James S. Baumstark
Vice President
Nuclear Engineering

Consolidated Edison Company of New York, Inc.
Indian Point 2 Station
Broadway & Bleakley Avenue
Buchanan, New York 10511

Internet: baumstarkj@coned.com
Telephone: (914) 734-5354
Cellular: (914) 391-9005
Pager: (917) 457-9698
Fax: (914) 734-5718

June 19, 2000

Re: Indian Point Unit No. 2
Docket No. 50-247

Document Control Desk
US Nuclear Regulatory Commission
Mail Station P1-137
Washington, DC 20555-0001

Subject: Response to the Staff's Requests for Additional Information (RAI) Regarding the Steam Generator Tube Examinations conducted during Spring of 2000 Outage, and the Root Cause Evaluation of the Steam Generator Tube Rupture Event of February 15, 2000 (TAC No. MA8219)

References:
1) NRC Letter to Con Edison dated March 14, 2000
2) NRC Letter to Con Edison dated March 24, 2000
3) NRC Letter to Con Edison dated April 28, 2000
4) Con Edison Letter to NRC dated April 14, 2000

Pursuant to 10 CFR 50.54(f), Consolidated Edison Company of New York, Inc. (Con Edison) hereby provides additional responses to the Staff's requests for additional information, which were provided to us in References 1 and 2. Also provided are our responses to the Staff's questions regarding the Root Cause Evaluation of the February 15, 2000 steam generator tube rupture event. This evaluation was previously transmitted to the Staff by Reference 4.

Specifically, this letter provides Con Edison's responses to Question 3 identified in Reference 1, Questions 3, 4, 5, 10, 11, 13, 14, and 18 identified in Reference 2, and Issues 5, 7, and 17 identified in Reference 3.

No new regulatory commitments are being made by Con Edison in this correspondence.

Should you or your staff have any concerns regarding this matter, please contact Mr. John McCann, Manager, Nuclear Safety and Licensing.

Sincerely,

J S Baumstark

Attachment

A001

C: Mr. Hubert J. Miller
Regional Administrator-Region I
US Nuclear Regulatory Commission
475 Allendale Road
King of Prussia, PA 19406

Mr. Patrick D. Milano, Project Manager
Project Directorate I-1
Division of Regulatory Projects I/II
US Nuclear Regulatory Commission
Mail Stop 14B-2
Washington, DC 20555

Senior Resident Inspector
US Nuclear Regulatory Commission
PO Box 38
Buchanan, NY 10511

Attachment

Response to Questions Regarding Steam Generator Tube Examinations
Performed During Spring 2000 Outage

Consolidated Edison Company of New York, Inc.
Indian Point Unit No. 2
Docket No. 50-247
June 2000

NRC RAI Letter dated March 14, 2000

Question 3

Provide a description and the basis of your proposed corrective actions, including any changes in hardware, operations, maintenance, monitoring, procedures and future inspections.

Reply

Hardware

- Inspection ports were installed in 21 and 24 steam generators to augment the inspections of the top support plates. Steam generators 22 and 23 already had the inspection ports.
- Con Edison will begin the replacement of the steam generators prior to the end of 2000.
- The four steam generators had 791 plugs installed to address the various inspection issues. Details are in the condition monitoring and operational assessment (CMOA)
- There were 185, Alloy 600, SG plugs in the Cold Legs of 21 and 24 steam generators that were drilled out and replaced with improved Alloy 690 plugs.
- Three PAP in 23 SG were identified as having slight leaks during the pressure tests of the SG. These were removed and replaced with mechanical plugs.
- In anticipation of replacing the steam generators, the last four low-pressure feedwater heaters with copper-bearing tubes were replaced during the current shutdown. The removal of the copper source will help make future inspections of the new steam generators better by maintaining the background signal an eddy current low.

Operations

- Plant operation will be limited to a maximum of 0.85 EFPY (310 EFPD), as analyzed in the CMOA
- Due to the number of steam generator tubes that have been plugged, capacity will be approximately 97%
- Due to the number of tubes plugged, the secondary side pressure will be approximately 15 psig lower

Maintenance

- In-Situ pressure testing was performed on 51 steam generator tubes to improve the assessment of the structural integrity of the steam generators. The details are contained in the CMOA.

- Sludge Lancing was performed on all four-steam generators. This is a routine maintenance task. However, this also helped remove residual radioactive material that had entered the secondary side of steam generator 24 when the tube R2/C5 leaked.
- Foreign Object Search and Retrieval (FOSAR) – This is a routine maintenance task that was performed on all four-steam generators. This was performed after the new inspection ports were placed on SG 21 and 24.

Monitoring

Extensive additional efforts were taken to monitor or inspect the results of the steam generators. These include:

- A high frequency, 800 kHz, +point eddy current probe was manufactured, qualified and used for the first time in the industry to improve the inspection of the low row u-bend tubes in the steam generators.
- An additional inspection was performed in the lower regions of the steam generators (e.g. the sludge pile area) after the normal inspection to re-check the area for indications. The first inspection used the normal CECCO/Bobbin probes. The second inspection uses a medium frequency +point probe to re-check the sludge pile area. The extent of the inspection was from the tube end to at least 24 inches above the tube sheet.
- A ceramic cap was utilized for the extended +point inspection. The ceramic cap extended the use of a +point probe by 5 - 10 times. This lowered the radiation dose to implement this part of the inspection.
- A different inspection probe was used that was based on ultrasonic signals in addition to the two different eddy current inspection methods of the sludge pile area. The ultrasonic inspection was used on a sample of the tubes to demonstrate there were no indications being missed due to possible interference from the oxides and copper deposits on the secondary side of the steam generators.
- Visual inspections were performed on the secondary side of all four-steam generators. These consisted of inspecting the lower support plates by viewing up from the bottom and from viewing the top support plates and being able to look down from the 'Hillside' ports.
- The secondary side of the steam generators was pressurized to 750 psig and then remote, visual inspections were performed on the steam generator tube sheets to check for leaking plugs. Three plugs were identified with very slight leaks. These were drilled out and replaced with new plugs.

Procedures

- The administrative limits for Primary to Secondary Leak rates have been reduced by 80%, from 150 gpd to 30 gpd. This is the limit above which the unit has to be shut down. The industry recommendation from the Electric Power Research Institute (EPRI) was reduced this year from 150 gpd to 75 gpd. To ensure conservative limits are being applied limits below the industry recommendation are being adopted until new steam generators are installed. Additional information on this issue was provided in the response to Question 4 from the Root Cause Report.

- Primary to Secondary Leakage is monitored by the 4 Nitrogen –16 radiation monitors, one per steam line.
- There is still some inventory of copper on the inside surfaces of the secondary side of the plant. To remove as much copper as reasonable, the pH on the secondary side of the plant will be increased slightly from a range of 9.4 – 9.6 to a range of 9.6 to 10.0. Industry experience has shown that this will help solubilize residual copper that is in the system and minimize what could be transported to the new steam generators after they have been replaced.
- Operations trained on procedure revisions of Primary to Secondary Leak Limits.

Future Inspections

In the June 2, 2000 letter from Consolidated Edison to the Nuclear Regulatory Commission, the commitment was made to begin the replacement of the steam generators by the end of 2000. Therefore, additional eddy current inspections will not have to be performed on the current set of steam generators.

NRC RAI Letter dated March 24, 2000

Question 3

Provide the trending analysis of dents in the upper support plates and ovalizaton of rows 2, 3, and 4 u-bends. This trending analysis should be displayed in graphical or tabular form as appropriate to best illustrate the trends. A summary discussion should be provided of denting trends in the lower support plates. The licensee's July 29, 1997, inspection reported 20 tubes (mostly in steam generator 22) failed to pass the 0.610 bobbin in rows 2 and 3. Were these tubes able to pass a 0.610 or larger bobbin in earlier inspections? Have the row 2-4 u-bends been inspected with bobbin during the current inspection so as to contribute to the above trending analysis?

Reply

Provide the trending analysis of dents in the upper support plates and ovalizaton of rows 2, 3, and 4 u-bends.

The dent trending information was provided in our response to Question 13 on the Root Cause Report.

The ovality trending information in the u-bends was provided in our response to Question 11 on the Root Cause Report. In addition, Attachment 1, in the u-bend CMOA also contains information on the ovality of the low row u-bend tubes.

A summary discussion should be provided of denting trends in the lower support plates.

The following information was taken from the aforementioned response to Question 13 on the Root cause Report.

Figure 10 shows the number of tubes plugged for 610 mil bobbin probe restrictions as a percentage of the number of tubes inspected each outage since 1975. Tubes that are restricted to the 610 mil bobbin probe were plugged in accordance with the IP2 Technical Specifications.

Tube restriction data has been tracked since 1978 to assess the progression of tube/tube support plate denting.

An investigation of the data acquisition process indicates the tube restriction data, other than for the 610 mil bobbin probe, is not a consistently reliable measure of actual tube denting at tube support plate intersections. To further understand the significance of the restriction data plotted in Figures 1 through 10 a direct comparison was made for tube/tube support plate intersection where restriction data was available for identical intersections in both 1997 and 2000. The results of the comparisons for each steam generator are included in Tables 1 through 4. In general, this data shows that approximately 50% - 70% of the intersection showed no change in dent size, 7% - 18% showed continued dent progression, and 16% - 32% indicated a reverse trend. Since denting is not reversible this latter information is an indication of probe restriction variability and reporting inconsistency as described below. Data shows that eddy current probe restriction data (other than the 610 mil bobbin) is qualitative and subject to error and can be easily misinterpreted. It is noteworthy that in SG22 on the cold leg of the sixth tube support plate a greater number of locations (18) became smaller compared to 5 that showed no change. The data in Table 2 is consistent with the trend in Figure 7 which showed 90 new cold leg restrictions. This trend does not hold true for the hot leg, however, where Table 2 showed only 2 intersections became more dented whereas Figure 7 indicates 40 new restrictions.

Tube inspections conducted in 1997 and 2000 did not attempt to quantify actual restriction or dent diameters at tube/tube support plate intersection other than the 610 mil bobbin probe which is required by Technical Specifications. Rather, the purpose of the inspection was to collect eddy current data over the length of steam generator tubing being inspected. The inspection starts by testing with a 0.700" diameter probe. If the data acquisition operator encounters resistance to the probe travel, he stops and messages "the tube is restricted @ X location". The operator does not attempt to force the probe in order to minimize damage to it. Data management then schedules the tube to be inspected with successively smaller diameter probes starting with 680 mil, then 640 mil and finally 610 mil probes. When the diameter reduction finally reaches 610 mil, the purpose of the inspection expands to include gauging the dent at the plate intersection. The operators are intentionally and actively attempting to pass the 610 mil probe as the inability to do so requires tube plugging. Therefore, the statistical significance is questionable for diameters above 610 mil. Intersections that pass a 610 mil diameter probe are subsequently tested with a "DIP" gimbaled +Point probe or 620 mil diameter probe.

Restriction to the movement of an eddy current inspection probe can be from a variety of causes based on the overall geometry, construction and stiffness of the probe assembly rather than the actual probe diameter. Examples are:

- Rotating coil probes may be used with a motor that has a larger diameter than the test coil, and the motor may be obstructed rather than the probe head, though the effect is the same.

- Rotating probe can sometime pass a restricted location as the probe is pushed into the tube indicating that the restriction has a larger diameter than the nominal probe size. However when the probe is spun and pulled through the tube to gather data the probe may become restricted or stop rotating.

- The Cecco 5 probe is an assembly that includes both the Cecco and a bobbin coil. This assembly tends to be stiff and does not easily pass some tube sheet dent restriction even though the actual restriction diameter is greater than the nominal probe diameter. These probes are easily restricted as they are pushed though the 6th tube support plate (TSP) and into the u-bend even though the tube diameter is greater than the nominal probe size.

- The tube may be bowed rather than dented around deformed flow slots thus making it more likely that the flexible probe cable will buckle and result in difficulty to push through the tube.
- During the current, year 2000 inspection outage a new conduit was used to introduce the eddy current probe into the steam generator and the tube to be inspected. This conduit was found to have a higher resistance to the motion of the probe than that used in previous outages and likely resulted in a correspondingly higher number of restriction calls.

Dent Voltages

In addition to comparing probe restriction data from 1997 to 2000 an effort was made to develop trends on the rate of denting by looking at the eddy current dent voltages from dented intersections. The eddy current dent voltage response is a function dent geometry as well as the extent of the dent. For this reason, the dent voltage does not conform linearly with the extent of denting. Rather dent voltage may vary significantly from one tube to another because of dent shape rather than dent size. A comparison of the voltage difference for the same tube/tube support plate intersection from one outage to the next is considered to provide a qualitative indication of denting progression.

The voltage difference data from 1997 to 2000, averaged by tube row, for tube support plates 5 and 6 is plotted in Figures 11 through 18 for each steam generator. These plots show a difference in average dent voltage from approximately –10 to + 10 volts. (Actual measured dent voltages ranged from 0-100 volts.) Since the tube cannot become less dented the dent voltages were averaged by hot and cold leg for the 5th and 6th tube support plate for each steam generator to determine whether any trend in the voltage differences could be determined. The results are provided in Table 5. Based on this data it would appear that, although essentially arrested, denting may be progressing at a very slow rate.

Based on the review of the various tube/tube support plate restriction/dent voltage data the following observations can be made:

- The number of tubes plugged as a percentage of those inspected has decreased from 2.5% – 10% in 1984 to <0.1% in 2000 (Figure 10).
- Most of the locations where a direct comparison between 1997 and 2000 could be made showed no change in restriction size (Tables 1-4).
- The rate of flow slot closure has leveled off since 1985.

The licensee's July 29, 1997, inspection reported 20 tubes (mostly in steam generator 22) failed to pass the 0.610 bobbin in rows 2 and 3. Were these tubes able to pass a 0.610 or larger bobbin in earlier inspections?

Information on this question was also addressed in Question 11 from the Root Cause Report set.

The twenty "restrictions" identified in 1997 were re-evaluated with respect to the location of the restrictions and the reason for the restrictions. Nineteen of the twenty tubes were identified as being restricted to a 610 mil bobbin probe at the hot and/or cold leg of the sixth tube support plate (TSP). The nineteen tubes were comprised of fifteen tubes in row 2, three tubes in row 3, and one tube in row 4. Three tubes of the nineteen, row 2 column 62 and row 2 column 63 in SG 22, and row 3 column 31 in SG23 were at hard spot locations, which are not subject to hourglassing and possible u-bend ovalization. The twentieth tube, which was row 29 column 15 in SG 24, is not a low radius u-bend tube.

The identification of restrictions in 1997 is not an indicator of abnormal ovality in the low row u-bends. Details of the examination data showed restrictions to the 610 mil bobbin probes at the sixth TSP; that is, the probes were not able to get to the bends. The terminology used in 1997, that stated u-bend restrictions, was used in a generic sense to describe that the restrictions to the probes were at the uppermost region of the steam generators.

The 2000 restriction data showed that four tubes were restricted to the 610 mil bobbin probe. None of these tubes were restricted at the sixth TSP or in the u-bend. Rather, these tubes were restricted at the third or fourth TSPs. These tubes were plugged as required by the IP2 Technical Specifications.

Have the row 2-4 u-bends been inspected with bobbin during the current inspection so as to contribute to the above trending analysis?

No, the u-bend tubes in rows 2 through 4 were inspected with 620 +Point mid range and high frequency probes. There were no row 2-4 tubes that were restricted in the u-bends that required plugging per Technical Specifications.

Table 1 Steam Generator 21 - Change in Restriction Size

Location	Restriction Size		
TSP	Smaller	No Change	Larger
6H	1	14	1
6C	0	8	0
5H	0	9	5
5C	0	4	2
4H	1	3	2
4C	0	9	1
3H	1	11	2
3C	1	7	3
2H	2	14	5
2C	1	14	5
1H	4	13	6
1C	0	5	0
Total	11	111	32
%	7.14%	72.08%	20.78%

Table 2 Steam Generator 22 - Change in Restriction Size

Location	Restriction Size		
TSP	Smaller	No Change	Larger
6H	2	1	6
6C	18	5	4
5H	0	0	0
5C	0	0	0
4H	1	8	16
4C	1	17	3
3H	6	4	5
3C	0	6	8
2H	1	11	3
2C	0	5	1
1H	11	48	25
1C	0	4	0
Total	40	109	71
%	18.18%	49.55%	32.27%

Table 3 Steam Generator 23 - Change in Restriction Size

Location	Restriction Size		
TSP	Smaller	No Change	Larger
6H	6	8	4
6C	11	17	5
5H	0	7	0
5C	1	7	3
4H	2	2	2
4C	1	11	2
3H	0	17	0
3C	2	16	8
2H	2	14	1
2C	0	13	2
1H	4	20	4
1C	0	14	2
Total	29	146	33
%	13.94%	70.19%	15.87%

Table 4 Steam Generator 24 - Change in Restriction Size

Location	Restriction Size		
TSP	Smaller	No Change	Larger
6H	12	36	6
6C	1	17	2
5H	1	26	2
5C	1	10	3
4H	6	21	2
4C	0	1	1
3H	1	15	1
3C	1	6	8
2H	7	53	10
2C	0	2	8
1H	0	0	1
1C	0	0	0
Total	30	187	44
%	11.49%	71.65%	16.86%

Table 5 Average Change in Dent Voltage

	SG21		SG22		SG23		SG24	
	TSP 5	TSP 6	TSP 5	TSP 6	TSP 5	TSP 6	TSP 5	TSP 6
Hot Leg	+0.48	+0.93	+0.48	+0.93	+0.50	+1.96	-1.65	+0.74
Cold Leg	+1.13	+1.15	+1.13	+1.15	+1.47	+1.13	+0.09	+1.57
Both Legs	+0.80	+1.04	+0.80	+1.04	+0.99	+1.55	-0.87	+1.16

Figure 1 Indian Point 2 S/G 4 2000
Restrictions 620 +Point Probe at TSP 6

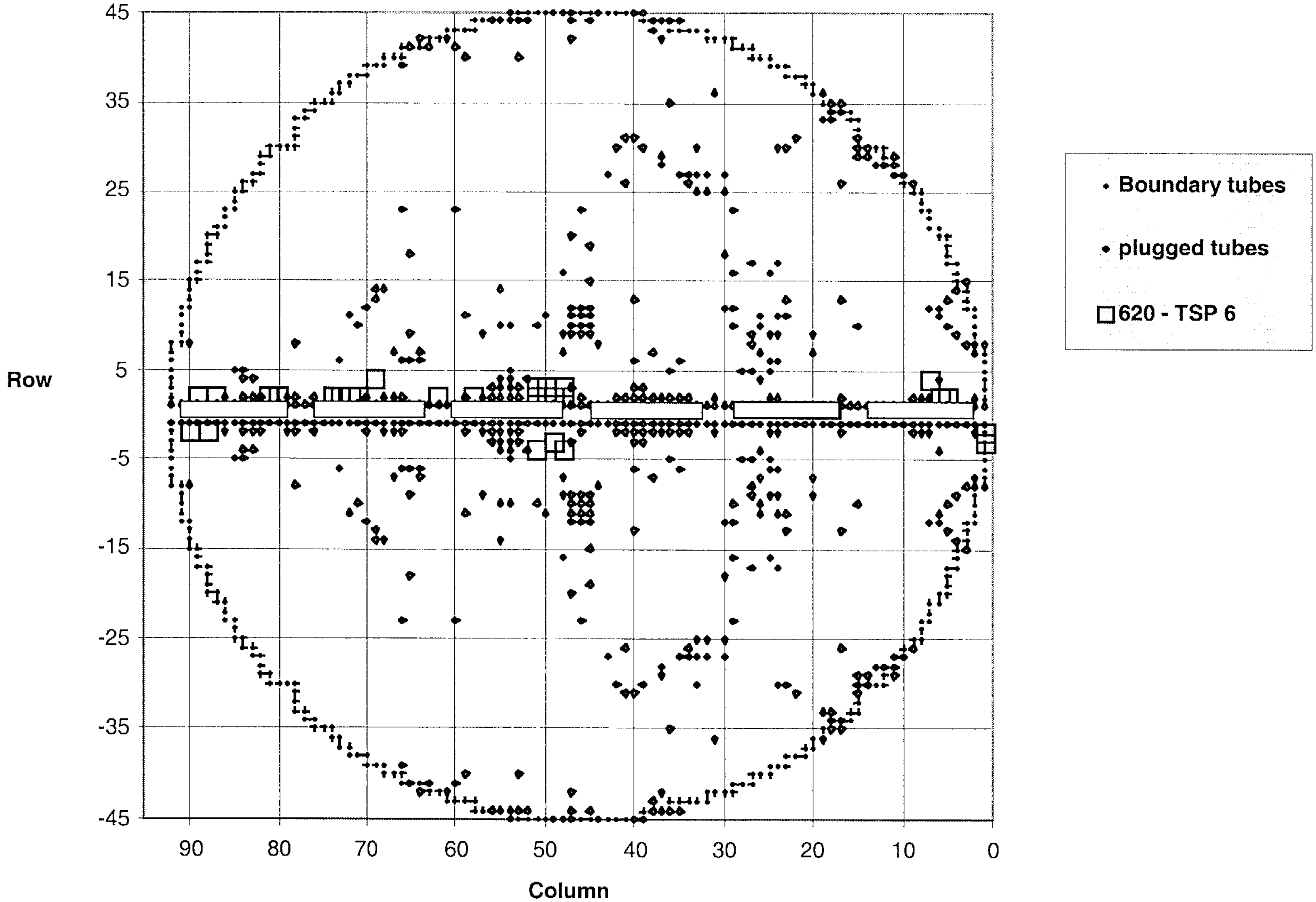


Figure 2 Indian Point 2 S/G 4 2000
Restrictions to Cecco Probe at TSP 6

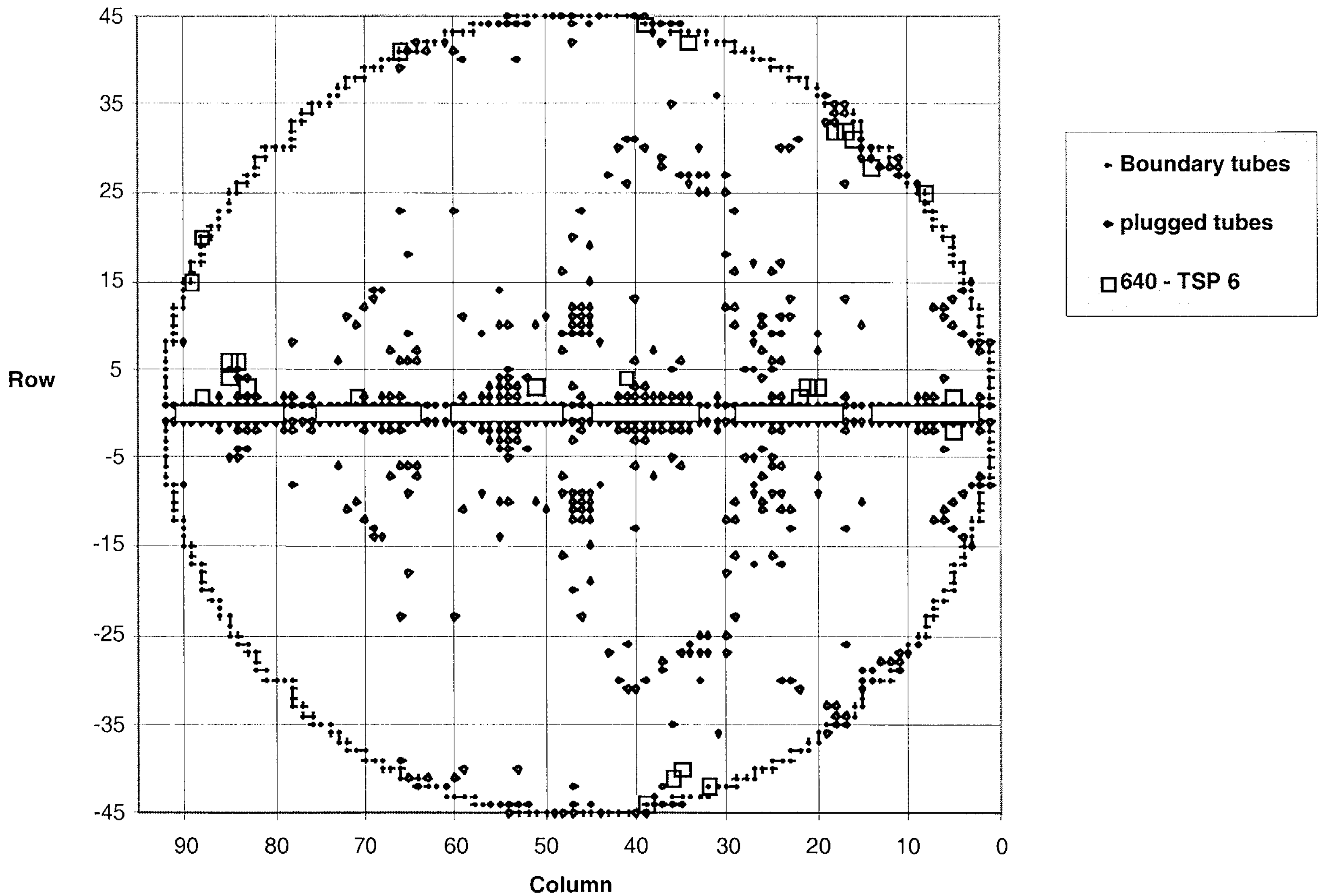


Figure 3 Indian Point 2 S/G 4 1997
Restrictions 610 +Point Probe at TSP 6

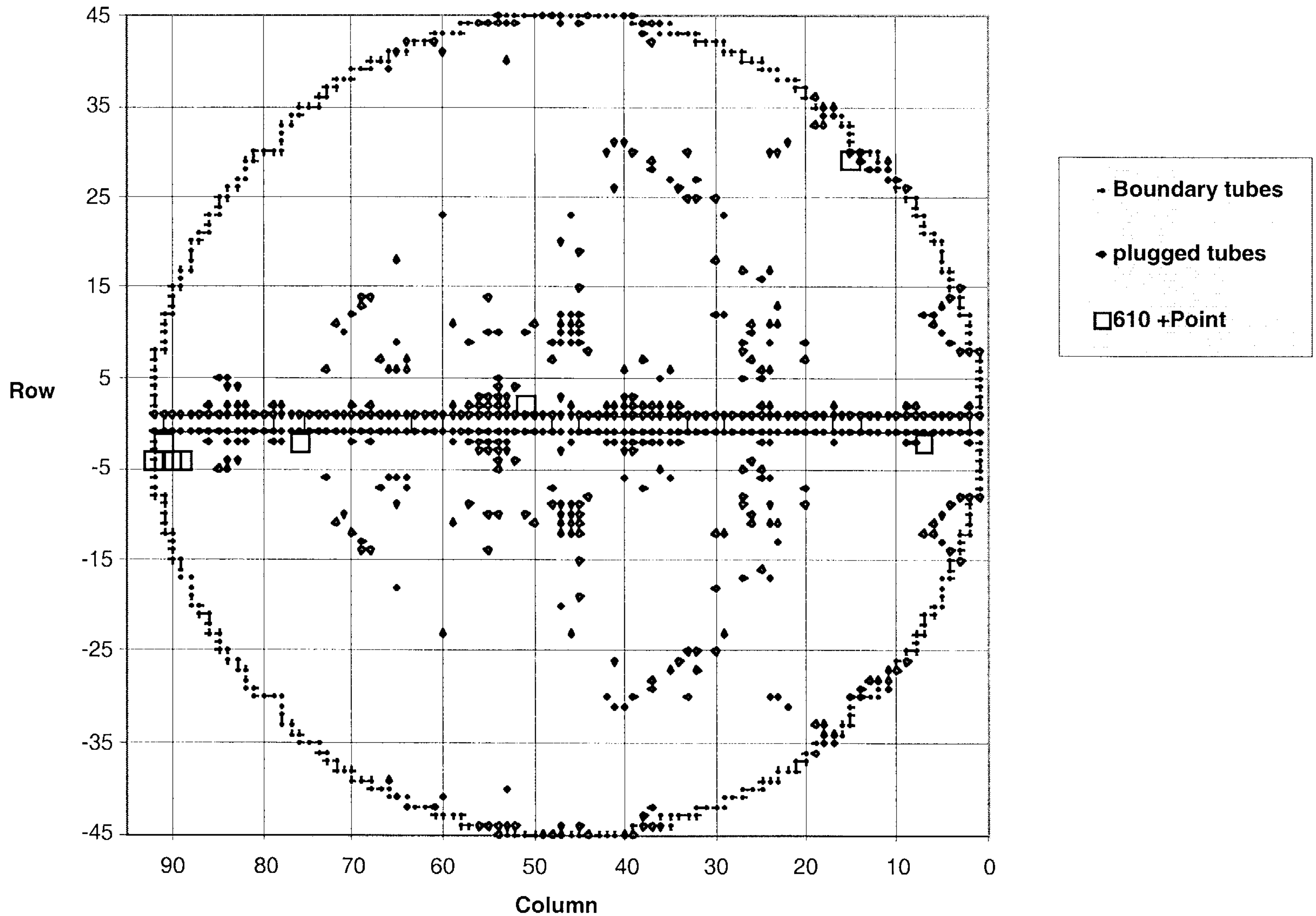


Figure 4 Indian Point 2 S/G 4 1997
Restrictions 620 Bobbin Probe at TSP 6

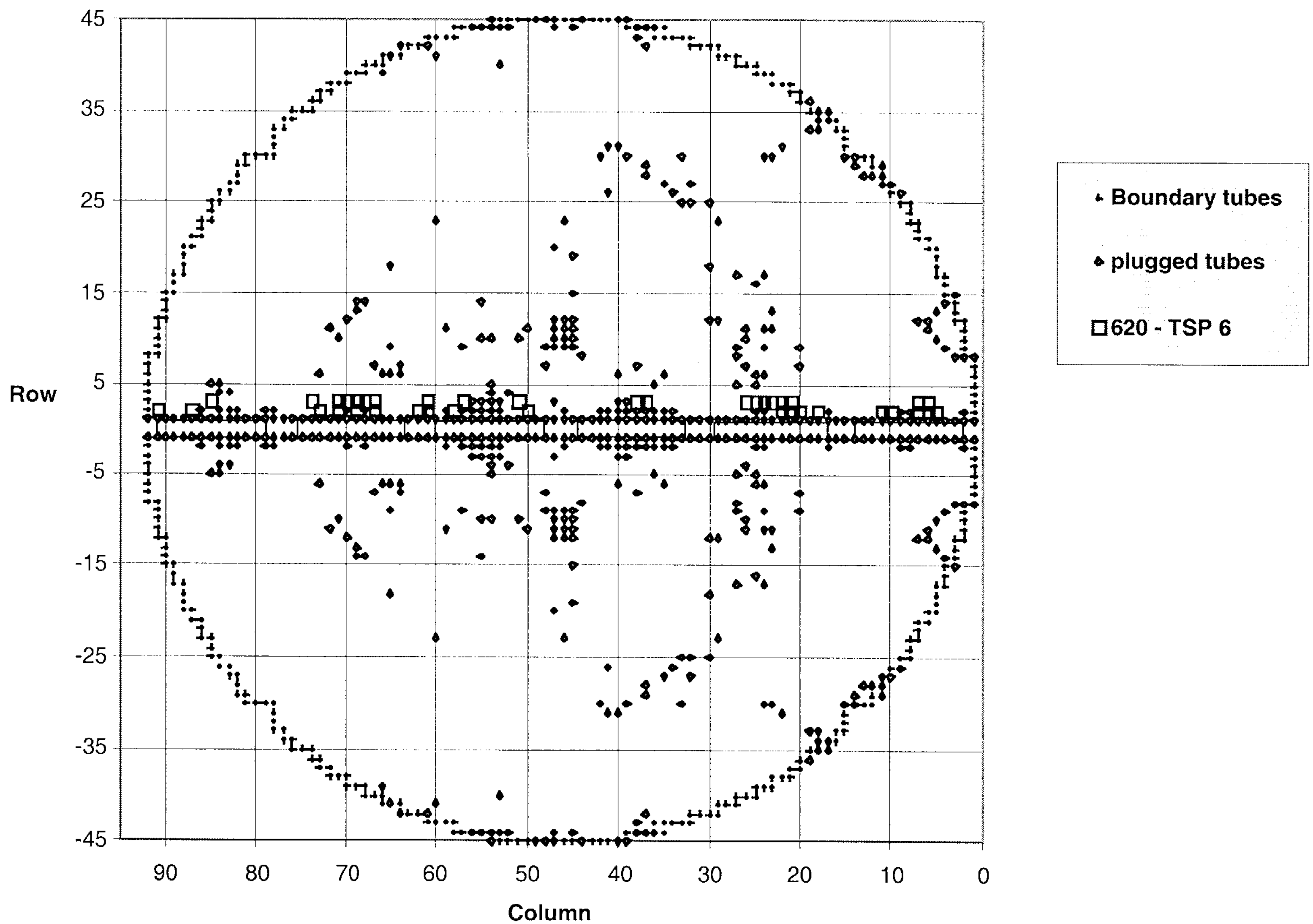


Figure 5 Indian Point 2 S/G 4 1997
Restrictions 640 Bobbin Probe at TSP 6

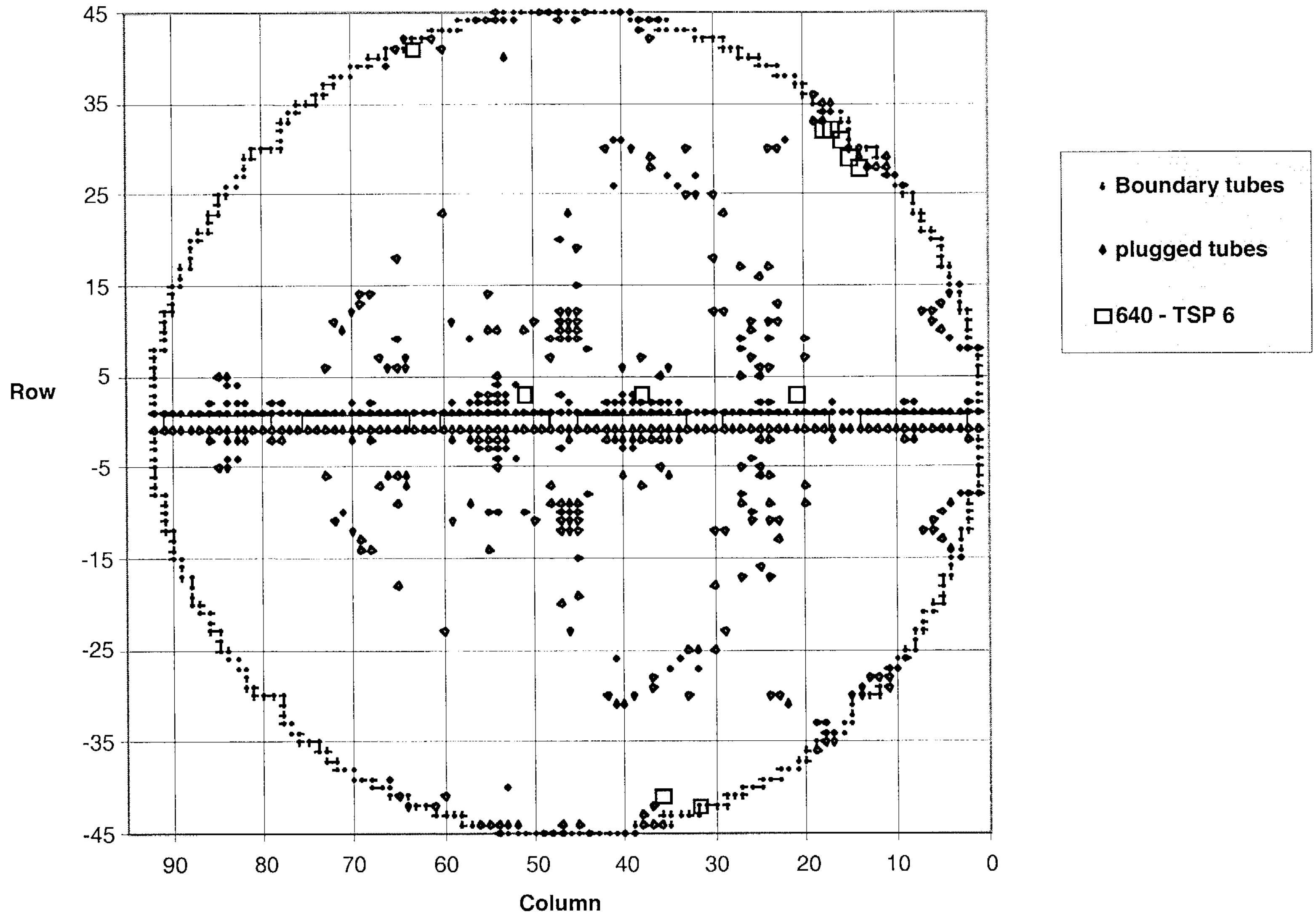


Figure 6 Indian Point 2 S/G 2 2000
Restrictions 620 +Point Probe at TSP 6

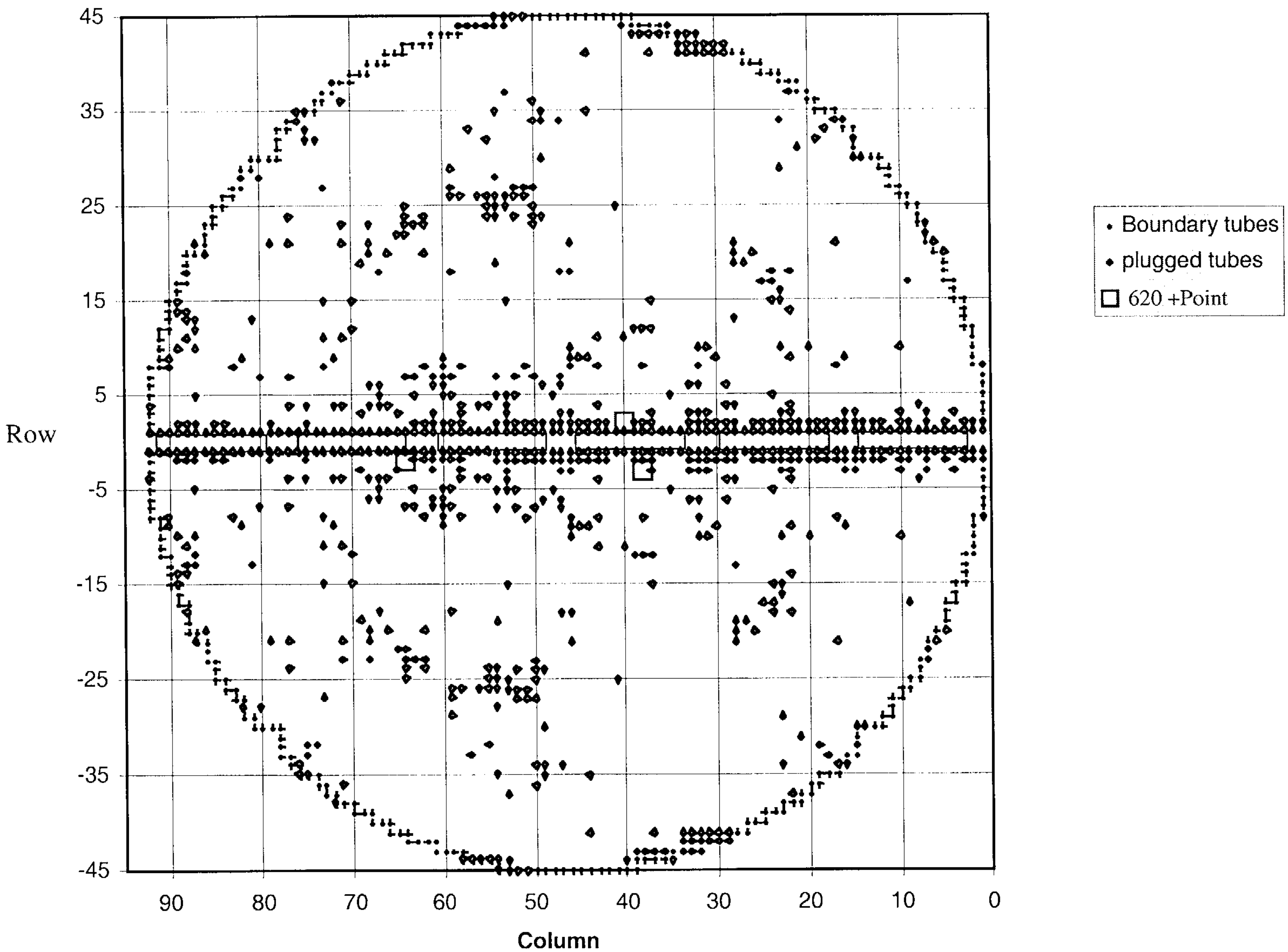


Figure 7 Indian Point 2 S/G 22 2000 Inspection Restrictions 640 Cecco Probe at TSP 6

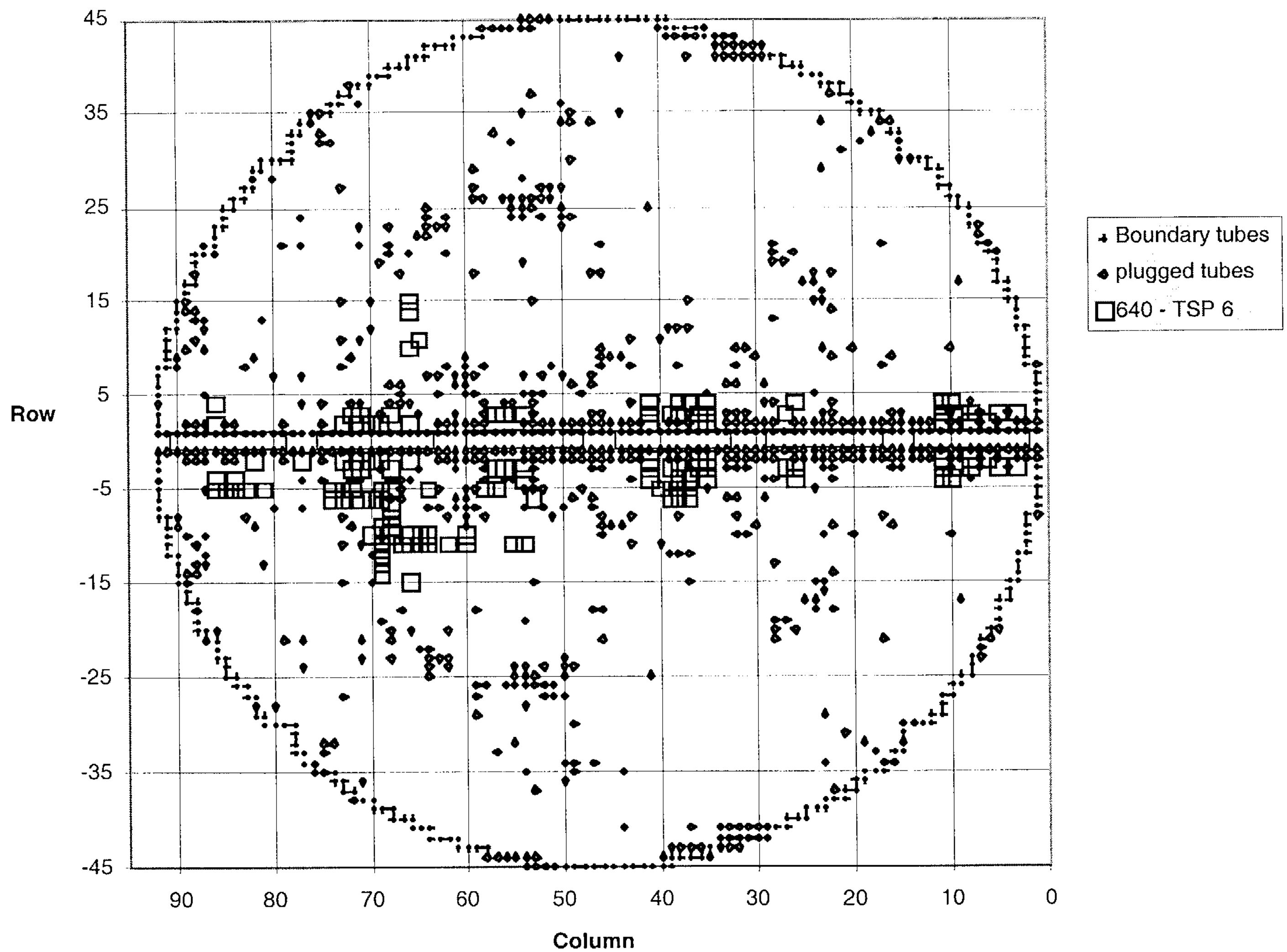


Figure 8 Indian Point 2 S/G 22 1997
Restrictions to 620 Bobbin Probe at TSP 6

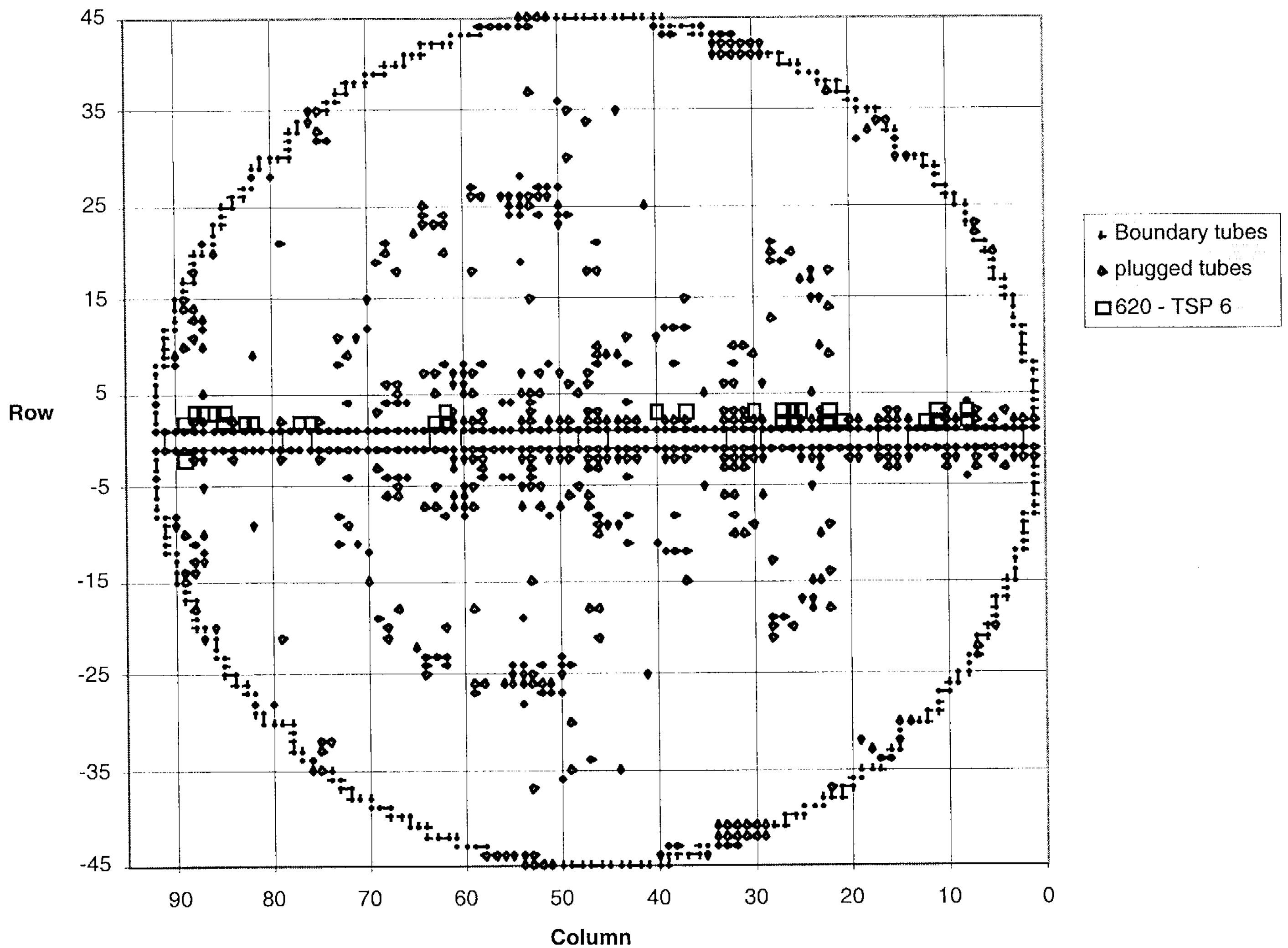
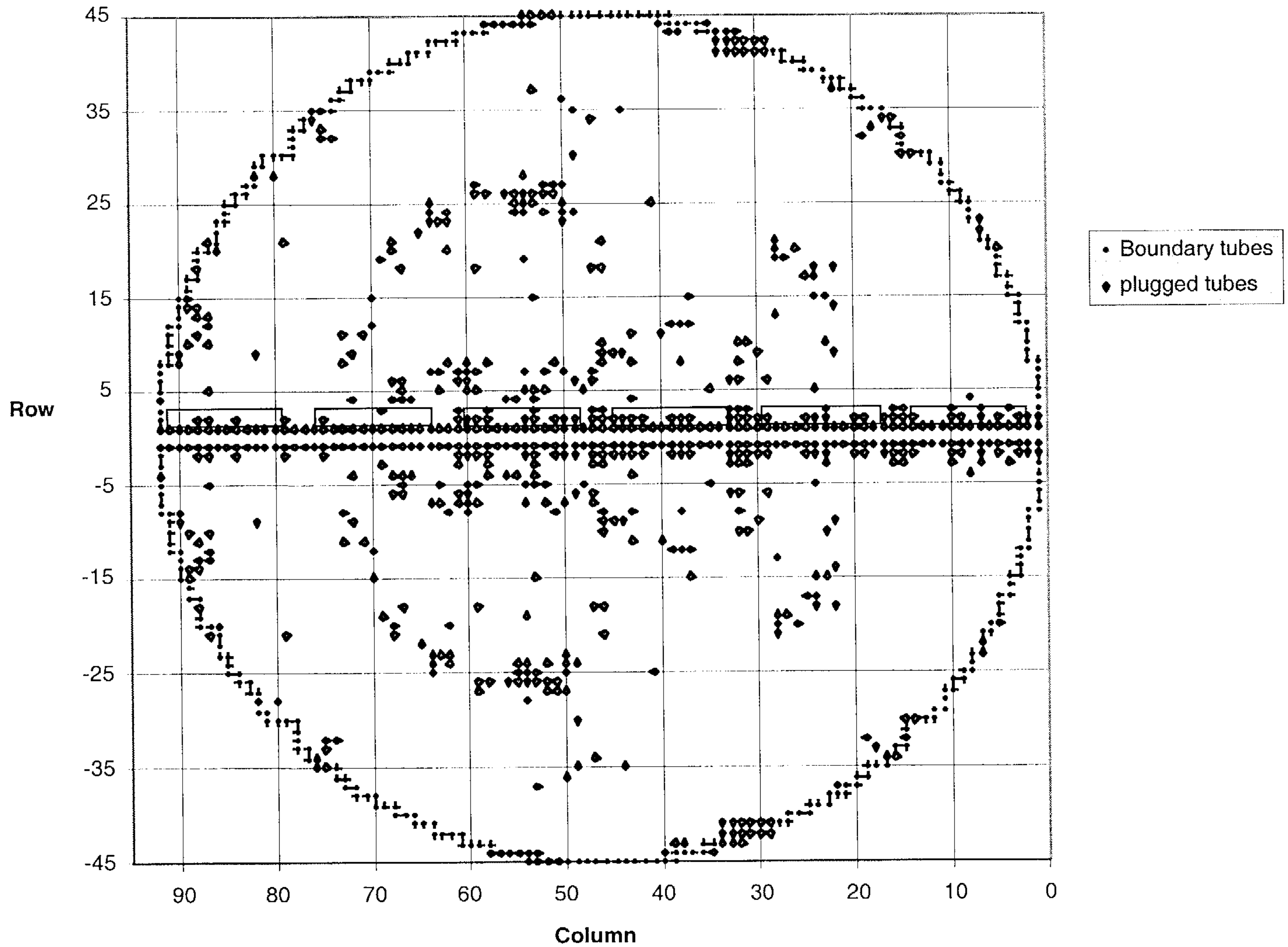


Figure 9 Indian Point 2 S/G 22 1997
Restrictions 640 Cecco Probe at TSP 6



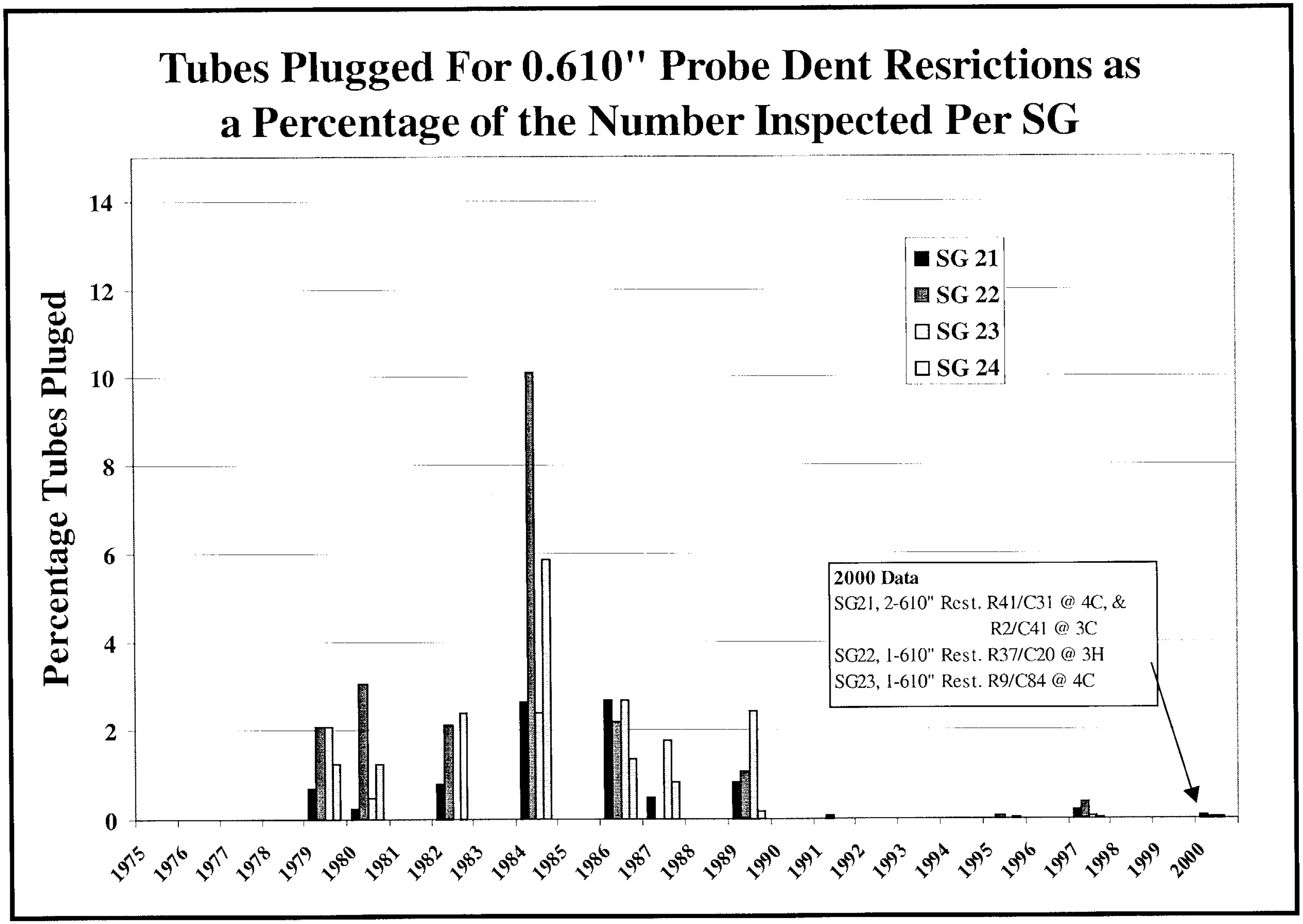


Figure 10 Comparison of Tubes Plugged for 0.610" Restrictions

Figure 11 Indian Point 2 S/G 21 TSP 5 Denting voltage progression 1997 to 2000

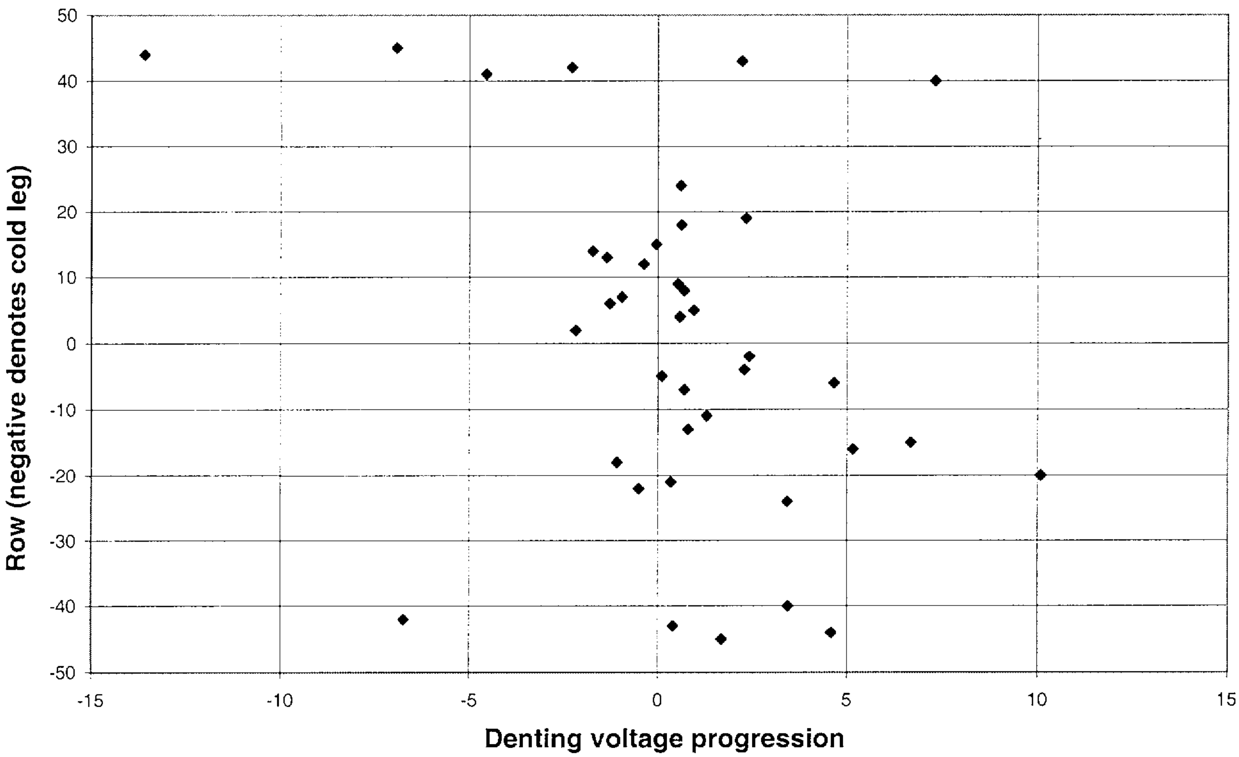


Figure 12 Indian Point 2 S/G 21 TSP 6 Denting voltage progression 1997 to 2000

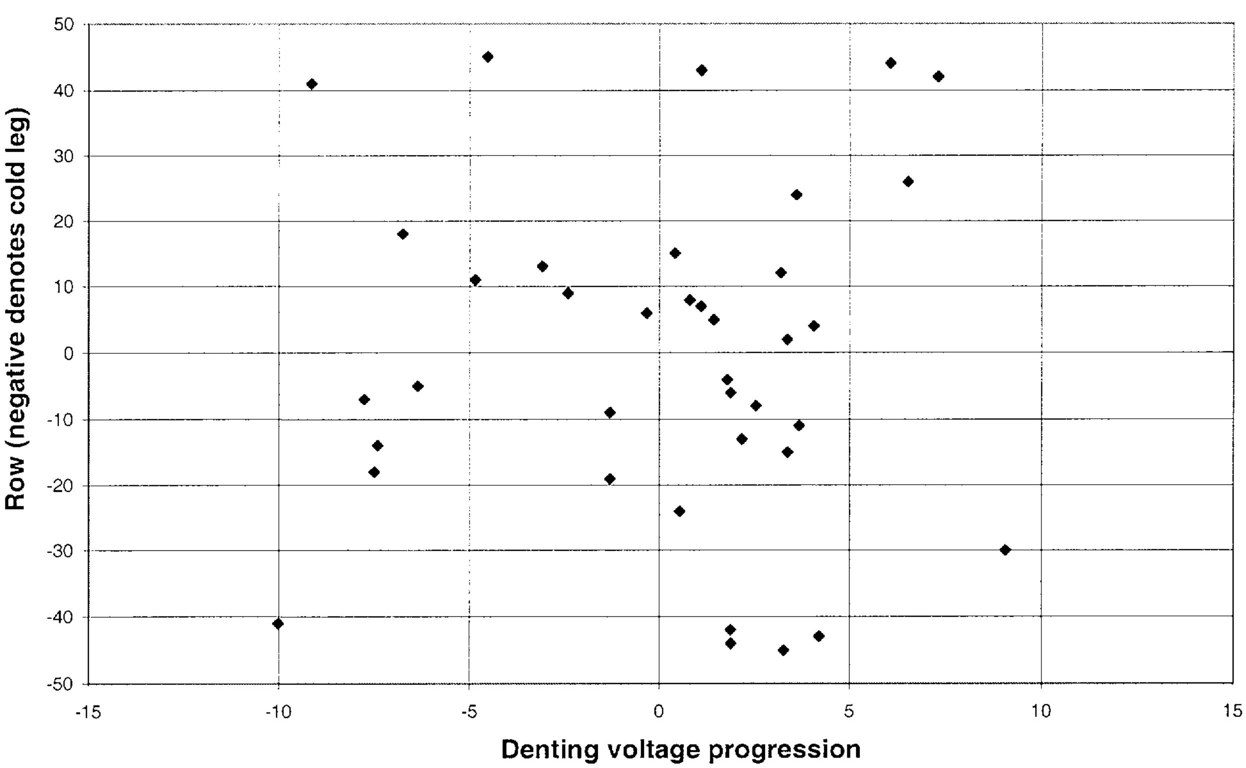


Figure 13 Indian Point 2 S/G 22 TSP 5 Denting Progression 1997 to 2000

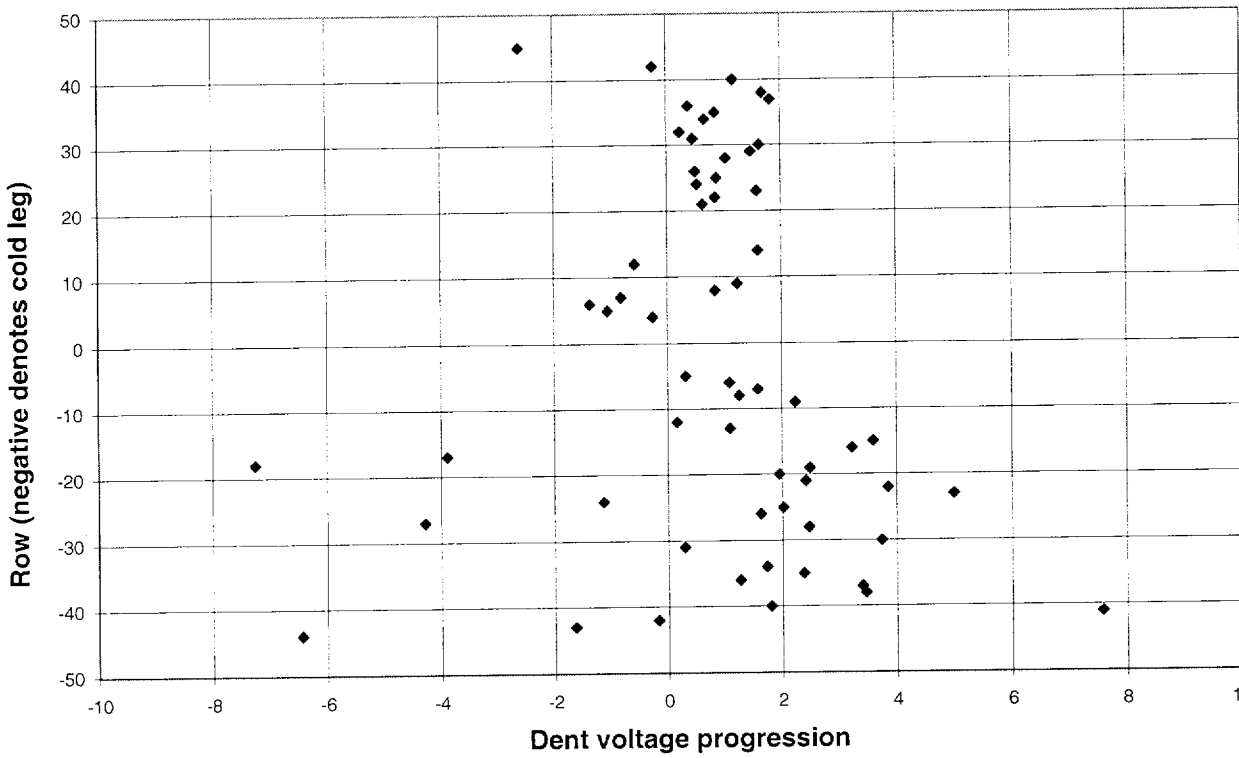


Figure 14 Indian Point 2 S/G 22 TSP 6 Denting Progression 1997 to 2000

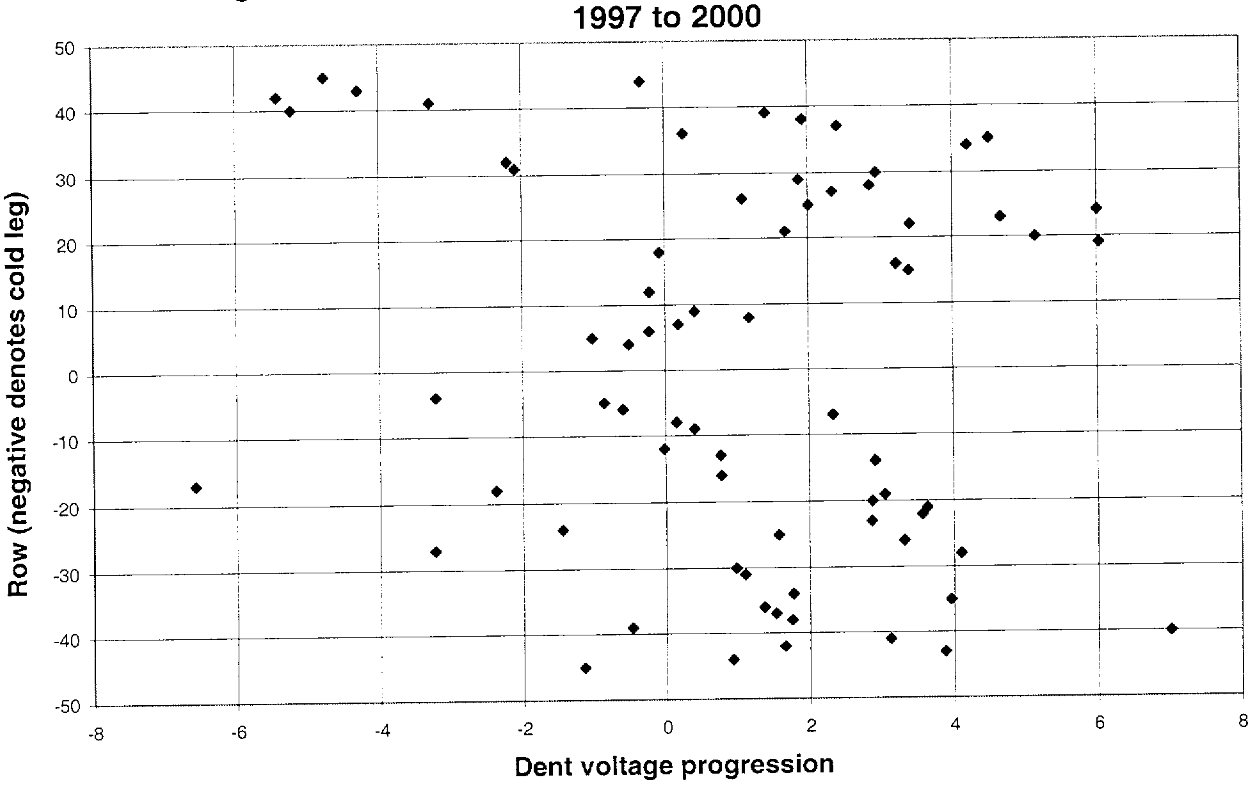


Figure 15 Indian Point 2 S/G 23 TSP 5 Denting voltage progression 1997 to 2000

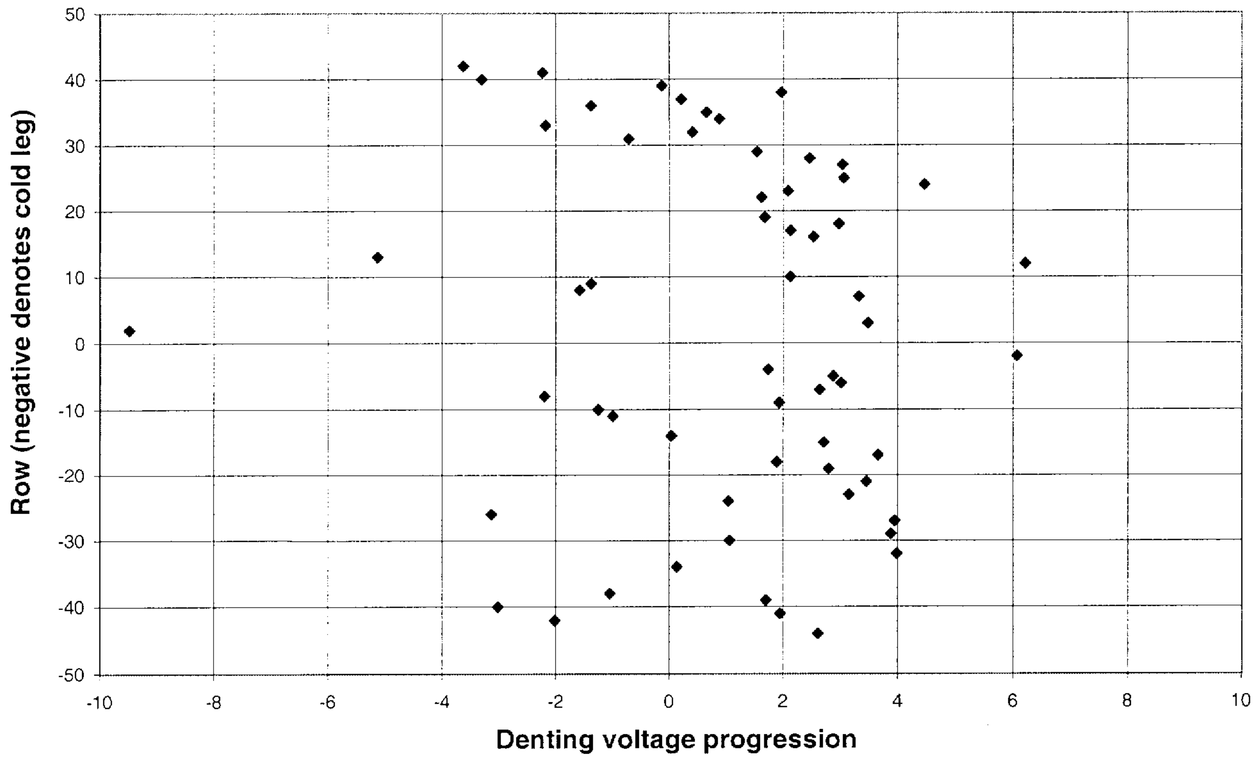


Figure 16 Indian Point 2 S/G 23 TSP 6 Denting voltage progression 1997 to 2000

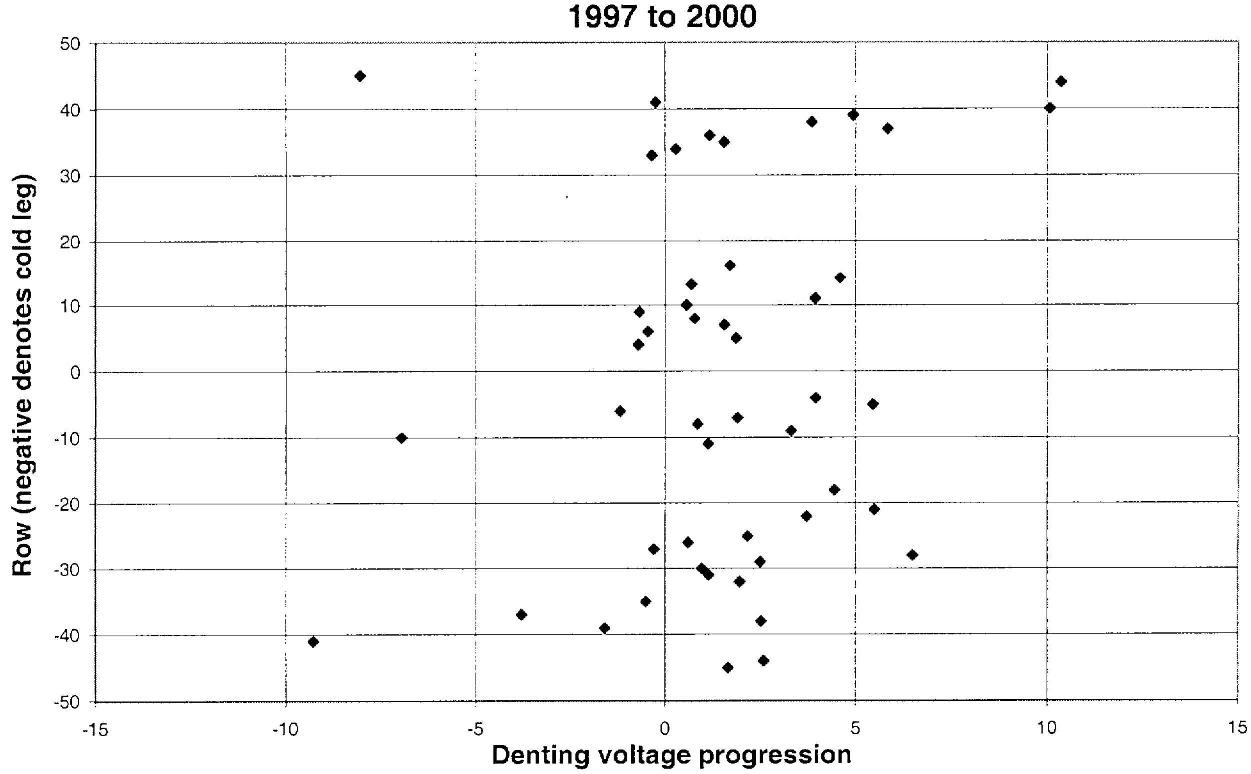


Figure 17 Indian Point 2 S/G 24 TSP 5 Dent Voltage Progression 1997 to 2000

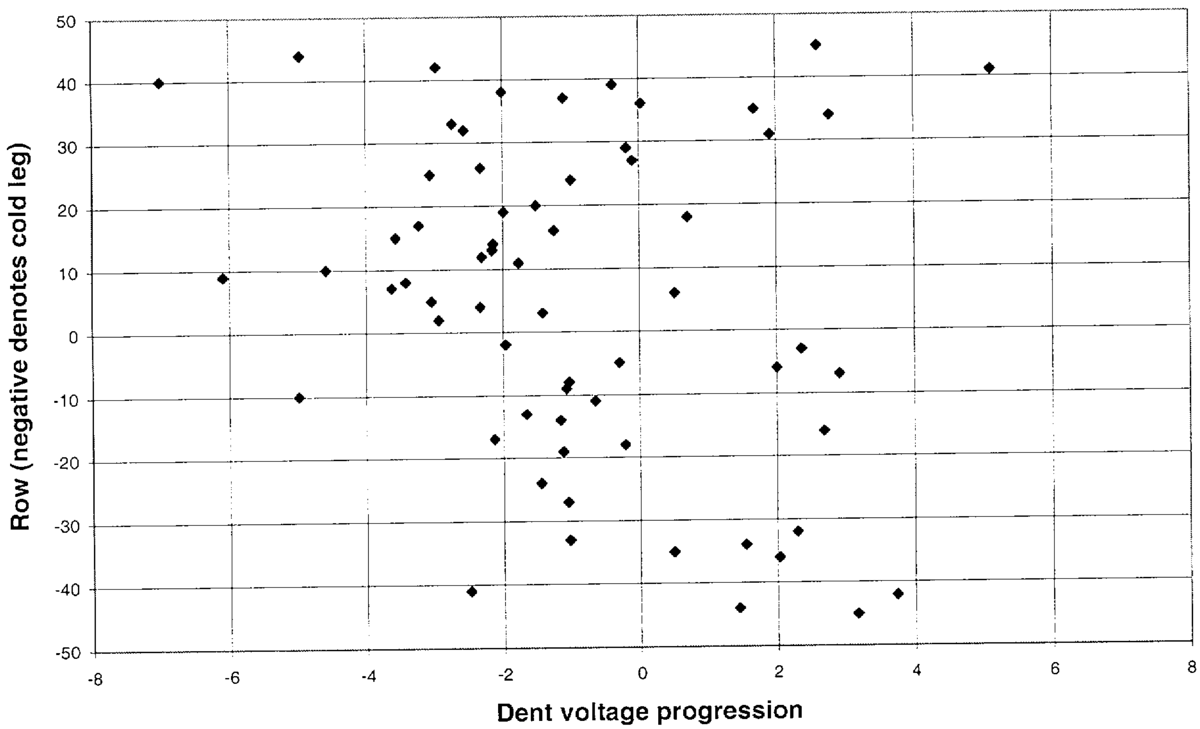
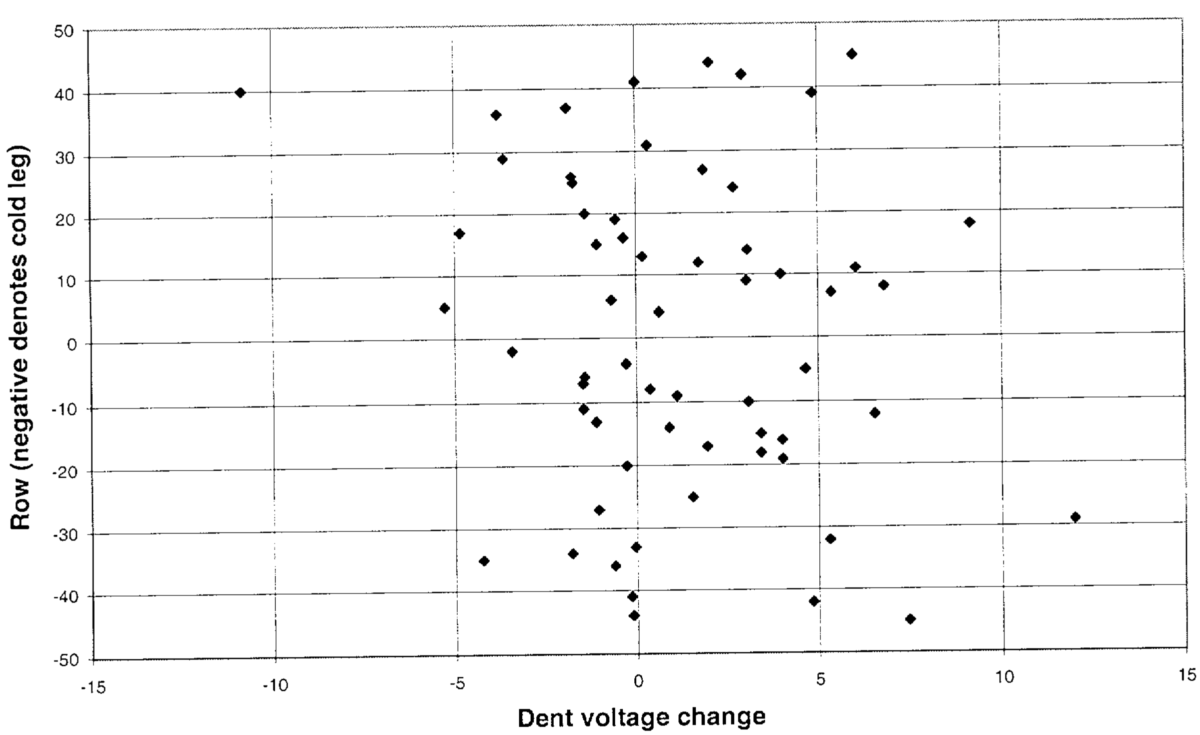


Figure 18 Indian Point 2 S/G 24 TSP 6 Dent voltage progression 1997 to 2000



NRC RAI Letter dated March 24, 2000

Question 4

Provide the documentation of the site qualification review of the eddy current techniques applied during the 1997 and 2000 inspections.

Reply

The use of eddy current inspection techniques for the 1997 Indian Point Unit 2 outage was performed in accordance with Revision 4 of the EPRI Steam Generator Examination Guidelines. Per the guidance of Revision 4, qualified techniques were utilized. EPRI Guidelines, Revision 4 did not require the formal documentation of 'site qualification' for the applicability of techniques. However the application of the techniques used was verified through a variety of qualification documents.

The Spring 2000 outage inspections were performed in accordance with the intent of Revision 5 of the EPRI Guidelines, which revision requires the documentation of the applicability of the techniques by comparison of the qualification basis to the site-specific conditions. The Westinghouse document MRS-TRC-1088 provides a comparison between the essential variables and conditions for the qualification data and the site-specific data. Based on the comparison, techniques are termed as qualified or site qualified. The bibliography for the qualification references can be found in the Westinghouse document MRS-TRC-1088, *Use of Appendix H Qualified Techniques at Indian Point Unit 2 Spring 2000 S/G Eddy Current Inspection* (attached). This document cites the same list that was used for the 1997 outage references (less more recent documents and revisions).

May 16, 2000

To:	K. Krieger, Indian Point 2 Nuclear Plant J. Mark, Indian Point 2 Nuclear Plant J. Parry, Indian Point 2 Nuclear Plant
From:	Gary Pierini, Westinghouse NDE Level III W. Spence, Westinghouse NDE Level III
cc:	Dan Malinowski , Engineer, Westinghouse A. Vaia, Engineer, Westinghouse D. Adamonis, Mgr. S/G NDE Applications, Westinghouse J. Divella, Service Lead, Westinghouse

Subject:	**Use of Appendix H Qualified Techniques at Indian Point Unit 2 Spring 2000 S/G Eddy Current Inspection**

Note: This Document has been electronically approved in EDMS2000

This letter is intended to document Westinghouse's position that the eddy current techniques being utilized during the Indian Point Unit 2 Spring 2000 Steam Generator eddy current inspection are qualified, or can be shown equivalent, to techniques qualified by EPRI in accordance with Appendix H, Revision 5 of the EPRI PWR Steam Generator Guidelines. Eddy current testing essential variables in the Indian Point Unit 2 ACTS (Acquisition Technnique Sheets) and ANTS (Analysis Technique Sheets) were compared to the EPRI Appendix H Examination Technique Specification Sheets (ETSS) to ensure that the site inspection essential variables are equivalent or within acceptable limits.

EPRI PWR Steam Generator Examination Guidelines, Rev. 5, Section 6.2.4 requires a documented review of qualified tubing essential variables (e.g., denting, deposits, tube geometry changes, the signal characteristics) to ensure the application is consistent with site steam generator conditions. In addition to documenting the industry qualifications, results from flawed tubes in the EPRI qualification data sets or actual tube pulls from plants with similar steam generators were compared to the in-generator degradation mechanisms reported at Indian Point Unit 2 and assessed for similarity in terms of voltage and signal-to-noise characteristics.

PARAMETERS

The eddy current testing parameters for Indian Point Unit 2 are as follows:

Material:

- Mill annealed Alloy 600, 0.875" OD x 0.050" wall

Testers:

- Westinghouse TC6700

Probes:

- WNSCD Cecco-5/bobbin 100 ft. max. - **700/C-5/HD**, **680/C-5/HD**, **640/C-5/HD** (Bobbin and Cecco)
- Westinghouse bobbin 100/110 ft. - **EB-700-LLMC**, (Bobbin only where Cecco/Bobbin cannot be used)
- Zetec Bobbin - **A-610LC** (Freespan beyond/between restrictions and gauging purposes only)
- Zetec Rotating Pancake/Plus Point - **+Point-720-115/36/S80, +Point-680-115/36/S80, +Point-640-115/36/S80, +Point-610-115/36/S80** (Confimation and characterization of all indications reported by Cecco probe)
- Zetec rotating dent inspection Plus Point - **+Point-610/MRPC/DI/52PH** (Severely dented intersections)
- Zetec rotating mag bias U-bend Plus Point - **M/+PT-620-MRPC/FH-52PH**
- Zetec rotating high frequency Plus Point - **+PT-620-MRPC/FHPH-52PH (775)** (800 kHz Plus Point)
- Zetec rotating .115" pancake coil for roll plugs - **620- PP/52B(3.5/.115)** (Roll plugs)
- Zetec combo bobbin /.115" pancake RPC - **720 MRPC 115 D#4084-11-A** (Location and length sizing of roll

transition cracks for tubesheet re-rolling)

Cable Extensions:

- Zetec RPC 900 RPM motor unit 50/83 feet long - 720-9D/MRPC/52MU (36Pin)
- Zetec RPC 300 RPM motor unit 50/83 feet long - 720-MRPC/52MU (36Pin)
- Zetec RPC 300 RPM motor unit 50/83 feet long - 610-MRPC/52MU (36Pin)
- Zetec low loss or RG174 probe extension cable 50 feet/110 feet maximum
- WNSCD C5 probe extension cable - 40 feet maximum

Frequencies:

- Bobbin: 400 kHz, 200 kHz, 100 kHz, 10 kHz
- Cecco: 400 kHz, 300 kHz, 200 kHz, 100 kHz, 10 kHz
- Non-mag bias +Point RPC/115/S80; Plus Point and .115"pancake: 300kHz, 200kHz, 100kHz, 10 kHz
- Non-mag bias +Point RPC/115/S80; .080" HF shielded pancake: 600 kHz, 300 kHz
- Mag bias U-Bend Mid-Range+Point RPC: 400kHz, 300kHz, 100kHz, 10 kHz
- U-Bend High-Frequency+Point RPC: 1000kHz, 800kHz, 600kHz, 400 kHz, 300 kHz
- .115"pancake coil for roll plug RPC: 600kHz, 400kHz, 300kHz, 100 kHz
- Combo bobbin /.115"pancake RPC (all coils) : 400 kHz, 300 kHz, 100 kHz, 10 kHz

Damage Mechanisms/Location:

Active Damage Mechanisms (Identified at Indian Pt. 2)

- Axial ODSCC, dented support plate intersections
- Axial PWSCC, dented support plate intersections
- Axial ODSCC, tubesheet crevice region
- OD pitting, sludge pile region above top of tubesheet
- Axial PWSCC, roll expanded region in tubesheet
- Axial PWSCC, rows 2 U-bends
- Circumferential PWSCC, roll expanded region in tubesheet
- Axial ODSCC, above tubesheet sludge pile, free span

Relevant Damage Mechanisms (Identified at Indian Pt 2* or in similar design S/G's)

- Circumferential ODSCC, expanded region in tubesheet
- Circumferential PWSCC, dented support plate intersections
- Tube wear*, AVB intersections
- Tube wear (loose parts), TTS periphery and tube lane
- Tube end cracking

Potential Damage Mechanisms (not identified at Indian Point 2 or similar design S/G's, but have a potential to occur)

- Alloy 600 Plug Cracking
- Thinning, cold leg support plates
- Ding ODSCC

REFERENCES

The following reference documentation provides evidence that the techniques, with the above parameters, are either qualified to Appendix H as published by EPRI or shown to be equivalent and/or qualified in separate testing by Westinghouse:

Reference A: **"Appendix H Qualified Techniques", EPRI Research Project #S530-10**

This document contains the base qualifications for common, but not every, coil/cable/tester/tube configuration. Typical configurations utilized 0-50 feet of probe extension and various lengths of Zetec probes.

Reference B: Westinghouse Report, **"Documentation of Appendix H Compliance and Equivalency", DDM-96-009 Rev. 0**

This report documents additional testing performed by Westinghouse to verify the equivalency of the following items which were not performed by EPRI or others:

- MIZ-18A, MIZ-30 and TC6700 testers given minimum setup parameters
- Zetec low loss and Westinghouse probe extension cables
- Bobbin probe lengths from 0 to 100 feet
- Probe extension lengths from 0 to 110 feet

This report also documents the Westinghouse qualification of the 0.115 mid-range (MR) pancake, 0.080 high frequency (HF) pancake, 0.080 mid-range (MR) pancake, Plus Point, axially and circumferentially wound coils in configurations which may or may not have been qualified by EPRI. This document is Westinghouse Proprietary.

Reference C: Westinghouse Reports, **"EPRI Appendix H Qualification of High Speed Bobbin and RPC Eddy Current Data", STD-DP-1995-7351/STD-DP-1995-7381**

This report documents the qualification of bobbin speeds up to 48 inches per sec and RPC at speeds up to 0.8 IPS. This document is Westinghouse Proprietary.

Reference D: Westinghouse Reports, **WEC002.DOC, "Eddy Current low row U-Bend Examination Non Mag Bias and Mag Bias"**

This report documents the equivalency qualification, performed by Westinghouse, of the non-mag bias and mag bias U-bend probe to the EPRI Appendix H qualification. Speeds of up to 300 RPM and 0.2 IPS were used.

Reference E: Westinghouse Document # **STD-DP-1994-7222, "Qualification Data Package for Appendix H Equivalency"**

This report documents equivalency and detectability of bobbin probes with fill factors from 0.77 and above using both MIZ-18 and TC6700 testers. This document is Westinghouse Proprietary.

Reference F: Westinghouse Document # **SG-99-03-005, "Bobbin Qualification for ODSCC at Dented Supports"**

This report documents detectability of ODSCC in freespan dings up to 5 volts with the bobbin probe.

Reference G: Westinghouse Report # **SGMS-98-135, "Analysis of Wear Using Bobbin Probes With Extension Cabling"**

This report demonstrates that there is little or no difference when measuring wear with the bobbin probe with up to 210 feet of total cable length.

Reference H: Westinghouse Letter, **SGIA-GP-97-074, "Appendix H Equivalency of 83 ft. Motor Units"**

This letter documents Appendix H equivalency to the qualified 50 ft. motor units used in the Appendix H qualifications.

Reference I: Westinghouse Letter, **SGIA-GP-97-066, "Appendix H Equivalency of 110 ft. Bobbin Probes"**

This letter documents Appendix H equivalency to the qualified 83/100 ft. bobbin probes used in the Appendix H qualifications.

Reference J: E-mail attachment from Gary Pierini, Westinghouse NDE Level III, **"Sizing of Pitting in 7/8" Tubing"**

Reference K: Westinghouse Data Package # **STD-TR-1994-7257, Rev. 0, "Report for the Comparison of Cecco-5 and RPC NDE Techniques for Inspection of Dented Tubes"**

This data package was created specifically for Indian Point 2 and uses the EPRI dented tube support lab samples as well as additional Westinghouse dented lab samples. This data package shows that the Cecco probe has an acceptable probability of detection and has equivalent or better detection capabilities at dented supports than the rotating pancake probe. The results of this document were verified and endorsed by EPRI.

Reference L: Westinghouse Data Package # **STD-TR-1997-8012, Rev. 0, "640 Cecco-5 Validation Report"**

This data package demonstrates equivalency to EPRI Appendix H for both the .640" Cecco-5 Probe and the .610" Plus Point dent inspection probe using severely dented (up to 0.125" diameter reduction) tube samples containing EDM notches.

Reference M: Westinghouse Study, '560 vs. 540 Bobbin Wear Sizing", letter pending

This study performed using in-generator data from an F model steam generator shows bobbin probe wear sizing equivalency to the EPRI qualification at a fill factor of 0.798.

TUBE SIZE

As stated in paragraph 8.3 of the Reference B, the equivalency of testing performed by bobbin for various tube sizes and wall thickness are compensated for by changing test frequencies to account for varying wall thickness and by changing probe sizes to account for different diameters of tubing. This is referred to as "scaling". Using the theory of "scaling", techniques that were qualified on different size tubing, with different size probes, can be applied to 7/8 inch tubing provided the minimum fill-factor used in the EPRI or Westinghouse equivalency qualifications is met or exceeded.

TESTERS

As documented in paragraph 6.2 of Reference B, the Zetec MIZ-30 and Westinghouse TC-6700 testers perform equivalent to the MIZ-18A when the total gain of the instrument is set equal to or above the minimum criteria for total gain. The minimum total gain is considered to be that of the MIZ-18A which was the tester used in a large portion of the Appendix H qualifications. Therefore, if the minimum parameters are met or exceeded, then the systems will be equivalent or exceed the capabilities of the original qualification. In all cases, the gain settings of the TC6700 to be used at Indian Point Unit 2 meet or exceed those of the MIZ-18A.

TEST SPEED

The high speed testing documented in Reference C shows that bobbin speeds up to 48 inches per second have acceptable detectability as long as the minimum digitization rate of 30 samples per axial inch are met or exceeded. For straight sections, RPC speeds up to 0.8 inches per second and 1200 RPM have acceptable detectability as long as the minimum digitization rate of 30 samples per inch circumferentially and 25 samples per inch axially are met or exceeded. The Cecco probe is qualified both by EPRI and Westinghouse at speeds of up to 12 inches per second. The testing documented in Reference D using the U-bend + Point probe shows that speeds up to 0.2 inches per second and 300 RPM are acceptable. All Cecco, bobbin, and RPC speeds to be used at Indian Point Unit 2 are within these requirements. The Cecco/bobbin probe is tested at 10 inches per second with a max speed of 12 inches per second. All separate bobbin tests are at 24 inches per second, and all RPC testing is performed at a speed of 0.1 inches per second and 300 RPM except for the .610 dent inspection Plus Point which is tested at 0.1 inches per second and 180 RPM to minimize the coil lift-off effects of severe dents and to match the speed used in the Westinghouse Appendix H equivalency qualification, Reference L.

SOFTWARE

For the Indian Point Unit 2 Spring 2000 inspection, Westinghouse will be utilizing ANSER software for data acquisition and for primary, secondary, and resolution data analysis. Both Zetec (Eddynet) and Westinghouse (ANSER) software utilize the UNIX operating system on HP computers. Both systems are designed to process raw eddy current data. Included in both systems are software programs for creating suppression mixes and filters. The raw data channels of the data are the same for both systems. Although not exactly the same, the mixing algorithms and filtering programs provide similar results between the two systems. To date, both systems have been utilized in EPRI Appendix H qualifications and the EPRI QDA program.

The ANSER software was also used in Reference B, "Westinghouse, Documentation of Appendix H Compliance and Equivalency". For the purpose of comparing EPRI Appendix H and site essential variables, the two systems are considered qualified and equivalent

BOBBIN PROBES

In Reference B, Paragraph 6.3 the LLMC Westinghouse probe and the Zetec MULC probe performed in an equivalent manner. Reference E shows the equivalency for detection and sizing the 0.680 inch probe with a fill factor of 77%. The bobbin coil used on the Cecco/bobbin probe at Indian Point 2 has the same coil dimensions and spacing as both the LLMC and MULC probes. Additionally, the resonant frequency of the bobbin on the Cecco probe is equivalent to that of the LLMC probe. All combinations of probe and probe extensions (varying from 0 to 120 feet) varied less than 10% of the measured voltages > 0.2 Vpp.

At Indian Point Unit 2, two bobbin probes with less than a 77% fill factor are used. The 0.640 inch probe has a fill factor of 68% and the 0.610 inch probe has a fill factor of 62%. These bobbin probe fill factors have not been formally qualified per Supplement 1 of Appendix H for detection or sizing. It is expected that, for low amplitude signals, the POD would be reduced and sizing accuracies would be affected by the probe motion. This would be especially true of the 0.610 inch bobbin which does not have centering devices designed for 7/8 inch OD x 0.050 inch wall tubing. Sizing data should be taken from the 0.700 inch or 0.680 inch bobbin probes. Bobbin signals from the 0.640 inch and 0.610 inch probes should be treated as non-quantifiable unless corroborated by the qualified probes.

In terms of detection, when compared with 0.700 inch probe on data in the sludge pile region in the steam generators at Indian Point Unit 2, the 0.610 inch probe exhibits equivalent detectability for signals greater than 0.5 Vpp. As a bounding case, some comparative graphics for the 0.610 inch and 0.700 inch probes have been provided later in this document.

Based on the tester, probe and cabling equivalencies discussed above and in Reference B, the following EPRI ETSS #'s qualifications apply.

Reference A, page A-233 (ETSS # 96007), qualified the bobbin probe for detection of IGA/ODSCC at non-expanded and non-dented support plates using the MIZ-18. This can be used as a basis for detection of freespan IGA/ODSCC. Table 1 below compares the EPRI ETSS essential variables to site ETSS essential variables.

Essential Variables	EPRI Appendix H ETSS # 96007	Indian Point 2 ACTS #'s IP2-00-001,002 & IPS-00-007. ANTS # IPS-00-A & IPS-00-F	Appendix H Equivalency
Instrument	MIZ-18	TC6700	DDM-96-009
Probe size & type	Zetec A-XXX-MULC or SF bobbin with fill factor ≥ 81% ,100ft	Westinghouse .700, .680 bobbin (both C-5/HD and LLMC) 100/110ft .	DDM-96-009 SGIA-GP-97-066
Extension cable type & Length	Zetec 100ft	Zetec Universal 100 ft. max or WNSCD C5 cable 40 ft. max	DDM-96-009
Frequencies	prime/quarter diff. Mix 400/100 kHz	Prime/quarter diff. mix 400/100 kHz	Equivalent
Drive voltage & gain	MIZ-18 equals 1.9 volts @38 db	5 volts @ 29db (700 C-5HD) 4.5 volts @ 29db (680 C-HD) 3.0 volts @ 38db (700LLMC)	DDM-96-009 Exceeds
Coil excitation modes	Differential & Absolute	Differential & Absolute	Equivalent
Calibration method (acquisition)	None stated	100% TWH 40 degrees	Equivalent
Minimum data to be Recorded	8 channels	8 channels per probe	Equivalent
Method of data Recording	Digital	Digital	Equivalent
Digitizing rate	33 samples per inch	30 samples per inch minimum	EPRI Guidelines page H-5, H.4.4
Scan pattern	Axial	Axial	Equivalent
Method of calibration (analysis)	400/100 kHz mix 100% @ 50% FSH probe motion horz. Flaws down first Phase curve 100%,60%,20% actuals	400/100 diff.mix 100% TWH @ 50% FSH probe motion horz. Flaws down first phase curve 100%,60%,20% actuals	Equivalent
Typical data review methodology (analysis)	400/100 kHz Diff. Mix and 100 kHz diff. In strip chart and 100 kHz in lissajous	400/100 kHz Diff. Mix and 100 kHz Abs. In strip chart and 400/100 kHz Diff. Mix in lissajous	Equivalent
Reporting requirements (analysis)	Noted in 100 Khz Diff. Reported from 400/100 kHz Differential Mix.	Reported from 400 kHz Differential or 400/100 Diferential Mix	Equivalent

Table 1
Bobbin Coil Examination at Non-Dented Support Plates and Freespan

Reference A, page A-240 (ETSS # 96008), qualified the bobbin probe for detection of IGA/ODSCC in freespan and at non-expanded and non-dented eggcrates and in the sludge pile on the MIZ-18. Table 2 below compares the EPRI ETSS essential variables to site ACTS and ANTS essential variables.

Essential Variables	**EPRI Appendix H ETSS # 96008**	**Indian Point 2 ACTS #'s IP2-00-001,002 & IPS-00-007. ANTS # IPS-00-A & IPS-00-F**	**Appendix H Equivalency**
Instrument	MIZ-18	TC6700	DDM-96-009
Probe size & type	Zetec bobbin with fill factor ≥ 73% ,100ft	Westinghouse .700, .680 bobbin (both C-5/HD and LLMC) 100/110ft .	DDM-96-009 SGIA-GP-97-066
Extension cable type & Length	Zetec 100ft	Zetec Universal 100 ft. max or WNSCD C5 cable 40 ft. max	DDM-96-009
Frequencies	prime/quarter diff. Mix 400/100 kHz	prime/quarter diff. mix 400/100 kHz	Equivalent
Drive voltage & gain	MIZ-18 equals 1.9 volts @38 db	5 volts @ 29db (700 C-5HD) 4.5 volts @ 29db (680 C-HD) 3.0 volts @ 38db (700LLMC)	DDM-96-009 Exceeds
Coil excitation modes	Differential & Absolute	Differential & Absolute	Equivalent
Calibration method (acquisition)	None stated	100% TWH 40 degrees	Equivalent
Minimum data to be recorded	8 channels	8 channels per probe	Equivalent
Method of data Recording	Digital	Digital	Equivalent
Digitizing rate	30 samples per inch minimum	30 samples per inch minimum	EPRI Guidelines page H-5, H.4.4
Scan pattern	Axial	Axial	Equivalent
Method of calibration (analysis)	prime/quarter diff mix 100% @ 50% FSH probe motion horz. Flaws down first Phase curve 100%,60%,20% actuals	400/100 diff.mix 100% TWH @ 50% FSH probe motion horz. Flaws down first phase curve 100%,60%,20% actuals	Equivalent
Typical data review methodology (analysis)	400/100 kHz Diff. Mix and 100 kHz Abs.in strip chart and 400/100 kHz Diff. Mix in lissajous	400/100 kHz Diff. Mix and 100 kHz Abs. in strip chart and 400/100 kHz Diff. Mix in lissajous	Equivalent
Reporting requirements (analysis)	Noted and Reported on 400/100 kHz Diff. Mix.	Noted and Reported on 400/100 kHz Diff. Mix.	Equivalent

Table 2
Bobbin Coil Examination in Freespan and Sludge Pile Region

Reference A, page A-41 (ETSS # 96004), qualified the bobbin probe for detection and sizing of wear at AVB's on the MIZ-18 @ 400kHz/100kHz using the 400/100 kHz differential mix. Table 3 below compares the EPRI ETSS essential variables to site ETSS essential variables.

Essential Variables	**EPRI Appendix H ETSS # 96004**	**Indian Point 2 ACTS #'s IP2-00-001,02 & IPS-00-007. ANTS # IPS-00-A & IPS-00-F**	**Appendix H Equivalency**
Instrument	MIZ-18	TC6700	DDM-96-009
Probe size & type	Zetec .720 bobbin 83ft	Westinghouse .700, .680 bobbin (both C-5/HD and LLMC) 100/110ft .	DDM-96-009 SGIA-GP-97-066 Ref. L
Extension cable type & Length	None stated	Zetec Universal 100 ft. max or WNSCD C5 cable 40 ft. max	DDM-96-009 SGMS-98-135
Frequencies	prime/quarter diff. Mix 400/100 kHz	prime/quarter diff. mix 400/100 kHz	Equivalent
Drive voltage & gain	MIZ-18 equals 1.9 volts @38 db	5 volts @ 29db (700 C-5HD) 4.5 volts @ 29db (680 C-HD) 3.0 volts @ 38db (700LLMC)	DDM-96-009 Exceeds
Coil excitation modes	Differential & Absolute	Differential & Absolute	Equivalent
Calibration method (acquisition)	None stated	100% TWH 40 degrees	Equivalent
Minimum data to be recorded	8 channels	8 channels per probe	Equivalent
Method of data recording	Digital	Digital	Equivalent
Digitizing rate	33 samples per inch	30 samples per inch minimum	EPRI Guidelines page H-5, H.4.4
Scan pattern	Axial	Axial	Equivalent
Method of calibration (analysis)	400/100 mix 40% wear @ 50% fsh probe motion horz. Flaws down first Volts curve 40%,20%, 0% actuals Default volts	400/100 diff.mix 60% TWH @ 50% FSH probe motion horz. Flaws down first Volts curve 40%,20%, 0% actuals 40% @ 5.00 volts	Equivalent
Typical data review methodology (analysis)	Lissajous mix channel mix on strip chart	Lissajous mix channel mix on strip chart	Equivalent
Reporting requirements (analysis)	vert max measurement from 400/100mix report % TW	vert max measurement from 400/100mix report % TW	Equivalent

Table 3
Bobbin Coil Examination for AVB Wear Sizing and Basis for Detection of Loose Parts Wear

Reference A, page A-36 (ETSS # 96001), qualified the bobbin probe for detection and sizing of thinning at tube support plates on the MIZ-18 with the 400kHz/100kHz differential mix. Table 4 below compares the EPRI ETSS essential variables to site ETSS essential variables.

Essential Variables	EPRI Appendix H ETSS # 96001	Indian Point 2 ACTS #'s IP2-00-001,002 & IPS-00-007. ANTS # IPS-00-A & IPS-00-F	Appendix H Equivalency
Instrument	MIZ-18	TC6700	DDM-96-009
Probe size & type	Zetec .720 bobbin 100 f t.	Westinghouse .700, .680 bobbin (both C-5/HD and LLMC) 100/110ft .	DDM-96-009 SGIA-GP-97-066
Extension cable type & Length	Zetec 100ft	Zetec Universal 100 ft. max or WNSCD C5 cable 40 ft. max	DDM-96-009
Frequencies	mid/quarter abs. 200/100 for .050" wall	prime/quarter diff. mix 400/100 kHz	Equivalent
Drive voltage & gain	MIZ-18 equals 1.9 volts @38 db	5 volts @ 29db (700 C-5HD) 4.5 volts @ 29db (680 C-HD) 3.0 volts @ 38db (700LLMC)	DDM-96-009 Exceeds
Coil excitation modes	Differential & Absolute	Differential & Absolute	Equivalent
Calibration method (acquisition)	None stated	100% TWH 40 degrees	Equivalent
Minimum data to be recorded	8 channels	8 channels per probe	Equivalent
Method of data recording	Digital	Digital	Equivalent
Digitizing rate	33 samples per inch	30 samples per inch minimum	EPRI Guidelines page H-5, H.4.4
Scan pattern	Axial	Axial	Equivalent
Method of calibration (analysis)	400/100 kHz mix 100% @ 50% FSH probe motion horz. Flaws down first Phase curve 100%,60%, 20%	400/100 diff.mix 100% TWH @ 50% FSH probe motion horz. Flaws down first phase curve 100%,60%,20% actuals	Equivalent
Typical data review methodology (analysis)	None Stated	400/100 kHz Diff. Mix and 100 kHz Abs. in strip chart and 400/100 kHz Diff. Mix in lissajous	Equivalent
Reporting requirements (analysis)	Report from 400/100 kHz diff. Mix	Noted and Reported on 400/100 kHz Diff. Mix.	Equivalent

Table 4
Bobbin Coil Examination for Thinning at Supports

Reference A, page A-18 (ETSS # 96005), qualified the bobbin probe for detection and sizing of pitting on the MIZ-18 using a 400kHz/100kHz differential mix. Table 5 below compares the EPRI ETSS essential variables to site ETSS essential variables.

Essential Variables	EPRI Appendix H ETSS # 96005	Indian Point 2 ACTS #'s IP2-00-001,002,003 & IPS-00-007. ANTS # IPS-00-A & IPS-00-F	Appendix H Equivalency
Instrument	MIZ-18	TC6700	DDM-96-009
Probe size & type	Zetec A-610-LC bobbin 100 ft	Westinghouse .700, .680,.640 bobbin (both C-5/HD and LLMC) 100/110ft .	DDM-96-009 SGIA-GP-97-066
Extension cable type & Length	Zetec 100ft.	Zetec Universal 100 ft. max or WNSCD C5 cable 40 ft. max	DDM-96-009
Frequencies	prime/quarter diff. Mix 400/100 kHz	prime/quarter diff. mix 400/100 kHz	Equivalent
Drive voltage & gain	MIZ-18 equals 1.9 volts @38 db	5 volts @ 29db (700 C-5HD) 4.5 volts @ 29db (680 C-HD) 3.0 volts @ 38db (700LLMC)	DDM-96-009 Exceeds
Coil excitation modes	Differential & Absolute	Differential & Absolute	Equivalent
Calibration method (acquisition)	None stated	100% TWH 40 degrees	Equivalent
Minimum data to be recorded	8 channels	8 channels per probe	Equivalent
Method of data recording	Digital	Digital	Equivalent
Digitizing rate	33 samples per inch	30 samples per inch minimum	EPRI Guidelines page H-5, H.4.4
Scan pattern	Axial	Axial	Equivalent
Method of calibration (analysis)	400/100 kHz mix 100% @ 50% FSH probe motion horz. Flaws down first Phase curve 100%,60%, 20%	400/100 diff.mix 100% TWH @ 50% FSH probe motion horz. Flaws down first phase curve 100%,60%,20% actuals	Equivalent
Typical data review methodology (analysis)	None Stated	400/100 kHz Diff. Mix and 100 kHz Abs. in strip chart and 400/100 kHz Diff. Mix in lissajous	Equivalent
Reporting requirements (analysis)	Report from 400/100 kHz Differential Mix using max rate.	Reported from 400/100HzDiff. Mix. Using max rate	Equivalent

Table 5
Bobbin Coil Examination for Pitting

ROTATING PROBE COILS

All of the following coils were tested by Westinghouse; Reference B, DDM96-009, on a variety of samples which contained ID and OD EDM notches in straight lengths, expansion transitions and dents (both symmetric and asymmetric) at frequencies of 600, 500, 400, 300, 200 and 100kHz. Additionally, all three testers (MIZ-18, MIZ-30 and TC-6700) in combination with various extension cable lengths (0-110 feet) and characteristics (Zetec low loss and RG174) were used in each of the tests. The acceptance criteria used was a POD ≥ 0.80 @ 90% confidence.

80 Mil HF Pancake

Paragraph 6.4.3, Reference B documents the POD's for ID and OD indications that were calculated at 90% confidence individually for all test frequencies and for various actual depth ranges for various extension and tester combinations using a binomial distribution. See Reference B, Table 6-5 and Appendix G for a more complete description.

115 Mil MR Pancake

Paragraph 6.4.2, Reference B documents the POD's for ID and OD indications that were calculated at 90% confidence individually for all test frequencies and for various actual depth ranges for various extension and tester combinations using a binomial distribution. See Reference B, Table 6-4 and Appendix F for a more complete description.

Plus Point Coil

Paragraph 6.4.6, Reference B documents the POD's for ID and OD indications that were calculated at 90% confidence individually for all test frequencies and for various actual depth ranges for various extension and tester combinations using a binomial distribution. See Reference B, Table 6-8 and Appendix I for a more complete breakdown. Also, Reference D documents the equivalency performed on the low row U-bend Plus Point probe (non-mag bias and mag bias).

The following table is a breakdown of acceptable frequency ranges of the various RPC test coils to be utilized at Indian Point 2:

FREQUENCY RANGE TO MEET ACCEPTANCE CRITERIA OF A POD≥ 0.80 @ 90% CONFIDENCE		
Coil Type	**OD Indications**	**ID Indications**
80 Mil HF Pancake	300 kHz - 400 kHz	100 kHz - 600 kHz
115 Mil Pancake	100 kHz - 400 kHz	100 kHz - 600 kHz
Plus Point	100 kHz - 400 kHz	100 kHz - 600 kHz

Plus Point Dent Inspection Coil

Westinghouse Data Package # STD-TR-1997-8012 (Reference L) demonstrated equivalency to EPRI Appendix H for the 610 Plus Point dent inspection probe at dented intersections. The samples used (68 total) contained more severe dents (up to 0.125" diameter reduction) and contained both ID and OD notches (115 total) of both axial and circumferential orientation. The motor units were 50 ft. long with a 60 ft. probe extension. The TC6700 tester drive voltage was 3 volts @ 38 db. The probe speed was 0.1 inches per second at 180 RPM and data was sampled at 450 samples per inch. The probe met the 80% POD at a 90% confidence level for detection of both ID and OD flaws at 300 kHz. All essential variables as stated from the qualification were identical to the Indian Point 2 as tested variables as stated on ACTS #IP2-00-010 except for the motor unit length of 83 ft. which is covered by Reference H, SGIA-GP-97-074.

EPRI RPC Qualifications

In addition to the above Westinghouse testing and based on the tester, probe and cabling equivalencies discussed above and in Reference B, the following Rotating Probe qualifications performed by EPRI, Reference A, also apply.

Reference A, page A-121 (ETSS # 96510), qualified the Plus Point for detection of circumferential and axial PWSCC at dented and non-dented support structures and expansion transitions using the TC6700. Table 6 below compares the EPRI ETSS essential variables to site ETSS essential variables.

Essential Variables	EPRI Appendix H ETSS # 96510	Indian Point 2 ACTS #'s IP2-00-004 ANTS # IPS-00-C	Appendix H Equivalency
Instrument	TC6700	TC6700	Equivalent
Coil type	Plus Point	Plus Point	Equivalent
Motor unit length	50ft motor unit	83ft max motor unit	SGIA-GP-97-074
Extension cable type & Length	Zetec 50ft Low loss coax	Zetec 0-110 ft. Low Loss coax	DDM-96-009
Frequencies	400 and 200 kHz	300kHz	Equivalent
Drive voltage & gain	5 volts @ 38db	3 volts @ 38db*	DDM-96-009 Exceeds
Coil excitation modes	Absolute	Absolute	Equivalent
Calibration method (acquisition)	none stated	100% axial notch 40 degrees	Equivalent
Minimum data to be recorded	2 channel	11 channels per probe	Equivalent
Method of data recording	Digital	Digital	Equivalent
Digitizing rate	30 samples per inch Circumferential 25 per inch axial	30 samples per inch Circumferential 25 scans per inch axial minimums	Equivalent
Scan pattern	none stated	push or pull	Equivalent
Method of calibration (analysis)	40% Circ. and Axial OD notches visible 40% ID circ and axial @ 15 degrees 20 volts on 100% axial notch	40% Circ. and Axial OD notches @ 50% FSH 40% ID circ and axial @ 15 degrees 20 volts on 100% axial and circ notches @ 300 kHz	Equivalent
Typical data review methodology (analysis)	Monitor the strip chart and scroll the region of interest. Terrain plot the raw and process channels in the area of interest	Monitor the strip chart and C-scans, scroll all data while monitoring lissajous.	Equivalent
Reporting requirements (analysis)	none stated	Volts P/P measurement	Equivalent

Table 6
Plus Point Examination for PWSCC, Expansion Transitions, Freespan, TSP, Dents

*EPRI ETSS # 96509 same qualification but using MIZ-18 which is equivalent to 1.9 volts @ 38 db with TC6700

Reference A, page A-99 (ETSS # 96404), qualified the Plus Point for detection of circumferential and axial ODSCC at dented and non-dented locations with and without support structures and expansion transitions using the TC6700. Table 7 below compares the EPRI ETSS essential variables to site ETSS essential variables.

Essential Variables	EPRI Appendix H ETSS # 96404	Indian Point 2 ACTS #s IP2-00-004 ANTS # IPS-00-C	Appendix H Equivalency
Instrument	TC6700	TC6700	Equivalent
Coil type	Plus Point	Plus Point	DDM-96-009
Motor unit length	50ft	83ft max motor unit	SGIA-GP-97-074
Extension cable type & Length	Zetec 50ft Low loss	Zetec 0-110 ft. Low Loss coax	DDM-96-009
Frequencies	400 and 200 kHz	300kHz	Equivalent
Drive voltage & gain*	5 volts @ 38db	3 volts @ 38db*	DDM-96-009
Coil excitation modes	Absolute	Absolute	Equivalent
Calibration method (acquisition)	none stated	100% axial notch 40 degrees	Equivalent
Minimum data to be recorded	3 channel	11 channels per probe	Exceeds
Method of data Recording	Digital	Digital	Equivalent
Digitizing rate	30 samples per inch Circumferential 25 per inch axial	30 samples per inch Circumferential 25 scans per inch axial minimums	Equivalent
Scan pattern	none stated	push or pull	Equivalent
Method of calibration (analysis)	40% Circ. and Axial OD notches visible 40% ID circ and axial @ 15 degrees 20 volts on 100% axial notch	40% Circ. and Axial OD notches @ 50% FSH 40% ID circ and axial @ 15 degrees 20 volts on 100% axial and circ notches @ 300 kHz	Equivalent
Typical data review methodology (analysis)	Monitor the strip chart and scroll the region of interest. Terrain plot the raw and process channels in the area of interest	Monitor the strip chart and C-scans, scroll all data while monitoring lissajous.	Equivalent
Reporting requirements (analysis)	none stated	Volts P/P measurement	Equivalent

Table 7
ODSCC, Axial & Circumferential: Plus Point Examination for Tubesheet Crevice, Freespan, TSP, Dents, Expansions

* EPRI ETSS # 96403 same qualification but using MIZ-18 which is equivalent to 1.9 volts @ 38 db with TC6700

Reference A, page A-224 (ETSS # 96511), qualified the Plus Point for the detection of circumferential and axial PWSCC in low row U-bend regions. Table 8 below compares the EPRI ETSS essential variables to site ETSS essential variables. Reference D, WEC.002.DOC, documents the U-bend Plus Point probe at speeds up to 300 RPM and 0.2 IPS.

Essential Variables	EPRI Appendix H ETSS # 96511	Indian Point 2 ACTS #s IP2-00-006 ANTS # IPS-00-E	Appendix H Equivalency
Instrument	MIZ-18A	TC6700	DDM-96-009
Coil type	Plus Point	Plus Point	DDM-96-009
Motor unit length	50ft motor unit	50-83ft motor unit	SGIA-GP-97-074
Extension cable type & Length	Zetec 50ft Low loss	Zetec 0-100 ft. Low loss	DDM-96-009
Frequencies	400kHz,300kHz 150kHz	400kHz,300kHz, 100kHz	Equivalent
Drive voltage & gain	MIZ-18 Equals 11 volts 1 gain	TC-6700 3 volts @ 38db	DDM-96-009 Exceeds
Coil excitation modes	Absolute	Absolute	Equivalent
Calibration method (acquisition)	none stated	100% axial notch 40 degrees	Equivalent
Minimum data to be recorded	3 channel	4 channels	Equivalent
Method of data recording	Digital	Digital	Equivalent
Digitizing rate	30 samples per inch Circumferential 30 per inch axial	30 samples per inch Circumferential 25 samples per inch axial minimums	EPRI Guidelines page H-5, H.4.4 Equivalent
Scan pattern	none stated	Push or pull	Equivalent
Method of calibration (analysis)	40% Circ. ID notch 2 divisions 40% ID @ 10 degrees 20 volts on 100% axial notch	40% Circ/Axial. OD notch @ 40% FSH 40% ID circ and axial notches @ 15 degrees (20% ID to be visible on C-scan) 20 volts on 100% axial/Circ. notch @ 300 kHz	Equivalent
Typical data review methodology (analysis)	Monitor the strip chart and scroll the region of interest. Terrain plot the raw and process channels in the area of interest	Monitor the strip chart and C-scans, scroll all data while monitoring lissajous.	Equivalent
Reporting requirements (analysis)	none stated	Volts P/P measurement	Equivalent

Table 8
PWSCC, Axial & Circumferential: Plus Point Examination Short Radius U-bend Region
Mid-Range Plus Point

ETSSs # 99997.1 and 99997.2 qualified a 800 kHz Plus Point probe for the detection of axial PWSCC in low row U-bend regions. Table 8 below compares the EPRI ETSS essential variables to site ETSS essential variables. Reference D, WEC.002.DOC, documents the U-bend Plus Point probe at speeds up to 300 RPM and 0.2 IPS.

Essential Variables	EPRI Appendix H ETSS # 99997.1 & ETSS # 99997.2	Indian Point 2 ACTS #s IP2-00-006 ANTS # IPS-00-J	Appendix H Equivalency
Instrument	MIZ-30	TC6700	DDM-96-009
Coil type	Plus Point	Plus Point	DDM-96-009
Motor unit length	50ft motor unit	83ft motor unit, max.	SGIA-GP-97-074
Extension cable type & Length	Zetec 50ft Low loss	Zetec 50 ft. Low loss	DDM-96-009
Frequencies	800kHz (#99997.1) 1000kHz (#99997.2)	800kHz 1000kHz	Equivalent
Drive voltage & gain	MIZ-30 Equals 11 volts 1 gain	TC-6700 3 volts @ 38db	DDM-96-009 Exceeds
Coil excitation modes	Differential	Differential	Equivalent
Calibration method (acquisition)	none stated	100% axial notch 40 degrees	Equivalent
Minimum data to be recorded	5 channel	5 channels	Equivalent
Method of data recording	Digital	Digital	Equivalent
Digitizing rate	30 samples per inch Circumferential 30 per inch axial	30 samples per inch Circumferential 30 samples per inch axial minimums	EPRI Guidelines page H-5, H.4.4 Equivalent
Scan pattern	none stated	Push or pull	Equivalent
Method of calibration (analysis)	40% axial ID notch 2 divisions 40% ID @ 15 degrees 20 volts on 100% axial notch	40% axial. ID notch @ 40% FSH 40% ID axial notch @ 15 degrees (20% ID to be visible on C-scan) 20 volts on 100% axial notch @ 800 kHz or 1000kHz	Equivalent
Typical data review methodology (analysis)	Monitor the strip chart and scroll the region of interest. Terrain plot the raw and process channels in the area of interest	Monitor the strip chart and C-scans, scroll all data while monitoring lissajous. Terrain plot the raw and process channels in the area of interest	Equivalent
Reporting requirements (analysis)	none stated	Volts P/P measurement	Equivalent

Table 9
PWSCC, Axial & Circumferential: Plus Point Examination Short Radius U-bend Region High Frequency Plus Point

Reference A, page A-165 (ETSS # 96504), qualified the .115" pancake coil for detection of circumferential and axial PWSCC at dented and non-dented locations with and without support structures and expansion transitions using theTC6700. Table 10 below compares the EPRI ETSS essential variables to site ETSS essential variables.

Essential Variables	EPRI Appendix H ETSS # 96504	Indian Point 2 ACTS #'s IP2-00-004,005 ANTS # IPS-00-C,D	Appendix H Equivalency
Instrument	TC6700	TC6700	Equivalent
Coil type	Plus Point	Plus Point	Equivalent
Motor unit length	50ft motor unit	83ft max.motor unit	SGIA-GP-97-074
Extension cable type & Length	Zetec 50ft Low loss	Zetec 0-110 ft. Low loss	DDM-96-009
Frequencies	400 and 200 kHz	300kHz	Equivalent
Drive voltage & gain	5 volts @ 38db	3 volts @ 38db*	DDM-96-009 Exceeds
Coil excitation modes	Absolute	Absolute	Equivalent
Calibration method (acquisition)	none stated	100% axial notch 40 degrees	Equivalent
Minimum data to be recorded	2 channel	11 channels per probe	Equivalent
Method of data recording	Digital	Digital	Equivalent
Digitizing rate	30 samples per inch Circumferential 25 per inch axial	30 samples per inch Circumferential 25 scans per inch axial minimums	Equivalent
Scan pattern	none stated	push	Equivalent
Method of calibration (analysis)	40% Circ. ID notch visible Probe motion horizontal 20 volts on 100% axial notch	40% Axial notch @ 40%FSH Probe motion horizontal 20 volts on 100% axial notch	Equivalent
Typical data review methodology (analysis)	Monitor the strip chart and scroll the region of interest. Terrain plot the raw and process channels in the area of interest	Monitor the strip chart, scroll the region of interest. Terrain plot the raw and process channels over the entire data.	Equivalent
Reporting requirements (analysis)	none stated	Volts P/P measurement	Equivalent

Table 10
.115" Pancake Coil Examination for PWSCC in Roll Plugs, Expansions Transitions, Dented and Non-Dented Supports, and Freespan Locations

* EPRI ETSS # 96503 same qualifications but using MIZ-18 which is equivalent to 1.9 volts @ 38 db with TC6700

CECCO –5 PROBES

Westinghouse CECCO-5 Probe Qualifications

The Cecco 5 probe was tested by Westinghouse; Reference K, Westinghouse Data Package # STD-TR-1994-7257, Rev. 0, "Report for the Comparison of Cecco-5 and RPC NDE Techniques for Inspection of Dented Tubes", on a variety of samples which contained ID and OD notches of both axial and circumferential orientation in support plate dents (both symmetric and asymmetric) with up to 0.060" of diametric reduction both with and without magnetite. The Cecco 5 detected the flaws in all 26 grading units used for this qualification which were at depths between 50 and 70%. The Cecco-5 probe used was a .680" diameter with a length of 100 ft. and a 20 ft. extension. A 200 kHz compensation mix was used for flaw detection. Probe speed was 10 inches per second and data was sampled at 500 samples per inch. The TC6700 tester drive voltage was 10 volts @ 38 db.

Westinghouse Data Package # STD-TR-1997-8012, Reference L, further qualified the Cecco-5 probe to EPRI Appendix H for flaw detection at dented intersections with a .640" diameter probe. The samples used (68 total) contained more severe dents (up to 0.125" diameter reduction) and contained both ID and OD notches (115 total) of both axial and circumferential orientation. The probes were 100 ft. long with a 40 ft. probe extension. The probe speed was 10 inches per second and data was sampled at 500 samples per inch. The probe met the 80% POD at a 90% confidence level for detection of both ID and OD flaws at both 100 and 200 kHz.

EPRI CECCO-5 Probe Qualifications

In addition to the above Westinghouse testing and based on the tester, probe and cabling equivalencies discussed above and in Reference B, the following Cecco-5 probe qualifications performed by EPRI, Reference A, also apply.

Reference A, page A-178 (ETSS # 96902), qualified the Cecco-5 probe for detection of circumferential and axial PWSCC at dented and non-dented locations with and without support structures and expansion transitions using the TC6700. Table 11 below compares the EPRI ETSS essential variables to site ETSS essential variables.

Essential Variables	EPRI Appendix H ETSS # 96902	Indian Point 2 ACTS #s IP2-00-001,2,3 ANTS # IP2-00-A,B	Appendix H Equivalency
Instrument	TC6700	TC6700	Equivalent
Probe size & type	WNSCD .720,.680, Cecco-5 110 ft.	WNSCD .720,.680,.640* Cecco-5 110 ft.	STD-TR-1994-7257 *STD-TR-1997-8012
Motor unit length	N/A	N/A	N/A
Extension cable type & Length	WNSCD C5 cable 0-20 ft.	WNSCD C5 cable 40 ft. max*	*STD-TR-1997-8012
Frequencies	200Khz	300,200,100 kHz	Equivalent
Drive voltage & gain	10 volts @ 38db	10 volts @ 38db (.720 & 680) 9 volts @ 32 db (.640)*	*STD-TR-1997-8012
Coil excitation modes	Transmit-Receive	Transmit-Receive	Equivalent
Calibration method (acquisition)	none stated	100% axial notch 40 degrees	Equivalent
Minimum data to be recorded	72 channels	72 channels (.720 & 680) 48 channels (.640)*	Equivalent *STD-TR-1997-8012
Method of data recording	Digital	Digital	Equivalent
Digitizing rate	30 samples per inch	30 samples per inch minimum	EPRI Guidelines page H-5, H.4.4
Scan direction	axial	axial	Equivalent
Method of calibration (analysis)	Span -83 maximum Dent horizontal 5 VPP on OD groove	10% OD groove @ ¾ Screen Dent horizontal 10 VPP on OD groove	Equivalent
Typical data review methodology (analysis)	Review strip chart displays for vert. dispacement on all freq. & Comp Mix	Review strip chart displays for vert.displacement on all freq. & Comp Mix	Equivalent
Reporting requirements (analysis)	Report from 200 kHz Compensation Mix	Report from 200 kHz Raw Channel or Compensation Mix*	Equivalent

Table 11
CECCO-5 Probe Examination for PWSCC in Expansion Transitions, Dented Supports, and Tubesheet Crevices

*Note: Reporting channel not mandated by procedure. Use of 200 kHz based channels is training practice.

Reference A, page A-170 (ETSS # 96904), qualified the Cecco-5 probe for detection of circumferential and axial ODSCC at dented and non-dented locations with and without support structures and expansion transitions using the TC6700. Table 12 below compares the EPRI ETSS essential variables to site ETSS essential variables.

Essential Variables	EPRI Appendix H ETSS # 96904	Indian Point 2 ACTS #s IP2-00-001,2,3 ANTS # IP2-00-A,B	Appendix H Equivalency
Instrument	TC6700	TC6700	Equivalent
Coil type	WNSCD .720,.680, Cecco-5 110 ft.	WNSCD .720,.680,.640* Cecco-5 110 ft.	STD-TR-1994-7257 *STD-TR-1997-8012
Motor unit length	N/A	N/A	N/A
Extension cable type & Length	WNSCD C5 cable 0-40 ft.	WNSCD C5 cable 40 ft. max*	Equivalent
Frequencies	200Khz	300,200,100 kHz	Equivalent
Drive voltage & gain	10 volts @ 38db	10 volts @ 38db (.720 & 680) 9 volts @ 32 db (.640)*	*STD-TR-1997-8012
Coil excitation modes	Transmit-Receive	Transmit-Receive	Equivalent
Calibration method (acquisition)	none stated	100% axial notch 40 degrees	Equivalent
Minimum data to be recorded	72 channels	72 channels (.720 & 680) 48 channels (.640)*	Equivalent *STD-TR-1997-8012
Method of data recording	Digital	Digital	Equivalent
Digitizing rate	30 samples per inch	30 samples per inch minimum	EPRI Guidelines page H-5, H.4.4
Scan pattern	axial	axial	Equivalent
Method of calibration (analysis)	Span -83 maximum Dent horizontal 5 VPP on OD groove	10% OD groove @ ¾ Screen Dent horizontal 10 VPP on OD groove	Equivalent
Data review requirements (analysis)	Review strip chart displays for vert. dispacement on all freq. & Comp Mix	Review strip chart displays for vert.displacement on all freq. & Comp Mix	Equivalent
Reporting requirements (analysis)	Report from 200 kHz Compensation Mix	Report from 200 kHz Raw Channel or Compensation Mix*	Equivalent

Table 12
CECCO-5 Probe Examination for ODSCC in Undeformed Regions, Sludge Pile, Expansion Transitions, Dented Supports, and Tubesheet Crevices

*Note: Reporting channel not mandated by procedure. Use of 200 kHz based channels is training practice.

The ETSS sheets listed below are additional techniques that could also be considered for applicability to the Indian Point 2 Spring 2000 inspection:

- Reference A, page A-303 (ETSS # 96012), qualified the bobbin probe for detection of axial PWSCC at support plates with dents $\geq$ 2.00 volts from the 400/100 kHz differential mix and using the TC6700 tester.
- Reference A, page A-299 (ETSS # 96910), qualified the Plus Point for detection and sizing of wear at broached support plates from a 300/100 kHz support mix and using the MIZ-30 tester. This ETSS can be used as a basis for detecting and sizing loose parts wear in freespan of the generator.
- Reference A, page A-293 (ETSS # 96911), qualified the .115" pancake coil for detection and sizing of wear at broached support plates from a 300/100 kHz support mix and using the MIZ-30 tester. This ETSS can be used as a basis for detecting and sizing loose parts wear in freespan of the generator.
- Reference A, page A-156 (ETSS # 96507), qualified the 80 mil pancake coil for detection of circumferential and axial PWSCC at dented and non dented support plates and expansion transitions using the TC6700 tester @ 800 and 400 kHz.
- Reference A, page A-210 (ETSS # 96702), qualified the Plus Point for depth sizing of circumferential PWSCC using phase angle at expansion transitions @ 400 and 300 Khz.
- Reference A, page A-272 (ETSS # 96703), qualified the Plus Point for length and depth sizing by phase angle of axial PWSCC at dented supports @ 300 Khz.

DATA REVIEW

To consider an eddy current technique site qualified, qualification results must be compared to site-specific results and conditions for each damage mechanism. Listed below are the types of damage mechanisms reviewed for site qualification:

<u>DAMAGE MECHANISMS</u>

1. Axial ODSCC has been reported at Indian Point 2 at dented support plate intersections. **Figure 1A** shows the results from a dented lab sample used to support the EPRI Appendix H qualification for the Cecco-5 probe. **Figure 1B** compares an in-generator signal reported at Indian Point 2 using the Cecco-5 probe. **Figure 2A** shows the results from a lab sample used to support the EPRI Appendix H qualification for the Plus Point coil. **Figure 2B** compares an in-generator signal reported at Indian Point 2 from the Plus Point coil.

2. Axial PWSCC has not been reported at Indian Point 2 at dented support plate intersections, but is a potential damage mechanism. **Figure 3** shows the results from a dented lab sample from the Westinghouse Appendix H equivalency qualification, Reference K, using the Cecco-5 probe. **Figure 4** shows the results from a dented support plate lab sample used to support the Westinghouse Appendix H qualification, Reference L, for the Plus Point coil.

3. Axial ODSCC has been reported at Indian Point 2 in the tubesheet crevice region. **Figure 5A** shows the results from a lab sample from the EPRI Appendix H qualification using the Cecco-5 probe. **Figure 5B** compares an in-generator signal reported at Indian Point 2 using the Cecco-5 probe. **Figure 6A** shows the results from a 1996 tube pull from Zion 2 using the Plus Point coil. **Figure 6B** compares an in-generator signal reported at Indian Point 2 using the Plus Point coil. The tube pull data displayed were collected in a manner consistent with the technique as defined in the ETSS. These data were used because they were more prototypical of the in-generator conditions than those used to support the ETSS.

4. Axial PWSCC has been reported at Indian Point 2 in the roll expanded region of the tubesheet. **Figure 7A** shows the results from a lab sample from the EPRI Appendix H qualification using the Cecco-5 probe. **Figure 7B** compares an in-generator signal reported at Indian Point 2 using the Cecco-5 probe. **Figure 8A** shows the results from a 1996 tube pull from Zion 2 from the Plus Point coil. **Figure 8B** compares an in-generator signal reported at Indian Point 2 from the Plus Point coil. The tube pull data displayed were collected in a manner consistent with the technique as defined in the ETSS. These data were used because they were more prototypical of the in-generator conditions than those used to support the ETSS.

5. OD pitting has been reported at Indian Point 2 above the top of the tubesheet. **Figure 9A** shows the results from a tube pull from one of the Indian Point 3 original Model 44 steam generators with the bobbin probe. The tube pull data displayed were collected in a manner consistent with the technique as defined in the ETSS. These data were used because they were more prototypical of the in-generator conditions than those used to support the ETSS. **Figure 9B** compares an in-generator signal reported at Indian Point 2 using the bobbin probe. **Figure 9C** shows the same indication with the Cecco-5 coils. **Figure 9D** shows this indication using the pancake and Plus Point coils.

6. Axial ODSCC has been reported at Indian Point 2 above the top of tubesheet in the sludge pile region. **Figure 10A** shows the results from a 1995 tube pull from Beaver Valley 1 using the Cecco-5 probe. The tube pull data displayed were collected in a manner consistent with the technique as defined in the ETSS. These data were used because they were more prototypical of the in-generator conditions than those used to support the ETSS. **Figure 10B** compares an in-generator signal reported at Indian Point 2 using the Cecco-5 probe. **Figure 11A** shows the results from a 1996 tube pull from Beaver Valley 1 using the Plus Point probe. The tube pull data displayed were collected in a manner consistent with the technique as defined in the ETSS. These data were used because they were more prototypical of the in-generator conditions than those used to support the ETSS. **Figure 11B** compares an in-generator signal reported at Indian Point 2 using the Plus Point probe.

7. Axial PWSCC has been reported at Indian Point 2 in low radius U-bends. **Figure 12A** shows the results from a lab sample used to support the EPRI Appendix H technique qualification using the mid-range Plus Point probe. **Figure 12B** compares an in-generator signal reported at Indian Point 2 using the mid-range Plus Point probe. **Figure 12C** shows the results from a lab sample used to support the EPRI Appendix H technique qualification using the high frequency Plus Point probe. **Figure 12D** compares an in-generator signal reported at Indian Point 2 using the high frequency Plus Point probe.

8. Circumferential PWSCC has been reported at Indian Point 2 in the roll expanded region of the tubesheet. **Figure 13A** shows the results from a lab sample from the EPRI Appendix H qualification using the Cecco-5 probe. **Figure 13B** compares an in-generator signal reported at Indian Point 2 using the Cecco-5 probe. **Figure 14A** shows the results from a pulled tube from Sequoyah Unit 1 for the Plus Point coil. The tube pull data displayed were collected in a manner consistent with the technique as defined in the ETSS. These data were used because they were more prototypical of the in-generator conditions than those used to support the ETSS. **Figure 14B** compares an in-generator signal reported at Indian Point 2 from the Plus Point coil.

9. Wear has been reported at Indian Point 2 at AVB locations. **Figure 15A** shows the results from a lab sample used to support the Appendix H technique qualification. **Figure 15B** compares an in-generator signal reported at Indian Point 2 using the bobbin probe. The deposit conditions at Indian Point Unit 2 do affect the signal formation, but the wear indication is still detectable.

ADDITIONAL REVIEWS

Figures 16, 17, 18, and 19 document comparisons between the 700LLMC bobbin probe and the bobbin coils on the Cecco-5 probe from standard responses and a typical signal from Indian Point 2 field data. The results of this review show that there is equivalence between the two bobbin probes. **Figures 20, 21, 22 and 23** document comparisons between the 0.700 inch and 0.610 inch bobbin probes on typical signals from Indian Point Unit 2 field data. This shows, on a site-specific basis, that there is equivalence in terms of detection for signals > 0.5 Vpp.

SUMMARY

Tables 12 and 13 provide a summary of the active, relevant, and potential damage mechanisms at Indian Point Unit 2 and indicates the qualification status for each corresponding examination technique. The POD's cited in the tables are for the generic qualifications. The impact of site-specific conditions on POD are addressed in the degradation assessment.

Eddy current signals for various forms of degradation and inspection techniques from the Indian Point Unit 2 steam generators were compared to eddy current signals from Westinghouse qualification samples, lab samples used in the EPRI Appendix H qualifications, and/or tube pull data from similar steam generators. The conclusion reached from this comparison is the Indian Point Unit 2 in-generator signal-to-noise characteristics are similar to those of the data used in Appendix H qualifications and tube pulls from similar type steam generators. The review also shows that the in-generator denting and tube geometry are similar to those used either in the EPRI Appendix H qualifications or supplemental Westinghouse Appendix H equivalency qualifications and should have little influence on the eddy current technique's ability to detect indications. However, the deposit conditions for the in-generator data do differ from the qualification bases. For dented regions, the deposit influence is comparatively small as compared to the denting. For freespan regions, the deposit signals are the most significant influence on detectability. This may have some effect on POD for shallow OD signals. The essential variable comparison shows that the site 'as-used' technique's essential variables for these areas are equivalent to EPRI or Westinghouse Appendix H 'as qualified' technique essential variables for all damage mechanisms reported at Indian Point 2.

Cecco and Plus Point techniques applied to the tubesheet roll expansion region and in the tubesheet crevice, where the deposit influence is not a factor, are considered 'site qualified'. Prior to application of the 800 kHz Plus Point U-bend technique,low row U-bend in-generator data were compared to in-generator low row U-bend results from the midrange U-bend Plus Point probe. Performance of the 800 kHz technique was shown to be superior for detection of axial PWSCC in the presence of OD deposits. Based on this in-generator demonstration and the fact the technique has been qualified for use at 800 Khz and 1000 kHz via EPRI ETSSs 99997.1 and 99997.2, respectively, it is considered 'site qualified' for use at Indian Point 2.

Table	Degradation Mechanism	Orientation	Location	Probe	EPRI ETSS for Detection	EPRI POD @90%CL	EPRI ETSS Sizing Technique	EPRI Sizing RSME	Reported At IPP	Qualification Category
1	ODSCC	Axial	Freespan	Bobbin	96007 A-233	.85 @ 40%TW	none	N/A	NO	Industry
2	ODSCC	Axial	Freespan, sludge pile region	Bobbin	96008 A-240	.85 @ 40% TW	none	N/A	YES	Industry
2	ODSCC	Axial	Freespan Dings <5 v	Bobbin	SG-99-03-005*	.88 @ ≥60%TW	none	N/A	NO	Industry
3	WEAR	N/A	AVB's	Bobbin	96004 A-41	.83 @ 60% TW	96004	3.8% TW	YES	Industry
4	THINNING	N/A	Cold Leg Supports, Loose Parts Wear detection	Bobbin	96001 A-36	82 @ ≥50% TW	96001	N/A	NO	Industry
5	PITTING	N/A	Above Top of Tubesheet	Bobbin	96005 A-18	.89 @≥50%TW	96005	21.6% TW	YES	Industry
6	PWSCC	Axial	Tubesheet Roll Expansion regions	Plus Point	96510 A-121	.81 @ 46% TW	96703	10.52% PDA .13" length	YES	Site/Industry
6	PWSCC	Circ.	Tubesheet Roll Expansion regions	Plus Point	96510 A-121	.81 @ 46% TW	96702	21.04 % max 10.09% PDA 21.02 degrees	YES	Industry
6	PWSCC	Axial	TSP with dents	Plus Point	96510	.81 @ 46% TW	none	N/A	YES	Industry
6	PWSCC	Circ.	TSP with dents	Plus Point	96510	.81 @ 46% TW	none	N/A	NO	Industry
7	ODSCC	Axial	TSP with dents	Plus Point	96404 A-99	.89 @>50% TW	none	N/A	YES	Industry
7	ODSCC	Axial	Tubesheet Crevice region	PlusPoint	96404	.89 @>50% TW	none	N/A	YES	Site/Industry
7	ODSCC	Axial	Sludge Pile Region Above tubsheet	PlusPoint	96404	.89 @>50% TW	none	N/A	YES	Industry
8	PWSCC	Axial	Small radius U-Bends	Plus Point	96511 A-224	.91 @ 27%TW	none	N/A	YES	Industry
8	PWSCC	Circ	Small radius U-Bends	Plus Point	96511	.91 @ 27%TW	none	N/A	NO	Industry

Table 12
Summary of Indian Point Unit 2 Appendix H Probe Qualifications by Damage Mechanism
BOBBIN and RPC PROBES

Table	Degradation Mechanism	Orientation	Location	Probe	EPRI ETSS for Detection and/or *West. APP H Qual	EPRI POD @90%CL	EPRI ETSS Sizing Technique	EPRI Sizing RSME	Reported At IPP	Qualification Category
9	PWSCC	Axial	Small radius U-Bends	Plus Point	99997.1 99997.2	.91@ 27%TW	none	N/A	YES	Site/Industry
9	PWSCC	Circ	Small radius U-Bends	Plus Point	99997.1 99997.2	.91@ 27%TW	none	N/A	NO	Industry
10	PWSCC	Axial	Roll Plug expansions	.115" Panc.	96504	.81 @ >46%TW	none	N/A	NO	Industry
11	PWSCC	Axial	Tubesheet Roll Expansion regions	CECCO-5	96902 A-178	.89 @50% TW	none	N/A	YES	Site/Industry
11	PWSCC	Circ.	Tubesheet Roll Expansion regions	CECCO-5	96902 A-178	.89 @50% TW	none	N/A	YES	Industry
11	PWSCC	Axial	TSP with dents	CECCO-5	96902 *STD-TR-1994-7257	.89 @50% TW	none	N/A	YES	Industry
11	PWSCC	Circ.	TSP with dents	CECCO-5	96902 *STD-TR-1997-7257	.89 @50% TW	none	N/A	NO	Industry
12	ODSCC	Axial	TSP with dents	CECCO-5	96904 *STD-TR-1997-7257	.83 @>40%TW	none	N/A	YES	Industry
12	ODSCC	Axial	Tubesheet Crevice region	CECCO-5	96904	.83 @>40%TW	none	N/A	YES	Site/Industry
12	ODSCC	Axial	Sludge Pile Region Above tubsheet	CECCO-5	96904	.83 @>40%TW	none	N/A	YES	Industry

Table 13
Summary of Indian Point Unit 2 Appendix H Probe Qualifications by Damage Mechanism
CECCO-5 PROBE

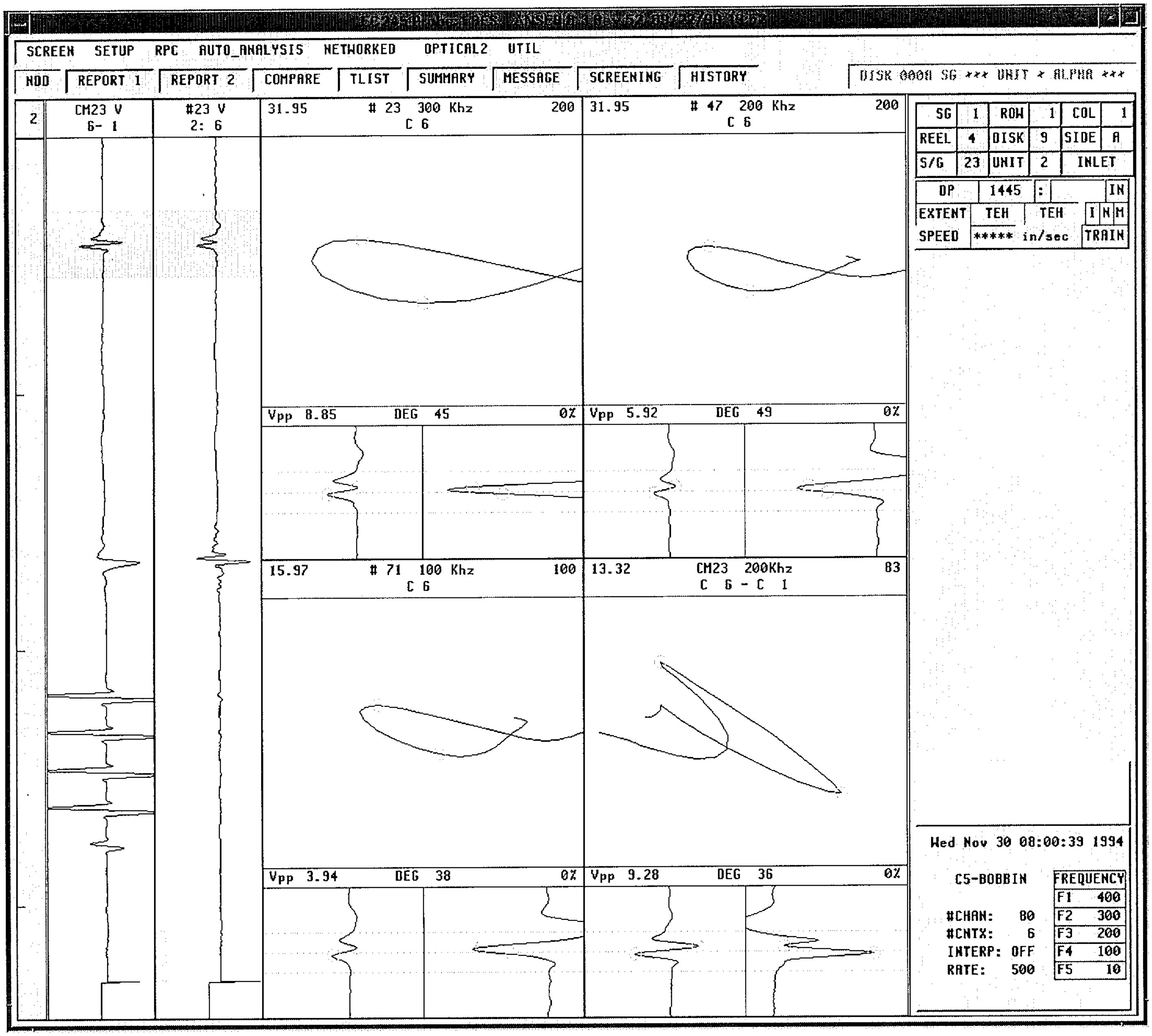


Figure 1A

Dented Support Lab Sample Used to Support EPRI Appendix H Qual. With .030" Dent, 62% OD Axial Notch .680" Cecco 5 Probe

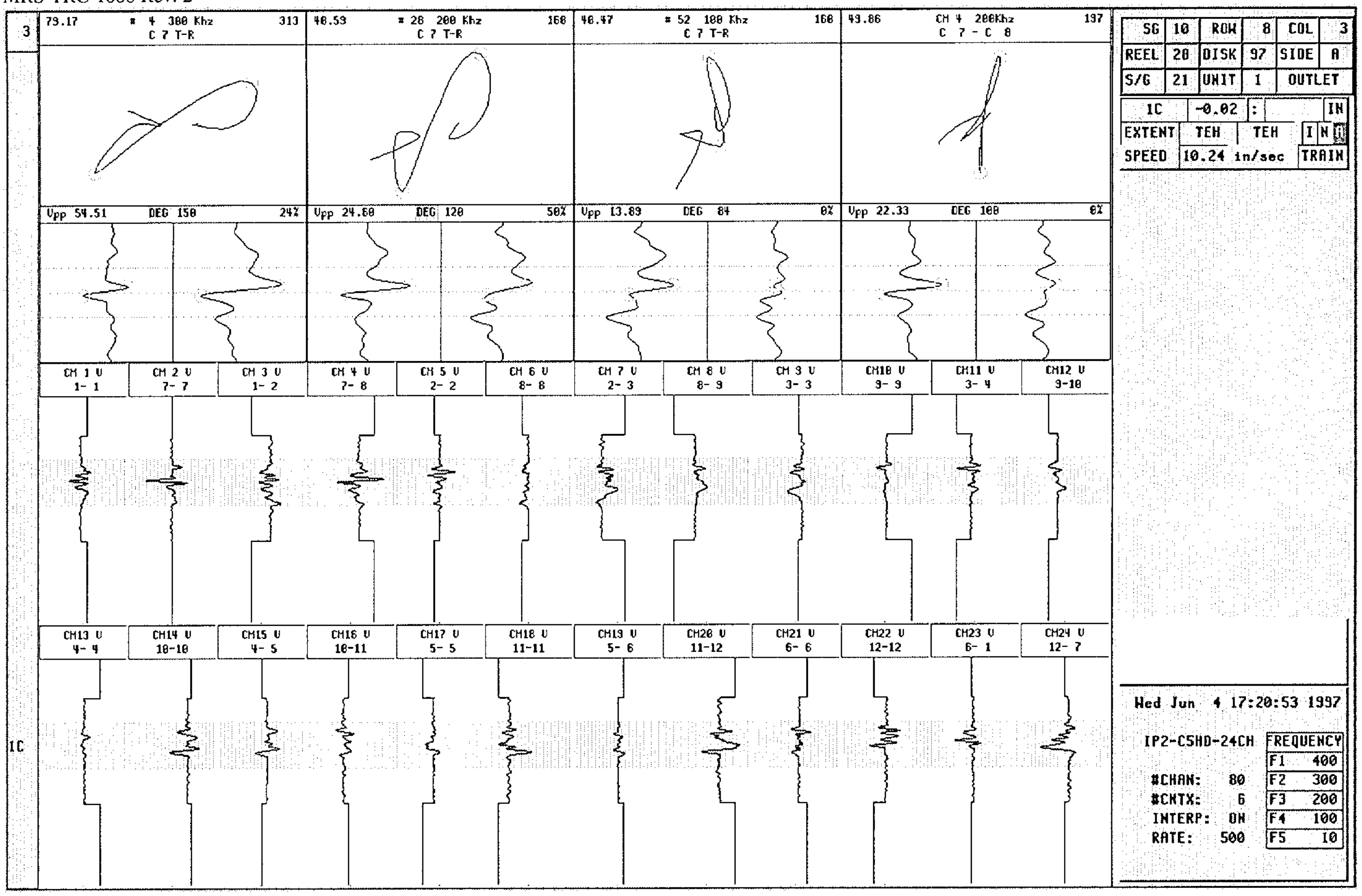


Figure 1B

Indian Point 2 In-Generator Dented Support Plate as Reported With .680" Cecco-5 Probe Confirmed with + Point Probe as OD Axial Flaw

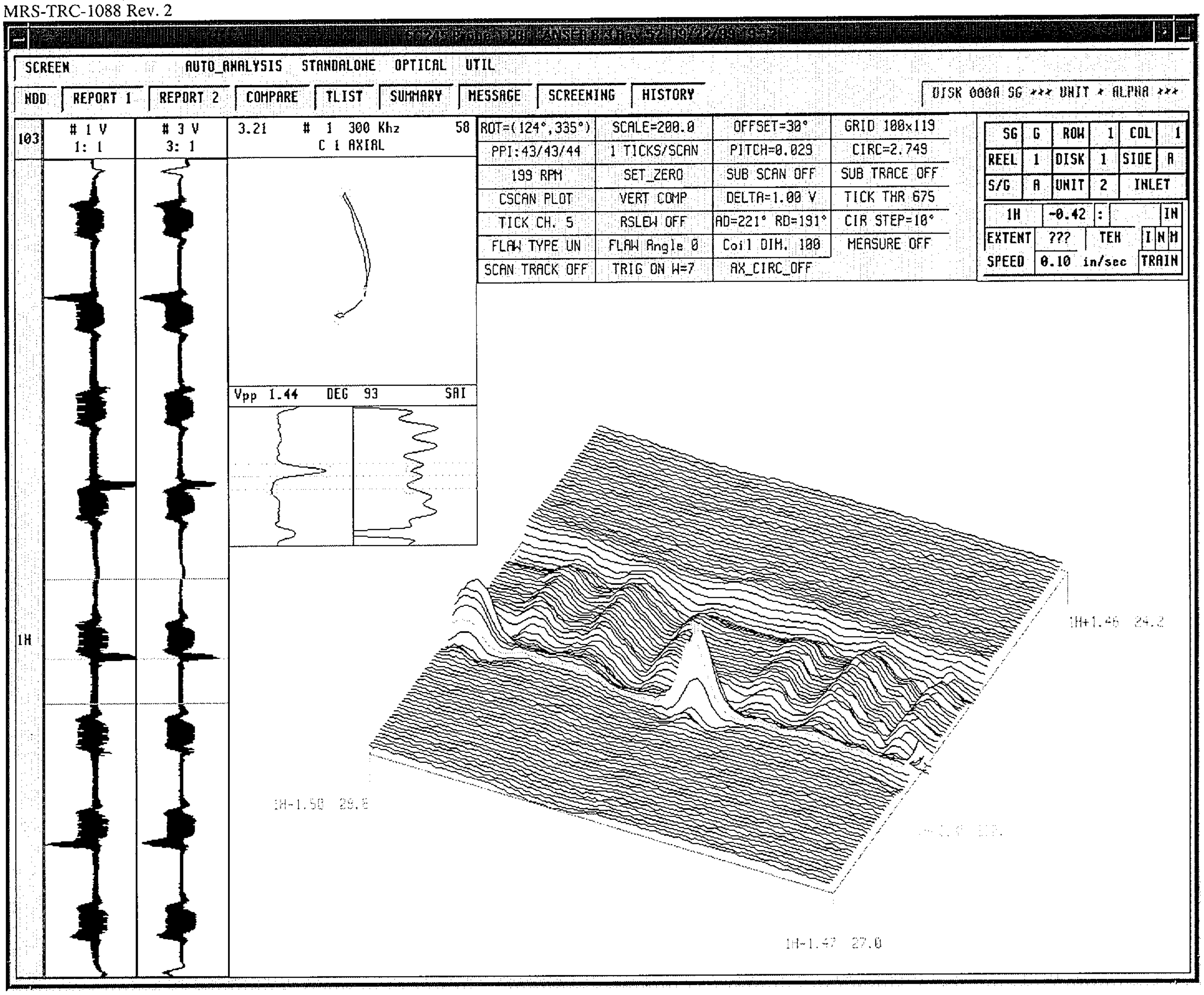


Figure 2A

Dented Support lab Sample Used to Support Westinghouse Appendix H Equivalency Qual (Ref.L).
.610 DIP Plus Point Coil .060" Dent With 72% OD Axial Notch

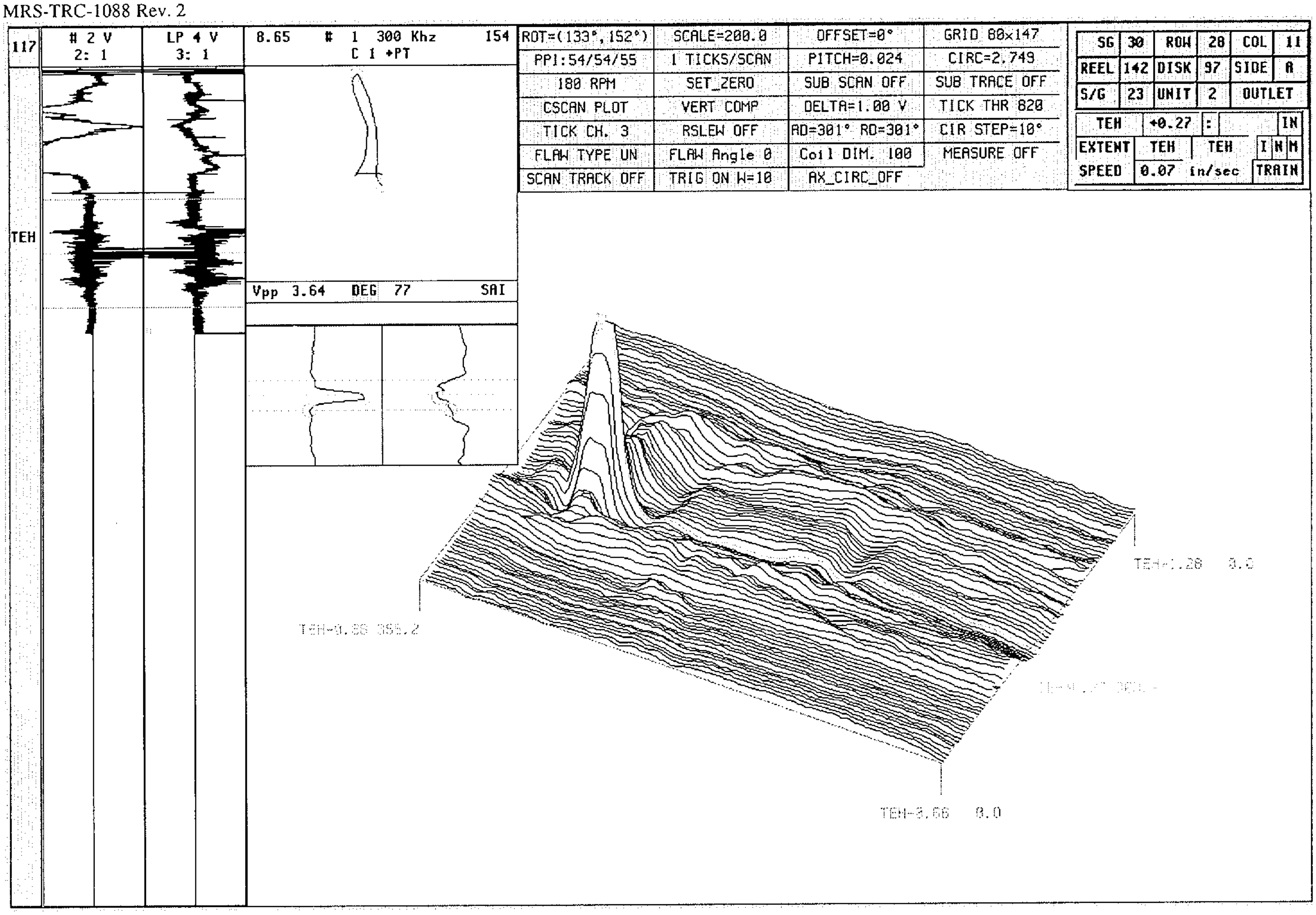


Figure 2B

Indian Point 2 In-Generator Dented Support Plate as Reported With Plus Point Probe (Confirmed Cecco SPI)

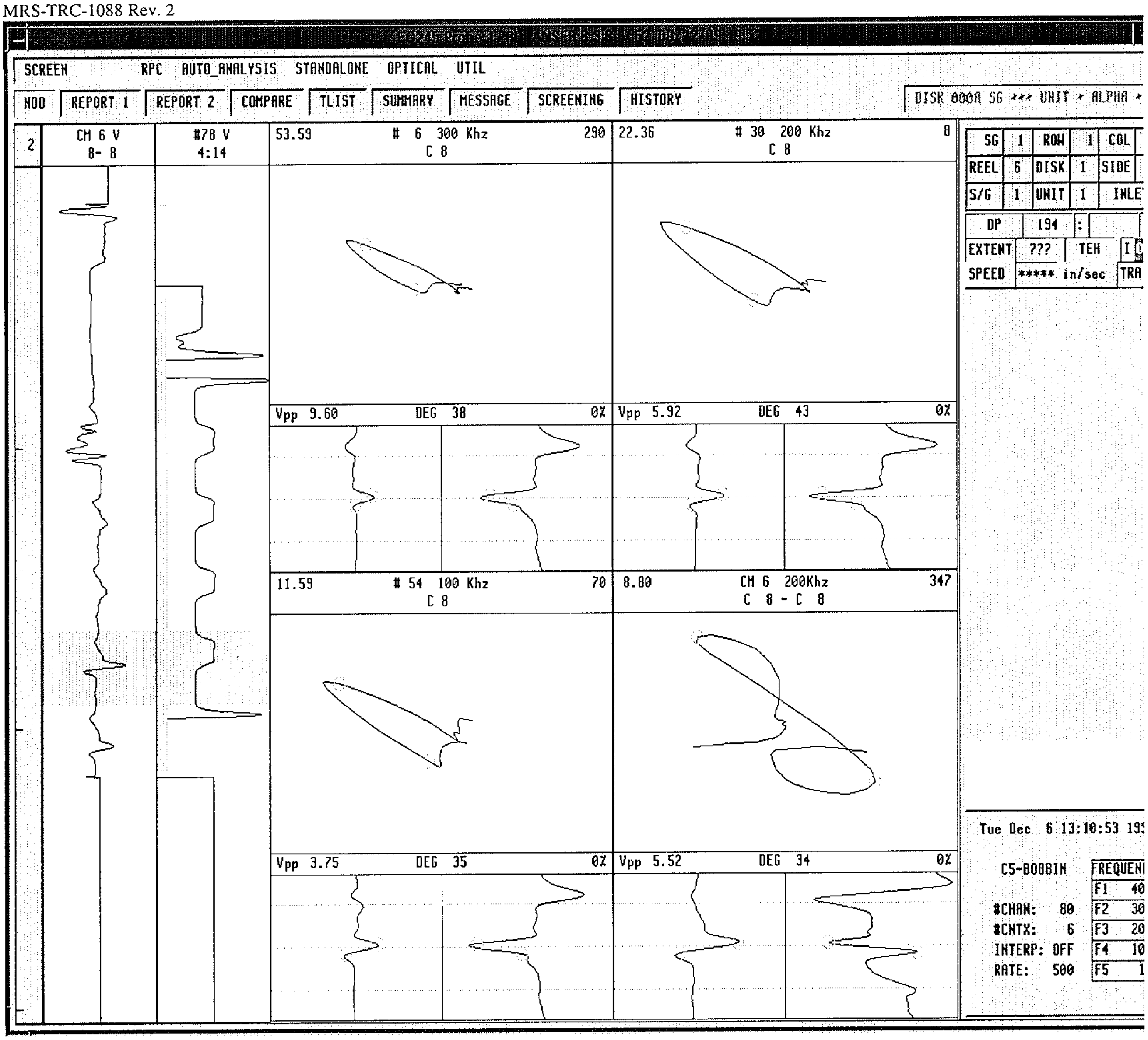


Figure 3

Dented Support Lab Sample Used to Support Westinghouse Appendix H Equivalency Qual.(Ref. K)
63% ID Axial Flaw, .040" Ovalized Dent
.680" Cecco-5 Probe

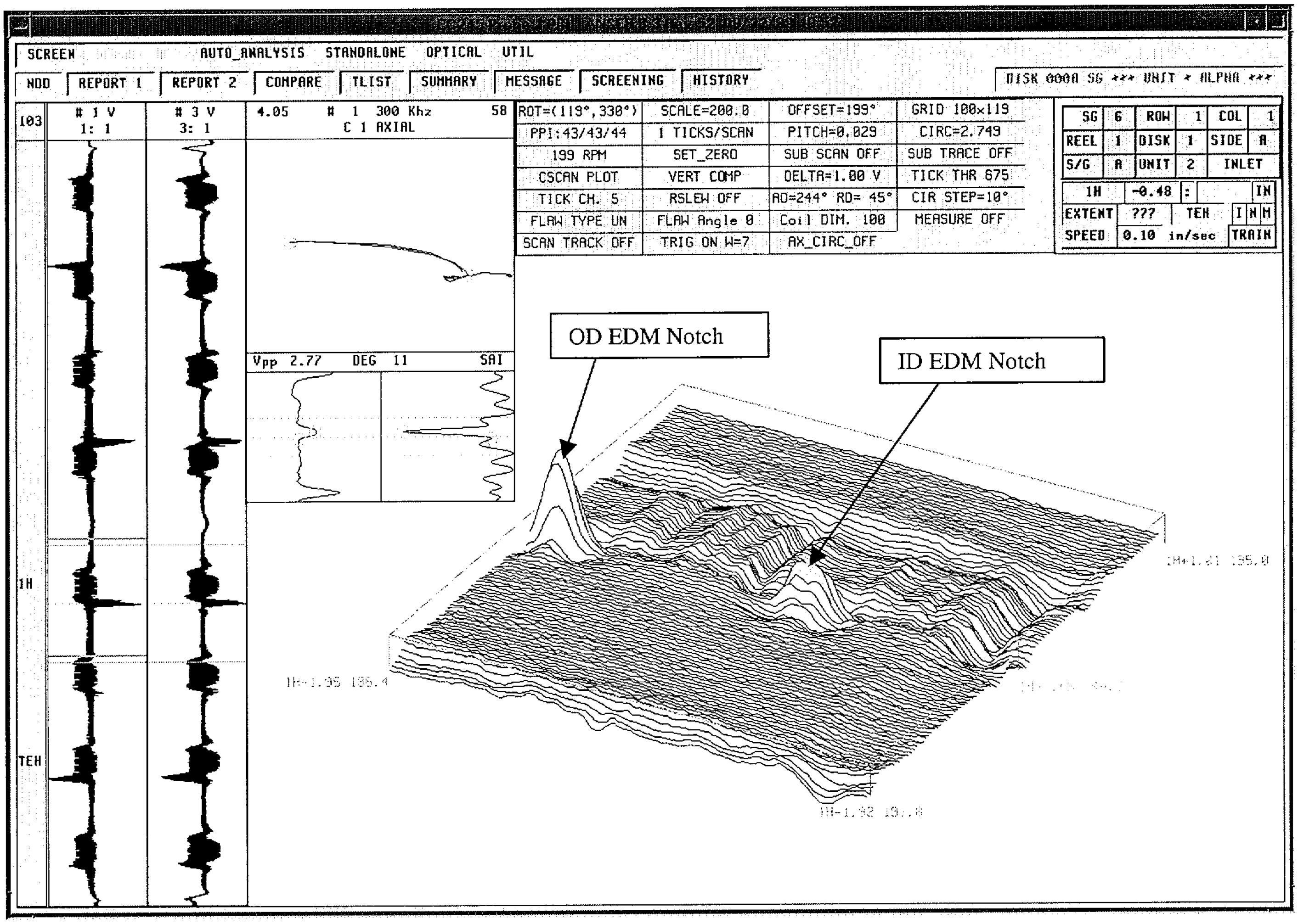


Figure 4

Dented Support Lab Sample Used to Support Westinghouse Appendix H Eqivalency Qual (Ref.K).
.610 DIP Plus Point Coil-.060" Asymmetric Dent With 68% ID Axial Notch

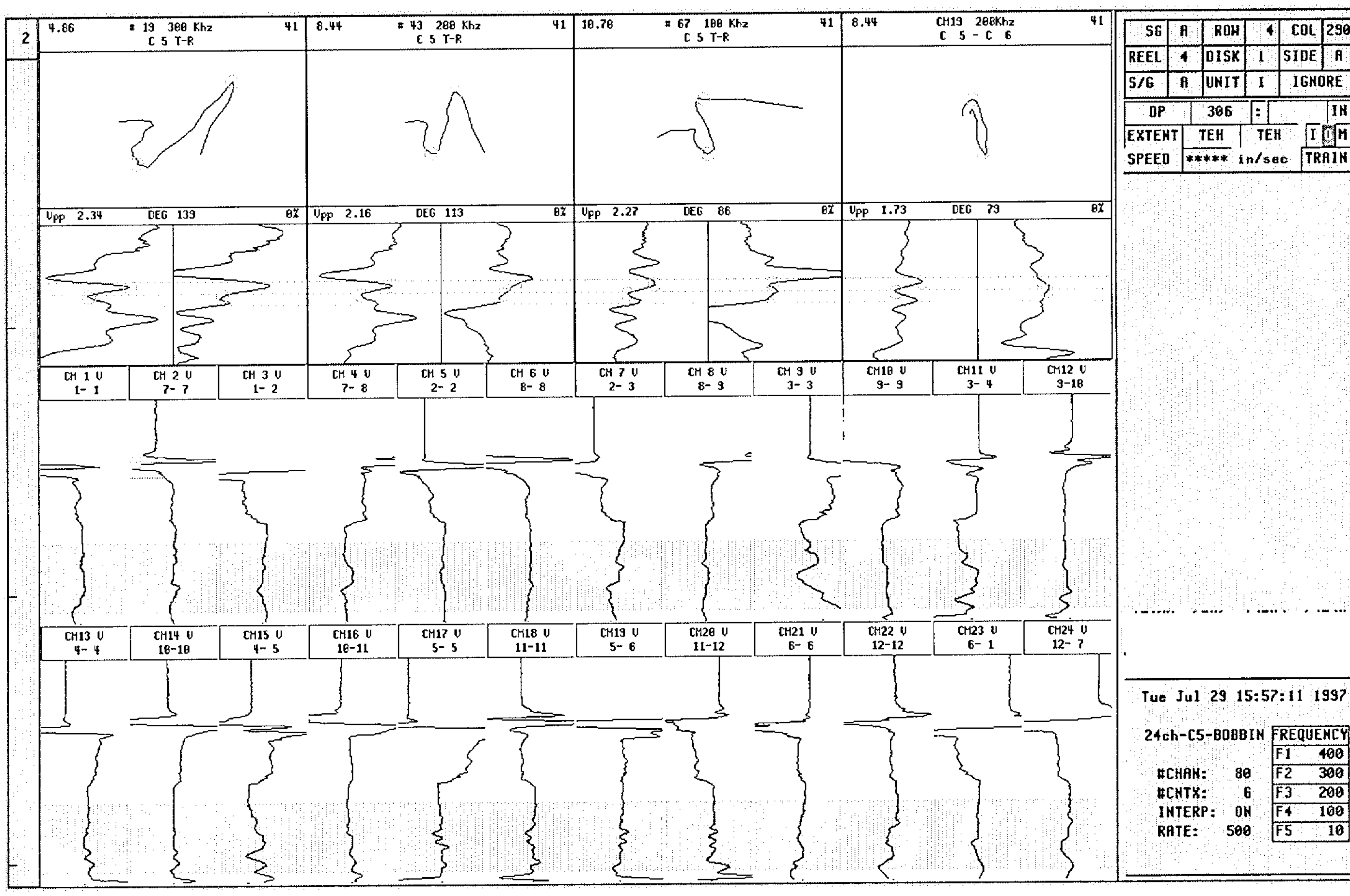


Figure 5A
Lab Sample Used to Support EPRI Appendix H Qual for Axial ODSCC in Tubesheet Crevice From Cecco-5 Probe

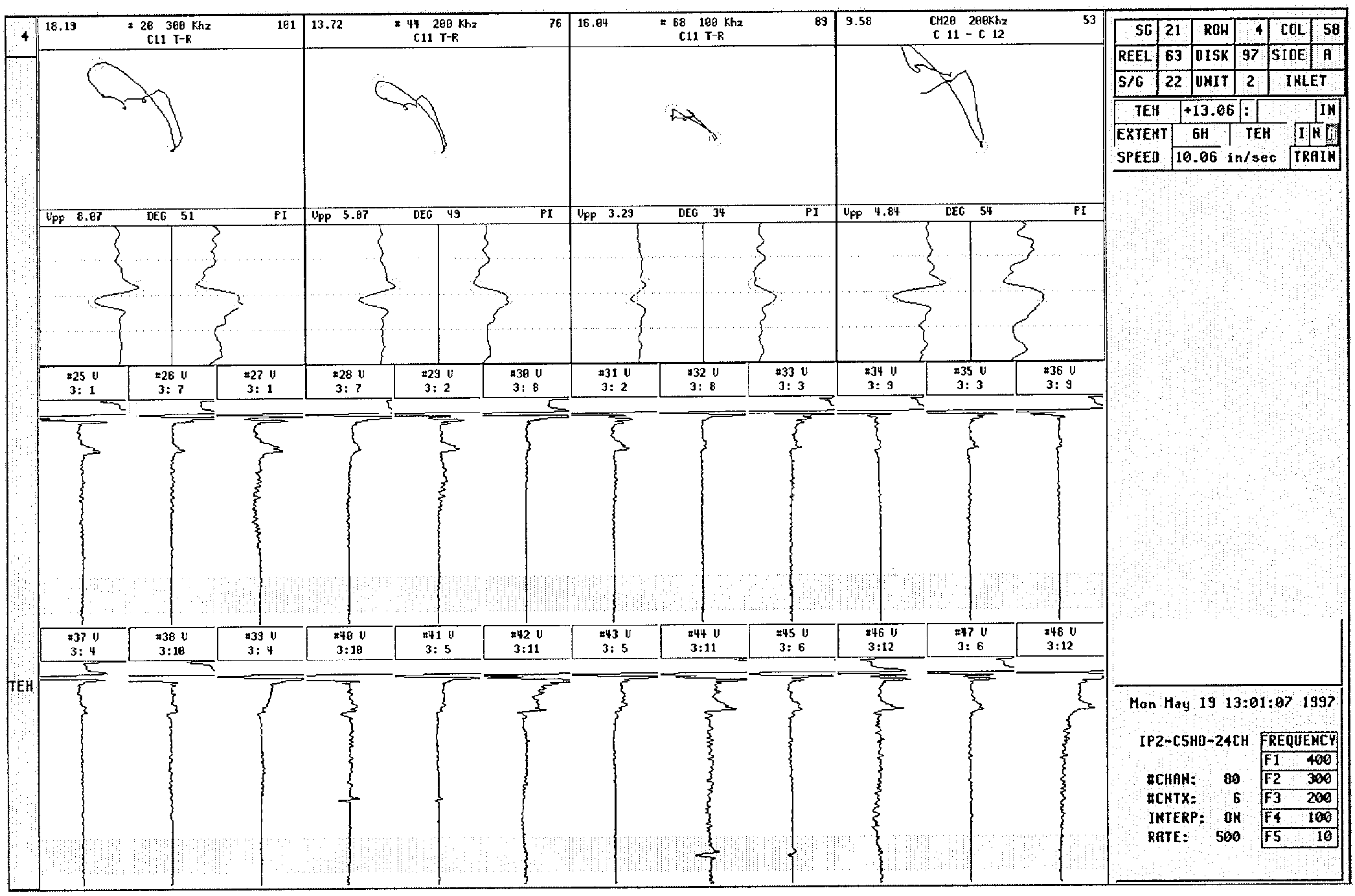


Figure 5B
Indian Point 2 In-Generator Tubesheet Crevice Indication as Reported With .680" Cecco-5 Probe Characterized with + Point Probe as OD Axial Flaw

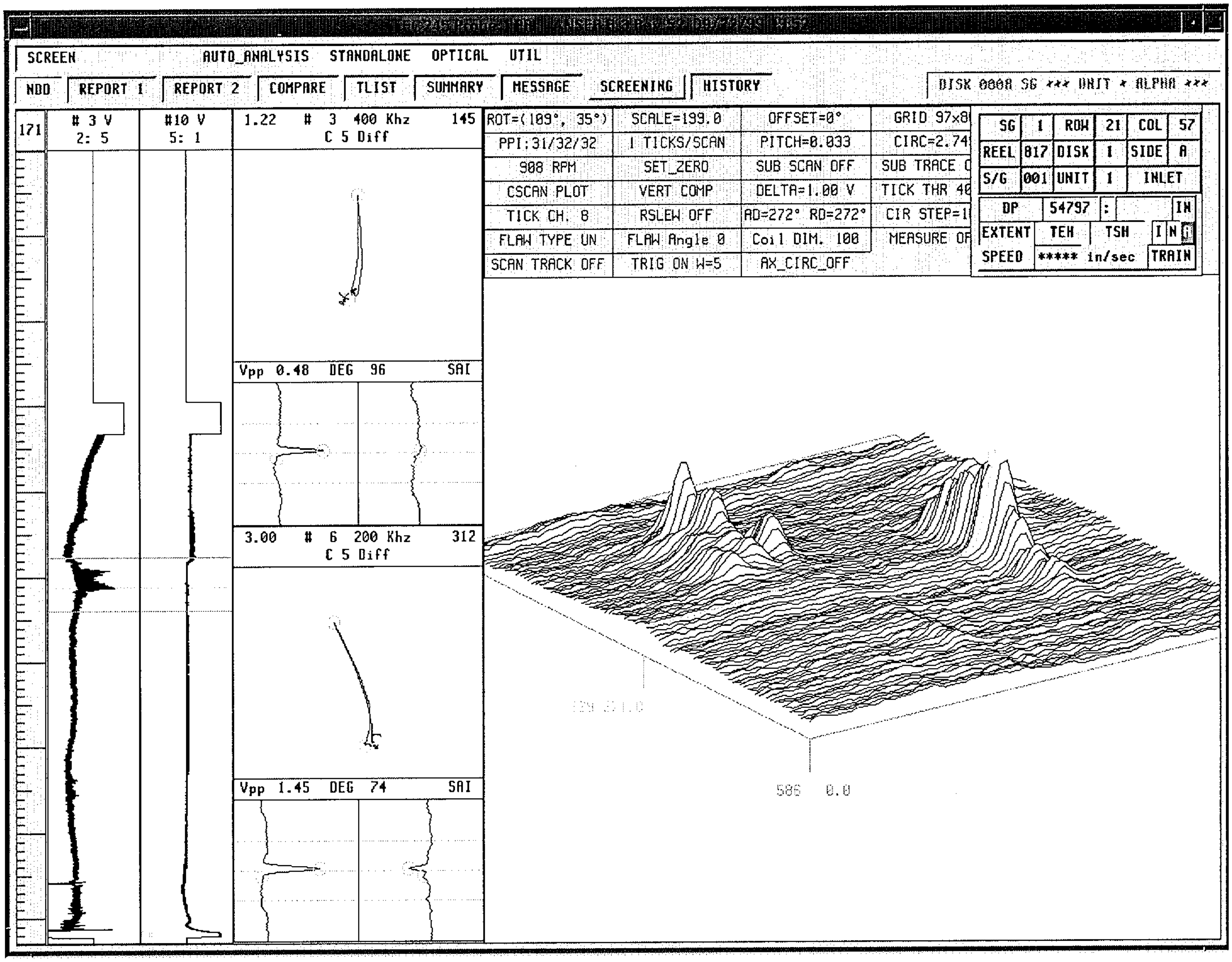


Figure 6A

1996 Tube Pull from Zion 2 with Crevice IGA/ODSCC- Plus Point Probe

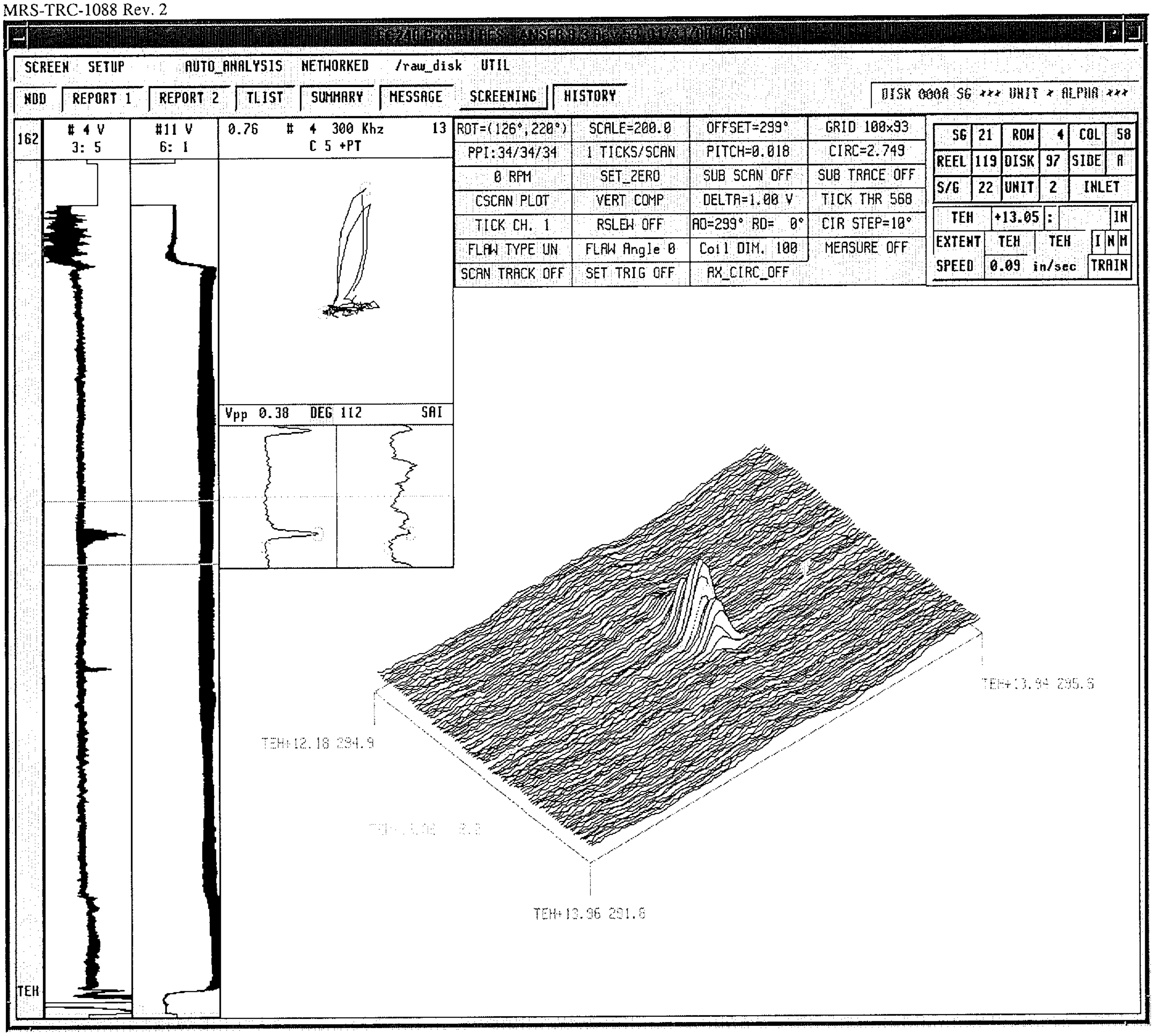


Figure 6B
Indian Point 2 In-Generator Tubesheet Crevice OD Axial Indication as Reported with Plus Point Probe

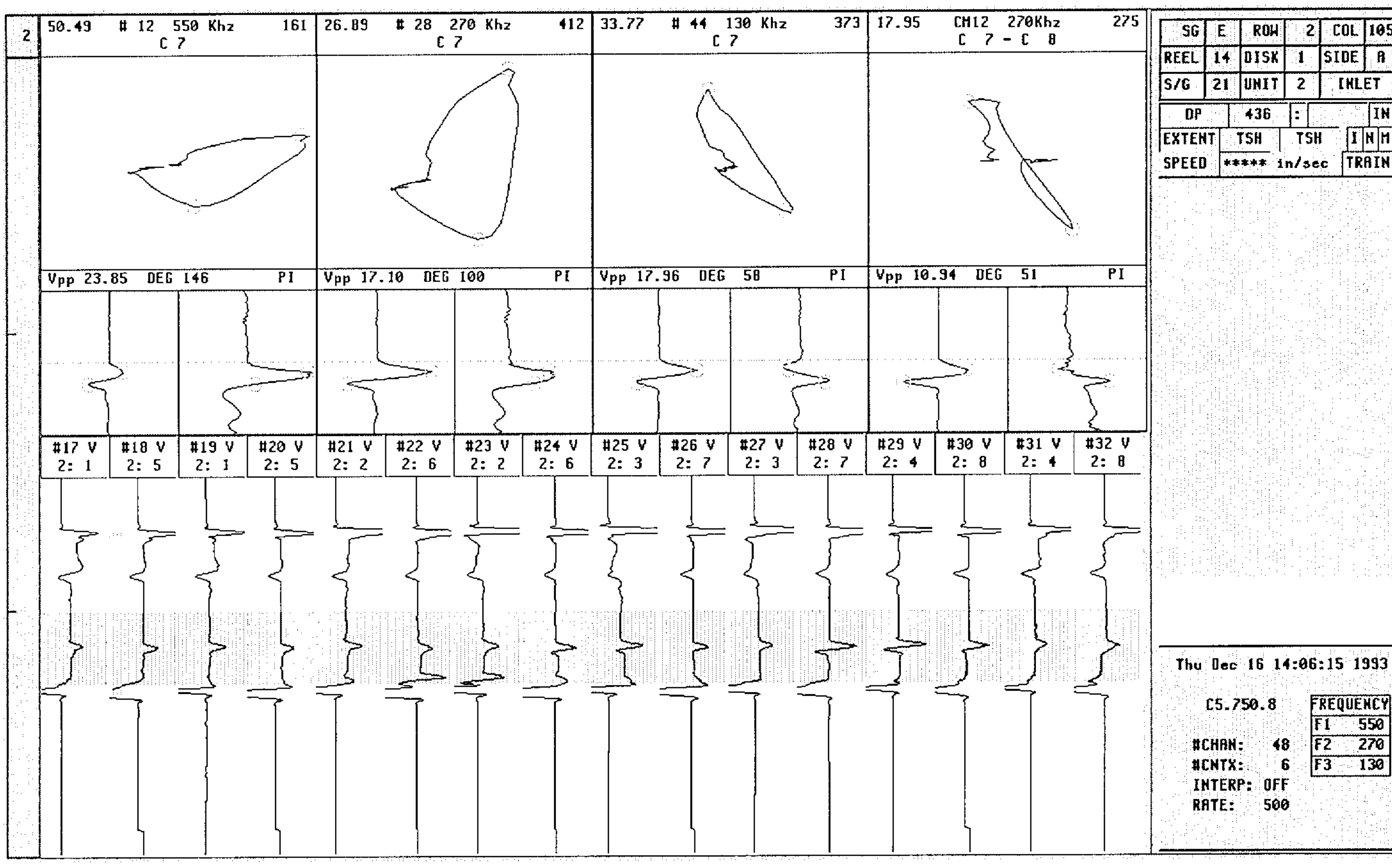


Figure 7A
Lab Sample Used to Support EPRI Appendix H Qualification for Roll Transition Axial PWSCC
Cecco-5 Probe

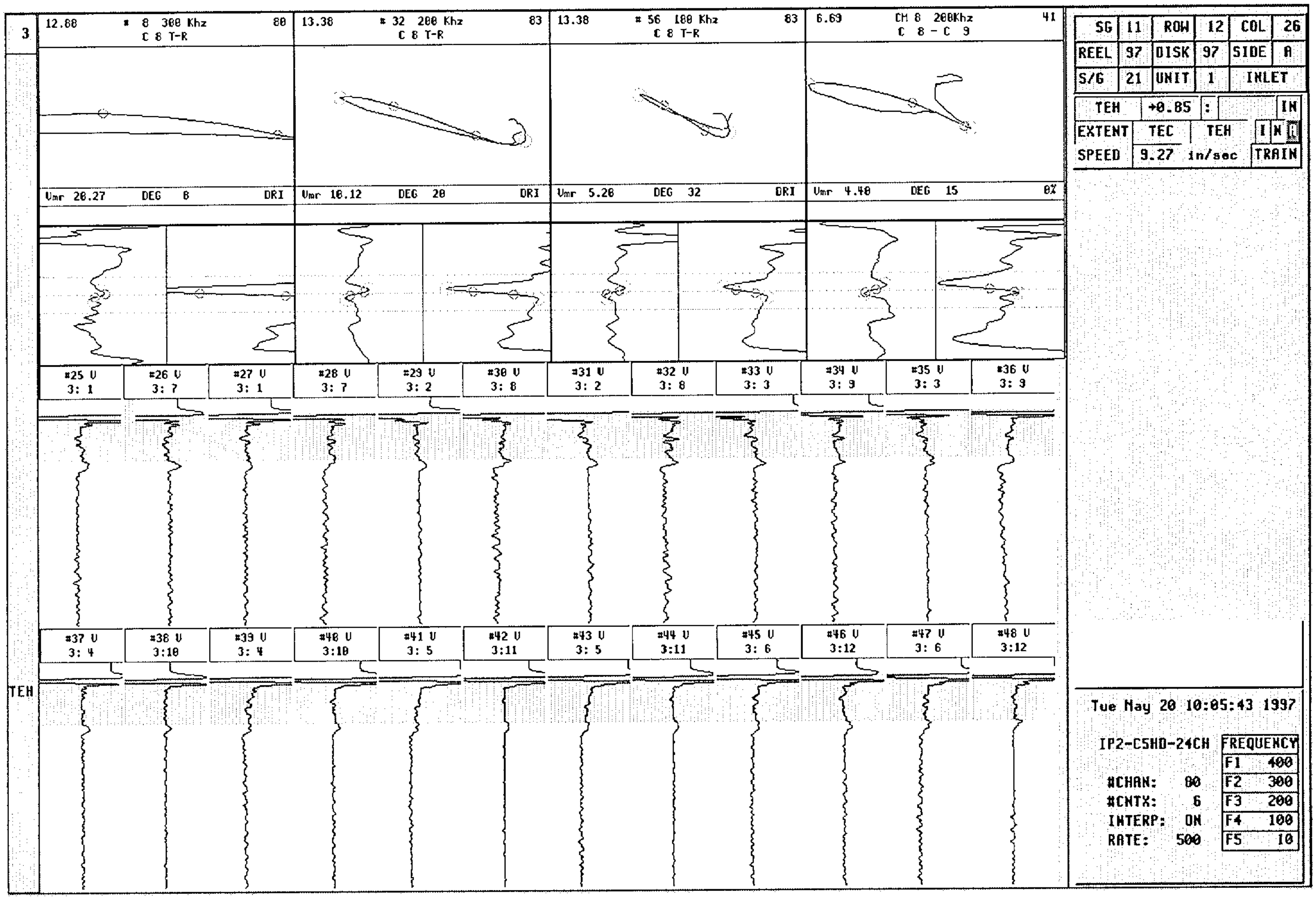


Figure 7B
In-Generator Signal at Indian Point 2 at Roll Transition Reported From Cecco-5 Probe Confirmed With Plus Point as ID Axial Indication

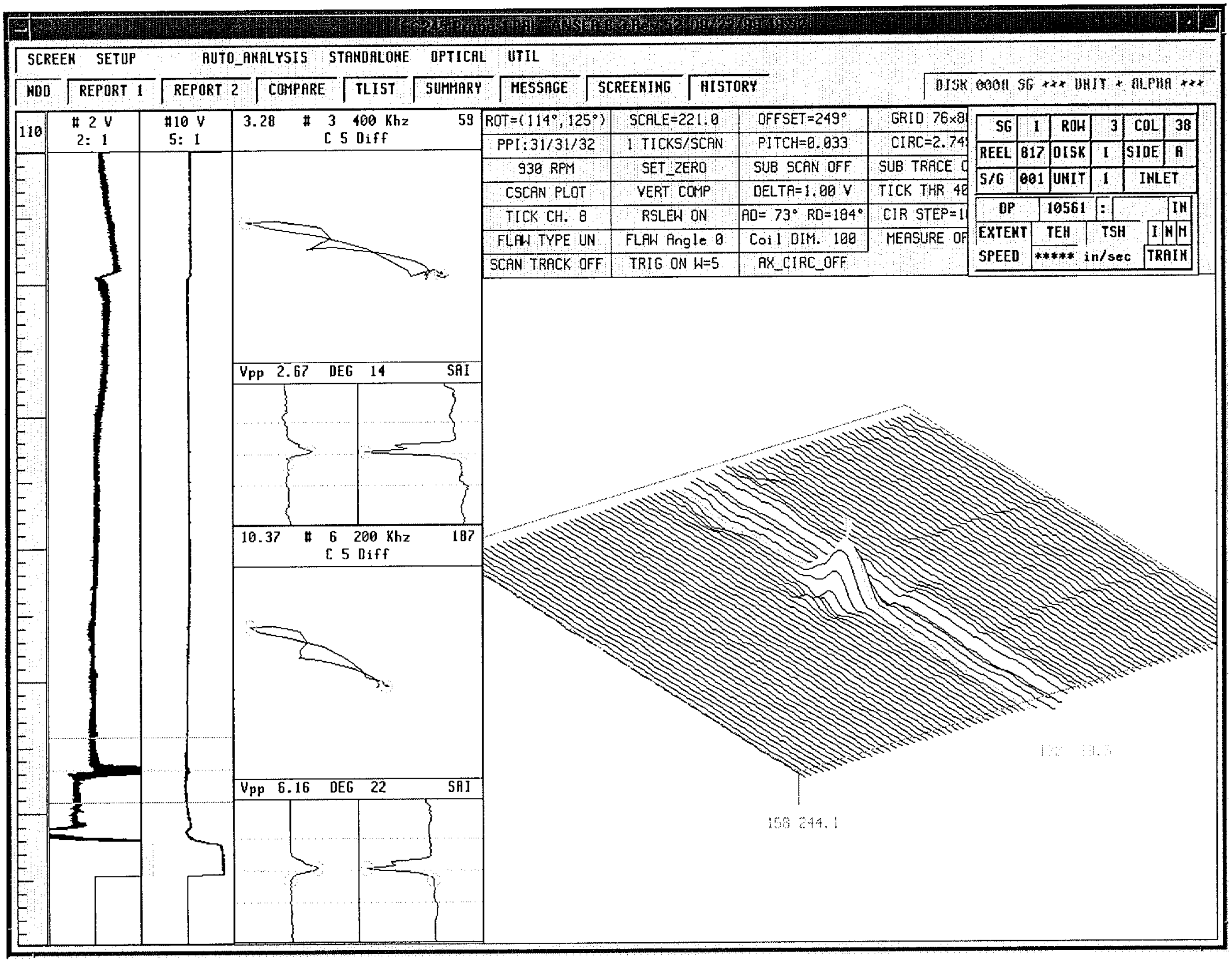


Figure 8A
1996 Tube Pull From Zion 2 with Axial PWSCC in Roll Transition
Plus Point Probe

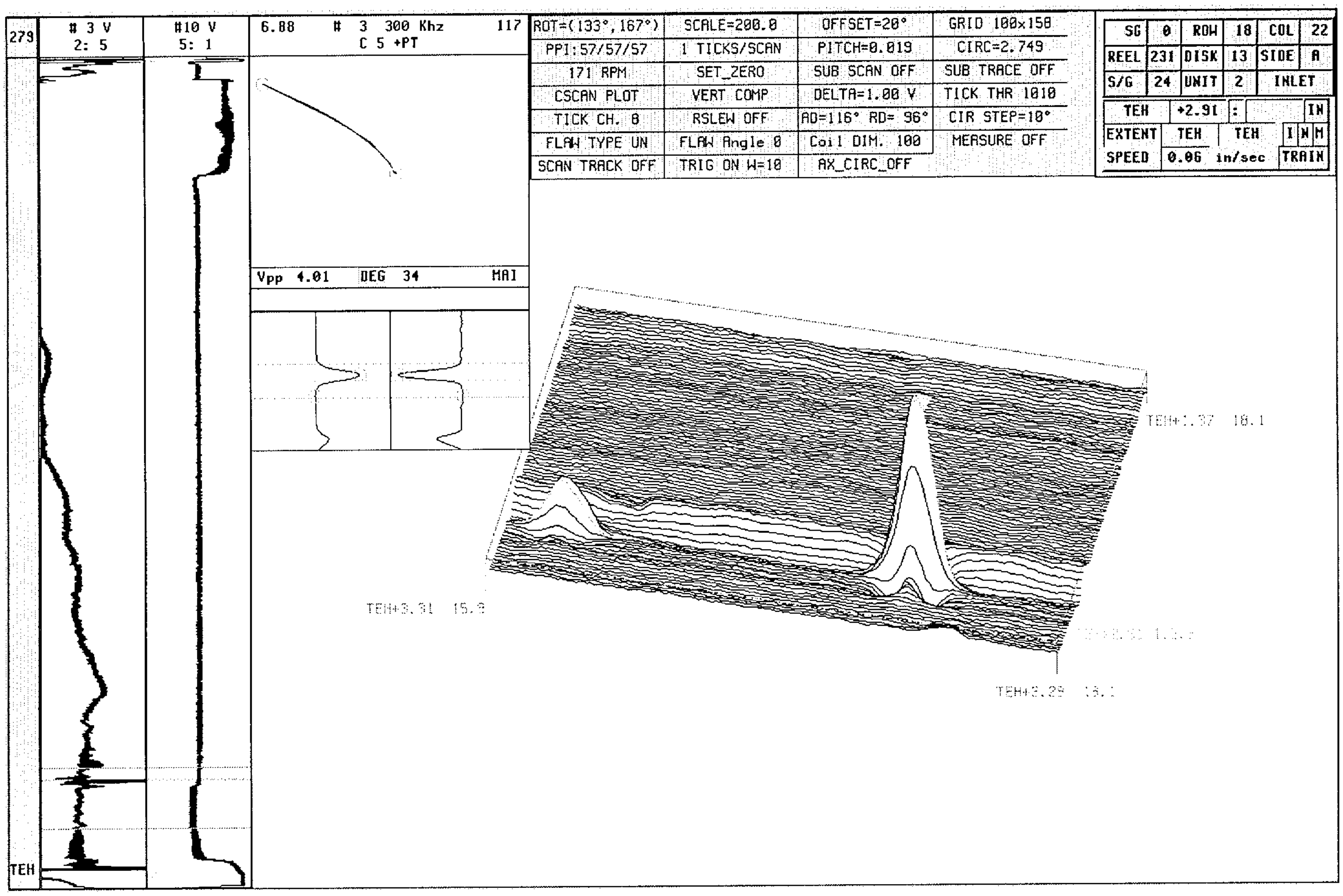


Figure 8B
ID Axial Indication Reported at Indian Pt. 2 with Plus Point in Roll Transition

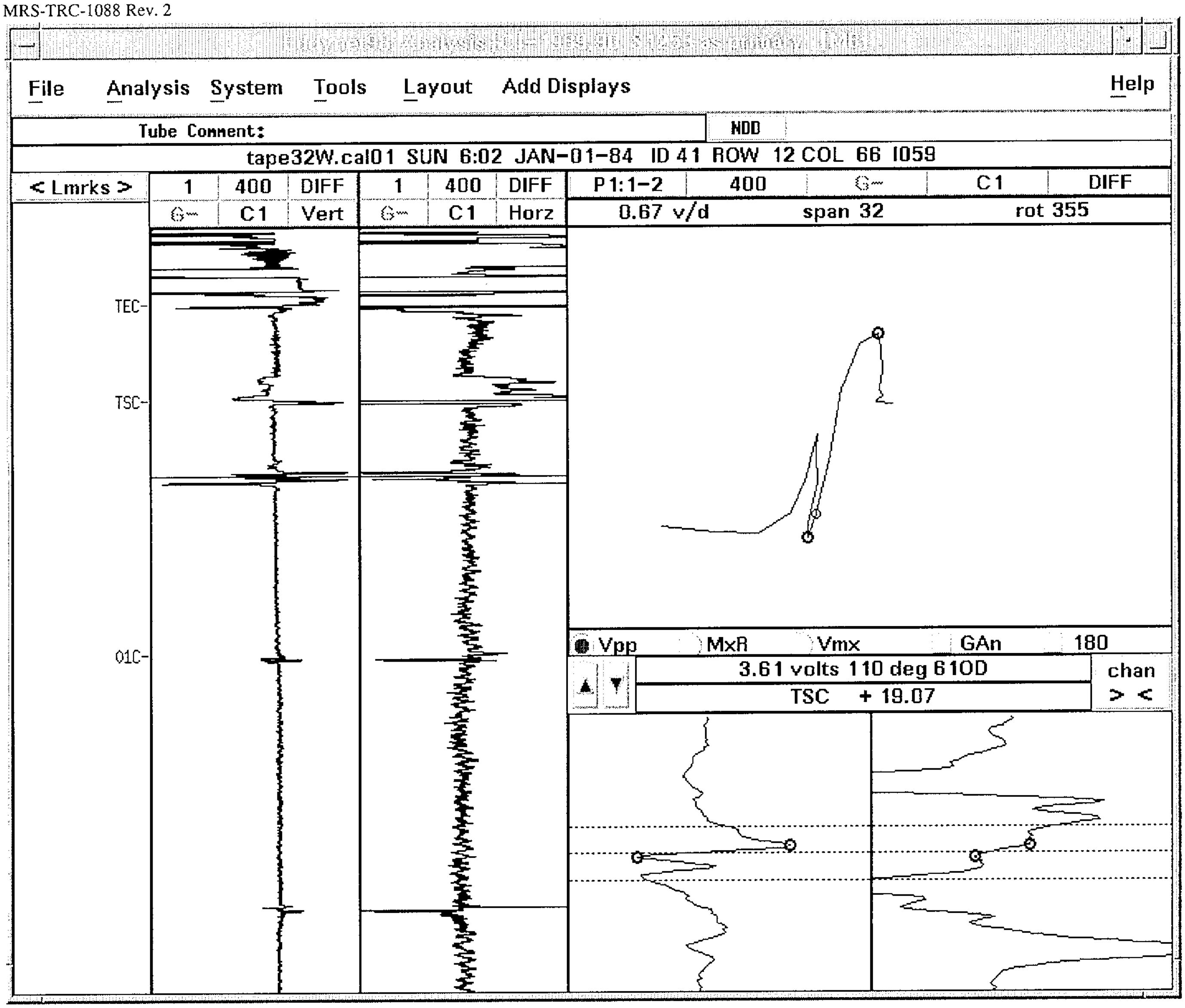


Figure 9A
Tube Pull From Original S/G at Indian Pt. 3 Confirmed as OD Pitting Above Tubesheet-60% Max. Depth
Bobbin Probe

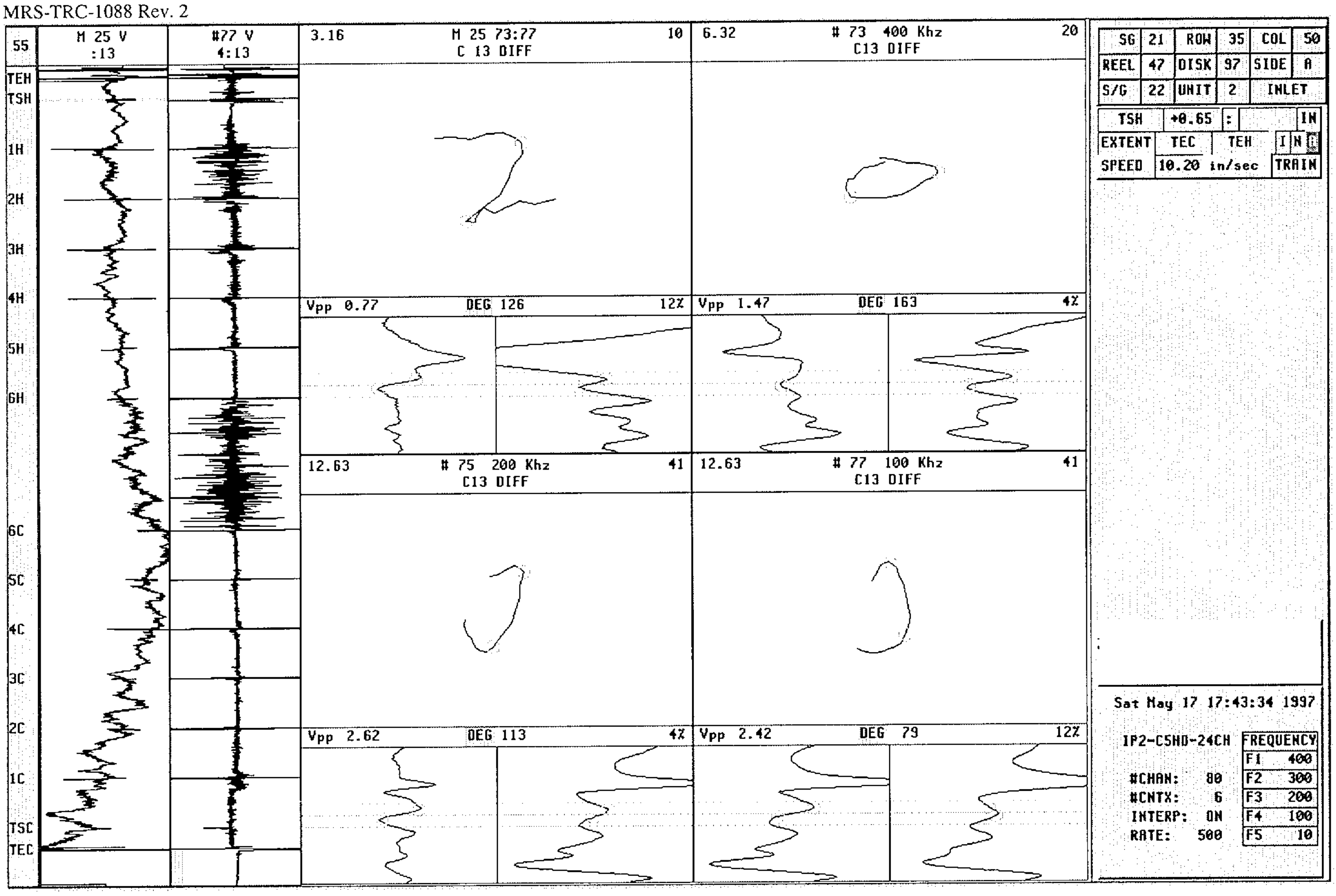


Figure 9B
In-Generator OD Pitting Indication Reported at Indian Point 2 from Bobbin Probe

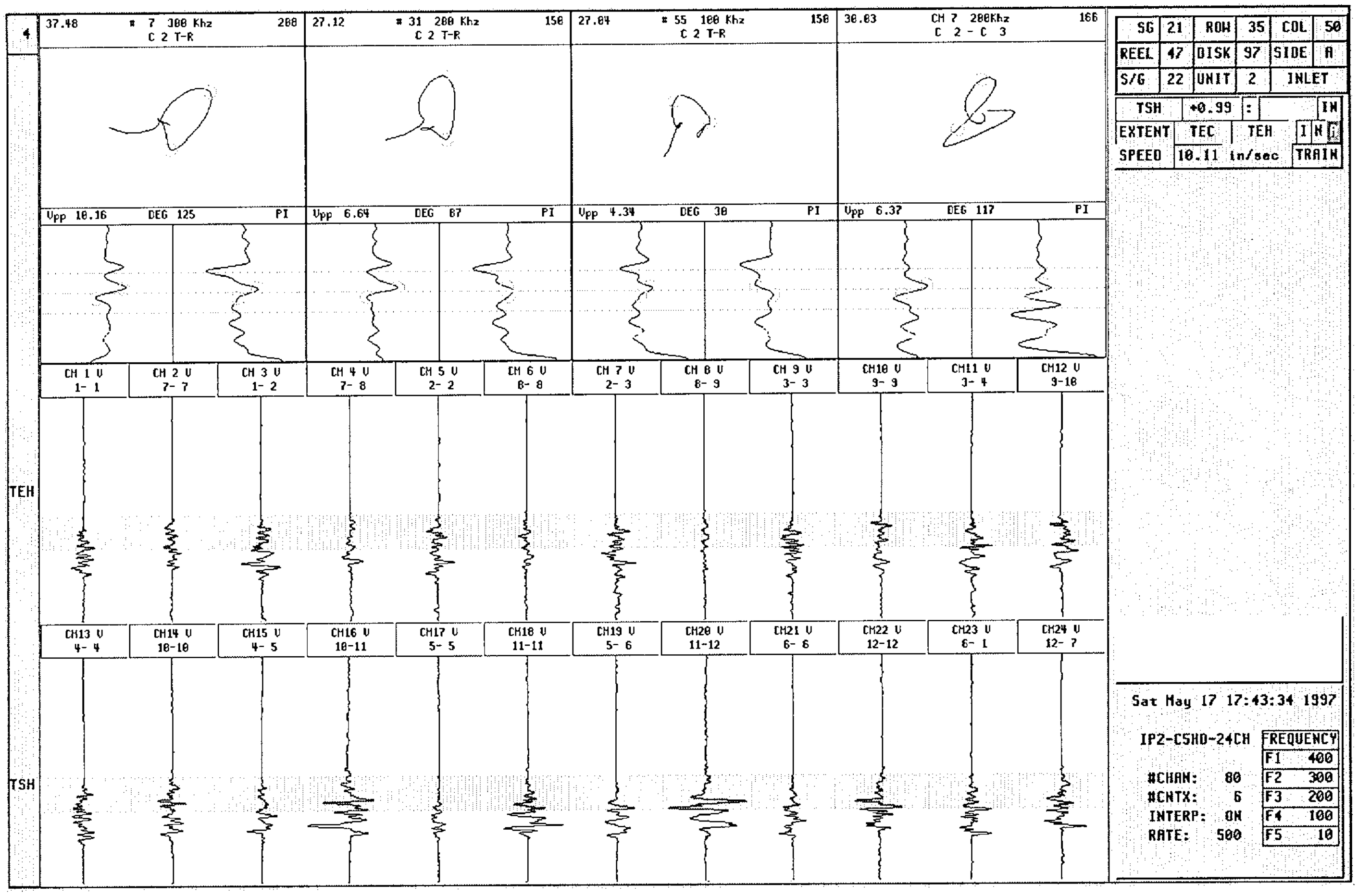


Figure 9C
In-Generator OD Pitting Indication Reported at Indian Point 2 from Cecco-5 Coils

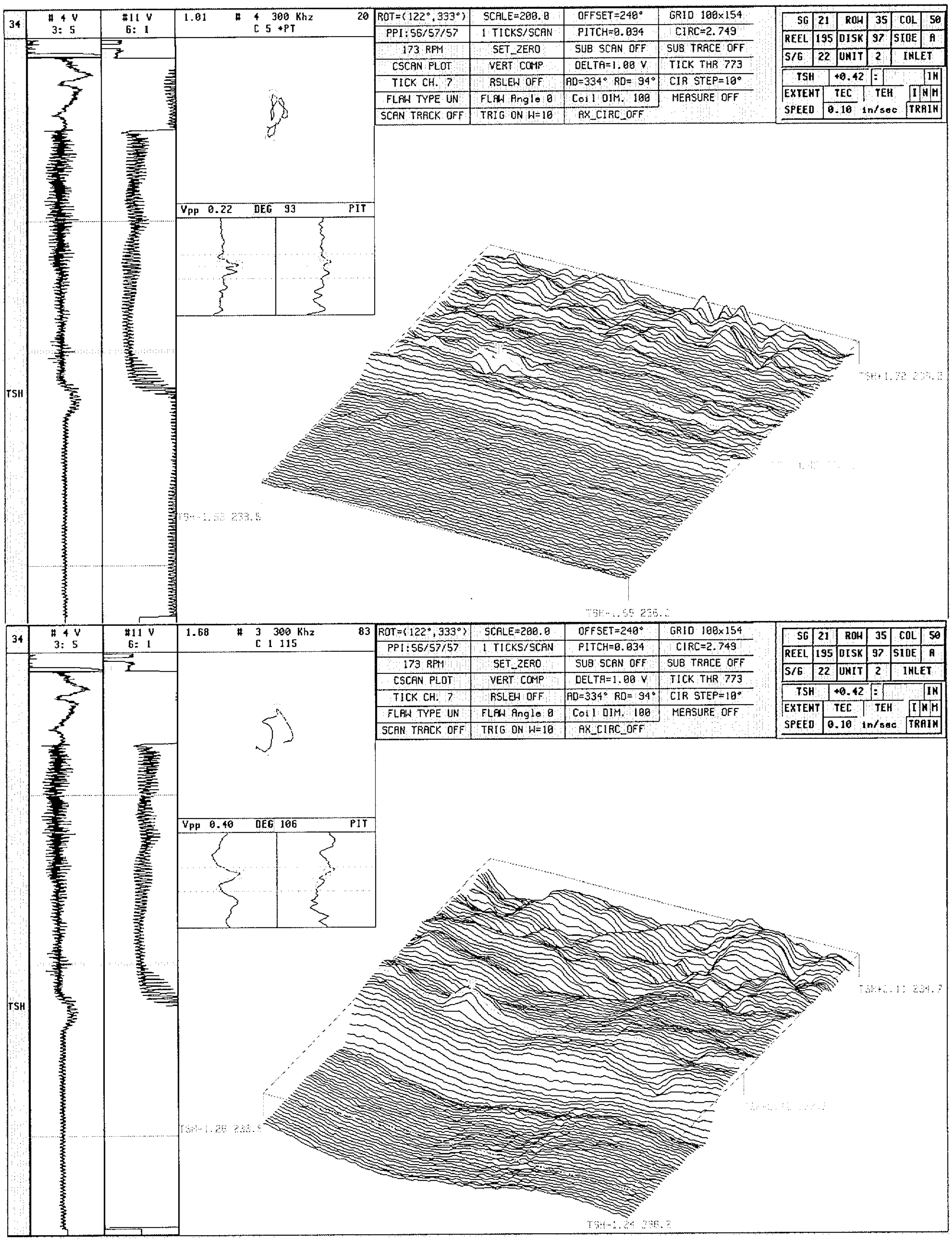


Figure 9D

In-Generator OD Pitting Indication Reported at Indian Point 2 from +Pt (**top**) and 115 mil pancake (**bottom**).

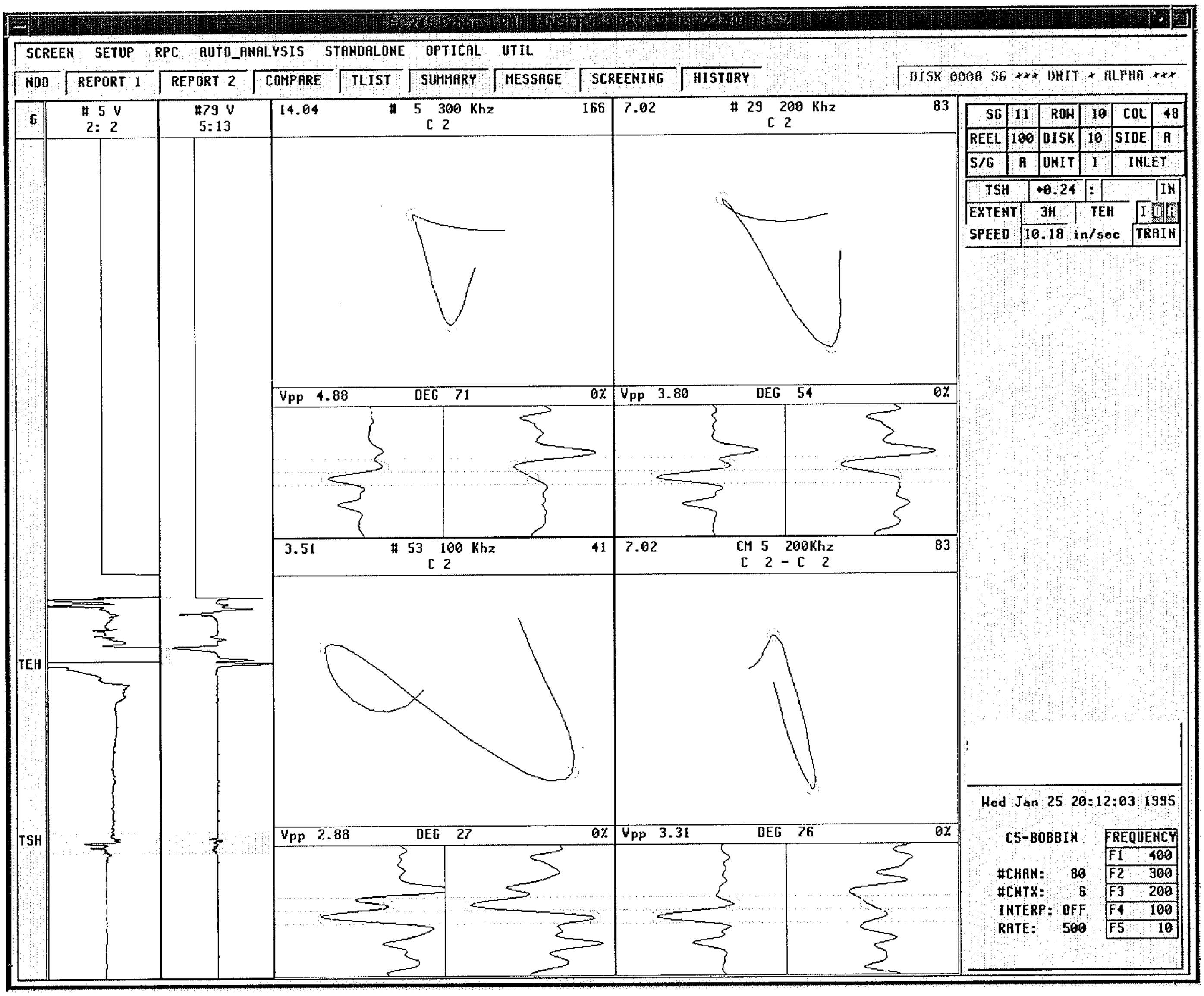


Figure 10A

1995 Tube Pull From Beaver Valley 1 With Axial ODSCC in Sludge Pile Region Above Tubesheet
Cecco-5 Probe

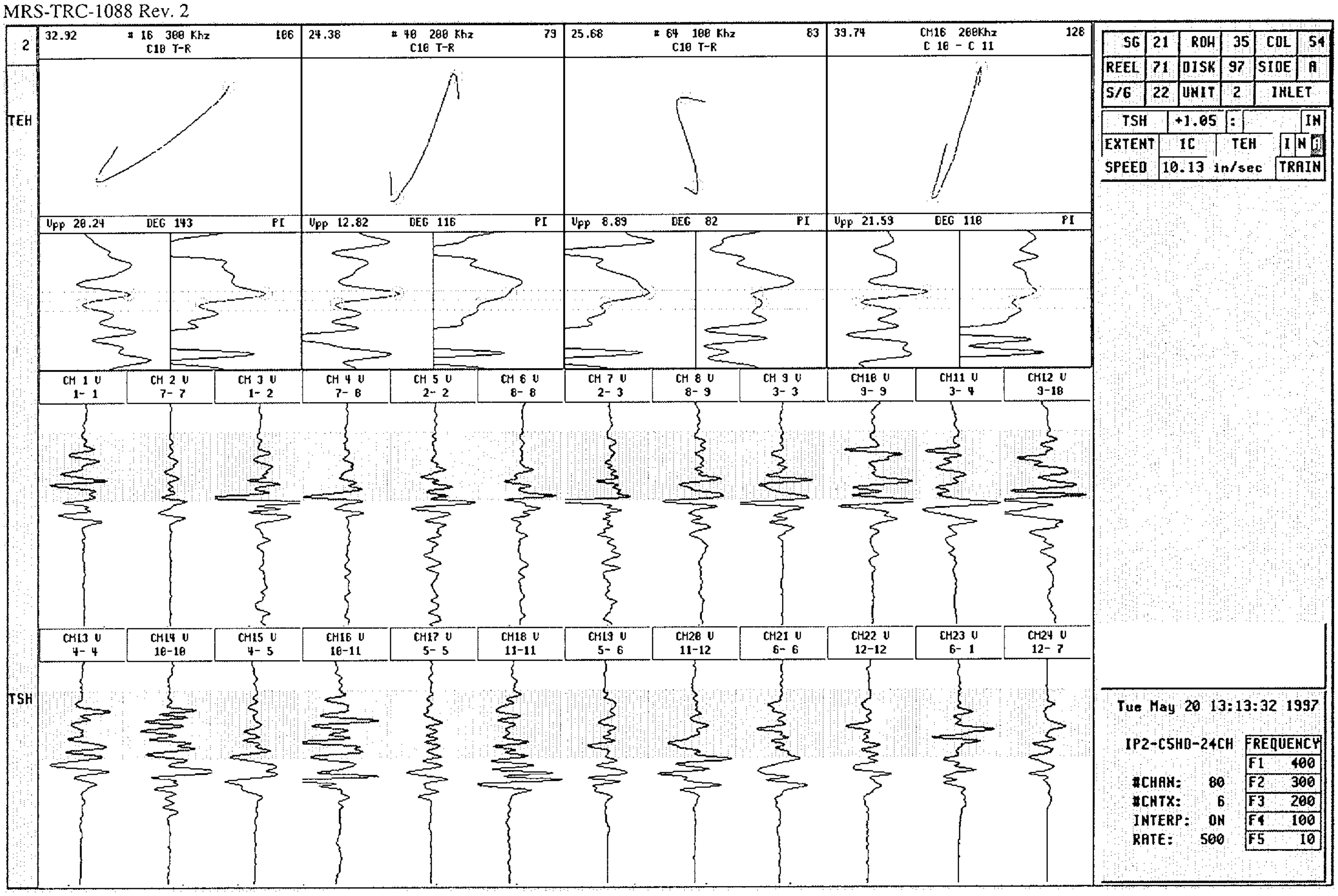


Figure 10B
In-Generator Signal Reported by Cecco-5 Probe at Indian Point 2 in Sludge Pile Above Tubesheet Characterized by Plus Point Probe as OD Axial Indication

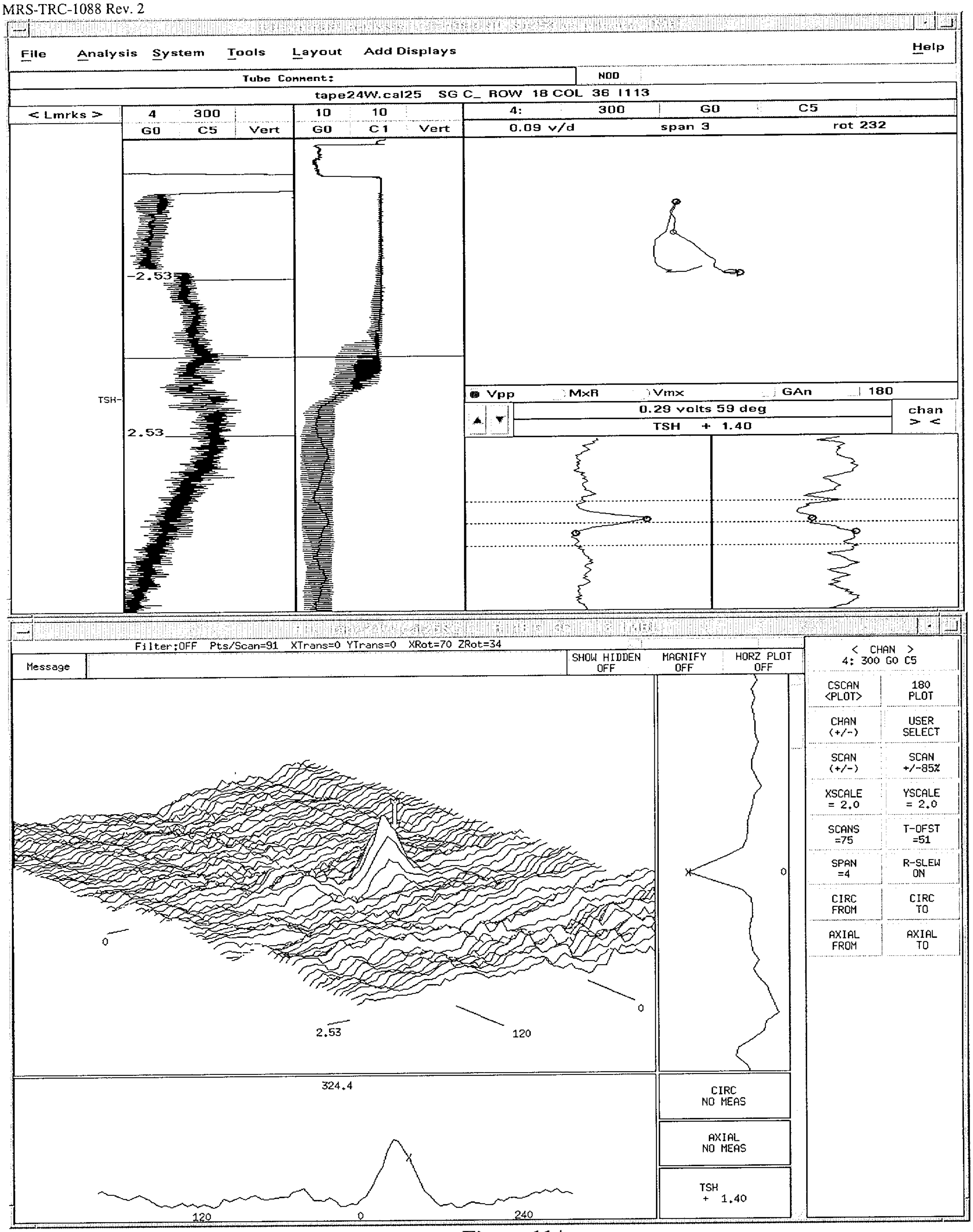


Figure 11A

1996 Tube Pull From Beaver Valley Confirmed as Axial ODSCC in Sludge Pile Region With Plus Point Probe (51% max depth)

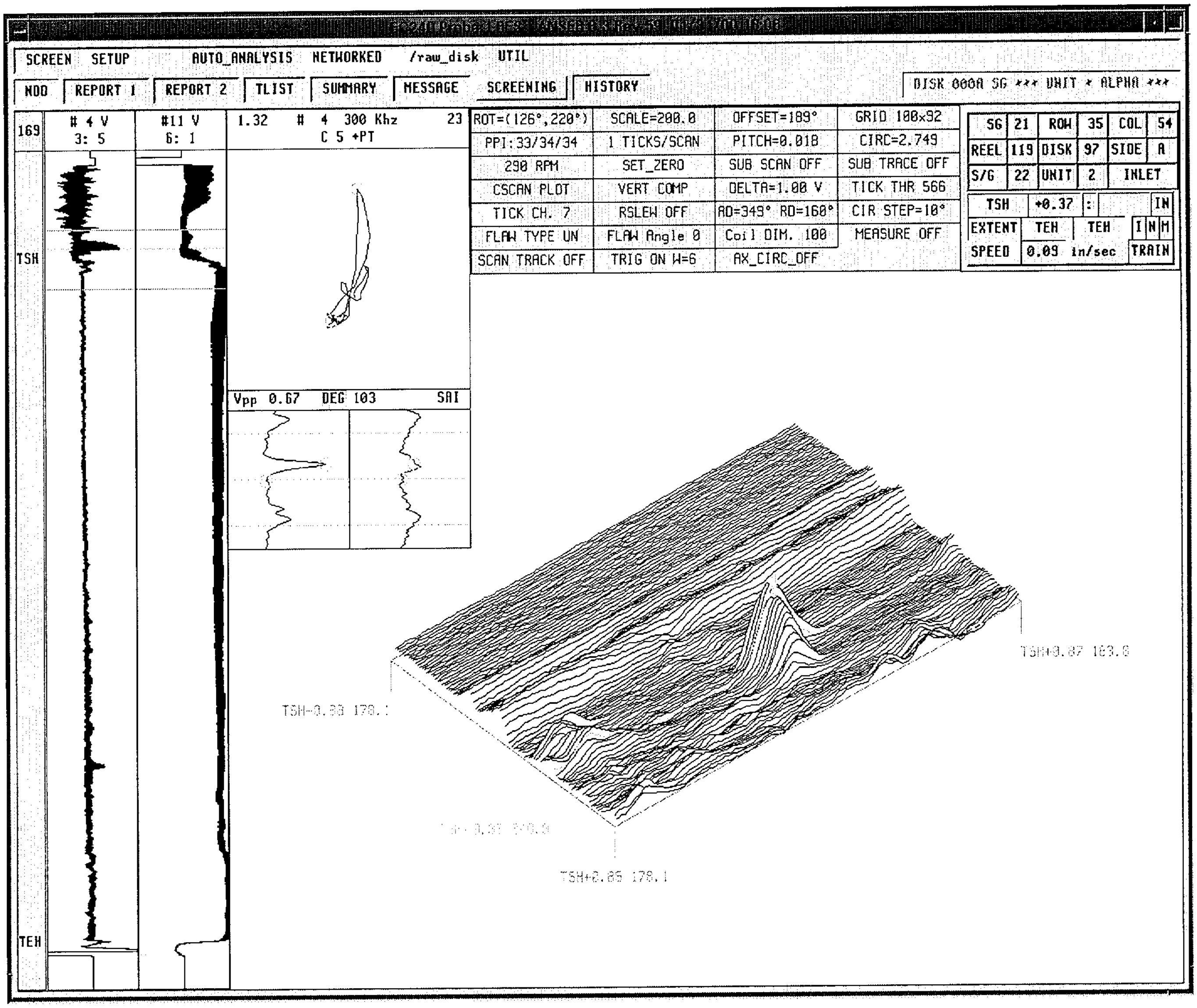


Figure 11B
In-Generator OD Axial Indication Above the Tubesheet in Sludge Pile Region at Indian Pt. 2
Reported From Plus Point Probe

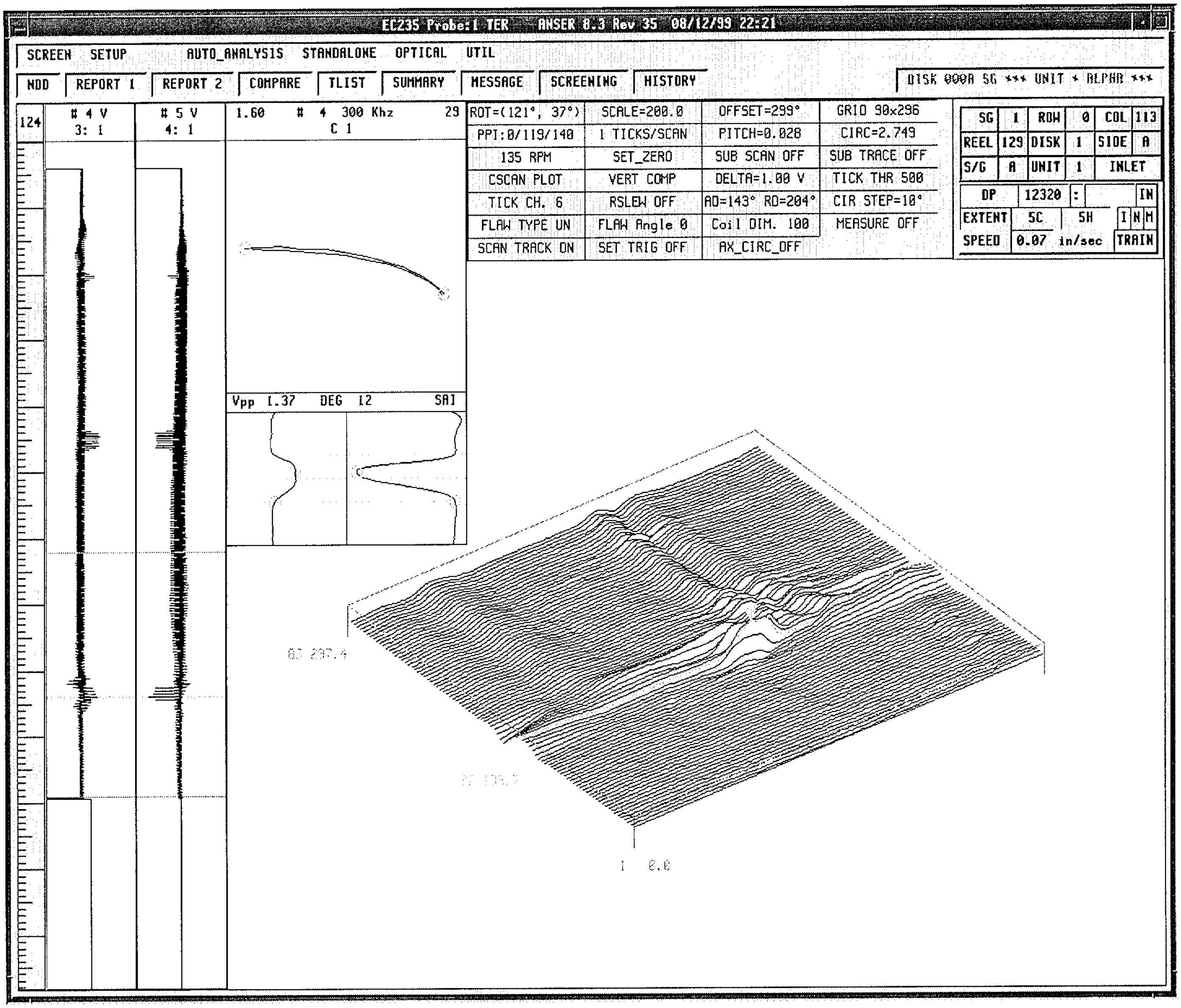


Figure 12A
Lab Sample Used to Support the EPRI Appendix H Qualification for PWSCC in a Small Radius U-bend From the Mid-Range Plus Point Probe

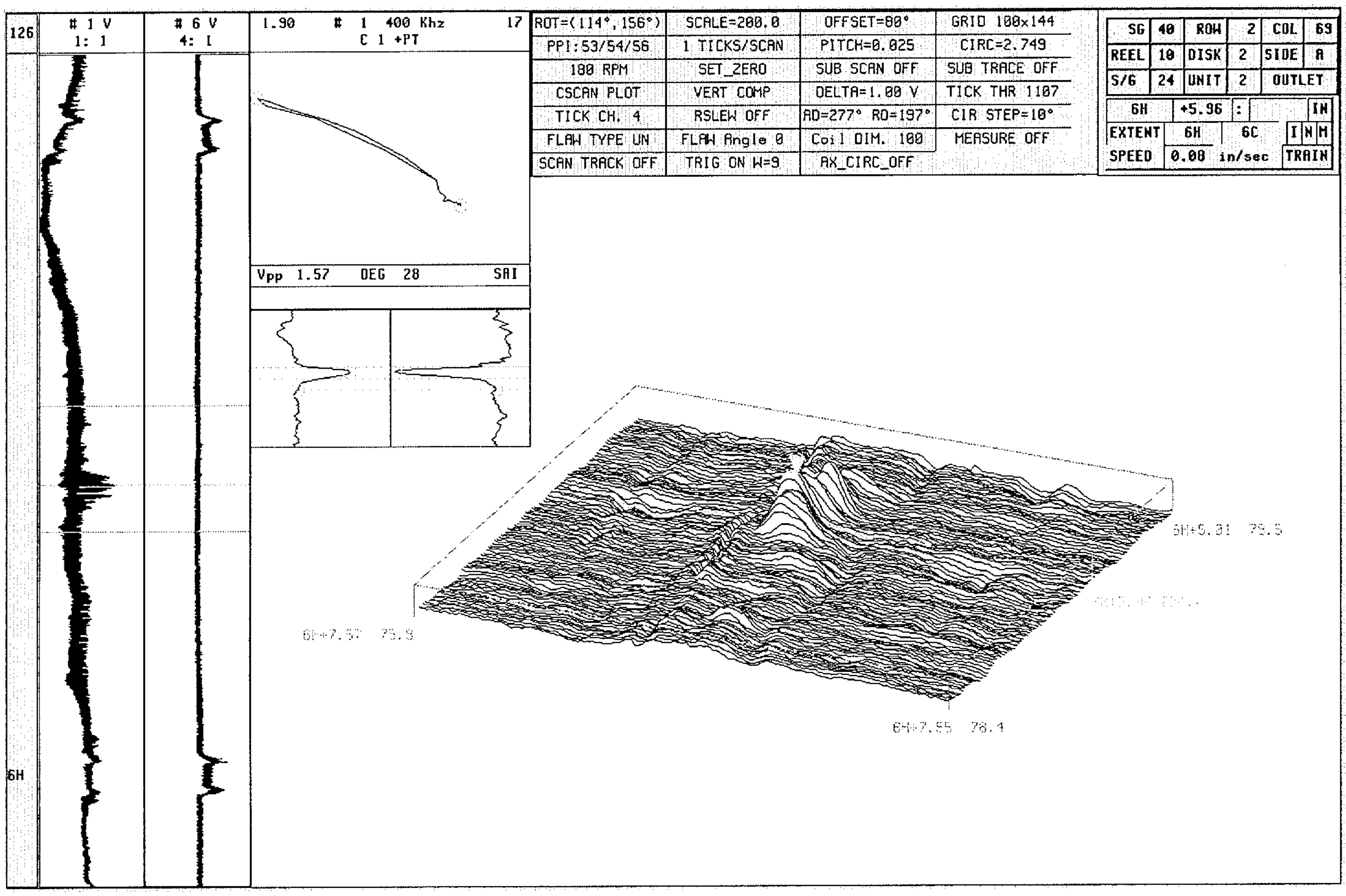


Figure 12B

In-Generator ID Axial Indication in Row 2 U-bend Reported at Indian Pont 2 From .620" Mid-Range Plus Point Probe

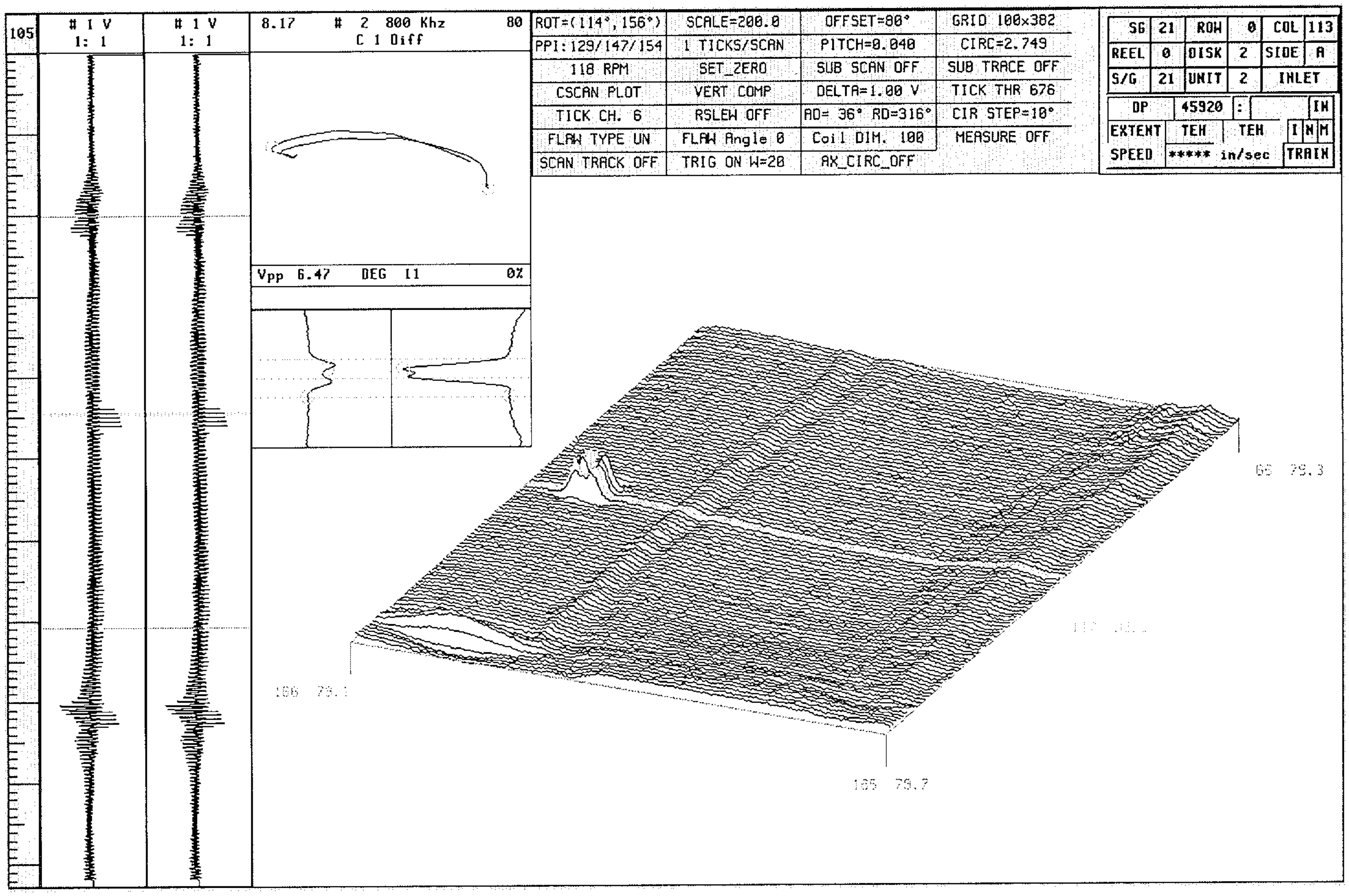


Figure 12C
Lab Sample Used to Support the EPRI Appendix H Qualification for PWSCC in a Small Radius U-bend From the High Frequency Plus Point Probe

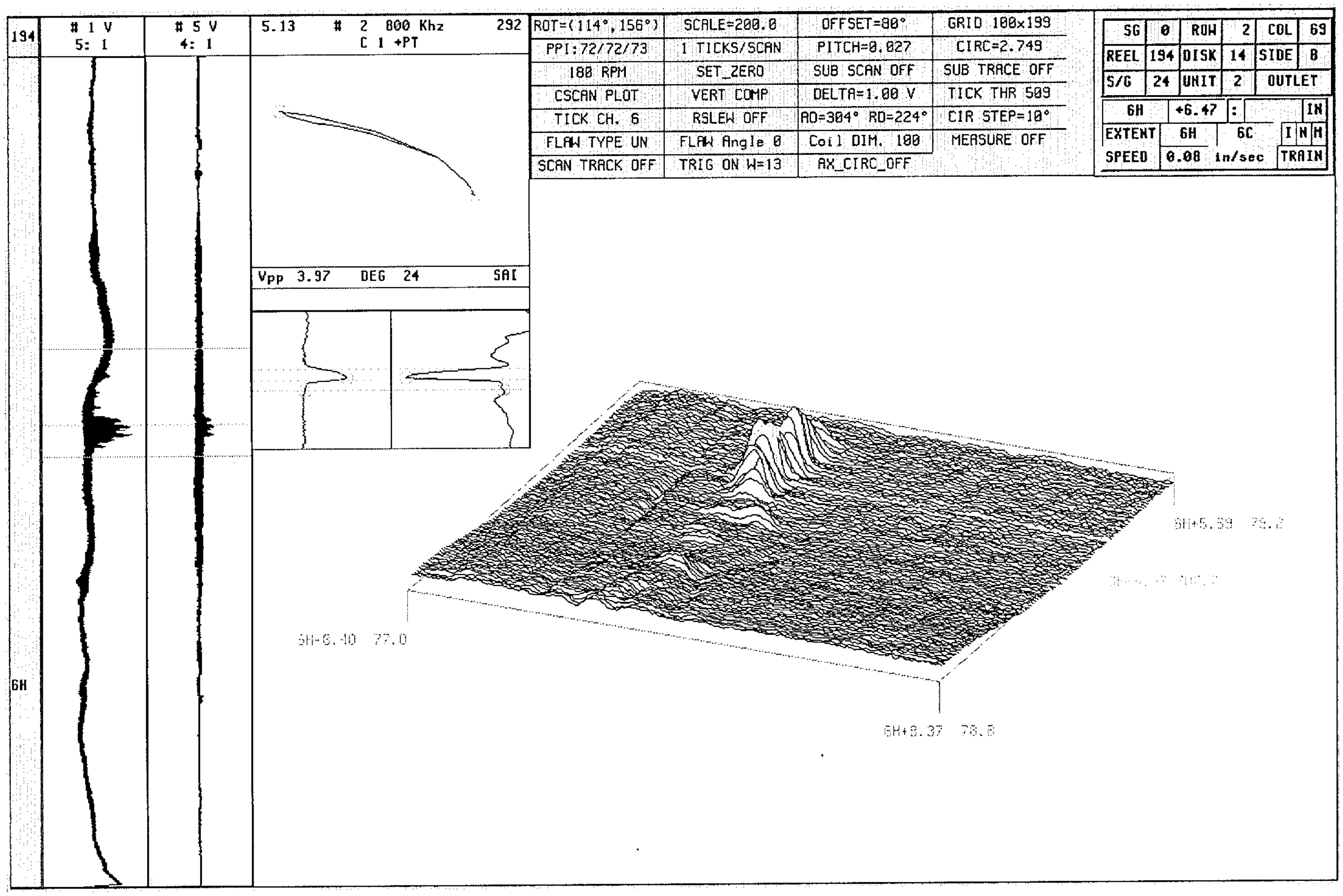


Figure 12D

In-Generator ID Axial Indication in Row 2 U-bend Reported at Indian Pont 2 From .620" High FrequencyPlus Point Probe

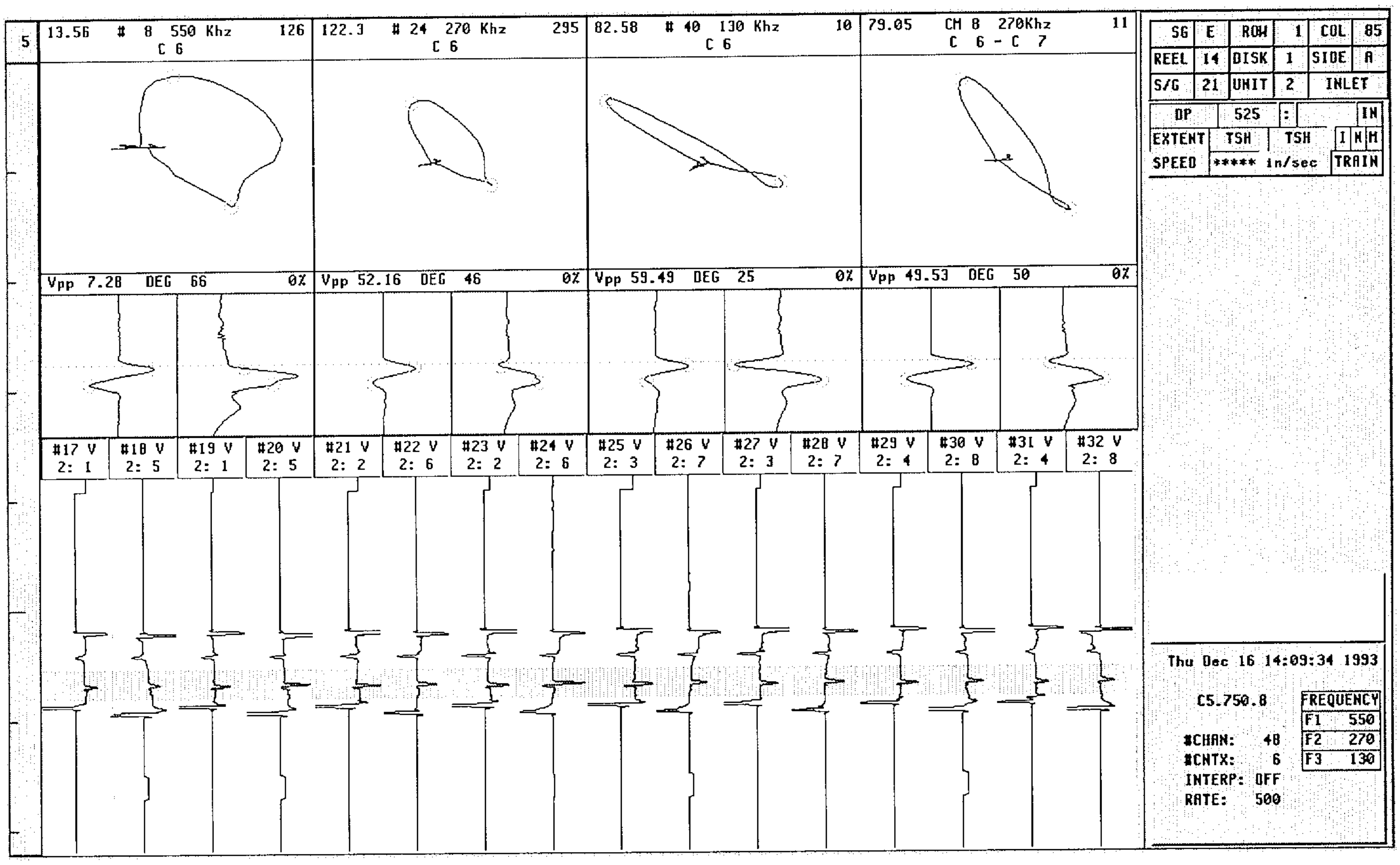


Figure 13A
Lab Sample Used to Support EPRI Appendix H Qualification for Circumferential PWSCC at Expansion Transitions With the Cecco-5 Probe

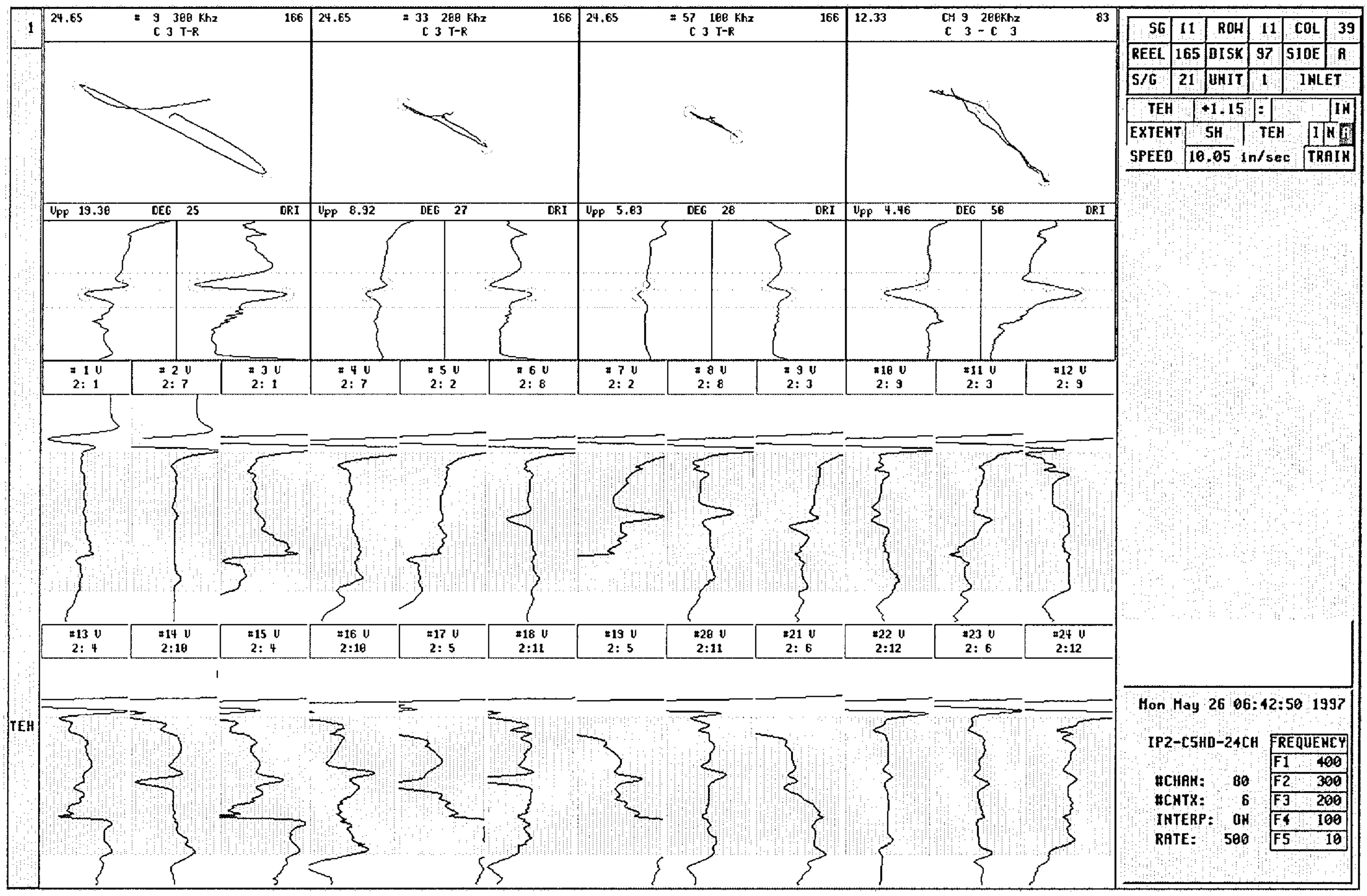


Figure 13B
In-Generator Indication in Roll Expanded Region of Tubesheet Reported at Indian Point 2 from Cecco-5 Probe Confirmed by Plus Point Probe as ID Circumferential Indication

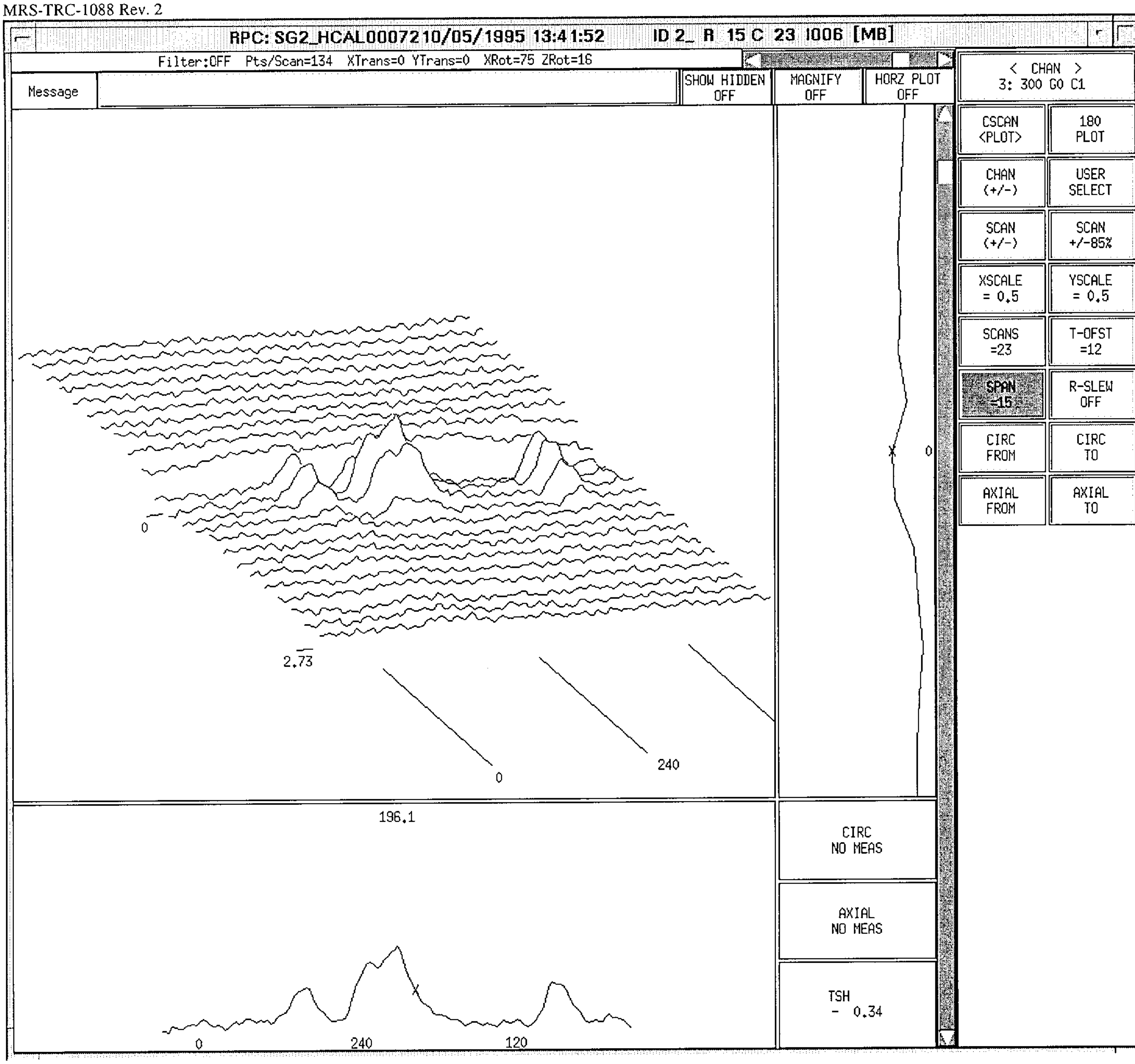


Figure 14A
1996 Sequoyah 1 Tube Pull With Circumferential PWSCC in Expansion Transition Using Plus Point Probe

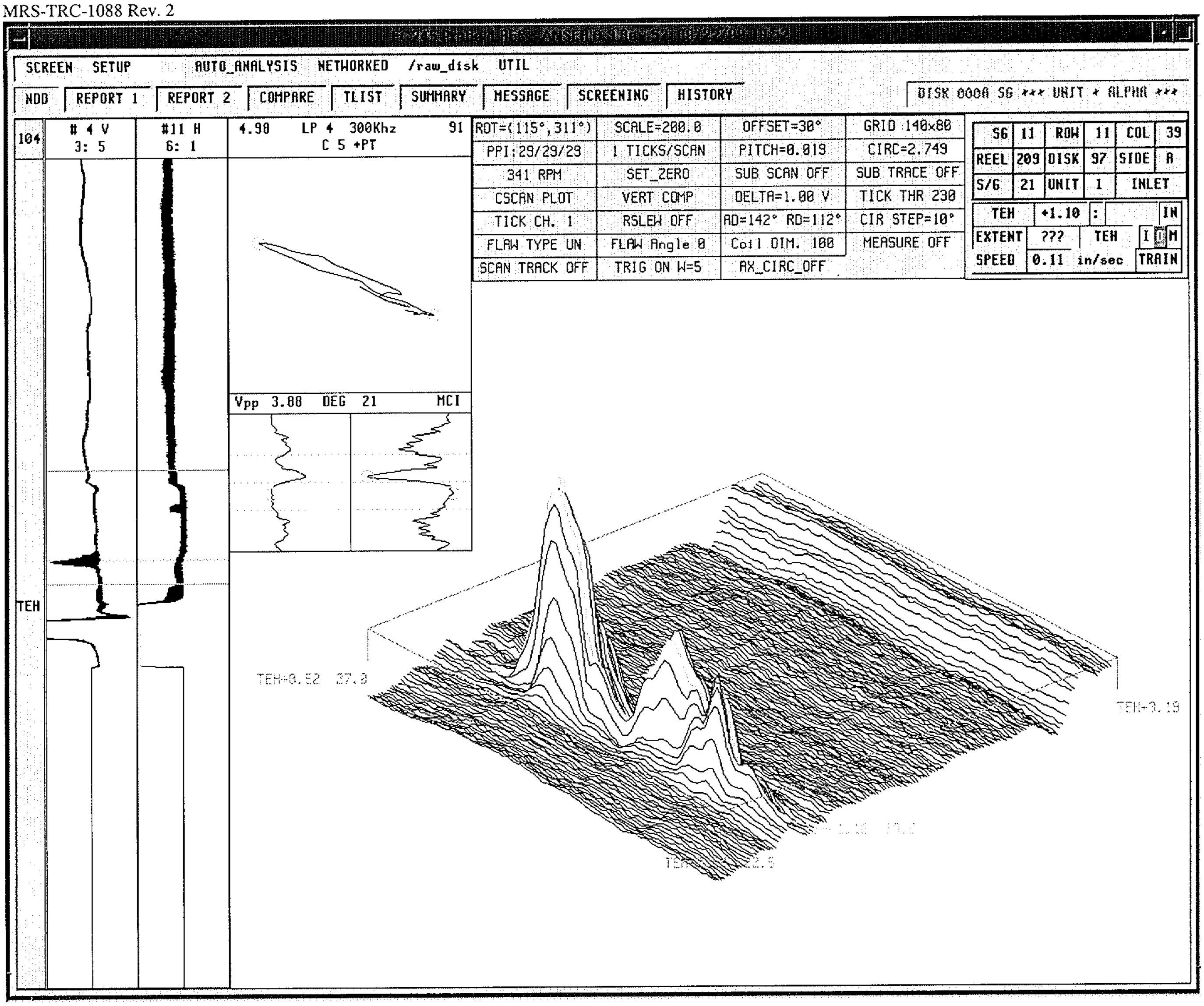


Figure 14B
In-Generator Indication in Roll Transition at Indian Point 2 Reported From Plus Point Probe as ID Circumferential Indication

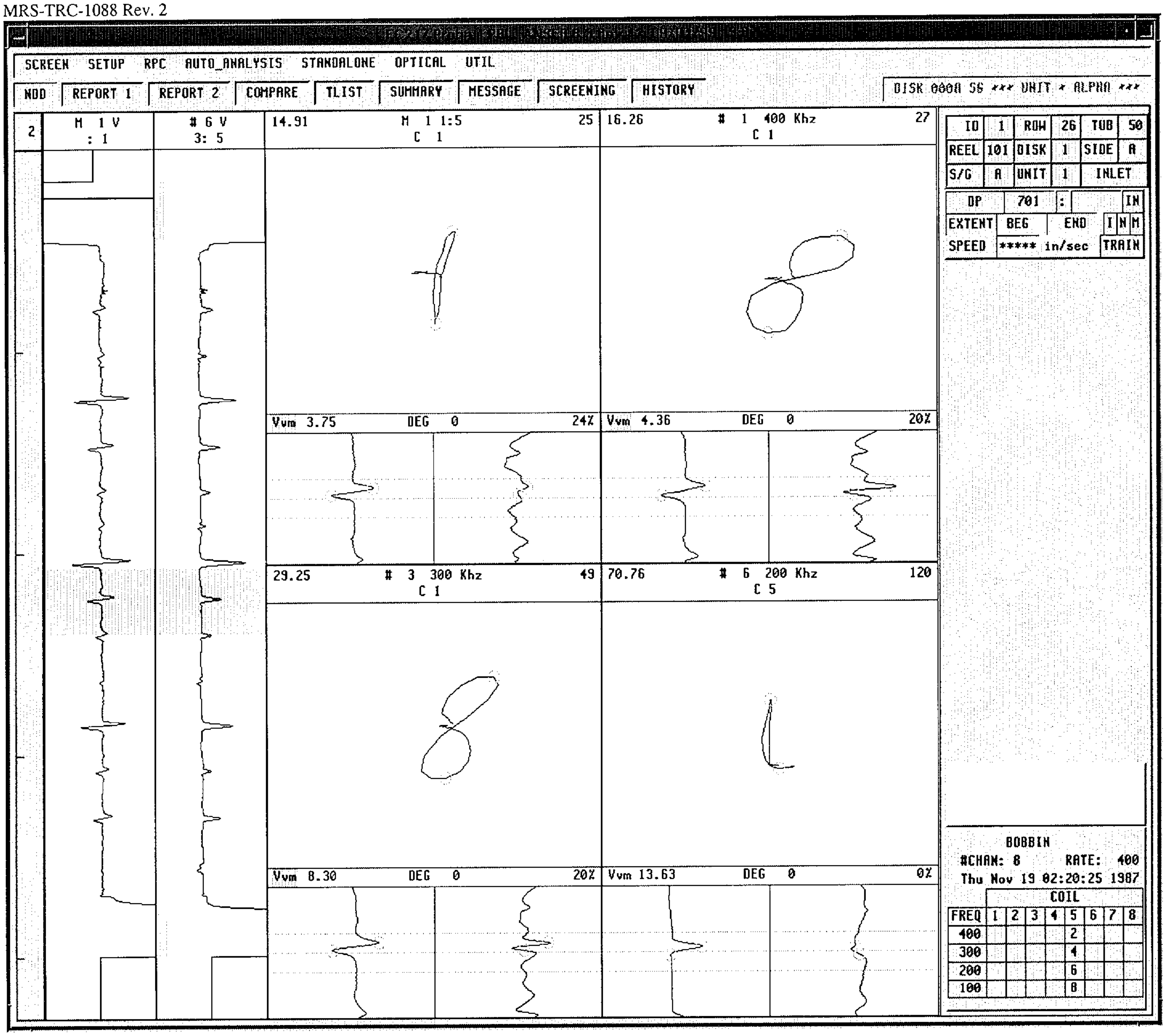


Figure 15A
Lab Sample Used to Support EPRI Appendix H Qualification for AVB Wear With Bobbin Probe

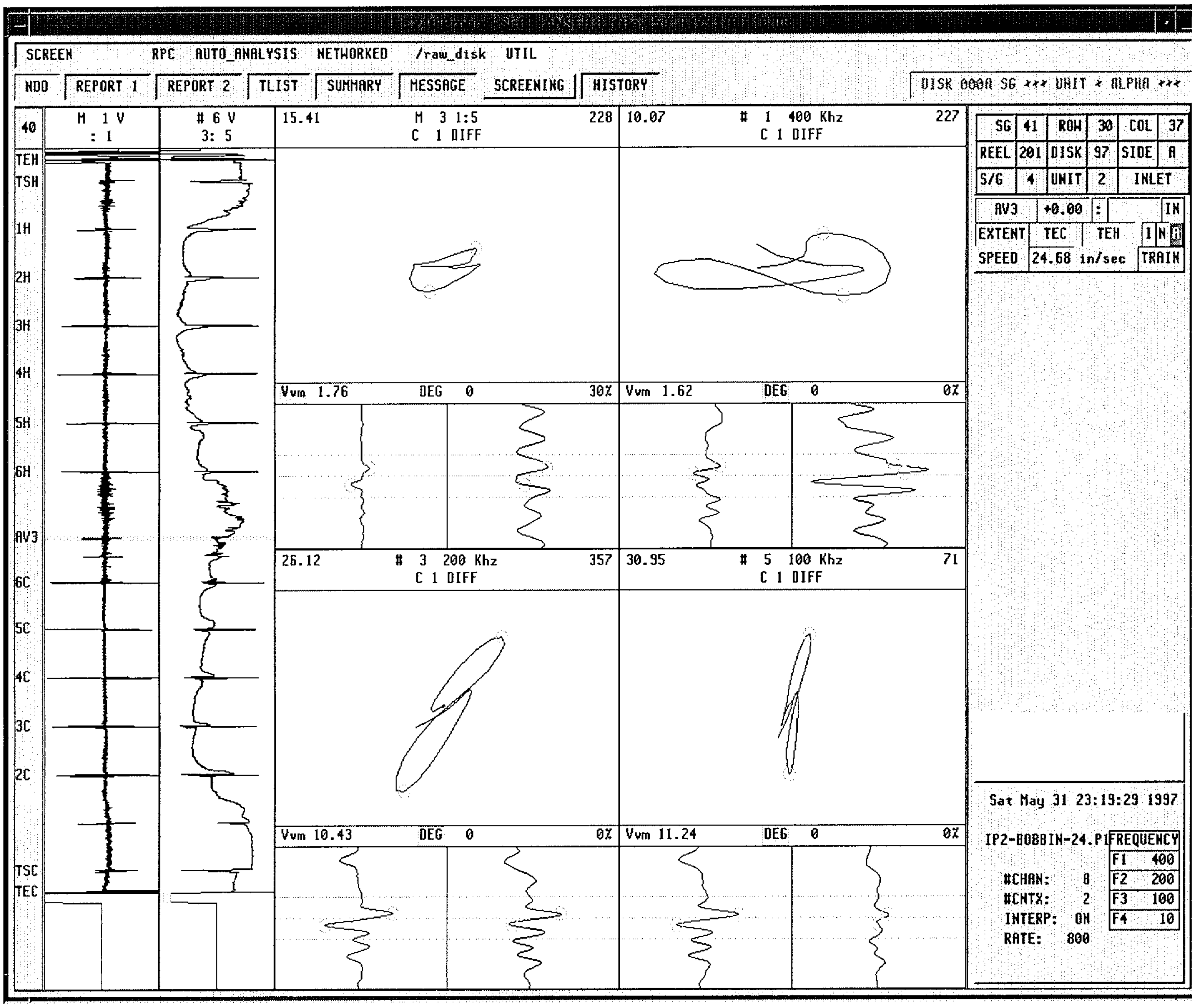


Figure 15B
Indian Point In-Generator Signal Reported at AVB from Bobbin Probe

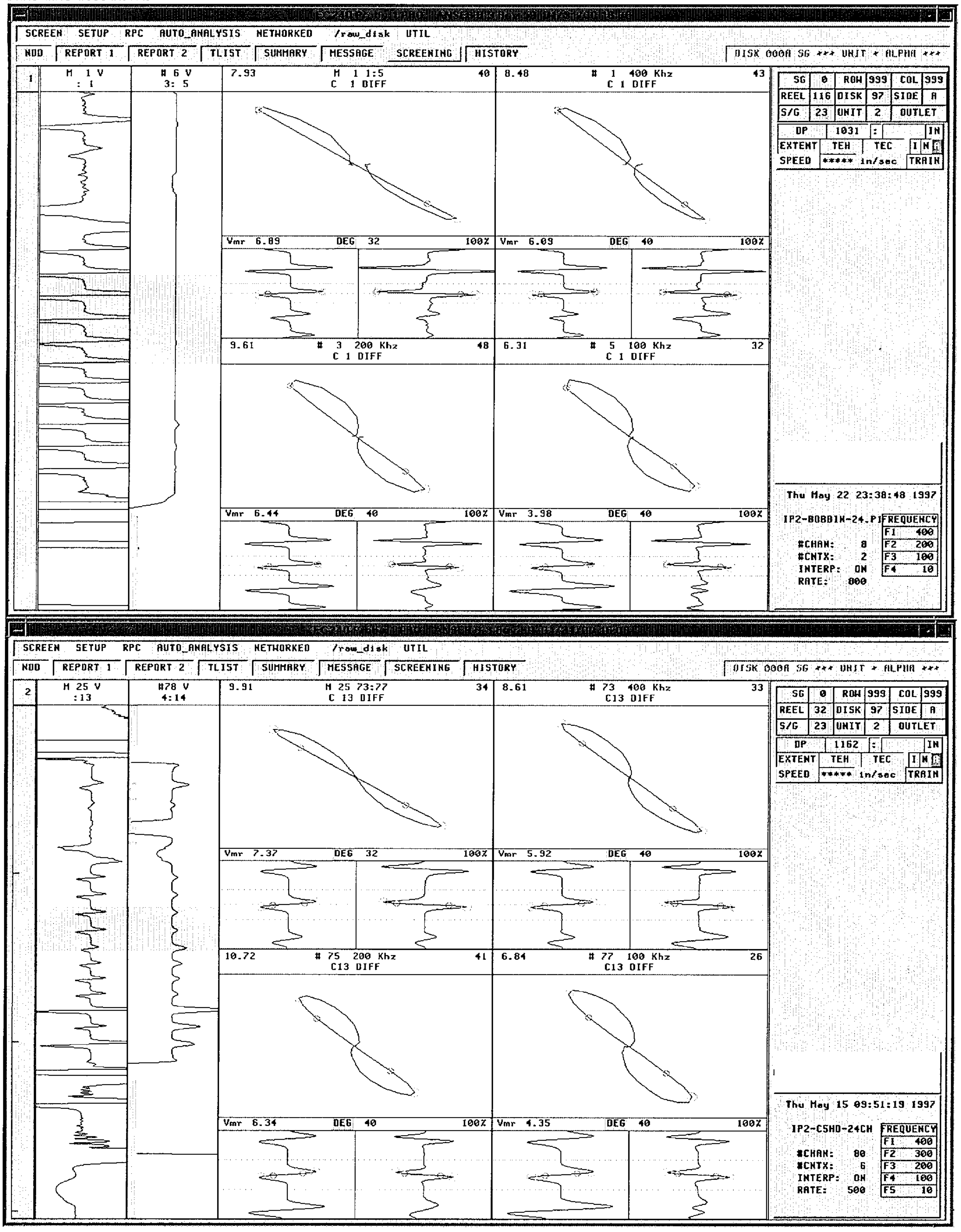


Figure 16

Comparison of 100% Thru Wall Hole on ASME Standard ADVB00597 from Indian Pt. 2 -.700" Bobbin Probes

Top- .700 LLMC Bobbin Probe **Bottom**- .700 Bobbin on Cecco-5 Probe

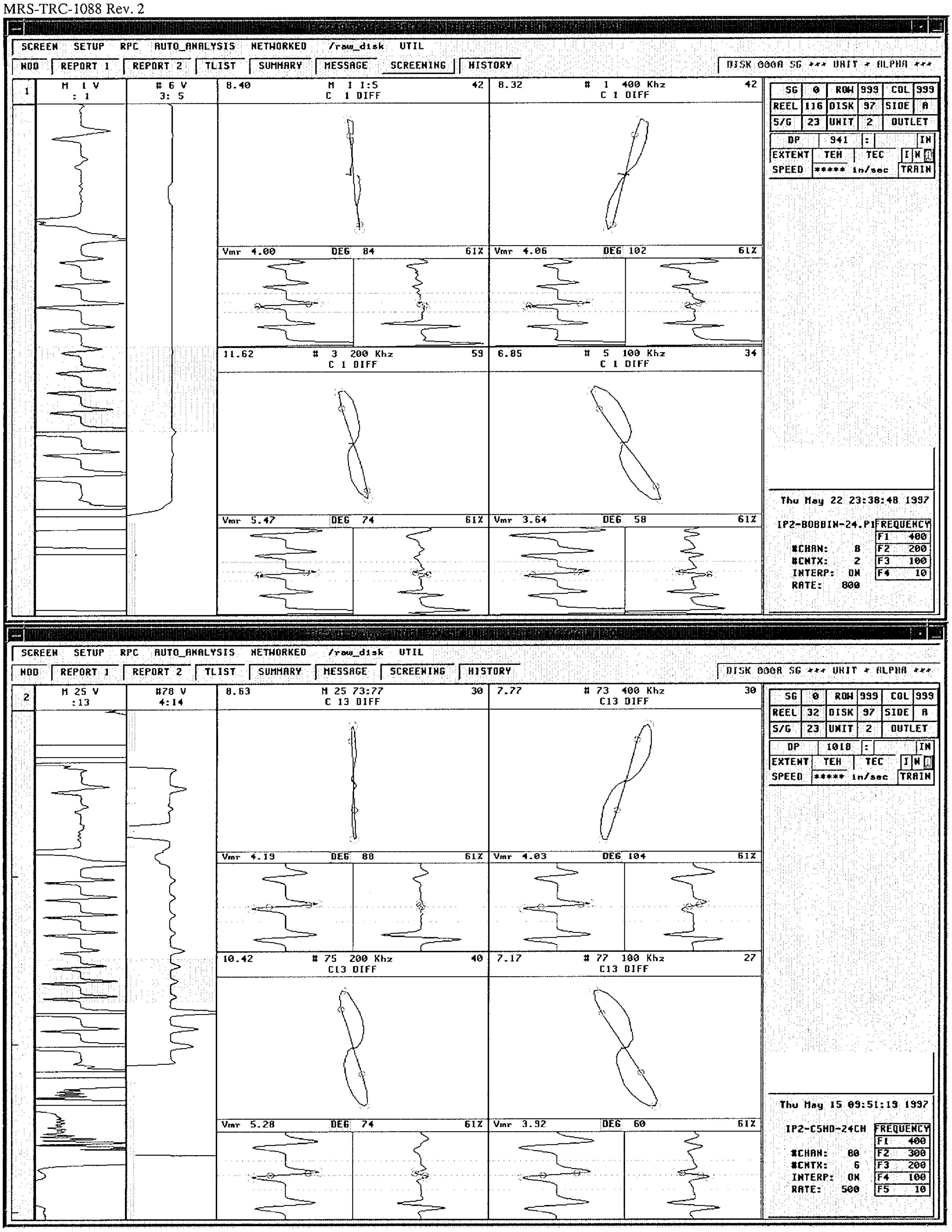


Figure 17

Comparison of 60% Thru Wall Hole on ASME Standard ADVB00597 From Indian Pt. 2 -.700" Bobbin Probes

Top- .700 LLMC Bobbin Probe **Bottom**- .700 Bobbin on Cecco-5 Probe

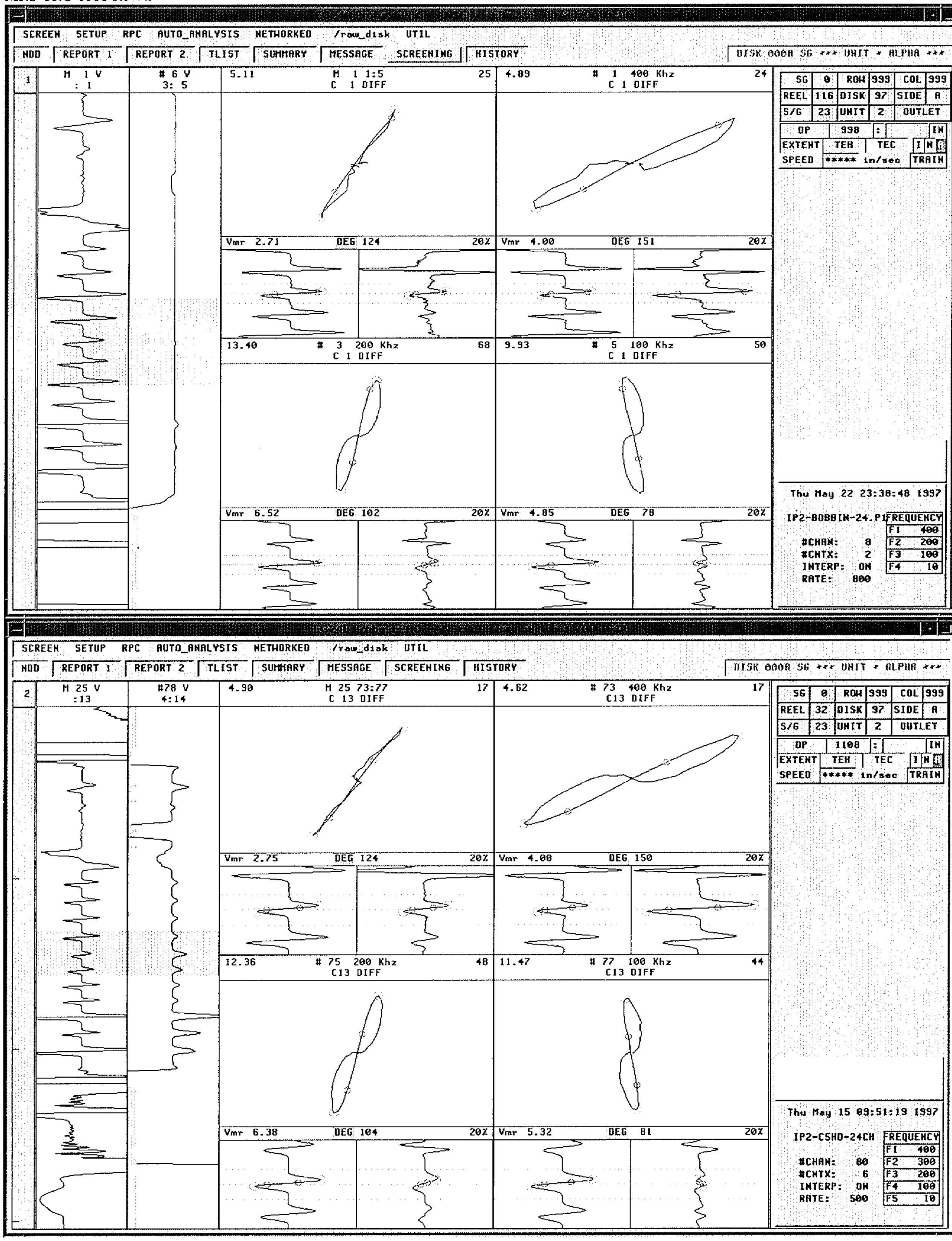


Figure 18

Comparison of (4) 20% Thru Wall Holes on ASME Standard ADVB00597
From Indian Pt. 2 -.700" Bobbin Probes
Top- .700 LLMC Bobbin Probe **Bottom**- .700 Bobbin on Cecco-5 Probe

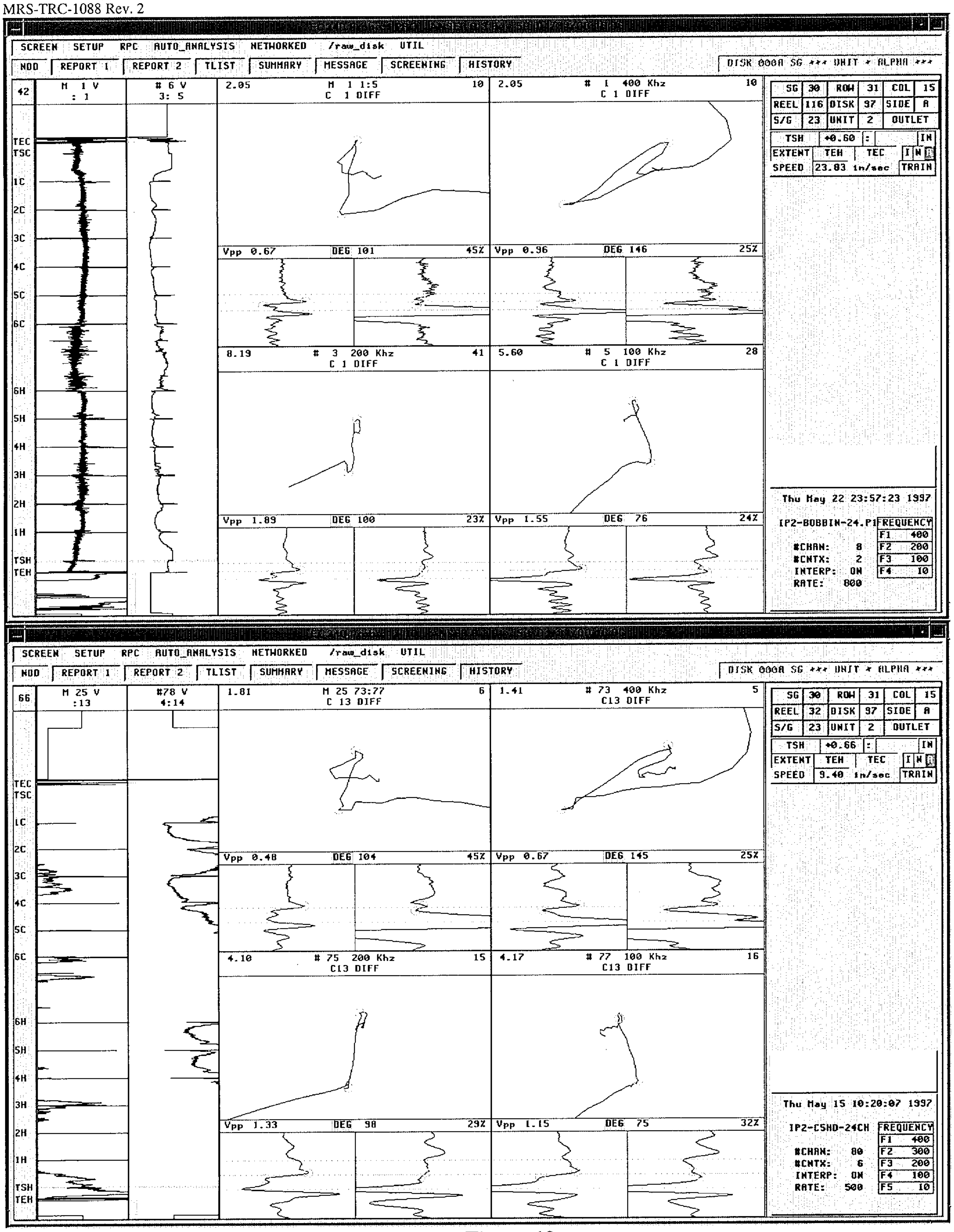


Figure 19

Comparison of Same In-Generator OD Pitting Indication from Indian Point 2 Field Data Reported With Bobbin

Top-700 LLMC Bobbin Probe **Bottom**-700 Bobbin on Cecco-5 Probe

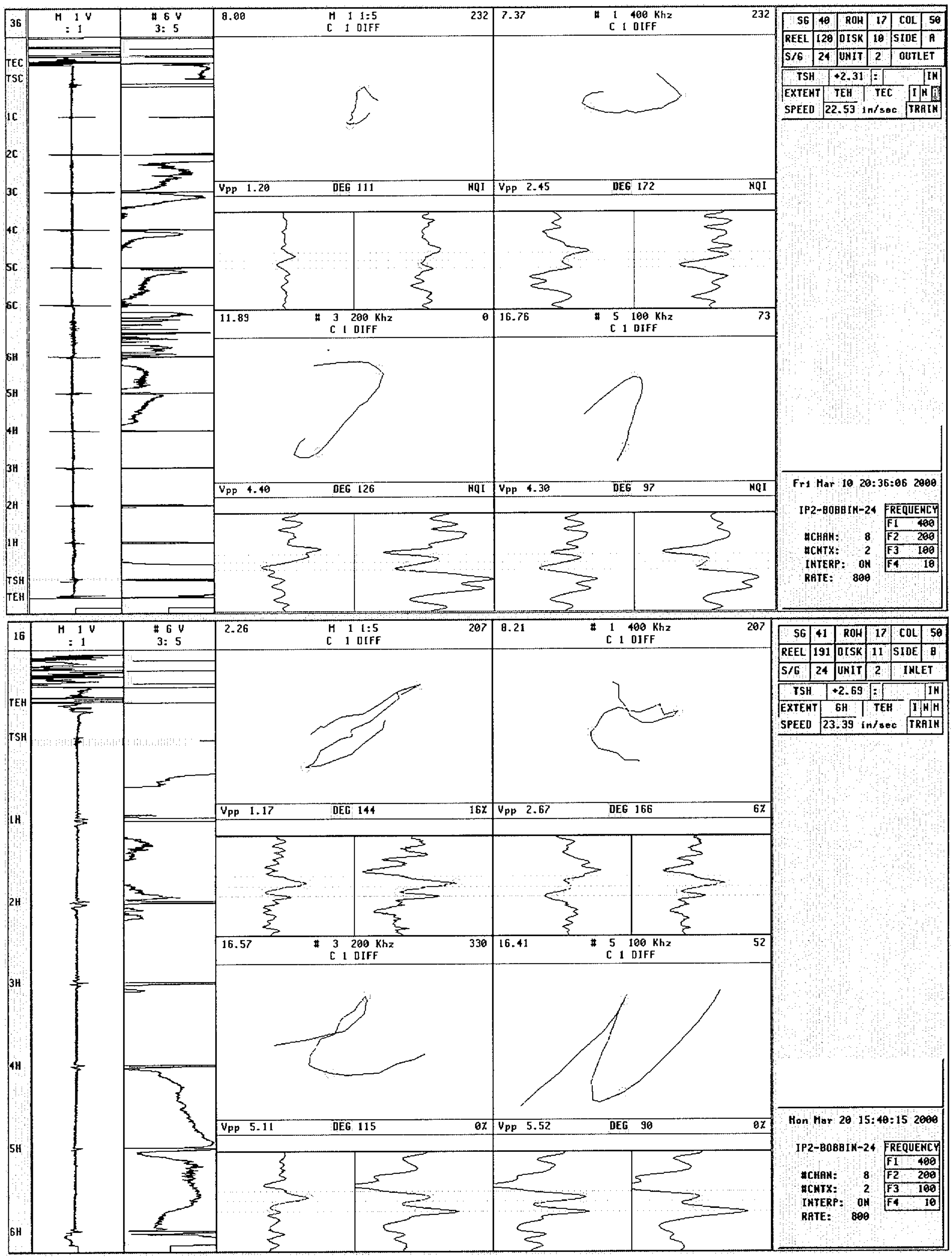


Figure 20
Comparison of Same In-Generator OD Pitting Indication from Indian Point 2 Field Data Reported With Bobbin
Top-700 Bobbin Probe **Bottom**-610 Bobbin Probe

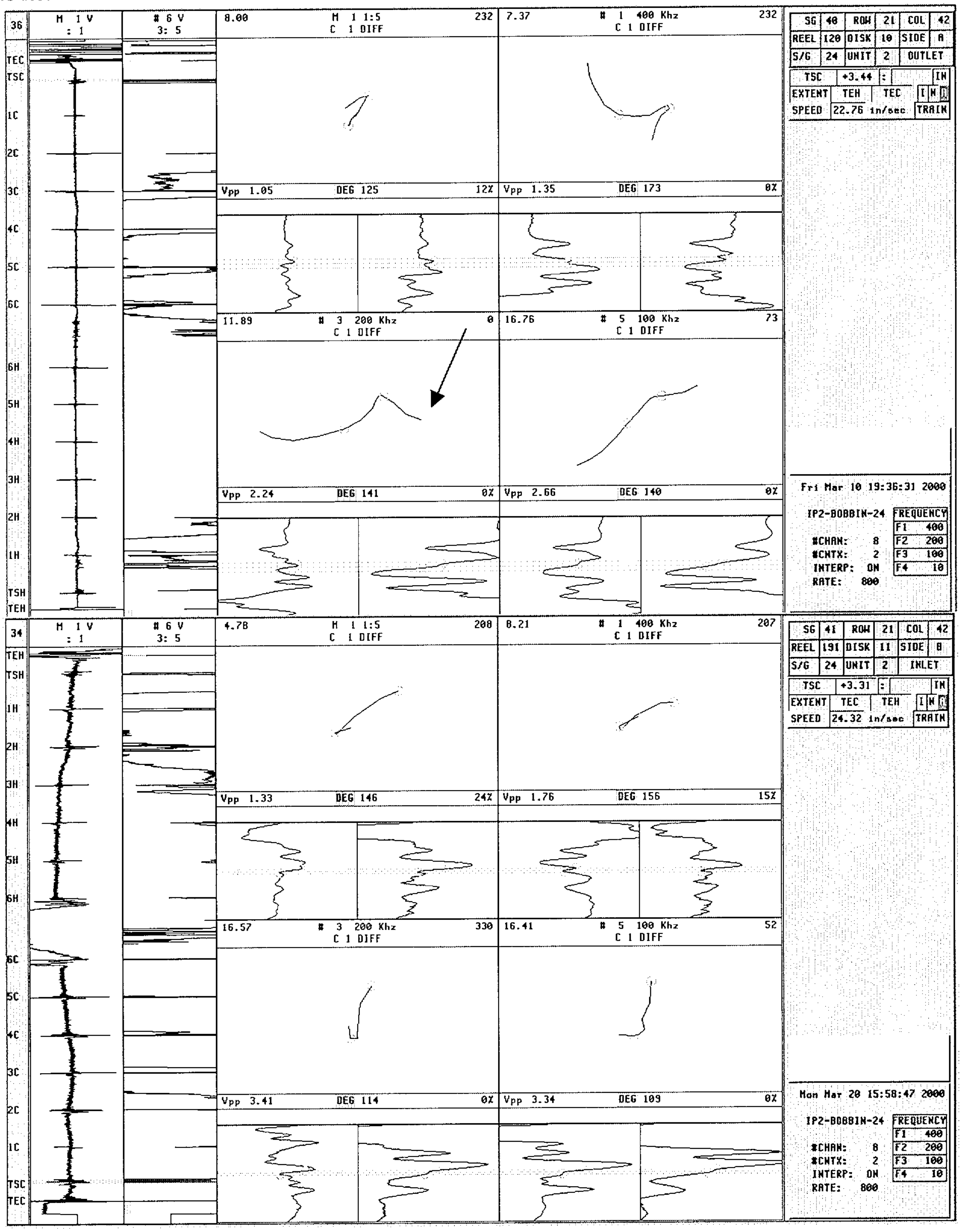


Figure 21

Comparison of Same In-Generator OD Pitting Indication from Indian Point 2 Field Data Reported With Bobbin

Top-700 Bobbin Probe **Bottom**-610 Bobbin Probe

Note: Data collected from different legs. Fill factor differences lead to some distortion.

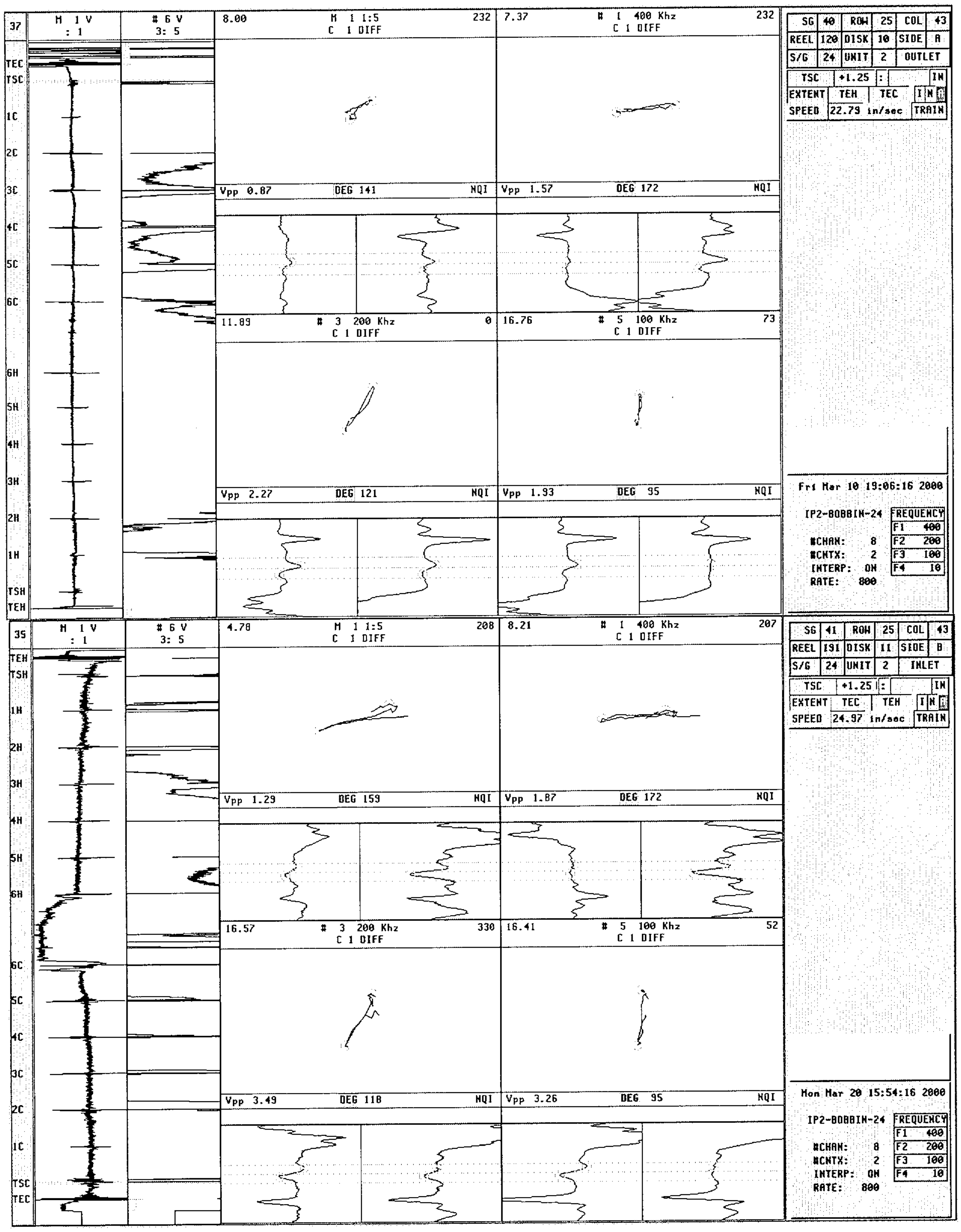


Figure 22

Comparison of Same In-Generator OD Pitting Indication from Indian Point 2 Field Data Reported With Bobbin
Top-700 Bobbin Probe **Bottom**-610 Bobbin Probe

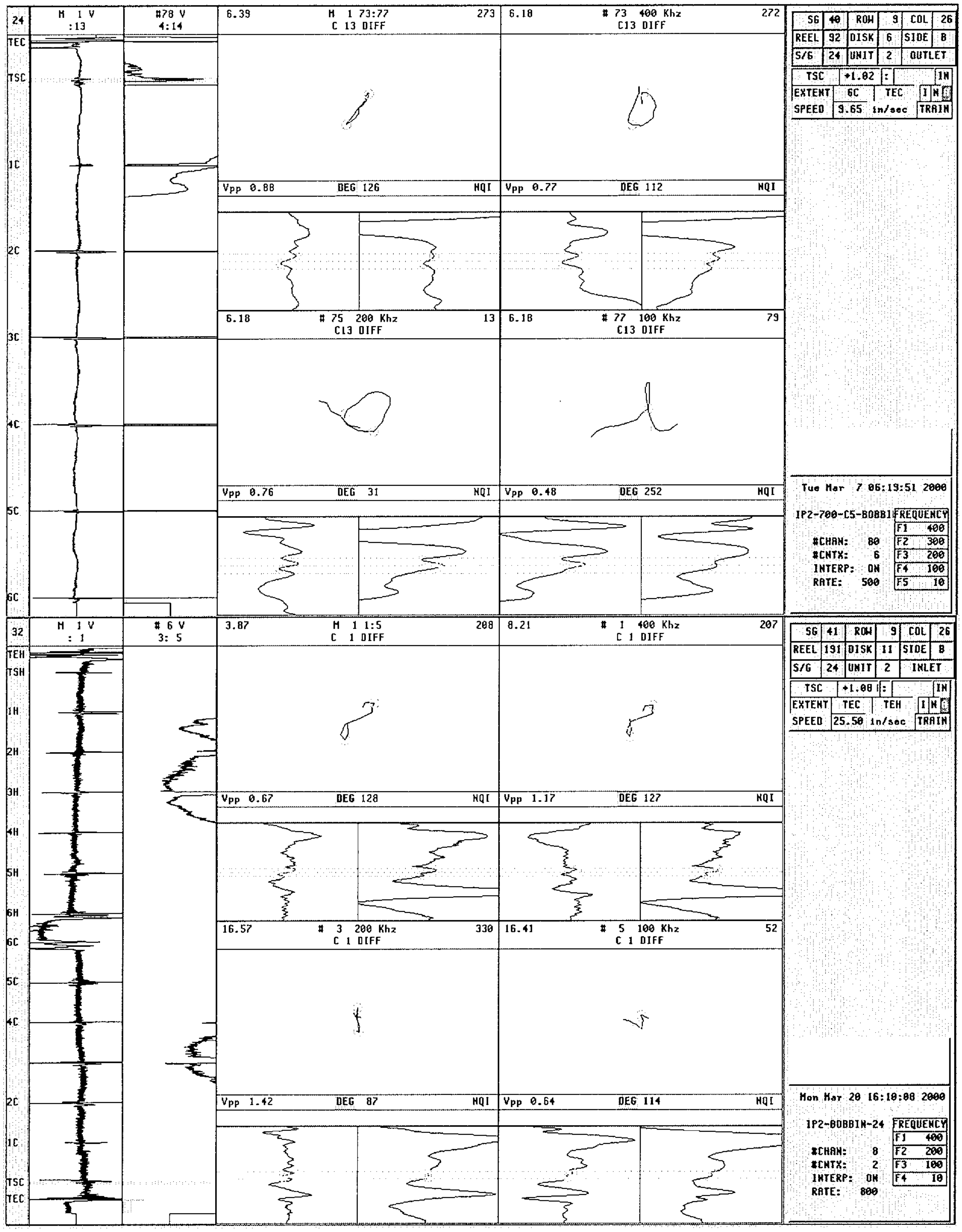


Figure 23

Comparison of Same In-Generator OD Pitting Indication from Indian Point 2 Field Data Reported With Bobbin
Top-700 Bobbin on Cecco-5 Probe **Bottom**-610 Bobbin Probe

NRC RAI Letter dated March 24, 2000

Question 5

Provide the structural analysis of TSPs assessing TSP structural integrity and deformation (including hourglassing) over the next inspection interval and impact of the predicted displacements on u-bend integrity and propensity to cracking. This analysis should be benchmarked against the inspection results from this outage and the results of trending analyses of denting progression.

Reply

This information is contained in Attachment 1 to the U-Bend Condition Monitoring/Operational Assessment Report (CMOA). This report was provided to the NRC on June 2, 2000. Highlights of the report are included below.

Distortion of the Tube Support Plates (TSP) in the flow slot regions results in movements of the steam generator (SG) tubes from their original design locations. The effect of this movement is greatest at the top support plate (TSP 6), as it introduces bending stresses in the U-bend region of the first few rows of tubes. These tubes are most susceptible because of their small bend radii and the relatively small length between the top TSP and the transition region of the U-bend.

Primary Water Stress Corrosion Cracking (PWSCC) has been a problem in the U-bends and transition regions of SG tubes with small bend radii throughout the nuclear power industry. A requirement for PWSCC to occur is a tensile stress. An increase in the tensile stress resulting from flow slot distortion of the TSP will have a corresponding increase in the susceptibility to PWSCC in the U-bend region of the small radius tubes. Attachment 1 to the CMOA investigates the relative susceptibility of small radius U-bends at Indian Point 2 (IP2) to PWSCC. The stress in the tube U-bends due to tube support plate and flow slot distortions are first determined. The increase in susceptibility to PWSCC is then quantified for the Row 3 tubes relative to the Row 2 tubes based on the calculated stress values for the Row 2 and 3 tubes. Since the leak in tube R2C5 in SG24 was from a longitudinal crack at the apex of the extrados (Ref. 1), the investigations reported herein concentrated on the hoop stress at the inside diameter (ID) at this location. This is the stress that would initiate and propagate such cracks.

The overall approach used in the investigation consisted of the following steps:

1. Determine the displacement of the tubes in the flow slot region of TSP 6 using a finite element model of the top support plate for a measured amount of hourglassing.
2. Investigate the extent and importance of the initial ovality resulting from bending during the manufacturing of the tubes.
3. Perform laboratory tests on similar U-bend tubes as those used in the IP2 SGs to determine material behavior, residual stresses from bending during manufacturing, and response to U-bend leg deformation.

4. Develop a finite element model of the Row 2 and 3 U-bend tubes, consistent with the results of the investigations of step 2, using appropriate stress-strain behavior and yield stress values, and benchmark it against the laboratory test results from step 3.
5. Using the U-bend model, determine the hoop stress at the inside of the apex extrados for the level of deformation of the top TSP calculated in step 1 and combine the normal operating stresses and the residual stresses derived experimentally.
6. Based on the resultant stress from step 5, assess the time to PWSCC initiation of Row 3 tubes relative to that of Row 2 tubes and assess susceptibility to the PWSCC mechanism observed in Row 2.

Time To Crack Initiation

Stress corrosion cracking occurs when a susceptible material is exposed to a particular environment while under a tensile stress. On the primary side, alloy 600 is susceptible to PWSCC in near neutral pH environments. PWSCC is strongly influenced by stress, microstructure (heat treatment & thermal-mechanical processing history), and local chemistry.

For a given microstructure and operating temperature, there is a significant stress dependence. As a result of the numerous microstructural and environmental parameters and their respective influences on the fracture mechanism, it is difficult to accurately determine the actual time to crack initiation. However, it is possible to estimate the relative time to crack initiation between the Row 2 and Row 3 tubes based on the relative magnitude of the stress in each row.

A simplified model for estimating crack initiation in A600 steam generator tubing is an inverse relationship between time for crack initiation, t_f, and the applied stress, σ, raised to the fourth power. This model, which has been presented and discussed in the literature (Ref. 4 and 5), is in the form:

$$\frac{1}{t_f} = C\sigma^4 \qquad (1)$$

Where C is a constant for the material and operational conditions. This model assumes the stress remains constant throughout this time. The expected time to crack initiation of tubes in Row 3, t_{f3}, relative to the time in a tube in Row 2, t_{f2}, with similar yield strength, is:

$$t_{f3} = t_{f2}\left[\frac{\sigma_2}{\sigma_3}\right]^4 \qquad (2)$$

Where σ_3 is the applied stress in Row 3 and σ_2 is the applied stress in Row 2. Note that this model conservatively does not consider the added potential difference in susceptibility due to the higher total plastic strain in Row 2 (Ref. 6). This relationship was used to define the expected crack initiation times of Row 3 tubes relative to the Row 2 tube.

Because of the range of the IP2 Row 2 and 3 yield strength values, it is considered appropriate to compare tubes with similar yield strengths in the work hardened condition in order to define an overall relative susceptibility to cracking. The time to cracking analysis was thus performed for several ranges of material yield strengths for each of the two rows and equation (2) applied within each range. This allows a relative susceptibility comparison between Row 2 and Row 3 tubes of similar yield strength. This approach results in the following range:

Low Yield Strength Tubes Row 2/Row 3: Factor $= (51.2 \text{ KSI}/ 40.7 \text{ ksi})^4 = 2.5$

High Yield Strength Tubes Row 2/Row 3: Factor $= (92.4 \text{ KSI}/65.4 \text{ ksi})^4 = 4.0$

This evaluation of the data resulted in relative susceptibility factors for the time to crack initiation between Row 3 and Row 2 tubes of between 2.5 and 4.0.

Conclusions

Based on the above investigations, it is concluded that:

- Based on analytical investigations, ovality resulting from the initial manufacturing of the tubes does not appear to have a significant effect on the ID hoop stress at the apex extrados for the Row 2 and Row 3 U-bends.

- As indicated by the high ID hoop stress at the apex extrados resulting from the in-plane deformation of the U-bend tube legs, hourglassing in the top TSP appears to be a primary contributor to the PWSCC at the apex of the U-bends.

- As indicated by the lower ID hoop stress at the apex extrados for the Row 3 tubes as compared to the corresponding Row 2 tube, Row 3 tubes are much less susceptible to the PWSCC mechanism that affected the Row 2 tubes. Also, based on the time to crack initiation study, PWSCC at the apex extrados of the mid flow slot Row 3 tube is expected to take 2.5 to 4.0 times the amount of time for PWSCC to initiate as the corresponding Row 2 tube.

References:

1. Westinghouse, "Indian Point 2 Root Cause Evaluation for SG-24, R2C5 Leakage Event," March 2000, Revision 2, 4/14/00.
2. ANSYS Computer Program, Version 5.5.1, ANSYS Incorporated, Canonsburg, PA.
3. American Society of Mechanical Engineering, Boiler and Pressure Vessel Code, Section III, 1989.
4. Bulischeck and Van Rooyen, "Effect of Environmental Variables on the Stress Corrosion Cracking on Inconel 600 Steam Generator Tubing," Nuclear Technology, Vol. 55, Nov 1981 pp. 383-93.

5. R. Bandy and D. van Rooyen, "Mechanisms of Intergranular Failures in Alloy 600 in High Temperature Environments," BNL-NUREG-34270, 1984.
6. "Assessment of Current Understanding of Mechanisms of Initiation, Arrest, and Reinitiation of Stress Corrosion Cracks in PWR Steam Tubing Generators," NUREG/CR-5752, ANL-99/4.

NRC RAI Letter dated March 24, 2000

Question 10

Provide a response to NRC's inspection recommendations for the low row u-bend which include (1) using a high frequency +Point probe, (2) using the midrange +Point run at 500kHz, (3) trying a 400/100 kHz mix, and/or (4) analyze using the 400 kHz channel. In addition, regarding the overall steam generator inspection program, discuss the need to improve analyst guidelines (e.g., clear setup guidelines, clear and objective noise criteria) and to develop a formal training program to incorporate "lessons learned."

Reply

Provide a response to NRC's inspection recommendations for the low row u-bend which include (1) using a high frequency +Point probe.

The use of a 0.075" diameter high frequency (800kHz-1Mhz) plus-point coil in the current U bend apparatus should increase detectability.

Result: The use of this HF probe was the most significant contributor to obtaining acceptable S/N conditions in the U bends.

Action: Probes with +Point coils capable of operation at higher frequencies were ordered on a custom basis and sent to EPRI who performed a qualification on this High Frequency (HF) probe using the same data set as the EPRI ETSS # 96511, the EPRI U-bend technique used for the mid-range (MR) +Point probe. Test frequencies were 300, 400, 600, 800, and 1000kHz. Only the 800kHz and 1000kHz frequencies were specifically qualified. The EPRI ETSS identification #'s are 99997.1 and 99997.2. To demonstrate the ability of the HF probe to detect small flaws in the presence of copper, a 40% and a 62% ID flaw were selected and covered with copper foil. These flaws were determined to be readily detectable. The qualification data were transmitted to the NRC's eddy current consultant shortly after the qualification was completed on 3/20/00. This information is also available in the Westinghouse field report for the current inspection.

The HF probe was then used to test the U bends of tubes R2C69 and R2C72 in SG 24. These tubes were previously reported as having PWSCC axial indications and were selected as a performance test. This HF data was compared with the original MR +Point 300-400kHz and the 750kHz data from the MR probe. (The use of the MR coil at 750kHz is discussed in Item 2, below.) Based on this comparison, the 800kHz probe was judged to give the best response with least noise, i.e., the best signal-to-noise (S/N). Other considerations were:

- The operating point on the swept frequency plot was at or near peak response on the HF probe at 800kHz.

- The operating point at 750kHz on the MR probe swept frequency plot is significantly off peak response on the capacitive side, a potentially noisy condition.

- The smaller HF coil has theoretically greater sensitivity to and resolution of near field (ID) indications.

- The electro-magnetic field extension through the tube wall is lower at higher frequencies resulting in the system being less sensitive to OD influences such as conductive deposits.

- The smaller HF coil diameter has a more localized field resulting in the system being less sensitive to OD influences such as conductive deposits.

- The signal response to conductive OD deposits undergoes a phase rotation into the direction of the horizontal plane with increasing frequency and most closely approaches the horizontal near 800kHz. On a C-scan plot, this greatly improves S/N.

- The mechanical properties of the HF probe were judged better than the MR, possibly due to the new epoxy coating on the wear surfaces. Even though both probes have the same diameter, the HF was easier to rotate in the Ubends.

Benefits seen by the use of the HF probe:

The use of the HF probe was the most significant contributor to obtaining acceptable S/N conditions in the Ubends. In order to detect additional flaws, all of the row 2 and 3 tubes plus the noise-rejected tubes in row 4 were re-inspected with the HF probe. The number of rejected tubes was 457 before the HF probe was used. At the conclusion of the HF program, only 5 tubes remained unacceptable, and these tubes were plugged.

Detection under these lower noise conditions was significantly improved, the number of PWSCC indications discovered in the initial Ubend program and subsequent Independent Review numbered 3. These tubes were R2C69 and R2C72 in SG24 and R2C87 in SG21. The HF program identified 4 PWSCC indications in Ubends preliminarily designated as having unacceptable S/N levels; these tubes were R2C71, R2C74, and R2C4 in SG24 and tube R2C85 in SG23. This more than doubled the number of indications found. In the case of 24 SG R2C4, R2C74 and 23SG R2C85, the indications found by the HF probe were 44%, 38%, and 50% maximum depth respectively, demonstrating a sufficiently low threshold of (depth) detection, as sized by the MR probe. For information regarding the sizing of these indications and other pertinent information, refer to ***Indian Point-2 U-bend PWSCC Condition Monitoring and Operational Assessment***, dated April 2000, Section 3.4, "+Point Sizing of U-bend Indications"

1997 Perspective – The 800kHz +point probe was first qualified by EPRI in March 20, 2000; and thus first available for commercial nuclear plant application after that date.

Provide a response to NRC's inspection recommendations for the low row u-bend which include (2) using the midrange +Point run at 500kHz.

Adding a higher frequency to the standard midrange plus point, perhaps as high as 500kHz may improve detection of ID flaws.

Result: the midrange probe improved the signal-to-noise conditions but was not effective compared to the HF +point probe and was not used for production testing.

Action: an additional 750kHz frequency was added to a normal MR +Point Ubend probe. Qualification of the coil at this frequency was performed during the ETSS# 96511 development qualifications, but was never recorded until Indian Point 2 requested that it be done. The qualification of the 750kHz data was done on 3/20/00 and assigned the EPRI ETSS # 96511.4. The reason that 750kHz was chosen instead of 500kHz is that the desired sludge phase angle rotation was expected to occur nearer to 800kHz and also because the 400kHz showed very marginal improvement over 300kHz and it was expected that 500kHz would be similarly incremental in improvement and therefore not as promising for noise reduction. The evaluation and application of this frequency is discussed under Item 1, above.

1997 Perspective – Using a mid-range probe excited at 500 kHz and above had never been previously utilized in a steam generator tube inspection program or submitted for EPRI Appendix H qualification. Utilizing the standard midrange probe at 500 kHz resulted in a slight improvement in the 400kHz channel as noted above, but this improvement was not great enough to materially affect signal to noise conditions and detectability of R2C5. Utilizing probes at frequencies in excess of their design would normally be contraindicated in light of the signal amplitude response. The feasibility or value of using higher frequencies would not have been examined in 1997 because they had never been previously applied in the field and were not qualified. In 1997, the conventional +point frequencies did identify a Primary Water Stress Corrosion indication in tube R2C67. Therefore, the data indicated the process used could detect that type of indication and there was no reason to implement a different type of inspection.

Provide a response to NRC's inspection recommendations for the low row u-bend which include (3) trying a 400/100 kHz mix.

400/100kHz mix based on a sludge/ferrite ring or an InSitu deposit signal may improve Signal-to-Noise conditions.

Result: experimentation with this mix proved no improvement over unmixed data and was not employed.

Action: Various mixing techniques were investigated while evaluating this Item. The application of signal mixing applies to bobbin tests in the TTS sludge pile and low row U-bends because some apex areas were noted to have deposit signals. Additionally, actual deposits were seen during the secondary side inspections on several ubends including the leaking tube, R2C5. The explanations presented in this section apply to signal mixing with Mid Range +Point U-bend probes, but are generally applicable to TTS sludge pile areas using bobbin probes as well. High Frequency +Point probes reject deposit noise inherently as discussed in Item 1, above.

Two-frequency suppression mix:

First, the support ring on the EPRI Revision 5 standard was used in a 400/100kHz support-suppression +point coil mix. The results were not better than the 400kHz raw data due to mix residuals noted in the actual data. For bobbin coils this mixing technique is state of the art in sludge piles, however, there are still residuals that interfere with data analysis. Generally, residuals are larger on +Point coils than bobbin because small coils are more sensitive to localized variations than the larger bobbin coil, which tends to "average" signals. The results of this experiment indicated no improvement and therefore the use of this standard mix was not employed.

Reproducing the sludge for use in mixing:

The chemical composition of the sludge is known, but attempts to reproduce the sludge in the laboratory have been unsuccessful until very recently when a method of sludge reproduction was developed. A sample of this material was baked onto a tubing sample (an old standard) but the effort failed to reproduce the signals seen by the in-generator conductive sludge and could not be used for mixing purposes and consequently was not used at IP2.

In situ signal mixing:

Next, in situ deposit signals in a small sample of U-bends and TTS sludge piles was investigated for suppression mixing using combinations of two frequencies in the range of 400/300/100kHz. The mixing algorithm suppressed the deposit signal adequately but noted no improvement over 400kHz by itself when other areas of the ubend/sludge pile were tested. A typical problem with in situ mixing is the lack of repeatability due to the variability of deposit signals caused by their shape (morphology), axial locations, and local conductivity. When a deposit varies from that originally mixed, or if an artificial deposit signal is used, residuals appear in the tested tube. Many variations in deposits are believed due to spalling or unequal deposition on the tubing free spans. This result is similar to 3-way mixing, discussed below. This technique was not used at IP2.

Suppressing permeability components:

Obtaining a ferrite ring for mixing purposes was discussed, but the sludge at IP2 does not seem to have a significant permeability component (ferrite would be used to simulate permeability). This is based on the observation that the MR +point Ubend probe, which is magnetically biased, does not appear to reduce noise in the Ubends at IP2 indicating that magnetic suppression of permeability is not taking place. Additionally, a ferrite ring could not be fabricated in time for use during this outage.

3-way mixes:

Finally, the use of 3-way mixes (mixing 3 frequencies) were considered and rejected for similar reasons to the in situ mix, that is, the mix depends entirely on the object mixed out, causing repeatability and false call issues.

It was concluded, based on experiments and experience, that signal mixing is not an effective means of +Point coil noise suppression at IP2, however the standard bobbin suppression mix remains an effective tool for data analysis.

1997 Perspective – Based on the investigation conducted during the 2000 inspection the use of signal mixing would not have been a method that would have helped find the indication in R2C5 in 1997.

Provide a response to NRC's inspection recommendations for the low row u-bend which include (4) analyze using the 400 kHz channel.

Require analysts to monitor 400kHz plus point in their analysis.

Result: Mandated by the supplement to ANTS Number IP2-00-E specifically, and by industry practices generally that specify "all data shall be analyzed and all degradation be reported". 400kHz, along with 300kHz, was used during the 2000 analysis Initial program and Independent Review. This requirement was specifically included in the data analysis training.

1997 Perspective – The investigation during the 2000 steam generator inspection did confirm slight signal improvements were obtained in some instances when using the 400 kHz frequency to identify a PWSCC indication in the low row u-bends to the steam generator tubes, however none of the various mid-range probe/frequency combinations materially improved detectability in the particular circumstances of R2C5. This technology was available and it was used during the 1997 inspection. The use of the 400 kHz frequency was also specified during the 2000 inspection, although the use of the 800 kHz probe, unavailable in 1997, ultimately proved to be a much more effective method to inspect the low row u-bends for PWSCC.

Set the phase of the 40% ID clockwise per ETSS

Result: Required by ANTS IP2-00-E (for ANalysis Technique Sheet, the Westinghouse equivalent to the EPRI ETSS) from the beginning of the ubend inspection and incorporated into the initial training given to the data analysts.

Discussion: 1997 phase settings are discussed in Question #1. It concludes that using the a slightly further clockwise phase setting (or the use of the 400kHz Vs 300kHz) on the mid range +point probe would not materially affect the detectability of flaws like R2C5, but that the high frequency +point was an effective alternative first made available during the 2000 outage.

In addition, regarding the overall steam generator inspection program, discuss the need to improve analyst guidelines (e.g., clear setup guidelines, clear and objective noise criteria) and to develop a formal training program to incorporate "lessons learned."

Discussion

Analyst training and guideline materials were reviewed during the 2000 inspections and changes were implemented as they were adopted. With the commitment to begin the replacement of the steam generators before the end of the year all of the analysts guidelines and training will have to be reviewed. The lessons learned from this outage will be reviewed to determine where it is applicable to incorporate them in the inspection and training programs for new steam generators. Indian Point Stations Administrative Order, 180, 'ADMINISTRATIVE STEAM GENERATOR PROGRAM PLAN contains the program elements that will require any program improvements.

NRC RAI Letter dated March 24, 2000

Question 11

Assess u-bend stress levels in the rows 2 – 4, broken down by residual stress introduced during fabrication, stress from denting related causes (including support plate deformation and hourglassing), thermally induced stress, and pressure induced stress.

Reply

As part of understanding the leakage from Steam Generator 24 R2C5, an investigation, that included historical research and laboratory simulation studies, was conducted. The issues raised by this question, although not reported here in a categorized format, were all fully addressed. The overall approach used in the investigation consisted of the following steps:

1. Determine the displacement of the tubes in the flow slot region of TSP 6 using a finite element model of the top support plate for a measured amount of hourglassing.

2. Investigate the extent and importance of the initial ovality resulting from bending during the manufacturing of the tubes.

3. Perform laboratory tests on similar U-bend tubes as those used in the IP2 SGs to determine material behavior, residual stresses from bending during manufacturing, and response to U-bend leg deformation.

4. Develop a finite element model of the Row 2 and 3 U-bend tubes, consistent with the results of the investigations of step 2, using appropriate stress-strain behavior and yield stress values, and benchmark it against the laboratory test results from step 3.

5. Using the U-bend model, determine the hoop stress at the inside of the apex extrados for the level of deformation of the top TSP calculated in step 1 and combine the normal operating stresses and the residual stresses derived experimentally.

6. Based on the resultant stress from step 5, assess the time to PWSCC initiation of Row 3 tubes relative to that of Row 2 tubes and assess susceptibility to the PWSCC mechanism observed in Row 2.

Steps 1 through 5 address the issues immediately related to the subject question. Step 6 assesses the time for PWSCC initiation.

In summary, the investigation concluded that:

- Based on analytical investigations, ovality resulting from the initial manufacturing of the tubes does not appear to have a significant effect on the ID hoop stress at the apex extrados for the Row 2 and Row 3 U-bends.

- As indicated by the high ID hoop stress at the apex extrados resulting from the in-plane deformation of the U-bend tube legs, hourglassing in the top TSP appears to be a primary contributor to the PWSCC at the apex of the U-bends.

- As indicated by the lower ID hoop stress at the apex extrados for the Row 3 tubes as compared to the corresponding Row 2 tube, Row 3 tubes are much less susceptible to the PWSCC mechanism that affected the Row 2 tubes. Also, based on the time to crack initiation study, PWSCC at the apex extrados of the mid flow slot Row 3 tube is expected to take 2.5 to 4.0 times the amount of time for PWSCC to initiate as in the corresponding Row 2 tube.

The investigation is part of the CMOA report "Indian Point 2 U-Bend PWSCC Cycle 14 Condition Monitoring and Cycle 15 Operational Assessments", Westinghouse Electric Company, SG-00-05-008,-May 30, 2000, as Attachment 1 in Reference 2.

NRC RAI Letter dated March 24, 2000

Question 13

Assess the time to crack initiation in initial tubes for Rows 2, 3, and 4 u-bends

Reply

An analysis of the time to crack initiation in Row 2, 3, and 4 tubes has been provided in Attachment 1 to SG-00-05-008, "Indian Point 2 U-Bend PWSCC Condition Monitoring and Operational Assessment," which was previously submitted to the NRC on June 2, 2000. For convenience, key sections of that submittal are summarized herein to respond to this question. Because of numerous microstructure and environment parameters, and their respective influences on the fracture mechanism, it is difficult to accurately determine the actual time to crack initiation. However, it is possible to reasonably estimate the relative time to crack initiation between two rows – in this case – Row 2 compared to Row 3, based on the relative magnitude of stress in each row.

Note that this analysis focused on Row 2 and Row 3 tubes. The analysis demonstrates that Row 3 tubes have a lower probability and a longer time to crack initiation when compared to Row 2. Based on the Row 3 finding, it was further concluded that Row 4 tubes are bounded by Row 3 results.

Tensile stress must be present for primary water stress corrosion cracking (PWSCC) to occur. For Row 2, and 3 tubes, high tensile stress results from deformation of the top tube support plate (TSP) which also results in hourglassing of the flow slots. It was reasonable, therefore, to first determine the stress in the tube U-bends due to the tube support plate and flow slot distortions. The increase in susceptibility to PWSCC was then quantified for Row 3 tubes relative to the Row 2 tubes based on the calculated stress values for the Row 2 and 3 tubes. These stress assessments were focused on the hoop stresses at the inside diameter (ID) at the apex of the extrados. This also is the same location that the R2C5 leak in SG24 occurred.

The overall approach of the analysis included the following key components:

- Use of a finite element model of the top support plate to calculate the amount of tube displacement in the flow slot region of TSP 6 for a certain measured amount of hourglassing.
- Investigate the extent and importance of initial ovality of the tubes.
- Perform laboratory tests on U-bend tubes that are similar to those present in the IP2 steam generators.
- Develop a finite element model of the Row 2 and 3 U-bend tubes, consistent with the impact of ovality and using appropriate stress-strain behavior and yield stress values. These results are benchmarked against laboratory tests discussed above.
- Use the U-bend model and determine the hoop stresses at the inside of the apex extrados for the level of deformation on the top TSP. Combine that result with normal operating stresses and experimentally determined residual stresses. Calculate the time to PWSCC initiation in Row 3 tubes relative to Row 2 tubes

and susceptibility to the PWSCC mechanism observed in Row 2 based on these model results.

Because of the range of the IP2 Row 2 and 3 yield strength values, it was reasonable to compare tubes with similar yield strengths in the work hardened condition in order to define an overall relative susceptibility to cracking. As a result, the analysis of time to cracking was performed for several ranges of material yield strengths for Row 2 and 3 tubes. This approach resulted in relative susceptibility factors for the time to crack initiation between Row 2 and Row 3 tubes of between 2.5 and 4.0. This is due to a hoop stress difference of at least 10,000 psi between the Row 3 and Row 2 tube values at the mid-flow slot location for the respective yield stress range. The mid-flow slot location results in the highest tube stress due to deformation of the top TSP. This conclusion is consistent with the fact that no indications were found in the Row 3 U-bend tubes.

Based on the above-discussed investigations, it has been concluded that:

- Ovality resulting from the initial manufacturing of the tubes does not appear to have a significant effect on the ID hoop stress at he apex extrados for the Row 2 and Row 3 U-bends.
- As indicated by the high ID hoop stress at the apex extrados resulting from the in-plane deformation of the U-bend tube legs, hourglassing in the top TSP appears to be a contributor to the PWSCC at the apex of the U-bends.

As indicated by the lower ID hoop stress at the apex extrados for the Row 3 tubes as compared to the corresponding Row 2, Row 3 tubes are much less susceptible to the PWSCC mechanism that affected the Row 2 tubes. Also, based on the time to crack initiation study, PWSCC at the apex extrados of the mid-flow slot Row 3 tube is expected to take 2.5 to 4.0 times the amount of time for PWSCC to initiate when compared to Row 2 tubes. It follows that since Row 3 tubes are much less susceptible, Row 4 tubes clearly are bounded by Row 3 results.

NRC RAI Letter dated March 24, 2000

Question 14

Provide the specific steam generator tube selection information for in-situ pressure testing for each defect mechanism.

Reply

The in-situ pressure testing selection criteria are set forth in the Indian Point 2 degradation assessment for refueling outage 14. The general methodology utilizes EPRI guidelines in TR-107620-R1 coupled with Indian Point 2 specific flaw screening parameters. The threshold values for NDE parameters given in Tables 1, 2 and 3 must be exceeded to recommend an indication for in situ testing.

The in-situ selection criteria is also discussed in the cycle 14 condition monitoring and cycle 15 operational assessment for non U-bend degradation mechanisms (Section 5), which was submitted to the NRC on June 2, 2000.

In-Situ Test Selection Screening Parameters for Free Span Axial Indications

The length-specific average depth is obtained statistically at 95% probabiity at 50% confidence level. As flaw characterization using a rotating probe is required to apply the statistical method, two initial screens will be applied to limit the number of indications to be depth profiled: The first screen ensures that the crack length exceeds the minimum length required to burst a 100% through wall crack, and the second screen compares maximum depth against the minimum average depth required for burst. Indications that exceed both screens are depth profiled.

The average depth over the crack length is determined from the depth profile and compared against a limiting average depth obtained from a table of average depth versus crack length at the structural limit per RG 1.121 recommendations. The screening parameters for proof testing axial indications represent lower 95% probability at 50% confidence values obtained by statistically combining uncertainties in the burst correlation, material properties and NDE uncertainties. The free span screening flaw length of 0.42" provides for $3\Delta p_{NO}$ burst margin for a single flaw morphology of 100% TW depth, but does not include NDE uncertainties since the 100% depth assumption bounds NDE depths and NDE tends to overestimate throughwall crack lengths. For example, the first screen for ID axial indications is maximum +Point field evaluation voltage $\geq$ 4.00 volts, and the second screen is max depth $\geq$ 80%. If both screens are exceeded the indication is depth profiled to determine length at max depth. Indications with> 0.1" lengths at the second screen max depth limit are leak tested.

Screening criteria for in-situ leakage or proof of pressure capability testing are established for stress corrosion cracking (SCC), both the primary side originating PWSCC and secondary side originating ODSCC, as well as for those secondary side damage mechanisms that result in actual or effective loss of tube thickness, (i.e., volumetric indications such as wear, thinning, pitting and intergranular attack). Table 1 details the selection bases for axial cracking. A length to average depth correlation for cracks that are less than through wall is provided to support candidate selection for Rows 2 U-bends as well as for Row 3 and large radius U-bend locations or straight section locations; these are presented in Figures 1 and 2. The data provided in Figures 1 and 2 are based on provision for 1.25 x σ (standard deviation) for NDE uncertainty and 79.44 ksi flow stress for the U-bends.

Axial indications located below the top of the tubesheet do not represent a potential for burst. Based on the testing program in support of the F* alternate repair criteria, 100% TW indications, regardless of TW length, in which the upper crack tip is located greater than 1 ¼" below the bottom of the roll transition would not be expected to leak at steam line break conditions.

In-Situ Test Selection Screening Parameters for Circumferential Indications

The screening parameters for proof testing of circumferential indications are determined using correlations for best estimate burst pressure with lower tolerance limit (LTL) material property values. Based on the burst correlation for circumferential indications presented in EPRI TR-107197, a critical crack angle value of 237° was obtained for a single, 100% TW flaw at the Indian Point 2 uprated conditions. To account for measurement uncertainties, the first screen for proof testing was taken as crack angle ≥ 216°. A voltage integral screening value of 0.40 volts (in Eddynet multiscan mode) was conservatively selected for Indian Point during inspections performed during refueling outage 12. The selected voltage integral screening value (0.30 volts) is bounded by previous in situ tested tubes that did not burst or leak during in situ testing. Indications exceeding both screens are depth profiled to determine percent-degraded area (PDA). Indications with PDA ≥ 21% are proof tested. For leak test screening, the first screen is maximum voltage in multiscan mode ≥ 1.50 volts for PWSCC, 1.00 volts for ODSCC, while the second screen is max depth ≥ 75% for PWSCC, 70% for ODSCC. Indications exceeding both screens are depth profiled to determine the arc length at depth ≥ the second screen depth limit value. Indications with arc length ≥ 20° at the second screen depth limit are leak tested.

In-Situ Test Selection Screening Parameters for Volumetric Indications

Selection of candidates for in situ testing based on indications that reflect volumetric wall loss as opposed to intergranular crack penetration is provided in Table 3. IGA is regarded as a volumetric effect even though it is an intergranular corrosion phenomenon, since the portion of the tube wall affected has lost its load-bearing capability even though the degraded portion of the tube thickness remains in place. Based on the results of the EOC 13 inspection, volumetric degradation mechanisms likely to be present include AVB wear, pitting, and IGA.

Table 1

In-Situ Test Selection Screening Parameters for Axial Crack Indications

(Indian Point Unit 2 Specific Values for 3ΔP = 4665 psi)

Parameter	Straight Leg		U-Bend Row 2	
	ID	**OD**	**ID/OD**	**OD**
Structural Limit, L_{STR}	0.42”	0.42”	0.605”	0.605”
Maximum Depth, $MD_{P\text{-}THR}$	52%	56%	62%	65%
Critical Voltage V_{CRIT}	4.00	2.50	4.00	2.50
Threshold Voltage, V_{THR}	3.00	1.50	3.00	1.50
$MD_{L\text{-}THR}$	80%	75%	80%	75%

(15% ID uncertainty, 20% OD uncertainty. included, with 5% allowance for ligament tearing effects)

Table 2

In-Situ Test Selection Screening Parameters for Circumferential Crack Indications

Updated Table E-4 - EPRI Circumferential Guidelines for In Situ Testing In-Situ Screening Parameters Indian Point Unit 2 Specific Values for $3\Delta P = 4665$ psi		
Parameter	**Westinghouse 7/8" OD, 0.050" Wall Thickness Tubing**	
	PWSCC	**ODSCC**
Crack Angle: CA_{TWSL}	$216^{\circ(1)}$	$216^{\circ(1)}$
PDA • PDA_{SL} • PDA_{THR}	 71% 23%	 71% 23%
Avg. Volts; +Point(2) • AV_{SL} • AV_{THR}	 Undefined 0.3	 Undefined 0.3
Max. Volts; +Point(2) • VM_{THR} • VM_{PLL}	 1.5 3.0	 1.00 3.0
Max. Depth • DM_{THR}	75%	70%

Notes:
1. Represents a conservative threshold angle compared to structural limit of about 237° for a throughwall crack
2. Voltages given are vertical amplitudes obtained using EDDYNET95 voltage integral software

Table 3

In situ Leak and Proof Pressure Test Screening Criteria for Indian Point 2: Volumetric Indications

Bobbin Maximum Depth	AVB Wear: 65% Pitting: 53% IGA: 50%	If the observed bobbin maximum depth does not exceed these values, leak test only if the signal voltage exceeds 4.5 volts (80% of single 100% through wall ASME hole.
MRPC Maximum Depth (+Point depth sizing should be based on ASME FBH standard or other volumetric (e.g., wear) standards).	AVB Wear: 65% Pitting: 53% IGA: 50%	If the observed +Point maximum depth does not exceed these values, leak test in the signal voltage exceeds 80% of +Point response for a single 100% through wall ASME hole.
+Point Axial Length: (For indications that satisfy both bobbin and +Point depth criteria.)	If the axial length > 0.7"	Perform leak test and proof of pressure test.
	If the axial length is not > 0.7"	Compare to length/depth table; if an indication exceeds criteria, perform leak test and proof of pressure test.
		If indication does not exceed the criteria in length/depth table, leak test in the signal voltage exceeds 80% of +Point response for a single 100% through wall ASME hole.

Average Depth Vs Axial Length

Axial Length	AVB Wear	IGA		Pitting: Structural Limit: 85% (NSD-E-SGDA-99-448); with NDE error at 32%, leak test if voltage > 80% of +Point or bobbin response for a single 100% through wall ASME hole.
		Elliptical Wastage	Uniform Thinning	
		< 100°	≥ 100°	
Up to 0.375"	N/A	55%	49%	
0.376" to 0.500"	64%	54%	44%	
0.501" to 0.625"	N/A	53%	40%	
0.626" to 0.750"	N/A	52%	38%	

If any indication fails the proof pressure test, proof pressure test at least 5 additional indications per each failed indication as follows:

(1) Indications exceeding maximum bobbin and +Point depth with the largest average depth;

(2) Indications with bobbin depths > above criteria with largest average depth but with +Point depths < above criteria;

(3) Indications with largest lengths.

Condition Monitoring Burst Resistance Acceptance Limits

ODSCC of 7/8" x 0.050" Alloy 600 MA SG Tubes at 650°F

3DPno = 4.655 ksi, 95/50 Probability/Confidence

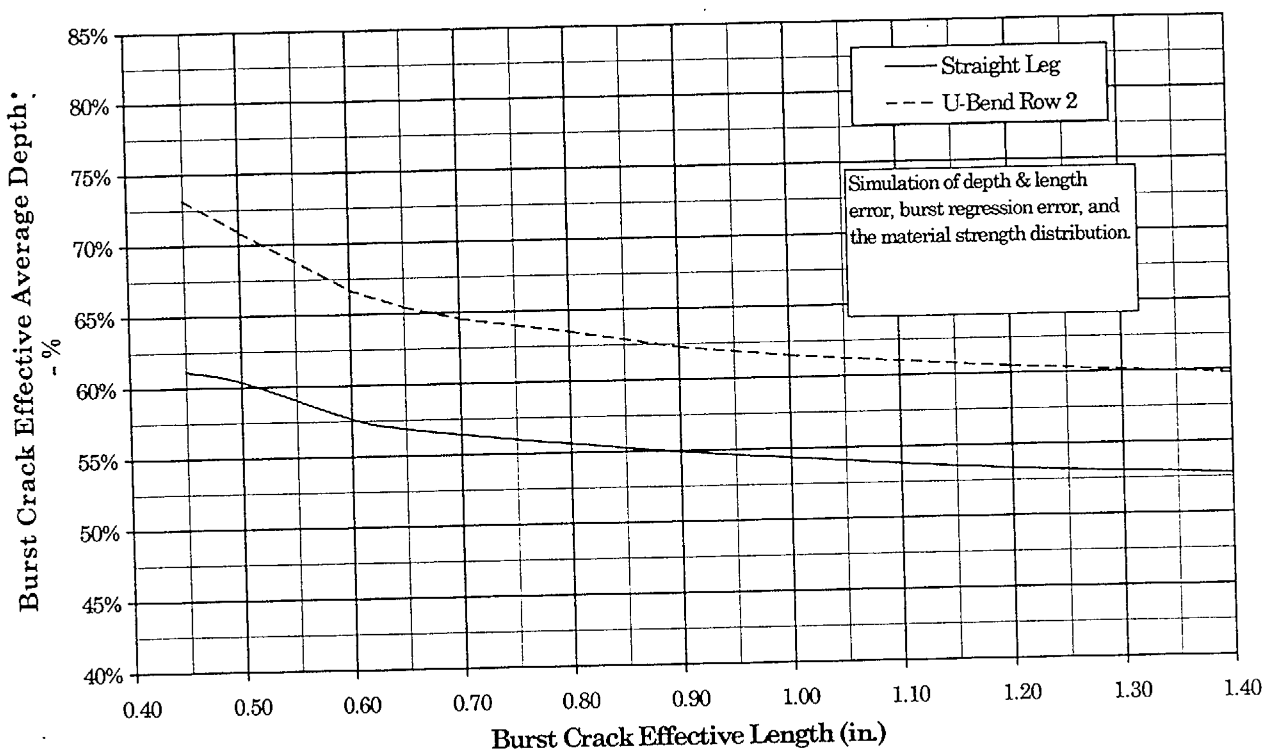
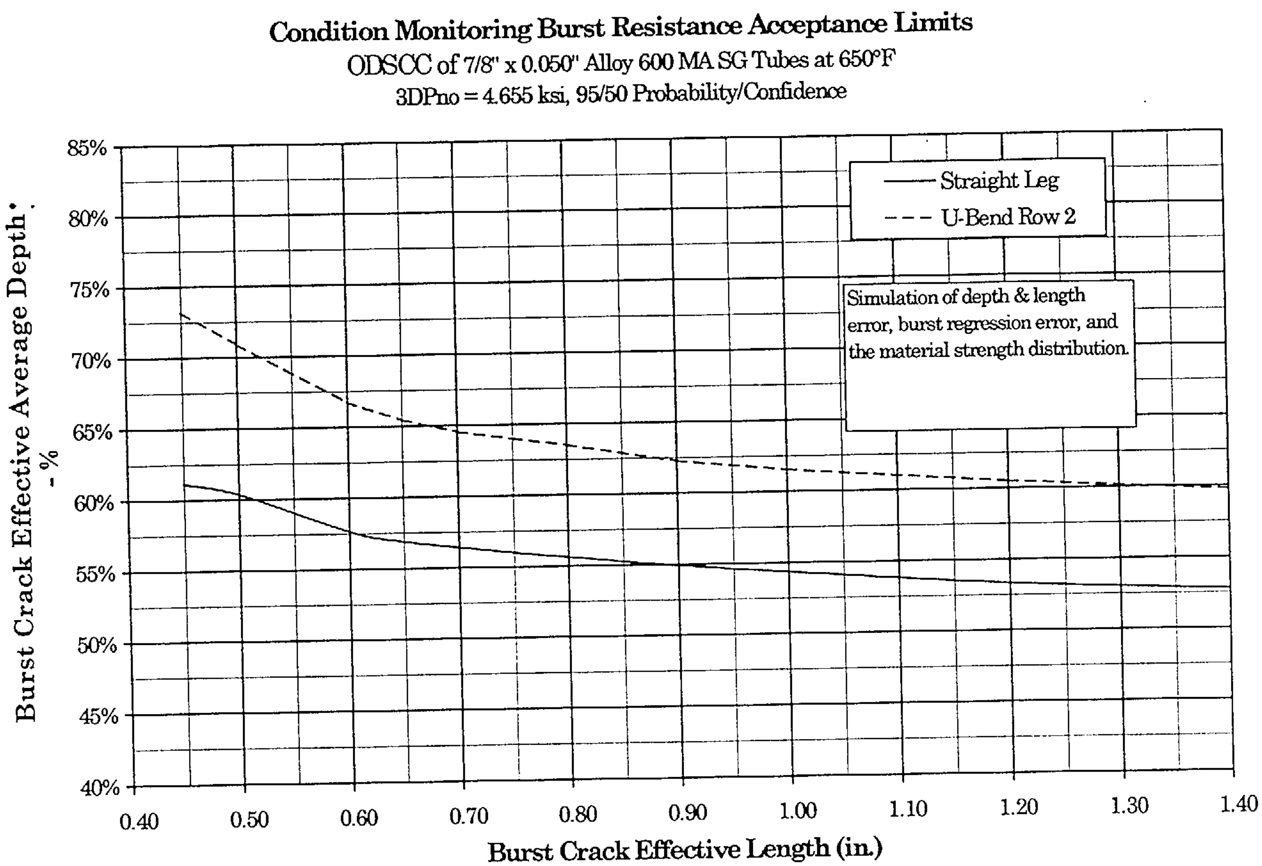


Figure 1

Notes:

1. These curves are based on a conservative pre-outage anticipated $3\Delta P_{NO}$ value of 4655 psi, rather than the actual IP2 value of 4617 psi.



Notes:

1. These curves are based on a conservative pre-outage anticipated $3\Delta P_{NO}$ value of 4655 psi, rather than the actual IP2 value of 4617 psi.

Figure 2

NRC RAI Letter dated March 24, 2000

Question 18

Identify how many tubes are affected by the "blind spot" located at the upper span of tubing between the TTS and 1H span and explain how you plan to disposition these tubes. Assess the potential for sludge pile ODSCC to be in the blind spot region. Given the results of this assessment, provide the basis for reasonable assurance that tube integrity will be provided while the plant is operating.

Reply

Identify how many tubes are affected by the "blind spot" located at the upper span of tubing between the TTS and 1H span and explain how you plan to disposition these tubes.

Based on the inspection results, there are no 'blind spots' that were encountered during the inspection of the steam generators. If there were any areas in a tube where the analysts felt the data quality was not adequate, the inspection result was listed as Bad Data. The tube was then either re-inspected or placed on the plugging list and taken out of service for the next operating cycle. There were NO tubes left in service that were not fully inspected and determined to be acceptable.

Assess the potential for sludge pile ODSCC to be in the blind spot region.

ODSCC was identified in the sludge pile region using eddy current techniques. Two other inspections methods, Ultrasonic and In-situ pressure testing were also used to confirm the results of the eddy current inspections were accurate and through. A detailed discussion of the results is summarized below. Table 4.4-3 (IP2 EOC-14 Sludge Pile Indications (attached))of the Non U-bend CMOA provides a summary of the ODSCC indications that were detected in the sludge pile area. All tubes with indications (e.g. cracks) were taken out of service by plugging the tube.

Given the results of this assessment, provide the basis for reasonable assurance that tube integrity will be provided while the plant is operating.

Relative to the time period defined in the Refueling Outage (RFO) 2000 Condition Monitoring and Operational Assessment (CMOA) for the IP2 SGs, multiple factors provide confidence that an acceptable level of confidence exists that the condition of the IP2 SGs is as stated in the 2000 RFO CMOA.

Evaluation of a potential "blind spot" in the IP2 data where degradation cannot be detected using eddy current due to the presence of deposits was conducted. Deposit conditions at IP2 are typical of older SGs, and eddy current techniques have been successfully used under these conditions. Deposits of this nature, while not typical of newer steam generators, have been common in the history of the industry and are reflected in the industry training via the QDA examination. These are also part of the site specific training.

Confidence in the inspection of the sludge pile region is addressed and developed using multiple sources. Two of these sources are ultrasonic testing and in-situ pressure testing. These two techniques are independent of the eddy current process and not subject to the same external influences. Additionally, an expanded RPC program was performed to better characterize that region.

Ultrasonic Testing

Two ultrasonic testing programs were performed at Indian Point Unit 2. The first was performed solely to characterize/confirm indications in 22 tubes from the initial inspection program. This program showed the eddy current to be conservative with respect to indications termed as pits. The second program was to address a perceived detection issue raised by the NRC and is discussed in the remainder of this section.

In order to better understand the effects of the deposit conditions on the IP2 inspection, a review of a number of tubes in one steam generator for eddy current noise was performed. Twenty-three of these tubes with a range of deposit signals and sludge influence between the tubesheet and the first support plate on the hot leg were selected for examination using ultrasonic testing (UT). Sixteen of these tubes were considered to have no detectable degradation by eddy current. The remaining seven tubes had axial (four tubes), pitting (two tubes) and wear or volumetric (one tube) indications by eddy current. The UT extended through the first support plate for twenty-two of these tubes. The twenty-third tube was restricted to the passage of the UT probe at the first support plate. In no case did UT of these 23 tubes detect any indication which was not previously reported by eddy current techniques.

The reason UT testing is important to assess the reliability of the eddy current analysis in the sludge pile and deposit regions is that the principles upon which UT operates are different than eddy current. Determination of the condition of the tube is determined by the time of flight of directed sound waves rather than by electromagnetic induction. Sound is directed in three different directions in order to detect and characterize axial, circumferential and volumetric indications. UT is not affected by conductive and magnetic variations due to deposits and can more easily separate out the deposits from the tube itself. Thus, the UT results provide an independent technique to confirm the eddy current analysis.

The results of the second UT program and the agreement of the results of the UT with the eddy current for the 23 tubes, provide further confidence in the eddy current techniques to detect degraded tube conditions in the presence of deposits. The correlation of the results between the eddy current and UT programs, provides further justification for not conducting further reviews of inspection results in regions of suspected deposits.

In-Situ Pressure Testing

All axial indications reported above the top of tubesheet, irrespective of measured depth or dimension, were in-situ pressure tested. The in-situ population also included all low row U-bends with axial indications, a sampling of pits and volumetric indications in the sludge pile region, crevice indications and a four (4) tubes with no detectable degradation (NDD). In all, 51 tubes were in-situ tested. Of the 40 tubes with indications in the deposit, sludge pile or crevice regions, only one leaked: S/G-22 R34 C51. This tube was identified as having an indication during the course of the initial Cecco-bobbin inspection scope. None of the tubes identified in the expanded RPC program – a population of smaller indications (in length, amplitude and depth) than those identified in the initial program - leaked when in-situ tested. This provides additional confidence that there were no significant unreported indications in the initial program.

Statistics From Independent Techniques

Information from other test techniques which are independent from eddy current techniques (i.e. not based on the same principles) also can be used to develop confidence in the technique and analysis used for the IP2 eddy current inspection. The two supplemental techniques which can be considered for this purpose are UT (as noted above) and in-situ pressure testing. When one considers the number of tubes in-situ pressure tested and the number of tubes tested by UT during the RFO 2000 IP2 inspection program, a population of tubes which exhibited no additional degradation in the sludge pile and deposit region can be developed. For the in-situ tubes, a population of 41 tubes is relevant. These tubes were post-in-situ eddy current tested with no additional indications were detected in the region of interest. For the UT population, the cross population with the in-situ tested tubes must be removed. This leaves 29 tubes where UT showed no additional indications when compared to eddy current. Using this total population of 70 tubes as representative of the ability of eddy current to accurately reflect the condition in 70 of 70 tubes, including that no additional 'hidden' indications exist, it can be stated that the eddy current technique and analysis exceed a 95% POD at 95% confidence.

Expanded RPC Program

During the bobbin and Cecco analyses in the initial program, questions were raised regarding the consistency of detection of flaws of small amplitude and those in regions influenced by deposits. Due to these questions, the region from the tube end to a minimum of 48 inches above the top of the tubesheet was RPC inspected for 20% of the hot leg, concentrating in the kidney region which should be most affected by scale deposits. The remaining 80% of the tubes were RPC inspected from 24 inches above the top of the tubesheet for the hot leg and for a

20% sample of the cold leg. The inspection was restricted to a height of 24 inches above the top of the tubesheet for most of the tubes since the initial 20% sample did not identify any axial indications more than a few inches above the top of the tubesheet.

Both the hot and cold leg programs had expansion criteria defined in a manner consistent with the EPRI PWR Steam Generator Examination Guidelines. This led to 40% samples in the cold leg of steam generators 23 and 24. As a result, a minimum of six reviews (three probe types, each with primary and secondary analyses), utilizing multiple techniques as mentioned previously, were performed for this region for all of the tubes in the expanded RPC program. As a result of this expanded RPC program, a total of seven (7) previously unidentified axial indications were found above the top of the tubesheet. Expert review of these seven (7) indications by the lead analyst, prior to in-situ testing, considered three of these to be marginal calls and more likely to be deposits.

Also, for the expanded RPC program, statistics for axial indications in the hot leg crevice and above the hot leg tubesheet were compiled based on a binomial distribution. These statistics did not include indications reported prior to the expanded program The primary analysis reported 180 of 210 indications for a probability of detection (POD) of 80% at a 98% confidence level (CL). The secondary analysis reported 175 of 207 indications for a POD of 80% at a 94% CL. (Note that the difference in the total population is due to the fact that the secondary analysis had considered three of the 210 tubes to be bad data and, therefore, they were not counted in the secondary statistic.)

To provide an additional check on analysis performance, single analyst statistics were reviewed with EPRI and CE Nuclear representatives. This was done when the statistics were initially compiled and as the aforementioned review proceeded. Based on this review, the general statistics were considered to be reasonable and what was expected by industry guidelines, and not an abnormal result for analysis statistics. The combined POD for the overall process for 210 of 210 indications is 98% at a 98% CL.

For the expanded RPC program, the primary and secondary analysis POD's were within accepted industry norms. The reviewed performance of selected individual analysts showed that they performed as would be expected. Based on these observations, it can be concluded that the performance of all of the analysts participating in the expanded RPC program fell within accepted industry guidelines, standards and expectations.

Summary

The above discussion demonstrates that the adequacy of the eddy current analysis of the sludge pile region can be considered to be within industry norms. This is corroborated by the multiple techniques utilized during the IP2 2000 RFO inspection program. The "blind spot" region has been demonstrated, by the means of independent techniques, to not be an issue in the inspection of the sludge pile region. As shown by this assessment, the confidence in the analysis of the data and results from the IP2 inspection is based on the eddy current analysis itself, as corroborated by other means. These means consisted of: the number of tests and analyses each tube received using multiple inspection techniques; the scope and results of the expanded RPC program; the acceptable performance level (POD) exhibited by the general analysis statistics; the validation of the eddy current techniques by UT and in-situ testing to detect in the presence of deposits; and the structural margin observed by in-situ pressure testing. All of these corroborating means viewed together as a whole, provide sufficient confidence that the condition of the IP2 SGs is as stated in the 2000 RFO CMOA.

The preponderance of data regarding the condition of the SGs and the adequacy of the eddy current and other testing supports the conclusion that the inspection techniques and the analysis results provide reasonable assurance that that tube integrity will be provided while the plant is operating. .

Table 4.4 -3
IP2 EOC-14 Sludge Pile Indications

				Unadjusted NDE				Adjusted NDE				Burst Adjusted NDE				Burst Pressure (ksi)
SG	Row	Col.	Crack No.	Length (in.)	Maximum Depth (%)	Average Depth (%)	Max. Volts	Length (in.)	Maximum Depth (%)	Average Depth (%)	Max. Volts	Length (in.)	Maximum Depth (%)	Average Depth (%)	Max. Volts	
1	34	41	1	0.520	66.0	46.12	0	0.540	56.5	38.24	0.26	0.410	56.5	43.91	0.26	7.852
2	32	48	1	0.280	71.0	40.13	0	0.280	62.0	35.29	0.16	0.230	62.0	37.80	0.16	8.855
2	33	49	1	0.400	56.0	32.49	0	0.400	38.0	22.05	0.18	0.310	38.0	25.85	0.18	9.610
2	33	51	1	0.770	67.0	44.16	0	0.770	47.0	34.31	0.39	0.530	47.0	42.07	0.39	7.841
2	33	54	1	0.260	73.0	38.35	0	0.260	30.0	15.76	0.33	0.130	30.0	22.68	0.25	10.353
2	33	54	2	0.130	42.0	24.69	0	0.130	30.0	17.64	0.28	0.100	30.0	20.46	0.28	10.637
2	34	51	1	1.260	91.0	63.48	1	1.260	84.0	63.48	0.88	1.160	84.0	65.79	0.88	4.962
2	34	51	2	1.330	90.0	66.12	1	1.350	88.0	65.34	0.89	0.540	88.0	77.41	0.89	4.405
2	34	51	3	0.590	93.0	75.29	1	0.590	75.0	60.72	0.55	0.490	75.0	65.90	0.55	5.639
2	34	54	1	0.170	40.0	18.74	1	0.190	40.0	18.87	0.75	0.140	40.0	24.32	0.75	10.202
2	34	54	2	0.070	25.0	20.93	0	0.110	30.0	20.24	0.19	0.090	30.0	22.47	0.19	10.592
2	34	54	3	0.270	48.0	26.94	1	0.270	30.0	16.84	0.56	0.150	30.0	26.27	0.47	10.028
2	35	51	1	0.590	80.0	52.70	1	0.590	62.0	44.15	0.51	0.390	62.0	54.74	0.51	6.917
2	35	52	1	0.420	80.0	25.77	1	0.420	30.0	11.29	0.55	0.220	30.0	17.52	0.55	10.438
3	3	88	1	2.280	75.0	30.39	0	2.280	30.0	12.16	0.18	0.740	30.0	21.34	0.12	9.693
3	29	46	1	0.270	50.0	35.19	0	0.270	44.0	31.59	0.47	0.205	44.0	37.14	0.47	9.008
3	29	46	2	0.370	40.0	22.61	0	0.370	30.0	16.96	0.27	0.160	30.0	23.55	0.21	10.168
3	29	46	3	0.290	30.0	20.27	0	0.305	30.0	19.57	0.34	0.260	30.0	21.93	0.34	10.020
3	30	46	1	0.750	40.0	26.69	0	0.750	33.0	22.88	0.32	0.490	33.0	27.92	0.32	9.206
3	31	46	1	1.080	81.0	53.34	1	1.080	62.5	46.30	0.56	0.930	62.5	48.93	0.56	6.848
3	31	47	1	0.570	32.0	19.68	1	0.585	30.0	18.03	0.56	0.315	30.0	23.98	0.56	9.759
3	31	47	2	0.270	49.0	32.83	0	0.270	47.5	31.83	0.46	0.210	47.5	38.24	0.46	8.903
3	31	47	3	0.210	45.0	23.60	0	0.210	45.0	23.60	0.31	0.170	45.0	27.38	0.31	9.865
4	30	27	1	2.350	44.0	18.80	1	2.350	30.0	12.82	0.51	0.460	26.6	17.45	0.41	10.186
4	42	43	1	0.330	93.0	36.22	0	0.350	30.0	17.60	0.22	0.350	30.0	17.60	0.22	10.257

Root Cause Evaluation – Issue No. 5

Section 4.3 [of the root cause report] should address flow slot hourglassing data for all of the u-bend indications found in 1997 and 2000. This is necessary to demonstrate a relationship between the occurrence of hourglassing and u-bend cracks.

Reply

All U-bend indications found in 1997 and 2000 during eddy current tests (ECT) are located in Row 2 tubes that line up with flow slots. These indications are all PWSCC indications. None of these tubes are located in the hard spot regions between the flow slots where support plate deformation due to hourglassing is minimal. Figure 1 provides a graphical representation of the location of the tubes with PWSCC indications in the U-bends with respect to the flow slots. This data is summarized in the following table and further discussed below:

SG	Tube No.	Outage	Flow Slot	Hard Spot
21	R2C87	2000	M-1	N/A
23	R2C85	2000	M-1	N/A
24	R2C67	1997	M-2	N/A
24	R2C5 (Leaked)	2000	N-1	N/A
24	R2C4	2000	N-1	N/A
24	R2C69	2000	M-2	N/A
24	R2C71	2000	M-2	N/A
24	R2C72	2000	M-2	N/A
24	R2C74	2000	M-2	N/A

- Tubes R2C87 in SG21 and R2C85 in SG23 were identified with indications in the U-bend during the 2000 inspection. These are in-line with the outermost flow slot M-1 on the manway side of the respective steam generators. One tube is located at the middle of the flow slot and the second is approximately one third of the way along the slot.
- The one tube that was found with an indication in the U-bend region during the 1997 inspection, R2C67 in SG24, is located in-line with slot M2. This tube is located approximately one third of the way along the slot.
- R2C5 in SG24, which experienced the leak in February 2000, is in-line with flow slot N-1, the first slot on the nozzle side. This tube is three tubes from the edge of the slot.

- Tube R2C4, which was identified with an indication in the U-bend section during the 2000 inspection, is also in-line with slot N-1 in SG24 and is located two tubes from the edge of the slot.
- Four more tubes in SG24 (R2C69, R2C71, R2C72, and R2C74) were also identified with indications in the U-bend during the 2000 inspection. These are in-line with flow slot M2, the second slot from the manway side and are located along one half of the slot.

Stress analyses of U-bend tubes have shown that displacement of the tube legs due to hourglassing at the top support plate increases the tube hoop stress at the inside diameter of the extrados of the apex [1]. The extrados apex of the U-bend is the location of highest stress in the U-bend region of the tube under hourglass conditions. These analyses have also shown that a stress plateau, or leveling off of hoop stresses, is reached for low row U-bends, at a level of hourglassing that is as low as 0.2 inch, where an increase in hourglassing results in a minimal increase in the hoop stress for the tubes with the lower yield stress. The tubes that reach yield can be grouped by tube rows, as result of geometry, manufacturing and operational loads. Since the Row 2 tubes will reach yield first, a decision was made during the 2000 outage to preventively plug all Row 2 tubes, thus precluding any additional concerns from Row 2 tubes. The row next affected by hoop stress considerations would be Row 3. Tube examinations have shown no indications on any Row 3 tubes. This is supported by the finite element stress model, which shows that the stresses in Row 3 are lower and the susceptibility toward cracking is at least 2.5 to 4.0 times lower than it is for the Row 2 tubes. The finite element stress model discussed in the Conditional Monitoring and Operational Assessment report also showed that the growth movement of the support plate due to cumulative denting throughout the plate initially affects the outermost flow slots. Based on the stress model, it is believed that very minor hourglassing, which is not visible during visual inspections, was most likely reached during the initial active-denting years of the IP2 steam generators.

Relative displacement of the U-bend tube legs, resulting from a given amount of hourglassing, was also determined from a finite element stress analysis of the top support plate [1]. This analysis has shown that due to flow slot hourglassing, U-bend leg displacement effects, and therefore U-bend hoop stress, decreases as the distance from the flow slot increases at larger radius bends in higher row tubes. U-bend leg displacements have also been shown to be minimal at the hard spot regions, as compared to the flow slot regions, resulting from flow slot hourglassing.

Since susceptibility to PWSCC increases with increasing stress, the conclusion is that tubes in the hourglassed flow slot regions (as opposed to the hard spot regions) and closer to the slots (i.e. Row 2 rather than Row 3 tubes) would exhibit the first indications of PWSCC in their U-bend regions. The ECT data from the 1997 and the 2000 inspections, presented above, corroborates this conclusion.

Additional Observations

Since all Row 2 tubes were preventively plugged in all steam generators, no further measurements were taken of the other flow slots.

The decision to not perform direct measurement of additional flow slots was considered to be acceptable for the following reasons:

a. Con Edison performed visual inspections of all upper support plate flow slots, and these flow slots all appeared to be similar (i.e. hourglassing was not visually detected, implying that the extent of hourglassing is minimally low).

b. Con Edison conservatively assumed that all flow slots were hourglassed in excess of the minimum amount (0.2 inch) necessary to impose the amount of hoop stress at the apex of the U-bends that is required to induce PWSCC. The finite element stress model showed that hourglassing beyond 0.2 inches does not significantly increase hoop stress, and thus would not have a significant effect on the propensity for PWSCC to occur. Thus, even if hourglassing effects were variable and non-uniform, the analysis conservatively would account for this.

c. All four SGs are similar in their manufacturing details, chemical environments and operating conditions, and are therefore expected to respond in a similar fashion.

d. Con Edison conservatively and preventively plugged all Row 2 tubes in response to the findings of the finite element stress model.

e. Since hourglassing is not visually apparent or minimal after 25 years of service at Indian Point 2, and since leg displacement beyond that necessary to induce PWSCC is conservatively assumed, there would be no benefit to establishing an hourglassing "base-line" for postulating additional hourglassing effects during the next cycle.

f. Con Edison conservatively applied a PWSCC-free boundary criteria whereby each succeeding row would be plugged if any PWSCC were detected in that row until a two row boundary of crack free tubes were in place.

g. Based on the foregoing factors, assumptions and activities, additional flow slot measurements would not provide materially significant technical information.

h. Conducting additional measurements would result in more man-rem exposure without a commensurate increase in useful data, thereby invoking ALARA considerations.

Additional analyses and laboratory testing were then performed on row 2 and 3 tubes to assess relative susceptibility of row 3 tubes to PWSCC as compared to that of row 2 tubes. As indicated in the Condition Monitoring and Operational Assessment (CMOA) report [3], it was concluded that it will take approximately 2.5 to 4 times longer for a longitudinal PWSCC indication at the extrados of the apex of a row 3 tube to develop than it would at the same location in a row 2 tube. Based on laboratory data, this is due to at least a 10,000 psi lower inside diameter hoop stress value in row 3 tubes than in row 2 tubes at the mid-flowslot location, which is the location of highest stress, resulting from lateral displacement of the U-bend legs. This is consistent with the fact that no indications were found in the row 3 U-bend tubes.

The CMOA [3] accounts for these analyses and provides the justification for operation. Based on the above, it is concluded that the level of measured hourglassing will not pose a leakage concern during the upcoming shorter operating cycle.

References:

1) Altran Corporation, "Overview of Small Radius U-Bend Tube Susceptibility to PWSCC for Indian Point 2 Steam Generators," Technical Report 00603-TR-005, Revision 0, May, 2000 (Attachment 1 to Reference 3).
2) Westinghouse Electric Company, "Indian Point Unit 2 (IP2), Cycle 14 Condition Monitoring Assessment and Cycle 15 Operation Assessment for Degradation Mechanisms Other than U-Bend PWSCC," SG-00-05-010, Rev. 0, May 2000.
3) Westinghouse Electric Company, "Indian Point 2, U-Bend PWSCC Cycle 14 Condition Monitoring and Cycle 15 Operational Assessments," SG-00-05-008, May 2000.

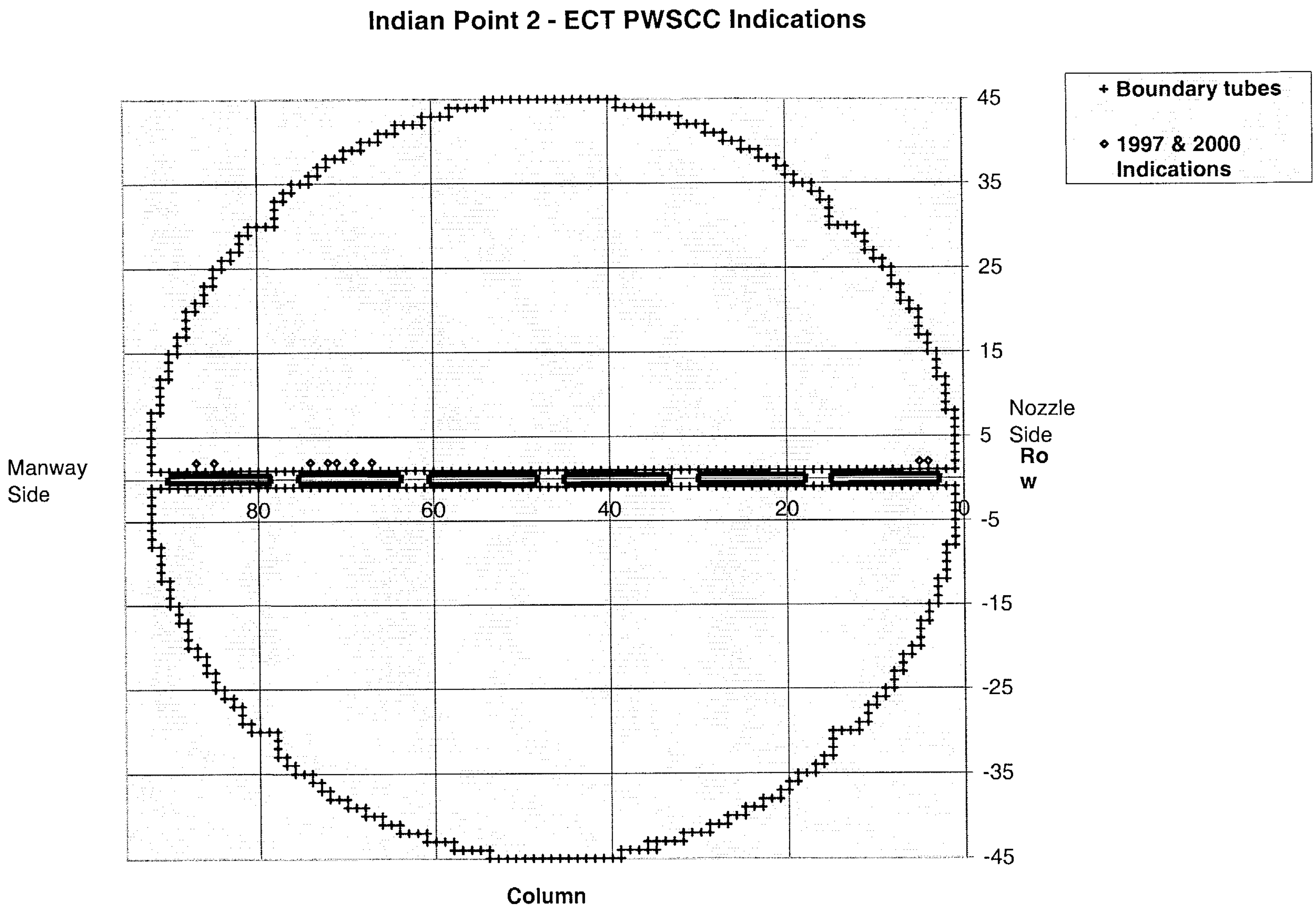


Figure 1: Location of Tubes with ECT PWSCC Indications in the U-Bends from the 1997 and 2000 Inspections

(Locations shown are from SG21, SG23 and SG24)

Root Cause Evaluation – Issue No. 7

What was the basis for assuming the generic EPRI Appendix H qualification of the plus point mid-range probe for small radius u-bend inspection to be applicable to the site specific conditions at IP2 (high noise due to copper and magnetite surface deposits)? Why wasn't a site-specific qualification performed as called for in the EPRI guidelines?

Reply

What was the basis for assuming the generic EPRI Appendix H qualification of the plus point mid-range probe for small radius u-bend inspection to be applicable to the site specific conditions at IP2 (high noise due to copper and magnetite surface deposits)?

As discussed previously in Con Edison's response to Root Cause Evaluation – Issue No. 1 (Reference 1), the use of the mid-range +Point probe was qualified in accordance with EPRI Appendix H requirements under ETSS # 96511. See also response to Question 4 of NRC Letter to Con Edison dated March 24, 2000 contained within. The conclusion that this +Point probe was applicable to specific conditions at IP2 was based on several actions taken and information available to ConEd and Westinghouse at the time of the 1997 inspections. EPRI's "PWR Steam Generator Guidelines, Revision 4, Volume I, Guidelines" (June 1996), Section H.2.1, "Techniques Requirements," states that, "the technique specification shall contain a statement of scope that specifically defines the limits of the technique's applicability in the context of damage mechanism/extraneous test variables combinations, material, and geometry." Attachment H2 to the EPRI recommendations notes in Section H2.2.1(d) that, "[w]here applicable, the influence of extraneous test variables associated with each of the damage mechanisms (e.g., denting, deposits, tube geometry changes) shall be addressed."

The EPRI recommendations are addressed in several different IP2-specific documents. Specification No. NPE-72217, "Eddy Current Examination of Nuclear Steam Generator Tubes, Indian Point 2," December 17, 1996, issued to Westinghouse, states in Section 4.4 that, "The frequencies and mixes selected [by Westinghouse] must be capable of identifying defects in the presence of sludge and/or copper deposits…". Westinghouse responded to this specification by committing to its parameters. Consideration of copper was confirmed in documents such as EPRI Examination Technique Specification Sheets (ETSS # 96005).

Additional parameters were addressed in a Cecco 5 Analysis Comparison Data Package, 640 Cecco-5 Probe Validation Report" (April 11, 1997), Section 2, Table 1. This table, which also summarized assessments of the +Point probe, provides the results of eddy current data collections at IP2 with the influence of magnetite deposits. This table concludes that both techniques (i.e., use of the Cecco and +Probe) detected all flaws with and without magnetite.

Why wasn't a site-specific qualification performed as called for in the EPRI guidelines?

Con Edison does not agree that Revision 4 of the EPRI guideline document, which was in effect during the 1997 probe qualification period, called for site-specific technique qualification of the mid-range +Point probe. Site-specific EPRI Appendix H qualifications currently required by EPRI steam generator inspection standards were not customarily performed in the industry in the 1997 timeframe when generic qualifications were deemed to be sufficient. Nonetheless, as discussed above, Westinghouse confirmed to Con Edison in 1996 and 1997 that the deposits in the IP2 steam generators were specifically accounted for, as necessary, in determining that the mid-range frequency +Point probe was acceptable for small radius U-bend inspections at IP2. As such, IP2 believes that since characteristic IP2 site-specific effects were considered, it can reasonably be concluded that the elements of a site-specific qualification of the +Point probe were performed.

References:

1. Con Edison letter to NRC dated June 16, 2000.

Root Cause Evaluation – Issue No. 17

[Root Cause Report] Section 9.1 states that prior to the IP2 event, there have been no significant industry leakage events at the row 2 apex location. Have there been reported row 2 apex cracks? What were the circumstances? What about row 3? Apart from axial apex cracks and tangent point cracks, have there been other kinds of axial or circ. ID or OD cracks affecting row 2 or row 3 u-bends? (NUREG/CR-5117 reported ODSCC at the apex of row 2 u-bends at Surry 2).

Reply

Background

The Condition Monitoring and Operational Assessment (CMOA), Section 7.0 [1] includes a detailed discussion on U-bend cracking in the industry.

In general the industry history of recirculating steam generators has included cracking of Row 1 and Row 2 U-bends but, with a few exceptions, essentially no cracking of Row 3 or higher U-bends. Much of the Row 1 and Row 2 U-bend cracking occurred fairly early in life with plants having Alloy 600 mill annealed tubing. In the 1970s and 1980s, PWSCC was reported in the U-bend apex region at Surry 1 and 2, Turkey Point 3 and 4, Obrigheim, Doel 2, and Beznau 2 [2]. The cause of this cracking was attributed to two different sources. The first source was denting at the tube support plates and the second was excessive ovality of the U-bends.

a. Have there been reported row 2 apex cracks?

Yes. Table 17-1 includes a summary of U-bend indications in rows 2. Diablo Canyon 2 identified a row 2 PWSCC indication near the apex of one U-bend in 1998. The indication had a low voltage (0.79 volts) and was 0.14 inches long.

b. What were the circumstances?

The PWSCC indication at Diablo Canyon 2 was in SG 23, R2 C 61 near the apex of the U-bend. The indication was detected by Plus Point. The tubing was manufactured by Westinghouse, Blairsville. The rows 1 and 2 U-bend tubing was heat treated after one cycle of operation. The hot leg temperature is 603^0F.

c. *What about row 3?*

A row 3, PWSCC indication was reported at McGuire in 1991 ~1 inch from the U-bend apex. Their SGs are Westinghouse Model D and operate at 618^{0}F which is significantly higher than the IP2 operating temperature of 589^{0}F. The industry review team that provided oversight to IP2 during the current SG inspection and evaluation included a representative from Duke Power the operator of the McGuire plant. There were no issues from the McGuire indication that were highlighted by the review team as being significant to the leak event at IP2.

A row 3 ODSCC indication was also identified at Farley 1 in 1997.

A row 3 ODSCC was identified at Kewaunee in 2000. Subsequent review of the data indicated these as potential manufacturing burnish marks (MBMs).

d. *Apart from axial apex cracks and tangent point cracks, have there been other kinds of axial or circ. ID or OD cracks affecting row 2 or row 3 u-bends? (NUREG/CR-5117 reported ODSCC at the apex of row 2 u-bends at Surry 2.)*

Table 17-1 summarizes the types of U-bend indications identified in rows 2 and 3 of Westinghouse supplied SGs. The only indications identified other than MBMs were axial or circumferential, ID or OD cracks.

NURE/CR-5117 described ODSCC identified at the apex of row 2 U-bends at Surry 2. This corrosion damage was attributed along with the ID initiated PWSCC to high stresses produced from the inward movement of the TSP into the flow slots (hourglassing) due to denting. It was also noted that SCC was not observed at the apex of row 3 U-bends or at the transition region of any specimens examined.

During the qualification of the high frequency 800 kHz +point probe (HF +Point) the probe was tested to determine if it could detect ODSCC. The HF +Point probe was tested against EPRI standards in addition to 3 tubes with ODSCC that were previously identified during the 2000 inspection report. These test verified the HF +Point probe could detect indications on the outside wall of the tubes. Therefore there is no concern for being able to detect the type of ODSCC experienced in the Surry U-bends.

References:

1. "Indian Point 2 U-Bend PWSCC Cycle 14 Condition Monitoring and Cycle 15 Operational Assessment," May 30, 2000.

2. Steam Generator Reference Book, Rev 1, EPRI TR-103824, December 1994, pp 7-27 to7-32.

Table 17-1 Summary of U-Bend Rows 2 and 3 Indications

Westinghouse Originally Supplied Model 44 and Model 51 Steam Generators

Plant	**Year Ind. Found**	**Heat Treat**	**Probe**	**Crack Type**		**ID or OD Crack**		**U-Bend Location**	
				Axial	**Circ.**	**PWSCC**	**ODSCC**	**Near Apex**	**Near Tangent**
Row 3 Indications									
Farley-1	1997	No	+Point	1			1	1	
	1997	No	+Point	1			1		1
Farley-2	None	No							
Diablo Canyon-1	None	No							
Diablo Canyon-2	None	No							
Sequoyah-1	None	No							
Sequoyah-2	None	No							
Kewaunee	2000	No	+Point	5 tubes 11 ind.			5 tubes 11 ind.(1)	1 tube 1 ind.	4 tubes 10 ind.(2)
	None	No					3 MBMs '95, '96		3
Prairie Island-1	None	No							
Prairie Island-2	None	No							
Indian Point-2	None	No							
McGuire-1	1991	No	Pancake	1		1		≈1"from apex	
Row 2 Indications									
Farley-1	1991	Yes	Pancake	1 tube 2 ind.		1 tube 2 ind.			1 tube 2 ind.
	1994	Yes	Pancake	2			2		2
Farley-2	None	Yes							
Diablo Canyon-1	1992	Yes	Pancake	1		1			1
	1994		Pancake	1		1			1
	1997		+Point	1		1			1
Diablo Canyon-2	1996	Yes	+Point	1		1			1
	1998		+Point	1		1		1	
Sequoyah-1	None	Yes							
Sequoyah-2	None	Yes							
Kewaunee	1990	No	Bobbin/ Pancake		1				1
	2000	No	+Point	1 tube 2 ind.		1 tube 2 ind.(1)			1 tube 2 ind.
Prairie Island-1	None	No					1 MBM '81		1
Prairie Island-2	None	No							
Indian Point-2	1997	No	+Point	1		1		1	
	2000	No	+Point	8 tubes 15 ind.		8 tubes 15 ind.		8 tubes 15 ind.	

Notes:

1. New inspection results under review as potential MBMs. Indications were plugged.
2. Indications located between 1 inch above tangent and 1 inch below apex.