STEAM GENERATOR EXAMINATION
1995 REFUELING OUTAGE

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
INDIAN POINT UNIT NO. 2
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Indian Point 2
Steam Generator Examination Program
1995 Refueling Outage

1. **Examination Program Description**

Details of the steam generator tube inservice examination program planned for the Indian Point 2 twelfth refueling outage were previously submitted to the NRC by Con Edison by letter dated December 16, 1994.

The scope, results and conclusions of the steam generator examination, as conducted during the twelfth refueling outage, are discussed below.

2. **Scope of the Examination**

a. Steam Generator Tube Eddy Current Examination

A standard 700 mil bobbin coil eddy current probe was used to perform the initial eddy current testing. If any tube did not permit passage of the standard probe, the tube was gauged and tested down to a 610 mil bobbin coil probe.

Any tube that did not permit passage of the 610 mil probe was plugged. Furthermore, the tubes immediately adjacent to any tube that did not pass the 610 mil probe were subjected to an eddy current examination.

One hundred percent of the tubes [both hot and cold legs] were examined from the tube end through the first support plate. The tubes in Row 1 were not examined because these tubes were plugged during original plant construction.

The Anti-Vibration Bar [AVB] baseline inspection started in 1993 was completed. In the process of conducting the full length tube examinations in 1993, AVB wear was noted in a few tubes at the U-bends. The wear was attributed to increased flow due to "full stretch" operation following the 1991 Refueling Outage. As a result, Con Edison conducted an augmented examination for an AVB or U-bend baseline. In 1993, all U-bends with a radius of Row 16 and larger in Steam Generator 24, 1394 tubes, and half the U-bends with a diameter of Row 16 and larger in Steam Generator 22, 763 tubes, were examined by the bobbin probe for wear. In 1993, one tube was plugged due to greater than 40% wall loss.

Selected tubes in Steam Generators 21, 22, 23, and 24 were eddy current examined for both dents and defects over their full length. The selection of tubes for the full length examination was based on the

tubes not being examined in 1989, 1991, or 1993, a reexamination of some tubes in the periphery hard spots of the tube bundle, and tubes with indications found during the 1993 examination. Additional tubes were examined for their full length based on productivity considerations. The examination was conducted from the hot and cold leg sides of the channel head. The examination was performed at 10, 100, 200 and 400 KHz and mixes of these frequencies.

In Steam Generator 21, 2122 tubes, or 71.0% of all active tubes, were examined over their full length. In Steam Generator 22, 1475 tubes, or 50.5% of all active tubes, were examined over their full length. In Steam Generator 23, 2103 tubes, or 70.0% of all active tubes, were examined over their full length. In Steam Generator 24, 2991 tubes, or 100% of all active tubes, were examined over their full length. The examination program as conducted represented an increase over the original scope submittal. This examination completes the full length tube examination cycle in a four examination period. The first examination of the cycle was conducted in 1989.

In Steam Generator 21, 204 tubes were to be examined with the Cecco™-5 array probe [Cecco] on an exploratory basis to detect defects, including axial and circumferential intergranular corrosion and/or cracking in the tubesheet, and tube support plate regions from the hot leg top support plate to the hot leg tube end. The U-bend regions were examined with the Rotating Pancake Coil probe [RPC] because of the limited flexibility of the Cecco for small radius bends.

To provide an enhanced inspection of the tube roll expansion region, as well as the top of the tubesheet and lower tube regions, Con Edison utilized the Cecco probe for examining all hot legs of the tubes from the first support plate down through the tube end for all four steam generators, the cold leg examination from the first support down through the tube end was done with the bobbin probe.

The Cecco probe was specifically qualified to Appendix H of the *EPRI PWR Steam Generator Examination Guidelines: Revision 3* to detect axial and circumferential cracks at dented support plates and tube roll transitions. Oversight of the qualification was provided by the EPRI NDE Center. The Cecco probe is a dual probe with a bobbin coil in addition to the Cecco array.

In addition, all bobbin coil and Cecco indications that exhibited distorted signals were re-examined by the RPC probe to characterize the signal.

b. Flow Slot and Lower Support Plate Inspections

Using the handhole above the tubesheet on Steam Generators 23 and 24, visual and photographic examinations of the flow slots in the lower support plates were made. Where feasible, higher support plates were also photographed through the flow slots in the lower support plates.

The "hillside" inspection port, located just above the top support plate, in Steam Generator 22 was used to conduct visual examinations of the flow slots in the uppermost support plate by means of a videoscope with a video recorder.

These inspections were conducted to provide a comparative examination cycle to cycle.

c. Secondary Side Examination

A video camera with a retrieval tool was passed around the annulus between the tube bundle and the shell and down the tube lane between the hot and cold legs to search for and retrieve foreign objects in the steam generators.

d. Steam Generator Sludge

The sludge removed from the steam generator tubesheets by lancing operations was sampled, weighed and will be analyzed.

3. **Examination Results**

a. Steam Generator Tube Eddy Current Examination Results

The number of tubes with eddy current indications revealed during the 1995 examination and the distribution of the most severe indication in each of the tubes are listed in Table 1. Tubes with indications evaluated at 40% or larger of the wall thickness or tube roll transition cracks that were not rerolled were plugged. In total, 21 tubes were plugged in all four steam generators. Twelve tubes were plugged for indications evaluated to be 40% or larger of the wall thickness and the balance of the tubes were plugged for other reasons. This total represents the lowest number of tubes plugged since 1982. The locations of the indications for the 1995 examination are listed in Tables 2 through 5.

Prior to the eddy current examination, a low pressure secondary hydrostatic test was performed on Steam Generators 22 and 24 to determine the presence of leaking steam generator plugs. The hydro revealed the presence of a leaking tube in Steam Generator 22, Row 4 Column 92; and leaking explosive plugs in Steam Generators 22 and 24.

Follow-up eddy current examination of the Steam Generator 22 tube [Row 4 Column 92] revealed a defect at the third support plate on the hot leg side. The data showed that the defect was at the lower edge of a dent near the bottom of the tube support plate. A review of previous eddy current data noted that the indication was present and essentially unchanged in the 1989-1993 period. In 1993, the third hot leg support plate location restricted 680 probe and passed the 610 probe. The indication changed over the last cycle to render it a pluggable defect in 1995. The Westinghouse Data Analysis Guidelines were changed prior to the 1995 outage to envelope this condition. As a result of this tube leak, a review of historical data of dented intersections was conducted against the 1995 Data Analysis Guidelines. The historical review included all data from the four steam generators for the 1991 and 1993 examinations. The review showed that out of 172,799 dented support plate intersections from 11,969 tubes, only Steam Generator 22's Row 4 Column 92 would have had a revised analysis at the third hot leg support plate. A Cecco examination was performed on all tubes in Steam Generators 21 and 22 that restricted the 700 or 680 mil diameter probes during the 1989, 1991, 1993 and 1995 outages. This was done to determine if tube cracking at support plates was occurring at Indian Point 2. This examination consisted of an additional 195 tubes in Steam Generator 21 and 201 tubes in Steam Generator 22. The Cecco examination, with RPC probe follow-up for characterization, showed no tube cracking at support plate intersections. All steam generator tubes will have had at least one full length examination within these four examinations. The *EPRI PWR Steam Generator Examination Guidelines: Revision 3* recommends that all tubes be examined over a five cycle interval. The completed 1995 examination showed that no tubes exhibited cracking at support plates.

The Cecco examination of all hot leg tubes from the tube end through the first support plate on the hot leg in all four steam generators also showed no tube cracking at the support plate locations.

The AVB baseline was completed in 1995. Some indications that were present in 1993 disappeared. This may have been caused by oxides or deposits spalling-off during service. A summary of the U-bend indications is shown on Table 6. The complete AVB baseline examination resulted in plugging two tubes with greater than 40% wall loss, with one tube being plugged in 1995.

During the 1995 examination, there was one tube that failed to pass a 610 mil diameter probe due to a restriction due to a dent, Steam Generator 24, Row 30 Column 23. This tube was plugged.

The 1995 examination revealed Primary Water Stress Corrosion Cracking [PWSCC] of the tubes in the roll transition region. This condition was first found in the 1993 examination when five tubes were affected. Since the 1993 outage and before the 1995 outage, Con Edison qualified an F* distance and a rerolling procedure in anticipation of additional PWSCC roll transition cracking. In 1995, roll transition PWSCC was found in 13 tubes in Steam Generator 21; 2 tubes in Steam Generator 22; 542 tubes in Steam Generator 23 and 37 in Steam Generator 24. Rerolling was performed on 580 tubes distributed among three steam generators. Since the Indian Point 2 steam generator tubes are rolled expanded for only a portion of the tubesheet, rerolling above the existing roll provides a new, sound, tube to tubesheet interface capable of meeting all design criteria. Twelve tubes in Steam Generator 24 met the F* criteria with respect to the location of the cracking and did not require rerolling. The 2 tubes in Steam Generator 22 were conservatively plugged for productivity reasons.

Due to ongoing industry and NRC concerns with cracking of Westinghouse Alloy 600 mechanical plugs, Con Edison elected to remove all remaining unrepaired Westinghouse Alloy 600 plugs from the hot legs of all steam generators during the 1995 outage. All Westinghouse explosive plugs and Babcock & Wilcox [B&W] Alloy 600 rolled plugs were also removed from the hot legs.

In Steam Generator 24, all hot leg plug ends were visually examined to detect damage from the split pin failure experienced during the last cycle; all damaged plugs were removed and replaced with Westinghouse Alloy 690 mechanical plugs and all tube ends were repaired. The cold leg Westinghouse Alloy 600 mechanical plugs have an earliest required repair year of 2021, according to the Westinghouse algorithm, *Steam Generator Tube Plug Integrity Summary, January 1995 WCAP-12245 Revision 3, Addendum 3.* Remaining B&W cold leg plugs will be examined during each tube examination on a sampling basis to include all susceptible heats and 20% of the less susceptible heats to assess the need to replace these plugs. Eddy current examination sampling of the cold leg plugs during the 1995 outage consisted of 86 plugs [100%] from the susceptible heats and 19 plugs [23%] from less susceptible heats from a total population of 168 plugs. No cracked plugs were found. A summary of the plugs removed is shown in Table 7 and the present plugging status is shown in Table 8. Subsequent to plug removals during the 1995 outage, Westinghouse issued an update to the algorithm, *WCAP-12245 Revision 3, Addendum 4, May 1995*, covering hot and cold leg plugs. Remaining hot and cold leg Westinghouse Alloy 600 mechanical plugs will be addressed in upcoming steam generator maintenance plans.

Summaries of the examination program trends and plugging trends for the current [1995] and previous [1993] refueling outages are presented in Tables 9 and 10, respectively. A summary of plugged tubes is listed in Table 11.

b. Flow Slot and Lower Support Plate Examination Results

The photographs taken of the lower support plate flow slots in Steam Generators 23 and 24 showed essentially no change in "hour-glassing" of the flow slots in the lower support plates when compared to photographs taken during previous steam generator examinations. The current and previous photographs also revealed cracks in the tube support plates at some flow slots. There was no change in the cracking previously observed.

The uppermost support plate in Steam Generator 22 was visually examined, as was done during previous examinations. The examination used a videoscope inserted through the "hillside" port in the steam generator shell. No significant "hour-glassing" of the flow slots in the top support plate was observed. The condition of the tube surfaces remained unchanged.

c. Secondary Side Examination Results

A Foreign Object Search And Retrieval [FOSAR] was conducted in the steam generators around the annulus and within the tube bundle. The FOSAR resulted in the removal of several items which previously could not be removed. The remaining items were evaluated for wear rates on adjacent tubes. The growth of eddy current indications from the previous outage were also reviewed and compared to determine if objects found on the secondary side of the steam generators contributed to localized external tube wear. The evaluation concluded that the Indian Point 2 steam generators could be returned to service with the identified items, and that operation during Cycle 13 with these foreign objects will not involve a change to any Technical Specification, and does not represent an unreviewed safety question in accordance with 10 CFR 50.59.

d. Steam Generator Sludge

Sludge was removed from each of the steam generators by lancing. The sludge removed in 1995 was approximately twice the amount removed in 1993. It is believed that the increase quantity was due to the longer operating period between refuelings, higher sludge lancing pressures, as well as longer lancing times used. The quantities are listed in Table 12. The sludge will be analyzed.

4. Conclusions

The 1995 steam generator tube inservice examination demonstrates that the Indian Point 2 steam generators are acceptable for continued service at full power.

Based on the results of this examination, the next steam generator examination will be scheduled for the next refueling outage, which is currently planned for the spring of 1997.

TABLE 1

Number of Tubes with Eddy Current Indications

SG Leg	20-29%	30-39%	40-49%	50-59	60-69%	≥70%	Pitting*
21 Hot	2	3	0	0	0	0	2
21 Cold	15	20	5	1	0	0	0
22 Hot	6	6	0	1	0	0	2
22 Cold	26	7	0	0	0	0	0
23 Hot	14	8	0	0	0	0	0
23 Cold	4	7	0	0	0	0	0
24 Hot	5	7	1	0	0	0	1
24 Cold	12	8	0	0	0	0	0
Total	84	66	6	2	0	0	5

Note: * Characterized by RPC

TABLE 2
Steam Generator 21 - Locations of Indications Plugged

Column	Row	Location	Comments
3	11	0.24 inch above 1H,	Preventive
6	15	0.11 inch above TSH	Pit [RPC]
15	30	0.09 inch below top of TSH	Pit [RPC]
32	12	12.42 inches above TSC	49%
35	9	13.22 inches above TSC	46%
40	9	11.56 inches above TSC	44%
51	45	0.19 inch above TSC	43%
61	6	2.47 inches above TSC	46%
70	13	0.55 inch above TSC	57%

TABLE 3
Steam Generator 22 - Locations of Indications Plugged

Column	Row	Location	Comments
22	37	0.24 inch above TSH	Pit [RPC]
43	4	15.47 inches above TEH	Preventive
62	20	2.32 inches above TEH	Roll Transit. Cracking
63	23	2.02 inches above TEH	Roll Transit. Cracking
87	10	0.58 inch above TSH	Pit [RPC]
92	4	0.46 inch below top of 3H	Leaked During Hydro

TABLE 4
Steam Generator 23 - Locations of Indications Plugged

Column	Row	Location	Comments
61	42	0.49 inch below top of 1H	Preventive

TABLE 5
Steam Generator 24 - Locations of Indications Plugged

Column	Row	Location	Comments
22	31	2H	Preventive
23	30	2H	610 probe restriction
24	30	2H	Preventive
32	27	3.68 inches above TEH	Pit [RPC]
34	45	AV1	46%

Notes: #H Hot leg support plate numbering; 1 is closest to tubesheet, 6 is furthest from tubesheet
TSH Top of tubesheet on hot leg side
TSC Top of tubesheet on cold leg side
TEH Tube end hot leg
AV# Antivibration bar numbering; 1 is closest to hot leg, 4 is closest to cold leg

TABLE 6
AVB and U-Bend Indications Summary

SG	Column	Row	Analysis	Location	History
21	43	25	13%	AV3	1993-NDD
	43	25	14%	AV4	1993-NDD
22	51	33	INR	AV3	1993-27% 1991-NDD
23	42	26	27%	AV3	1989-NDD
	50	26	30%	AV2	1993-28% 1991-28%
	56	38	INR	AV4	1993-18%
	58	16	INF	AV3	1993-19%
24	32	24	28%	AV2	1993-NDD
	32	26	22%	AV3	1993-NDD
	33	24	27%	AV2	1993-31% 1987-NDD
	34	24	29%	AV2	1993-NDD
	34	24	28%	AV4	1993-NDD
	34	25	32%	AV2	1993-NDD
	34	25	33%	AV4	1993-NDD
	34	31	29%	AV4	1989-NDD
	34	35	INF	AV3	1993-22% 1991-NDD
	34	39	INF	AV3	1993-22% 1991-NDD
	40	23	32%	AV3	1993-24% 1984-NDD
	44	18	INR	AV2	1993-32% 1987-NDD
	44	45	46%*	AV1	1993-NDD
	48	24	INF	AV3	1993-23% 1984-NDD
	54	36	34%	AV3	1993-NDD

Notes: * Pluggable indication, i.e. greater than 40% wall loss

AV# Antivibration bar numbering; 1 is closest to hot leg, 4 is closest to cold leg

NDD No Detectable Degradation

INR Indication, Non-Reportable, i.e. minor non-quantifiable indication not reportable per 1995 Westinghouse Data Analysis Guidelines

INF Indication Not Found

TABLE 7
Alloy 600 Plugs Removed

SG Leg	(W) A-600 Mech	(W) A-600 Explosive	(W) A-600 Mech PIP/PAP	B&W A-600 Rolled
21 Hot	5	3	0	0
21 Cold	0	0	0	0
22 Hot	18	11	0	48
22 Cold	0	0	0	0
23 Hot	57	20	0	0
23 Cold	0	0	0	0
24 Hot	15	18	57	42
24 Cold	0	19	0	0
Total	95	71	57	90

Table 8
STEAM GENERATOR TUBE PLUG TYPES/QUANTITIES AFTER 1995 RFO

	SG21H	SG21C	SG22H	SG22C	SG23H	SG23C	SG24H	SG24C	H Leg Total	C Leg Total	Totals
Clad Repr	92	92	92	92	92	92	92	92	368	368	736
A600Weld	1	1	7	3	2	2	10	11	20	17	37
A600Expl	-	3	-	20	-	20	-	-	-	43	43
A600Roll	-	48	-	67	-	11	-	42	-	168	168
A600Mech	-	101	-	121	-	109	-	84	-	415	415
A600PIP	47	-	37	-	-	-	-	-	84	-	84
A600PAP	49	-	58	-	52	-	-	-	159	-	159
A600Sent	-	2	10	-	1	-	11	-	22	2	24
A600Sent PAP	2	-	-	-	-	-	-	-	2	-	2
A600Stab PAP	5	-	-	-	-	-	-	-	5	-	5
A690Weld	1	-	1	-	1	-	3	4	6	4	10
A690Roll	8	1	18	-	-	-	-	-	26	1	27
A690Mech	74	31	121	41	108	22	157	40	460	134	594
Totals	279	279	344	344	256	256	273	273	1152	1152	2304

Notes:

Clad Repr	Cladding weld overlay repair prior to operation
A600Weld	Westinghouse (W) welded plug fabricated from Alloy 600
A600Expl	(W) explosive plug fabricated from Alloy 600
A600Roll	B&W rolled mechanical plug fabricated from Alloy 600
A600Mech	(W) mechanical plug fabricated from Alloy 600
A600PIP	(W) mechanical plug fabricated from Alloy 600 with PIP repair
A600PAP	(W) mechanical plug fabricated from Alloy 600 with PAP repair
A600Sent	(W) sentinel mechanical plug fabricated from Alloy 600
A600SentPAP	(W) sentinel mechanical plug fabricated from Alloy 600 with PAP
A600StabPAP	(W) stabilizer mechanical plug fabricated from Alloy 600 with PAP
A690Weld	(W) welded plug fabricated from Alloy 690
A690Roll	B&W rolled mechanical plug fabricated from Alloy 690
A690Mech	(W) mechanical plug fabricated from Alloy 690

TABLE 9
Steam Generator Tube Examination Program Trend Comparison - 1993-1995

1993 - Inspection Program	SG 21	SG 22	SG 23	SG 24
1993 FL/Total	707/3003	568/2936	680/3021	705/3008
FL Inspected	23.5%	19.3%	22.5%	23.4%
1SP Inspected	100%	100%	100%	100%

1995 - Inspection Program	SG 21	SG 22	SG 23	SG 24
1995 FL/Total	2122/2990	1475/2922	2103/3005	2991/2992
FL Inspected	71.0%	50.5%	70.0%	100%
1SP Inspected	100%	100%	100%	100%

Notes: FL Full Length examination from tube end to tube end.
1SP Examination from tube end [hot and cold legs] to the first support plate.

TABLE 10
Steam Generator Tube Plugging Summary Comparison - 1993-1995

1993 Tube Plugging	SG 21	SG 22	SG 23	SG 24
≥40% Indications	13	12	12	14
Tube Roll Transition Cracking	0	0	4	1
610 Probe Restrictions	0	0	0	0
Others	0	2*	0	1*
Total Plugged	13	14	16	16

1995 Tube Plugging	SG 21	SG 22	SG 23	SG 24
≥40% Indications	8	2	0	2
Tube Roll Transition Cracking	0	2	0	0
610 Probe Restrictions	0	0	0	1
Others	1*	2#	1*	2*
Total Plugged	9	6	1	5

Note: * Preventively plugged
One tube leaked during hydro, one tube preventively plugged

TABLE 11
Summary of Plugged Tubes

SG	Plugged in 1995	Previously Plugged	Total Plugged	Plugged
21	9	270	279	8.6%
22	6*	338	344	10.6%
23	1	255	256	7.9%
24	5	268	273	8.4%
Total	21	1131	1152	8.8%

Note: * Includes 1 tube leaking during hydro.

TABLE 12
Sludge Removed

SG	1993	1995
21	372 lb.	460 lb.
22	388 lb.	654 lb.
23	254 lb.	699 lb.
24	326 lb.	686 lb.
Total	1340 lb.	2499 lb.