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Watts Bar Nuclear Plant, Unit 2
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Subject: **Watts Bar Nuclear Plant (WBN) Unit 2 - Cycle 1 Steam Generator Tube Inspection Report**

In accordance with the requirements of WBN Technical Specification (TS) 5.9.9, "Steam Generator Tube Inspection Report," the Enclosure provides the 180 Day Steam Generator Inspection Report for Unit 2 Cycle 1. This report is required to be submitted within 180 days after the initial entry into MODE 4 following the completion of an inspection performed in accordance with TS 5.7.2.12, "Steam Generator (SG) Program." The report provides the complete results of the tube inspections.

There are no regulatory commitments in this submittal. Please direct any questions concerning this matter to Kim Hulvey, Site Licensing Manager, at 423-365-7720.

Respectfully,

Paul Simmons
Site Vice President
Watts Bar Nuclear Plant

Enclosure:
Watts Bar U2R1 180 Day Steam Generator Tube Inspection Report

cc: See Page 2

Enclosures
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Enclosure

Watts Bar U2R1 180 Day Steam Generator Tube Inspection Report

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Watts Bar U2R1
180 Day Steam Generator
Tube Inspection Report

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Watts Bar U2R1
180 Day Steam Generator
Tube Inspection Report

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Record of Revisions

Revision	Date	Description
0a	December 2017	Preliminary draft for Tennessee Valley Authority review and comment.
0	January 2018	Incorporated comments from Tennessee Valley Authority, final approved and issued.

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List of Tables and Figures

1.0 Introduction

The first in-service inspections (ISI) of the Watts Bar Unit 2 (WBN2) steam generators (SGs) were performed during the fall 2017 refueling outage designated as U2R1. The U2R1 inspection was performed after 0.74 effective full power years (EFPY) of plant operation. The inspections included eddy current testing of the SG tubing as well as primary side visual inspections, secondary side visual inspections and secondary side cleanings. This report documents the "Watts Bar U2R1 180-Day Steam Generator Tube Inspection Report" as required by the WBN2 Technical Specifications. The steam generators at WBN2 are a Westinghouse Model D3 preheater-type design where the majority of the feedwater enters near the top of the tubesheet on the cold leg side and the tubing is made from mill annealed Alloy 600 (Alloy 600MA) material. Figure 1-1 below provides the arrangement and location designation of the tube support structures for the WBN2 SGs.

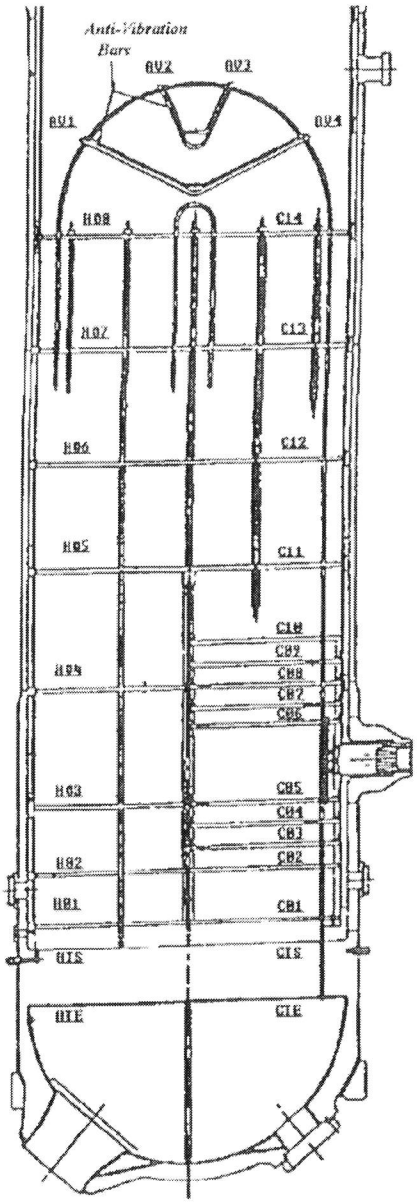

Figure 1-1: Tube Support Arrangement for Watts Bar Unit 2 Model D3 Steam Generators

Notes: H/C/AV = Hot Leg Support/Cold Leg Support/Anti-Vibration Bar (AVB) Location
HTS/CTS = Hot Leg Top of Tubesheet/Cold Leg Top of Tubesheet
HTE/CTE = Hot Leg Tube End/Cold Leg Tube End

2.0 180 Day Steam Generator Tube Inspection Report

In accordance with WBN2 Technical Specification Section 5.7.2.12, "Steam Generator Program", and Technical Specification Section 5.9.9, "Steam Generator Tube Inspection Report", this report documents the scope and results of the Watts Bar U2R1 SG inspections. There are seven specific reporting requirements associated with the Technical Specification. Each lettered reporting requirement listed below is followed with the associated information based on the inspections performed during U2R1.

a. The Scope of Inspections Performed on each SG

The inspection program addressed the known degradation observed in the Watts Bar Unit 2 SGs during the pre-service inspection, potential in-service SG tube degradation mechanisms and included proactive examinations to address areas where no degradation is anticipated but monitoring is performed regardless. The inspections were performed with qualified non-destructive examination (NDE) techniques for each existing and potential mechanism. The defined scope that was implemented in all four SGs included:

- 100% bobbin inspection of all open tubes in all four SGs full length and tube Rows 1 through 4 to the top tube support plate from both the hot leg (HL) and cold leg (CL) sides.
- 100% +POINT probe inspection of tube Rows 1 through 4 from the top tube support plate on the HL side to the top tube support plate on the CL side.
- +POINT probe 'Special Interest' inspections of tube locations with non-resolved bobbin and/or Array probe signals.
- 100% +POINT probe inspection of the hot leg top of tubesheet region from HTS+2/-2 inches.
- 50% Combination bobbin and Array probe inspection from C06 to CTS-2 inches. This inspection included all CL peripheral tubes two (2) tubes deep.
- 100% +POINT or Array probe inspection of DNTs and DNGs $\geq$ 5 Volts in the HL straight lengths, U-bends and the top tube support plate (TSP) on the CL side
- 20% +POINT or Array probe inspection of all DNTs and DNGs $\geq$ 2 Volts
- 100% +POINT probe inspection of any DNT or DNG signal located within 1.0 inch or less of a manufacturing burnish mark (MBM).
- +POINT or Array probe inspection of tubes surrounding known locations of foreign objects from the pre-service inspection.
- +POINT or Array probe inspection of all tubes within a two (2) tube pitch of the region surrounding any foreign object wear or possible loose part (PLP) locations.
- +POINT probe inspection of SG3 tube Row 47 Column 48 at H01 and all tubes within one (1) tube of this location at the same elevation. An anomaly in the support plate was identified at this location during the pre-service inspection.
- +POINT probe inspection of bobbin tube-to-tube proximity (PRO or PRX) signals >1.25 Volt.
- 100% visual inspection of all installed tube plugs from the primary side on both the HL and CL side.
- Visual inspection in all SGs of channel head primary side HL and CL inclusive of the entire divider plate to channel head weld and all visible clad surfaces.

The Watts Bar U2R1 inspection included all tubes with prior indications of degradation. The table below summarizes the number and type of eddy current examinations performed during U2R1 excluding the special interest inspection scope.

Table 2-1: Watts Bar U2R1 Steam Generator Eddy Current Inspection Scope

Eddy Current Exam Type	SG 1	SG 2	SG 3	SG 4
Full Length Bobbin	4,200	4,197	4,214	4,204
CL R1-R4 Low Row Bobbin	451	452	454	454
HL R1-R4 Low Row Bobbin	451	450	454	454
U-Bend +Point R1-R4	451	450	454	454
HL +Point Tubesheet	4,651	4,647	4,668	4,658
CL Straight Leg X-Probe C06 to CTS-2 inch	2,662	2,649	2,711	2,705

In addition to the NDE and primary side inspections discussed, visual inspection was performed in all SGs in order to determine the deposit and foreign object removal effectiveness of the tubesheet cleaning process applied. This was followed by a foreign object search and retrieval (FOSAR) inspection performed at the top of the tubesheet in all four SGs. Finally, visual inspection was also performed of the SG upper internal components in SG1 and SG4 during Watts Bar U2R1.

b. Degradation Mechanisms Found

Volumetric tube wear was the only degradation mechanism detected during the U2R1 inspection. All of the in-service volumetric wear indications detected were located at tube intersections with either TSPs or AVBs. Volumetric indications generated during tube manufacture and bundle assembly and initially detected during the pre-service inspections were also detected during U2R1. These indications are not considered an active or ongoing in-service degradation mechanism but are listed for completeness. Table 2-2 below shows the number of indications reported for each degradation mechanism during the U2R1 inspections. It is notable that no indications of stress corrosion cracking were detected during U2R1.

Table 2-2: Number of Indications Detected for Each Degradation Mechanism

Degradation Mechanism	SG1	SG2	SG3	SG4	Total
Volumetric Indications (Pre-Service)	12	3	8	15	38
Wear at Tube Support Plates	0	0	5	0	5
Wear at Anti-Vibration Bars	3	5	1	8	17

c. Nondestructive Examination (NDE) Techniques Utilized for Each Degradation Mechanism

Table 2-3 provides the NDE techniques that were used for the detection of each degradation mechanism considered as existing or potential for the U2R1 inspection. NDE techniques are also listed which were available for diagnostic testing, resolution and confirmation of anomalous indications. All the examination technique specification sheets (ETSSs) used during U2R1 are from the electric power research institute (EPRI) database. In some cases a variable 'X' is used in the listing of techniques in Table 2-3 which is in reference to a series of ETSSs.

Table 2-3: NDE Techniques for Each Existing or Potential Degradation Mechanism

Degradation Mechanism	ETSS Detection Technique
Existing	
Volumetric Indications due to Tube Fabrication and Installation (Pre-Service)	B: 27091.1 B: 27091.2
Wear at AVBs	B: 96041.1 +Pt: 10908.4 A: 17908.1 A: 17908.2
Wear at Tube Support Plates	B: 96042.1 A: 11956.1 A: 11956.2 A: 11956.3 A: 11956.4
Potential	
Wear due to Foreign Objects	B: 27091.1 +Pt: 21998.1 A: 1790X.1 A: 1790X.3
Tube-to-Tube Contact Wear	B: 13091.2
OD Pitting of the Tube Material	B: 96005.3 +Pt: 21998.1 A: 24998.1
Axial and Circumferential PWSCC at the TTS	+Pt: 20511.1 Ax +Pt: I11524 Cir A: 20501.1 Ax A: 20500.1 Cir
Axial and Circumferential ODSCC at the TTS	+Pt: I28424 Ax +Pt: I28425 Ax +Pt: 21410.1 Cir A: 20400.1 Ax/Cir
Axial ODSCC at Tube Support Plates	B: I28411 +Pt: I28424 A: 20402.1
Axial and Circumferential PWSCC in the Low Row U-bends	+Pt: 96511.2 or +Pt: 99997.1
ODSCC at Tube Dents and Dings	B: I28411 or B: 24013.1 B: 10013.1 +Pt: 22401.1 A: 20400.1 A: 20403.1
SCC at Tube Bulges and Overexpansions	+Pt: I28424 Ax +Pt: I28425 Ax +Pt: 21410.1 Cir A: 20400.1 Ax/Cir
Axial ODSCC in the Freespan	B: I28413 A: 20403.1
ODSCC at Dents and Dings Coincident with an MBM	+Pt: 22401.1
Diagnostic	
Anomalous Indications	Gh: 20406.1 Gh: 20507.1 Gh: 20508.1 Gh: 20509.1

Acronym Definitions for Table 2-3

+Pt: +POINT Probe
A: Array Probe
AVB: Anti-Vibration Bar
Ax: Axial
B: Bobbin Probe
Cir: Circumferential
ETSS: Eddy current Technique Specification Sheet
Gh: Ghent Probe
MBM: Manufacturing Burnish Mark
OD: Outer Diameter
ODSCC: Outer Diameter Stress Corrosion Cracking
PWSCC: Primary Water Stress Corrosion Cracking
SCC: Stress Corrosion Cracking
TTS: Top of the Tubesheet

d. Location, Orientation (if Linear), and Measured Sizes (if Available) of Service Induced Indications

Table 2-4 through Table 2-6 provide a listing of all pre-service and service-induced indications reported during the U2R1 inspection including the estimated depths from the associated NDE technique and an indication of whether the tube has been plugged.

Table 2-4: Watts Bar U2R1 Pre-Service Volumetric Indications – All SGs

SG	Row	Col	Location	Inch1	Indication	%TW	Plugged?
1	3	99	C14	0.08	VOL	17	No
1	10	38	C12	-2.5	VOL	23	No
1	10	55	C13	32.84	VOL	11	No
1	14	18	AV1	3.8	VOL	14	No
1	14	98	C14	1.69	VOL	18	No
1	**28**	**83**	**C14**	**0.49**	**VOL**	**46**	**Yes – Pre-Service**
1	30	73	C13	28.64	VOL	5	No
1	31	80	C14	1.84	VOL	24	No
1	32	65	C01	2.4	VOL	8	No
1	34	77	C14	1.52	VOL	6	No
1	**34**	**87**	**C14**	**0.2**	**VOL**	**41**	**Yes – Pre-Service**
1	35	48	H08	25.26	VOL	18	No
1	**38**	**72**	**AV4**	**29.55**	**VOL**	**39**	**Yes – Pre-Service**
1	39	72	C14	-2.74	VOL	17	No
1	41	73	C14	0.58	VOL	30	No
2	5	103	H01	0.62	VOL	14	No
2	**5**	**110**	**H01**	**0.44**	**SVI**	**46**	**Yes – U2R1**
2	21	16	H03	33.19	VOL	11	No
2	**25**	**28**	**C10**	**13.37**	**VOL**	**48**	**Yes – Pre-Service**
2	**27**	**31**	**C01**	**12.32**	**VOL**	**57**	**Yes – Pre-Service**
3	19	37	C13	2.74	VOL	14	No
3	21	41	C01	3.88	VOL	20	No
3	22	43	C01	1.46	VOL	15	No
3	32	46	H01	4.89	VOL	32	No
3	38	42	H01	1.75	VOL	21	No
3	38	42	H01	1.12	VOL	11	No
3	38	58	H06	40.09	VOL	21	No
3	40	42	H01	1.97	VOL	38	No
4	1	87	H01	2.96	VOL	21	No
4	3	106	C11	12.01	VOL	10	No
4	8	84	H04	21.84	VOL	20	No
4	9	44	H07	30.94	VOL	10	No
4	20	46	H07	22.43	VOL	10	No
4	21	31	H06	9.99	VOL	18	No
4	21	31	H06	2.03	VOL	14	No
4	21	31	H06	17.06	VOL	7	No
4	23	77	C09	7.31	VOL	13	No
4	27	46	H04	22.89	VOL	20	No
4	28	95	H04	25.6	VOL	16	No
4	29	100	C13	36.1	VOL	30	No
4	30	14	C10	9.02	VOL	20	No
4	30	35	C10	8.8	VOL	23	No
4	38	84	H04	3.39	VOL	15	No

Table 2-5: Watts Bar U2R1 Anti-Vibration Bar Wear Indications – All SGs

SG	Row	Col	Location	Inch1	Indication	%TW	Plugged?
1	40	79	AV2	0.16	PCT	10	No
1	36	91	AV3	0.18	PCT	14	No
1	24	108	AV4	0.18	PCT	15	No
2	24	8	AV2	0	PCT	15	No
2	35	85	AV3	0	PCT	14	No
2	22	8	AV3	0.19	PCT	11	No
2	30	23	AV4	0.12	PCT	11	No
2	23	6	AV4	0.16	PCT	13	No
3	30	105	AV3	-0.09	PCT	10	No
4	42	65	AV3	0.16	PCT	11	No
4	44	40	AV3	0	PCT	8	No
4	42	40	AV3	0.21	PCT	14	No
4	42	36	AV3	-0.11	PCT	15	No
4	44	28	AV3	0.12	PCT	10	No
4	41	24	AV3	0.17	PCT	8	No
4	38	21	AV3	0.12	PCT	14	No
4	33	14	AV3	0.04	PCT	9	No

Table 2-6: Watts Bar U2R1 Tube Support Plate Wear Indications – All SGs

SG	Row	Col	Location	Inch1	Indication	%TW	Plugged?
3	48	66	C06	-0.26	PCT	5	No
3	49	61	C06	-0.21	PCT	7	No
3	49	60	C06	-0.14	PCT	10	No
3	48	60	C06	-0.28	PCT	11	No
3	47	60	C06	-0.24	PCT	14	No

e. Number of Tubes Plugged During the Inspection Outage for Each Degradation Mechanism

There were eight (8) tubes plugged during the Watts Bar U2R1 SG in-service inspection. Only one (1) tube was required to be plugged in accordance with the plant Technical Specification requirements due to having a measured depth of 40% through-wall (TW) or greater. This was a 46%TW volumetric indication in SG2 at tube location Row 5 Column 110 as listed in Table 2-4. The remainders of tubes were plugged for preventative measures including two (2) restricted tubes, one (1) for an indication of permeability variation and four (4) due to a foreign object which was unable to be retrieved. Table 2-7 below provides the numbers and percentages of tubes plugged following U2R1 and the subsequent sections elaborate on the plugging basis.

Regarding the restricted tube locations in SG2 which were plugged, a complete test of the full tube length was not able to be obtained on the first data collection attempt. However, a full test was later completed using alternate means which included data collection from the opposite leg and/or use of downsized eddy current probes. These tubes were plugged in order to eliminate the possibility of being unable to collect data along the full tube length and evaluate condition monitoring at future inspections.

One tube in SG3 had a permeability variation indication in the tube material fully contained within the U-bend region. The use of alternative eddy current probes, such as a Ghent probe, to clear the permeability indication was not an option since the solid body Ghent probe is not capable of traversing the U-bend region. Condition monitoring was subsequently demonstrated through the use of a combination of simulated eddy current flaw signal injection and engineering

assessment of potential degradation mechanisms. This tube was plugged for its potential to mask degradation at future inspections.

Four tubes were plugged due to a foreign object located at the hot leg top of tubesheet which was unable to be retrieved. The object was identified as a piece of weld slag which was rigidly contained in between a group of four tubes. Multiple retrieval attempts from all accessible angles and orientations were made to remove the object from the SG and none were successful. Three of the tubes surrounding the foreign object had possible loose part indications (PLPs) from the eddy current test program, although none of the four surrounding tubes had indications of wear. All four tubes were stabilized with a cable stabilizer traversing the tubesheet region and plugged.

Table 2-7: Number of Tubes Plugged for each Degradation Mechanism

	SG1	SG2	SG3	SG4	Total
Plugged Tubes prior to U2R1	23	27	6	16	72
Plugging Reason	**Tubes Plugged during U2R1**				
Volumetric Indication from Pre-Service	0	1	0	0	1
Restricted Tube	0	2	0	0	2
Permeability Variation	0	0	1	0	1
Foreign Object Unable to be Retrieved	0	4	0	0	4
Total Plugged Following U2R1	23	34	7	16	80
Percentage Plugged Following U2R1	0.49%	0.73%	0.15%	0.34%	0.43%

f. The Number and Percentage of Tubes Plugged to Date and the Effective Plugging Percentage in each SG

Table 2-7 in the previous section provides the number and percentage of tubes plugged to date.

g. The Results of Condition Monitoring, Including the Results of Tube Pulls and In-Situ Testing

Condition Monitoring, Tube Pulls and In-Situ Testing

A condition monitoring (CM) assessment was performed as required by the Watts Bar Unit 2 steam generator program. Volumetric tube wear was the only in-service degradation mechanism detected during the Watts Bar U2R1 inspection. All of the in-service volumetric wear indications detected were located at tube intersections with either AVBs or TSPs. Volumetric indications generated during tube manufacture and assembly and initially detected during the pre-service inspections were also detected during U2R1.

The deepest indication of AVB wear had an estimated depth of 15%TW which is significantly less than a conservatively determined CM limit of 66%TW. The deepest indication of TSP wear had an estimated depth of 14%TW which is significantly less than a conservatively determined CM limit of 64%TW. The largest volumetric indication from the pre-service measured 46%TW which is less than a conservatively determined CM limit of 58%TW. These CM limits include uncertainties for material properties, NDE depth sizing, and the burst pressure relationship. Since the deepest flaws have an estimated depth less than the associated CM limits, the structural integrity performance criterion was met for the operating interval preceding U2R1.

The limiting pressure differential associated with accident induced leakage integrity is much lower than the three times normal operating pressure differential associated with the CM limits

for structural integrity. Therefore, CM for accident-induced leakage integrity was also demonstrated since volumetric wear indications will leak and burst at essentially the same pressure. Operational leakage integrity was demonstrated by the absence of any detectable primary-to-secondary leakage during the operating interval prior to U2R1. Since tube integrity was demonstrated analytically, in-situ pressure testing was not required nor performed during the U2R1 outage. No tube pulls were planned or performed during U2R1.

Primary and Secondary Side Visual Inspection Results

Visual inspections were performed on both the primary and secondary sides during U2R1 in accordance with Westinghouse nuclear safety advisory letter NSAL-12-1. Primary side inspections included visual inspections of all previously installed tube plugs as well as the channel head bowl cladding and the divider plate. The installed tube plug inspections showed no conditions indicative of degradation. However, the inspections of the channel head bowl cladding and the divider plate showed visually apparent evidence of minor indications of degradation of the cladding in SG1 located on the hot leg side just above the primary manway opening. A site condition report (CR) was initiated to document the condition and an associated engineering evaluation was performed. The conclusion of the engineering evaluation was that acceptable margin exists for maintenance of structural integrity of the SG channel head base metal for at least six cycles of operation.

Prior to the secondary side foreign object search and retrieval (FOSAR) inspections, sludge, scale, foreign objects, and other deposit accumulations at the top of the tubesheet were removed as part of the top of tubesheet sludge lancing process. The secondary side FOSAR inspections performed in all four SGs included visual examination of tube bundle periphery tubes from the hot leg and cold leg annulus and center no-tube lane. A total of 25 foreign objects were removed from the top of the tubesheet region. Any foreign objects not able to be retrieved were characterized and an analysis performed to demonstrate acceptability of continued operation without exceeding the tube integrity performance criteria. A limited top of tubesheet in-bundle visual inspection was also performed for the purpose of assessing and trending the level of hardened deposit buildup in the kidney region. Finally, there were no structurally significant anomalies observed during inspection of the upper internals of SG1 and SG4. Only a limited amount of foreign material was observed and retrieved during the upper internals inspections. Therefore, no potential for the upper internal components to have an effect on SG tube integrity.