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Serial: RA-22-0017 10 CFR 50.90
January 6, 2022

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

H.B. Robinson Steam Electric Plant, Unit No. 2
Docket No. 50-261
Renewed License No. DPR-23

Subject: Supplement to Application to Revise Technical Specifications to Adopt TSTF-577, "Revised Frequencies for Steam Generator Tube Inspections"

Reference:

1. Letter from E.J. Kapopoulos, Jr. (Duke Energy Progress, LLC) to U.S. Nuclear Regulatory Commission, "Application to Revise Technical Specifications to Adopt TSTF-577, 'Revised Frequencies for Steam Generator Tube Inspections'," dated December 9, 2021 (ADAMS Accession No. ML21343A047).

By letter dated December 9, 2021 (Reference 1), Duke Energy Progress, LLC (Duke Energy) requested an amendment to the H.B. Robinson Steam Electric Plant, Unit No. 2 (HBRSEP2) Technical Specifications (TS). The proposed amendment would adopt Technical Specifications Task Force (TSTF) Traveler TSTF-577, Revision 1, "Revised Frequencies for Steam Generator Tube Inspections." Additionally, Duke Energy proposed a steam generator tube inspection period of 72 effective full power months (EFPM) for the HBRSEP2 inspection period that began December 8, 2020. This is a variation from the TS changes described in TSTF-577 because the enhanced probe inspection method has not previously been used for steam generator tube inspections at HBRSEP2. For all future steam generator tube inspections, the enhanced probe inspection method will be utilized.

To support the NRC staff's detailed review of the proposed amendment, Duke Energy is providing the steam generator operational assessment relative to the HBRSEP2 refueling outage 32 steam generator inspection as the enclosure to this letter.

Duke Energy has reviewed the information supporting the No Significant Hazards Consideration and the Environmental Consideration that was previously provided to the NRC in Reference 1. The additional information provided in this license amendment request (LAR) supplement does not impact the conclusion that the proposed license amendment does not involve a significant hazards consideration. The additional information also does not impact the conclusion that there is no need for an environmental assessment to be prepared in support of the proposed amendment.

There are no regulatory commitments made in this submittal.

In accordance with 10 CFR 50.91, Duke Energy is notifying the State of South Carolina of the supplement to this LAR by transmitting a copy of this letter and enclosure to the designated State Official.

If there are any questions or if additional information is needed, please contact Mr. Lee Grzeck, Manager – Nuclear Fleet Licensing (Acting) at 980-373-1530.

I declare under penalty of perjury that the foregoing is true and correct. Executed on January 6, 2022.

Sincerely,

Nicole L. Flippin

Nicole L. Flippin
Site Vice President

NLF/jlv

Enclosure: Westinghouse Document SG-CDMP-20-25, Revision 1, "H.B. Robinson Unit 2 RO32 Steam Generator Condition Monitoring and Final Operational Assessment"

cc (with enclosure):

L. Dudes, USNRC Region II – Regional Administrator
M. Fannon, USNRC Senior Resident Inspector – RNP
T. Hood, NRR Project Manager – RNP
A. Gantt, Chief, Bureau of Radiological Health (SC)
A. Wilson, Attorney General (SC)
S. E. Jenkins, Manager, Radioactive and Infectious Waste Management (SC)

Enclosure

Westinghouse Document SG-CDMP-20-25, Revision 1, “H.B. Robinson Unit 2 RO32 Steam Generator Condition Monitoring and Final Operational Assessment"

[42 Pages Follow this Cover Page]

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Purchase Order: 02003382-00407
Sales Order: 156908
Our Ref: PGN-21-19, Revision 1

November 5, 2021

DUKE ENERGY PROGRESS
HB ROBINSON NUCLEAR POWER PLANT UNIT 2
Transmittal of SG-CDMP-20-25, Revision 1, "H.B. Robinson Unit 2 RO32 Steam Generator Condition Monitoring and Final Operational Assessment"

Dear Mr. Mayes:

Please find attached the following document relative to the H.B. Robinson Unit 2 RO32 Steam Generator Inspection:

- Westinghouse Document SG-CDMP-20-25, Revision 1, "H.B. Robinson Unit 2 RO32 Steam Generator Condition Monitoring and Final Operational Assessment," November 2021.

The attached document replaces the SG-CDMP-20-25, Revision 1 report that was transmitted via Revision 0 of this project letter.

If there are any questions concerning this transmittal, please contact me at (724) 722-5284.

Sincerely,
WESTINGHOUSE ELECTRIC COMPANY LLC

*Electronically Approved**

Bradley T. Carpenter
Principal Engineer, Component Design & Management Programs

WESTINGHOUSE NON-PROPRIETARY CLASS 3

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//Attachment

SG-CDMP-20-25, Revision 1, " H.B. Robinson Unit 2 RO32 Steam Generator Condition Monitoring and Final Operational Assessment"

cc:	Leigh Anne Kelley	Duke Energy
	Chuck Cauthen	Duke Energy
	Tim Thulien	Duke Energy
	Sonya Forrai	Westinghouse
	Tova Anderson	Westinghouse
	John Scarfutti	Westinghouse
	Michael Bradley	Westinghouse
	Damian Testa	Westinghouse
	David Suddaby	Westinghouse
	Logan Clark	Westinghouse

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SG-CDMP-20-25
Revision 1

November 2021

H.B. Robinson Unit 2 RO32 Steam Generator Condition Monitoring and Final Operational Assessment

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SG-CDMP-20-25
Revision 1

H.B. Robinson Unit 2 RO32 Steam Generator Condition Monitoring and Final Operational Assessment

Logan T. Clark*, Engineer
Component Design & Management Programs

November 2021

Verifier: Bradley T. Carpenter*, Principal Engineer
Component Design & Management Programs

Manager: Michael E. Bradley*, Manager
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RECORD OF REVISIONS

Revision	Date	Revision Description
0	November 2020	Original Issue
1	November 2021	Evaluated potential stress corrosion cracking mechanisms for the next inspection interval to support TSTF-577 licensing submittal for extended operation between SG inspections.

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LIST OF FIGURES

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1.0 INTRODUCTION

This condition monitoring and final operational assessment (CMFOA) report has been prepared in accordance with the Electric Power Research Institute (EPRI) steam generator (SG) tube integrity assessment guidelines (Reference 2). It is based on the H.B. Robinson Unit 2 refueling outage (RO) 32 SG tube in-service inspection (ISI). At the end of the operation cycle just completed, the SGs have accumulated 29.55 effective full-power years (EFPY) (Reference 4 and Reference 11 email). The last SG inspection was at RO30 at which point the SGs had accumulated 26.26 EFPY of service time. The operating time from RO30 to RO32 is 3.29 EFPY. The operational assessment (OA) in this evaluation is performed for three cycles of operation (6 EFPY) to allow flexibility for the next SG inspection to occur at RO35 should the H.B. Robinson Technical Specifications be updated to permit three cycles between inspections. Because no changes in operating conditions are anticipated, the $3\Delta P_{NOP}$ criteria from the degradation assessment (Reference 4), the bounding value of 4650 psi, will continue to apply for Cycles 33, 34 and 35.

The RO32 inspection scope and plan were based on the degradation assessment (Reference 4). The following are existing degradation mechanisms at H.B. Robinson Unit 2:

- Mechanical tube wear at anti-vibration bar (AVB) intersections
- Mechanical tube wear at tube support plate (TSP) intersections
- Mechanical tube wear due to foreign object (FO) to tube interaction
- Tube wear from maintenance activities
- Circumferential primary water stress corrosion cracking (PWSCC) at tube ends

An alternate repair criterion, H*, was approved by the U.S. Nuclear Regulatory Commission (NRC) for application at H.B. Robinson Unit 2 as stated in Reference 4. H* is the minimum engagement distance between the tube and the tubesheet, measured downward from the top of the tubesheet (TTS), that is proposed as needed to ensure the structural and leakage integrity of the tube-to-tubesheet joints. For H.B. Robinson Unit 2, the H* distance is 18.11 inches. Therefore, inspections with a qualified probe to detect SCC in the tubesheet region is required only from the TTS to 18.11 inches below the TTS. As a result, any PWSCC indications that are detected during RO32 in the tube ends below H* do not need to be addressed in this CMOA.

Section 2.0 presents a summary of the tube inspection results. The condition monitoring evaluation of identified degradation during RO32 is presented in Section 3.0. The final OA for all existing degradation mechanisms at H.B. Robinson Unit 2 is presented in Section 4.0. A 3-cycle (6 EFPY) OA is performed for all degradation mechanisms in order to support the next SG inspection to occur at RO35.

Revision 1 of this report was created to address potential stress corrosion cracking (SCC) degradation mechanisms for the next inspection interval of 3 cycles (6.0 EFPY). Section 4.5 includes Operational Assessment evaluations for the most likely potential degradation mechanisms to occur in Alloy 600TT tubing based on industry experience in SGs with the same tubing.

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1.1 SUMMARY OF RESULTS

Tube wear depths detected at AVB intersections were well below condition monitoring limits, so the SG performance criteria for the past inspection interval are satisfied. The maximum AVB wear growth rate observed in a single indication is 0.91% TW (through wall)/EFPY, which is smaller than the growth observed during RO30. AVB wear growth appears to have stabilized at a low rate, which assures that the structural and leakage integrity criteria will continue to be satisfied for all AVB wear locations until at least RO35.

Tube wear depths detected at broached TSP intersections are well below the condition monitoring limit, so the SG performance criteria for the past inspection interval are satisfied. Effectively no growth was observed from the existing TSP indications, so a bounding growth of 5% TW/EFPY had to be applied for the OA, which is the same growth applied during RO30 (though no indications were found to have grown that much at RO30 either). The observation that effectively displays no growth having been exhibited in TSP wear indications provides further confidence to the OA evaluation that the structural and leakage integrity criteria will continue to be satisfied for all TSP wear locations until at least RO35. No indications at the drilled flow distribution baffle were detected during RO32.

Tube wear depths due to foreign object interaction are below the condition monitoring limit, so the SG performance criteria for the past inspection interval are satisfied. No growth is considered for tube wear from foreign objects since there are no known objects remaining at locations where in-service tubes have experienced this type of wear. With no growth projected, structural and leakage integrity are maintained for these indications until at least RO35.

All plugs were visually inspected and were deemed acceptable for operation until the next planned plug inspection. A video inspection of the channel heads was performed in accordance with Nuclear Safety Advisory Letter (NSAL) 12-1 (Reference 8) and no changes were observed from the prior inspection and was deemed acceptable for continued operation until the next planned inspection.

The condition monitoring evaluation concludes that the H.B. Robinson Unit 2 SGs meet the NEI 97-06 (Reference 1) SG performance criteria at the present time (end of operating Cycle 32). The OA for all existing degradation mechanisms concludes that NEI 97-06 SG performance criteria will be met for an inspection interval to RO35.

H.B. Robinson Unit 2 has not experienced any SCC degradation to date, but an OA was performed for the most likely potential SCC mechanisms to occur. The OA for these mechanisms concludes that structural and leakage integrity would be maintained for the next inspection interval of 3 cycles (6 EFPY) should one of these mechanisms initiate in that timeframe.

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1.2 TUBE PLUGGING

Table 1-1: Tubes Plugged at RO32			
SG	**Row**	**Column**	**Reason for Plugging**
C	45	44	New 27% TW TSP Wear at 06H

There are a total of 56 tubes plugged at H.B. Robinson Unit 2 after RO32. Only one tube was plugged during RO32 SG inspections. The total number of tubes plugged, in addition to the effective tube plugging percentage for each SG is included in Table 1-2. The total tube plugging percentage from all four SGs is 0.58%.

Table 1-2: Total Tube Plugging at H.B. Robinson Unit 2		
SG	**Tubes Plugged (Prior / RO32)**	**Effective Tube Plugging Percentage**
A	9 / 0	0.28%
B	24 / 0	0.75%
C	22 / 1	0.72%
Total	55 / 1	0.58%

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2.0 SUMMARY OF TUBE INSPECTION RESULTS

2.1 INSPECTION SCOPE

The intent of the SG eddy current inspections is to examine for existing and potential degradation mechanisms identified for the H.B. Robinson Unit 2 SGs. Tube end to tube end bobbin inspections were performed on all accessible tubes in the H.B. Robinson Unit 2 SGs during the RO32 refueling outage. An array probe was used to inspect the U-bend region for tubes in Rows 1 and 2. Array probe inspections were performed at the top of the tubesheet (TTS) from tube end hot (TEH) to +4 inches above the TTS. Peripheral and tubelane exams were performed five tubes deep on both the hot and cold leg from TE to the first TSP. Full length array probe exams were performed on the "2-sigma" tubes. The complete list of these tubes, along with their respecting ranking, is in the Reference 4 DA. The following is the full primary inspection scope outline:

Bobbin Inspection

- 100% full length (except Row 1-2 U-bend)
- Row 1-2 hot leg (HL) straight section
- Row 1-2 cold leg (CL) straight section

Array Inspection

- 100% HL TTS from TEH to TSH+4
- HL and CL TTS periphery and tube lane five tubes deep from TE to the first TSP
- 100% Row 1 and 2 U-bends
- 20% Row 9 U-bends
- Full length of tubes screened as high stress (2-sigma)
- 100% DNT ≥ 4V
- All dents at the upper TSP (6H, 6C +/- 1.25 inches) regardless of voltage

Pre-Planned Array Special Interest

- All tube locations with indication calls that required array sizing from R30
- Possible loose part (PLP) calls with a one tube box-in of target tube
- Two tube box-in of target tube of known foreign object location
- New wear indications
- All bobbin "I-codes"

Visual Inspection

- Previously installed plugs
- Bowl cladding (NSAL-12-1) inspection
- Bowl closeouts

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Miscellaneous

- Tube slippage monitoring (based on bobbin results)
- +POINT and/or Ghent probe on any crack-like indication detected (aside from those exempted by H*)

Upon completion of the RO32 inspections, H.B Robinson Unit 2 has satisfied inspection requirements for the 4th sequential inspection period. RO32 was the last inspection in the 4th sequential inspection period of 72 EFPM.

2.2 INSPECTION SCOPE EXPANSION

No expansion to the inspection scope was performed during RO32 as no new types of degradation were identified from the planned inspection scope.

2.3 INSPECTION RESULTS

The final inspection results and associated data for SG inspections performed at H.B. Robinson Unit 2 RO32 are maintained in the Westinghouse **ST MAX™**[1] software eddy current database. The graphic depicting 100% completion of eddy current inspection scope is contained in Appendix A.

2.3.1 Mechanical Wear Indications at Anti-Vibration Bars

A total of 25 indications of AVB wear were detected in 18 tubes at RO32. None of these indications required plugging per engineering disposition and all remained in service. All AVB wear indications were sized with the bobbin coil using Appendix I ETSS 96041.1. The deepest AVB wear indication was measured at 34% through-wall (TW) depth in SG C Tube R35 C61 at 03A and the largest growth observed in a single indication from RO30 to RO32 was 3% TW, or 0.91% TW/EFPY, at multiple AVB locations. No tubes were plugged from AVB wear.

There were eight new AVB wear indications reported for the first time in RO32. The largest new AVB wear indication was detected in SG 2C Tube R35C61 and sized at 19% TW. A review of the RO30 inspection data at this location confirmed that the indication was present at the time. The other new AVB wear flaws measured at between 10% and 12% TW were all found to be NDF from array probe.

All AVB wear indications from RO30 were detected again during RO32; however, one historical AVB wear indication at SG B R10C53 04A was resized as foreign object wear due to the ECT signal and location.

Table 2-1 includes the full listing of RO32 AVB wear indications with measurements from the past two inspections.

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Table 2-1: RO32 AVB Wear Summary

SG	ROW	COL	LOCN	INCH1	RO32 Depth (%TW)	RO30 Depth (%TW)
A	36	22	02A	0	10	11
A	44	57	04A	0.07	10	New
B	17	26	02A	0.02	15	12
B	23	22	02A	-0.05	12	New
B	30	24	02A	-0.07	11	New
B	30	77	02A	-0.06	11	New
B	35	36	03A	-0.32	11	11
B	35	74	03A	-0.03	10	New
B	36	24	02A	-0.02	11	New
B	36	24	04A	-0.06	10	New
B	41	30	02A	0.03	10	9
B	44	38	04A	-0.15	8	14
C	32	78	03A	-0.09	6	9
C	35	61	01A	-0.28	8	9
C	35	61	02A	0.18	23	24
C	35	61	02A	-0.21	19	New
C	35	61	03A	-0.22	34	31
C	35	61	04A	-0.15	8	9
C	35	73	04A	-0.08	12	13
C	37	45	03A	0.05	30	31
C	37	45	04A	0.07	28	29
C	40	50	03A	-0.07	7	11
C	40	50	04A	-0.1	9	11
C	40	52	04A	0.09	12	12
C	45	42	02A	-0.05	17	21

2.3.2 Mechanical Wear Indications at Tube Support Plates

Mechanical wear was detected at broached support plate locations during RO32. No support plate wear was detected at the drilled flow distribution baffles. All TSP wear indications were sized from array probe using ETSS 11956.2 for wear at broached supports.

A total of five indications of broached TSP wear were detected in five tubes at RO32. One of these tubes was plugged (27% TW in SG C Tube R45C44 at 06H) while the rest remained in service per engineering disposition of the indications. The deepest broached TSP wear indication left in service was measured at 21% TW depth in SG C Tube R36C47 at 03H and the largest growth

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observed in a single indication from RO30 to RO32 was 2% TW, or 0.61% TW/EFPY, at multiple TSP locations.

There were two broached TSP wear indications that had been reported for the first time in RO32 with sizes measuring 20% TW and 27% TW. A review of the RO30 data confirmed that these indications essentially grew from null over the last operating cycle.

The total number of TSP wear indications reported in RO32 is less than RO30. This is due to a combination of indications being resized as foreign object wear due to the ECT signal and location and indications being assigned a historical call no change (HNC) inspections providing confirmation that the wear progression has halted. Six indications reported as TSP wear during RO30 were dispositioned as HNC during RO32. Two indications were resized as foreign object wear.

Table 2-2 includes the full listing of RO32 TSP wear indications with measurements from the past two inspections.

Table 2-2: RO32 TSP Wear Summary

SGID	ROW	COL	LOCN	INCH1	RO32 Depth (%TW)	RO30 Depth (%TW)
B	2	17	06C	-0.52	20	New
B	41	28	03H	-0.51	19	18
C	30	71	03H	-0.66	22	20
C	36	47	03H	-0.61	21	19
C	45	44	06H	-0.41	27	New

2.3.3 Mechanical Wear Indications from Foreign Objects

Foreign object wear indications were observed in each SG during RO32. Foreign object wear was sized with the array probe using Examination Technique Specification Sheet (ETSS) Techniques 17902.1, 17902.3 or 11956.2.

There were 12 foreign object wear indications in 11 tubes in SG 2A. Five of these indications were newly detected during RO32. None of these indications required plugging per engineering disposition and all remained in service. The deepest foreign object wear indication in SG 2A was measured at 31% TW at two separate tube locations.

There were 22 foreign object wear indications in 18 tubes in SG 2B. Six of these indications were newly detected during RO32. None of these indications required plugging per engineering disposition and all remained in service. The deepest foreign object wear indication in SG 2B was measured at 38% TW in Tube R3C5 at the CTS.

There were 20 foreign object wear indications in 19 tubes in SG 2C. Nine of these indications were newly detected during RO32. None of these indications required plugging per engineering

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disposition and all remained in service. The deepest foreign object wear indication in SG 2C was measured at 32% TW in Tube R20C9 at the CTS.

Many historical foreign object wear indications from RO30 were dispositioned as HNC during RO32 inspections upon confirming that the ECT signal has not changed for three successive inspections. Eleven indications in SG A, seven indications in SG B and eight indications in SG C that were previously foreign object wear were determined to be HNC during RO32.

Table 2-3 includes the full listing of RO32 foreign object wear indications with measurements from the past two inspections.

Table 2-3: RO32 Foreign Object Wear Summary

SGID	ROW	COL	LOCN	INCH1	RO32 Depth (%TW)	RO30 Depth (%TW)
A	11	87	CTS	0.07	20	20
A	13	9	02H	-0.73	24	New
A	13	56	04H	-0.65	15	16
A	15	64	06H	0.69	16	18
A	23	86	CTS	0.49	14	14
A	25	62	02H	-0.49	16	17
A	28	81	04H	-0.71	31	New
A	31	30	HTS	-0.19	20	19
A	33	41	HTS	0.07	21	20
A	36	20	03H	-0.6	24	New
A	36	20	04H	-0.64	26	New
A	37	20	04H	-0.57	31	New
B	3	5	CTS	0.14	38	38
B	5	81	03H	-0.65	15	New
B	7	92	CTS	0.72	12	12
B	10	53	04A	0.55	18	17
B	11	91	CTS	0.74	15	15
B	14	13	HTS	0.27	13	17
B	14	69	03A	2.13	16	New
B	15	75	02H	-0.57	16	New
B	16	45	02H	-0.52	26	25
B	16	82	05C	-0.55	17	New
B	28	14	FBC	0.43	21	20
B	28	73	06H	1.98	18	New
B	30	58	02H	-0.69	24	New
B	34	52	HTS	0.41	15	17
B	34	76	CTS	1.98	17	16

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SGID	ROW	COL	LOCN	INCH1	RO32 Depth (%TW)	RO30 Depth (%TW)
B	42	30	CTS	0.73	17	21
B	42	30	HTS	0.66	14	18
B	43	33	HTS	0.73	16	16
B	44	36	CTS	0.8	19	16
B	44	36	CTS	0.75	18	16
B	44	36	HTS	0.74	12	14
B	44	36	HTS	0.71	13	14
C	2	31	01C	-0.79	13	16
C	2	51	05C	-0.46	15	New
C	6	23	01H	-0.45	16	17
C	6	76	01C	51.21	20	New
C	8	30	03H	-0.91	26	24
C	9	46	04A	0	17	18
C	13	54	03H	-0.81	24	22 (Note 1)
C	14	49	05H	0.42	27	21
C	14	50	01H	-0.86	22	New
C	16	19	03H	-0.71	30	New
C	17	17	02H	-0.62	30	25
C	17	32	03H	-0.57	13	New
C	18	24	02H	-0.6	24	New
C	20	9	CTS	6.48	31	24
C	20	9	CTS	6.12	32	24
C	25	34	03C	-0.59	20	New
C	26	77	02H	-0.53	25	22
C	30	72	03H	-0.64	21	22
C	31	16	HTS	0.72	13	14
C	44	36	06C	-1.19	30	New

Note 1: This indication was NDF in RO30 but review of the ECT data showed that it should have been sized at 22% foreign object wear.

2.3.4 "2-Sigma" Tube Inspections for SCC

All 2-sigma tubes were fully inspected with bobbin and array probe during RO32. The inspection results concluded that no SCC indications relative to the 2-sigma susceptibility were reported from either probe.

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2.3.5 Possible Loose Parts / Foreign Objects

During ECT, PLP signals were reported by bobbin during RO32. These locations were inspected, as accessibility allows, during the secondary side TTS Foreign Object Search and Retrieval (FOSAR) examination. Assessment of the PLP calls from ECT against findings from FOSAR was performed and documented in Reference 6.

No tubes were plugged due to the presence of foreign objects or PLPs at a tube. No PLPs were found to be present in any of the tubes with existing foreign object indications. A summary of PLP dispositions from the RO32 inspections is documented in Reference 6.

2.3.6 PWSCC at Tube Ends

PWSCC at the tube ends is a degradation mechanism that has occurred at H.B. Robinson Unit 2. The mechanism is essentially non-relevant due to approval of H* alternate repair criteria which designates any degradation detected in the portion of tube below 18.11 inches as measured from the TTS as acceptable. The portion of the tube below H* distance does not affect tube integrity and does not require consideration in this evaluation. Historically, two circumferential PWSCC have been detected at H.B. Robinson at one tube location in SG A and one tube location in SG C. During RO32, these indications were assigned as indication not reportable (INR) in the ECT database due to the non-relevance of the indications given the H* criteria. No new PWSCC indications at tube end locations were detected during RO32.

2.3.7 Visual Inspections

As specified in the Reference 4 Degradation Assessment, a visual inspection of the SG channel head was performed to determine if degradation of the cladding and/or of the channel head base material had occurred. The inspection was performed per the recommendations in Nuclear Safety Advisory Letter NSAL-12-1 (Reference 8). Per the attached Reference 10 email, NSAL-12-1 examinations for each SG were satisfactory.

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3.0 CONDITION MONITORING

All existing and potential degradation mechanisms identified in the degradation assessment, Reference 4, were addressed by the RO32 inspection plan. Structural limits and condition monitoring limits, as presented in Reference 4, were validated and are referred to in this section for demonstration of condition monitoring of degradation observed during RO32. The CM limits calculated in Reference 4 are based on the bounding primary-to-secondary differential pressure of 1550 psi.

The following existing degradation mechanisms were observed during RO32:

- Mechanical tube wear at AVB intersections
- Mechanical tube wear at TSP intersections
- Mechanical tube wear due to foreign object interaction
- PWSCC at tube ends (dispositioned per H* alternate repair criteria)

3.1 AVB WEAR

The complete list of AVB wear indications detected during RO32 SG inspections is contained in Table 2-1. No tubes were plugged from AVB wear during RO32.

The largest AVB wear indication detected was measured at 34% TW at SG 2C R35C61 03A. AVB wear was measured from bobbin using Appendix I ETSS technique 96041.1. The CM limit from Reference 4 for AVB wear is 50.6% for a conservatively bounding AVB wear scar with a flat profile and an axial length of 1.5 inches. Therefore, condition monitoring is met for all detected AVB wear indications.

The largest projected AVB wear flaw from the RO30 OA (Reference 3) was 52.5% TW. Since the largest flaw detected during RO32 is much smaller than this, the OA method performed at RO30 was conservative and acceptable.

3.2 WEAR AT TUBE SUPPORT PLATES

The complete list of broached TSP wear detected during the RO32 SG inspections is contained in Table 2-2. No TSP wear indications were detected at the drilled hole flow distribution baffle. One tube was plugged from TSP wear during RO32 for a new indication at 27% TW.

The largest TSP wear indication at a broached support was measured at 27% TW at SG 2C R45C44 06H. TSP wear was measured from array probe using Appendix H ETSS Technique 11956.2. The CM limit from Reference 4 for flat broached support plate wear of circumferential extent up to 135 degrees and an axial length of 1.12 inches is 51.7% TW when the indication is sized using 11956.2. Therefore, CM is met for all detected TSP wear indications.

The largest projected wear indication at broached TSP intersections from the RO30 OA (Reference 3) was 51.6% TW. Since the largest flaw detected during RO32 is much smaller than this, the OA method performed at RO30 is conservative and acceptable.

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The largest projected wear indication at a drilled FDB intersection from the RO30 OA (Reference 3) was 39.8% TW. Since no flaws were detected at the FDB during RO32, the OA method performed at RO30 is conservative and acceptable.

3.3 FOREIGN OBJECT WEAR

The complete list of foreign object wear indications detected during RO32 SG inspections is contained in Table 2-3. No tubes were plugged from foreign object wear during RO32.

The largest foreign object wear indication detected during RO32 was measured at 38% TW at SG 2B R3C5 CTS. Foreign object wear depth was measured by an array probe using ETSS techniques 17902.1 and 17902.3, depending on the shape of the wear scar, or 11956.2. The CM limit from Reference 4 for foreign object wear, with bounding length of 1.5 inches, measured using ETSS 17902.1 is 53.1% TW and using ETSS 17902.3 is 49.9% TW. The calculated CM limit for foreign object wear with a bounding length of 1.5 inches using ETSS 11956.2 is 50.5% TW. Therefore, condition monitoring is met for the population of foreign object wear flaws.

Largely no growth was observed, or is expected to occur, on indications that were caused from foreign object interaction on the tube. This is due to foreign objects not being present at tube locations where the wear exists and, as such, the wear initiation mechanism has been eliminated. For indications that did grow, it is judged that it is likely the result of a combination of measurement uncertainty and the potential for objects that remained in the SG following last inspection to periodically interact with tubes during operation. This is unpredictable and provided there is ample margin between the flaw size and the condition monitoring limit it is considered to not be a concern for tube integrity.

3.4 PWSCC AT TUBE ENDS

Tube slippage is monitored through analyzing bobbin data from within the tubesheet. The voltage is screened for signals greater than or equal to 50 volts and phase angle between 25 and 50 degrees. These signals would be indicative of tube slippage. Bobbin signals that fit these criteria are assigned as a Non-Quantifiable Indication (NQI) code during data analysis and specified as an indication of possible tube slippage in the utility field of the eddy current database. There were no NQI calls made associated with tube slippage during RO32.

For condition monitoring of tube end cracks, primary-to-secondary leakage attributable to the portion of tubing below the H* depth must be multiplied by a factor of 1.87. This evaluation is discussed in Section 3.8.

3.5 IN SITU PRESSURE TEST SCREENING

All indications of degradation were considered for in situ pressure test (ISPT) screening in accordance with Reference 5. Since the tube wear mechanisms were determined to meet condition monitoring no screening for ISPT was required.

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3.6 TUBE PLUG VISUAL INSPECTIONS

A 100% visual inspection of tube plugs in all SGs was performed from the primary side during RO32. There were no visually anomalous conditions, such as a degraded tube plug or abnormal amounts of surrounding boron deposits, reported during performance of the tube plug visual inspections. These visual examinations were considered to be satisfactory per the Reference 10 email.

3.7 SG CHANNEL HEAD PRIMARY BOWL INSPECTION

A visual inspection of the SG channel head bowl has been performed for all three SGs during RO32 per the degradation assessment (Reference 4) and in accordance with Reference 8. These visual examinations were considered to be satisfactory per the Reference 10 email.

3.8 PRIMARY-TO-SECONDARY LEAKAGE

There has been no primary-to-secondary leakage identified at H.B. Robinson Unit 2 over Cycles 31 and 32. Due to having H* alternate repair criteria implemented, the identified operating leakage that could be attributable to the tubesheet region is multiplied by a leak factor of 1.87 (Reference 4). For Cycles 31 and 32 this value is zero. Therefore, the leakage associated with the tubesheet regions from PWSCC at tube ends meets the criteria and condition monitoring is met.

3.9 SECONDARY SIDE ACTIVITIES

Secondary side activities during RO32 were performed by Framatome. Reference 6 provides the results of the secondary side activities and disposition of potential impacts to SG tube integrity.

3.9.1 Tubesheet Cleaning

A top of tubesheet deposit cleaning process (i.e., sludge lancing) was performed in all three SGs during RO32. The deposit removal amounts are listed in Table 3-1.

Table 3-1: H.B. Robinson Unit 2 RO32 Sludge Lancing Totals

SG	Sludge Removed (lbs)
2A	65.5
2B	55.4
2C	64.6
Total	185.5

3.9.2 Foreign Object Search and Retrieval

Foreign object search and retrieval (FOSAR) inspections were conducted in the secondary side of all three SGs during RO32. The FOSAR inspections were performed at the top of the tubesheet around the annulus and open tube lane as well as specified in-bundle locations. FOSAR results including objects found, and whether they were retrieved or left in the SG, is contained in Reference 6.

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3.10 CONDITION MONITORING CONCLUSIONS

The existing wear mechanism indications observed during RO32 are well below the condition monitoring limits, considering burst relation, material property and NDE measurement uncertainties, as specified in the degradation assessment (Reference 4).

The visual examinations performed of the SG channel head and tube plugs demonstrated acceptable findings. The RO32 inspection results validate the projections and conclusions of the OA of the previous inspection at RO30. Therefore, the condition monitoring criteria of NEI 97-06 are satisfied.

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4.0 OPERATIONAL ASSESSMENT

An operational assessment (OA) is the process of projecting forward, the severity of returned-to-service degradation (for those mechanisms which can be depth sized and justified for continued operation) and postulated mechanisms which may initiate during operation up to the next scheduled eddy current inspection, against the CM or structural limits. This process must address any degradation found as well as any degradation that might have escaped detection during the inspection. The potential for degradation not being detected is dependent on the capability of the inspection probes to detect each type of degradation being sought.

The OA for tube wear mechanisms is performed to justify three cycles of operation to allow for flexibility on when the next inspection of these mechanisms was to occur. An EFPY of 6.0 is used as the 3-cycle inspection interval for the OA calculations; this is a conservative value since the estimated EFPY for three cycles in 5.82 (Reference 11).

4.1 ASSESSMENT OF AVB WEAR

In order to evaluate the progression of AVB wear during future operation, the growth rate can be estimated from the wear depth measured in the RO32 inspection for existing indications that have historical sizes.

The measured or "apparent" indication growth per EFPY is computed by taking the difference between two successive measurements and dividing by the EFPY of the inspection interval. NDE uncertainties are not added to the measurements since they would essentially "cancel out" when calculating the difference between the two successive measurements. The duration of plant operation from RO30 to RO32 is 3.29 EFPY. The growth rates from the previous inspection interval were developed in the prior CMOA (Reference 3).

Since there are not enough growth data points to develop a statistically significant upper 95th percentile growth rate per the SG integrity assessment guidelines, the maximum growth observed at a single AVB location was considered for the OA. The maximum growth occurred at multiple indications, which exhibited a growth of 2.0% TW, or 0.91% TW/EFPY, over the last operating cycle. A growth rate of 1.5% TW/EFPY is conservatively applied for the OA.

The maximum measured AVB wear indication that was returned to service was 34% TW as noted in Section 2.3.1. The length of the largest indication left in service is assumed to be 1.5 inch, which is the bounding length from the DA (Reference 4). To predict the maximum wear depth at RO32 the following parameters were considered:

- The estimated duration for the next inspection interval is conservatively assumed to be 2.0 EFPY for each cycle for a total OA period of 6.0 EFPY.
- A bounding growth rate of 1.5% TW/EFPY, which exceeds the largest observed growth of 0.91% TW/EFPY, is applied for the OA. For most existing flaws, no growth was observed from RO30 to RO32.
- H.B. Robinson SG tubing material properties from the DA and NDE uncertainties from EPRI Appendix I Technique ETSS I96041.1 are applied.

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The RO35 flaw depth for the largest flaw returned to service (34% TW) can be calculated deterministically using equations from Reference 9 while applying NDE uncertainties from Appendix I Technique 96041.1 at 95% probability 50% confidence levels and the maximum observed growth rate from all AVB wear flaws detected during RO32.

$$RO35\ Projected\ Depth =$$
$$1.01 * 34\%TW + 0.99\%TW + 1.645 * 3.29\%TW + \left(1.5\% \frac{TW}{EFPY} x\ 6.0\ EFPY\right)$$
$$= 49.7\%TW$$

The EOC structural limit for AVB wear with 1.5-inch bounding length, assuming less than 135 degrees in extent, is 54% TW. Therefore, a 3-cycle OA is demonstrated for the population of AVB wear indications detected at RO32. For pressure-only loading of volumetric flaws, 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 $3\Delta P_{NO}$.

The result bounds the assumed undetected population of AVB wear flaws since the ETSS technique 95th percentile POD depth is much less than the largest flaw remaining in service. The bobbin noise measured at AVB locations in RO32 is not bounded by the noise used in the qualification of Appendix I ETSS Technique 96041.1 as discussed in Section 4.4. Therefore, a MAPOD simulation (Reference 7) is performed which results in a site-specific POD for AVB wear detection. The simulation results and result POD function is shown in Figure 4-1. It is demonstrated that given the H.B. Robinson noise at AVB tube locations, a 17% TW indication can be detected at 0.95 probability. This is much smaller than the largest flaw returned to service at 34% TW which provides confidence that any flaws that escaped detection will not challenge tube integrity over the next operating cycle.

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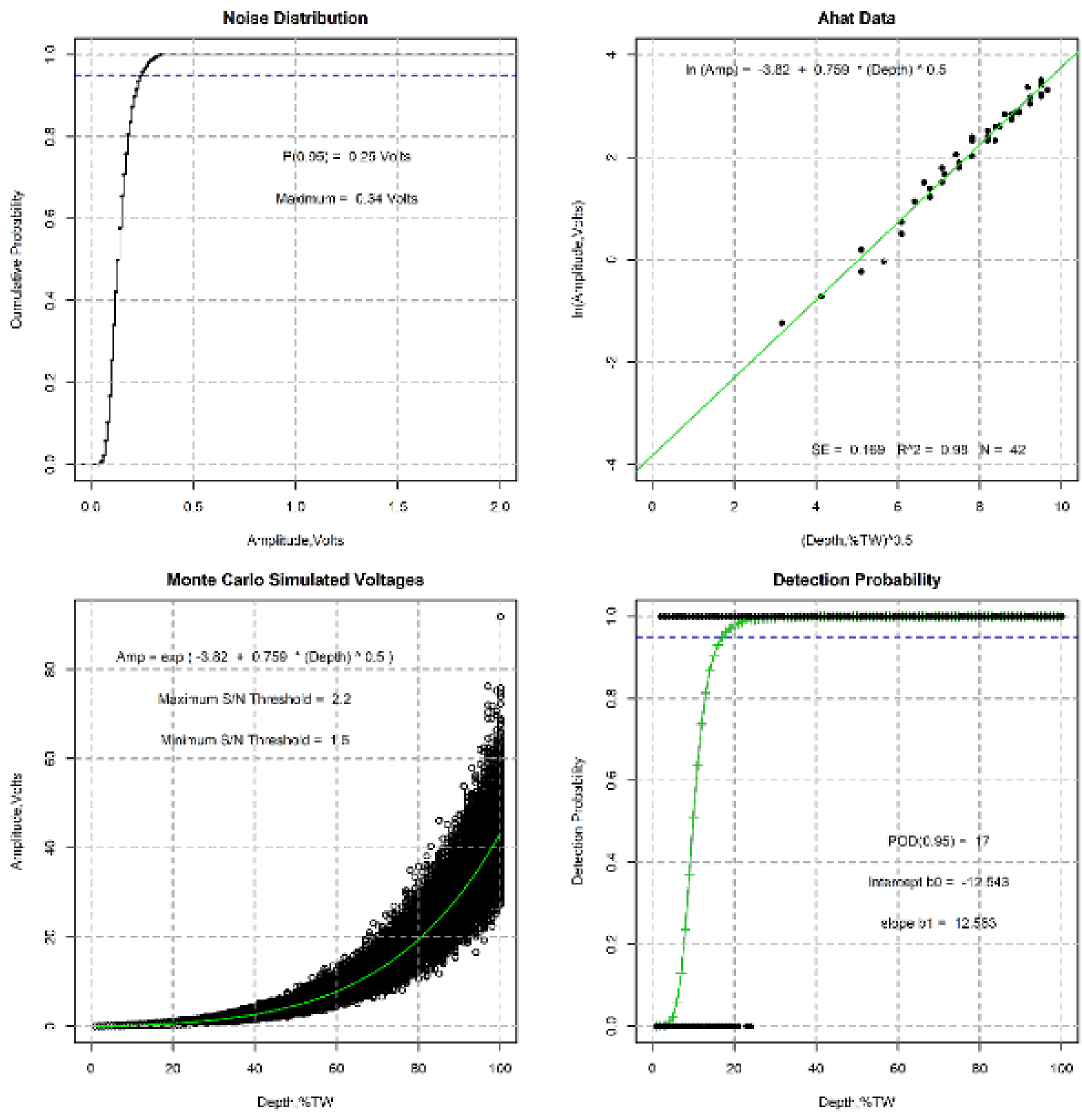

Figure 4-1: MAPOD Simulation for POD of AVB Wear

This OA evaluates the growth rate of AVB wear indications on a per EFPY basis, considers both detected and undetected flaws, and shows margin from the requirements for structural and leakage integrity over the upcoming inspection interval. Therefore, the OA projects that AVB wear degradation will not violate the SG tube integrity performance criteria for a 3-cycle (6.0 EFPY) operating interval.

4.2 ASSESSMENT OF TSP WEAR

4.2.1 Broached TSP Wear

Tube wear at both broached tube support plates was detected at five tube locations in RO32, only three of which were historical indications that could provide growth data. While those three locations exhibited little to no growth, it is not reasonable to apply those growth rates for the OA

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since the dataset is far too small. Since the prior OA (Reference 3) applied a growth rate of 5.0% TW/EFPY, and this produced a conservative OA at RO30, the same input will be utilized for the RO32 OA.

The maximum measured wear indication at a broached TSP that was left in service was 22% TW. The bounding length assumed from the structural and condition monitoring limit calculations in the DA is 1.12 inch, but from a review of the indications it was found to be a far too conservative assumption. The flaw lengths for the TSP wear flaws are shown in Table 4-1. Based on the flaw population, a bounding flaw length of 0.4 inches can be applied, in which case a new EOC structural limit of 63.5% TW can be calculated.

Table 4-1: Flaw Lengths for TSP Wear Detected During RO32

SG	Row	Col	Location	Depth (%TW)	Length (inches)
B	2	17	06C	20	0.22
B	41	28	03H	19	0.36
C	30	71	03H	22	0.29
C	36	47	03H	21	0.24
C	45	44	06H	27 (Note 1)	0.23

Note 1: The SG C Tube R45C44 was plugged due to new TSP wear at 06H that was measured at 27% TW.

For OA, the wall thinning with limited axial extent (less than 135 degrees) is applied for broached support plate wear. To predict the maximum wear depth at broached TSP intersections at RO32 the following parameters were considered:

- The estimated duration for the next inspection interval is conservatively assumed to be 2.0 EFPY for each cycle for a total OA period of 6.0 EFPY.
- A bounding growth rate of 5.0% TW/EFPY given the lack of plant-specific data for this mechanism. For the few flaws that have measurements at both RO30 to RO32, negligible growth was exhibited.
- H.B. Robinson SG tubing material properties from the DA and NDE uncertainties from EPRI Appendix H array Technique ETSS 11956.2.

The RO35 flaw depth for the largest flaw returned to service (22% TW) can be calculated deterministically using equations from Reference 9 while applying NDE uncertainties from Appendix H Technique 11956.2 at 95% probability 50% confidence levels and a bounding 5.0% TW/EFPY growth rate.

$$RO35\ Projected\ Depth = 0.98 * 22\%TW + 1.55\%TW + 1.645 * 4.33\%TW + \left(5.0\% \frac{TW}{EFPY} x\ 6.0\ EFPY\right) = 60.2\%\ TW$$

The EOC structural limit for TSPB wear with 0.4-inch bounding length, assuming less than 135 degrees in extent, is 63.5% TW. Therefore, a 3-cycle OA is demonstrated for the population of

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TSP wear indications detected and returned to service following RO32. For pressure-only loading of volumetric flaws, 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 $3\Delta P_{NO}$.

During RO32, two new TSP flaws (27% TW and 20% TW) were detected where no detected degradation (NDD) was recorded during RO30. The possibility of this occurring again during the next operating cycle of 6 EFPY is considered. The maximum growth observed from a new flaw was 27% TW, which is 8.2% TW/EFPY over the 3.2 EFPY since RO30. This is conservatively rounded to 9% TW/EFPY to compensate for measurement uncertainties. If a new TSP wear flaw were to initiate following the RO32 inspection and grow at this rate until RO35, the flaw size at RO35 would be 54% TW, which is less than the EOC structural limit of 63.5% TW.

The bobbin noise measured at TSP locations is bounded by the Appendix I ETSS 96043.4 noise and therefore, the 0.95 probability of detection of a 20% TW flaw is applicable to H.B. Robinson Unit 2. Since this assumed undetected flaw size is smaller than the largest TSP wear flaw returned to service, it is judged that any flaws that escaped detection will not be a threat to tube integrity over a 3-cycle (6.0 EFPY) operating cycle.

4.2.2 Drilled FDB Wear

No flaws were detected at the drilled FDB during RO32. The bobbin noise measured at FDB locations is bounded by the Appendix I ETSS 96042.1 noise and therefore, the 0.95 probability of detection of an approximately 10% TW flaw is applicable to H.B. Robinson Unit 2. Since no OA was performed for detected flaws during RO32, a deterministic OA is calculated below for the largest assumed undetected flaw of 10% TW applying NDE. The bounding growth rate of 5% TW/EFPY is applied. The EOC structural limit for 0.75-inch flat FDB wear is 57.6% TW. No NDE measurement uncertainty is included since the flaws are assumed undetected.

$$RO35\ Projected\ Depth = 10\%TW + \left(5.0\%\frac{TW}{EFPY}x\ 6.0\ EFPY\right) = 40\%\ TW$$

The EOC flaw size of 40% TW is much lower than the EOC structural limit. Therefore, structural integrity is demonstrated for the population of assumed undetected FDB wear flaws.

This OA evaluates the growth rate of TSP and FDB wear indications on a per EFPY basis, considers both detected and undetected flaws, and shows margin from the requirements for structural and leakage integrity over the upcoming inspection interval. Therefore, the OA projects that TSP and FDB wear degradation will not violate the SG tube integrity performance criteria for a 3-cycle (6.0 EFPY) interval.

4.3 ASSESSMENT OF FOREIGN OBJECT WEAR

The maximum measured wear indication from foreign object interaction on a tube is 38% TW at a historical flaw in SG B. During RO32, foreign object wear indications were sized from the array probe using either ETSS 17902.1 or 17902.3, dependent on the shape of the flaw, or ETSS 11956.2. Historical foreign object wear flaws were sized using ETSS 11956.2 in RO30. This

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results in a discrepancy between the sizes of the same flaws in many cases, when most of the indications are actually not growing at all. Therefore, the ECT database included re-sizing of the flaws at RO30 for all foreign object wear indications using the 17902.X ETSS techniques in the UTIL1 field so that a proper comparison between sizes of the indications between inspections could be made.

Many foreign object wear indications were assigned a HNC code due to sizing at three successive inspections demonstrating no growth. For indications that showed a change since the RO30 measurement, the delta was minor and typically less than 1% TW/EFPY, if not zero or “negative.” The average growth for all foreign object wear indications was found to be 0.14% TW/EFPY.

There were four indications where the wear growth was between 1%-3% TW/EFPY over the last operating cycle, all in SG C. This could be the result of transient objects having interacted at these tube locations over the last cycle. No objects were found to be remaining in the SG at these locations and no PLPs were detected at these locations so it is not expected that these indications would continue to grow over the next operating cycle. It is considered reasonable to return these tubes to service given that no wear initiation mechanism is in place and that ample margin exists between the wear depths and the EOC structural limit of 54.3% TW. This structural limit is for a bounding wear scar length of 1.5 inches which significantly bounds the measured length of detected FO wear indications.

The complete list of foreign object wear indications returned to service is contained in Table 2-3. None of the indications that were left in service were found to have a PLP present that would represent a continued mechanism for wear on the tube. As such, growth on these indications is assumed to be zero over the next inspection interval. Therefore, by virtue of meeting CM, which includes all uncertainties, OA is met for three cycles for this population of flaws.

Engineering assessment of foreign objects found during secondary side inspections and not removed during FOSAR, as well as historical objects known to be remaining in the generators and investigation of PLPs called by ECT was performed by Framatome and documented in Reference 6. The assessment concluded that operation could continue for the next three cycles (6.0 EFPY) without any threat to tube integrity from known foreign objects.

4.4 NOISE MONITORING

The eddy current noise monitoring process discussed in the degradation assessment (Reference 4) was implemented during RO32 for the collected bobbin and array probe data. The bobbin probe data was monitored for noise and the potential for noise to mask degradation in the various regions of interest (ROI). The ROI for bobbin data includes broached TSP, drilled FDB and AVB locations. The ROI for array data includes TTS, sludge pile and freespan locations. Noise exceeders were monitored and reported at the 99.95% threshold. Locations where the noise measurements exceeded the amplitude thresholds, as specified in the site-specific ETSS qualification documents (References 13, 14, 15 and 16), were reviewed by the eddy current data analysis team for the need to perform further analysis or NDE testing. Noise measurements were collected by Framatome and provided via the Reference 12 email.

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Noise measurements were assessed at TSP and AVB locations in order to determine the site-specific POD for these existing degradation mechanisms and the largest size of potential undetected flaws being returned to service for use in the OA. The noise data from RO32 at these locations in each SG were compiled and are electronically attached to this document. The Appendix I techniques used for detection require comparison of the noise data against the noise used in the ETSS qualification. These include ETSS 96041.1 for detection of wear at AVB locations, ETSS 96043.4 for detection of wear at broached support plates and ETSS 96042.1 for detection of wear at the drilled FDB. Figure 4-2, Figure 4-3 and Figure 4-4 display the RO32 measured noise against the ETSS noise at these locations. As seen from the figures, the H.B. Robinson noise is bounded by the ETSS noise data for measurements taken at the TSP and FDB. However, the noise collected at AVB locations is not bounded by the ETSS noise. As such, a plant-specific POD for detection of AVB wear has been developed using MAPOD. The inputs to MAPOD include the qualification dataset from Appendix I ETSS 96041.1 and the H.B. Robinson RO32 plant-specific noise CDF collected at AVB locations.

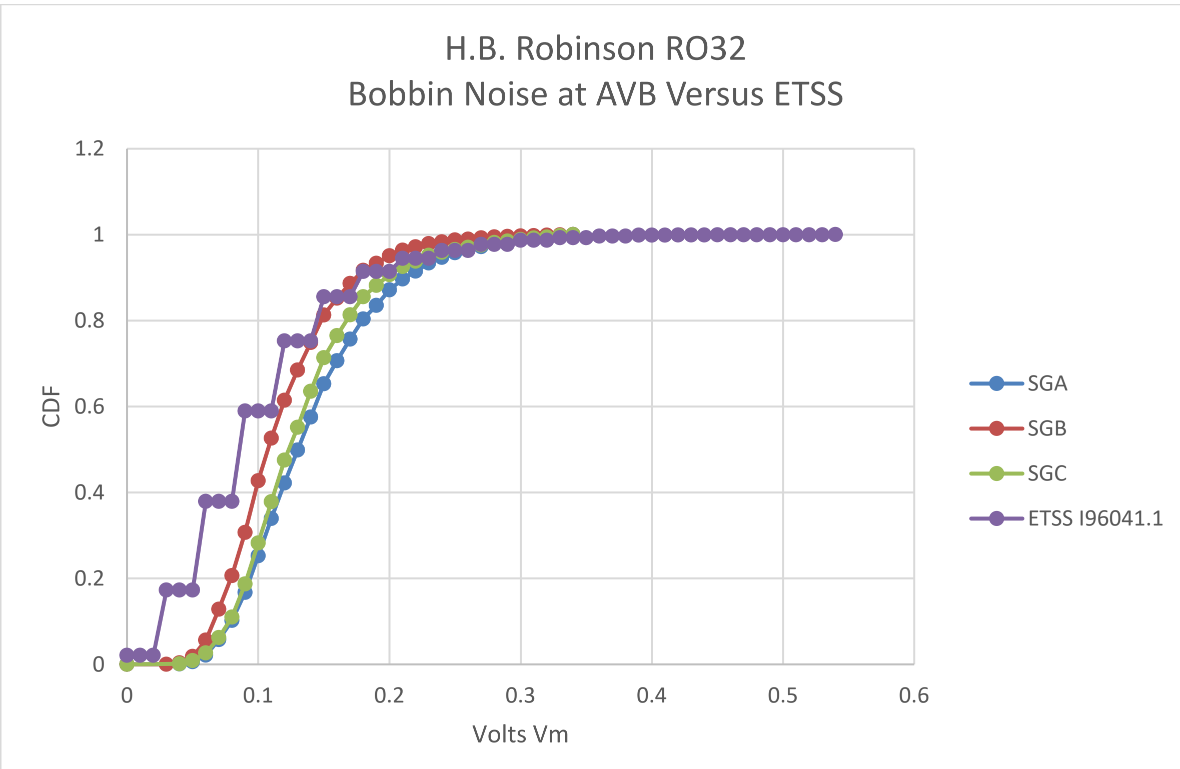

Figure 4-2: RO32 Bobbin Noise at AVB Locations

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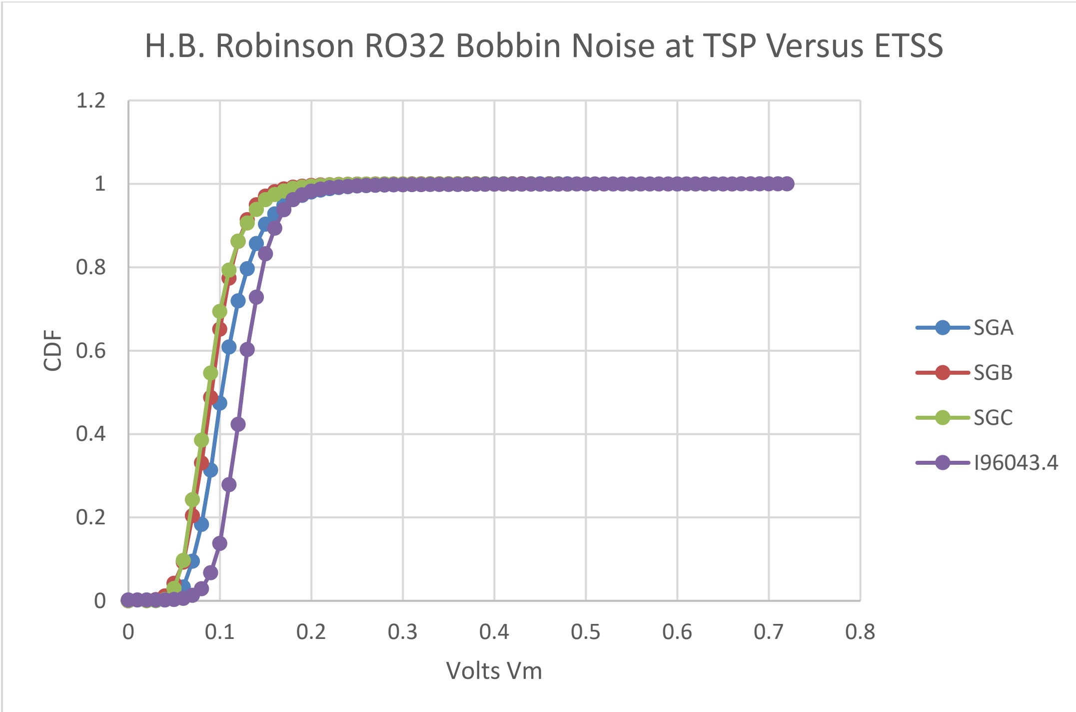

Figure 4-3: RO32 Bobbin Noise at TSP Edge Locations

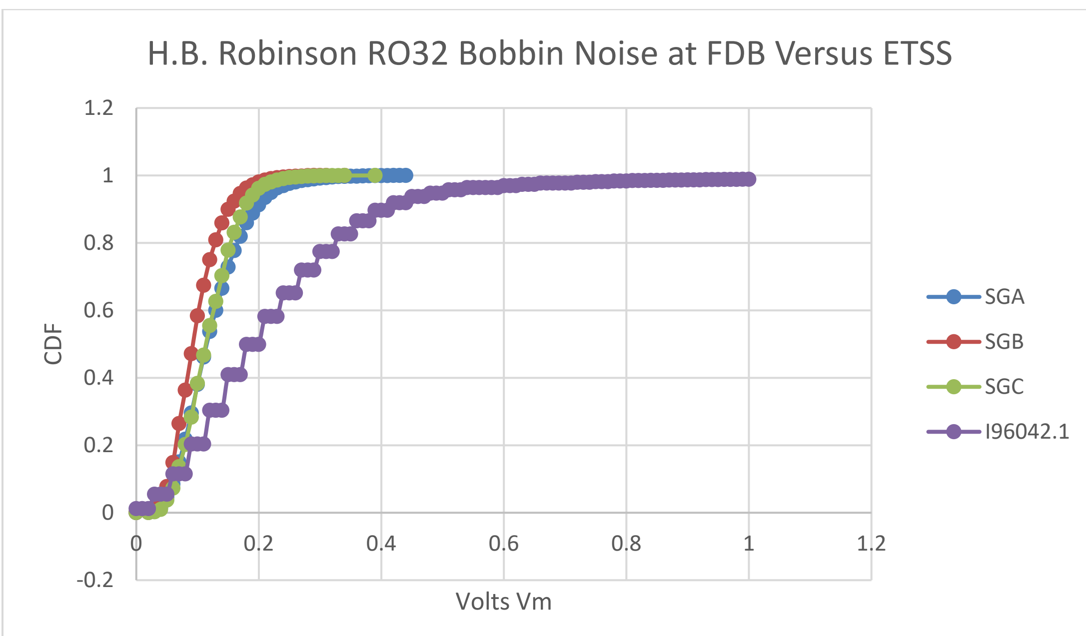

Figure 4-4: RO32 Bobbin Noise at FDB Edge Locations

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Since the noise data is bounded by that used in the ETSS qualification, it is concluded that larger flaws than those returned to service did not escape detection using the detection techniques employed at RO32. No additional OA evaluations need to be performed for TSP/FDB wear mechanisms due to noise effects.

4.5 POTENTIAL STRESS CORROSION CRACKING

Stress corrosion cracking has been known to be a potential, and in some A600TT plants an active/existing, degradation mechanism. Since H.B. Robinson Unit 2 has not experienced any stress corrosion cracking, the three most common types of stress corrosion cracking in other A600TT SG units will be evaluated for a 3-cycle (6 EFPY) operational assessment until the next inspection at RO35. Two-cycle (4 EFPY) OA results for structural and leakage integrity are provided as well for each mechanism evaluated. Circumferential and axial ODSCC at the top of TTS expansion transition and axial ODSCC at TSPs will be evaluated. The operational assessment of SCC degradation mechanisms is performed using fully probabilistic methods through application of the Westinghouse Full Bundle Model (FBM) software package (Reference 18). The basic methodology for the fully probabilistic analysis is the same for each degradation mechanism, however, the specific inputs for each mechanism may be different. The basic fully probabilistic analysis method includes:

- Determination of the beginning-of-cycle (BOC) flaw size distribution for undetected flaws. This is typically performed with probability of detection distributions, simulations, and assumptions to develop the postulated flaw size distributions for maximum flaw depth, length and percent degraded area (PDA). The BOC PDA distribution is applicable to circumferential SCC degradation.
- Determination of the number of undetected flaws at the BOC. This is determined through trending of flaw initiation and projection or by conservative assumption.
- Flaw growth rate distributions for maximum depth, length, and PDA (for circumferential SCC degradation). Flaw growth rate distributions are determined by EPRI typical default growth rates and adjusted for hot leg temperature. The EPRI default growth rates are normalized to a hot leg temperature of 611°F, while the H.B. Robinson Unit 2 hot leg temperature over the past 3 cycles has been 605°F (Reference 4). The growth rates are adjusted by a correction factor determined from the Arrhenius correlation which considers the difference between these two temperature values. There is no data at H.B. Robinson to support site-specific growth rates.
- Determination of the maximum depth to structural equivalent depth (SED) correlation. This parameter is applicable to axial flaws and is used to convert a flaw maximum depth to SED as the burst equations of Reference 2 use SED as calculational input. This correlation is a normal distribution with an mean value of 1.25 and a standard deviation of 0.08.
- Total length to structural equivalent length (SEL) correlation. This parameter is applicable to axial flaws and is used to convert a flaw total length to SEL as the burst equations of Reference 2 use SEL as a calculational input. This correlation is typically a uniform distribution from 1 to 3 based on historical industry flaw data, however, other values may be used when justified.

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- An inspection interval of 6.0 EFPY was applied for evaluations covering three cycles of operation to RO35.
- An inspection interval of 4.0 EFPY was applied for evaluations covering three cycles of operation to RO34.
- The remainder of critical inputs to the fully probabilistic model, including tube geometry, material properties, normal operating, accident pressures, and leakage limits are taken from the Reference 4 Degradation Assessment.

The fully probabilistic model combines the BOC flaw sized distributions with the growth distributions to determine the probability of burst (POB), probability of accident induced leakage (POL), burst pressure and accident leak rate at the end of the inspection interval. The results are compared to the following SG performance criteria:

- POB, ≤5%
- POL, ≤5%
- Burst Pressure, ≥4650 psi. This is associated with $3\Delta P_{NOP}$ as specified in Reference 4.
- Accident Induced Leak Rate, ≤0.06 gpm (Reference 4)

4.5.1 Circumferential ODSCC at the Expansion Transition

Even though circumferential ODSCC at the expansion transition was not reported and is not an existing degradation mechanism for H.B. Robinson Unit 2, a fully probabilistic full bundle analysis was performed using the Westinghouse Full Bundle Model (FBM) software package (Reference 18). The analysis assessed the SG performance criteria for POB, POL, burst pressure and accident induced leakage performance criteria for circumferential ODSCC flaws over 3 full cycles of operation with a total duration of 6.0 EFPY until the next planned SG inspections at RO35. The performance criteria was also met for a total duration of 4.0 EFPY until RO24.

The fully probabilistic analysis begins with development of the flaw POD function and distribution of undetected flaws. For detection of the potential mechanism circumferential ODSCC at the hot leg top of tubesheet during RO32, the array probe was used with EPRI ETSS technique 20500.1. A site-specific POD function for maximum flaw depth was developed using the EPRI Model Assisted POD (MAPOD) code (Reference 17). The MAPOD model combines the array probe detection voltage amplitude to true depth distribution correlation (Ahat) with the site-specific top of tubesheet expansion transition noise distribution to generate a site-specific noise-based POD curve for maximum flaw depth. The flaw dataset from ETSS 20500.1 was used for the Ahat correlation. The RO32 circumferential noise at the top of the tubesheet from the bounding SG was used in this assessment. The resulting POD has 0.95 probability of detection for a 78% TW flaw.

The fully probabilistic analysis uses flaw size distributions for assumed flaws that may not have been detected during the RO32 inspection. The flaw size parameters for the undetected flaw population include maximum depth, length, and PDA. The undetected flaw distributions describe the BOC flaw sizes to which the flaw growth is applied. The undetected flaw size distributions for each parameter were derived by the following methods:

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- The undetected maximum depth distribution was developed from the site-specific POD distribution (described above) applied uniformly to the full range of possible depths.
- The undetected flaw total length distribution was derived from industry data from actual indications.
- The undetected flaw PDA distribution was derived through simulations of the undetected maximum depth distribution, described above, and a shape factor distribution. The shape factor distribution is used to convert the maximum depth of a flaw to a PDA size. The shape factor distribution was determined through evaluation of the pulled tube data set from ETSS 21410.1 and is a uniform distribution from 1.15 to 6.
- EPRI typical default growth rates, adjusted for temperature, were used since there is no site specific data.
- The number of undetected flaws is assumed to be 2. Since there has not been any indications reported previously, a Weibull failure analysis is unable to be completed. After reviewing industry data and the inspection history at Robinson, it is concluded that an assumption of 2 undetected flaws in all of the SGs combined is appropriate.

The POB and POL results for 2 undetected flaw assumption for two and three cycles are provided in Table 4-2. These results were within the ≤5% performance criteria for burst and accident induced leakage probabilities. Additionally, the accident induced leakage satisfies the accident induced leakage limit of 0.06 gpm. The lower 5th percentile burst pressure also satisfies the minimum burst pressure requirement of 4650 psi. Therefore, circumferential ODSCC at the hot leg expansion transition meets the OA performance criteria for structural and leakage integrity for two (4.0 EFPY) and three (6.0 EFPY) full cycles of operation.

Table 4-2: Circumferential ODSCC at HTS FBM Simulation Results Summary

Number of Non-Detected Flaws	Cycle Duration (EFPY)	Number of Cycles	Prob. of Burst (POB) (%)	Prob. of Leakage (POL) (%)	Burst Pressure at Lower 5% (psi)	Leak Rate at Lower 5% Burst Pressure (gpm)
2	2.0 EFPY	2	1.213	0.936	5654	0.00
2	2.0 EFPY	3	2.911	2.159	5156	0.00
Acceptance Criterion	A600TT		≤5%	≤5%	≥4650 psi	≤0.06 gpm

4.5.2 Axial ODSCC at Tubesheet Expansion Transitions

Axial ODSCC at Tubesheet Expansion Transitions

Even though axial ODSCC at the expansion transition was not reported and is not an existing degradation mechanism for Robinson, a fully probabilistic full bundle analysis was performed using the Westinghouse FBM software package (Reference 18). The analysis assessed the SG performance criteria for POB and POL, burst pressure and accident induced leakage performance criteria for axial ODSCC flaws located at expansion transition and sludge pile regions over three

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full cycles of operation with a total duration of 6.0 EFPY until the next planned SG inspections at RO35. The performance criteria was also met for a total duration of 4.0 EFPY until RO24.

A POD distribution for axial ODSCC flaws located at the top of the tubesheet and sludge pile was developed as input to the full probability analysis model. For axial ODSCC at these locations, the array probe detection technique applied during inspections was ETSS 20402.1, which was extended in the Reference 4 DA from its intended use of detection of axial ODSCC at support structures. A site-specific POD function for maximum flaw depth was developed using the EPRI MAPOD computer code (Reference 17). The MAPOD model combines the array probe detection voltage amplitude to destructive examination depth distribution correlation (Ahat), from the ETSS 20402.1 flaw dataset, with the site-specific top of tubesheet expansion transition axial noise distribution to generate a site-specific noise-based POD function for maximum flaw depth. The RO32 Vvm noise distribution applicable to axial degradation at the top of the tubesheet from the bounding SG was used for the development of the POD function. The resulting POD has a 0.95 detection capability of an 88% TW flaw

The fully probabilistic analysis uses flaw size distributions for assumed flaws that may not have been detected during the RO32 inspection. The flaw size parameters for the undetected flaw population include maximum depth and length. The undetected flaw distributions describe the BOC flaw sizes to which the flaw growth is applied. The undetected flaw size distributions for each parameter were derived by the following methods:

- The undetected maximum depth distribution was developed by processing a uniform flaw distribution of the full range of flaw depths through the POD function.
- The undetected flaw total length distribution was derived from industry data of previously detected flaws. This length distribution considers NDE uncertainty and one cycle of growth. The resulting function has a 50th percentile length of approximately 0.28 inch and 95th percentile length of approximately 0.48 inch. Since length growth is built into the undetected length distribution, and the EPRI SG IAGL note that length growth for axial flaws is not significant, therefore no additional length growth is applied in the OA.
- The number of undetected flaws is assumed to be 2. Since there has not been any indications reported previously, a Weibull failure analysis is unable to be completed. After reviewing industry data and the inspection history at Robinson, it is concluded that an assumption of 2 undetected flaws in all of the SGs combined is appropriate.

The POB and POL results for 2 undetected flaw assumption for two and three cycles are provided in Table 4-3. These results were within the ≤5% performance criteria for burst and accident induced leakage probabilities. Additionally, the accident induced leakage satisfies the accident induced leakage limit of 0.06 gpm. The lower 5th percentile burst pressure also satisfies the minimum burst pressure requirement of 4650 psi. Therefore, circumferential ODSCC at the hot leg expansion transition meets the OA performance criteria for structural and leakage integrity for two (4.0 EFPY) and three (6.0 EFPY) full cycles of operation.

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Table 4-3: Axial ODSCC at HTS FBM Simulation Results Summary						
Number of Non-Detected Flaws	**Cycle Duration (EFPY)**	**Number of Cycles**	**Prob. of Burst (POB) (%)**	**Prob. of Leakage (POL) (%)**	**Burst Pressure at Lower 5% (psi)**	**Leak Rate at Lower 5% Burst Pressure (gpm)**
2	2.0 EFPY	2	1.465	0.038	5347	0.00
2	2.0 EFPY	3	3.085	0.084	4924	0.0004
Acceptance Criterion	A600TT		≤5%	≤5%	≥4650 psi	≤0.06 gpm

4.5.3 Axial ODSCC at TSP Intersections

Even though axial ODSCC at TSP intersections was not reported and is not an existing degradation mechanism for Robinson, a full probability full bundle analysis was performed using the Westinghouse FBM software package (Reference 18). The analysis assessed the SG performance criteria for POB and POL, burst pressure and accident induced leakage performance criteria for axial ODSCC flaws at TSP intersections over three full cycles of operation with a total duration of 6.0 EFPY until the next planned SG inspections at RO35. The performance criteria was also met for a total duration of 4.0 EFPY until RO24.

The EPRI ETSS I28411 POD distribution for axial ODSCC flaws located at drilled hole TSP intersections was used as input to the full probability analysis model. A site-specific POD function for maximum flaw depth was developed using the EPRI MAPOD computer code (Reference 17). The MAPOD model combines the array probe detection voltage amplitude to destructive examination depth distribution correlation (Ahat) with the site-specific TSP noise distribution to generate a site-specific noise-based POD curve for maximum flaw depth. The RO32 noise distribution applicable to axial degradation at the TSP intersections for the bounding SG was used for the development of the POD curve. The output for this POD was then put into Westinghouse GLM software to make a final POD curve.

The fully probabilistic analysis uses flaw size distributions for assumed flaws that may not have been detected during the RO32 inspection. The flaw size parameters for the undetected flaw population include maximum depth and length. The undetected flaw distributions describe the BOC flaw sizes to which the flaw growth is applied. The undetected flaw size distributions for each parameter were derived by the following methods:

- The undetected maximum depth distribution was developed using a combined POD from the bobbin and array probes since both were used for detection of this potential mechanism. A uniform flaw distribution of the full range of potential flaw depths (1% to 99% TW) was processed through the bobbin technique I28411 POD function to develop the non-detected population from the bobbin exam. Then, this non-detected population was input into the site-specific array POD, considering noise effects at TSP locations, to developed the final undetected depth distribution from both exams.

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- The undetected flaw total length distribution was derived from industry experience.
- Flaw growth rate distributions are applied to the BOC flaw distributions for maximum depth and total length. Consequently, in lieu of using site-specific growth distributions in this assessment, the EPRI typical default growth rate, adjusted for temperature, was used for maximum depth growth rates. No length growth was applied since industry lookbacks at actual flaws showed essentially no length growth (Reference 19).

The POB and POL results for 2 undetected flaw assumption for two and three cycles are provided in Table 4-4. These results were within the ≤5% performance criteria for burst and accident induced leakage probabilities. Additionally, the accident induced leakage satisfies the accident induced leakage limit of 0.06 gpm. The lower 5th percentile burst pressure also satisfies the minimum burst pressure requirement of 4650 psi. Therefore, axial ODSCC at TSP locations meets the OA performance criteria for structural and leakage integrity for three cycles (6.0 EFPY) of operation.

Table 4-4: Axial ODSCC at TSPs FBM Simulation Results Summary

Number of Non-Detected Flaws	Cycle Duration (EFPY)	Number of Cycles	Prob. of Burst (POB) (%)	Prob. of Leakage (POL) (%)	Burst Pressure at Lower 5% (psi)	Leak Rate at Lower 5% (gpm)
2	2.0 EFPY	2	1.709	0.377	5411	0.00
2	2.0 EFPY	3	4.274	1.232	4758	0.011
Acceptance Criterion	A600TT		≤5%	≤5%	≥4650 psi	≤0.06 gpm

Typically, the POL would be combined by the product rule to obtain a cumulative POL for all mechanisms. Since these degradation mechanisms have not been found at Robinson, it would be overly conservative to assume all three indications would occur so each result is individually compared to the acceptance criteria under the assumption that if a potential mechanism were to initiate during the next operating cycle, that it would most likely only be one of these that have been evaluated. The largest POB for three cycles was 4.274% and 1.709 for two cycles which is under the acceptance criteria of 5%. The largest POL for three cycles is 2.159% and 0.936% for three cycles which is under the acceptance criteria of 5%. The lowest burst pressure for three cycles is 4758 psi and 5347 psi for two cycles which is greater than the $3\Delta P_{NOP}$ of 4650 psi. The largest leak rate found for three cycles was 0.011 gpm and there was no leakage predicted for two cycles which is under the AILPC limit of 0.06 gpm.

4.5.4 Other Potential Mechanisms

The other potential degradation mechanisms identified in the Reference 4 DA are the following:

- Axial PWSCC at TTS Expansion Transition
- Circumferential PWSCC at TTS Expansion Transition
- Axial ODSCC in Freespan

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These additional potential degradation mechanisms have not been seen at H.B. Robinson Unit 2. These mechanisms are also less frequently seen in the industry as well. Since the operational assessment was performed on the three most likely stress corrosion mechanisms, that assessment bounds these less likely potential degradation mechanisms. Further, the assessments performed in the A600TT feasibility study report (Reference 20) determined that PWSCC growth rates are bounded by ODSCC growth rates as well as PWSCC historical flaw lengths being bounded by ODSCC flaw lengths. Lastly, the detection capability with array probe is greater for PWSCC than ODSCC flaws meaning the undetected flaw distribution for ODSCC mechanisms would result in greater BOC flaw depths.

For these reasons, along with the greater prevalence of ODSCC flaws in the industry, PWSCC mechanisms are not evaluated in this assessment of potential SCC mechanisms for H.B. Robinson Unit 2 for the next inspection interval.

4.6 LEAKAGE ASSESSMENT

For pressure loading of volumetric degradation that is predominantly axial in character with a circumferential extent that is less than 135°, the onset of pop-through and burst is coincident. Satisfaction of structural integrity therefore implies satisfaction of leakage integrity under accident pressure loading. Thus, the projected AVB and TSP wear that meets the structural integrity performance criteria also meets leakage integrity performance criteria. Further, since margin is demonstrated between the projected size of the flaws at the end of Cycle 35 and the EOC structural limits, no leakage is predicted for existing mechanisms.

Leakage is also evaluated for the potential degradation mechanisms evaluated using fully probabilistic methods as discussed in Section 4.5, for three cycles of operation. The total 95/50 predicted leakage from the three mechanisms evaluated is 0.0114 gpm. The H* correction factor for H.B. Robinson which applies to predicted leakage from sources other than within the tubesheet region is 1.87. This correction factor is applied to the OA projected leakage to determine if an administrative limit is required to be established over the next operating cycle. This calculation is performed below.

$$Administative\ Limit = \frac{0.10417\ gpm}{1.87} - 0.0114\ gpm = 0.04431\ gpm = 63.8\ gpd$$

With the OA predicted leakage for potential mechanisms, the calculated administrative limit for the last cycle of operation is 63.8 gpd. No leakage is projected from existing degradation mechanisms, in which case the H* leakage limit of 80.2 gpd would remain applicable.

There is no leakage predicted from any of the existing or potential mechanisms for two cycles of operation, therefore no changes need made to the administrative leakage limit for the next two cycles of operation.

4.7 OPERATIONAL ASSESSMENT CONCLUSIONS

Tube wear at AVB intersections was evaluated for three cycles (6 EFPY) using deterministic OA methods. The growth rate of AVB wear flaws has been shown to be slow for flaws with growth

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data. By applying the maximum growth experienced for a single AVB wear indication to the indication with the maximum depth returned to service it was determined to be well below the EOC structural limit when considering burst relation, material, and NDE measurement uncertainties. The largest flaw predicted to have potentially escaped detection is smaller than the largest flaw returned to service, so tube integrity is demonstrated for the next operating cycle for the assumed undetected flaw population.

Tube wear at broached TSP intersections was evaluated for three cycles (6 EFPY) using deterministic methods. The growth rate of existing TSP wears flaws has been shown to be negligible, but there are too few of them to confidently apply that growth to the OA. A bounding growth of 5% TW/EFPY was applied to the indication with the maximum depth returned to service and the projected depth was found to be less than the EOC structural limit when considering burst relation, material, and NDE measurement uncertainties. Since the bobbin noise measured at broached TSP and drilled FDB locations was bounded by the ETSS noise, the ETSS POD is applicable. The largest TSP wear flaw predicted to have potentially escaped detection is smaller than the largest flaw returned to service, so tube integrity is demonstrated for the next operating cycle for the assumed undetected flaw population. No indications were found at the drilled FBD during RO32. The largest FDB flaw predicted to have potentially escaped detection was determined to be well below the EOC structural limit when considering burst relation, material and NDE measurement uncertainties. Therefore, structural integrity was demonstrated for the population of assumed undetected FDB wear flaws.

Tube wear due to foreign objects was evaluated for a 3-cycle OA (6 EFPY). Foreign object wear without a part being present at the location is considered to have low potential for growth due to the mechanism for wear initiation having been removed. OA of foreign objects remaining in the SG is performed in Reference 6.

For volumetric degradation such as AVB and TSP wear, the on-set of pop-through and burst is coincident. Therefore, demonstration of structural integrity through standard OA methods at $3\Delta P_{NO}$ performance criteria implies leakage integrity for the same population of flaws. With no projected leakage over the next operating cycle, no establishment of (or correction to) an administrative leakage limit is required as a result of H* criteria leakage correction factor.

Potential stress corrosion cracking could occur before the next inspection at RO35. The three most common types of stress corrosion cracking, circumferential and axial ODSCC at expansion transitions and axial ODSCC at TSPs, were evaluated in an operational assessment for burst and leakage integrity. These indications all passed POB, POL and leak rate acceptance criteria. PWSCC at the expansion transition and axial ODSCC in the freespan were not evaluated due to the A600TT feasibility study report (Reference 20) concluding that the indications evaluated are bounding and that these indications meet the OA performance criteria for structural and leakage integrity for two (4.0 EFPY) and three (6.0 EFPY) cycles of operation.

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4. Duke Report, "H.B. Robinson Unit 2 RO32 Steam Generator Degradation Assessment," Revision 1, November 2020 (electronically attached).

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6. Framatome Report, 51-9321335-00, Revision 0, "Disposition of Foreign Object(s) Remaining in HB Robinson RSGs (Post-Secondary Side Inspection 2RFO 32)," November 2020, (electronically attached).

7. EPRI Computer Software 3002010334, "Steam Generator Management Program: Model Assisted Probability of Detection Using R (MAPOD-R), Version 2.1," 2017.

8. Westinghouse Nuclear Safety Advisory Letter, NSAL-12-1, Revision 1, "Steam Generator Channel Head Degradation," October 2017.

9. *Steam Generator Degradation Specific Management Flaw Handbook, Revision 2.* EPRI, Palo Alto, CA: 2015. 3002005426.

10. Email from Dan Mayes (Duke) to Brad Carpenter (Westinghouse), Topic: NSAL and Plug Inspections, dated 11/23/2020, (electronically attached).

11. Email from Dan Mayes (Duke) to Brad Carpenter (Westinghouse), Topic: RNP EFPY, dated 11/16/2020, (electronically attached).

12. Email from Dan Mayes (Duke) to Brad Carpenter (Westinghouse), Topic: HB Robinson R2R32 Noise Questions, dated 11/24/2020, (electronically attached).

13. H.B. Robinson R2R32 Eddy Current Examination Technique Specification Sheet, Bobbin, Rev. 0, (electronically attached).

14. H.B. Robinson R2R32 Eddy Current Examination Technique Specification Sheet, 3 Coil, Rev. 0, (electronically attached).

15. H.B. Robinson R2R32 Eddy Current Examination Technique Specification Sheet, 1 coil, Rev. 0, (electronically attached).

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16. H.B. Robinson R2R32, Eddy Current Examination Technique Specification Sheet, Array, Rev. 0, (electronically attached).

17. EPRI Computer Software 3002010334, "Steam Generator Management Program: Model Assisted Probability of Detection Using R (MAPOD-R) Version 2.1," 2017.

18. Westinghouse Letter LTR-CDMP-20-33, Revision 0, "Software Release Letter for Full Bundle Model, Version 2.3 on the Windows 10 System State," October 2020.

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20. *Feasibility Study for Multi-Cycle 600TT Operational Assessment, Revision 0.* EPRI, Palo Alto, CA: 2020. 3002018258.

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Appendix A: Final Eddy Current Testing Summary

11/21/2020 11:23 PM

HB Robinson
R2R32 - 11/2020
Final ECT Status

		S/G A					S/G B					S/G C				
Scope Description	Extent	Plan	Acq'd	%	Comp	%	Plan	Acq'd	%	Comp	%	Plan	Acq'd	%	Comp	%
Bobbin Coil Exams																
Full Length	CTEHTE	2841	2841	100.00%	2841	100.00%	2824	2824	100.00%	2824	100.00%	2828	2828	100.00%	2828	100.00%
H/L CandyCane (Row 3-4)	06CHTE	183	183	100.00%	183	100.00%	183	183	100.00%	183	100.00%	183	183	100.00%	183	100.00%
C/L Straight (Row 1-4)	06CCTE	364	364	100.00%	364	100.00%	366	366	100.00%	366	100.00%	364	364	100.00%	364	100.00%
H/L Straight (Row 1-2)	06HHTE	181	181	100.00%	181	100.00%	183	183	100.00%	183	100.00%	181	181	100.00%	181	100.00%
Bobbin Subtotal		3569	3569	100.00%	3569	100.00%	3556	3556	100.00%	3556	100.00%	3556	3556	100.00%	3556	100.00%
Array Exams																
100% H/L Tubesheet	01HHTE	3200	3200	100.00%	3200	100.00%	3180	3180	100.00%	3180	100.00%	3165	3165	100.00%	3165	100.00%
F/L 2-sigma tubes	CTEHTE	5	5	100.00%	5	100.00%	10	10	100.00%	10	100.00%	27	27	100.00%	27	100.00%
C/L Tubesheet	01CCTE	1258	1258	100.00%	1258	100.00%	1250	1250	100.00%	1250	100.00%	1248	1248	100.00%	1248	100.00%
100% Rows 1-2 U-bend	06C06H	181	181	100.00%	181	100.00%	183	183	100.00%	183	100.00%	181	181	100.00%	181	100.00%
20% Row 9 U-bend	06C06H	18	18	100.00%	18	100.00%	18	18	100.00%	18	100.00%	18	18	100.00%	18	100.00%
New C/L PLP/FO Bounding	01CCTE	0	0	0.00%	0	0.00%	13	13	100.00%	13	100.00%	7	7	100.00%	7	100.00%
Preplanned Array Special Interest																
H/L Pre-planned Array (DNT, array TWD)	Various	22	22	100.00%	22	100.00%	242	242	100.00%	242	100.00%	29	29	100.00%	29	100.00%
C/L Pre-planned Array (DNT,array TWD)	Various	14	14	100.00%	14	100.00%	28	28	100.00%	28	100.00%	31	31	100.00%	31	100.00%
Ubend Pre-planned Array (DNT,array TWD))	06C06H	22	22	100.00%	22	100.00%	22	22	100.00%	22	100.00%	25	25	100.00%	25	100.00%
Preplanned Array Subtotal		4720	4720	100.00%	4720	100.00%	4946	4946	100.00%	4946	100.00%	4731	4731	100.00%	4731	100.00%
Special Interest																
H/L Array SI	Various	23	23	100.00%	23	100.00%	13	13	100.00%	13	100.00%	9	9	100.00%	9	100.00%
C/L Array SI	Various	7	7	100.00%	7	100.00%	7	7	100.00%	7	100.00%	7	7	100.00%	7	100.00%
Ubend Array SI	Various	3	3	100.00%	3	100.00%	9	9	100.00%	9	100.00%	2	2	100.00%	2	100.00%
H/L RPC SI	Various	1	1	100.00%	1	100.00%	4	4	100.00%	4	100.00%	2	2	100.00%	2	100.00%
C/L RPC SI	Various	0	0	0.00%	0	0.00%	1	1	100.00%	1	100.00%	0	0	0.00%	0	0.00%
Ubend RPC SI	Various	0	0	0.00%	0	0.00%	0	0	0.00%	0	0.00%	1	1	100.00%	1	100.00%
Special Interest subtotal		34	34	100.00%	34	100.00%	34	34	100.00%	34	100.00%	21	21	100.00%	21	100.00%
Plug Visual Exam																
H/L Plugs	HTEHTE	9			9	100.00%	24			24	100.00%	22			22	100.00%
C/L Plugs	CTECTE	9			9	100.00%	24			24	100.00%	22			22	100.00%
	Total	8323	8323	100.00%	8323	100.00%	8536	8536	100.00%	8536	100.00%	8308	8308	100.00%	8308	100.00%

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