PCT	21	17	1.0
4	97	88	C03	-0.74	PCT	18	17	0.2
4	97	88	C07	-0.86	PCT	18		
4	98	43	C07	0.77	PCT	19	14	1.2
4	98	43	C03	-0.95	PCT	18	0	4.4
4	98	45	C03	-0.94	PCT	30	17	3.2
4	98	81	C03	0.59	PCT	18		
4	98	85	C03	0.71	PCT	23	16	1.7
4	99	44	C03	0.88	PCT	19	0	4.7
4	99	44	C06	0.79	PCT	17	0	4.2
4	99	44	C08	0.71	PCT	17	0	4.2
4	99	46	C03	-0.89	PCT	22	17	1.2
4	100	81	C03	0.7	PCT	18		
4	100	83	C03	-0.86	PCT	21	0	5.2
4	100	83	C07	-1.17	PCT	18		
4	101	80	C03	0.7	PCT	20	0	4.9
4	102	49	C03	0.8	PCT	21	0	5.2
4	102	51	C04	0.78	PCT	19		
4	102	79	C03	0.73	PCT	19		
4	103	76	C03	0.67	PCT	21	16	1.2
4	104	71	C03	-0.9	PCT	23	18	1.2

Note 1: Determined either from production data results or lead analyst review of raw eddy current data history.

Figure A4-9: Watts Bar U1R14 Horizontal ATSG Wear Indications Map – SG1

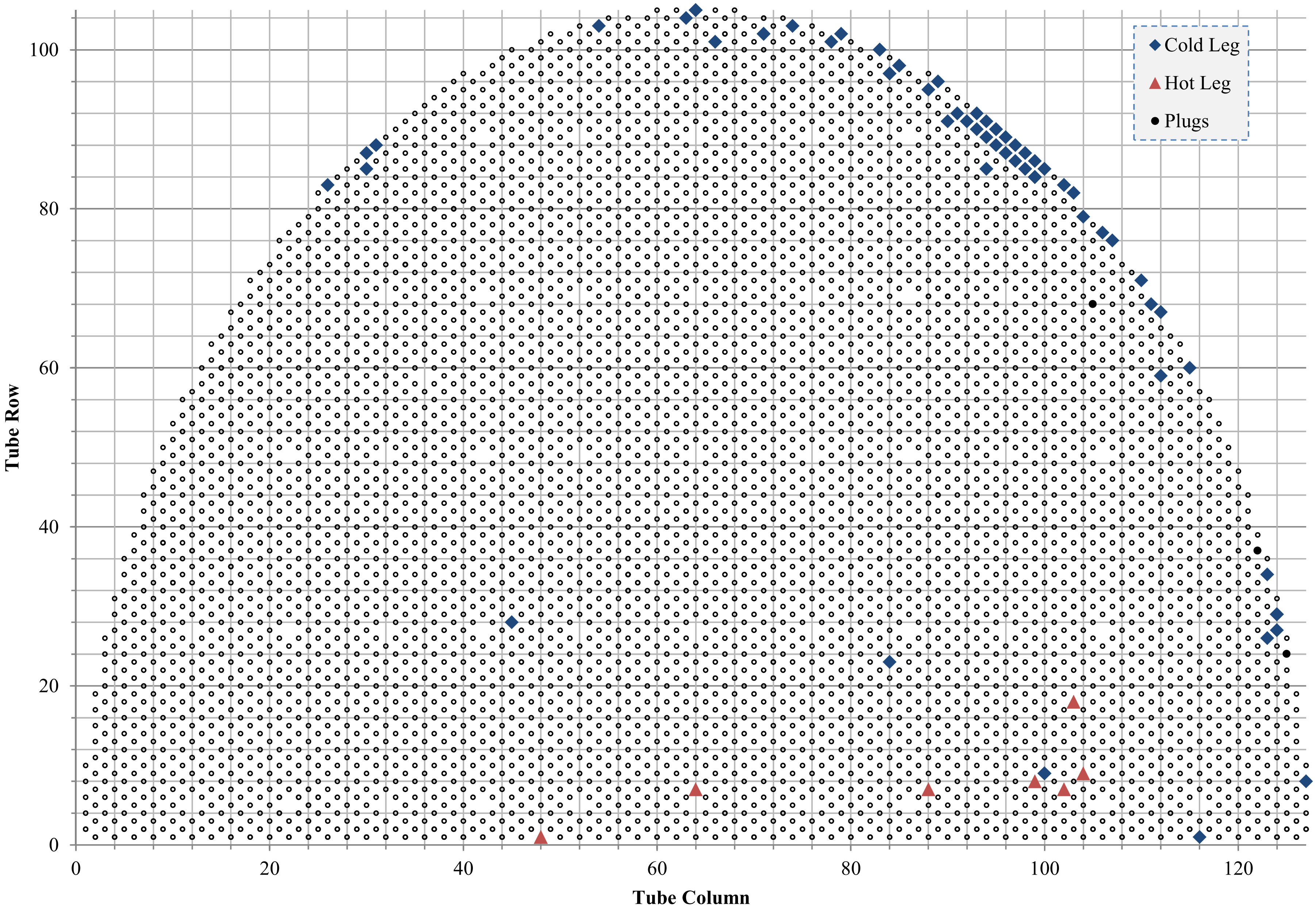


Figure A4-10: Watts Bar U1R14 Horizontal ATSG Wear Indications Map – SG2

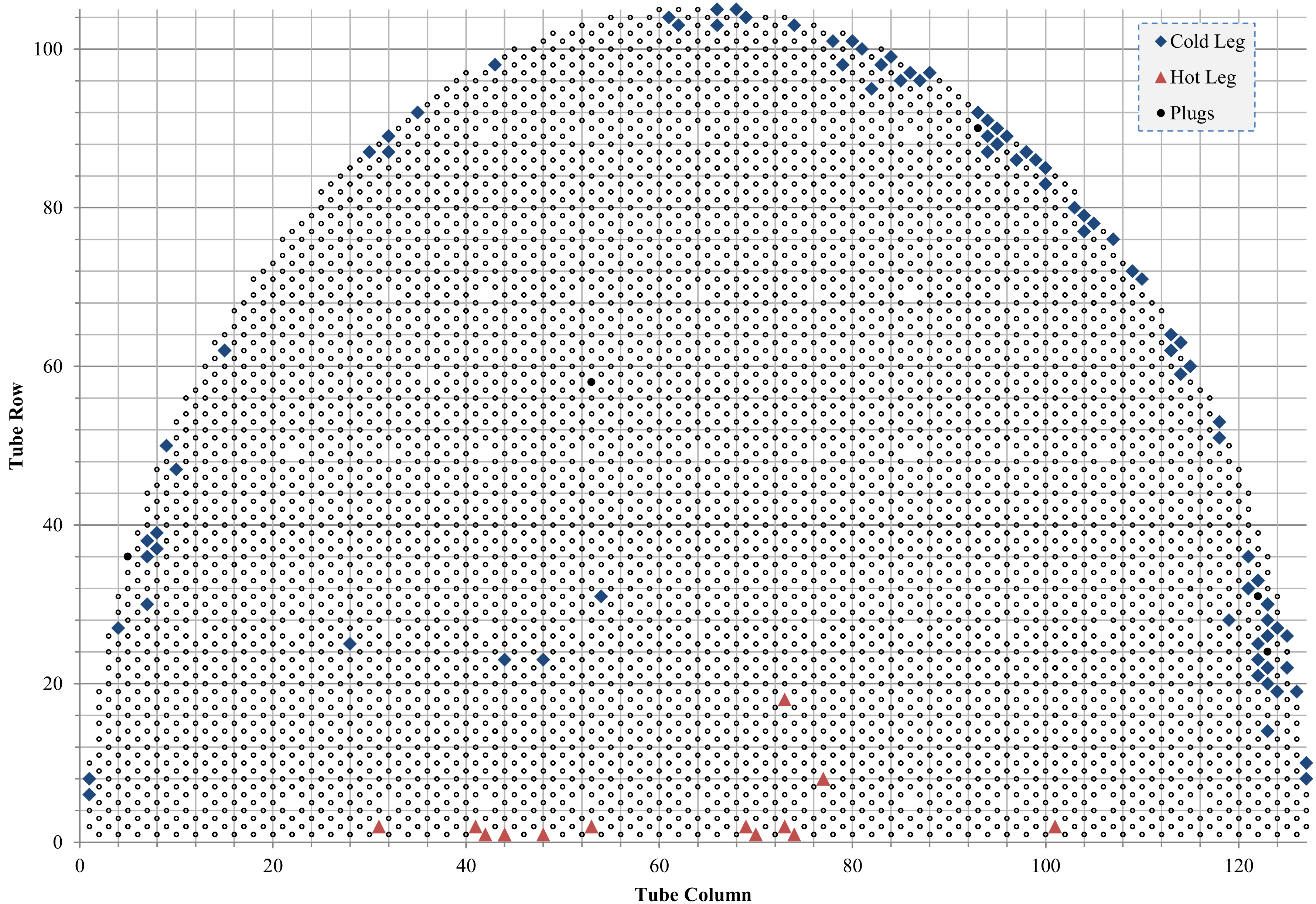


Figure A4-11: Watts Bar U1R14 Horizontal ATSG Wear Indications Map – SG3

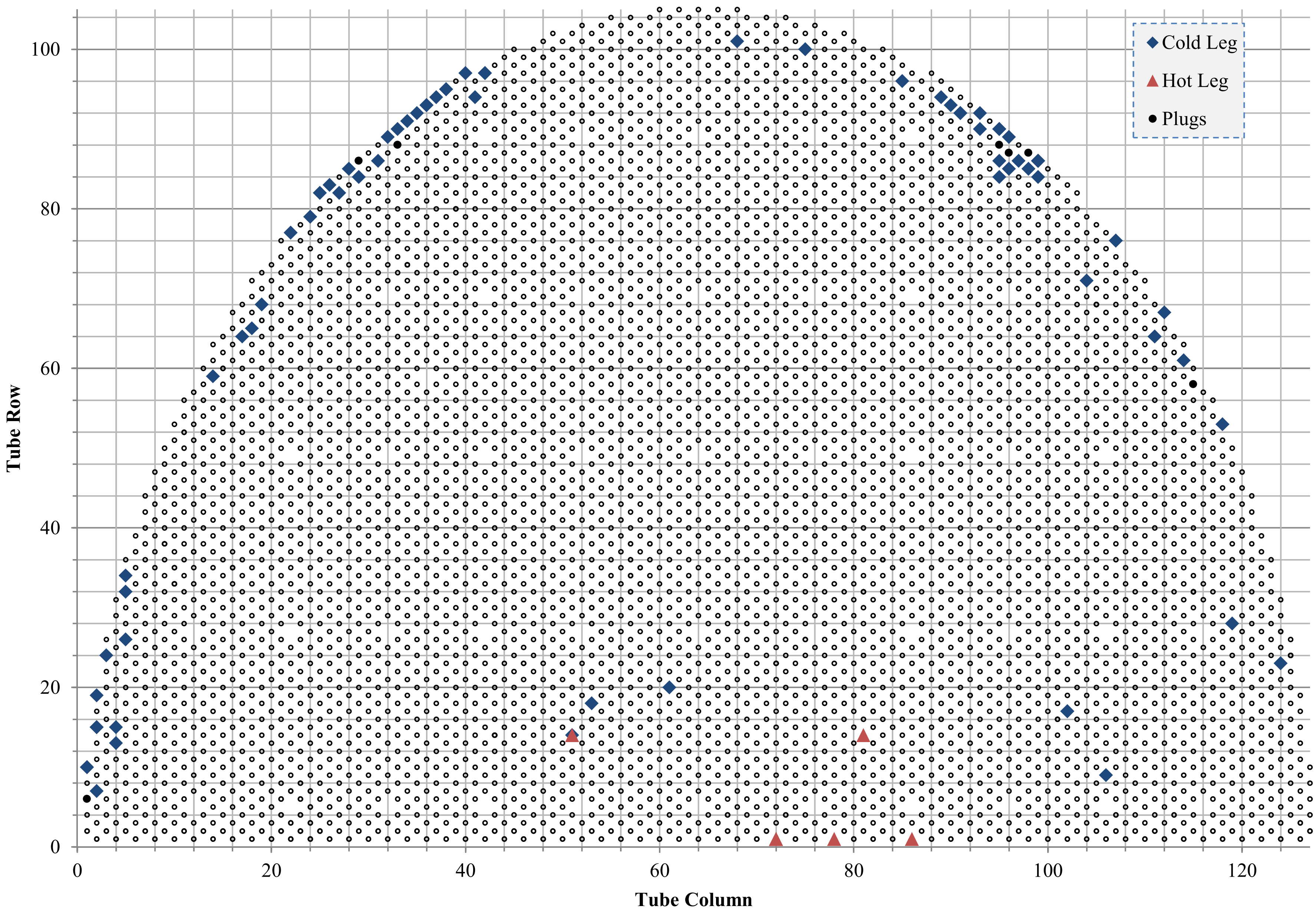


Figure A4-12: Watts Bar U1R14 Horizontal ATSG Wear Indications Map – SG4

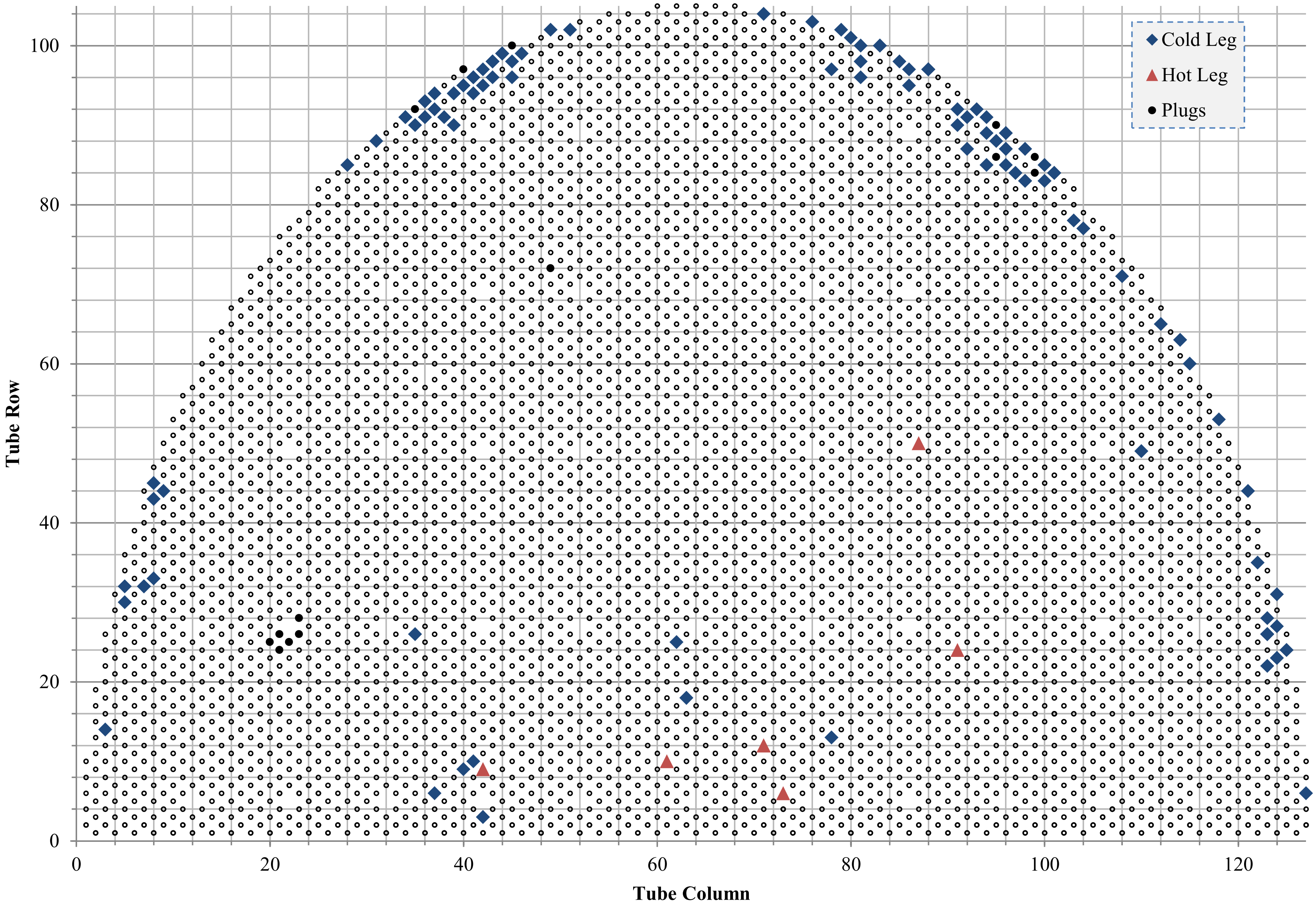


Figure A4-13: Watts Bar U1R14 Horizontal ATSG Wear Growth Cumulative Frequency Distributions

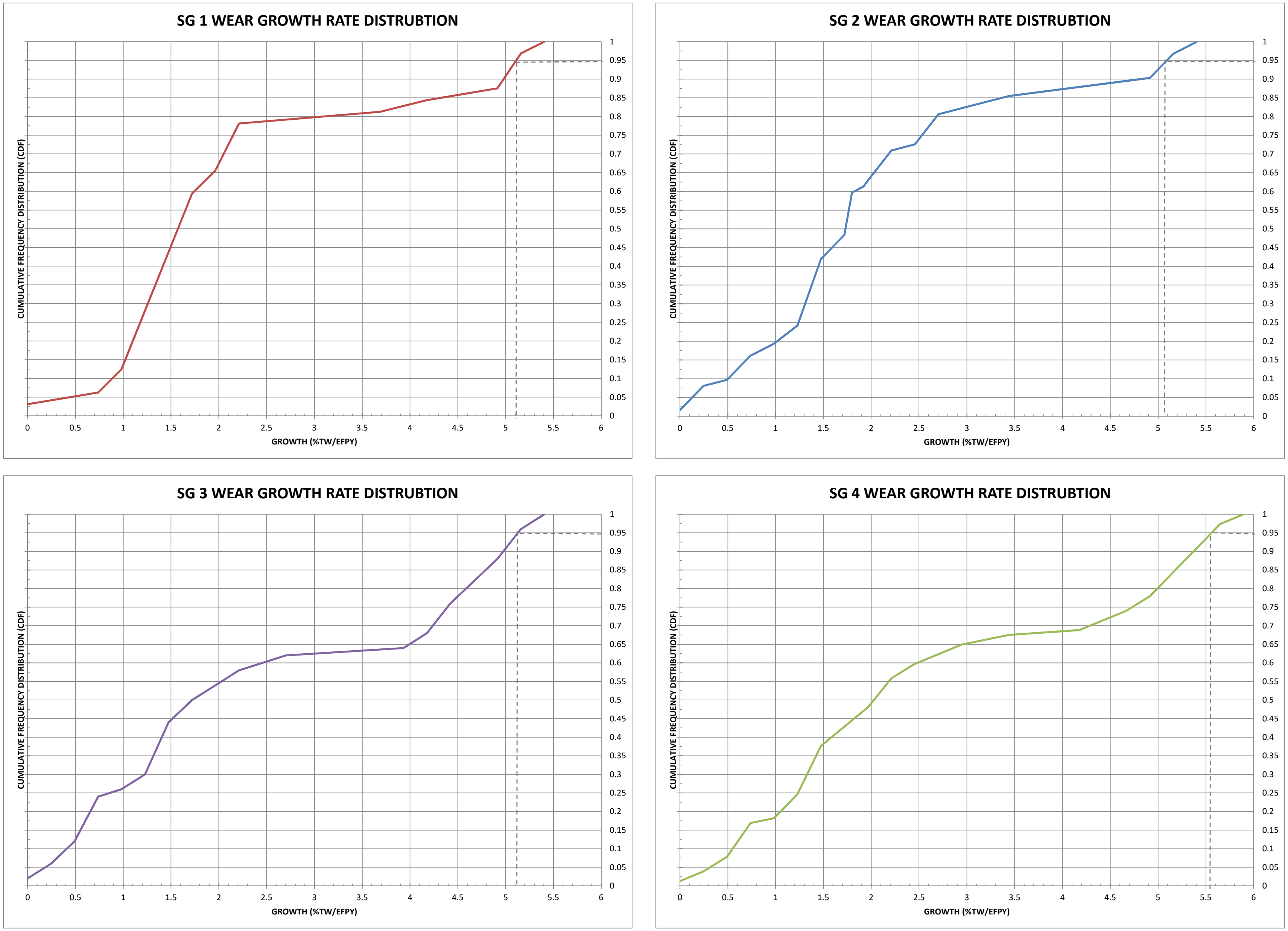
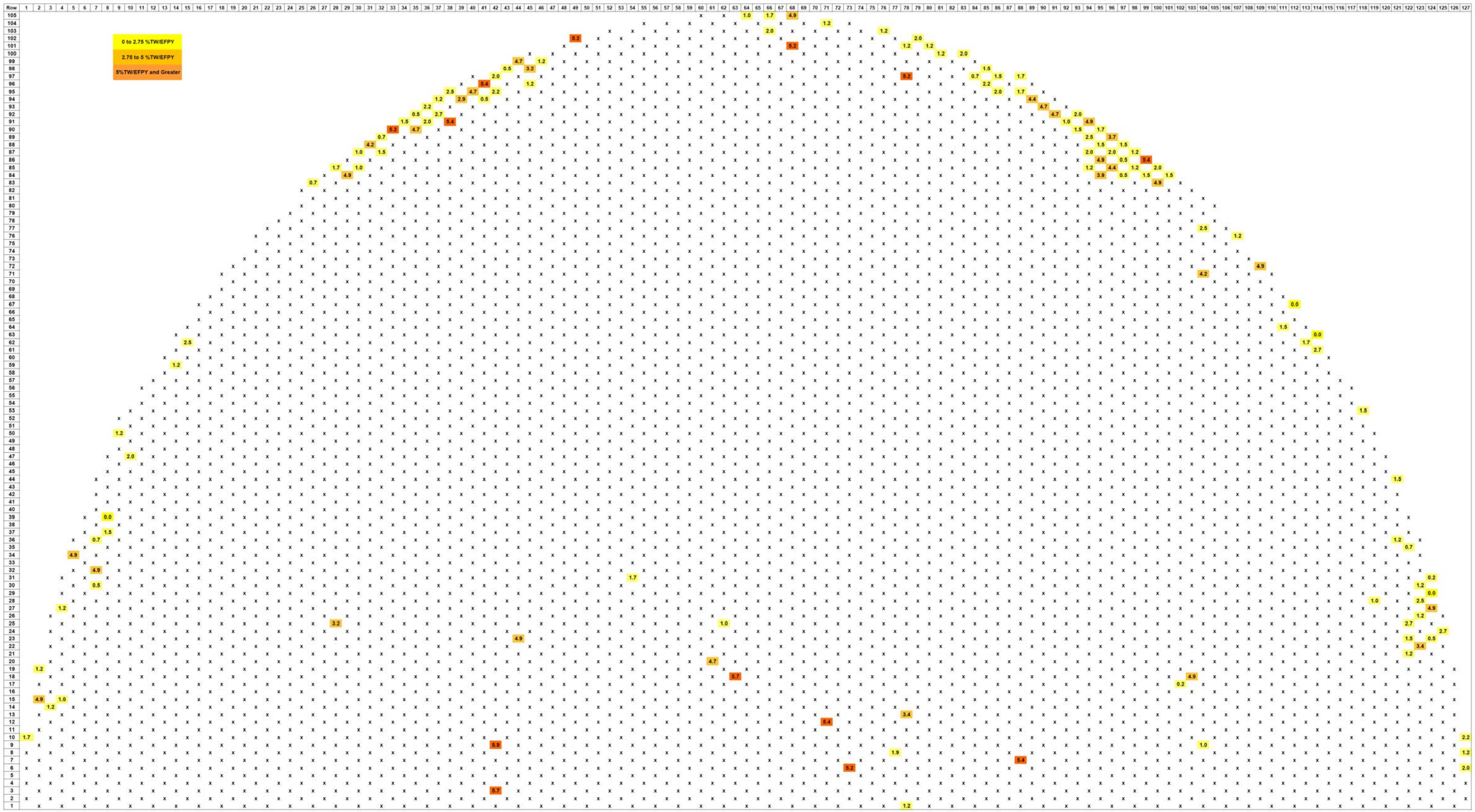


Figure A4-14: **Watts Bar U1R14 Horizontal ATSG Wear Indication Growth Rates Map – All SGs**



Note: The plotted locations include both HL and CL wear indications in all four (4) RSGs and only those indications where a history review was performed are shown. The largest growth rate is indicated for tube locations with indications in multiple RSGs. Refer to the listing in Table A4-1 through Table A4-4

Figure A4-15: Watts Bar U1R14 Horizontal ATSG Wear - Monte Carlo Simulation

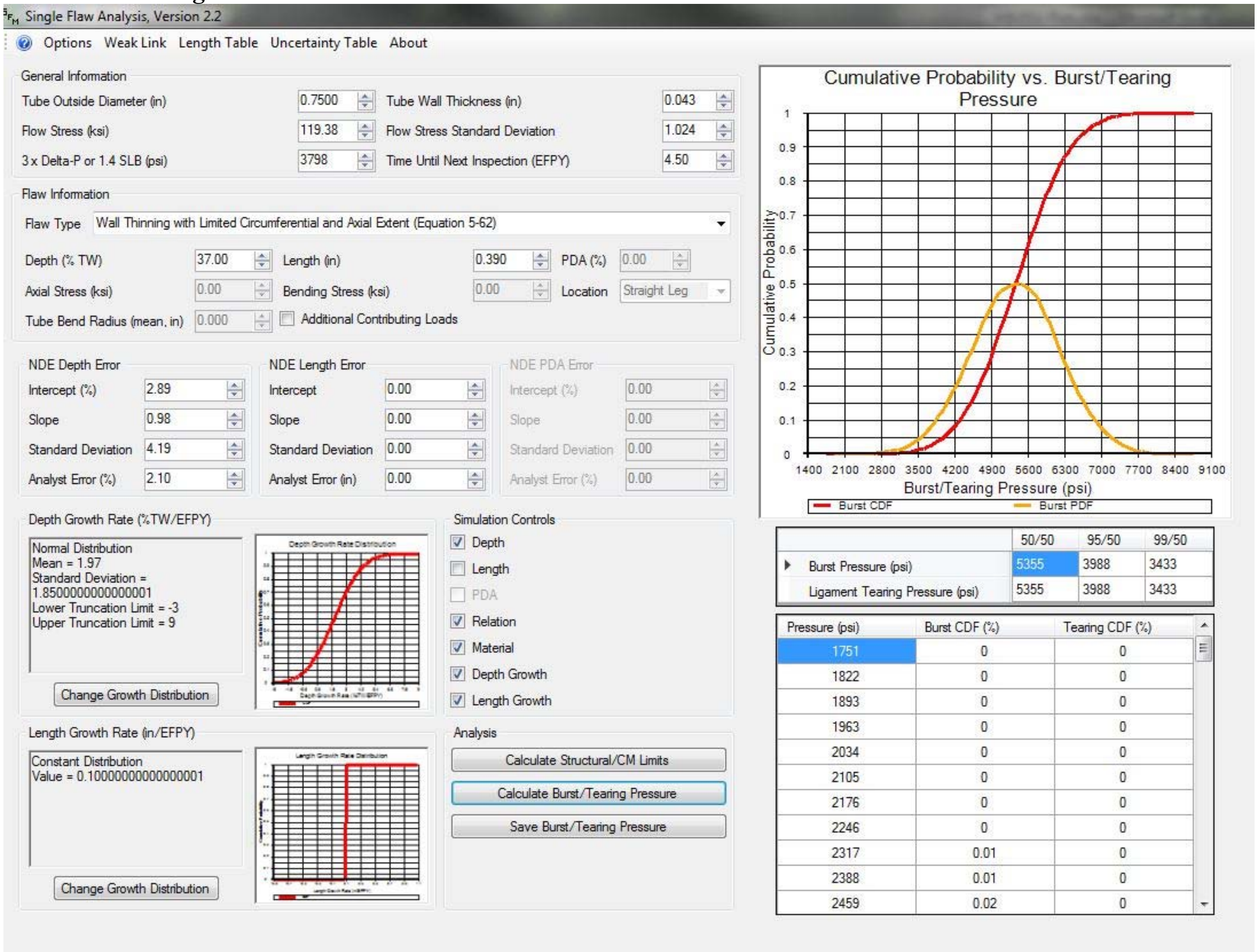
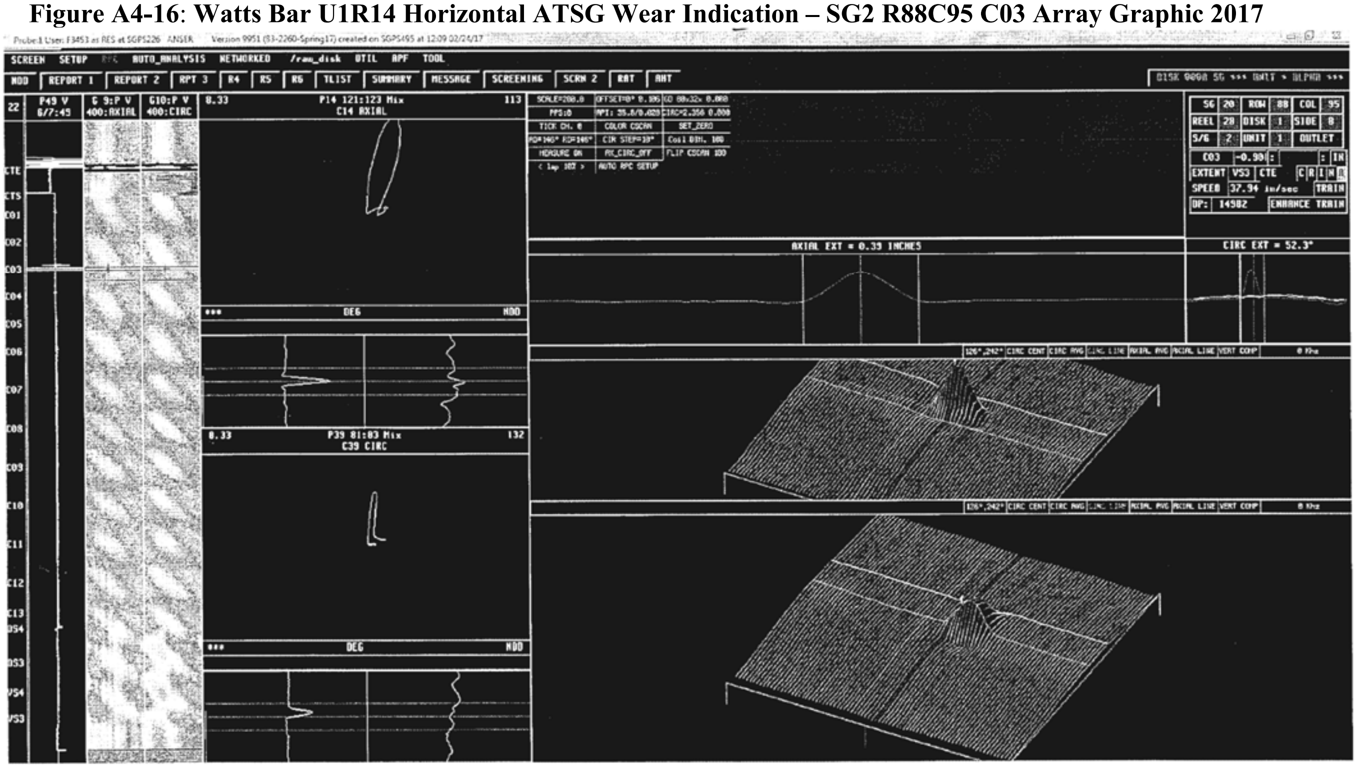


Figure A4-16: Watts Bar U1R14 Horizontal ATSG Wear Indication – SG2 R88C95 C03 Array Graphic 2017



Attachment 5 – Watts Bar U1R14 Tube Proximity Indications

Table A5-1: Watts Bar U1R14 Tube Proximity Indications (PRX) – All SGs

SG	Row	Col	Volts	Deg	Ind	Chn	Locn	Inch1	Inch2	PDia	PType	Cal
1	80	101	0.49	86	PRX	P52	DS1	4	41.66	0.61	ZYAXH	3
1	95	62	0.44	87	PRX	P52	DS1	16.74	57.29	0.61	ZYAXH	25
1	95	62	0.66	103	PRX	P52	DS3	4.43	33.05	0.61	ZYAXH	28
1	94	85	0.42	77	PRX	P52	DS4	6.01	58.15	0.61	ZYAXH	24
1	92	85	0.49	263	PRX	P52	DS4	7.08	58.84	0.61	ZYAXH	22
1	96	75	0.48	262	PRX	P52	VS5	2.25	28.68	0.61	ZYAXH	28
2	101	64	0.77	110	PRX	P52	DS1	18.52	59.45	0.61	ZYAXH	37
2	99	64	0.55	239	PRX	P52	DS1	16.71	60.5	0.61	ZYAXH	37
2	103	74	0.48	92	PRX	P52	DS3	0.34	17.56	0.61	ZYAXH	50
2	103	64	0.27	0	PRX	P52	DS4	8.03	60.25	0.61	ZYAXH	64
2	97	50	0.72	97	PRX	P52	DS4	2.13	22.13	0.61	ZYAXH	22
2	103	72	0.89	267	PRX	P52	VS2	2.69	25.11	0.61	ZYAXH	33
3	81	100	0.68	109	PRX	P52	DS1	5.85	41.43	0.61	ZYAXH	25
3	97	68	0.43	86	PRX	P52	DS1	3.71	-	0.61	ZYAXH	65
3	99	60	0.73	110	PRX	P52	DS2	2.11	33.43	0.61	ZYAXH	9
3	97	60	0.55	104	PRX	P52	DS2	2.87	32.75	0.61	ZYAXH	9
3	93	46	0.41	328	PRX	P52	DS4	2.32	23.5	0.61	ZYAXH	28
3	77	38	0.33	236	PRX	P52	DS4	2.77	43.13	0.61	ZYAXH	28
3	101	68	0.44	101	PRX	P52	VS2	4.41	-	0.61	ZYAXH	65
3	103	58	0.63	90	PRX	P52	VS4	4.33	22.88	0.61	ZYAXH	64
4	95	86	0.95	355	PRX	P52	DS1	7.94	56.39	0.61	ZYAXH	1
4	96	67	0.69	85	PRX	P52	DS1	24.71	57.81	0.61	ZYAXH	49
4	94	65	0.8	94	PRX	P52	DS1	6.27	53.61	0.61	ZYAXH	51
4	96	51	0.68	104	PRX	P52	DS1	24.5	56.57	0.61	ZYAXH	23
4	91	90	0.42	122	PRX	P52	DS4	5.93	50.6	0.61	ZYAXH	16
4	87	56	0.61	266	PRX	P52	DS4	1.8	24.07	0.61	ZYAXH	30
4	99	52	0.36	115	PRX	P52	DS4	4.64	39.15	0.61	ZYAXH	12
4	92	45	0.59	79	PRX	P52	DS4	3.02	24.12	0.61	ZYAXH	10

Figure A5-2: Watts Bar U1R14 Tube Proximity Indications in All SGs

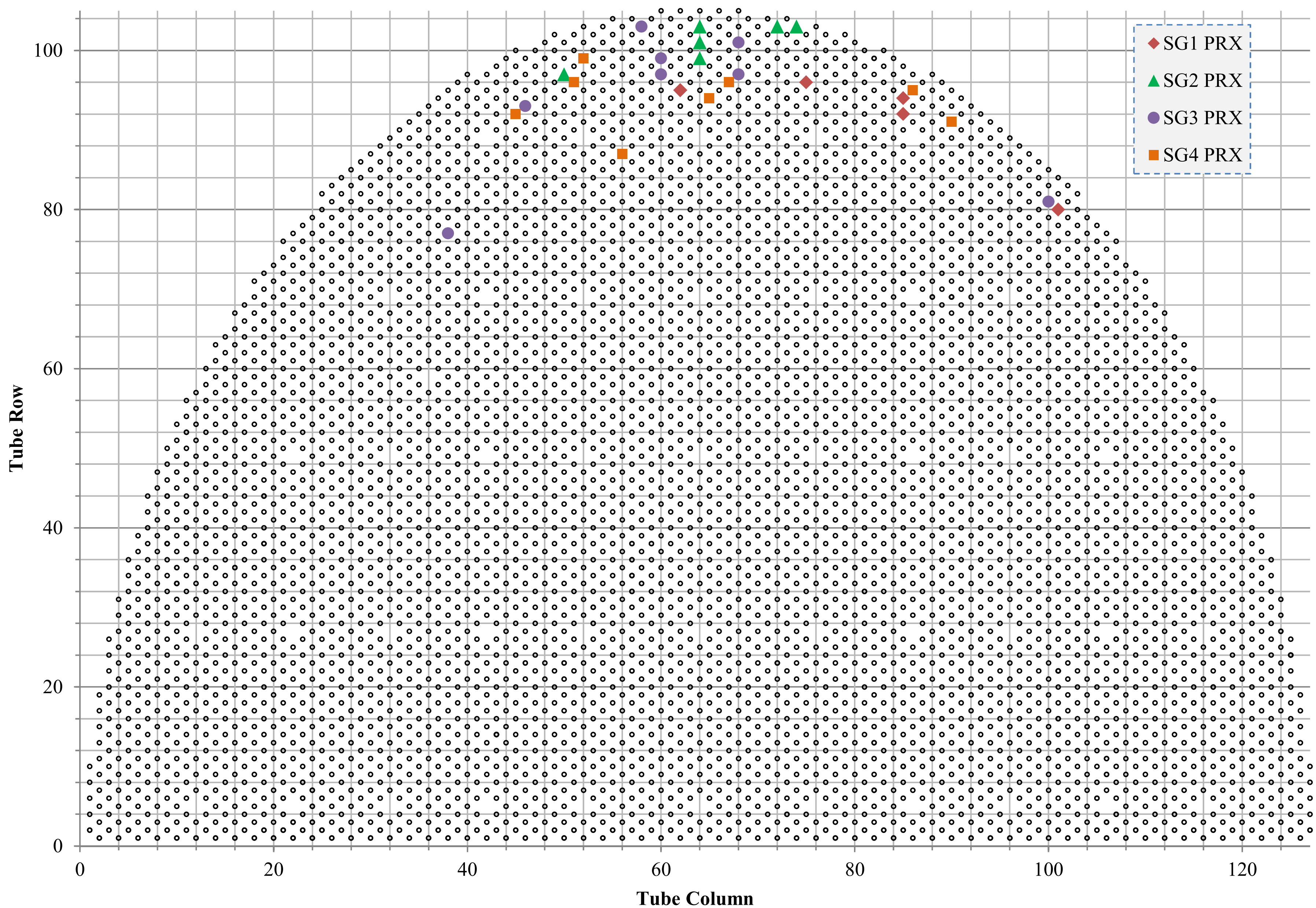


Figure A6-5: **Watts Bar U1R14 U-bend Support and Horizontal ATSG Noise Distributions**

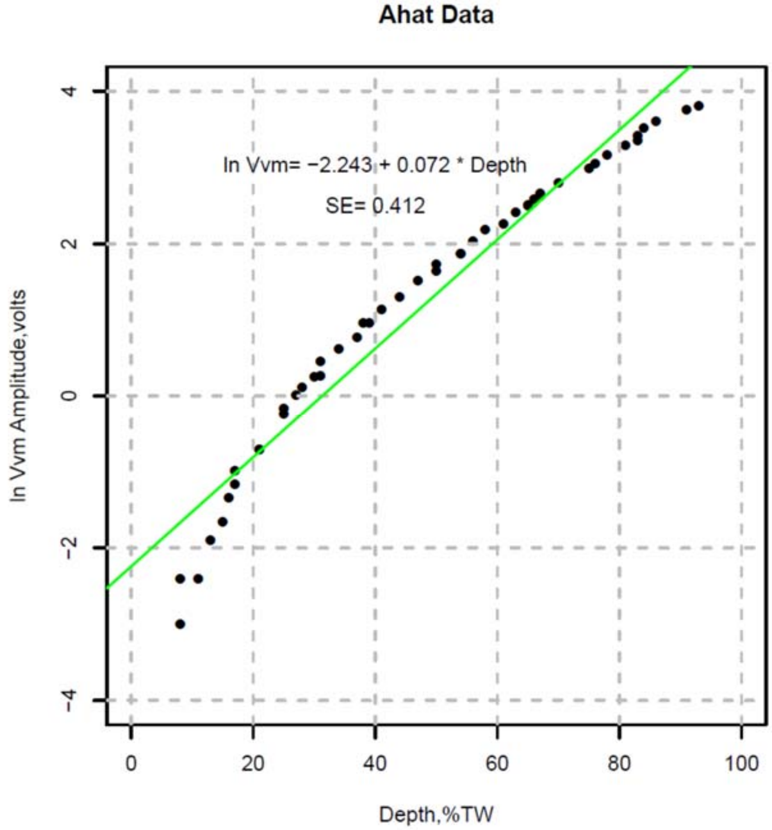
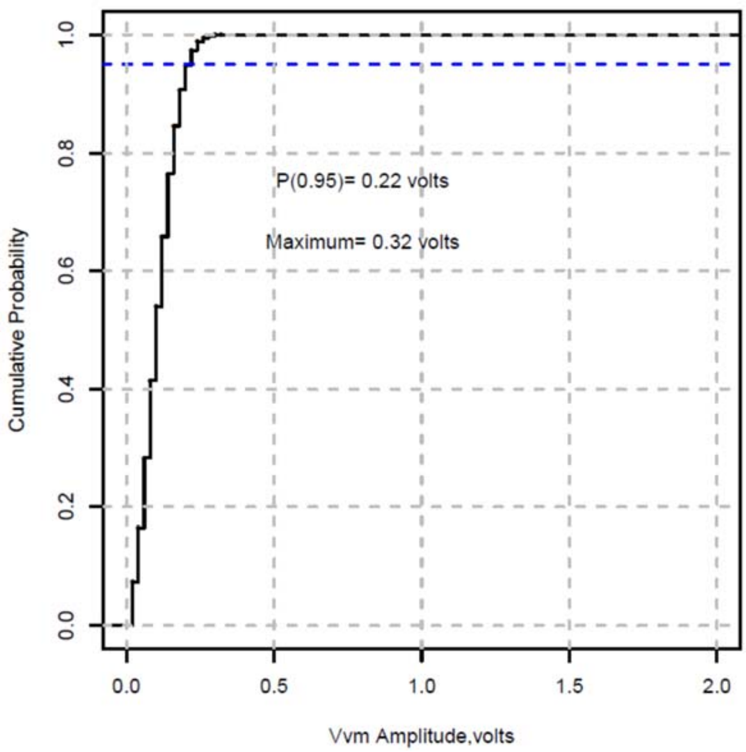
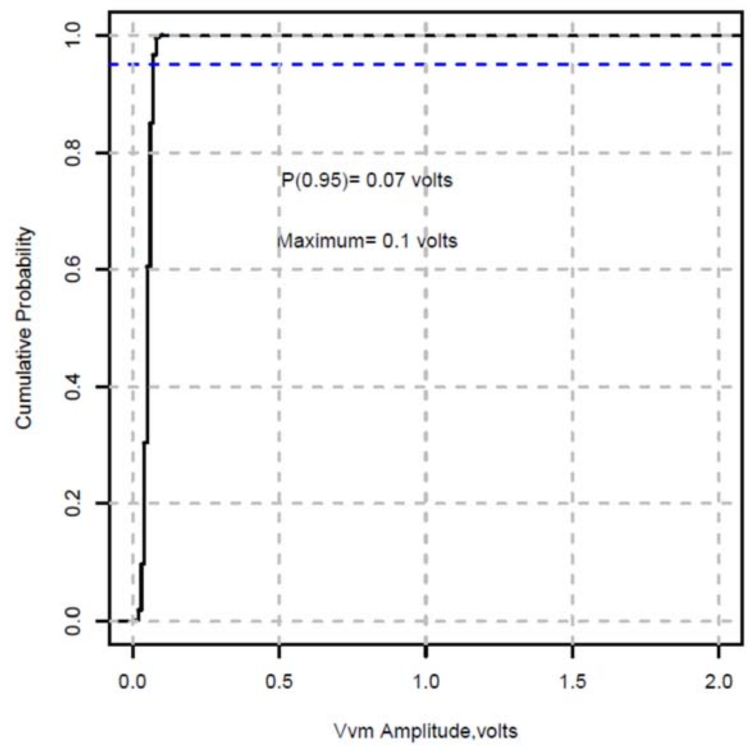


Figure A6-6: **Watts Bar U1R14 U-bend Support and Horizontal ATSG Noise Distributions**

Diagonal Bar Noise Distribution



Vertical Strap Noise Distribution



Horizontal ATSG Noise Distribution

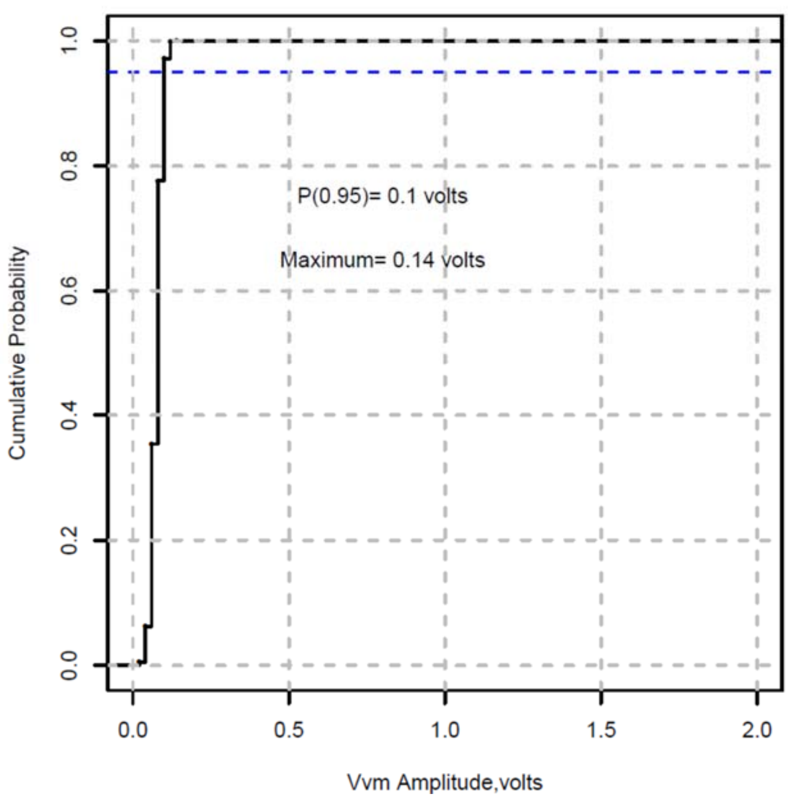
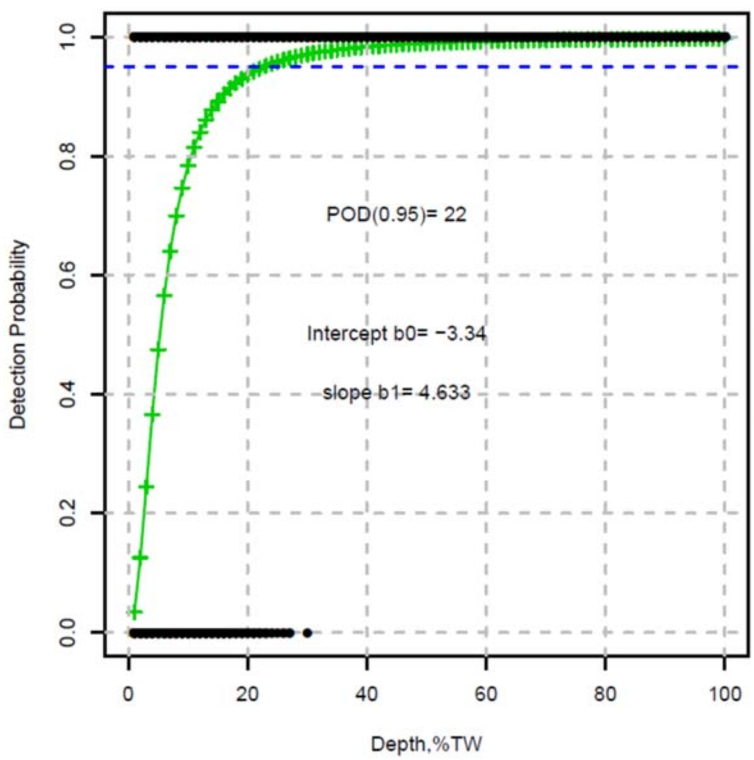
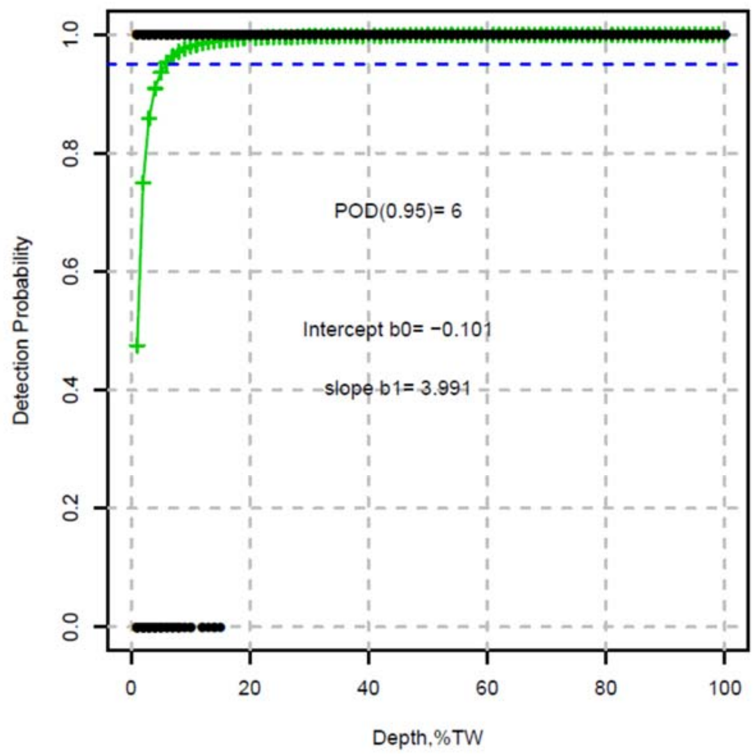


Figure A6-7: **Watts Bar U1R14 U-bend Support and ATSG MAPOD Curves**

Diagonal Bar Wear POD



Vertical Strap Wear POD



Horizontal ATSG Wear POD

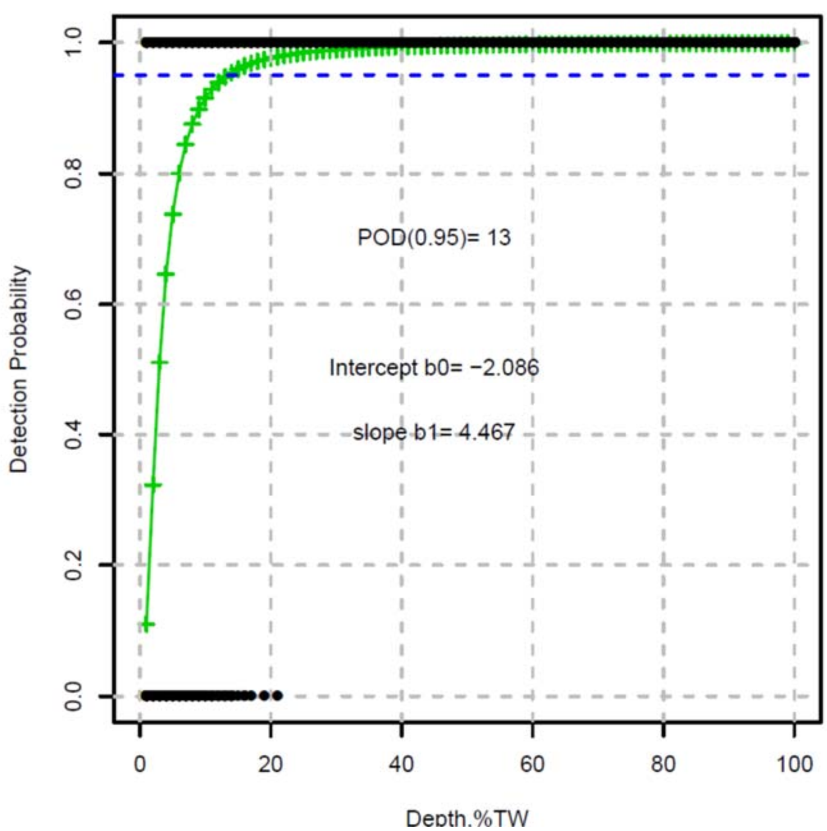
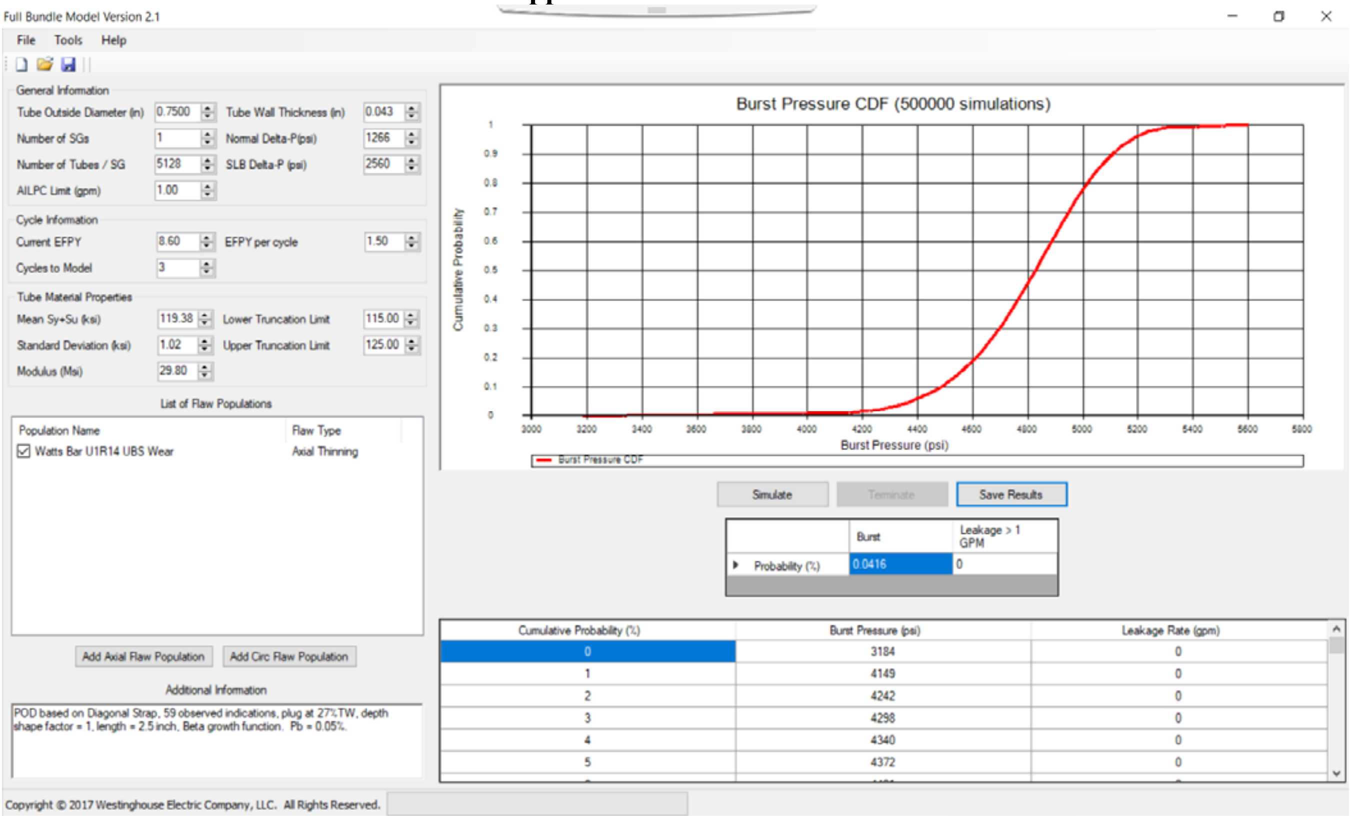


Figure A6-8: Watts Bar U1R14 U-bend Support and ATSG FBM Software Outputs

U-bend Support Structure Wear – 4.5 EFPY



Horizontal ATSG Wear – 4.5 EFPY

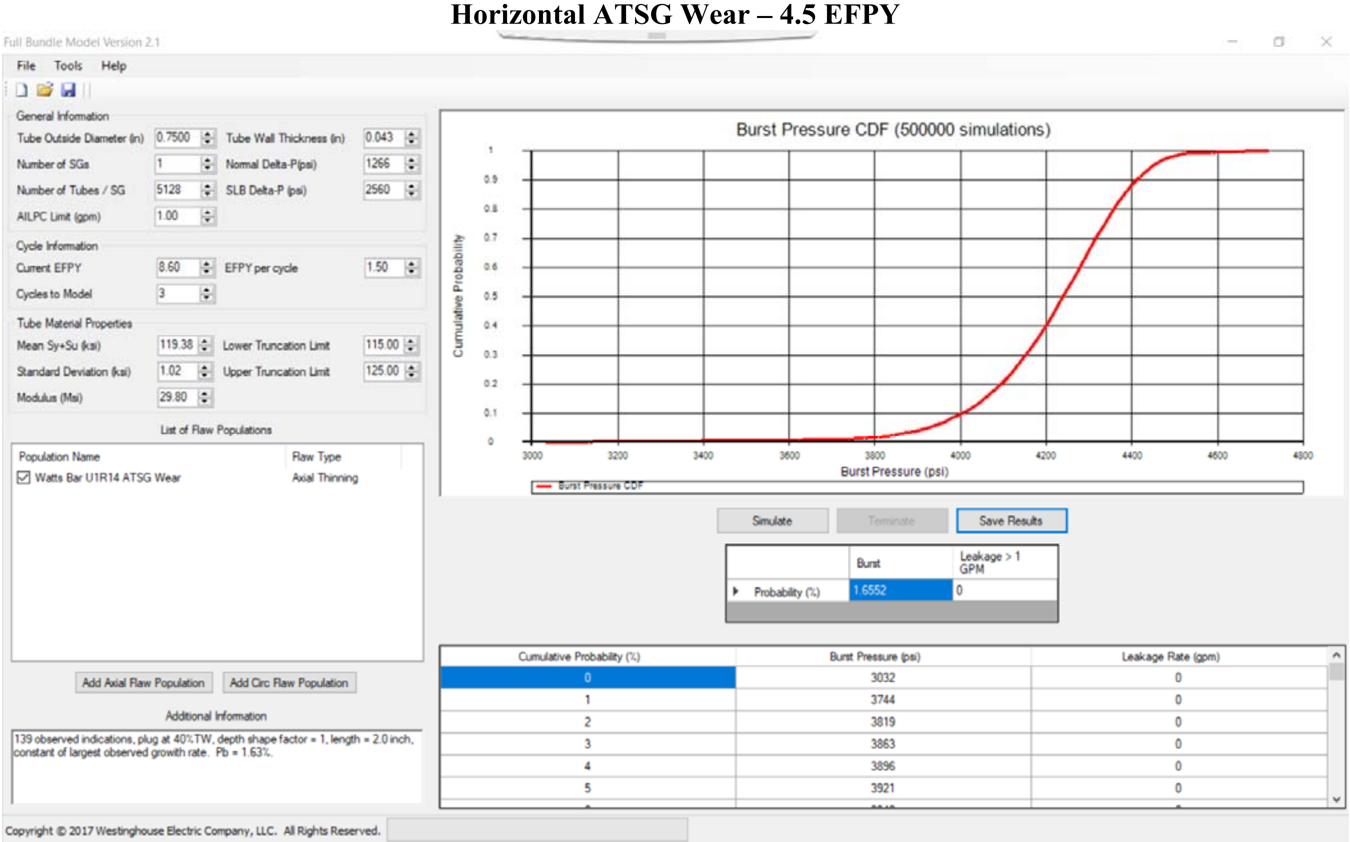
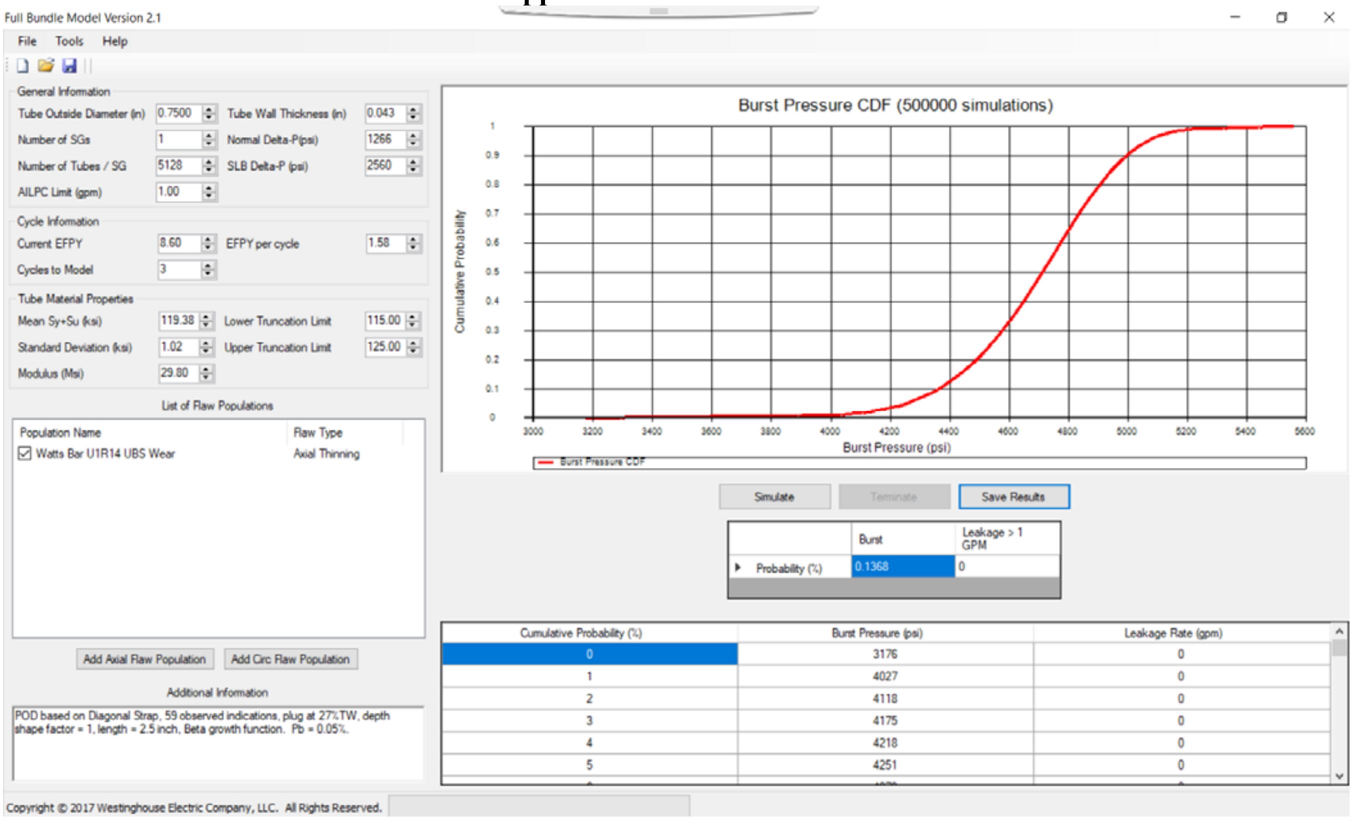
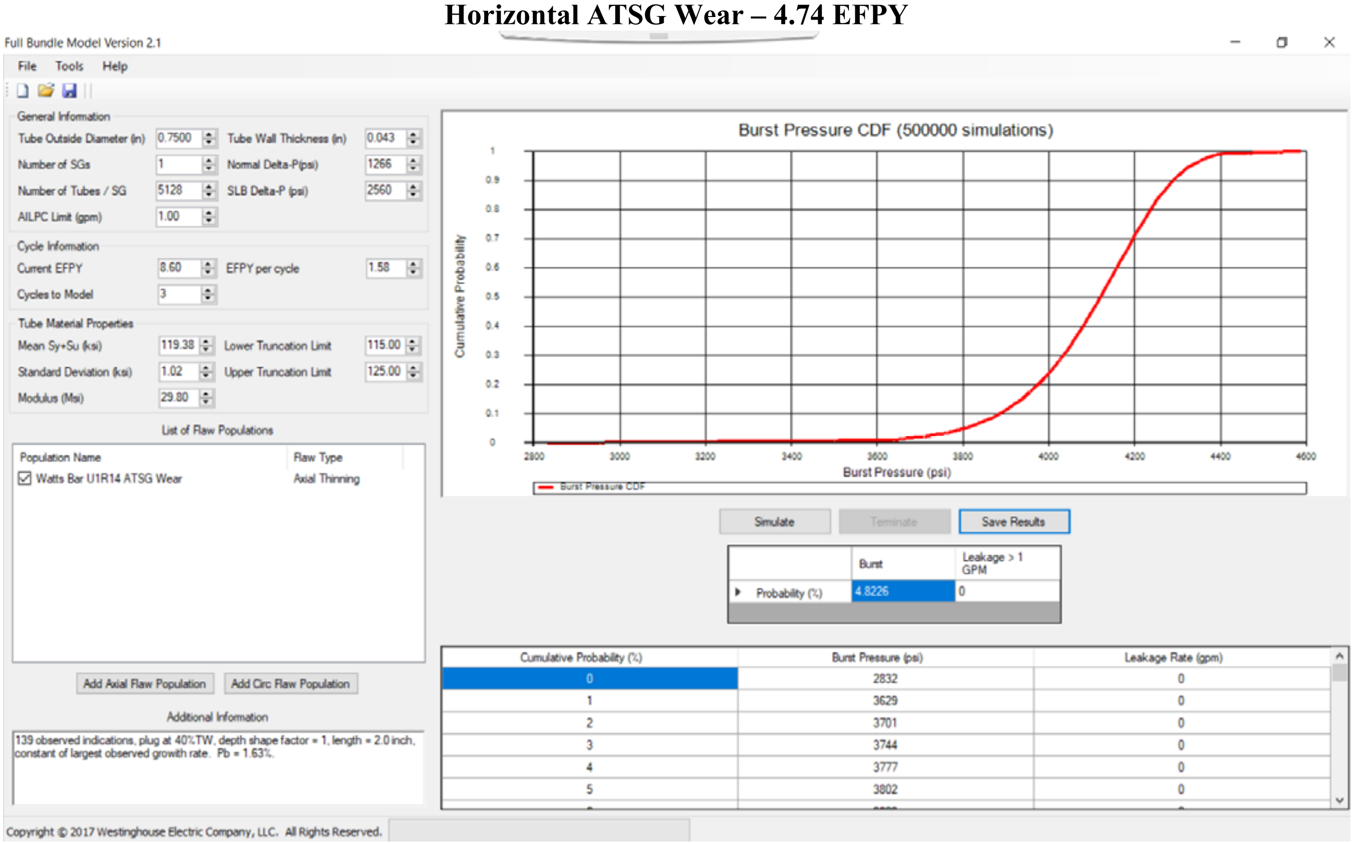


Figure A6-9: Watts Bar U1R14 U-bend Support and ATSG FBM Software Outputs (Continued)

U-bend Support Structure Wear – 4.74 EFPY



Horizontal ATSG Wear – 4.74 EFPY

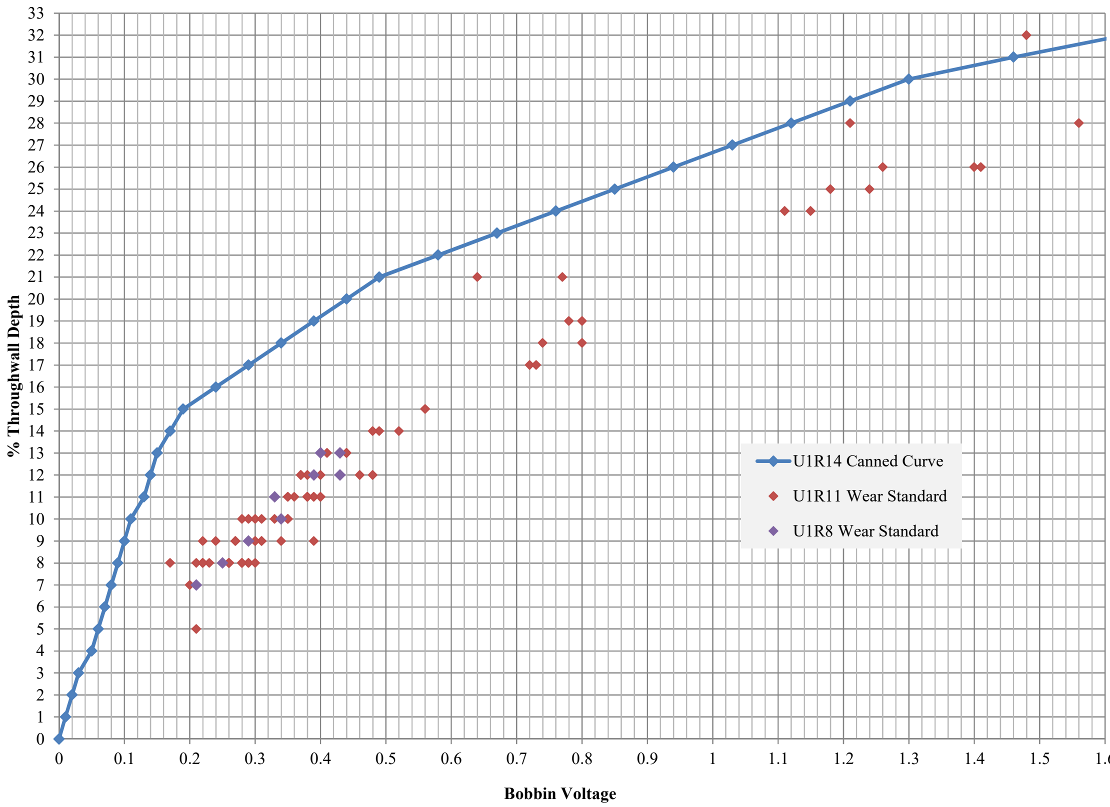


A change was made to the NDE process for sizing wear indications at Watts Bar leading up to the U1R14 inspection. Indications of support structure wear were sized using the bobbin coil which was calibrated to the flat wear eddy current standard through the U1R11 and U1R8 inspections. However, TVA elected to move to the combination bobbin and Array coil probe for the U1R14 inspection. The combination probe requires the use of different inline calibration standards specific to the Array coil which do not include the eddy current wear flaws used to size support structure wear indications at previous inspections.

Instead, a pre-determined voltage versus depth curve was generated in advance of the inspection in order to allow for sizing of volumetric wear with bobbin and still support use of the Array probe. This 'canned' curve was created based on the tapered wear flaws of the EPRI 27091 series of ETSSs. Data was collected at EPRI on the actual tapered wear standards that makeup the ETSS. These standards are of the same tube material and size as the Watts Bar Unit 1 RSGs. Further, the same data collection process used to capture the data in the EPRI standards was used during the U1R14 inspection. Figure A7-1 shows the voltage versus depth sizing curve used during U1R14 plotted against data points from the P2 mix channel during U1R11 and U1R8. Use of this sizing method is considered supplementary to the application of the condition monitoring limits associated with ETSS 96004.1.

Reviewing the two sizing methods, it becomes apparent that adjustment is necessary when comparing historical wear indications against those from the U1R14 inspection in developing growth rates. This is particularly relevant for historical indications in the range of approximately 0.2 to 0.55 volts where the wide majority of the wear indications reside. Variation in this range is on the order of about 10%TW or less. This adjustment has been made in the process of determining degradation growth rates throughout this operational assessment. TVA currently plans to continue the use of the 'canned' curve for sizing of wear degradation in future outages such that wear depth measurements can be compared directly. However, if any further changes are made to the degradation sizing process then similar considerations in degradation growth rate development may become necessary.

Figure A7-2: **Watts Bar U1R14 Support Structure Wear Sizing Method Comparisons**



Enclosure 2

Revised TS Changes (Mark-Ups) for WBN Unit 1

non-faulted steam generators. For design basis accidents that do not have a faulted steam generator, accident induced leakage is not to exceed 150 gpd per steam generator.

5.7.2.12 Steam Generator (SG) Program (continued)

3. The operational leakage performance criterion is specified in LCO 3.4.13, “RCS Operational LEAKAGE.”

c. Provisions for SG tube pluggingrepair criteria. Tubes found by inservice inspection to contain flaws with a depth equal to or exceeding 40% of the nominal tube wall thickness shall be plugged.

d. Provisions for SG tube inspections. Periodic SG tube inspections shall be performed. The number and portions of the tubes inspected and methods of inspection shall be performed with the objective of detecting flaws of any type (e.g., volumetric flaws, axial and circumferential cracks) that may be present along the length of the tube, from the tube-to-tubesheet weld at the tube inlet to the tube-to-tubesheet weld at the tube outlet, and that may satisfy the applicable tube pluggingrepair criteria. The tube-to-tubesheet weld is not part of the tube. In addition to meeting the requirements of d.1, d.2, and d.3 below, the inspection scope, inspection methods, and inspection intervals shall be such as to ensure that SG tube integrity is maintained until the next SG inspection. An assessment of degradation assessment shall be performed to determine the type and location of flaws to which the tubes may be susceptible and, based on this assessment, to determine which inspection methods need to be employed and at what locations.

1. Inspect 100% of the tubes in each SG during the first refueling outage following SG replacemeninstallationt.

2. After the first refueling outage following SG installation, inspect each SG at least every 96 effective full power months. Tube inspections shall be performed using equivalent to or better than array probe technology. For regions where a tube inspection with array probe technology is not possible (such as due to dimensional constraints or tube specific conditions), the tube inspection techniques applied shall be capable of detecting all forms of existing and potential degradation in that region. In addition, the minimum number of tubes inspected at each scheduled inspection shall be the number of tubes in all SGs divided by the number of SG inspection outages scheduled in each inspection period as defined in a and b below. If a degradation assessment indicates the potential for a type of degradation to occur at a location not previously inspected with a technique capable of detecting this type of degradation at this location and that may satisfy the applicable tube repair criteria,

(continued)

the minimum number of locations inspected with such a capable inspection technique during the remainder of the inspection period may be prorated. The fraction of locations to be inspected for this potential type of degradation at this location at the end of the inspection period shall be no less than the ratio of the number of times the SG is scheduled to be inspected in the inspection period after the determination that a new form of degradation could potentially be occurring at this location divided by the total number of times the SG is

(continued)

5.7 Procedures, Programs, and Manuals

5.7.2.12 Steam Generator (SG) Program (continued)

scheduled to be inspected in the inspection period. Each inspection period defined below may be extended up to 3 effective full power months to include a SG inspection outage in an inspection period and the subsequent inspection period begins at the conclusion of the included SG inspection outage.

a) After the first refueling outage following SG installation, inspect 100% of the tubes during the next 144 effective full power months. This constitutes the first inspection period.

b) During the next 96 effective full power months, inspect 100% of the tubes. This constitutes the second and subsequent inspection periods.~~Inspect 100% of the tubes at sequential periods of 144, 108, 72, and thereafter, 60 effective full power months. The first sequential period shall be considered to begin after the first inservice inspection of the SGs. In addition, inspect 50% of the tubes by the refueling outage nearest the midpoint of the period and the remaining 50% by the refueling outage nearest the end of the period. No SGs shall operate for more than 72 effective full power months or three refueling outages (whichever is less) without being inspected.~~

3. If crack indications are found in any SG tube, then the next inspection for each affected and potentially affected SG for the degradation mechanism that caused the crack indication shall not exceed 24 effective full power months or one refueling outage (whichever results in more frequent inspections~~is less~~). If definitive information, such as from examination of a pulled tube, diagnostic non-destructive testing, or engineering evaluation indicates that a crack-like indication is not associated with a crack(s), then the indication need not be treated as a crack.

e. Provisions for monitoring operational primary-to-secondary LEAKAGE.

(continued)

Enclosure 3

Revised TS Changes (Final Typed) for WBN Unit 1

5.7 Procedures, Programs, and Manuals

5.7.2.12 Steam Generator (SG) Program (continued)

3. The operational leakage performance criterion is specified in LCO 3.4.13, “RCS Operational LEAKAGE.”

c. Provisions for SG tube plugging criteria. Tubes found by inservice inspection to contain flaws with a depth equal to or exceeding 40% of the nominal tube wall thickness shall be plugged.

d. Provisions for SG tube inspections. Periodic SG tube inspections shall be performed. The number and portions of the tubes inspected and methods of inspection shall be performed with the objective of detecting flaws of any type (e.g., volumetric flaws, axial and circumferential cracks) that may be present along the length of the tube, from the tube-to-tubesheet weld at the tube inlet to the tube-to-tubesheet weld at the tube outlet, and that may satisfy the applicable tube plugging criteria. The tube-to-tubesheet weld is not part of the tube. In addition to meeting the requirements of d.1, d.2, and d.3 below, the inspection scope, inspection methods, and inspection intervals shall be such as to ensure that SG tube integrity is maintained until the next SG inspection. A degradation assessment shall be performed to determine the type and location of flaws to which the tubes may be susceptible and, based on this assessment, to determine which inspection methods need to be employed and at what locations.

1. Inspect 100% of the tubes in each SG during the first refueling outage following SG installation.

2. After the first refueling outage following SG installation, inspect each SG at least every 96 effective full power months. Tube inspections shall be performed using equivalent to or better than array probe technology. For regions where a tube inspection with array probe technology is not possible (such as due to dimensional constraints or tube specific conditions), the tube inspection techniques applied shall be capable of detecting all forms of existing and potential degradation in that region. In addition, the minimum number of tubes inspected at each scheduled inspection shall be the number of tubes in all SGs divided by the number of SG inspection outages scheduled in each inspection period as defined in a and b below. If a degradation assessment indicates the potential for a type of degradation to occur at a location not previously inspected with a technique capable of detecting this type of degradation at this location and that may satisfy the applicable tube repair criteria, the minimum number of locations inspected with such a capable inspection technique during the remainder of the inspection period may be prorated. The fraction of locations to be inspected for this potential type of degradation at this location at the end of the inspection period shall be no less than the ratio of the number of times the SG is scheduled to be inspected in the inspection period after the determination that a new form of degradation could potentially be occurring at this location divided by the

(continued)

5.7 Procedures, Programs, and Manuals

5.7.2.12 Steam Generator (SG) Program (continued)

total number of times the SG is scheduled to be inspected in the inspection period. Each inspection period defined below may be extended up to 3 effective full power months to include a SG inspection outage in an inspection period and the subsequent inspection period begins at the conclusion of the included SG inspection outage.

a) After the first refueling outage following SG installation, inspect 100% of the tubes during the next 144 effective full power months. This constitutes the first inspection period.

b) During the next 96 effective full power months, inspect 100% of the tubes. This constitutes the second and subsequent inspection periods.

3. If crack indications are found in any SG tube, then the next inspection for each affected and potentially affected SG for the degradation mechanism that caused the crack indication shall not exceed 24 effective full power months or one refueling outage (whichever results in more frequent inspections). If definitive information, such as from examination of a pulled tube, diagnostic non-destructive testing, or engineering evaluation indicates that a crack-like indication is not associated with a crack(s), then the indication need not be treated as a crack.

e. Provisions for monitoring operational primary-to-secondary LEAKAGE.

(continued)