**Tennessee Valley Authority**, Post Office Box 2000, Spring City, Tennessee 37381

WBL-19-041

August 27, 2019

10 CFR 50.4

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

Watts Bar Nuclear Plant, Unit 2
Facility Operating License No. NPF-96
NRC Docket No. 50-391

Subject: **Watts Bar Nuclear Plant (WBN) Unit 2 - Cycle 2 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 2. 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 Tony Brown, Site Licensing Manager, at 423-365-7720.

Respectfully,

Anthony L. Williams IV
Site Vice President
Watts Bar Nuclear Plant

Enclosure:
Watts Bar U2R2 180 Day Steam Generator Tube Inspection Report

cc: See Page 2

Enclosures
cc (Enclosures):

NRC Regional Administrator, Region II
NRR Project Manager
NRC Senior Resident Inspector

**Enclosure**

**Watts Bar U2R2 180 Day Steam Generator Tube Inspection Report**

T25 190819 200

QA Record

WESTINGHOUSE NON-PROPRIETARY CLASS 3

SG-CDMP-19-11
Revision 1

August 2019

APPROVED
This approval does not relieve the Contractor from any part of his responsibility for the correctness of design, details and dimensions.
Letter No. W-8321
Date: August 19, 2019
TENNESSEE VALLEY AUTHORITY
WBEP (N) BY: Beth A. Jenkins

# Watts Bar U2R2
# 180 Day Steam Generator
# Tube Inspection Report

PROJECT Watts Bar DISCIPLINE N
CONTRACT 11054 UNIT 2
DESC. SG Tube 180 Day Inspection Report - U2R2
DWG/DOC NO. SG-CDMP-19-11
SHEET - OF - REV. 01
DATE 08/19/19 ECN/DCN - FILE N/A

EDMS, WT CA-K

*** This record was final approved on 8/14/2019 2:10:44 PM. (This statement was added by the PRIME system upon its validation)

**SG-CDMP-19-11**
**Revision 1**

# Watts Bar U2R2 180 Day Steam Generator Tube Inspection Report

Prepared for:
Tennessee Valley Authority

| **Author's Name:** | Signature / Date | For Pages |
|---|---|---|
| Bradley T. Carpenter<br>Component Design & Management Programs | ***Electronically Approved*** | All |
| **Verifier's Name:** | Signature / Date | For Pages |
| Lucas Hickey<br>Component Design & Management Programs | ***Electronically Approved*** | All |
| **Manager's Name:** | Signature / Date | For Pages |
| Michael E. Bradley, Manager<br>Component Design & Management Programs | ***Electronically Approved*** | All |
| **Reviewer's Name:** | Signature / Date | For Pages |
| Jeremy W. Mayo<br>TVA SG Program Manager | [signature] 8/12/19 | All |
| **Reviewer's Name:** | Signature / Date | For Pages |
| Tammy C. Sears<br>TVA Watts Bar SG Program Owner | [signature] 8/12/19 | All |
| **Reviewer's Name:** | Signature / Date | For Pages |
| Daniel P. Folsom<br>TVA NDE Level III | [signature] 8/12/19 | All |

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

## Record of Revisions

| Revision | Date | Description |
|---|---|---|
| 0a | 6/3/2019 | Draft provided for Tennessee Valley Authority review and comment. |
| 0 | 7/1/2019 | Incorporated review comments from the Tennessee Valley Authority. Final approved original issuance of document |
| 1 | See EDMS | Revised section g of the report to correctly identify the largest pre-service volumetric indication on a tube remaining in service consistent with the listing of these indications in Table 2-4 of section d. Changes are identified with a bar in the left-hand margin. |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

## Table of Contents



## List of Tables and Figures

## 1.0 Introduction

The second in-service inspections (ISI) of the Watts Bar Unit 2 (WBN2) steam generators (SGs) were performed during the spring 2019 refueling outage designated as U2R2. The U2R2 inspection was performed after 1.995 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 U2R2 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.

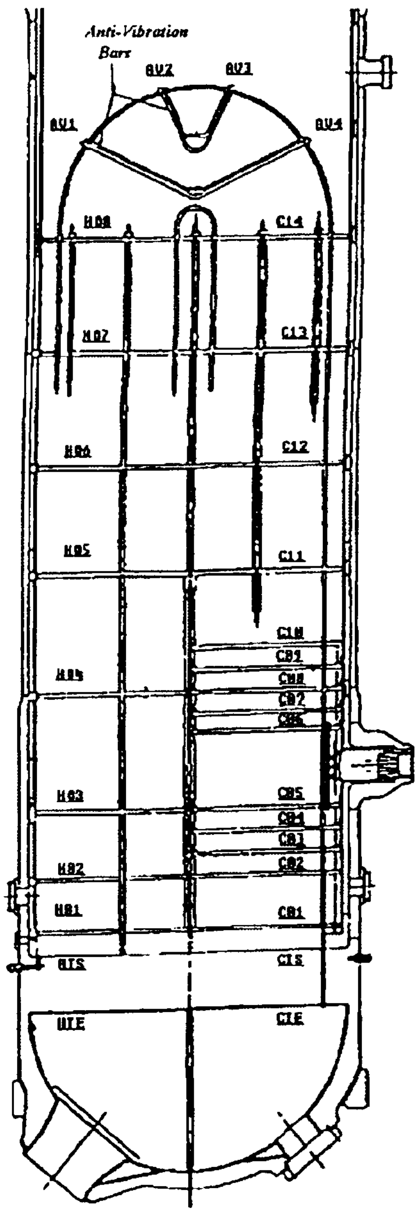


**Figure 1-1:** Tube Support Arrangement for Watts Bar Unit 2 Model D3 Steam Generators

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 U2R2 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 U2R2.

### 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 or the first in-service inspection as well as potential SG tube degradation mechanisms relevant to the design and material of the Watts Bar Unit 2 SG tubing. 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 in a checkerboard pattern. This inspection included all CL peripheral tubes two tubes deep.
- 100% +POINT or Array probe inspection of DNTs and DNGs ≥ 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 ≥ 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 first in-service inspection.
- +POINT or Array probe inspection of all tubes within a two 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 tube of this location at the same elevation.
- +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 U2R2 inspection included all tubes with prior indications of degradation. The table below summarizes the number and type of eddy current examinations performed during U2R2 excluding the special interest inspection scope.

**Table 2-1:** Watts Bar U2R2 Steam Generator Eddy Current Inspection Scope

| Eddy Current Exam Type | SG 1 | SG 2 | SG 3 | SG 4 |
|---|---|---|---|---|
| Full Length Bobbin | 4200 | 4190 | 4213 | 4204 |
| CL R1-R4 Low Row Bobbin | 451 | 450 | 454 | 454 |
| HL R1-R4 Low Row Bobbin | 451 | 450 | 454 | 454 |
| U-Bend +Point R1-R4 | 451 | 450 | 454 | 454 |
| HL +Point Tubesheet | 4651 | 4640 | 4666 | 4658 |
| CL Straight Leg X-Probe C06 to CTS-2 inch | 2641 | 2640 | 2665 | 2654 |

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 SG2 and SG3 during Watts Bar U2R2.

**b. Degradation Mechanisms Found**

The following degradation mechanisms were detected during the U2R2 inspection:

- Volumetric Indications (Pre-Service)
- Mechanical Wear at Anti-Vibration Bars (AVBs)
- Mechanical Wear at Tube Support Plates (TSPs)
- Circumferential Outer Diameter Stress Corrosion Cracking (ODSCC) at the Hot Leg Top of Tubesheet (HTS)
- Axial ODSCC at TSPs

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 U2R2. These indications are not considered an active or ongoing in-service degradation mechanism but are listed for completeness. Circumferential ODSCC at the HTS and Axial ODSCC at TSPs are new degradation mechanisms for Watts Bar Unit 2 first observed during U2R2.

Table 2-2 below shows the number of indications reported for each degradation mechanism during the U2R2 inspections.

**Table 2-2:** Number of Indications Detected for Each Degradation Mechanism during U2R2

| Degradation Mechanism | SG1 | SG2 | SG3 | SG4 | Total |
|---|---|---|---|---|---|
| Volumetric Indications (Pre-Service) | 13 | 2 | 8 | 15 | 38 |
| Wear at Tube Support Plates | 0 | 0 | 18 | 1 | 19 |
| Wear at Anti-Vibration Bars | 5 | 8 | 1 | 21 | 35 |
| Circumferential ODSCC at HTS | 0 | 0 | 2 | 3 | 5 |
| Axial ODSCC at Tube Support Plates | 1 | 0 | 5 | 2 | 8 |

## 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 U2R2 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 U2R2 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** | B: 27091.1<br>B: 27091.2 |
| **Wear at AVBs** | B: 96041.1<br>+Pt: 10908.4<br>A: 17908.1<br>A: 17908.2<br>A: 17908.4<br>A: 17908.5 |
| **Wear at Tube Support Plates** | B: 96042.1<br>A: 11956.1<br>A: 11956.2<br>A: 11956.3<br>A: 11956.4 |
| **Potential** | |
| **Wear due to Foreign Objects** | B: 27091.1<br>+Pt: 21998.1<br>A: 1790X.1<br>A: 1790X.3 |
| **Tube-to-Tube Contact Wear** | B: 13091.2 |
| **OD Pitting of the Tube Material** | B: 96005.3<br>+Pt: 21998.1<br>A: 24998.1 |
| **Axial and Circumferential PWSCC at the TTS** | +Pt: 20511.1 Ax<br>+Pt: I11524 Cir<br>A: 20501.1 Ax<br>A: 20500.1 Cir |
| **Axial and Circumferential ODSCC at the TTS** | +Pt: I28424 Ax<br>+Pt: I28425 Ax<br>+Pt: 21410.1 Cir<br>A: 20400.1 Ax/Cir |
| **Axial ODSCC at Tube Support Plates** | B: I28411<br>+Pt: I28424<br>A: 20402.1 |
| **Axial and Circumferential PWSCC in the Low Row U-bends** | +Pt: 96511.2<br>or<br>+Pt: 99997.1 |
| **ODSCC at Tube Dents and Dings and Axial PWSCC at Dents** | <u>ODSCC</u><br>B: I28411<br>or<br>B: 24013.1<br>B: 10013.1<br>+Pt: 22401.1<br>+Pt: 21410.1<br>A: 20400.1<br>A: 20403.1<br><br><u>PWSCC</u><br><u>B: 96012.1</u><br><u>A: 20500.1</u> |

| Degradation Mechanism | ETSS Detection Technique |
|---|---|
| **SCC at Tube Bulges and Overexpansions** | +Pt: I28424 Ax<br>+Pt: I28425 Ax<br>+Pt: 21410.1 Cir<br>A: 20400.1 Ax/Cir |
| **Axial ODSCC in the Freespan** | B: I28412<br>B: I28413<br>A: 20403.1 |
| **ODSCC at Dents and Dings Coincident with an MBM** | +Pt: 22401.1<br>+Pt: 21410.1 |
| **Diagnostic** [illegible] | |
| **Anomalous Indications** | Gh: 20406.1<br>Gh: 20407.1<br>Gh: 20507.1<br>Gh: 20508.1<br>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 2-9 provide a listing of all pre-service and service-induced indications reported during the U2R2 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 U2R2 Pre-Service Volumetric Indications – All SGs

| SG | Row | Col | Location | Inch1 | Indication | %TW | Plugged? |
|---|---|---|---|---|---|---|---|
| **1** | **6** | **74** | **HTS** | **-0.19** | **VOL** | **30** | **Yes – U2R2** |
| 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 | 32 | 96 | C14 | 0.52 | VOL | 27 | 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** | **Yes – Pre-Service** |
| 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 U2R2 Anti-Vibration Bar Wear Indications – All SGs

| SG | Row | Col | Location | Inch1 | Ind | %TW | Plugged? |
|---|---|---|---|---|---|---|---|
| 1 | 24 | 108 | AV4 | 0.11 | PCT | 15 | No |
| 1 | 36 | 91 | AV3 | 0.19 | PCT | 17 | No |
| 1 | 40 | 79 | AV2 | 0.16 | PCT | 10 | No |
| 1 | 42 | 90 | AV3 | -0.10 | PCT | 15 | No |
| 1 | 43 | 54 | AV3 | 0.14 | PCT | 12 | No |
| 2 | 22 | 8 | AV3 | 0.19 | PCT | 14 | No |
| 2 | 23 | 6 | AV4 | 0.20 | PCT | 16 | No |
| 2 | 24 | 8 | AV2 | 0.16 | PCT | 17 | No |
| 2 | 25 | 9 | AV2 | 0.23 | PCT | 16 | No |
| 2 | 30 | 23 | AV4 | 0.16 | PCT | 11 | No |
| 2 | 32 | 15 | AV2 | 0.16 | PCT | 12 | No |
| 2 | 35 | 85 | AV3 | -0.10 | PCT | 18 | No |
| 2 | 35 | 93 | AV2 | -0.10 | PCT | 13 | No |
| 3 | 30 | 105 | AV3 | -0.10 | PCT | 12 | No |
| 4 | 28 | 79 | AV3 | 0.14 | PCT | 10 | No |
| 4 | 29 | 79 | AV3 | 0.14 | PCT | 10 | No |
| 4 | 29 | 90 | AV1 | 0.64 | PCT | 10 | No |
| 4 | 33 | 14 | AV3 | 0.07 | PCT | 9 | No |
| 4 | 34 | 13 | AV2 | 0.21 | PCT | 11 | No |
| 4 | 38 | 21 | AV3 | 0.16 | PCT | 16 | No |
| 4 | 41 | 24 | AV2 | 0.02 | PCT | 10 | No |
| 4 | 41 | 24 | AV3 | 0.00 | PCT | 12 | No |
| 4 | 41 | 74 | AV3 | 0.14 | PCT | 11 | No |
| 4 | 41 | 88 | AV3 | -0.10 | PCT | 12 | No |
| 4 | 41 | 90 | AV4 | 0.03 | PCT | 10 | No |
| 4 | 41 | 94 | AV3 | 0.16 | PCT | 13 | No |
| 4 | 42 | 29 | AV2 | 0.19 | PCT | 18 | No |
| 4 | 42 | 29 | AV3 | 0.14 | PCT | 11 | No |
| 4 | 42 | 36 | AV3 | -0.20 | PCT | 20 | No |
| 4 | 42 | 40 | AV2 | 0.21 | PCT | 10 | No |
| 4 | 42 | 40 | AV3 | 0.25 | PCT | 16 | No |
| 4 | 42 | 65 | AV3 | 0.17 | PCT | 15 | No |
| 4 | 44 | 28 | AV3 | 0.19 | PCT | 12 | No |
| 4 | 44 | 40 | AV3 | -0.20 | PCT | 10 | No |
| 4 | 49 | 60 | AV4 | -0.30 | PCT | 10 | No |

**Table 2-6:** Watts Bar U2R2 Tube Support Plate Wear Indications – All SGs

| SG | Row | Col | Location | Inch1 | Ind | %TW | Plugged? |
|---|---|---|---|---|---|---|---|
| 3 | 46 | 56 | C05 | -0.26 | PCT | 5 | No |
| 3 | 46 | 56 | C06 | -0.21 | PCT | 7 | No |
| 3 | 46 | 61 | C05 | 0.00 | PCT | 12 | No |
| 3 | 47 | 56 | C06 | -0.21 | PCT | 6 | No |
| 3 | 47 | 57 | C06 | -0.19 | PCT | 6 | No |
| 3 | 47 | 59 | C02 | 0.00 | PCT | 7 | No |
| 3 | 47 | 59 | C05 | 0.12 | PCT | 12 | No |
| 3 | 47 | 60 | C06 | -0.19 | PCT | 21 | No |
| 3 | 47 | 64 | C06 | 0.00 | PCT | 10 | No |
| 3 | 48 | 60 | C06 | -0.19 | PCT | 21 | No |
| 3 | 48 | 61 | C02 | 0.00 | PCT | 6 | No |
| 3 | 48 | 61 | C05 | -0.26 | PCT | 11 | No |
| 3 | 48 | 64 | C05 | 0.00 | PCT | 18 | No |
| 3 | 48 | 64 | C06 | 0.00 | PCT | 9 | No |
| 3 | 48 | 65 | C05 | -0.02 | PCT | 22 | No |
| 3 | 48 | 66 | C06 | -0.19 | PCT | 16 | No |
| 3 | 49 | 60 | C06 | -0.24 | PCT | 19 | No |
| 3 | 49 | 61 | C06 | -0.21 | PCT | 13 | No |
| 4 | 49 | 74 | C06 | -0.26 | PCT | 5 | No |

**Table 2-7:** Watts Bar U2R2 Circumferential ODSCC at HTS Indications – All SGs

| SG | Row | Col | Location | Inch1 | Ind | %TW | Circ Ext. (deg) | PDA(1) | Plug and Stabilize |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 17 | 53 | HTS | -0.05 | SCI | 99 | 155 | 25.5 | Yes |
| 3 | 49 | 37 | HTS | -0.08 | SCI | 83 | 182 | 19.2 | Yes |
| 4 | 10 | 72 | HTS | -0.07 | SCI | 70 | 86 | 10.4 | Yes |
| 4 | 21 | 70 | HTS | -0.11 | SCI | 62 | 104 | 8.4 | Yes |
| 4 | 21 | 71 | HTS | -0.06 | MCI | 59 | 187 | 12.9 | Yes |

(1) PDA calculated using depth profiling over the entire flaw circumferential extent.

**Table 2-8:** Watts Bar U2R2 Axial ODSCC at TSP Indications – All SGs

| SG | Row | Col | Location | Inch1 | Ind | %TW | Axial Ext. (in.) | Plugged? |
|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 8 | H04 | 0.00 | SAI | 37 | 0.14 | Yes |
| 3 | 9 | 11 | H03 | -0.01 | SAI | 62 | 0.23 | Yes |
| 3 | 14 | 20 | H02 | 0.02 | SAI | 74 | 0.5 | Yes |
| 3 | 17 | 6 | H02 | -0.03 | MAI | 54 | 0.36 | Yes |
| | | | | | | 54 | 0.28 | |
| 3 | 40 | 57 | H03 | 0.02 | SAI | 50 | 0.28 | Yes |
| 3 | 41 | 80 | H03 | 0.01 | SAI | 50 | 0.28 | Yes |
| 4 | 10 | 3 | H02 | 0.06 | SAI | 50 | 0.28 | Yes |
| 4 | 11 | 53 | H04 | 0.12 | SAI | 71 | 0.29 | Yes |

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

There were fourteen tubes plugged during the Watts Bar U2R2 SG in-service inspection. One tube was plugged due to a volumetric indication traceable to pre-service that was located within the F* distance. Eight tubes were plugged due to axial ODSCC at TSP intersections. Five tubes were plugged and stabilized due to circumferential ODSCC at HTS. Both cracking degradation mechanisms are new degradation mechanisms for Watts Bar Unit 2. Table 2-9 below provides the numbers and percentages of tubes plugged following U2R2.

**Table 2-9:** Number of Tubes Plugged for each Degradation Mechanism

| | SG1 | SG2 | SG3 | SG4 | Total |
|---|---|---|---|---|---|
| Plugged Tubes prior to U2R2 | 23 | 34 | 7 | 16 | 80 |
| **Plugging Reason** | **Tubes Plugged during U2R2** | | | | |
| Volumetric Indication from Pre-Service | 1 | 0 | 0 | 0 | 1 |
| Axial ODSCC at TSP | 1 | 0 | 5 | 2 | 8 |
| Circumferential ODSCC at HTS | 0 | 0 | 2 | 3 | 5 |
| | | | | | |
| Total Plugged Following U2R2 | 25 | 34 | 14 | 21 | 94 |
| Percentage Plugged Following U2R2 | 0.53% | 0.73% | 0.30% | 0.45% | 0.50% |

One of the tubes plugged in SG1 was a volumetric indication newly reported during U2R2 but observable in eddy current data history back to the pre-service inspection. While the measured depth was less than the Technical Specification plugging limit of 40% through-wall, this particular indication was located within the F* tubesheet expansion depth where no degradation is permitted. Therefore, the tube was plugged during U2R2. The remaining tubes were plugged due to indications of cracking degradation which are plugged on detection according to the requirements of the WBN2 Technical Specification.

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

Table 2-9 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, Axial ODSCC and Circumferential ODSCC were the in-service degradation mechanisms detected during the Watts Bar U2R2 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 U2R2. Axial ODSCC indications were observed at TSP intersections. Circumferential ODSCC indications were observed at the HL side of the top of the tubesheet.

The deepest indication of AVB wear had an estimated depth of 20%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 22%TW which is significantly less than a conservatively determined CM limit of 64%TW. The largest volumetric indication from the pre-service inspection, on a tube remaining in-service, measured 32%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 corresponding burst pressure relationship. Since the deepest volumetric flaws have an estimated depth less than the associated CM limits, the structural integrity performance criterion was met for the operating interval preceding U2R2.

The largest indication of axial cracking had an equivalent average depth of 65.4% TW and average length of 0.313 inch. A flaw of this character has a burst pressure of 4300 psig and a ligament tearing pressure of 4143 psig including all material and NDE uncertainties at 95/50 probability and confidence levels. This calculated burst pressure exceeds the CM limit of $3\Delta P_{NOP}$ of 3840 psi and calculated ligament tearing pressure exceeds the limiting accident differential pressure of 2560 psi. Therefore, the CM limits for structural and leakage integrity are satisfied for indications of axial ODSCC.

The largest indication of circumferential cracking had a calculated Percent Degraded Area (PDA) of 25.5. A conservative CM limit for this form of degradation is a PDA of 55. Therefore, the SG structural performance criterion has been satisfied for this flaw. The average depth of the flaw was calculated to be 59.2% TW which results in a ligament tearing pressure of 5441 psi when considering all material and NDE uncertainties at 95/50 probability and confidence levels. This is well in excess of the limiting accident differential pressure of 2560 psi, and therefore the SG leakage integrity performance criterion is also satisfied.

Operational leakage integrity was demonstrated by the absence of any detectable primary-to-secondary leakage during the operating interval prior to U2R2. Since tube integrity was demonstrated analytically, in-situ pressure testing was not required nor performed during the U2R2 outage. No tube pulls were planned or performed during U2R2.

Primary and Secondary Side Visual Inspection Results

Visual inspections were performed on both the primary and secondary sides during U2R2 in all four SGs. Primary side inspections performed in accordance with Westinghouse Nuclear Safety Advisory Letter NSAL-12-1 included the hot leg and cold leg divider plate, inclusive of the divider plate-to-channel head weld, and all visible clad surfaces of the SG channel head. The NSAL-12-1 examinations performed during U2R1 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. This indication was re-inspected during U2R2. The conclusion of the engineering evaluation performed after U2R1 was that acceptable margin exists for maintenance of structural integrity of the SG channel head base metal for at least six cycles of operation. This conclusion was considered to remain applicable following the U2R2 inspection. No new indications were reported from the visual examinations of the channel head cladding.

All previously installed tube plugs were visually inspected from the primary side in all four SGs. The inspection results were satisfactory and showed no indication of tube plug leakage or failure.

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. A total of 76.5 pounds of deposit was removed as a result of sludge lancing from all four SGs in total. 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 sixteen foreign objects were identified, nine of which were removed from the top of the tubesheet region. None of the objects known to be remaining in the SGs at the tubesheet elevation following the FOSAR are metallic. Any foreign objects remaining in the SGs were characterized and an analysis performed to demonstrate acceptability of continued operation without exceeding the tube integrity performance criteria.

Secondary side inspections of the steam drum upper internals were performed in SG2 and SG3 during U2R2 to assess for structural integrity, degradation, excessive deposits, flow-assisted corrosion, blockage and overall sound condition. There were no anomalies observed during the steam drum upper internals inspections and therefore no potential effects on SG tube integrity.