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10 CFR 50.90
10 CFR 50.91(a)(5)

April 6, 2020

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

Braidwood Station, Unit 2
Renewed Facility Operating License No. NPF-77
NRC Docket No. 50-457

Subject: Emergency License Amendment Request for a One-Time Extension of the Steam Generator Tube Inspections

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit, or early site permit," Exelon Generation Company, LLC (EGC) requests an amendment to the Technical Specifications (TS) for Renewed Facility License No. NPF-77 for Braidwood Station, Unit 2 (Braidwood). The proposed change is being requested on an emergency basis pursuant to 10 CFR 50.91(a)(5).

This proposed emergency amendment request revises TS 5.5.9, "Steam Generator (SG) Program," for a one-time revision to the frequency for Steam Generator Tube Inspections. The requested TS amendment supports deferral of the TS required inspections until the next Unit 2 refueling outage.

Emergency circumstances are present in that the Centers for Disease Control and Prevention has issued recommendations advising isolation activities (e.g., social distancing, group size limitations, self-quarantining, etc.) to prevent the spread of the COVID-19 Virus. The nature of the Steam Generator inspections conflicts with the recommendations in that they require workers to be in constant proximity to each other in a hot and radiological environment that exponentially increases the likelihood of individuals contracting COVID-19 and potentially inducing a rapid spread. Additionally, these inspections require a specialty vendor that maintains unique and complex qualifications. Losing resources due to a virus spread would cause a situation where the proper technical knowledge would not be available to satisfactorily complete this work (minimal 14-day isolation and likely to be more than one individual based on having to work in close proximity for the work).

As a result of the current pandemic situation, an Operational Assessment (OA) is being developed to justify deferral of the Steam Generator inspections until the next Unit 2 refueling outage (approximately 52 effective full power months from the last inspection). EGC has

determined this deferral to involve less risk than performing the inspections under the current situation. The above circumstances were beyond the ability of EGC to foresee and avoid.

Attachment 1 provides a description and assessment of the proposed change. Attachment 2 provides the preliminary OA which addresses the limiting degradation mechanisms and all existing degradation mechanisms. Attachment 3 provides the existing TS page marked-up to show the proposed change. Attachment 4 provides the revised (clean) TS page. The final OA which addresses all degradation mechanisms will be submitted by April 17, 2020.

The proposed change has been reviewed by Braidwood Plant Operations Review Committee in accordance with the requirements of the EGC Quality Assurance Program.

Approval of the proposed amendment is requested by April 20, 2020. Once approved, the amendment shall be implemented within 2 days.

In accordance with 10 CFR 50.91, "Notice for public comment; State consultation," paragraph (b), EGC is notifying the State of Illinois of this application for license amendment by transmitting a copy of this submittal and its attachment to the designated State Officials.

This submittal contains no regulatory commitments. Should you have any questions concerning this submittal, please contact Ms. Lisa Zurawski at (630) 657-2816.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 6th day of April 2020.

Respectfully,

Dwi Murray
Sr. Manager – Licensing
Exelon Generation Company, LLC

Attachments:
1. Description and Assessment
2. Preliminary Operational Assessment
3. Proposed Technical Specification Change (Mark-Up) for Braidwood Station
4. Proposed Technical Specification Change (Clean) for Braidwood Station

cc: NRC Regional Administrator, Region III
NRC Senior Resident Inspector – Braidwood Station
Illinois Emergency Management Agency – Division of Nuclear Safety

ATTACHMENT 1
Description and Assessment

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1.0 SUMMARY DESCRIPTION

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2.0 DETAILED DESCRIPTION

2.1 Reason for the Proposed Change

The Centers for Disease Control and Prevention (CDC) has issued recommendations advising "social distancing" or sequestering staff to prevent the spread of the COVID-19 Virus. There are an estimated 170 people onsite to support the specific Steam Generator (SG) inspections, many of whom travel from other areas of the country. As such, this request is being made to support the Braidwood Station proactive efforts to follow the CDC recommendations (e.g., social distancing, group size limitations, self-quarantining, etc.) by limiting the number of people onsite and in our neighboring community.

The nature of the Steam Generator inspections conflicts with the recommendations since it requires workers to be in constant proximity to each other in a hot and radiological environment that exponentially increases the likelihood of individuals contracting COVID-19 and potentially inducing a rapid spread. Additionally, these inspections require a specialty vendor that maintains unique and complex qualifications. Losing resources due to a virus spread would cause a situation where the proper technical knowledge would not be available to satisfactorily complete this work (minimal 14-day isolation and likely to be more than one individual based on having to work in close proximity for the work).

As a result of the current pandemic situation, an Operational Assessment (OA) is being developed to justify deferral of the Steam Generator inspections until the next Unit 2 refueling outage (approximately 52 effective full power months from the last inspection). Attachment 2 provides the preliminary OA which addresses the limiting degradation mechanisms and all existing degradation mechanisms. EGC has determined this deferral to involve less risk than performing the inspections under the current situation.

2.2 Description of the Proposed Change

The proposed TS change will add a statement to the Braidwood TS 5.5.9, “Steam Generator (SG) Program,” as described below.

TS 5.5.9.d.3 currently states (in part):

> For Unit 2, after the first refueling outage following SG installation, inspect each SG at least every 48 effective full power months or at least every other refueling outage (whichever results in more frequent inspections). In addition, the minimum number of tubes inspected at each scheduled inspection shall be the number of tubes in all SGs divided by the number of SG inspection outages scheduled in each inspection period as defined in a, b, and c below. If a degradation assessment indicates the potential for a type of degradation to occur at a location not previously inspected with a technique capable of detecting this type of degradation at this location and that may satisfy the applicable tube plugging criteria, the minimum number of locations inspected with such a capable inspection technique during the remainder of the inspection period may be prorated. The fraction of locations to be inspected for this potential type of degradation at this location at the end of the inspection period shall be no less than the ratio of the number of times the SG is scheduled to be inspected in the inspection period after the determination that a new form of degradation could potentially be occurring at this location divided by the total number of times the SG is scheduled to be inspected in the inspection period. Each inspection period defined below may be extended up to 3 effective full power months to include a SG inspection outage in an inspection period and the subsequent inspection period begins at the conclusion of the included SG inspection outage.

The revised TS 5.5.9.d.3 (in part) will state:

> For Unit 2, after the first refueling outage following SG installation, inspect each SG at least every 48 effective full power months or at least every other refueling outage (whichever results in more frequent inspections), with the exception that each SG is to be inspected during the third refueling outage in A2R22 following inspections completed in refueling outage A2R19. In addition, the minimum number of tubes inspected at each scheduled inspection shall be the number of tubes in all SGs divided by the number of SG inspection outages scheduled in each inspection period as defined in a, b, and c below. If a degradation assessment indicates the potential for a type of degradation to occur at a location not previously inspected with a technique capable of detecting this type of degradation at this location and that may satisfy the applicable tube plugging criteria, the minimum number of locations inspected with such a capable inspection technique during the remainder of the inspection period may be prorated. The fraction of locations to be inspected for this potential type of degradation at this location at the end of the inspection period shall be no less than the ratio of the number of times the SG is scheduled to be inspected in the inspection period after the determination that a new form of degradation could potentially be occurring at this location divided by the total number of times the SG is scheduled to be inspected in the inspection period. Each inspection period defined below may be extended up to 3 effective full power months to include a SG inspection outage in an inspection period and the subsequent inspection period begins at the conclusion of the included SG inspection outage.

Attachment 3 provides the marked-up page of the Braidwood Station, Units 1 and 2 TS showing the proposed change. Attachment 4 provides the revised (clean) TS page.

3.0 TECHNICAL EVALUATION

3.1 System Description

The Steam Generators (SG) are vertical shell and U-tube heat exchangers with integral moisture separating equipment. Braidwood Unit 2 has Westinghouse Model D-5 SGs equipped with 4,570 Alloy 600 thermally treated (Alloy 600TT) tubes. The tubes have an outer diameter of 0.75 inches with a 0.043-inch nominal wall thickness. The tube support plate is stainless steel. The tubes were hydraulically expanded to the full length of the tube sheet. Braidwood Unit 2 SG have been operating for approximately 28.45 effective full power years.

On the primary side, the reactor coolant flows through the inverted U-tubes, entering and leaving through nozzles located in the hemispherical bottom head of the SG. The head is divided into inlet and outlet chambers by a vertical divider plate extending from the head to the tube sheet.

Steam is generated on the shell side, flows upward and exits through the outlet nozzle at the top of the vessel. During normal operation for Braidwood Unit 2, feedwater flows through a flow restrictor, directly into the counter flow preheat section and is heated almost to saturation temperature before entering the boiler section. Subsequently, the water-steam mixture flows upward through the tube bundle and into the steam drum section, where individual centrifugal moisture separators remove most of the entrained water from the steam. The steam continues to the secondary separators for further moisture removal, increasing its quality to a minimum of 99.75% for Unit 2. The moisture separators recirculate the separated water through the annulus between the shell and tube bundle wrapper via the space formed by the distribution plate. The returning flow then combines with the already preheated water-steam mixture for another passage through the SG. Dry steam exits through the outlet nozzle which is provided with a steam flow restrictor.

3.2 Technical Analysis

The current TS requirement is to inspect each SG at least every 48 effective full power months (EFPM) or at least every other refueling outage (whichever results in more frequent inspections). The proposed one-time revision allows the inspection deferral of each SG to after three operating cycles following refueling outage A2R19 performed in April 2017.

Significant operating experience has been gained over the course of 17 years since the current TS inspection frequency was established and provides justification for deferring the inspection by one operating cycle.

The susceptibility to stress corrosion cracking (SCC) in Alloy 600TT has limited the maximum SG inspection frequency allowed by TS to every other refueling outage. However, operating experience for nearly forty years has shown no propensity for rapidly increasing crack initiation rates in Alloy 600TT SG tubes. Braidwood Unit 2 has successfully operated three cycles and performed two inspections since it identified one tube with SCC in 2012. The proposed change of one-time revision to allow three operating cycles between inspections has been evaluated to meet the structural integrity and accident induced leakage performance criteria even for SGs that have experienced cracking in the past. Based on this operating experience and a

supporting Operational Assessment, the proposed TS change to require inspection of the tubing after three operating cycles is acceptable.

To justify the deferral of the inspections to after a third operating cycle, the SG Program requires assessments to ensure safe SG inspection intervals that are based on measurable parameters that monitor SG performance, such as results of SG tube inspections and operational leakage. Objective criteria to assess performance are established based on deterministic and probabilistic analyses and performance history. In addition, the TS requirements on operational leakage require a plant shutdown if the limits are exceeded. During the extended operating cycle form A2R21 to A2R22, Braidwood Unit 2 will lower its normal 100 gpd shutdown criteria for primary-to-secondary leakage down to 30 gpd for confirmed and sustained leakage at or above that level. This ensures that the failure to meet a performance criterion, while undesirable, will not result in an immediate safety concern. Therefore, the proposed one-time extension of the existing SG inspection frequency is acceptable.

3.2.1 Recent operational experience summary

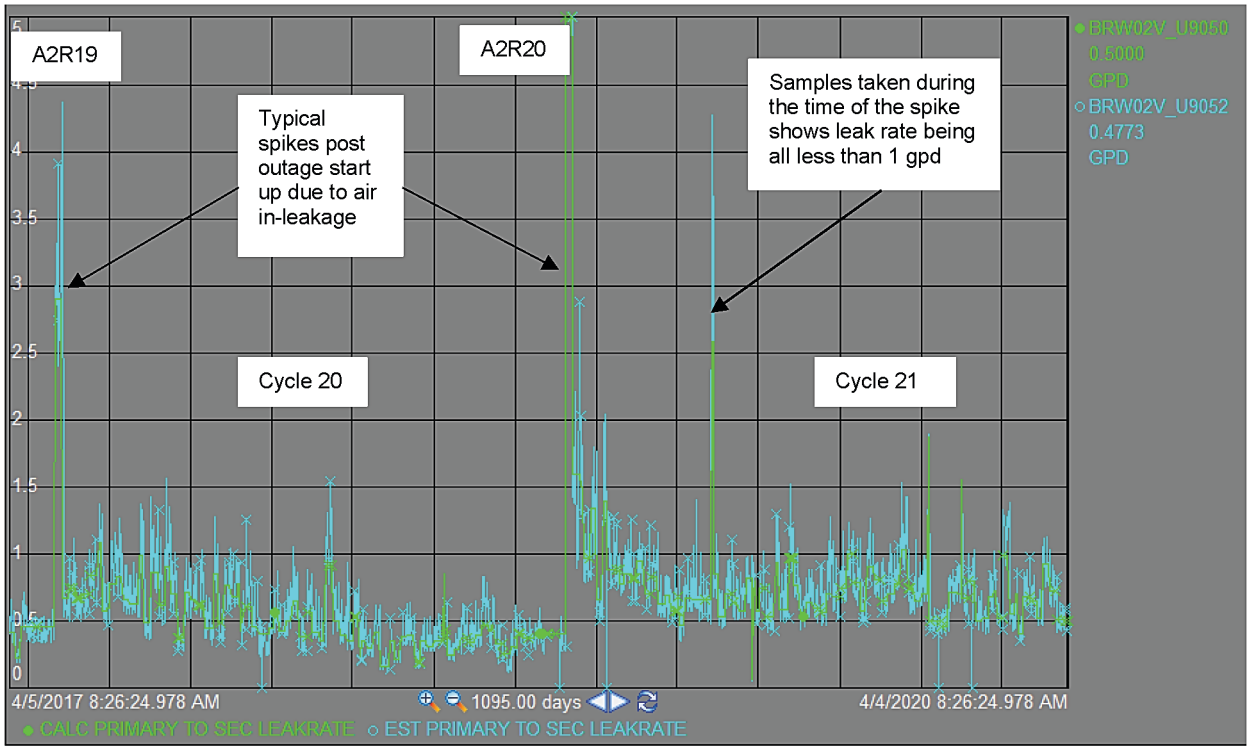
3.2.1.a Trends of primary to secondary leakage

No primary to secondary side leakage has been noted for operating Cycles 20 and 21. All trends are below 3 gallons per day (gpd), except for a spike occurring between April 1, 2019 and April 3, 2019 due to computer point error. Actual samples showed that during this time frame, the trend was determined to be less than 1 gpd. Other typical spikes which occurred post refueling outages were due to air in-leakage issues and not related to primary to secondary leakage. The primary to secondary leak rate determination utilizes the Condenser Offgas method, which uses steam jet air ejector (SJAE) flow. During unit start-ups, these flows are normally higher due to systems being returned to service. The high SJAE flow causes a higher primary to secondary leak rate during start-up and post outage which are not related to primary to secondary leakage.

Primary to secondary leak rates are quantified through periodic sampling of the primary coolant system and the condenser off gas/air ejectors, with leak rate calculated based on mass-balance of noble gas isotopes. Leak rates are continuously monitored using on-line radiation monitors and supporting software available in the control room.

Section 3.2.4 discusses the mitigation actions for required shutdown thresholds.

Figure 1: Primary to Secondary Leak Rate for Operating Cycles 20 and 21



3.2.1.b Summary of the most recent primary and secondary (e.g., FOSAR) inspections, detected degradation and its location

The Braidwood Unit 2 (A2R19) report, "Braidwood Station, Unit 2 Steam Generator Tube Inspection Report for Refueling Outage 19," dated August 24, 2017 (ML17236A457) contains the high level summary of the most recent primary and secondary inspections, including degradation detected and location of the degradation.

3.2.1.c Number of tubes plugged and reason for plugging

The number of tubes plugged for Braidwood Unit 2 will not adversely impact tube integrity, as noted in Table 1. Table 2 represents the reasons for tube plugging during each SG inspection outage.

TABLE 1: Braidwood Unit 2 Plugging Percent

Plugging Summary (Post A2R19)	SG 2A	SG 2B	SG 2C	SG 2D	TOTAL
Total Tubes Plugged	107	66	72	44	289
Total PCT Plugged	2.34%	1.44%	1.58%	0.96%	1.58%
Plugging Limit	5%	5%	5%	5%	5%

TABLE 2: Braidwood Unit 2 Plugging History by Degradation Mechanism

Date	Outage	EFPY[1]	TSP ODSCC	U-Bend PWSCC[5]	Lower TS PWSCC	Circ Ind. [3]	AVB Wear	OD Vol Near TSPs	Foreign Object Wear	TSP Wear	Prev. High Res Stress	Other / Prev.	Total
	PSI	0	0	0	0	0	0	0	0	0	0	5	5
03/90	A2R01	1.18	0	0	0	0	2	0	0	0	0	0	2
11/91	A2R02	2.30	0	0	0	0	11	0	0	0	0	0	11
03/93	A2R03	3.42	0	0	0	0	16	0	0	0	0	0	16
10/94	A2R04[2]	4.58	0	0	0	0	6	0	0	0	0	0	6
03/96	A2R05	5.85	0	1	0	0	29	3	2	0	0	0	35
10/97	A2R06	7.19	0	0	0	15[3]	12	1	0	0	0	0	28
04/99	A2R07	8.57	0	0	0	0	6	0	0	0	0	0	6
10/00	A2R08	9.97	0	0	0	0	10	0	0	0	0	1	11
4/02	A2R09[4]	11.33	0	0	0	0	2	0	0	0	0	0	2
11/03	A2R10	12.78	3	0	0	0	10	0	3	0	3	39	58
4/05	A2R11	14.16	0	0	0	0	5	0	1	0	0	0	6
10/06	A2R12	15.60	0	0	0	0	10	0	2	2	0	0	14
4/08	A2R13	17.05	0	0	16	0	6	0	1	0	0	0	23
10/09	A2R14	18.42	0	0	0	0	1	0	5	0	0	0	6
4/11	A2R15	19.85	1	0	0	0	5	0	18	2	0	4	30
10/12	A2R16	21.27	1[6]	0	0	0	2	0	6	0	2[7]	0	11
5/14	A2R17	22.72	0	0	0	0	3	0	0	0	0	5	8
10/15	A2R18	24.08	SG Skip Inspection										0
4/17	A2R19	25.56	0	0	0	0	7	0	1	0	0	3	11
9/18	A2R20	26.99	SG Skip Inspection										0
		TOTAL	5	1	16	15	143	4	39	4	5	57	289

[1] Braidwood Unit 2 Cumulative Effective Full Power Years
[2] During A2R04 only the B and C SGs were inspected
[3] Circ indications were shown to be irrelevant indications based on Byron Unit 2 tube pull
[4] During A2R09 only SG A was inspected
[5] PWSCC was subsequently determined not to be SCC by industry analysts (Ref EPRI Report 1003589)

[6] Tube R44-C47 was deemed as a high residual stress tube with potentially high stress after further review during A2R16. The tube contained three indications: two hot leg TSP axial ODSCC indications and one hot leg freespan axial ODSCC indication.

[7] Tubes were preventatively plugged since they were classified within the high residual stress population, but also had a bobbin coil u-bend offset trace similar to tube Row 44 Column 47 in SG 2C.

3.2.1.d Relevant operating experience that could impact tube integrity

Deposit Loading:

Based on the deposit loading amounts for Braidwood Unit 2, as shown below, the deposits do not impose an advese impact to tube integrity. During A2R19 in April 2017, the total inventory of deposits was reduced by 3,480 lbs, or 23% by means of a "soft" chemical cleaning application. The SG water level has trended steady and visual inspections of the uppermost tube support quatrefoil broach openings during A2R19 did not show any significant blockage.

TABLE 3: Braidwood Unit 2 Historical Deposits

Refueling Outage	Iron (as Fe_3O_4) Transported (4 SG Total)	Lbs Removed via Blowdown (4 SG Total)	Lbs Removed via SL and SC (4 SG Total)	Lbs Sludge Remaining (cycle net) (4 SG Total)	Cumulative Lbs Sludge Remaining (4 SG Total)
A2R08	356	17.8	269.5	68.7	14356
A2R09	386	19.3	185	181.7	14538
A2R10	385	19.25	207	158.8	14696
A2R11	600	30	192.5	377.5	15074
A2R12	349	17.45	204.5	127.1	15201
A2R13	286.3	14.315	284.5	-12.5	15188
A2R14	448	22.4	292	133.6	15322
A2R15	162.8	5.8	139.5	17.5	15340
A2R16	192.78	277.33	146.5	-231.05	15109
A2R17	228	187	0	41	15150
A2R18	156	231	0	-75	15075
A2R19	145	188	3480*	-3523	11552
A2R20	141	307	0	-166	11386

*Advanced Scale Conditioning Agent (ASCA) cleaning performed during A2R19

Chemistry (Operating Cycles 20 and 21):

There were no adverse changes to SG Chemistry in Cycle 20 or Cycle 21. See below results for SG Chemistry during Cycle 20.

- Elevated SG contaminants on startup resulted in 3.174 Chemistry Effectiveness Indicator (CEI-R) points accrued in May 2017. An additional 0.08 and 0.039 CEI-R points were accrued in June and July 2017 due to chronic SG contaminant. The cause of the ingress of sodium to the SG on June 23, 2017 was due to residual welding soot from A2R19 in a pipe that has had not seen flow since A2R19.

- Startup FW iron was 10.57 ppb and startup FW copper was 0.39 ppb. Although FW Iron was above the 10.0 ppb time-weighted average limit with Polyacrylic Acid (PAA) dispersant, Steam Generator Blowdown (SGBD) Iron removal efficiency was 100% for the month so no CEI-R points were accrued.

- A total of 102 pounds of iron (141 pounds as iron oxide) were transported to the 4 steam generators during Cycle 20, while 223 pounds of iron (307 pounds as iron oxide) were removed from the steam generators via blowdown.

See below results for SG Chemistry during Cycle 21.

- No CEI penalty from A2R20 start-up.

  Received a 0.667 CEI-R condition-3 penalty due to RCS lithium being in action level 1 in December 2019 for 6.4 hours, which caused a Unit 2 CEI-R cycle average being now at 0.230.

- SG iron removals have been improved with the stable injection of PAA dispersant into both SGs.

- Maintaining the frequency of swapping out the SGBD demineralizer every 5-6 months to prevent the intrusion of any containments into the SG from exhausting the any of the SGBD demineralizers.

Foreign Material:

A search of issue reports related to Foreign material, was performed for Braidwood Unit 2 operating Cycles 20 and 21 and no indications of ingress of foreign material into the Unit 2 Steam Generators occurred from other systems during that time frame.

Steam Drum:

The only Steam Drum component where active degradation has been observed is in the Primary Moisture Separators. Ultrasonic data has been taken shortly after discovery in 2005 and during SG inspections ultrasonic testing is performed on one to two SGs and the data from each inspection outage is used for developing wear rates, which are used for predicting through wall penetration. Based on review of ultrasonic thickness reading data on all four Braidwood Unit 2 SG Primary Moisture Separators, that includes the orifice ring assemblies, riser barrels, swirl vane blades, downcomer barrels, and tangential nozzles, the earliest prediction that a through-wall penetration could appear would be no sooner than 2024.

The spacer tab is the only component that could become a loose part if the tab thinned and broke off. During A2R19, six of thirty-two spacer tabs in SG 2C were visually observed to possess degradation (i.e., missing material). Given that the visual estimates of all spacer plates' thicknesses in SG 2C and SG 2D were greater than the 0.10 inch acceptance criteria, the as-found conditions of the spacer tabs are acceptable. Though the wear rate is not known, for the spacer tab, due to only one data set, these spacer tabs have been in operation since start-up and would not be expected to degrade enough to cause a loose part within the SGs for one additional cycle.

Therefore, based on the operating experience summary described above, it was concluded that one additional operating cycle is justified with no adverse consequences to extend the planned SG inspection until the next Unit 2 refueling outage (A2R22).

3.2.2. Condition Monitoring (CM) during refueling outage A2R19 (April 2017)

A summary of the Condition Monitoring (CM) results for A2R19 was submitted to the NRC on August 24, 2017, "Braidwood Station, Unit 2 Steam Generator Tube Inspections Report for Refueling Outage 19," (ML17236A457). The detailed inspection results and inputs used to perform the CM assessment are provided in the CM and Operational Assessment (OA) developed for A2R19 (Westinghouse Report SG-SGMP-17-17 dated May 2017 (Reference 8)).

3.2.2.a For each degradation mechanism detected, the most limiting as found condition compared to the tube performance criteria

For each degradation mechanism detected at the last Braidwood Unit 2 Steam Generator inspection in A2R19 (April 2017), the most limiting as found condition was compared to the tube performance criteria and is provided in Table 4 below.

The limiting case degraded condition detected at A2R19 for each degradation mechanism was less than the condition monitoring limit; therefore, Structural Integrity Performance Criteria (SIPC) were satisfied. The severity of the limiting degraded condition for each degradation mechanism is expressed as a percent through wall (%TW) depth for a given bounding axial extent using a deterministic approach (identified in the Electric Power Research Institute (EPRI) SG Integrity Assessment Guideline, Reference 1.b, as the "Mixed Arithmetic/Simplified Statistical" method). The SIPC is met if the as found worst case depth ("Maximum Depth Recorded" in Table 4) is less than the allowable depth ("CM Limit Depth" in Table 4). As can be seen for all degradation mechanisms detected in A2R19, the smallest margin, which was for Anti-Vibration Bar (AVB) wear, was approximately 19%TW.

TABLE 4: Summary of Condition Monitoring performance for Existing Degradation Mechanism during A2R19 (April 2017) (Reference 8)

Degradation Mechanism Detected at A2R19	Maximum Depth Recorded (%TW)	Projected Max Depth at A2R19 from A2R17 OA (%TW)	CM Limit Depth (%TW) (1)	Margin to CM Limit (%TW)	Bounding Axial Extent (inch)	ETSS
Cracking Mechanisms (ODSCC/ PWSCC)	None Detected	N/A	N/A	N/A	N/A	N/A
AVB Wear	46	59.4	64.9	18.9	0.5 (4)	96004.3
TSP Single Land Flat Wear	15	37.9	50.5	35.5	1.125 (4)	96910.1
Baffle Plate Flat Wear	5	32.7	61.5	56.5	0.75 (4)	96004.3
Point Wear at Quatrefoil Land	28	Self-Limiting (2)	64.8	36.8	0.25 (0.18 measured)	21998.1
Foreign Object Wear	39	New (3)	64.8	25.8	0.25 (0.21 measured)	21998.1

(1) CM Limit based on minimum Secondary Side pressure of 865 psig and 3ΔP of 4089 psid at Bounding Axial Extent and on effective (i.e., structural) depth and axial extents rather than max depth and axial extents.
(2) Little, to no growth predicted, no growth measured at A2R19 within Non-Destructive Examination (NDE) technique repeatability
(3) Existing Foreign Object (FO) Wear was not predicted to grow due to FOs removed at A2R17 or earlier outage
(4) Limiting size, based on dimension of support structure

In summary, based on the inspection data and the CM assessment, no tubes exhibited degradation in excess of the condition monitoring limits. No tubes required in situ pressure testing to demonstrate structural and leakage integrity. There was no reported SG primary-to-secondary leakage prior to the end of the current inspection interval. Therefore, SG performance criteria for operating leakage and structural integrity were satisfied for the preceding Braidwood Unit 2 SG 2-cycle operating interval (A2R17 to A2R19).

3.2.2.b Discuss any tubes that required flaw profiling to demonstrate condition monitoring was met

No tubes required flaw profiling to demonstrate that the CM limit was not exceeded.

3.2.3 Operational Assessment (OA) during an additional operating cycle

3.2.3.a. The existing degradation mechanisms observed at Braidwood Unit 2 which require an OA are:

- Mechanical wear from Anti-Vibration Bar (AVB) support structures
- Mechanical wear from quatrefoil Tube Support Plate (TSP) structures
- Mechanical wear from drilled hole baffle plate structures
- Mechanical wear from foreign objects
- Axial Outer Diameter Stress Corrosion Cracking (ODSCC) at TSP intersections on known high residual stress tubes locations
- Axial ODSCC at freespan dings on known high residual stress tubes

In addition to the existing degradation mechanisms above, several potential degradation mechanisms were considered in light of Braidwood Unit 2 request to operate for 3-cycles between SG inspections. An OA for potential degradation mechanisms predicts the behavior of postulated flaws that could have been present at or prior to the last SG inspection in A2R19 and those that could have initiated during the 3-cycle operating period. The potential degradation mechanisms for which an OA was performed are:

- Circumferential ODSCC at the hot leg Top of Tubesheet (TTS) expansion transition
- Axial ODSCC at TSP intersections on non-high residual stress tubes
- Axial ODSCC at dents and freespan dings on non-high residual stress tubes
- Axial ODSCC at the hot leg TTS expansion transition
- Axial Primary Water Stress Corrosion Cracking (PWSCC) in small radius U-bends
- Axial and Circumferential PWSCC at the TTS (generally bounded by ODSCC analyses)

3.2.3.b Inspection strategy details during A2R19 inspection for the degradation mechanisms described above are as follows:

- All mechanical wear mechanisms – Full length bobbin inspections of 100% of in-service tubes using qualified techniques were used to detect mechanical wear. In addition, at the TTS where the bobbin probe's detection capabilities are challenged, supplemental array probe testing was used. These exams included full coverage of the tube periphery where the flow velocities and operating experience have shown a greater susceptibility to foreign object wear. This scope was approximately 63% of all tubes on the hot leg and approximately 26% of all tubes on the cold leg. Bobbin or +Point™[1] probe was used to

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depth size all detected mechanical wear. The +Point™ probe was used to length size foreign object wear.

- Axial ODSCC at TSP intersections on known high residual stress tubes locations - In addition to a full length bobbin probe inspection, each of the 68 tubes identified as high residual stress received augmented inspections. Specifically, all hot and cold leg TSP intersections were tested with an X-Probe™.

- Axial ODSCC at tubing dents and dings - Full length bobbin inspections of 100% of in-service tubes using qualified techniques were used to detect Axial ODSCC at tubing dents and dings up to 5 Volts. In addition, a 50% sample of dents and dings greater than 5 Volts in the hot leg, U-bend and outside the preheater were tested with the +Point™ probe. In the preheater and flow distribution baffle on the hot leg, a 50% sample of dents and dings greater than 2 Volts were tested with the +Point™ probe. Note, the remaining 50% of the population were tested during the prior inspection performed in refueling outage A2R17 (March 2014). In addition, all dents and dings greater than 2 Volts in known high residual stress tubes locations were tested with a +Point™ probe.

- Circumferential and Axial ODSCC and PWSCC at the hot leg TTS expansion transition (including overexpansions) and inside the tubesheet (including bulges) – To detect all SCC mechanisms at the top of tubesheet and inside the tubesheet (to the H* depth) on the Hot leg, a 63% Array probe scope was performed (50% inner bundle plus 3 periphery). Note, the same program was implemented at A2R17, thus, the remaining 37% of this population of tubes were tested during the prior inspection performed in refueling outage A2R17.

- Axial PWSCC in small radius U-bends - A 50% sample to detect PWSCC in the Row 1 and Row 2 U-bends with the +Point™ probe was performed. Note, the remaining 50% of the population were tested during the prior inspection performed in refueling outage A2R17. In addition, all tubes with the "Blairsville Bump" manufacturing anomaly were tested with a +Point™ probe at both A2R17 and A2R19. Therefore, at A2R19 the effective percentage inspected ranged from 50% to 62% of the Row 1 and Row 2 U-bends.

3.2.3.c Specific to Alloy 600TT tubing:

- Braidwood Unit 2 has 68 tubes identified as potentially having high residual stress in service.

- Any potentially high residual stress tubes that were not identified by the screening process are tested in the 100% full length bobbin program every inspection outage. An enhancement to improve the probability of detection for axial ODSCC was added to the inspection program in A2R17 (March 2014) and continued in A2R19 (April 2017) was to require any TSP with a mix residual of 0.4 Vm to be tested with the +Point™ probe. In addition, the possibility for other high stress tubes to be present is considered analytically in the OA. Specifically, for the high stress tube analysis, two OA models are used; an acute initiation model which closely mimics the prior Braidwood history by introducing a discrete quantity of flaws into the model in a short time period, and low Weibull slope model which introduces flaws on a more traditional basis, i.e., spread out over time. The susceptible population size applied for the low Weibull slope model is extremely conservative; i.e., it assumes there are

significantly more high stress tubes than the 68 known high stress tubes, thus this OA model would cover any potential cases of high stress tubes not being in the identified know high stress tube population. An additional conservatism is that for both high stress tube models the upper bound EPRI IAGL (Reference 6) default growth rate was applied.

- As discussed previously, in addition to a full length bobbin probe inspection, each of the 68 tubes identified as high residual stress received augmented inspections. Specifically, all hot and cold leg TSP intersections were tested with an X-Probe™. This combination of bobbin and X-Probe™ testing greatly improves the overall detection performance of the applied inspection program. Furthermore, all dents and dings greater than 2 volts were tested with a +Point™ probe. No crack indications were noted during any inspections performed in A2R17 (March 2014) or in A2R19 (April 2017).

3.2.3.d Operational assessment summary for all degradation mechanisms; including predicted margin to the tube integrity performance criteria at A2R22 (October 2021):

The technical justification for deferring the A2R21 SG tube examination by one operating cycle for SCC and mechanical wear at structures mechanisms is based on a new operational assessment (OA) performed in accordance with EPRI Steam Generator Integrity Assessment Guidelines (IAGL) (Reference 6). This OA supplements the current OA (Reference 8) from the end of operating Cycle 21 condition to the end of operating Cycle 22, thus justifying operation of the SGs for three operating cycles between SG eddy current inspections. Based on the attached preliminary OA, the results of the final OA report will fully support the deferral of the A2R21 SG inspections until the next Unit 2 refueling outage (A2R22) where, for the existing and potential degradation mechanisms:

1. Structural integrity performance criterion (SIPC) margin requirement of three times normal operating pressure (3xNOPD) on tube burst will be satisfied at A2R22 for the existing and potential degradation, and

2. Accident-induced leakage performance criteria (AILPC) for the limiting accident condition will be met for the end of Cycle 22 condition.

SG tubing is subject to two types of degradation; existing degradation, or degradation modes previously observed within the Braidwood Unit 2 SGs, and potential degradation, or degradation modes not yet observed within the Braidwood Unit 2 SGs but judged to have a meaningful likelihood of occurrence based on operation of similar units or laboratory testing.

Due to the emergent need to develop a technical justification for deferral of the planned SG examinations during A2R21, this technical justification is divided into two phases. The preliminary OA provided in Attachment 2 provides the OA predictions for all existing degradation mechanisms and two potential degradation mechanisms which are considered to be most challenging to justifying extended operation of Braidwood Unit 2 until A2R22 (October 2021). The final OA will cover the remaining potential degradation mechanisms and provide the OA for all mechanisms. A summary of the methodology and results of the preliminary OA analysis are presented below.

The Stress Corrosion Cracking (SCC) mechanisms judged to be most challenging to achieving a 3-cycle OA which were selected to be addressed in the preliminary OA are:

- Axial ODSCC at TSP intersections on known high residual stress tubes (existing)
- Circumferential ODSCC at the hot leg TTS expansion transition (potential)
- Axial ODSCC at tube dings and dents (both high residual stress – existing (only at one ding) and non-high residual stress tubes - potential)

Methodology for SCC Mechanisms

These SCC mechanisms were each evaluated by performing full-bundle probabilistic analyses to calculate the probability of tube burst and leakage potential in accordance with Section 8.3 of the EPRI IAGL (Reference 6). The probabilistic model included the important input distributions for; material strength properties of the tubing, probability of detection for the eddy current inspection technique, a lognormal crack growth rate model appropriate for each mechanism at T_{Hot}, and the use of a Weibull initiation function predicting when SCC flaws have developed over time. One important feature built into the model is its ability to predict and account for the cumulative effect of a population of newly initiated SCC indications and preexisting undetected SCC indications which were either missed or too small to be detected by the eddy current technique used.

The OA approach was developed based on Braidwood Unit 2 prior operating experience and benchmarking of other Alloy 600TT units which have experienced these SCC mechanisms. Several conservatisms, such as the number of assumed SCC indications present, are factored into the analyses and when required, bounding cases are considered. Discussion of all the inputs, conservatisms and cases evaluated for the most challenging and existing SCC mechanisms for Braidwood Unit 2 are provided in Attachment 2.

OA Results for SCC Mechanisms

For all mechanisms evaluated in Attachment 2, the probability of burst is less than the limit of 0.05 and the probability of leakage at steam line break conditions exceeding the applied AILPC limit for Braidwood Unit 2 of 0.5 gpm is less than the limit of 0.05. Therefore, extending the inspection interval to three-cycles will satisfy the tube integrity requirements of NEI 97-06 (Reference 7) and justifies deferring the A2R21 inspections to A2R22 in October 2021. Table 5, for the most challenging and existing SCC mechanisms for Braidwood Unit 2, provides a summary of the probabilistic analysis inputs (i.e., growth rate parameters and assumed number in SCC indications), results (i.e., probability of burst and of exceeding accident induced leakage criteria) and margin to the tube integrity performance criteria at the next inspection at A2R22 in October 2021, accounting for flaw growth over the 3-cycle operating period. For the circumferential ODSCC cases the probabilities are combined using a Boolean Sum process. The combined burst probability is 2.77% and the combined leakage probability of leakage exceeding the AILPC value is 0.9%. The probabilities for dings (all voltages) and dents (all voltages) were combined as a separate mechanism. If a length distribution judged most appropriate for Alloy 600TT plants is used, the combined burst probability for dings and dents is less than 1% and the probability of leakage exceeding the AILPC limit is essentially 0%. The analysis of axial ODSCC on high residual stress tubes does not require combination of probabilities. The probability of burst and leakage for the two models considered are 3.6% (acute-burst) and 2.4% (low slope Weibull burst) and 1.1% (acute-leakage) and 1.6% (low slope

Weibull-leakage), respectively. The analysis of axial ODSCC at freespan dings on high residual stress tubes is addressed by the low Weibull slope analysis model.

Expected OA Results for other SCC Mechanisms

Axial ODSCC at TSP intersections on non-high residual stress tubes was reported for the first time in the A600TT fleet during the fall of 2019. The final OA will address this mechanism and based on analyses performed for another plant, it is expected that the analysis will produce acceptable results for three-cycles of operation. This is based on using the low Weibull slope initiation model and the assumption that the non-high stress tubes would be expected to experience growth rates bounded by the EPRI IAGL (Reference 6) typical default value. Therefore, it is expected that the OA case developed for this mechanism in the final OA will show a burst probability significantly less than 1%.

Axial ODSCC at the hot leg TTS expansion transition would be expected to be bounded by the greater than 5 Volts (V) dent analysis case of Table 5. For both these mechanisms, the applicable growth rate is bounded by the EPRI IAGL (Reference 6) default, the susceptible population size is similar, and the assumed initiation point based on the applied inspection program is the same. However, the applied length distribution for the ding and dent analyses bounds that of the TTS and the greater than 5 V dent analysis this represents a conservative bound of the axial ODSCC at TTS analysis. The OA case addressing axial ODSCC at the hot leg TTS will be presented in the final OA.

Prior experience has indicated that PWSCC growth rates and length distributions are bounded by the ODSCC growth and length distributions. As such, it is expected that the analyses of PWSCC mechanisms presented in the final OA will also produce acceptable results for a three-cycle operating period.

Methodology for Mechanical Wear Mechanisms

Mechanical Wear at Structures

Fretting wear at tube supports, has also been evaluated in Attachment 2. The number, location and size of these indication was previously reported to the NRC for A2R19 via "Braidwood Station, Unit 2 Steam Generator Tube Inspections Report for Refueling Outage 19," dated August 24, 2017 (ML17236A457). For all structural wear mechanisms, a deterministic OA strategy was applied using an arithmetic treatment of uncertainties.

TABLE 5: Summary of Operational Assessment key inputs, results and margins for existing and most challenging potential SCC degradation mechanisms through A2R22 (October 2021)

Mechanism	Structural Average Growth/ EFPY (Lognormal)	Maximum Depth Growth/ EFPY (Lognormal)	Missed Indications at Most Recent Inspection	Number Predicted Indications at A2R22	Probability of Burst	Margin to SIPC	Probability of Leak Rate > AILPC	Margin to AILPC
Circ ODSCC A2R17 Inspected	Mean: 1.50 SD: 0.65	Mean: 1.73 SD: 0.65	2	7	2.18%	3.82%	0.9%	4.1%
Circ ODSCC A2R19 Inspected	Mean: 1.50 SD: 0.65	Mean: 1.73 SD: 0.65	2	5	0.6%	4.4%	0.0%	5.0%
Axial ODSCC at TSPs High Stress Tubes (Acute Model)	Mean: 1.95 SD: 0.65	Mean: 2.19 SD: 0.65	4	4	3.6%	1.4%	1.1%	3.9%
Axial ODSCC at TSPs High Stress Tubes (Low Weibull Slope Model)	Mean: 1.95 SD: 0.65	Mean: 2.19 SD: 0.65	2	5	2.4%	2.3%	1.6%	3.4%
Axial ODSCC Hot Leg <5V Dings	Mean: 1.50 SD: 0.65	Mean: 1.73 SD: 0.65	2	5	0.12%	4.88%	0.1%	4.9%
Axial ODSCC Hot Leg >5V Dings	Mean: 1.50 SD: 0.65	Mean: 1.73 SD: 0.65	2	3	1.24%	3.76%	0.6%	4.4%
Axial ODSCC Hot Leg <5V Dents	Mean: 1.50 SD: 0.65	Mean: 1.73 SD: 0.65	2	5	0.12%	4.88%	0.1%	4.9%
Axial ODSCC Hot Leg >5V Dents	Mean: 1.50 SD: 0.65	Mean: 1.73 SD: 0.65	2	3	1.24%	3.76%	0.6%	4.4%

Table 6 presents a summary of the analysis parameters and OA results using the largest remaining flaw left in service for each wear location. A sufficiently large data base for antivibration bar (AVB) wear growth rates indicates that the 95th percentile depth growth rate can be applied. Accounting for 3-cycles of growth, there is still approximately 17% TW of margin before the condition monitoring limit is reached for the deepest AVB wear left in service at A2R19.

For quatrefoil tube support (TSP) and drilled support plate (DSP) wear, the available quantity of growth rate data is not sufficient for development of a depth growth distribution; therefore, the maximum observed growth rate is applied. There are only two TSP wear indications in the Braidwood Unit 2 SGs. One of these is associated with a "burr" or small tab of rolled material at the edge of the TSP. This phenomenon has been observed at other plants using a similar style of TSP, most recently at plants with replacement SGs. EPRI Examination Technique Specification Sheet 21998.1 was used for depth sizing of this "point-like" indication based on its short axial length (0.18 inch). Any further depth progression at this location would be expected to cause interaction between the tube and land of the quatrefoil TSP. When this occurs, this will then greatly increase the contact area between the tube and TSP and effectively stunt any future depth progression. Accounting for 3-cycles of growth, there is still approximately 12% TW of margin before the condition monitoring limit is reached for the deepest TSP wear left in service at A2R19. The largest of the three DSP wear indications is only 5%TW, therefore, accounting for 3-cycles of growth, there is still approximately 41% TW of margin before the condition monitoring limit is reached for the deepest DSP wear left in service at A2R19.

In summary, using the deterministic method, which is considered to be the most conservative OA approach, tubes with any of the three existing structural support mechanical wear mechanisms can safely operate for three cycles (approximately 52 EFPM) until October 2021 without challenging the tube integrity limits for each type of wear.

TABLE 6: Summary of Input Parameters and OA Results for Mechanical Wear at Structures

	AVB	**TSP**	**DSP**
OA Methodology	Deterministic	Deterministic	Deterministic
Uncertainty treatment	Arithmetic	Arithmetic	Arithmetic
Largest indication returned to service after A2R19 (%TW, NDE)	39%TW	28%TW	5%TW
ETSS used to size this indication	96004.3 R13	21998.1 R4	96004.3 R13
Bounding degradation growth rate (%TW/EFPY)	2.9	2.1	2.1
Basis for growth rate selection	(Note 1)	(Note 2)	(Note 2)
Projected size at A2R22, 52 EFPM (%TW, NDE)	52%TW	37%TW	14%TW
Bounding degradation geometry	(Note 3)	(Note 3)	(Note 4)
Burst pressure at projected actual A2R22 size (psi)	5330	5110	7530
Condition Monitoring limit at 3xNODP, 4110 psi (%TW, NDE)	69%TW	49%TW	55%TW
Approximate margin (%TW)	~17%TW	~12%TW	~41%TW

Notes:
(1) Basis for selection: 95th percentile of paired AVB wear indications at A2R17; A2R17 observed growth rates bound observed A2R19 growth rates
(2) Basis for selection: largest observed growth rate for paired wear indications at both TSP and Drilled Support Plate, for both outages (A2R17 and A2R19) [drawn from a total population of 9 growth rates]
(3) Volumetric with limited circumferential and axial extent
(4) Volumetric uniform thinning with limited axial extent

Mechanical Wear due to Foreign Objects

During the Spring 2017 refueling outage at Braidwood Unit 2 (A2R19), Foreign Object Search and Retrieval (FOSAR) was performed at the top of the secondary tubesheet in all four SGs and within the preheater region of SG 2A and SG 2C. These inspections identified a small variety of foreign objects and material in the preheater region and at the top of tubesheet. In addition to the foreign objects identified by visual inspections, eddy current inspection identified volumetric wear and possible loose part signal indications indicative of foreign object wear and presence of foreign objects. These indications were located near the tube support plates (TSPs) in the upper tube bundle. All new and previous foreign object wear indications including their location and size were previously reported to the NRC for A2R19 via "Braidwood Station, Unit 2 Steam Generator Tube Inspections Report for Refueling Outage 19," dated August 24, 2017 (ML17236A457).

Before returning from A2R19, a separate 2-cycle Operational Assessment specifically covering the potential for future Foreign Object (FO) wear was developed. To support a third operating cycle, this OA was recently revised (Reference 9). This assessment addresses the foreign objects identified during the A2R19 FOSAR inspections as well as the newly reported volumetric wear indications in the upper tube bundle. This assessment also addresses foreign objects and upper bundle wear indications known to be remaining in the Braidwood Unit 2 SGs from previous operating cycles.

The foreign objects identified during the A2R19 inspections at top of tubesheet and preheater baffle plate remaining in the SGs are documented in Table A-1 of Reference 9. Not counting scale and sludge “rocks”, which are native to SGs and benign with respect to causing tube wear, there were 16 metallic FOs. These FOs generally were small wires (bristles), found on the top of the tubesheet or on a preheater baffle. In addition, there were three fixed, legacy objects present (wedge, bushing and weld slag) which have never not caused any tube wear over 9 or more operating cycles. All tubes in contact with weld slag were preventatively plugged during the outage it was discovered.

It should be noted that during A2R19 all foreign objects deemed have the potential for causing foreign object wear were removed from the SGs, when possible. A total of 5 small wires and a piece of scale were removed in A2R19 and are documented in Table A-4 of Reference 9. In addition to the foreign objects identified, eddy current results showed seven newly reported volumetric wear indications near a tube support plate (TSP) and three adjacent tubes with potential loose part indications (PLPs) located on the TSP 08C in SG 2D. These are documented in Table A-2 of Reference 9. At all seven locations of new volumetric wear, evaluation using the +Point™ probe determined that no foreign objects were still present, thereby arresting any further tube wear. Due to the location of the PLP at TSP 08C it could not retrieved. In order to prevent any possible future wear degrading these tubes and challenging structural or leakage integrity, the 3 tubes in contact with PLP were preventatively plugged.

It was determined that the potential for mechanical wear or impact damage (i.e., dings) from the foreign objects remaining inside the Braidwood Unit 2 SGs over three operating cycles is low. This is based on the fact that the non-fixed FOs are smaller and have less mass than the bounding objects known not to cause wear or impact damage as determined by operating experience and thermal-hydraulic analysis and modelling of the foreign object wear mechanism.

In addition, the small foreign objects identified during A2R19 have insufficient mass to affect other systems, structures or components that are connected to the steam generators. They cannot cause flow blockage in the tube bundle and are not likely to migrate to other structures. Even if they do migrate, they are too small to fully block instrumentation taps or to affect any downstream components such as the main steam isolation valves or blowdown valves. Thus, these foreign objects will not result in mechanical interferences with any active components and will not adversely affect systems either upstream or downstream of the SGs.

The result of the revised Operational Assessment (Reference 9) based on the evaluation of foreign objects identified in A2R19, concludes that they will not cause significant tube wear for at least three cycles at current operating conditions. Eddy current inspection of in-service tubes at an interval not to exceed three operational cycles is sufficient to ensure these foreign objects will not affect tube structural or leakage integrity at A2R22. Since SG inspection in A2R19 there have been no documented foreign object intrusions into the SGs or Feedwater system.

3.2.4. Mitigating strategies

The normal Mode 1 (Power Operation) requirement under the EPRI Primary-to-Secondary Leak Guidelines state that Action Level 1 is reached at a leakage rate of 30 gallons per day (gpd.) However, the guidelines require a site to enter an "Increased Monitoring" condition when total primary-to-secondary leakage is detected to be equal to or greater than 5 gpd. After entering the

increased monitoring condition, radiation monitors alert/alarm set points are reset, as necessary, to above their existing baseline reading (but not over 30 gpd) to permit detection of rapidly increasing leakage.

The EGC Primary-to-Secondary Leak Program procedure (CY-AP-120-340) (Reference 10) currently in effect has lower administrative limits on Primary-to-Secondary leakage in order to ensure Braidwood Unit 2 is prepared to quickly respond should the leakage rate increase. Steam Generator Management Program Monitoring condition is entered when normal radiochemical grab sampling and process radiation monitors indicate leakage of greater than or equal to 3 gpd. This describes the condition in which leakage has been detected and quantified and is greater than or equal to 3 gpd but is not in a range that can be accurately monitored by most radiation monitors. When this occurs, Engineering is notified, and the appropriate Corrective Action Processes are initiated to document and track the excursion. The activities when this condition is entered are described in EGC procedure ER-AP-420-0051, "Conduct of Steam Generator Management Program Activities." (Reference 11)

When operational leakage is equal to or greater than 3 gpd is confirmed during the operating period between inspections, at the next outage, in situ pressure testing, tube pull, or analysis should be performed to quantify the expected accident leak rate to assess compliance with accident leakage performance criteria. In addition, prior to entering an outage, an action plan is developed to address means of identifying the defective tube(s), flowchart sampling methods to bound the defect and provide reasonable assurance that unit restart is prudent.

During the extended operating cycle from A2R21 to A2R22, Braidwood Unit 2 will lower its normal 100 gpd shutdown criteria for primary-to-secondary leakage down to 30 gpd for confirmed and sustained leakage at or above that level. This action will provide more margin by requiring shutdown at a lower leakage level, thereby lowering the likelihood of a steam generator tube burst.

Braidwood Unit 2 maintains a Loose Parts Detection System on the Steam Generators that monitors for activity on the primary side of the Hot Leg and Cold Leg. Planned maintenance during refueling outage A2R21 will ensure all 8 monitoring channels continues to operate. Should a loose part be present in the hot leg or cold leg primary bowl during operating Cycle 22 Braidwood Unit 2 will take appropriate action to minimize any damage to the Steam Generators.

4.0 REGULATORY ANALYSIS

4.1 Applicable Regulatory Requirements/Criteria

10 CFR 50.36(b) requires that each license authorizing operation of a utilization facility will include technical specifications. The technical specifications will be derived from the analyses and evaluation included in the safety analysis report, and amendments thereto, submitted pursuant to 10 CFR 50.34, "Contents of applications; technical information."

The categories of items required to be in the TS are provided in 10 CFR 50.36(c). As required by 10 CFR 50.36(c)(5), administrative controls are the provisions relating to organization and management, procedure, recordkeeping, review and audit, and reporting necessary to assure

operation of the facility in a safe manner. The proposed one-time revision will defer the Steam Generator inspection to be performed after three operating cycles following refueling outage A2R19. Therefore, the proposed change does not alter Braidwood Unit 2 compliance with the requirements of 10 CFR 50.36.

10 CFR 50, Appendix A, "General Design Criteria for Nuclear Power Plants," Criteria 14, 15, 16, 30, 31, and 32, define the requirements for the reactor coolant pressure boundary with respect to structural and leakage integrity. Steam generator tubing and tube repairs constitute a major fraction of the RCS pressure boundary surface area. Steam generator tubing and associated repair techniques and components, such as plugs and sleeves, must be capable of maintaining reactor coolant inventory and pressure.

Criterion 14, "Reactor Coolant Pressure Boundary"
The reactor coolant pressure boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, or rapidly propagating failure, and of gross rupture.

Criterion 15, "Reactor Coolant System Design"
The reactor coolant system and associated auxiliary, control, and protection systems shall be designed with sufficient margin to assure that the design conditions of the reactor coolant pressure boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences.

Criterion 16, "Containment design"
Reactor containment and associated systems shall be provided to establish an essentially leak-tight barrier against the uncontrolled release of radioactivity to the environment and to assure that the containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.

Criterion 30, "Quality of reactor coolant pressure boundary"
Components, which are part of the reactor coolant pressure boundary, shall be designed, fabricated, erected, and tested to the highest quality standards practical. Means shall be provided for detecting and, to the extent practical, identifying the location of the source of reactor coolant leakage.

Criterion 31, "Fracture prevention of reactor coolant pressure boundary"
The reactor coolant pressure boundary shall be designed with sufficient margin to assure that when stressed under operating, maintenance, testing, and postulated accident conditions (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures and other conditions of the boundary material under operating, maintenance, testing, and postulated accident conditions and the uncertainties in determining (1) material properties, (2) the effects of irradiation on material properties, (3) residual, steady state and transient stresses, and (4) size of flaws.

Criterion 32, "Inspection of reactor coolant pressure boundary"
Components, which are part of the reactor coolant pressure boundary, shall be designed to permit (1) periodic inspection and testing of important areas and features to assess their structural and leak-tight integrity, and (2) an appropriate material surveillance program for the reactor pressure vessel.

Regulatory Guide (RG) 1.83, "Inservice Inspection of Pressurized Water Reactor Steam Generator Tubes," Revision 1
Regulatory Guide 1.83 describes an acceptable method of complying with the Commission's regulations with regard to inservice inspection of pressurized water reactor steam generator tubes.

RG 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes," Revision 0
RG 1.121 describes the minimum acceptable wall thickness at which the tube must be removed from service by plugging.

EGC has reviewed the basis for conformance to these GDC and Regulatory Guides, as described in the Braidwood Station Updated Final Safety Analysis Report and has concluded that the proposed one-time revision to defer the Braidwood Unit 2 Steam Generator inspection to be performed after three operating cycles following refueling outage A2R19 remains in conformance with all requirements.

4.2 No Significant Hazards Consideration

Exelon Generation Company, LLC (EGC) requests an emergency amendment to the Technical Specifications (TS) for Renewed Facility License No. NPF-77 for Braidwood Station, Unit 2 (Braidwood). The proposed change is being requested on an emergency basis pursuant to 10 CFR 50.91(a)(5). This proposed emergency amendment request to revise Technical Specifications (TS) Section 5.5.9, "Steam Generator (SG) Program."

The proposed amendment would make a one-time revision to the Braidwood Unit 2 frequency for Steam Generator Tube Inspections by deferring the inspections to be performed during the next Braidwood Unit 2 refueling outage after three operating cycles.

EGC has evaluated the proposed change against the criteria of 10 CFR 50.92(c) criteria to determine if the proposed change results in any significant hazards. The following is the evaluation of each of the 10 CFR 50.92(c) criteria:

1) Does the proposed amendment involve a significant increase in the probability or consequences of an accident previously evaluated?

   Response: No.

   The proposed one-time change will defer the Steam Generator (SG) inspection to be performed after three operating cycles. This change does not physically change the SGs, the plant or the way the SGs or plant are operated. This change does not change the design of the SG. Inspection frequencies and inspection activities are not an initiator to a Steam Generator tube rupture accident, or any other accident previously evaluated. As a result, the

probability of an accident previously evaluated is not significantly increased. The SG tubes inspected by the SG Program continued to be required to meet the SG Program performance criteria and to be capable of performing any functions assumed in the accident analysis. As a result, the consequences of any accident previously evaluated are not significantly increased.

Therefore, the proposed change does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2) Does the proposed amendment create the possibility of a new or different kind of accident from any accident previously evaluated?

Response: No.

The proposed one-time change will defer the Steam Generator (SG) inspection to be performed after three operating cycles. The proposed change does not alter the design function or operation of the SGs or the ability of an SG to perform the design function. The SG tubes continue to be required to meet the SG Program performance criteria. An analysis has been performed which evaluates all credible failure modes. This analysis resulted in no new or different kind of accident then has been previously evaluated. The proposed change does not create the possibility of a new or different kind of accident due to credible new failure mechanisms, malfunctions, or accident initiators that not considered in the design and licensing bases.

Therefore, the proposed change does not create the possibility of a new or different kind of accident from any accident previously evaluated.

3) Does the proposed amendment involve a significant reduction in a margin of safety?

Response: No.

The proposed one-time change will defer the Steam Generator (SG) inspection to be performed after three operating cycles. The proposed change does not change any of the controlling values of parameters used to avoid exceeding regulatory or licensing limits. The proposed change does not affect a design basis or safety limit, or any controlling value for a parameter established in the UFSAR or the license.

Therefore, the proposed change does not involve a significant reduction in a margin of safety.

Based on the above, EGC concludes that the proposed amendment does not involve a significant hazards consideration under the standards set forth in 10 CFR 50.92(c), and, accordingly, a finding of "no significant hazards consideration" is justified.

4.3 Precedent

The following is a similar amendment requests currently being reviewed by the NRC:

Letter from B. Stamp (Florida Power & Light Company) to US NRC, "Exigent License Amendment Request 272, One-Time Extension of TS 6.8.4 Steam Generator Inspection Program," dated April 4, 2020 (ML20095J926). (Reference 1)

Letter from J. T. Polickoski (Tennessee Valley Authority) to US NRC, "Application to Revise Sequoyah Nuclear Plant (SQN) Unit 1 Technical Specifications for Steam Generator Tube Inspection Frequency," dated February 24, 2020 (ML20056C857). (Reference 2)

The following are precedence for one-time changes to SG inspection frequencies.

Letter from M. Webb (NRC) to J. J. Sheppard (STP Nuclear Operating Company), "South Texas Project, Unit 1 – Issuance of Amendment RE: One-Time Extension of the Steam Generator Inspection Frequency (TAC No. MC1046)," dated June 8, 2004 (ML041610073). (Reference 3)

Letter from K.R. Cotton (NRC) to S.A. Byrne (South Carolina Electric & Gas Company), "Virgil C. Summer Nuclear Station, Unit 1 – Issuance of Amendment RE: One-Time Extension of the Steam Generator Inspection Frequency (TAC No. MB7312)," dated October 29, 2003 (ML033020450). (Reference 4)

Letter from T. W. Alexion (NRC) to C. G. Anderson (Entergy Operations, Inc.), "Arkansas Nuclear One, Unit 2 – Issuance of Amendment RE: One-Time Extension of the Steam Generator Inspection Frequency (TAC No. MB6808)," dated May 28, 2003 (ML031490475). (Reference 5)

4.4 Conclusion

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

5.0 ENVIRONMENTAL CONSIDERATION

A review has determined that the proposed amendment would change a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, or would change an inspection or surveillance requirement. However, the proposed amendment does not involve (i) a significant hazards consideration, (ii) a significant change in the types or a significant increase in the amounts of any effluents that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22(c)(9). Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

6.0 REFERENCES

1. Letter from B. Stamp (Florida Power & Light Company) to US NRC, "Exigent License Amendment Request 272, One-Time Extension of TS 6.8.4 Steam Generator Inspection Program," dated April 4, 2020 (ML20095J926).

2. Letter from J. T. Polickoski (Tennessee Valley Authority) to US NRC, "Application to Revise Sequoyah Nuclear Plant (SQN) Unit 1 Technical Specifications for Steam Generator Tube Inspection Frequency," dated February 24, 2020 (ML20056C857).

3. Letter from M. Webb (NRC) to J. J. Sheppard (STP Nuclear Operating Company), "South Texas Project, Unit 1 – Issuance of Amendment RE: One-Time Extension of the Steam Generator Inspection Frequency (TAC No. MC1046)," dated June 8, 2004 (ML041610073).

4. Letter from K.R. Cotton (NRC) to S.A. Byrne (South Carolina Electric & Gas Company), "Virgil C. Summer Nuclear Station, Unit 1 – Issuance of Amendment RE: One-Time Extension of the Steam Generator Inspection Frequency (TAC No. MB7312)," dated October 29, 2003 (ML033020450).

5. Letter from T. W. Alexion (NRC) to C. G. Anderson (Entergy Operations, Inc.), "Arkansas Nuclear One, Unit 2 – Issuance of Amendment RE: One-Time Extension of the Steam Generator Inspection Frequency (TAC No. MB6808)," dated May 28, 2003 (ML031490475).

6. Electric Power Research Institute (EPRI) Report 3002007571, "Steam Generator Management Program: Steam Generator Integrity Assessment Guidelines," Revision 4, June 2016

7. Nuclear Energy Institute (NEI) 97-06 Revision 3, "Steam Generator Program Guidelines," January 2011

8. Westinghouse Report SG-SGMP-17-17 dated May 2017 (Proprietary)

9. Westinghouse Report LTR-CECO-20-027, Rev 0, "Evaluation of Braidwood Unit 2 Steam Generators for Deferral of Secondary Side Foreign Object Inspection in the Spring 2020 Outage (A2R21)," dated April 6, 2020 (Proprietary)

10. CY-AP-120-340, Primary-to-Secondary Leak Program, Revision 10

11. ER-AP-420-0051, Conduct of Steam Generator Management Program Activities, Revision 23

Attachment 2

Braidwood Station, Unit 2
NRC Docket No.50-457

Preliminary Operational Assessment

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Braidwood Unit 2 Operating Cycle Extension to A2R22

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Executive Summary

The purpose of this letter is to document the results from the Intertek AIM preliminary operational assessment of the degradation mechanisms that may challenge successful completion of a steam generator tube integrity operational assessment which supports extending the next scheduled eddy current inspection of the Braidwood Unit 2 steam generator tubes from the A2R21 (Spring 2020) outage to A2R22 (Fall 2021). A final operational assessment which documents all analyses for both the most challenging and less challenging degradation mechanisms will be provided at a later date. Throughout this process, conservative input assumptions have been applied to represent bounding analysis conditions. All calculations and methodologies applied are consistent with the EPRI Steam Generator Tube Integrity Assessment Guideline, Revision 4.

Contents

List of Tables and Figures

1 | Braidwood Unit 2 Technical Justification for Deferring Steam Generator Inspections to A2R22

Background

The technical justification for deferring the A2R22 steam generator (SG) tube examination by one operating cycle is based on an operational assessment (OA) performed in accordance with EPRI Steam Generator Integrity Assessment Guidelines (IAGL). The OA supplements the current OA from the end-of-cycle (EOC) 21 condition to EOC22, thus justifying operation of the SGs for three operating cycles between SG eddy current inspections. It is expected that the results of the final OA report will fully support the skipping of the A2R21 SG inspections where, for the existing and potential degradation mechanisms:

1. Structural integrity performance criterion (SIPC) margin requirement of three times normal operating pressure (3xNOPD) on tube burst will be satisfied at A2R22 for the existing and potential degradation, and
2. Accident-induced leakage performance criteria (AILPC) for the limiting accident condition will be met for the EOC22 condition.

Further, the Exelon SG Management Program complies with the guidance and recommendations of EPRI Steam Generator Management Program for conducting tube examinations, primary-to-secondary leakage monitoring, performing tube integrity assessment for condition monitoring and operational conditions, conducting in situ pressure testing, when required, and water chemistry controls. Braidwood Unit 2 has implemented current industry guidelines with respect to primary and secondary water chemistry. No significant chemistry excursions have occurred in Braidwood Unit 2 since the last tube examination in April 2017 (A2R19).

No increased SG tube degradation is expected in the extended operating period as supported by the revised OA. No operational leakage has been reported in the Braidwood Unit 2 SGs during Cycles 20 and 21. Active monitoring for primary-to-secondary leakage provides assurance that proper plant response will occur in the event primary-to-secondary leakage were to develop during the proposed operating period.

At the last two inspections of the Braidwood Unit 2 SGs, no stress corrosion cracking (SCC) degradation was reported. At the A2R21 outage (Spring 2020), the Braidwood Unit 2 SGs will have accumulated approximately 28.45 effective full power years (EFPY) of operation and the projected total operation at A2R22 is approximately 29.9 EFPY.

SG tubing is subject to two types of degradation; existing degradation, or degradation modes previously observed within the Braidwood Unit 2 SGs, and potential degradation, or degradation modes not yet observed within the Braidwood Unit 2 SGs but judged to have a meaningful likelihood of occurrence based on operation of similar units or laboratory testing.

Due to the emergent need to develop a technical justification for deferral of the planned SG examinations at A2R21, this technical justification is broken into two phases. Phase 1, which this report summarizes, covers the degradation mechanisms which are considered to be most challenging to justifying extended operation of Braidwood 2 until A2R22 (October 2021). Phase 2 will cover the

remaining mechanisms and provide a final OA for all mechanisms. A summary of the Phase 1 analysis results is described herein.

Current Condition of the Braidwood Unit 2 SGs

The Braidwood Unit 2 SGs are Westinghouse Model D5 type, utilizing Alloy 600 thermally treated (A600TT) tube material, full depth hydraulic expansion in the tubesheet region, and stainless steel tube support structures. The tube hole style at tube support plates is a quatrefoil lobe design. These SGs utilize a preheater design which introduces the majority of the feedwater to the lower region of the cold leg side of the tube bundle. Within the preheater region, the tube hole style is a simple drilled hole.

To date, Braidwood Unit 2 has experienced fretting wear at tube supports (antivibration bars, tube support plates (TSPs), and preheater baffles), axial outside diameter stress corrosion cracking (ODSCC) at TSP intersections on high residual stress tubes (five affected tubes to date), axial ODSCC at a freespan ding on one high residual stress tube (this tube also contained ODSCC at a TSP intersection), and tube wear due to interaction with foreign objects. SCC indications have also been reported near the tube end; however, the location of these degradation modes is outside of the pressure boundary as defined by application of the H* alternate tube repair criterion and is not evaluated. Foreign object wear, while observed within the SGs, is not an artifact of SG design or manufacture and is dependent on ingress of material from the balance-of-plant, thus foreign object wear can be considered a potential degradation mechanism.

Generally speaking, there are several corrosion-related degradation mechanisms that are classified as potential for the A600TT tube material utilized in the Braidwood Unit 2 SGs. These mechanisms involve forms of SCC on the primary or steam-side, oriented either axial or circumferential to the tube axis, and occurring at different locations in the tube bundle. For SGs utilizing A600TT tubing, these potential mechanisms ordered according to their judged risk level, from highest to lowest are:

- Axial ODSCC at TSP intersections on known high residual stress tubes
- Circumferential ODSCC at the hot leg top-of-tubesheet (TTS) expansion transition
- Axial ODSCC at tube dings and dents (both high stress and non-high stress tubes)
- Axial ODSCC at TSP intersections on non-high residual stress tubes
- Axial ODSCC at the hot leg TTS expansion transition
- Axial primary water stress corrosion cracking (PWSCC) in small radius U-bends
- Axial and circumferential PWSCC at the TTS (generally bounded by ODSCC analyses)
- Tube wear mechanisms

Of this list of SCC degradation mechanisms, only axial ODSCC at TSP intersections and at freespan dings on high residual stress tubes has been reported at Braidwood Unit 2.

The mechanisms judged most challenging to establishing that the OA satisfies the tube integrity criteria are:

- Axial ODSCC at TSP intersections on known high residual stress tubes
- Circumferential ODSCC at the hot leg TTS expansion transition
- Axial ODSCC at tube dings and dents (both high residual stress and non-high residual stress tubes)

Most Recent Inspection Programs

For the most challenging of the mechanisms evaluated, the most recent inspection scope and inspection strategy is provided. Table 1 outlines the inspection scopes performed at A2R17 and A2R19 for the most challenging mechanisms.

The Braidwood Unit 2 inspection scope aggressively targeted high residual stress tubes and dings and dents.

Table 1 — Summary of A2R17 and A2R19 Inspection Scope for Most Challenging Mechanisms

	A2R17			A2R19		
Mechanism	**Bobbin**	**X-Probe**	**+Point**	**Bobbin**	**X-Probe**	**+Point**
Axial ODSCC at TSPs High Stress Tubes	100%	100% all hot leg and cold TSPs		100%	100% all hot leg and cold leg TSPs	
Dings and Dents: High Stress Tubes	100%		100% dents >2V, 100% dings >5V	100%		100% dings/dents >2V (all)
Circumferential ODSCC at Hot Leg TTS		63% TSH+4 to H* (1) 100% TSH+4 to H* high stress tubes	50% hot leg BLG/OXP within H*		63% TSH+4 to H* (1) 100% TSH and TSC+/-3 inches about TTS on high stress tubes 50% hot leg BLG/OXP with H* 26% TSC +/-3 inches about TTS	
Dings and Dents: Non-High Stress Tubes	100%		SGA, B, D: 50% HL dents >2V, 100% >5V dings (all), 100% dents >5V CL SGC: 100% HL dents >2V, 100% >5V dings (all), 100% dents >5V CL	100%		50% dings/dents >5V (all)

Notes: (1)The 63% inspection scope includes 50% general tube bundle inspection plus 3-tube deep pattern around the SG periphery, tube lane, and T-slot.

High Stress Tubes Inspections

At both A2R17 and A2R19, all high residual stress tubes were tested full length with the bobbin probe and all hot and cold leg TSP intersections were tested with an X-Probe. The combination of bobbin inspection followed by either X-Probe or +Point probe inspection produces an overall improvement in the simulated non-detected population depth distribution. This concept was presented in a

presentation at the 2016 EPRI NDE Workshop[1]. In addition, at A2R17, 100% of all >2V dents and 100% of all >5V dings were tested with a +Point probe and at A2R19, 100% of all >2V dings and dents were tested with a +Point probe on high residual stress tubes. Therefore, applied probability of detection curve for <2V dings and dents on high residual stress tubes then becomes similar to that of the freespan axial ODSCC probability of detection of ETSS I28413.

Ding and Dent Inspections

At A2R17, in SGs A, B, and D, the applied ding/dent +Point inspection scope on non-high residual stress tubes included:

- 50% hot leg >2V dents
- 100% >5V dings (hot leg, cold leg, and U-bend)
- 100% cold leg >5V dents
- 100% AV1 and AV2 >2V dents, plus 50% AV3, AV4, and 11C >2V dents

At A2R17, in SG C, the applied ding/dent +Point inspection scope on non-high residual stress tubes included:

- 100% hot leg >2V dents
- 100% >5V dings (hot leg, cold leg, and U-bend)
- 100% cold leg >5V dents
- 100% AV1, AV2, AV3, AV4, and 11C >2V dents

At A2R19, in all SGs, the applied ding/dent +Point inspection scope on non-high residual stress tubes included:

- 50% hot leg, cold leg, and U-bend >5V dents
- 50% hot leg, cold leg, and U-bend >5V dings
- 50% 2V to 5V dents at 01H, 01C, 02C, 03C, 04C, 05C, and 06C
- 50% 2V to 5V dings below 01H (down to top-of-tubesheet (TTS) and below 06C (down to TTS)

Tubesheet Region Inspections

The tubesheet region inspection included 50% X-Probe inspection at both A2R17 and A2R19 from 4 inches above the hot leg TTS to the H* distance. In addition, a three tube deep peripheral tube X-Probe inspection was performed at both A2R17 and A2R19 in all SGs on both the hot and cold leg side. The peripheral tube program includes the outer periphery, the (no) tube lane region, and the T-slot region. The addition of this program is significant to the OA development as the historic sludge deposition region in this style of SG is concentrated around the T-slot, inferring that the actual applied inspection scope for the region susceptible to ODSCC is greater than the 50% inspection level assumed in the circumferential ODSCC OA model. The effective percent inspected in each SG with regard to detection of ODSCC and PWSCC at the TTS was a minimum of 63%. The effect of this inspection scope at A2R19 would then allow a reduced percentage of the susceptible tube population is allotted to the OA model which addresses initiations prior to A2R17. The overall effect on burst probability for the

[1] 35th EPRI Tube Integrity and NDE Workshop, "A600TT Inspection Strategy for an Aging Fleet: ODSCC Growth Rate and POD Update," Bill Cullen, Westinghouse Electric.

population only inspected at A2R17 would be to reduce the probability of burst and probability of leakage exceeding the AILPC by about 26%.

Other Inspections

Regarding the lesser challenging mechanisms, 50% Row 1 and 2 U-bend inspection was performed using a +Point probe. In addition, all tubes with the “Blairsville Bump” manufacturing anomaly were tested with a +Point probe at both A2R17 and A2R19. At A2R19, the effective percentage inspected ranged from 58% to 62% of the Row 1 and Row 2 U-bends.

Inspection for PWSCC at bulges and over-expansions included 50% +Point inspection at A2R17 and 50% X-Probe inspection at A2R19.

At each inspection from A2R10 through A2R19, 100% full length bobbin inspection was performed in all SGs.

2 | OA Strategy

Conservatively, the above mechanisms were all postulated to exist within the Braidwood Unit 2 SGs prior to the last inspection, either prior to A2R19 for mechanisms inspected at a 100% sample level or prior to A2R17 for mechanisms inspected using a 50% sampling strategy. These mechanisms were each evaluated by performing full-bundle probabilistic analyses to calculate the probability of tube burst and leakage potential in accordance with Section 8.3 in the EPRI IAGL. The probabilistic model included the important input distributions for material strength properties for the tubing, probability of detection for the eddy current inspection technique, a lognormal crack growth rate model appropriate for each mechanism at T_{Hot}, and the use of a Weibull initiation function predicting when SCC flaws have developed over time. Plant specific inputs used in the OA analyses are provided below:

- Tube Outside Diameter — 0.75 inch
- Tube Wall Thickness — 0.043 inch
- T-hot — 611°F
- Normal Operation Pressure Differential — 1370 psi
- Performance Criterion — 4110 psi
- Steam Line Break Pressure Differential — 2560 psi
- Tubing $S_y + S_u$ at 650°F — 137,370 psi
- Standard Deviation of $S_y + S_u$ — 7242 psi

The following conservative conditions were applied in the OA analysis:

1. All mechanisms are assumed to be present within the SGs.
2. For mechanisms that the inspection at A2R19 included 100% testing, indications within each category were assumed to have initiated during Cycle 18. Thus during the A2R19 (EOC19) inspection, indications were present and permitted to remain in-service either as a miss (having sufficient depth that detection is possible but not detected) or having a depth below the detection threshold of the inspection technique (e.g., the depth is not sufficient for functional flaw reporting). These assumptions will create a population of undetected flaws that will exist at the start of the cycle following the inspection.
3. For mechanisms that were sampled (<100% inspection) at the last inspection, dividing the tube population according to the sampling plan was performed in accordance with Section 8.6 of EPRI IAGL. This requires that two separate OA analyses be performed; one to address the tubes last inspected at A2R17 and one to address the tubes last inspected at A2R19. The probability of burst and leakage assessment was individually computed for each partially inspected group and later numerically combined to give the total probabilities for the mechanism.
4. All OA analyses were performed using a bounding SG approach where assumed susceptible populations are represented by the largest number of locations for any SG.

In support of the probabilistic OA for these mechanisms, a lead-plant evaluation was performed where the operating history of Braidwood Unit 2 was compared with those plants that have experienced SCC to estimate equivalent initiation times for each mechanism. This evaluation concludes that for circumferential ODSCC at the TTS expansion transition and axial ODSCC at dings and dents, based on the equivalent initiation time for Braidwood Unit 2, the application of prior inspection programs would have resulted in a very high likelihood that indications would have reported at a prior inspection. This analysis can be used to conclude that this mechanism either has not initiated at Braidwood Unit 2, or

that the mechanism has initiated but the in situ growth rates are too low to have supported reliable detection at the most recent inspection. This information was also used to define the range of Weibull initiation function parameters appropriate for Braidwood Unit 2 for the OA. As the OA was performed using growth rates significantly larger than the growth required to support non-detection within the initiation model, the OA results will remain conservative for any assumed initiation point following the equivalent initiation times for Braidwood Unit 2.

Additional conservatisms incorporated into these analyses include:

- Application of typical default growth rates included in the EPRI IAGL for circumferential ODSCC at the hot leg TTS expansion transition and axial ODSCC at dings and dents.
- Application of upper bound default growth rate included in the EPRI IAGL for axial ODSCC at TSP intersections on previously identified high residual stress tubes.
- A normal operating condition primary to secondary pressure differential of 1370 psi was applied.

Growth rate information provided by the licensee that has experienced the largest number of circumferential ODSCC indications in the A600TT fleet, is shown to be well bounded by the EPRI IAGL typical default growth rates. Additional information provided by another licensee with original vintage SGs utilizing A600MA tubing, and a total number of circumferential ODSCC indications reported to date of approximately 800 indications, also shows that the circumferential ODSCC growth rates for this plant are bounded by the EPRI IAGL typical default growth rates. Therefore, it can be concluded that application of the EPRI IAGL typical default growth rates is conservative.

For the high stress tube analyses, the EPRI IAGL upper bound structural average growth rate (lognormal mean value of 1.95) was applied. This growth rate is consistent with the recommendations of the EPRI IAGL and is judged conservative for the Braidwood Unit 2 high residual stress tubing performance. The probabilistic tube integrity software used has the capability to predict the number of detected indications and the probabilistic simulated maximum depth distribution. Figure 1 presents a plot of the simulated A2R10 axial ODSCC depth distribution using the above growth rate. This plot shows excellent prediction capability; however, the number of indications used in the model is larger than the number of indications reported in SG C. When the model is rerun using the number of indications observed in SG C, the predicted depth distribution significantly bounds the observed depth distribution, suggesting that the applied growth rate is conservative. The simulation software was used to optimize the growth rate for the observed A2R10 indications. This effort shows that an alternate non-linear function form benchmarks well to the observed A2R10 depths and this growth rate distribution is also bounded by the upper bound default of the EPRI IAGL. Thus, application of the upper bound EPRI IAGL default growth rate will produce a conservative assessment.

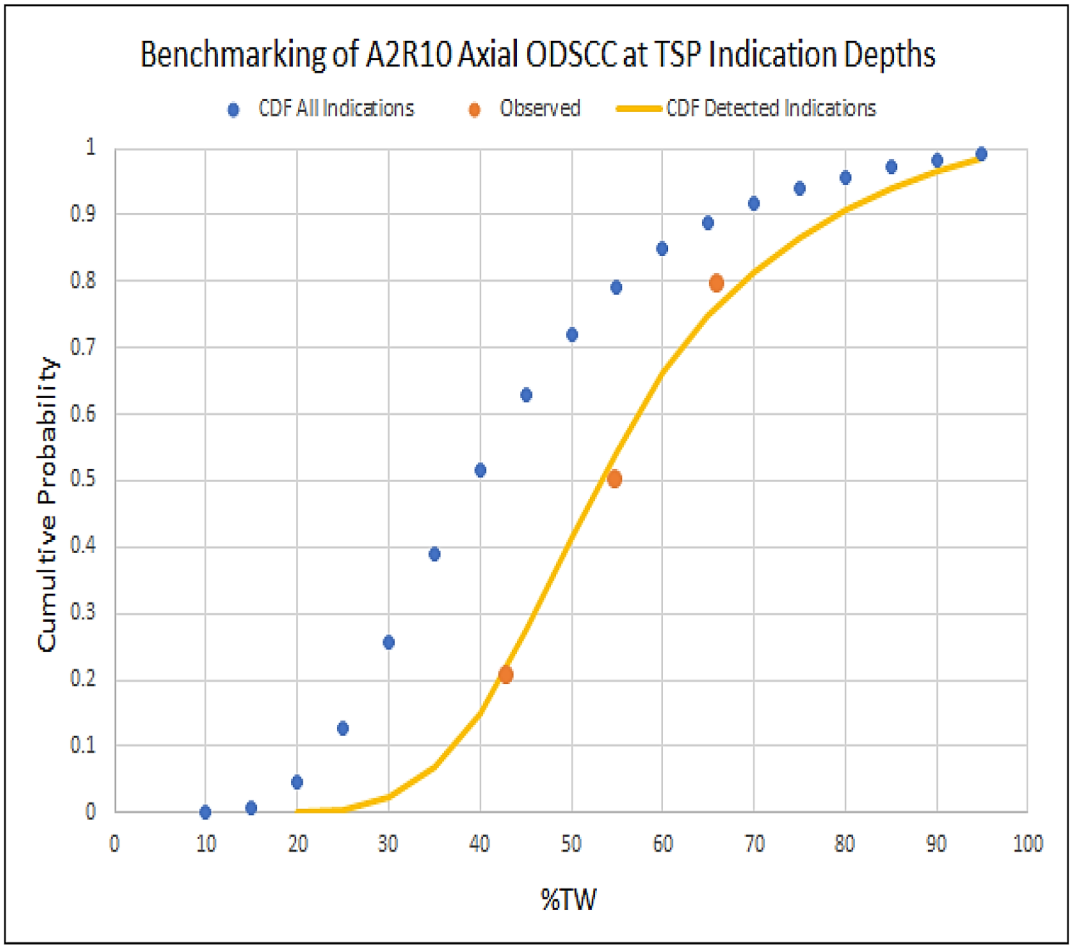

Figure 1 — Depth Benchmarking of A2R10 Axial ODSCC Indications.

A conservative flaw length distribution based on the axial ODSCC indications from the first plant to experience this mechanism was applied. This length distribution conservatively bounds the Braidwood Unit 2 axial ODSCC indication lengths as well as the flaw lengths reported from another plant which has experienced this mechanism.

The high stress tube analysis used two OA models; an acute initiation model and a low Weibull slope model. The acute model introduces all flaws within a short operational time window. All indications are assumed to have initiated prior to the A2R19 inspection and all assumed to have been missed by the inspection process. The low Weibull slope model utilizes a steady flaw introduction process over time.

The acute model uses an indication count equal to the largest number of indications observed in any outage that this mechanism was observed at Braidwood Unit 2. At the A2R10 outage, four indications were reported on three tubes in two SGs. Thus, the assumed susceptible population for the acute model bounds the A2R10 results for any single SG. At the A2R15 outage, four indications were reported on one tube. However, this tube was a “Seabrook Signature” tube. All Seabrook Signature tubes (located in Rows 1 through 9) have been preventively plugged at Braidwood Unit 2; only “2-Sigma” high residual stress tubes (located in Rows 10 and above) remain in service.

The low Weibull slope model uses an extremely conservative susceptible population size. The population size applied is larger than the total number of axial ODSCC indications on high residual stress

tubes for all affected plants combined. This population is assumed to exist in one SG. The conservatism surrounding the population size applied for the low Weibull slope model will provide assurance that should potential non-identified high residual stress tubes be present, the evaluation of structural and leakage integrity will be addressed by this model. Given that the low Weibull slope model accounts for potential non-identified high residual stress tubes, supplemental inspection methods to locate such tubes is not required to establish compliance with the performance criteria. The axial ODSCC at freespan ding on high residual stress tube analysis is addressed by the conservatism of the low Weibull slope model.

For the ding/dent analysis, the EPRI IAGL typical default growth rate was applied. This growth is shown to be conservative compared to both the A600TT and A600MA ding/dent ODSCC experience. A conservative length distribution from a plant with the largest number of ding cracks and A600MA tubing was applied. This length distribution is judged to be conservative for all plants. At this plant, repairs performed on the tube bundle during manufacture and after tube installation resulted in dings judged to be of greater axial influence and severity compared to all other plants (none of which experienced such a repair). The flaw length distribution from this plant bounds the A600TT plant experiences, and therefore, is judged conservative. The susceptible population size used is based on the SG with the largest number of dings or dents. Since the maximum number of <5V dings and <5V dents for the limiting SG are very similar, one bounding case was developed and applied to <5V dings and to <5V dents. The same condition applies for >5V dings and dents; one bounding case was developed and applied to >5V dings and to >5V dents. Given the performance of A600TT tubing to date and the judgment that even with extended operation well beyond the current plant license, not all dings or dents would develop SCC; this susceptible population size is extremely conservative.

The applied normal operating condition primary-to-secondary pressure differential of 1,370 psi is conservative when compared with the actual current value of approximately 1,363 psi.

Determination of the susceptible population size for circumferential ODSCC at the hot leg TTS expansion transition was performed using the same methodology as described in the A600TT Inspection Interval Extension Feasibility Study and as described in NRC/SGTF meeting held February 24, 2020.

The probabilistic OA used Monte Carlo simulation process to numerically solve for the probability of tube burst for the SIPC margin requirement and leakage potential to the AILPC. The Monte Carlo method is standard industry procedure for performing OA evaluations to the following performance standards:

- The worst-case degraded tube for each existing degradation mechanism shall meet the SIPC requirements with at least a probability of 0.95 at 50% confidence.
- The probability for satisfying the limit requirements of the AILPC shall be at least 0.95 at 50% confidence.

3 | OA Results and Conclusions

For all mechanisms evaluated in Phase 1, the probability of burst is less than the limit of 0.05 and the probability of leakage at steam line break conditions exceeding the applied AILPC limit of 0.5 gpm is less than the limit of 0.05. Therefore, extending the inspection interval to three cycles will satisfy the tube integrity requirement of NEI 97-06 and justifies deferring the A2R21 inspections to A2R22 in October 2021. Table 2 presents a summary of the probabilistic analysis inputs and results. For the circumferential ODSCC cases, the probabilities are combined using a Boolean Sum process. The combined burst probability is 2.77% and the combined leakage probability of leakage exceeding the AILPC value is 0.9%. The probabilities for dings (all voltages) and dents (all voltages) were combined as a separate mechanism. The combined burst probability is 3.1% and the combined probability of leakage greater than the AILPC limit is 1.6%. Section 2 indicates that a very conservative length distribution (from A600 mill annealed tubing experience) was applied for the ding/dent analysis. Other A600TT plant analyses have utilized a length distribution which combines all axial ODSDC at TTS, axial ODSCC at dings/dent, and axial PWSCC at TTS for the A600TT fleet. Using this distribution, which is judged the most appropriate for A600TT plants, the combined burst probability for dings and dents is then <1% and the probability of leakage exceeding the AILPC limit is essentially 0%.

Prior experience has indicated that PWSCC growth rates and length distributions are bounded by the ODSCC growth and length distributions. As such, it is expected that the analyses of PWSCC mechanisms presented in the final OA will also produce acceptable results for a three-cycle operating period.

Axial ODSCC at TSP intersections on non-high residual stress tubes was reported for the first time in the A600TT fleet during the fall of 2019. The final OA will address this mechanism and based on analyses performed for another plant, it is expected that the analysis will produce acceptable results for three-cycle operation.

A prior study[1] indicates the estimated axial ODSCC at TSP intersection affected percentage is 0.1% up to the end of the current license. This analysis was performed prior to the high stress tube SCC experience, thus the application of an affected percentage of 0.1% can be considered to apply to the non-high stress tube population. For Braidwood Unit 2, this would imply approximately five indications would be observed up to the end of the original 40-year license. The number of simulated indications for the high stress tube, low Weibull slope model at A2R22 (~29.9 EFPY) is five indications. As the non-high stress tubes would be expected to experience growth rates bounded by the EPRI IAGL typical default (lognormal mean of 1.5), the low Weibull slope model for the high residual stress tubes represents a conservative bounding analysis for postulated axial ODSCC at TSP intersections on non-high stress tubes. It is then expected that the OA case developed for this mechanism in the final OA will show burst probability significantly less than 1%.

Axial ODSCC at the hot leg TTS expansion transition would be expected to be bounded by the >5V dent analysis case of Table 2. For both these mechanisms, the applicable growth rate is bounded by the EPRI IAGL default, the susceptible population size is similar, and the assumed initiation point based on the applied inspection program is the same. However, the applied length distribution for the ding and dent analyses bounds that of the TTS and the >5V dent analysis then represents a conservative bound of the axial ODSCC at TTS analysis. An OA case addressing axial ODSCC at the hot leg TTS will be presented in the final OA.

In addition, the other existing degradation mechanism within the Braidwood Unit 2 SGs, fretting wear at tube supports, has also been evaluated within the Phase 1 program. A deterministic OA strategy

(arithmetic uncertainty treatment) was applied. Table 3 presents a summary of the analysis parameters and OA results. A sufficiently large data base for antivibration bar wear growth rates indicates that the 95th percentile depth growth rate can be applied. For TSP and preheater baffle plate wear (drilled hole support plates), the available quantity of growth rate data is not sufficient for development of a depth growth distribution; therefore, the maximum observed growth rate is applied. There are only two TSP wear indications in the Braidwood Unit 2 SGs. One of these is associated with a “burr” or small tab of rolled-over material at the edge of the TSP. This phenomenon has been observed at other plants using a similar style of TSP, most recently at plants with replacement SGs. EPRI Examination Technique Specification Sheet (ETSS) 21998.1 was used for depth sizing of this indication based on the short axial length of the indication (0.18 inch). Any further depth progression would be expected to cause interaction between the tube and land of the quatrefoil TSP. This will then greatly increase the contact area between the tube and TSP and effectively stunt any future depth progression.

Table 2 — Summary of OA Input Parameters and Results

Mechanism	Structural Average Growth/EFPY (Lognormal)	Maximum Depth Growth/EFPY (Lognormal)	Missed Indications at Most Recent Inspection	Number Predicted Indications at A2R22	Probability of Burst	Margin to SIPC	Probability of Leak Rate > AILPC	Margin to AILPC
Circ ODSCC A2R17 Inspected	Mean: 1.50 SD: 0.65	Mean: 1.73 SD: 0.65	2	7	2.18%	3.82%	0.9%	4.1%
Circ ODSCC A2R19 Inspected	Mean: 1.50 SD: 0.65	Mean: 1.73 SD: 0.65	2	5	0.6%	4.4%	0.0%	5.0%
Axial ODSCC at TSPs High Stress Tubes (Acute Model)	Mean: 1.95 SD: 0.65	Mean: 2.19 SD: 0.65	4	4	3.6%	1.4%	1.1%	3.9%
Axial ODSCC at TSPs High Stress Tubes (Low Weibull Slope Model)	Mean: 1.95 SD: 0.65	Mean: 2.19 SD: 0.65	2	5	2.4%	2.3%	1.6%	3.4%
Axial ODSCC Hot Leg <5V Dings	Mean: 1.50 SD: 0.65	Mean: 1.73 SD: 0.65	2	5	0.12%	4.88%	0.1%	4.9%
Axial ODSCC Hot Leg >5V Dings	Mean: 1.50 SD: 0.65	Mean: 1.73 SD: 0.65	2	3	1.24%	3.76%	0.6%	4.4%
Axial ODSCC Hot Leg <5V Dents	Mean: 1.50 SD: 0.65	Mean: 1.73 SD: 0.65	2	5	0.12%	4.88%	0.1%	4.9%
Axial ODSCC Hot Leg >5V Dents	Mean: 1.50 SD: 0.65	Mean: 1.73 SD: 0.65	2	3	1.24%	3.76%	0.6%	4.4%

Table 3 — Input Parameters and OA Results for Wear Mechanisms

	Antivibration Bars	TSP	Drilled Support Plate
OA Methodology	Deterministic	Deterministic	Deterministic
Uncertainty treatment	Arithmetic	Arithmetic	Arithmetic
Largest indication returned to service after A2R19 (%TW, NDE)	39%TW	28%TW	5%TW
ETSS used to size this indication	96004.3 r13	21998.1 r4	96004.3 r13
Bounding degradation growth rate (%TW/EFPY)	2.9	2.1	2.1
Basis for growth rate selection	(Note 1)	(Note 2)	(Note 2)
Projected size at A2R22, 52 effective full power month (%TW, NDE)	52%TW	37%TW	14%TW
Bounding degradation geometry	(Note 3)	(Note 3)	(Note 4)
Burst pressure at projected actual A2R22 size (psi)	5330	5110	7530
Condition monitoring limit at 3xNODP, 4110 psi (%TW, NDE)	69%TW	49%TW	55%TW
Approximate margin (%TW)	~17%TW	~12%TW	~41%TW

Notes:

(1) Basis for selection: 95th percentile of paired antivibration bar wear indications at A2R17; A2R17 observed growth rates bound observed A2R19 growth rates.

(2) Basis for selection: largest observed growth rate for paired wear indications at both TSP and Drilled Support Plate, for both outages (A2R17 and A2R19) [drawn from a total population of nine growth rates]

(3) Volumetric with limited circumferential and axial extent

(4) Volumetric uniform thinning with limited axial extent

Attachment 3

Braidwood Station, Unit 2
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Proposed Technical Specifications Change (Mark-Up)

5.5.9 Steam Generator (SG) Program (continued)

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

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

b) During the next 120 effective full power months, inspect 100% of the tubes. This constitutes the second inspection period;

c) During the next 96 effective full power months, inspect 100% of the tubes. This constitutes the third inspection period; and

d) During the remaining life of the SGs, inspect 100% of the tubes every 72 effective full power months. This constitutes the fourth and subsequent inspection periods.

, with the exception that each SG is to be inspected during the third refueling outage in A2R22 following inspections completed in refueling outage A2R19.

For Unit 2, after the first refueling outage following SG installation, inspect each SG at least every 48 effective full power months or at least every other refueling outage (whichever results in more frequent inspections). In addition, the minimum number of tubes inspected at each scheduled inspection shall be the number of tubes in all SGs divided by the number of SG inspection outages scheduled in each inspection period as defined in a, b, and c below. If a degradation assessment indicates the potential for a type of degradation to occur at a location not previously inspected with a technique capable of detecting this type of degradation at this location and that may satisfy the applicable tube plugging criteria, the minimum number of locations inspected with such a capable inspection technique during the remainder of the inspection period may be prorated. The fraction of locations to be inspected for this potential type of degradation at this location at the end of the inspection period shall be no less than the ratio of the number of times the SG is scheduled to be

Attachment 4

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Proposed Technical Specifications Change (Clean)

5.5 Programs and Manuals

5.5.9 Steam Generator (SG) Program (continued)

2. Accident induced leakage performance criterion: The primary to secondary accident induced leakage rate for any design basis accident, other than a SG tube rupture, shall not exceed the leakage rate assumed in the accident analysis in terms of total leakage rate for all SGs and leakage rate for an individual SG. Leakage is not to exceed a total of 1 gpm for all SGs.

3. The operational LEAKAGE performance criteria is specified in LCO 3.4.13, "RCS Operational LEAKAGE."

c. Provisions for SG tube plugging criteria. Tubes found by inservice inspection to contain flaws with a depth equal to or exceeding 40% of the nominal wall thickness shall be plugged. The following alternate tube plugging criteria shall be applied as an alternative to the 40% depth based criteria:

For Unit 2, tubes with service-induced flaws located greater than 14.01 inches below the top of the tubesheet do not require plugging. Tubes with service-induced flaws located in the portion of the tube from the top of the tubesheet to 14.01 inches below the top of the tubesheet shall be plugged upon detection.

d. Provisions for SG tube inspections. Periodic SG tube inspections shall be performed. The number and portions of the tubes inspected and methods of inspection shall be performed with the objective of detecting flaws of any type (e.g., volumetric flaws, axial and circumferential cracks) that may be present along the length of the tube, from the tube-to-tubesheet weld at the tube inlet to the tube-to-tubesheet weld at the tube outlet, and that may satisfy the applicable tube plugging criteria. For Unit 2, portions of the tube below 14.01 inches from the top of the tubesheet are excluded from this requirement.

5.5.9 Steam Generator (SG) Program (continued)

The tube-to-tubesheet weld is not part of the tube. In addition to meeting the requirements of d.1, d.2, and d.3 below, the inspection scope, inspection methods, and inspection intervals shall be such as to ensure that SG tube integrity is maintained until the next SG inspection. A degradation assessment shall be performed to determine the type and location of flaws to which the tubes may be susceptible and, based on this assessment, to determine which inspection methods need to be employed and at what locations.

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

2. For Unit 1, after the first refueling outage following SG installation, inspect each SG at least every 72 effective full power months or at least every third refueling outage (whichever results in more frequent inspections). In addition, the minimum number of tubes inspected at each scheduled inspection shall be the number of tubes in all SGs divided by the number of SG inspection outages scheduled in each inspection period as defined in a, b, c, and d below. If a degradation assessment indicates the potential for a type of degradation to occur at a location not previously inspected with a technique capable of detecting this type of degradation at this location and that may satisfy the applicable tube plugging criteria, the minimum number of locations inspected with such a capable inspection technique during the remainder of the inspection period may be prorated. The fraction of locations to be inspected for this potential type of degradation at this location at the end of the inspection period shall be no less than the ratio of the number of times the SG is scheduled to be inspected in the inspection period after the determination that a new form of degradation could potentially be occurring at this location divided by the total number of times the SG is scheduled to be inspected in the inspection period. Each inspection period defined below may be extended up to 3 effective full power months to include a SG inspection outage in an inspection period and the subsequent inspection period begins at the conclusion of the included SG inspection outage.

5.5.9 Steam Generator (SG) Program (continued)

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

b) During the next 120 effective full power months, inspect 100% of the tubes. This constitutes the second inspection period;

c) During the next 96 effective full power months, inspect 100% of the tubes. This constitutes the third inspection period; and

d) During the remaining life of the SGs, inspect 100% of the tubes every 72 effective full power months. This constitutes the fourth and subsequent inspection periods.

3. For Unit 2, after the first refueling outage following SG installation, inspect each SG at least every 48 effective full power months or at least every other refueling outage (whichever results in more frequent inspections), with the exception that each SG is to be inspected during the third refueling outage in A2R22 following inspections completed in refueling outage A2R19. In addition, the minimum number of tubes inspected at each scheduled inspection shall be the number of tubes in all SGs divided by the number of SG inspection outages scheduled in each inspection period as defined in a, b, and c below. If a degradation assessment indicates the potential for a type of degradation to occur at a location not previously inspected with a technique capable of detecting this type of degradation at this location and that may satisfy the applicable tube plugging criteria, the minimum number of locations inspected with such a capable inspection technique during the remainder of the inspection period may be prorated. The fraction of locations to be inspected for this potential type of degradation at this location at the end of the of degradation at this location at the end of the inspection period shall be no less than the ratio of the number of times the SG is scheduled to be inspected in the inspection period after the determination that a new form of degradation could potentially be occurring at this location divided by the total number of times the SG is scheduled to be inspected in the inspection period. Each inspection period defined below may be extended up to 3 effective

5.5 Programs and Manuals

5.5.9 Steam Generator (SG) Program (continued)

full power months to include a SG inspection outage in an inspection period and the subsequent inspection period begins at the conclusion of the included SG inspection outage.

a) After the first refueling outage following SG installation, inspect 100% of the tubes during the next 120 effective full power months. This constitutes the first inspection period;

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

c) During the remaining life of the SGs, inspect 100% of the tubes every 72 effective full power months. This constitutes the third and subsequent inspection periods.

4. For Unit 1, if crack indications are found in any SG tube, then the next inspection for each affected and potentially affected SG for the degradation mechanism that caused the crack indication shall not exceed 24 effective full power months or one refueling outage (whichever results in more frequent inspections). For Unit 2, if crack indications are found in any SG tube from 14.01 inches below the top of the tubesheet on the hot leg side to 14.01 inches below the top of the tubesheet on the cold leg side, then the next inspection for each affected and potentially affected SG for the degradation mechanism that caused the crack indication shall not exceed 24 effective full power months or one refueling outage (whichever results in more frequent inspections).

If definitive information, such as from examination of a pulled tube, diagnostic non-destructive testing, or engineering evaluation indicates that a crack-like indication is not associated with a crack(s), then the indication need not be treated as a crack.

e. Provisions for monitoring operational primary to secondary LEAKAGE.