

**OFFICIAL TRANSCRIPT OF PROCEEDINGS  
UNITED STATES OF AMERICA  
NUCLEAR REGULATORY COMMISSION**

**Title:           NRC AND CONSOLIDATED EDISON  
                  TECHNICAL MEETING REGARDING IP2  
                  STEAM GENERATOR**

**Work Order No.:   NRC-1263**

**LOCATION:           Rockville, MD**

**DATE:            Wednesday, May 3, 2000**

**PAGES: 1 - 157**

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UNITED STATES OF AMERICA  
NUCLEAR REGULATORY COMMISSION

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NRC AND CONSOLIDATED EDISON TECHNICAL  
MEETING REGARDING IP2 STEAM GENERATOR

Nuclear Regulatory Commission  
Two White Flint North  
Room 3B-45  
11545 Rockville Pike  
Rockville, Maryland

Wednesday, May 3, 2000

The above-entitled meeting commenced, pursuant to  
notice, at 11:05 a.m.

PARTICIPANTS:

JEFF ALLAN, NRC Project Manager for Indian  
Point-2

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## 1 PARTICIPANTS: [continued]

2 STEPHANIE KAUFMANN, Materials and Chemical  
3 Engineering, NRR

4 EMMETT MURPHY, Material and Chemical Engineering,  
5 NRR

6 JACK STROSNIDER, Director of the Division of  
7 Engineering

8 MARSHA GAMBORINI, Division of Licensing Project  
9 Management, acting Section Chief, IP-2

10 DAVID LU, Region I

11 TED SULLIVAN, Section Chief in the Materials and  
12 Chemical Engineering Branch

13 TOM PITTERLE, Westinghouse, Steam Generator  
14 Engineering

15 TOM ESSELMAN, ALTRAN Corporation

16 ANDY NEFF, Independent QDA for Con Ed

17 JIMMY MARK, Con Edison Engineering

18 JACK PARRY, Project Management, Con Edison

19 JIM BAUMSTARK, Vice President of Engineering for  
20 Con Edison

21 DON McADAM, Director of Nuclear Safety and  
22 Licensing

23 DON ADANONIS, Westinghouse

24 GARY HENRY, EPRI

25

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## P R O C E E D I N G S

[11:05 a.m.]

1  
2  
3 MR. ALLAN: My name is Jeff Allan. I'm the  
4 Project Manager for Indian Point-2, the NRC Project Manager,  
5 and I'm here to open up a meeting here between Con Ed and  
6 NRC. This is a technical meeting between NRC technical  
7 staff and Consolidated Edison, the licensee for Indian  
8 Point-2.

9 This meeting is going to be different from other  
10 meetings we've held in the past in that the other meetings  
11 have pretty much been management level meetings. This one  
12 is going to be a very technical discussion between us and  
13 Con Ed, in which we're going to -- we've put some topics of  
14 discussion, last week, on the 28th of April, which had  
15 topics related to their root cause evaluation that they  
16 performed and submitted to the NRC on April 14.

17 We'll have conversations and questions regarding  
18 the root cause evaluation and other topics that Con Ed wants  
19 to discuss related to inspection of the steam generators.

20 There are some handouts. Con Ed is going to have  
21 a presentation with slides. We're having copies made as we  
22 sit now, and they will be handed out to the members of the  
23 public as we go through the meeting.

24 This meeting is open to the public for observation  
25 and that means that this is going to be between the tech

1 staff here and Con Ed. We're scheduled for 11:00 until 4:00  
2 this afternoon. We're going to take a break approximately  
3 around 1:00 to allow lunch.

4 At the end of the technical meeting, if time  
5 allows, we're going to have a question and answer session  
6 between NRC staff and members of the public who are  
7 interested in asking questions of us. That's if we have  
8 time at the end.

9 This meeting is being transcribed and for the  
10 participants here, I'd ask that when you state questions, at  
11 least the first time, that you state your name for the  
12 purposes of the transcription. And for members of the  
13 public, this transcript will be made available on the NRC's  
14 web page, along with the slides from this particular  
15 presentation.

16 Just a little about the web, in case you haven't  
17 had an opportunity to view it, we started an initiative with  
18 this particular response to this event on February 15. We  
19 have an NRC IP-2 event web page. This web page can be  
20 found, if you go to the NRC's home page, which is  
21 [www.nrc.gov](http://www.nrc.gov), and under "What's New," you can go to the link  
22 that says Indian Point-2 event.

23 There we've taken efforts to put all the  
24 correspondence related to the event that's been transferred  
25 between Con Ed and NRC on that site. We are trying to

1 maintain it to give you guys the best access we can to all  
2 the documentation that we have.

3 Just a little bit about the room and this floor.  
4 This room, there's no food or beverages allowed in this  
5 room. Just outside the doorway, there is a public telephone  
6 and in the elevator lobby, there are restrooms just towards  
7 the television. The men's room is to the left, the ladies'  
8 room is to the right.

9 With that, do you have any opening comments you'd  
10 like to make?

11 MR. SHARRON: No, not really, Jim. I just want to  
12 thank you and your staff for coming down here and making  
13 this presentation. I know you're still busy trying to get  
14 the inspection finished up and everything, so we appreciate  
15 that.

16 It might be worthwhile if we go around and at  
17 least identify who is at the table here. My name is Brian  
18 Sharron. I'm the Associate Director for Project Licensing  
19 and Technical Assessment. Stephanie?

20 MS. KAUFMANN: Stephanie Kaufmann, Materials and  
21 Chemical Engineering, NRR.

22 MR. MURPHY: Emmett Murphy, the same.

23 MR. STROSNIDER: I'm Jack Strosnider, Director of  
24 the Division of Engineering.

25 MS. GAMBORINI: I'm Marsha Gamborini, Division of

1 Licensing Project Management, acting Section Chief, IP-2.

2 MR. LU: I'm David Lu, Region I.

3 MR. SULLIVAN: I'm Ted Sullivan. I'm a Section  
4 Chief in the Materials and Chemical Engineering Branch.

5 MR. PITTERLE: Tom Pitterle, Westinghouse, Steam  
6 Generator Engineering.

7 MR. ESSELMAN: Tom Esselman, ALTRAN Corporation.

8 MR. NEFF: Andy Neff. I'm the independent QDA for  
9 Con Ed.

10 MR. MARK: Jimmy Mark, Con Edison Engineering.

11 MR. PARRY: Jack Parry, Project Management, Con  
12 Edison.

13 MR. BAUMSTARK: I'm Jim Baumstark, Vice President  
14 of Engineering for Con Edison.

15 MR. McADAM: Don McAdam, Director of Nuclear  
16 Safety and Licensing.

17 MR. ADANONIS: I'm Don Adanonis, with  
18 Westinghouse.

19 MR. HENRY: I'm Gary Henry, with EPRI.

20 MR. ALLAN: And Region I may join us via  
21 videoconferencing as we go. With that, I'll turn it over to  
22 Jim Baumstark, Con Ed, for Con Ed's presentation.

23 MR. BAUMSTARK: Thank you, Jeff. Dr. Sharron,  
24 members of NRC staff, thank you for providing us with the  
25 opportunity today to discuss our steam generators with you.

1 Last Friday, you provided us with 17 topics for discussion  
2 in today's meeting.

3           Sorting through these topics, we came up with four  
4 presentations, which will form the basis for our discussion.  
5 We have attempted to weave the 17 topics into the four  
6 presentations.

7           Please don't hold me strictly accountable for  
8 that, because a number of the topics will overlap the  
9 various presentations we have prepared.

10           Jack Parry will begin with an overview of our root  
11 cause analysis. He will address discussion topics four,  
12 six, 12, 13 through 15, and 17.

13           Jimmy Mark and Andy Neff will follow with a  
14 further discussion of the '97 inspection program and how it  
15 contrasts with the 2000 inspection program. They will cover  
16 topic numbers one and seven through ten.

17           Tom Esselman will describe the finite element  
18 analysis used to predict stresses in lower row U-bends. He  
19 will address topics three, five, 11 and 16.

20           And, lastly, Tom Pitterle will discuss key  
21 elements of our condition monitoring operational assessment,  
22 which is final states of development. He will cover topic  
23 two.

24           Without questions, these presentations will cover  
25 about two and a half hours. So if possible, I'd like to see

1 if we could hold questions to a minimum until we conclude  
2 our presentations.

3 Before we begin, I would like to state that our  
4 industry has learned much about steam generators and their  
5 inspection methodology over the last two and a half months.

6 Had we, as an industry, known, in 1997, what we  
7 know now because of recently evolved technology, the event  
8 most probably would have been preventable. We conducted an  
9 adequate inspection in 1997 based on the then current  
10 equipment, processes and procedures. In fact, we believe we  
11 exceeded the industry standard at the time by examining all  
12 tubes in 1997 and conservatively plugging both indications  
13 we understood, as well as those indications which could not  
14 be resolved as to a specific tube deterioration mechanism.

15 In retrospect, we also need to be as critical of  
16 our 1997 methods as possible. We need to learn as much as  
17 we possibly can and pass that information on to others in  
18 our industry, so that similar events can be prevented.

19 Working with the NRC, that is our common resolve.  
20 Jack Parry will now begin with an overview of our root cause  
21 analysis.

22 MR. PARRY: As Jim indicated, my name is Jack  
23 Parry, with Consolidated Edison. In this job, I was the  
24 Project Manager in the Steam Generator Inspection Program.

25 There are a number of topics rolled into my

1 presentation. I will provide an overview of the inspection  
2 program for the U-bends and how involved. I'm going to try  
3 and address some of the questions that were put to us; in  
4 particular, primary to secondary leakage, history of the  
5 tube restrictions in the steam generators, other issues. We  
6 were asked about the primary water chemistry, for example.

7 I'll try and put in perspective what we knew about  
8 row two tubes from the eddy current inspection in 1997 and  
9 also highlight the study done by Dominion Engineering for us  
10 from '95 to '97 and 2000 and what we should expect for  
11 various types of defects in the steam generators.

12 Starting off with February 15. At 1950 hours, or  
13 7:15 p.m. that night, primary to secondary leakage was three  
14 and a half gallons per day, which was below any action point  
15 that we had in our procedures.

16 At 1929 hours, approximately 7:30 that night,  
17 primary to secondary leakage escalated to 75 to 100 gallons  
18 per minute, and we shut the plant down. We went through a  
19 number events in the cool-down process. From the steam  
20 generator perspective, the first step is we identified a  
21 tube in 24 steam generator, row two, column five, that was  
22 leaking, and this occurred February 27 this year.

23 The first inspection step was to put a  
24 Welch-Allyn, which is a small video probe camera, into the  
25 tube, and we identified a large axial. By large, I mean

1 approximately two inches, at the top of the tube.

2 Next, you have to try and quantify that indication  
3 with a +Point probe into tube R2C5, from the cold leg side,  
4 and try to analyze the indication. The shoes on the probe  
5 got caught on the indication at the top of the tube. We  
6 only obtained partial data.

7 From that data, looking at the crack tip, the  
8 estimated locations is at the extrados of the tube.

9 Our next step for that tube was we put a bobbin  
10 probe, a flexible bobbin probe into the area and were able  
11 to quantify the length a little better. We felt it was 1.7  
12 to 1.8 inches long, again, at the apex of the tube.

13 To continue to try and quantify the data, what we  
14 did is something a little innovative. We took a +Point  
15 probe and glued the shoes down. The shoes are what keeps it  
16 being a surface-gliding probe and by securing those down,  
17 that prevented it from catching on the indication of the  
18 tube, and we were then able to obtain an eddy current  
19 analysis of the indication.

20 So by doing that, we confirmed this at the  
21 extrados, determined the axial indication, length about two  
22 inches to two and a half inches long, and, at the same time  
23 all this was going, we were also performing inspections on  
24 the secondary side of the steam generators.

25 Once we identified where it was, we also went back

1 and started looking historically at what the last inspection  
2 program can tell us. We went back and we looked in the '97  
3 data and using 20/20 hindsight and knowing some indications  
4 probably in that tube, we identified the indication at the  
5 U-bend at the apex in tube R2C5.

6 We then concluded the problem was primary water  
7 stress corrosion, based on looking at the phase angle of the  
8 analysis. We also wanted to look and determine what  
9 weaknesses and how we've improved from '97 to 2000. Some of  
10 the things we identified was the signal-to-noise issue,  
11 which is significant in determining, analyzing the eddy  
12 current program, sources of the signal-to-noise problems,  
13 the outside tube deposits and mass signals, and also we had  
14 some concern with probe location speed and varying the tube  
15 as the Point probes examined the tube.

16 Examined the data, looked at the setup used in  
17 1997, we developed noise criteria and in '97, the industry  
18 did not have, per se, noise criteria. There was an  
19 individual assessment done by each analyst. So what we  
20 developed was noise criteria, about when a tube will be  
21 called too noisy. We analyzed and determined that 400  
22 kilohertz frequency in the probes has a better  
23 signal-to-noise ratio, and we set up procedures such that if  
24 a tube similar to the one R2C5, shown in this '97  
25 indication, would be classified for re-analysis in the 2000

1 program.

2 We took all this information we learned in the '97  
3 program and incorporated it into the 2000 inspection program  
4 and then began. We started the 2000 program following the  
5 EPRI-5, Rev. 5 guidelines, particularly for the phase setup  
6 for the inspection.

7 In the next discussion, Jimmy Mark and Andy Neff  
8 will provide additional information on that.

9 We provided instructions to the analysis on when  
10 an inspection should be called, perhaps reanalysis due to  
11 signal-to-noise ratio, and concluded that that should be  
12 rejected.

13 We set up a program to analyze the tube due to the  
14 noisy data. We provided training to all the analysts,  
15 approximately three days, the first phase of the program,  
16 and, again, provided additional information and training  
17 evolved as we went through this.

18 We developed lessons learned as the whole program  
19 evolved and we kept improving the program as we went  
20 through.

21 Once we established that, initial inspection  
22 began. Initial inspection of the U-bends in the low row  
23 tubes consisted of 100 percent of the U-bends, looking at  
24 rows two, three and four. Row one's were plugged initially  
25 before the plant started up, so we do not have those in

1 service.

2 During that examination, we identified three  
3 additional tubes that had indication of primary water stress  
4 corrosion cracking and the extrados of the U-bend in the row  
5 two tubes. We found no indications of primary water stress  
6 corrosion cracking in row three or four tubes.

7 We conducted extensive re-testing on tubes that we  
8 considered noisy and many of our tubes, and I'll give you  
9 some numbers in just a moment, we still considered  
10 unacceptable from being initially re-analyzed. That was at  
11 the end of the first phase of our inspection program.

12 Our second phase began with an independent  
13 analysis of the information again. What we did, in looking  
14 at what we had just learned from the first phase, we updated  
15 the training program. We brought in new additional analysts  
16 who had not seen this project before. We set up another  
17 primary, secondary and resolution team for the eddy current  
18 data and we re-analyzed all of the 2000 U-bend midrange  
19 +Point information. Midrange would be midrange frequency.

20 During that review, we found no new indications.  
21 The three row two indications were reconfirmed by the  
22 separate team. The result was we still had 53 percent of  
23 our tubes being classified as unacceptable due to a low  
24 signal-to-noise ratio.

25 As that was going on, we also looked at other

1 options that were not available to us in 1997. Two of them  
2 we pursued was looking at the midrange probe using a higher  
3 frequency, 750 kilohertz, and also a new probe that was  
4 recommended, 800 kilohertz, high frequency +Point probe. We  
5 tested both of those probes looking at indications that knew  
6 were present in tubes and in our evaluation, we determined  
7 the 800 kilohertz, high frequency probe was the best one to  
8 use to expand and continue our examination program.

9 The site and EPRI conducted a program and that 800  
10 kilohertz frequency probe was qualified for use at the site  
11 and in the industry the first time on March 20 this year.

12 We then, again, went back and looked at the same  
13 low row tubes. We re-tested row two and all of row three  
14 and all of the row four tubes that we had classified as  
15 questionable data.

16 During that phase, we found four new indications  
17 of primary water stress corrosion cracking in tubes. These  
18 indications were found in tubes that were previously  
19 classified as noisy and had eventually been plugged. We  
20 hadn't gone this extra step.

21 There were no new indications found in tubes that  
22 we had classified as no defect. So the high frequency probe  
23 did not find anything in a row two tube that we had cleared  
24 with our program. And, again, using a high frequency probe,  
25 we found no indications in rows three or four tubes.

1           What this resulted in is we were able to recover  
2 450 tubes for use that we would have plugged. The data in  
3 the high frequency probe was much better. Of those 452,  
4 five we still felt the analysis was not what we wanted and  
5 we put those on our plugging list to take out of service.

6           Of those row two tubes, we also used in situ  
7 pressure tests, which I know you know is high pressure test  
8 of all the axial indications in the U-bends. That resulted  
9 in seven row two tubes being tested. This exceeded the  
10 number we had to do, if you follow strictly the EPRI  
11 guidelines. Of those seven, three of the U-bends leaked or  
12 they met the burst criteria, and I believe Tom Pitterle will  
13 discuss that later on in his presentation.

14           At the end of the program, all the row two tubes,  
15 whether we found indications or not, are plugged and taken  
16 out of service to isolate this concern.

17           Jimmy Mark and Tom Pitterle will also talk about  
18 the inspection program, provide more details for you, but I  
19 wanted to try and start off giving you a chronology of  
20 events, how we started, our first steps, how we moved into  
21 high frequency probe, what the final result was.

22           From an overview standpoint, while the primary  
23 side was going on, we also had a number of events going on  
24 in the secondary side. One of the actions we took is we  
25 pressurized the secondary side of each generator, where we

1 had cameras in the primary side to look for any leaks.

2 During that process, in 23 generator, we found  
3 three plugs that had small leaks. Those were drilled out  
4 and replaced during this outage. We also performed  
5 secondary side component inspections, and that this is is  
6 visual inspections, looking inside the generators, both in  
7 the hand-holes at the bottom of the secondary side, looking  
8 up, then the ports at the top, looking in and down.

9 Two of our four generators, we had ports already  
10 that had been observed at the support plate, 22 and 23. The  
11 24 generator, we have a port, but it wasn't exactly where we  
12 wanted, where we wanted to look at. So this outage, we  
13 ended up installing two ports, one in 21 generator and one  
14 in 24 generator, to give us a better view of the six support  
15 plate at the top of the steam generator. So that was going  
16 on at the same time.

17 In doing that, then we also performed measurements  
18 on 24 generator, which is the one that had the leaking tube,  
19 to quantify hourglassing, which is an inward movement of the  
20 tubes. In row one is a device, a field gauge type device.  
21 We measured about half an inch hourglassing between the low  
22 one tubes in 24 generator, approximately even with the tube  
23 that leaked. That was then put in our counts for our stress  
24 evaluation, and Tom Esselman will be bringing that up in his  
25 talk later on.

1           Then, finally, as a routine measure, we performed  
2 Sludge Lancing and Fosar at all four generators.

3           There will be a lot of other discussions as far as  
4 what's going on in the generators, but, again, that's an  
5 overview for you of what we did from the U-bend inspection  
6 program.

7           The other topics we wanted to talk about was  
8 primary to secondary leakage. On February 15, the start of  
9 the shutdown, nitrogen-16 rad monitors, which is one for  
10 each individual line for each steam generator, were  
11 monitoring and in-service. Alarm points in those monitors  
12 are ten gallons per day, 25 gallons per day, and 150 gallons  
13 per day, which is our administrative limit to shut down.  
14 Our technical specifications are approximately 450 gallons  
15 per day. Our administrative limits are lower than that.

16           There was a recorder on the instrument that was  
17 not working, but those instruments do have a common alarm  
18 for their control room, what we call the accident assessment  
19 panel. That comes up, the operators respond locally to see  
20 what was causing the alarm, and it also is the local alarm,  
21 the N-16 monitors, to help an operator qualify that in his  
22 investigation. Those alarms did not go off.

23           Another thing I'll put up here is the leak rate  
24 trend that we have. I know some of you may have seen this.  
25 This is our primary to secondary leakage, January 1, '99 up

1 until February 15. You can see it's four gallons per day.  
2 At the height of the event, we're monitoring it and it went  
3 from 3.4 gallons per day to about 75 to 100 gallons per  
4 minute at the start of the event.

5 MR. MURPHY: Excuse me. Jack, you indicated the  
6 alarms didn't go off. They did go off.

7 MR. PARRY: You're right. I'm saying normally,  
8 for 3.4, they did not. But they did go off when we spiked  
9 up to the 100 gallons per minute. Thank you.

10 Also, in the primary to secondary leakage program,  
11 chemistry, as a routine, when they check these monitors once  
12 per shift. Another indication we have to monitor primary to  
13 secondary leakage is what we call our error check, the  
14 radiation monitor. That quantifies total. It does not  
15 isolate it to a single generator. Chemistry also pulls  
16 samples from that halfway, performs laboratory analysis  
17 using approved procedures, and, again, at about 7:15, just  
18 before the event occurred on February 15, the leak rate was  
19 approximately 3.4 gallons per day on the N-16 monitor.

20 One of the things this event caused us to do is  
21 we're looking at our limits for administrative limits for  
22 primary to secondary leakage. EPRI has issued new guidance  
23 as of February of this year. It's approximately half of  
24 what's in place now. There's also two limits. There's one  
25 for total leakage per day and also rate of change.

1 We at least implement those EPRI guidelines and  
2 that will be one of the actions we'll follow up on. This  
3 was a review by our steam generator committee, which was put  
4 into place, and then also we had to change the operation  
5 procedures and implement these.

6 Another issue we looked at is tube restrictions.  
7 One of the parameters we have in doing the steam generator  
8 inspection is any tube that won't pass a probe that's called  
9 a 610, which is the size of the probe, has to be plugged.  
10 So we look at how many tubes each outage we have to plug  
11 that won't pass a 610 probe.

12 This outage, there were two tubes that would not  
13 pass a 610 probe. To try and give you a perspective from a  
14 cracking standpoint, let me put up a graph. This is the  
15 tubes plugged for 610 probe for the life of the plant.  
16 Earlier in the life of the plant, there was an issue with  
17 denting, which is a corrosion phenomenon that increases the  
18 rate. This occurs due to some operational changes, changing  
19 the temperature we operate the primary side at.

20 This process, as you can see, after about 1989,  
21 was reduced. In 1997, we went to inspecting the generators  
22 100 percent for the first time. We had an increase in how  
23 many tubes we plugged due to not passing the 610 probe up to  
24 20. So, again, in this outage, we only identified two  
25 additional ones that we had to plug due to not being able to

1 pass the 610 probe.

2 Now, that in itself doesn't give you a full  
3 perspective.

4 MR. SULLIVAN: Can I ask a question? What you  
5 just put up, the support plates?

6 MR. PARRY: Anywhere. Because if it couldn't pass  
7 a 610 probe, whether it was through the first support plate  
8 or the sixth one, then you couldn't inspect the full length  
9 of the tube, that caused us to take it out of service. We  
10 had to take it out of service.

11 Now, historically, '97 and 2000 were the first  
12 times we inspected 100 percent of all tubes and all  
13 restrictions. So we performed a comparison this time,  
14 looking at what was the change for each restriction and each  
15 support plate. Now, this is for 23 steam generator.

16 What you can see is, looking at each, 6H means the  
17 top support plate on the hot side, 6C is the top support  
18 plate on the cold side, and you work down through the six  
19 support plates.

20 What you can see is about 14 percent of the  
21 restrictions decreased, 70 percent stayed the same, but the  
22 one piece of information we never had before from being able  
23 to do this comparison is about 16 percent were able to get a  
24 larger probe through them.

25 For example, in '97, we had a 640 probe go through

1 it, now we can get a 680, or last time we had a 620 get  
2 through it, we had a 640. That's the first time I've been  
3 able to compare that. I don't know the history of what the  
4 other outages would be. So '97 to 2000 is the first time we  
5 had the data collected to be able to make this comparison on  
6 a restriction by tube, by support plate, for all four  
7 generators.

8 MR. SULLIVAN: Is this a comparison based on  
9 exactly the same components?

10 MR. PARRY: Yes. For example, if indication for  
11 an intersection passes 700 and then this time it wouldn't  
12 pass a 700, had to use a 680, that would go into the smaller  
13 column. If it was the same, no change, that before, I could  
14 get a 620 through it, and now I could not get a 620 through  
15 it, and now I can, that would be in the larger column.

16 There's a couple of issues I've lumped together.  
17 One of them was the susceptibility of our Alloy-600 to  
18 primary water stress corrosion cracking. As you all know,  
19 primary water stress corrosion cracking is a function of  
20 material stressing the environment.

21 We looked at the material, the yield temperatures  
22 it's manufactured at, which is about 1,850 degrees  
23 Fahrenheit, this is higher than a lot of the other tubes in  
24 the industry, which is about 1,700. So this makes it less  
25 susceptible to primary water stress corrosion cracking due

1 to the initial annealing temperatures it was manufactured  
2 at.

3 The environment has to do with the temperature  
4 that the primary side operates at, T-hot it's called. We  
5 operate for the past ten years at approximately 590 degrees  
6 Fahrenheit. Before that, we operated even lower,  
7 approximately 575.

8 A number of the units in the industry operate at  
9 600 or higher. So, again, this is a parameter that makes  
10 our tubes less susceptible to primary water stress corrosion  
11 cracking while operating at the lower temperature.

12 We also look at primary water chemistry, because  
13 that would be an effect. Looking at these parameters, our  
14 assessment was these were not an impact on this event  
15 occurring.

16 Stress was also evaluated, and that will be talked  
17 upon in Tom Esselman's presentation, as far as the material  
18 annealing, the environment and the primary water chemistry.  
19 Our assessment is these were not a factor in this event  
20 occurring.

21 Assessing the primary water chemistry, we follow  
22 the industry guidelines. Some of the main parameters you  
23 look at are boron and lithium curves, which then matches  
24 your pH and your hydrogen concentrations. And, again, we  
25 assessed this as not an issue.

1 I'll have a graph here in a second that I'll put  
2 up.

3 The last issue we looked at in what I call other  
4 issues is we looked at outside diameter stress corrosion  
5 cracking potential in the row two tubes. There's some  
6 industry data, at least one event that cites this potential  
7 for happening. This was a consideration in plugging our row  
8 two tubes.

9 It was also a consideration in using a high  
10 frequency probe. What we did is we checked the high  
11 frequency probe for tubes that we knew had indications and  
12 against test samples to convince ourselves that a high  
13 frequency probe could see outside diameter stress corrosion  
14 cracking in the analysis.

15 The chemistry. The graph, the upper one shows the  
16 band we keep our boron/lithium between and the bottom one  
17 shows our hydrogen concentration, and, in both cases, we  
18 have maintained between those boundaries.

19 The next topic I want to try and highlight is from  
20 the perspective of what we knew about row two of some of the  
21 steam generators back in '97. One of the things we look at  
22 each outage is the secondary side support plates. In 1997,  
23 on 22 and 23 steam generators, we do have the ports that  
24 allow us to see the six support plates. Those were  
25 inspected.

1           One of the things we looked for were any  
2 indications of cracking in the flow slots. There were no  
3 indications of cracking in the sixth support plate of the  
4 flow slots of the 22 and 23 generators in 1997.

5           And looking back on the videos, the engineers, at  
6 the time, we assessed there was no observable hourglassing  
7 in 22 and 23 steam generators at the sixth support plate.

8           MR. MURPHY: Jack, when looking at, I think, the  
9 flow slot from steam generator 23, some hourglassing was  
10 observed and it was reported in this inspection that this  
11 condition was unchanged from previous inspections.

12           MR. PARRY: What we looked at, those flow slots,  
13 there may have been a slight one, but in '97, when the  
14 engineers looked at it and what they reported was their  
15 observation; our observation was it was viewed as having no  
16 cracks in the flow slots and no hourglassing.

17           I know what you're talking about for 23 and it may  
18 be present, okay, but I'm trying to put in perspective what  
19 was analyzed in '97 and then how we looked at it for back  
20 then.

21           The '97 inspection program, we felt it was  
22 consistent with industry standards. Looking at the row two  
23 and row three tubes in '97, we used the best probe  
24 available. It was the +Point probe for looking at those  
25 tubes. The probe did detect one indication of primary water

1 stress corrosion cracking.

2 Our interpretation was that it could see that  
3 method of tube degradation. There was no indications of row  
4 three primary water stress corrosion cracking in '97.

5 Another perspective we had back then is there was  
6 a company called Dominion Engineering and one of their main  
7 expertise is looking at your analysis from your inspections,  
8 looking at frequency for different types of failures you  
9 see, and then predicting what you should see in future  
10 outages.

11 We contracted with Dominion in '95, '97, and also  
12 in 2000 to look at our steam generator program, help us  
13 predict what we should see each outage. Then, again, this  
14 outage, they were asked to update the information, and I'll  
15 highlight that here in a second.

16 Starting with their review in '95, there were no  
17 U-bend cracks detected. The prediction they performed,  
18 looking at industry data, they defined a slope which  
19 correlates to how many indications you should see in the  
20 future, called a Weibull slope. Based on having no cracks  
21 seen in 1995, predictions were we should see none in '97 or  
22 2000.

23 Two of their main factors for making that  
24 assessment was the lower temperature we operate our primary  
25 system at compared to other plants and what we call the

1 Huntington tubes, which were the tubes that were annealed at  
2 a higher temperature, at 1,850 versus 1,700, I mentioned  
3 earlier.

4 In '97, they, again, looked at our data. In '97,  
5 we detected the one indication of primary water stress  
6 corrosion cracking in the U-bend. They then assessed that,  
7 assigned what they call a Weibull slope of four, which is  
8 consistent with the industry, and predicted that we should  
9 see potentially one new flaw in our next operating cycle of  
10 primary water stress corrosion cracking in the U-bend tubes.

11 What we also had them do is come back and look at  
12 the data in 2000, from two perspectives. One of the things  
13 they do is they take a consistent inspection method, one  
14 using the midrange, what we should have seen for  
15 indications, the midrange in '97, looking forward, and then  
16 as a check, what we saw in 2000, with the high frequency  
17 probe and back-calculating and seeing if the slope, the  
18 Weibull slope is consistent for both processes.

19 Starting off, what they did is they looked at the  
20 rate of increase at the U-bend, the primary water stress  
21 corrosion cracking, using the midrange data, what we think  
22 we should have seen with the midrange probe in '97 and 2000.  
23 Their analysis shows, '97 should have shown three flaws,  
24 with a cumulative five in 2000, which gives a Weibull slope  
25 of 4.7, which, again, is consistent with the industry.

1           Using that Weibull slope of 4.7, we then looked at  
2 what we found in 2000 using the high frequency probe,  
3 back-calculated it, and again confirmed that this slope,  
4 this rate of expectation of the primary water stress  
5 corrosion cracking is consistent.

6           Now, when I say industry data, the two main  
7 reports that they used were these two EPRI reports, which  
8 Dominion had a major hand in writing, and developed a lot of  
9 the industry data on this.

10           Again, in saying it's within the industry  
11 standards, what Dominion uses is a median of four for a  
12 slope, with a range of two to six, which the higher the  
13 slope is, the higher your frequency of steam the next time  
14 will be.

15           Again, the industry perspective, stress corrosion  
16 cracking has a large scatter value with it, depending,  
17 site-to-site. Normally you'll see small numbers, failures  
18 early, and then an increase as time progresses. What this  
19 process does is it takes your frequency, matches it to the  
20 what the industry has seen, and then helps you predict what  
21 you expect to see the next time.

22           Using that, what they told us in '97, seeing one  
23 indication, in our perspective, was reasonable. If we were  
24 to keep row two in service, which we were not, we're  
25 plugging it, their prediction is we see a modest increase in

1 the number of primary water stress corrosion cracking flaws  
2 in row two.

3 The other issue that we asked them to look at is  
4 row three tubes. This will also be talked of by Tom  
5 Esselman. We asked them what's the potential for row three  
6 tubes developing primary water stress corrosion cracking.  
7 There's no known case of row three tubes having that. Our  
8 inspections detected no indication of primary water stress  
9 corrosion cracking in row three tubes.

10 The crack initiation in row three would be a lot  
11 lower, due to lower stress and the lower cold work in row  
12 three versus row two. The crack growth rates are expected  
13 to be a lot lower in row three versus row two, due to the  
14 lower stress and lower cold work.

15 MR. STROSNIDER: Just a quick clarification point  
16 on the first bullet there. You indicated no leaks in row  
17 three U-bends. But have there been any indications?

18 MR. PARRY: I spoke to Jeff yesterday on this. I  
19 don't remember. He stressed to me that there were no leaks.  
20 I don't know if he -- I don't remember if he told me there  
21 were no indications. I can follow up for you.

22 MR. STROSNIDER: Okay. Appreciate that, thank  
23 you.

24 MR. PARRY: The conclusion they reached for us is  
25 there is very low likelihood of any flaws developing, large

1 flaws developing from the next inspection. There is a low  
2 potential for crack initiation, a low growth rate for the  
3 row three tubes, and for a modified operating interval.

4 I went through a lot of information in a very  
5 short period of time. We've got three more people who are  
6 going to be just as concentrated. So I appreciate your  
7 attention, and hope I've helped try to answer some of the  
8 questions.

9 MR. MURPHY: Jack, early on, you indicated that  
10 the magnitude of the leak associated with the failure was on  
11 the order of 75 to 100 gpm. Haven't you folks done more  
12 recent calculations indicating the number is up around 150?

13 MR. PARRY: The number I remember, and I've got to  
14 go back and look, because to be honest, I've been focused on  
15 this inspection program and may have lost some of the  
16 details. I've heard a number like of 103. Again, I can  
17 follow up on that for you. I know it wasn't 200, 300, 400  
18 or anything like that. The 75 to 100, I thought, is in the  
19 right range. Maybe it's 103 or something like that, but  
20 that was the last number I heard, was around 75 to 100 gpm  
21 is where we keep that.

22 I would like to next introduce Jimmy Mark, who  
23 will talk about the inspection programs in '97 and 2000,  
24 with Andy Neff, also.

25 MR. MARK: With me will be Andy Neff. He is our

1 independent QDA. My name is Jimmy Mark, Con Ed Engineering.  
2 I will be reviewing the low row U-bend examinations that we  
3 did in 1997, the qualification work, and also the same in  
4 the 2000 outage.

5 The technique qualification that we did leading up  
6 to the 1997 examination for the row two and row three  
7 U-bends was based on Rev. 4 of the EPRI guidelines. That  
8 included the work that was done with the midrange probe. We  
9 did qualification using 150, 300 and 400 kilohertz. Our  
10 qualification sample set that we worked with had two pulled  
11 tubes from our plants. We also had 24 EDM samples and in  
12 all cases, we were able to detect these 26 flaws, which  
13 gives us a POD of 91.5 percent and at a 90 percent  
14 confidence level.

15 At that time, with Rev. 4 of the guidelines, there  
16 was no requirement for site-specific technique  
17 qualification. This '97 use of the +Point probe was the  
18 first time that we had used this probe at Indian Point.

19 For the examinations, we did a site-specific  
20 performance demonstration, also in accordance with Rev. 4 of  
21 the guidelines. We used a practical exam that consisted of  
22 data from the industry, because at that point, row two  
23 U-bend was not detected at Indian Point.

24 The calibration setup that we used was within the  
25 industry variance. The data quality was non-existent at

1 that time. There was no specific written requirement for  
2 data quality. So it was left up to the analysts, and these  
3 analysts are highly trained personnel. They're level three  
4 eddy current people, as well as EPRI qualified QDA,  
5 qualified data analyst.

6 There's a very rigorous training program, exam  
7 program that they go through, and within the whole word,  
8 there's about 300 of these people that go through all the  
9 outages and view all this data for us.

10 The +Point noise level that they found was similar  
11 to other steam generators that had Alloy-600 mil-anneal  
12 tubing. So the data that we saw at Indian Point as far as  
13 noise goes was not any different than what we saw at some  
14 other plants that had mil-anneal Alloy-600, there's some  
15 noise, also.

16 PWSCC was identified in the one tube, steam  
17 generator 24, row two, column 67. That gave us a level of  
18 confidence that the technique that we were using had a  
19 qualification that was able to detect the flaw.  
20 Andy Neff is next and is going to review some of the  
21 differences between the analysis setup that we used in 1997  
22 and 2000 for the midrange +Point probe.

23 MR. NEFF: These graphs illustrate the comparison  
24 between the '97 and 2000 data. We looked at the ETASS,  
25 which is the document that defines the technique, and found

1 that in '97, the phase was about five to six degrees lower  
2 than is currently required.

3 We also looked at the various frequencies to  
4 determine if one frequency would provide better detection  
5 than the others. Then, finally, we looked back at the  
6 effect of applying the differences to see if some conclusion  
7 could be made regarding the detectability versus the setup  
8 and the frequency used.

9 This graphic shows the defect as it was originally  
10 discovered. As you can see, there are patterns along here  
11 from the noise and this is the defect. This is the same,  
12 this is using the 1997 setup. This is using the 400  
13 kilohertz. As you can see, the change in the noise level is  
14 not very apparent. It is slightly better, but it is not  
15 drastically better.

16 This shows the same data using the year 2000 setup  
17 at 300 kilohertz and at 400 kilohertz. Our conclusion is  
18 that the setup changes are marginally better, but not  
19 greatly better.

20 Next, we looked at the setups in row two, column  
21 five. This is the tube that failed. This is called NDD in  
22 1997. This level of noise is not uncommon. It would not  
23 probably be recognized in 1997 as being defective. However,  
24 with the lessons learned, we would now call that bad data.

25 This is the 400 kilohertz in 1997. This is all

1 1997 data. And this is with the 2000 setup and with the  
2 2000 setup at 400 kilohertz.

3 So during this current outage, the 2000 outage, we  
4 qualified the midrange +Point probe again under Rev. 5 to  
5 the guidelines. We did a site-specific performance  
6 demonstration and we had a written training supplement that  
7 was developed based on information that we now know.  
8 We also developed a document called the IP-2 spring 2000  
9 outage U-bend +Point analysis training, and, along with  
10 that, we looked at the setup for the 20 degree, 20 percent  
11 ID EDM notch and it was visible at six to ten degrees phase  
12 rotation, which is consistent with the industry variance.

13 There was now a requirement for data quality. We  
14 put that in based on the data that we just saw and the  
15 review with you on the row two, column five situation. So  
16 now we included a data quality requirement.

17 What we did was examined all row two, all row  
18 three, and all row four U-bends with this +Point probe and  
19 we identified three PWSCC indications in three low row  
20 U-bends. In the 21 generator, we had one, and we had a tube  
21 in steam generator 24, and the data quality evolved as we  
22 conducted the exam.

23 BDA was the call that we gave and it's the call  
24 that the analysts made and it was data that was not clearly  
25 clean and there's some question and it should be

1 re-reviewed.

2           After we had the initial team review of the data,  
3 the primary, the secondary and the reso team, while this was  
4 going on and all this learning about data quality was  
5 evolving, we said, okay, let's set up another team to review  
6 everything.

7           So we set up a team called a tertiary review team  
8 and this team was a new group of analysts coming in. These  
9 were senior people that have been doing this type of work  
10 for a long time and very experienced, and we gave them  
11 additional information that we learned along the way.

12           They reviewed all the data from two, three and  
13 four, and they came up with the same three indications that  
14 the initial team found and just confirmed it. And as far as  
15 the data quality goes, they called 457 out of the 863 tubes  
16 would have BDA, or bad data, because there would be low  
17 signal-to-noise ratio.

18           Because of the signal-to-noise ratio being the way  
19 that it was on watch point of your tube, we did an  
20 assessment of the high frequency +Point probe to see if it  
21 would enhance the detection of PWSCC.

22           So we took the midrange probe, qualified it for  
23 750 kilohertz, and we also qualified an 800 kilohertz probe.  
24 The 800 kilohertz probe was the prototype probe that we had  
25 Ztech build for us. We ran it on two tubes that we had

1 indications and we see that the indication was much clearer.  
2 The high frequency showed a better signal-to-noise ratio.

3 So based on that, we decided to re-inspect all row  
4 two, row three, and all the row four data that had low  
5 signal-to-noise ratios using the high frequency probe.

6 The qualification program for this high frequency  
7 probe was also based on Rev. 5 of the guidelines. The  
8 qualification document covered the qualification at 800  
9 kilohertz and also 1,000 kilohertz. The sample set that we  
10 used for the qualification was the same sample set that we  
11 used for the initial midrange qual. Those were the two  
12 pulled U-bends from other plants, as well as the .4 EDM  
13 nodules, and just like the other probe, all flaws were  
14 detected. We had the same 91.5 percent POD at 90 percent  
15 confidence level.

16 We also did a deposit simulation with copper foil  
17 and it showed that there was no effect on the detectability  
18 of the flaw. So by doing this, the high frequency probe was  
19 qualified for our particular site.

20 After we did the testing -- correction. This is  
21 the listing of the flaws in the qualification data set. We  
22 had two pulled tubes, with 40 percent flaws, and a variety  
23 of laboratory EDM notches, the lowest in depth being 27  
24 percent, going all the way to thruwall.

25 This is just a graphic presentation of the POD and

1 the confidence level.

2 So now we had a qualified 800 kilohertz probe for  
3 our row two U-bends. We were the first ones in the industry  
4 to use the 800 kilohertz probe for these low row U-bends and  
5 like I just said, we re-inspected all the row two and row  
6 three, we reexamined all the row fours that had the BDA or  
7 bad data classification.

8 We applied all the data quality requirements as  
9 far as signal-to-noise ratio based on what we had learned  
10 from the midrange probe that we had used up to now.

11 The high frequency +Point probe identified PWSCC  
12 in four tubes that were previously classified as BDA or RST.  
13 And five of the tubes remained, even after testing with the  
14 high frequency probe, as DBA.

15 This table is a summary of midrange work that was  
16 done by the first team, as well as the work that was done  
17 with the high frequency probe. It's a little busy, but it  
18 has a lot of information on it.

19 We have each generator. We have, under the  
20 tertiary team or independent review team, a list of all the  
21 acceptable data that we have. The low signal-to-noise data  
22 on the BDAs and what we did was reexamined all the row twos  
23 and all the row threes with the high frequency probe. So if  
24 you add up 40 for steam generator 21, row two, 40 plus 32  
25 gives you 71 plus the one, and out of this 72, 71 had

1 acceptable data using the high frequency probe and one was  
2 below signal-to-noise ratio which ended up getting plugged.

3 Under row four, we only took low signal-to-noise  
4 data, like I just said, and we reanalyzed it with the high  
5 frequency probe, and, hence, the 46 shows up here. When you  
6 add up all these numbers and you add up the acceptable and  
7 low signal-to-noise data, the difference in the total will  
8 be the difference in the row fours that had acceptable data.

9 So just to point out, again, we have 53 percent of  
10 BDA under the original midrange +Point probe and now we have  
11 .8 percent BDA under the 800 kilohertz high frequency probe.  
12 This is an improvement in signal-to-noise ratio and also  
13 quality of the data.

14 This is a listing of all the row two U-bends with  
15 defects that we will be plugging. These were the findings  
16 with the midrange probe. We have SAI, single axial  
17 indications. We have BDAs, and we have one with an RST, or  
18 a restriction.

19 This one was tested with the midrange probe, but  
20 was restricted at the sixth support plate on the hot leg and  
21 the U-bend. But when we put the 800 kilohertz probe and  
22 managed to make it through, so it was called based on the  
23 high frequency probe. So that was SAI. The BDAs, like I  
24 said, were resolved with the high frequency probe and the  
25 signal showed much clearer and they were called as single

1 axial indications.

2 In conclusion, the 1997 examination met industry  
3 guidelines and at that time, it was Revision 4 of the EPRI  
4 guidelines. It was an industry qualified technique at that  
5 time. It was a site-specific performance demonstration that  
6 was conducted. The calibration setup that we used was  
7 within industry variance and the U-bend +Point data was  
8 similar to other plants that had steam generators with  
9 Alloy-600 mil-anneal tubing that has some noise in it.

10 The current 2000 examination met the industry  
11 requirements. It's now called requirements because of  
12 NEI-9706, which mandates following the EPRI guidelines, now  
13 with Rev. 5. We have a site-specific qualified technique.  
14 We have a site-specific performance demonstration.  
15 Calibration setups that we use now were also still within  
16 the industry variance.

17 We have new data quality requirements, based on  
18 what we know now from our earlier examinations with the  
19 midrange probe this year.

20 MS. KAUFMANN: Andy, I wanted to ask you a couple  
21 of questions. Earlier on in the presentation, you said that  
22 the ETSS is developed through the midrange +Point probe.  
23 You talked about the 150, 300 and 400 kilohertz frequencies.

24 MR. MARK: Right.

25 MS. KAUFMANN: Did your plant-specific guidelines

1 include looking at all thicknesses when you did the  
2 inspection in 1997?

3 MR. MARK: I'm not sure about that. Yes.

4 MS. KAUFMANN: And your signal-to-noise ratio, do  
5 you have a specific number that you put in your guidelines  
6 for your noise criteria? How did you work that?

7 MR. MARK: Back in those days, it was left up to  
8 the analysts. We have the written guidelines that we wrote,  
9 plus the information that was picked up from the earlier  
10 testing that we did.

11 MS. KAUFMANN: Is it a specific criteria or not?  
12 I'm not quite sure how the analysts -- what they looked at  
13 to decide.

14 MR. NEFF: The thing that we were focusing on, if  
15 we go back to the row two, column five, was the registry.  
16 If you see this little part, this mound that seems to be  
17 sticking out from the others, this is an indication that  
18 possibly the rotational -- the probe rotation is interrupted  
19 or not steady. So whenever -- and this was a key feature of  
20 row two, column five. So if we saw any of that, then it  
21 would have been bad data for that reason.

22 Some of the other things that they were looking at  
23 was the end plot, if there were speed variations which you  
24 can see along this line. If we had any kind of deposits  
25 that were sticking up about the size of what we would expect

1 a defect to be, they would have been called bad data.

2 MR. MURPHY: You referred to the U-bend +Point  
3 data quality in 1997 as being similar to the industry.  
4 You're saying that the quality of the data that you were  
5 obtaining in the U-bends in 1997 was comparable to what we  
6 would typically see at PWRs in the U.S. industry today or in  
7 1997?

8 MR. MARK: PWRs.

9 MR. MURPHY: Yes, PWRs.

10 MR. MARK: Some generators have noisier tubes than  
11 others. What we saw when we looked at our noise and  
12 compared it to some of the other plants that had noise, it's  
13 not much different than what they have.

14 MR. MURPHY: Are these plants that have been long  
15 since retired or are you speaking about a number of plants  
16 that continue to be in service?

17 MR. MARK: This is all historical data, for older  
18 plants.

19 MR. MURPHY: That have been retired.

20 MR. MARK: I believe so.

21 MR. MURPHY: Thank you.

22 MR. STROSNIDER: Just one follow-up question in  
23 that area. You're indicating that the quality of the data  
24 may be the same. Was your analysis the same as some of  
25 these other licensees may have used in terms of how you

1 evaluated those data?

2 MR. MARK: Well, those older plants never had the  
3 benefit of the +Point probe. The +Point probe is a fairly  
4 new probe, because within the last five, eight years.

5 So the data that those earlier plants saw is not  
6 really the same quality of probe because the technology has  
7 changed quite a bit.

8 MR. STROSNIDER: It's an important point here. I  
9 want to make sure we're comparing apples and apples in terms  
10 of probes that are used, quality of the data, and how those  
11 data were analyzed.

12 I'm a little confused with your response.

13 MR. MURPHY: The root cause report that you  
14 submitted took note of the improved noise quality obtained  
15 with the high frequency probe and indicated that that kind  
16 of indicated that most of your noise problem with the  
17 midrange probe was coming from the surface deposits, the  
18 copper and the magnetite.

19 Is it fair to say that in recent years, that your  
20 plant is relatively unique in this respect?

21 What we're trying to get at it, from the root  
22 cause report, you have indicated that it was the surface  
23 deposits rather than ovality or geometry considerations that  
24 was largely responsible for the noise.

25 These surface deposits are uniquely a -- in terms

1 of the degree of problem, degree of obfuscation, this  
2 problem is relatively unique to Indian Point, is it not?

3 MR. ADANONIS: Don Adanonis, from Westinghouse.  
4 Just as a means of clarification, the types of signals that  
5 we see here due to deposit influence and effects or probe  
6 riding are not atypical to Indian Point, as an operating  
7 plant.

8 MR. MURPHY: Could you repeat that, please?

9 MR. ADANONIS: They are not unique to Indian  
10 Point.

11 MR. MURPHY: Due to surface deposits.

12 MR. ADANONIS: Well, the combination of deposits  
13 and probe riding effects.

14 MR. MURPHY: Does the degree of noise associated  
15 with the surface deposits, is that comparable to other steam  
16 generators that we commonly see in the field today?

17 MR. ADANONIS: Yes.

18 MR. STROSNIDER: And, again, is there any  
19 difference in the way the data are then analyzed from site  
20 to site in terms of using different frequencies or different  
21 guidance to the examiners?

22 MR. ADANONIS: This at Indian Point-2 was the  
23 first recognition that this kind of situation could lead to  
24 some masking of potential for degradation. So this is  
25 really the first in the industry, that I'm aware, attempt to

1 begin to put criteria in place that would identify such  
2 conditions and then take actions to mitigate it, that action  
3 to mitigate it was moving forward with the 800 kilohertz  
4 probe.

5 In my mind, that's the solution. The setup, I  
6 know there was a question of setup in some of the questions  
7 that came from the NRC, we don't see a significant  
8 improvement based on setup. There was a question on  
9 frequency. We don't see a significant improvement based on  
10 frequency, the frequency of the analysis.

11 The frequency of the examination going from the  
12 400 kilohertz, the midrange probe, to the 800 kilohertz  
13 probe, is the action that handles this problem, and that's  
14 where we had to go.

15 In fact, I think Jimmy made the point, and I'll  
16 reiterate it, that this 800 kilohertz probe wasn't -- has  
17 not been used before in the industry and probably is only an  
18 idea in somebody's mind, until we move forward and apply it  
19 out there.

20 MS. KAUFMANN: For your qualification effort for  
21 both the midrange and the +Point, you have a data set. How  
22 did you evaluate that set as being applicable to IP-2 in  
23 terms of noise levels of those samples compared to what you  
24 see at IP-2?

25 MR. ADANONIS: When we said that this was

1 site-qualified, Stephanie, we based that on our ability to  
2 go in not only the qualification that was done by Gary Henry  
3 at EPRI, but also based on then taking the information that  
4 we had collected through the qualification process, going in  
5 and looking at two flaws that we knew to exist, saw the  
6 improvement in results, went on to examine the rest of the  
7 tubes, identify new flaws, and we're able to -- and I think  
8 we have two other graphics that can show you, more clearly  
9 than these show you, the effect of application of the 800  
10 kilohertz probe in eliminating the signal-to-noise issues  
11 that you see in these graphics. I think it may be helpful  
12 to show it now.

13 MS. KAUFMANN: I'm familiar with that. I'm just  
14 asking, was the 26 data set, the 26 sample data set, do you  
15 think that's representative of the conditions at IP-2?

16 MR. NEFF: We also used the copper to qualify the  
17 response to the certain flaws. We put copper foil over  
18 flaws on the standards, which we determined did not affect  
19 the detectability of defects. So this was an additional  
20 step.

21 MR. ADANONIS: I guess --

22 MS KAUFMANN: Still looking for an answer.

23 MR. ADANONIS: Copper, to the extent that we could  
24 on the laboratory samples, yes, we represented the  
25 conditions. Did we represent the exact conditions relative

1 to probe ride? We didn't know that, so we took it to the  
2 field.

3 We believe that, based on the results that we've  
4 seen, the improved detectability, our ability to eliminate  
5 that noise, and given the results of an additional four  
6 PWSCC indications in row two tubes, that, yes, we have a  
7 technique now that we consider site qualified at Indian  
8 Point-2.

9 MR. MURPHY: Are there any efforts underway within  
10 the industry to demonstrate performance on a statistically  
11 significant set of U-bend specimens with real cracks?

12 MR. ADANONIS: At this point, I would have to ask  
13 Gary Henry.

14 MR. HENRY: There are none right at this moment.  
15 There are some that are proposed right now, but we don't  
16 know what the status is going to be of that program.

17 MR. ADANONIS: This is pretty new news. I think  
18 if you look at when our first delivery of a high frequency  
19 probe was March 20, but certainly that's something that  
20 we'll be looking into.

21 MR. MURPHY: When you state that the calibration  
22 setups were within industry variance, what specifically do  
23 you mean?

24 MR. NEFF: When the ETSS sheet, that specifies the  
25 technique, requires that you set the 40 percent IDE ten

1 degrees. There was no 40 percent ID flaw on Rev. 4 versus  
2 the 1997 inspection. So another flaw was referenced.

3 When we used the setup on 2000 data and  
4 experimented to try to find out how much that altered the  
5 setup, we determined that the phase rotation was about five  
6 to six degrees, more shallow than it should have been.

7 Normally, we have a three degree setup error that  
8 is common in the industry. So this is not far removed from  
9 being within normal industry standards. We found that we  
10 did improve slightly the detection of IDE by rotating the  
11 phase.

12 MR. MURPHY: Thank you. The site specific  
13 performance demo guidelines in Rev. 4, these guidelines in  
14 Rev. 4 apply to the analysts rather than to techniques.

15 MR. NEFF: They apply to the techniques.

16 MR. MURPHY: And analysts? I'm talking about Rev.  
17 4, the guidelines that you --

18 MR. NEFF: You define a technique which we then  
19 have to incorporate in our inspection program.

20 MR. ADANONIS: I think there might be a little  
21 confusion. The site specific performance demonstration  
22 program is basically the test that you administer to the  
23 analysts and it usually includes question relative to the  
24 training that you've given them, relative to plant specific  
25 conditions, what are the forms of degradation, there's a

1 written examination that goes along with it, and then they  
2 are required to take a practical test, which includes  
3 samples or data from tubes.

4 If you've seen degradation in a plant, they will  
5 have plant specific data. As Jimmy mentioned, in 1997, we  
6 had not -- number one, had not applied a +Point probe at  
7 this point at Indian Point, nor had we seen any PWSCC in  
8 U-bends.

9 So the site specific performance demonstration  
10 consisted of a test on industry data that had been collected  
11 with the +Point probe on U-bends.

12 Now, where I say there is some confusion, is your  
13 question relative to site specific performance demonstration  
14 or to the site technique qualification or the site  
15 validation of the technique? It is included in Rev. 5 as a  
16 requirement, but it was not a requirement in Rev. 4.

17 MR. MURPHY: Well, I was asking whether Rev. 4,  
18 the performance demo requirements, applied strictly to the  
19 analysts or whether those guidelines also applied to  
20 techniques that were being --

21 MR. HENRY: Gary Henry, with EPRI. They're using  
22 qualified techniques and you're applying an analyst  
23 performance demonstration to those qualified techniques. So  
24 it applies to both.

25 MR. MURPHY: But the purpose of even the Rev. 4

1 performance demo would have been to address the  
2 applicability of the generically qualified techniques for  
3 the plant specific conditions.

4 MR. HENRY: It's implied in Rev. 4, but it's not  
5 specifically stated as a requirement in Rev. 4. That's why,  
6 in Rev. 5, when we wrote Rev. 5, that we explicitly put it  
7 as a requirement in Rev. 5 to address those issues.

8 MR. MARK: Also, one of our conclusions, when all  
9 the lessons learned were evaluated, the use of the high  
10 frequency probe was determined to be the most significant  
11 thing that we did to improve the POD and these are a couple  
12 of examples that show the difference between the midrange  
13 probe and the high frequency probe, as far as improving POD.

14 MR. NEFF: As you can see, there are lots of  
15 deviations from the presentation on the 400 kilohertz. And  
16 here it is much clearer on the 800 kilohertz. This is  
17 typical of all the data that we looked at.

18 MR. MARK: So earlier, when I talked about the  
19 setup rotations and the 300 kilohertz versus the 400  
20 kilohertz midrange data, it really only provided minimal  
21 improvement. The high frequency probe has now been site  
22 validated for Indian Point-2, and the technology and the  
23 other things that we've learned based on these inspections  
24 are being passed on to industry and vendors involved in this  
25 kind of work.

1           Next, Tom Esselman is going to review the finite  
2 element work that we did on the support plates.

3           MR. ESSELMAN: Good afternoon. The subject I  
4 would like to discuss is the susceptibility of the small  
5 radius U-tubes in the U-bend region to primary water stress  
6 corrosion cracking. In doing this, I will touch upon the  
7 effects, the behavior of the tube support plates, primarily  
8 the top tube support plate, look at modality, and we will  
9 look at the differences between primarily the row two tube,  
10 a stiffer tube than a row three tube, and how those two  
11 tubes behave relative to each other and what we would expect  
12 to see in row three.

13           The approach that we've used is to look at, first,  
14 the tube support plates and determine, for the amount of  
15 hourglassing that was measured, how much each of the tubes  
16 in the vicinity of the tube support plate moves.

17           That will allow us to then move to see how that  
18 tube support plate motion affects the individual tubes. We  
19 then want to determine the stresses in the U-bend due to  
20 that tube support plate deformation and all the other  
21 operating conditions. We've done work on residual stresses  
22 that I will report to you and discuss residual stresses. We  
23 have included the effect of residual stresses in the row two  
24 and three tube, and we want to use that to assess the time  
25 or indicate the time to initiate cracking in the row two and

1 the row three tubes.

2 We use that to discuss and provide an indicator of  
3 the expected lifetime of a row three and a row two tube.  
4 We've performed both analyses and we performed tests on  
5 tubes that we've received from EPRI. I will discuss those  
6 tubes, the as-received condition, and then we'll discuss the  
7 tests that we performed on the tubes.

8 We've also performed stress analyses on row two  
9 and row three tubes.

10 The first step is to determine how much of the hourglassing  
11 is affecting individual tubes in the vicinity of a flow  
12 slot, because, in fact, the displacements are different.

13 We wanted to quantify the motion of all of the row  
14 three -- all of the row two and three tubes for a given  
15 amount of hourglassing. We performed a finite element  
16 analysis of a quarter plate model. We applied corrosion  
17 packing load, and I will describe this, inside the tube  
18 holes, so as to induce the in-plane compression that's  
19 caused by the denting process.

20 This is denting that, by primarily looking at the  
21 lower tube support plates and the behavior of them over the  
22 life of the plant, denting that occurred in the late '70s  
23 and early '80s, and that by tracking the lower support  
24 plates, which have been measured, appears to be leveled off  
25 and appears to be relatively constant. Probably not

1 stopped, but yet clearly behaving on a plateau.

2 That corrosion packing load causes in-plane compression and  
3 that's what causes the tube support plates to move into the  
4 flexibility, if you will, or the opening at the flow slot.

5 We've taken that analysis and I will show you some  
6 details of it, but the conclusion of it is that the tubes  
7 that go across a flow slot, this is focused on row six, a  
8 row two tube will move 62 percent, which would represent a  
9 tube at the end of the flow slot, to 97 percent, which would  
10 represent a tube at the center of the flow slot.

11 A row three tube in that range would be from 63 to  
12 92 percent. So as you move away from the flow slot, we  
13 included row one, of course, in the analysis, it moves 100  
14 percent, and as we move away, the row two tube moves more in  
15 the center than does the row three tube, when you take  
16 different motion into account.

17 The model that we've included is shown here, it's  
18 a quarter plate model. On half of the plate, in the  
19 vicinity of the flow slot, and there's three flow slots,  
20 there's six flow slots across the whole tube support plate,  
21 in the region of these flow slots, we've included a detailed  
22 finite element array, and on the rest of the plate, we've  
23 smeared it because they're really away from the effects of  
24 the flow slot.

25 A detail in the region of the flow slot shows

1 that, in fact, we model the flow slots and then each tube  
2 hole and each flow hole is represented, but inside the tube  
3 holes, we've put elements that we used to expand basically  
4 inside the hole to induce this in-plane compression.

5 We then increased that loading, and, again, we've  
6 allowed the plasticity to occur in the plate, in a greatly  
7 exaggerated view of the behavior, as you increase this  
8 corrosion packing load, the flow slot moves into the -- the  
9 tube support plate moves into the flow slot.

10 Now, this is greatly exaggerated for purposes of  
11 visualizing the behavior. We've been able to take the flow  
12 slot and calibrate this to the -- basically increase it so  
13 that we get the motion that was measured in the plant.

14 There is a measurement that was mentioned earlier  
15 of a flow slot in steam generator 24 that indicated, and I  
16 will show this in a minute, that the total motion was  
17 measured at just under a half an inch. So the total closure  
18 was measured at just under half an inch, 475 mils, and we've  
19 increased this to calibrate it, so it moved that much.

20 We then took the region of that flow slot and  
21 we've tabulated for all the column numbers across a flow  
22 slot, approximately ten or 11 columned numbers or rows  
23 across a flow slot, and then for each of the first four  
24 rows, we've tabulated the percentages, all normalized to the  
25 worst tubes, the center tubes in row one.

1           So this is the percentage of motion that every  
2 tube will see relative to its position across the flow slot.

3           This is a piece of input for the tube analysis.  
4 We're interested in taking these displacements in row two  
5 primarily and in row three and incorporating those into the  
6 analysis that we're doing in tubes to see how the tubes are  
7 behaving.

8           With that information, we're able to consider the  
9 U-tube itself and the objective of this analysis is to  
10 quantify the row two and row three tube stresses due to the  
11 hourglassing of the top tube support plate, the number six  
12 tube support plate.

13           This also is a 3D elastic/plastic finite element  
14 model. We included temperature and pressure. We measured  
15 the tubes that we received, we measured the wall thinning  
16 that you would see at the extrados of the tube, and the  
17 thickening that you would see at the intrados of the tube,  
18 and we've incorporated that wall thinning due to the bending  
19 process into the model.

20           We've incorporated residual stresses that I will  
21 discuss. We've imposed U-bend length displacements to  
22 correspond to those displacements that I just described from  
23 the tube support plate model. We also included the effects  
24 of strain hardening, because as you bend the tubes, you  
25 strain harden them and you're going to yield them, because

1 you're bending them permanently. You're going to push them  
2 up the stress strain curve, so that locally, on the U-bend,  
3 you're going to have a higher yield stress that will affect  
4 the behavior.

5 The strain that's induced is calculatable. We  
6 calculated it. We also took one of the tubes that we saw  
7 and did a test on an apex, extrados apex sample and a tube  
8 straight-leg sample and saw approximately a 50 percent  
9 increase in the strength, which corresponded to the amount  
10 that you would expect to get by looking at the strain that  
11 you induce in order to bend the tubes.

12 The analysis --

13 MR. MURPHY: Is this 50 percent increase  
14 associated with the fabrication bending process?

15 MR. ESSELMAN: Only with the fabrication. Again,  
16 that's input into the analysis. We performed the analysis  
17 considering the real condition of the tubes because of  
18 fabrication. So we incorporate the hourglassing in the flow  
19 slot and then reduce it as we go out to different tubes.

20 We also went into the records for these steam  
21 generators and we obtained the CMTRs, the certified material  
22 test reports, for every tube in row two and every tube in  
23 row three, and the CMTRs for all the row two and all the row  
24 three tubes were available, so we're able to know what the  
25 temperature material properties were, and we were able to

1 also use that and use that range in order to make sure we  
2 were looking at the weakest tube, one with the lowest strain  
3 and one with the highest strain.

4 The thing we also did prior to the analysis is we  
5 took -- we were interested in ovality and we did some work  
6 on ovality. We received three row two tubes and three row  
7 three tubes from the EPRI archives. These were tubes that  
8 were original Huntington alloys. They were bent in the  
9 early 1980s, to simulate the bending process for a row two  
10 and a row three tube.

11 These we believe are very unusual tubes and, in  
12 fact, that they were located and that they were well tagged  
13 and that the -- that heat numbers that take them all the way  
14 back to their original formation was available for five of  
15 the six tubes that we had.

16 They were 7/8 inch tubes, with 50 mil walls. They  
17 were Inconel 600 mil-anneal tubes. We had performed  
18 mechanical material composition, mechanical property  
19 testing, mostly in the tubes that didn't have the heat  
20 number, to make sure that it was in the family, and it was.

21 We also did ovality measurements, wall thickness  
22 measurements, and then measurement of yield stress in a bent  
23 versus a straight run for the tubes as we received them.

24 The six samples are shown here. This is the  
25 as-received tube samples. We had three row two tubes, the

1 wall thinning, and three row three tubes, wall thinning is,  
2 as I indicated, three mils to four mils; in the row three  
3 tubes, it was four mils to two mils. This is, again, on the  
4 extrados or on the outside up towards the apex, which would  
5 be the thinnest portion.

6 We also measured the ovality in the tubes and the  
7 ovality in the tubes were basically on five percent range,  
8 except for a single row two tube that had lower ovality.

9 With respect to ovality, we were interested in  
10 starting with an ovality like this and considering how a  
11 tube that was initially five percent ovalized would behave  
12 differently than a tube that had a circular cross-section.  
13 The analyses that we've performed had a tube with a circular  
14 cross-section and we did a finite element analysis to  
15 consider the effects of the as-manufactured ovality and the  
16 U-tube leg displacements on the apex stress.

17 We ran a row two, three and four tube. We ran  
18 with ovalities of zero, five percent and ten percent, and  
19 leg displacements, and this is a half displacement, so the  
20 quarter inch here corresponds to a half-inch total  
21 displacement. The lateral displacement is up to a quarter  
22 of an inch.

23 The conclusion that we had is that a U-bend analysis model  
24 with a circular cross-section, for a circular tube, when it  
25 is bent due to hourglassing, would give you higher stresses

1 than a tube that has initially as-manufactured ovalization  
2 in them.

3 The results are shown here for a tube that has a  
4 yield stress of 40 KSI, and the diamonds represent a row two  
5 tube. What you can see is a zero oval tube gives you this  
6 number.

7 There's two things. I also want to talk about the  
8 behavior of this. But if you look at a quarter of an inch,  
9 half leg displacement or single leg displacement, with zero  
10 ovality, you can see a stress here approximately 46 or 47  
11 thousand psi. With five percent ovality, you can see that  
12 drops to about 40,000 psi, and with ten percent ovality,  
13 that drops to about 32,000 psi.

14 So, in fact, the two that are initially oval, when  
15 it's hourglassed, will give you lower stresses than if it's  
16 circular. We were interested in this to investigate the  
17 behavior and also to justify our use of a circular cross  
18 section, starting with both row two and three, as that gives  
19 us a slightly conservative stress.

20 The stresses we're interested in are the stresses  
21 occurring at the inside, across the tube thickness, mostly  
22 at the ID stress and the OD. So this was important to us as  
23 we looked at the effects of modality.

24 MR. MURPHY: Yield stress is the initial yield  
25 stress before fabrication of the U-bends.

1 MR. ESSELMAN: In this analysis, this is the yeild  
2 stress that was put into the model in the bent condition,  
3 and that was for this study. As we went to analyze all the  
4 cases, if this were 50 or 60 KSI, the trend would be the  
5 same.

6 As we went to individual analyses, that I will  
7 describe, we took and extended the CMTR data, which was room  
8 temperature data, to width temperature and then strain  
9 hardened property, also.

10 MR. MURPHY: You're assuming the same yield stress  
11 for each row. Why do you get a difference in comparing  
12 yeild for each row of tubes?

13 MR. ESSELMAN: You're also applying pressure,  
14 which has an effect, a large effect in the ovality tubes,  
15 and you can see that at the zero leg displacement, as you  
16 pressurize an oval tube, it's going to flatten out, so that  
17 skews your ID.

18 This is the ID hoop stress, the stress inside, at  
19 the extrados, on the inside of the tube. The initial  
20 pressurization of the tube is going to induce compression on  
21 the inside of the tube. So that's what skews this like that  
22 mostly.

23 The other thing that we wanted to do with the  
24 tubes we received from EPRI were to perform some U-bend leg  
25 displacement tests. We designed a fixture that would allow

1 us to take these tubes and simulate the application of a  
2 displacement and then compose displacement at the location  
3 of the top tube support plate.

4 Our intent was to develop a fixture that would  
5 limit the rotation at the tube support plate, because in the  
6 plant, of course, your top tube support plate has an  
7 hourglass that is going to remain flat. So we wanted to get  
8 as low a rotation as was reasonable.

9 We developed a fixture. We applied internal  
10 pressure and incrementally squeezed the tube or displaced  
11 the legs and measured ovalization as we imposed the leg  
12 displacement. We also measured strain in displacements.

13 The fixture and the tube in the fixture is shown  
14 here. Basically, the fixture was designed with a three  
15 quarter inch plate. This plate was split and we were able  
16 to simulate denting by squeezing down on the tube at the  
17 tube support plate. The fixture was designed with  
18 bolt-throughs and tightened to the point where we could  
19 impose a displacement and limit the rotation, and we were  
20 successful in greatly limiting rotation, but not eliminating  
21 rotation.

22 But you can see we measured strains around the  
23 extrados and the intrados at about the apex and about the 30  
24 degree point, pressurized it and imposed displacement, and  
25 as we imposed the displacement, we stopped at increasing

1 displacements and measured tube diameters around the tubes,  
2 so that we could look at ovality.

3 The ovality tests were for the row two tubes that  
4 we tested and are shown here. It was the tube that started  
5 with an initial ovality of two and a half percent. That  
6 ovality, as we went up to a -- and this is a leg-to-leg, so  
7 this is a two-leg displacement, if you will -- went up to  
8 .55 inches, which is approximately a 75 mils greater than  
9 what was measured in the plant.

10 You could see that at the apex, the ovality went  
11 up to approximately seven percent, a five percent increase,  
12 and at the 45 percent point, you could see that the ovality  
13 change was lower.

14 This is the step changes and then we move below,  
15 we then release the sample, the clamping, and then we  
16 depressurize the sample.

17 With the row three tube, we started with a five  
18 and a half percent or approximately a five percent oval tube  
19 and the data was taken by hand and it's a very small change,  
20 this was a smaller ovalization change, but this was from  
21 five percent and this went up to three quarters of an inch,  
22 approximately a quarter of an inch more than what we've seen  
23 in the plant.

24 Your ovality, in that case, changed, went up to  
25 approximately eight percent at the place where they are in

1 the clamp, which is just under half an inch, then ovality  
2 would be on the order of six, maybe six and a half, to seven  
3 percent.

4 So the ovality change that we saw in a row three  
5 tube, as you would expect, as you go to larger tubes,  
6 reducing and was relatively controlled without severe  
7 flattening of the tube.

8 We also have strain data that we took that we've  
9 been able to use and correlate to the finite element model  
10 of the tube to show that the behavior of the tube,  
11 originally circular, but it is allowed to ovalize, and the  
12 strain that you're seeing here also includes ovalization.

13 We did those correlations to make sure that we  
14 were accurately predicting the behavior of the tube.

15 We also took a tube, clearly the tube that was not  
16 the tube that we ran this test on, but a tube that was as  
17 received and we measured the residual stresses on the tubes.

18 We measured the residual stresses using a very  
19 classical technique, which is to apply strain gauges, then  
20 to release the constraint or the restraint by cutting the  
21 tube, and then measuring the strain, as you cut the tube and  
22 relieve the constraint.

23 We did that with OD gauges, applied to both a row  
24 two and a row three tube. Those are shown here for a row  
25 three tube. You can see that we applied extrados, obviously

1 outside diameter, while the tube is in this configuration,  
2 tubes at three locations. There are also introdos gauges at  
3 these three locations.

4 And then we cut the tube into pieces on each side  
5 of these; first of all, making only circumferential cuts,  
6 releasing a section here, a section here, and a section  
7 here. We then took those sections and applied internal  
8 gauges, prior to releasing the flags, if you will, and  
9 letting the tube expand in the circumferential direction,  
10 and you can see the ID gauges here.

11 We also have the OD gauges, and once we have this  
12 gauge, which is the OD on the inside of the tube, the  
13 extrados, we then cut the flanks and measured the strain  
14 change there.

15 The data that we saw show that for the row two  
16 tube, the total ID hoop strain that was measured is 380  
17 micro-inches and the row three is 360 micro-inches. Now,  
18 this is the measured data. When you do this test, what you  
19 measure is opposite to what is in there, because you're  
20 relieving the strain, so what you're measuring is basically  
21 the strain release.

22 So what you see is opposite in sign. What this  
23 means is that if, on the ID, you have positive stresses,  
24 strains that were measured as you release the constraint,  
25 which means that you initially have compressive hoop

1 stresses on the ID of the tube at the extrados.

2 The equivalent elastic stress is approximately  
3 10,000 psi. Compression on the ID, the row two and the row  
4 three tubes were very close to each other. They were nearly  
5 on top of each other.

6 At the outside wall thickness, this is across the  
7 wall thickness, plus or minus 25 mils, at the outside wall  
8 thickness, you had a tensile stress of around eight or 9,000  
9 psi.

10 Clearly, what you know here is you know these  
11 points and you know these points. We're drawn a line to  
12 represent what that distribution probably looked like, in  
13 probably nearly linear across there.

14 This was important data because this allowed us,  
15 in the stress analysis, then to incorporate the effects of  
16 the residual stresses.

17 MR. MURPHY: So at the apex, we're talking about  
18 the extrados here at the apex.

19 MR. ESSELMAN: This is the apex. It's the  
20 extrados through thickness at the apex extrados. This is  
21 the ID surface and this is the OD surface.

22 MR. MURPHY: Okay. So without the help of  
23 hourglassing effects, the ID surface is in a state of  
24 compression.

25 MR. ESSELMAN: When it was first bent, before it

1 was installed or as it was installed, before it was started  
2 up, this is the state of stress, residual stress that you  
3 had.

4 MR. MURPHY: Now, it's my understanding that the  
5 rows one and two tubes were fabricated a little differently  
6 than the row three.

7 MR. ESSELMAN: Right.

8 MR. MURPHY: Was that taken into account?

9 MR. ESSELMAN: The row three -- we've traced these  
10 six tubes very carefully. We've collected what we think is  
11 all the information that we can. The row three tubes were  
12 manufactured without a mandrill, which is the way that the  
13 Con Ed, that the IP-2 tubes were manufactured. The row  
14 three tubes classically were manufactured without a  
15 mandrill.

16 The IP-2 tubes, the row two tubes were  
17 manufactured with a mandrill and we believe that these row  
18 two tubes, at least two of the row two tubes were  
19 manufactured without a mandrill. We believe the third tube,  
20 the one with lower ovality, was manufactured with a  
21 mandrill.

22 So these row two tubes --

23 MR. MURPHY: Are you talking about tubes at IP or  
24 are you talking about your sample?

25 MR. ESSELMAN: IP-2 was our -- and it's reported

1 that row two was made with an internal mandrill, row three  
2 was made without an internal mandrill. These row three  
3 tubes we know were made that way, without an internal  
4 mandrill. We believe that we have both a with and without.

5 In the row two tubes, although we're reasonably  
6 confident that two of the row two tubes were made without an  
7 internal mandrill. We believe the third was.

8 That would make them slightly different than the  
9 IP-2 tubes. The row three tubes, though, are manufactured  
10 in a very similar manner to what we know is --

11 MR. MURPHY: I'm maybe misunderstanding you.  
12 Among the population of IP-2 tubing, row two, there may be  
13 one or two tubes that were made without a mandrill.

14 MR. ESSELMAN: Well, IP-2 row two tubes were made  
15 with an internal mandrill. Row three tubes were made  
16 without an internal mandrill.

17 MR. MURPHY: Okay.

18 MR. ESSELMAN: In the three row two tubes that we  
19 tested, that we had available for testing, we believe that  
20 two of them were made without an internal mandrill and had  
21 higher ovality. One of them, we believe, was made with an  
22 internal mandrill, which is a tube that had the two percent  
23 ovality as opposed to the five percent.

24 MR. MURPHY: These were row three or row two?

25 MR. ESSELMAN: The row three tubes that we tested,

1 all were made without an internal mandrill. So we're sure  
2 that the row three tubes that we tested are very similar to  
3 the row three tubes at Indian Point.

4 MR. STROSNIDER: Just out of curiosity, when you  
5 did these residual stress measurements, did you do any  
6 strain gauging at the tangent point? Did you look at that  
7 area at all or just did you look at the apex?

8 MR. ESSELMAN: We have the apex and then we had  
9 two other gauges.

10 MR. MURPHY: Just one more question then. Among  
11 your sample, then, two of the three row two tubes, your lab  
12 sample, two of the three row two tubes were made with the  
13 mandrill and all three row three's were not made with a  
14 mandrill.

15 MR. ESSELMAN: Internal mandrill, yes.

16 MR. MURPHY: Internal mandrill. That doesn't  
17 affect the stress distribution that we see here on the  
18 screen, whether they were. The fact whether a mandrill was  
19 used or not doesn't affect this internal stress  
20 distribution.

21 MR. ESSELMAN: The single tube in row -- this is  
22 two tubes that we believe -- a row three tube that was made  
23 without an internal mandrill, also a row two tube that we  
24 believe was made without an internal mandrill.

25 MR. MURPHY: Okay.

1 MR. ESSELMAN: The tube that was made with an  
2 internal mandrill was used for the leg displacement test.

3 What is important here is -- what's mostly  
4 important is the magnitudes. If we get ten more of these,  
5 we're very -- despite the fact that these were very close to  
6 each other. What's important is the sign of this and I  
7 think that we had believed that the internal stresses in the  
8 circumferential direction would be compressive.

9 MR. MURPHY: Do we know -- did you do an analysis  
10 or a test to figure out what the stress distribution looks  
11 like for a row two tube with an internal mandrill?

12 MR. ESSELMAN: No. We believe that it's not  
13 dramatically different. We looked at that and we believe  
14 that it's not dramatically different, because, in fact, what  
15 you're doing with the internal mandrill is restraining  
16 ovalization a bit, but yet much of this is coming from the  
17 stretching that you're doing axially and the stretching that  
18 accompanies that circumferential -- you need to think about  
19 all that's happening circumferentially, as you're bending  
20 the tube axially.

21 We think that the internal mandrill gives you  
22 lower -- controls ovalization a bit more. We don't believe  
23 that the internal mandrill on row two would have a  
24 significant effect on the results.

25 I mentioned the stress strain properties of the

1 tubes. The row two and row three yield stresses will be  
2 higher than normal due to strain hardening. That's the  
3 stretching to the manufacturing process.

4 We made a yield strength adjustment that has been  
5 determined from the elongation induced during bending. Row  
6 two strain hardening, so it's bent to a tighter radius, is  
7 greater than row three.

8 For the purposes of analyses, we made that  
9 extrapolation from the stress strain curve knowing that the  
10 strain that was induced in these two tubes. We did tests,  
11 though, on a tube where we took the apex -- an apex and a  
12 straight leg, and we saw that the yield strength in the apex  
13 is approximately 50 percent higher.

14 I'll talk more about the CMTR records. We  
15 performed the analysis with a variation. The CMTRs, the  
16 yield stresses from the CMTRs have a large variation in  
17 them, all above the minimum specified, and I will show you  
18 those.

19 But because of the large variation, number one,  
20 large variation, and, number two, you don't know where the  
21 higher strength tubes might be in row two. You know that  
22 they're in row three. We analyzed both the lower yeild  
23 strength and the higher yield strength and a median or an  
24 average yield strength.

25 The analysis was performed with pressure,

1 temperature, residual stress and leg displacements. These  
2 yield stresses shown here are corrected for temperature.  
3 These are the actual CMTR yield stresses reported, corrected  
4 for temperature, because that had already been done a little  
5 bit, and also corrected for strain hardening.

6 That is, pushing up the row two tubes because of  
7 the additional strain a little bit higher in yield stress,  
8 and you can see the variation driven largely by the original  
9 yield stresses are really quite large.

10 What we did was we ran analyses for row two and  
11 row three using lower yeild, average yield, and higher  
12 yield, and report those stresses.

13 I have some plots and some more charts that will  
14 show you the distribution of the stresses. We have both the  
15 ID and OD stresses, on the inside surface and the outside  
16 surface.

17 We tabulated the stresses that we talked about,  
18 which were from residual stress. We looked at -- we  
19 tabulated separately the stress that would come from only  
20 applying differential pressure, plus thermal expansion, and  
21 this is without the residual stress. There's also less in  
22 plastic, so this is not -- the residual stresses are  
23 incorporated on a strain basis and not just added on the  
24 stress basis.

25 And then for row two, the range of ID -- this is

1 inside diameter, circumferential stress on the extrados  
2 ranged from approximately 51,000 psi up to 92,000 psi,  
3 always compresses on the ID, always -- I'm sorry -- always  
4 tensile on the ID, always compressive on the OD. And in row  
5 three, calculated the same stress, as you can see here, that  
6 the -- for the -- these are, again, the stresses that are in  
7 the tube for the lower yield strain, materials range from 40  
8 to 65 KSI in the row three tubes.

9 So these are all the effects incorporated. The  
10 lower stress is caused by several things, mostly by greater  
11 flexibility and also has lower displacement because it's one  
12 tube further out.

13 You have lower strain hardening in those tubes,  
14 also. So it's a number of effects that are being  
15 incorporated so that we're looking at the range of stresses  
16 that exist in the row two and the row three tubes.

17 We've taken these stresses and we've asked what  
18 does this mean relative to how these tubes would be expected  
19 to be susceptible to stress corrosion cracking.

20 MR. STROSNIDER: Before you leave that slide.

21 MR. ESSELMAN: Yes.

22 MR. STROSNIDER: I want to make sure I understand  
23 that. Where you show total loading and for the three  
24 different cases of yield stress, that includes some amount  
25 of hourglassing.

1           MR. ESSELMAN: It includes a maximum amount of  
2 hourglassing. It includes residual stresses, it includes  
3 the effects of strain hardening. So that is all of the  
4 effects.

5           MR. STROSNIDER: And as you say, this is not a  
6 linear thing. What is the delta between adding the  
7 hourglassing and without the hourglassing?

8           MR. ESSELMAN: If you didn't -- the increase  
9 between differential pressure plus thermal expansion is  
10 almost all recognized. There is no hourglassing, you have  
11 this stress and, frankly, that would be elastic, so you  
12 would just subtract the residual stresses, so you have a  
13 very low stress state on the ID surface, without any  
14 hourglassing.

15           So this is the pressure effects, plus the thermal  
16 expansion.

17           MR. MURPHY: And you've assumed the amount of  
18 hourglassing is, what, the 48?

19           MR. ESSELMAN: It's 480 mils. I wanted to point  
20 out, on the curve, and this is very important, on the curve,  
21 where we look at the ovalization effects, you saw that that  
22 went up to a plateau of about 100 mils.

23           In fact, what we see because of the actual  
24 behavior is that once you pass a threshold, that is, once  
25 you go across a flow slot, the stresses in the tubes don't

1 change very dramatically, even as your displacements drop  
2 down.

3 So once you pass the threshold, you get some  
4 plasticity in the tubes. In fact, the tube stresses are  
5 leveled out on the plateau, which also means, as we increase  
6 the displacements across the flow slot, you don't have a  
7 very dramatic difference in stress across the flow slot  
8 even.

9 But this is with a 480 mil total displacement.  
10 The important point, though, is that it's not very sensitive  
11 to that, whether that's 450 mils or 520 mils.

12 So the question we asked is what can we do with  
13 this to relate row two behavior to row three behavior, since  
14 row three behavior is -- well, behavior of both rows is of  
15 primary importance.

16 We know that -- going to crack initiation, a  
17 number of references over a number of years, and a number of  
18 studies that have indicated that time to crack initiation,  
19 and that's the time from the application of the stress to  
20 the time that action would initiate, is proportional to the  
21 applied stress rates to the fourth power.

22 What this is most useful for is the two tubes that  
23 have different stresses applied to them and it allows you to  
24 relate the behavior of a single tube to another tube.

25 So what we're saying is if you have two tubes, the

1 time to initiating of cracking of a single tube, in one  
2 tube, is related to the ratio between a different tube and  
3 the tube that you're in, raised to the fourth power.

4 So this isn't a linear unit. It's not an increase  
5 of stress rate of 20 percent. This is 20 percent longer.  
6 It's really a fourth power relationship, so there is a very  
7 strong relationship due to the ratio of stresses.

8 We believe that the denting occurred in the late  
9 '70s or early '80s. We don't know when a crack initiated in  
10 the row two tube, but yet we can use this to assess how the  
11 other row two tubes would be expected to be behave and how  
12 the row three tubes would be expected to be behave relative  
13 to the row two.

14 I'll just talk a little bit about this yield  
15 stress distribution again, the apex stress distribution, and  
16 what does the row two and row three comparison mean.

17 The CMTR yield stress distribution for the row two  
18 tubes, this is the room temperature data taken right off the  
19 certified material test report, are shown here, where this  
20 is the number of tubes and this is the yield strength and  
21 this is 300-some, 380-some tubes. I'd have to go back and  
22 look at the total number of tubes, but this represents all  
23 the row two tubes that are there and you can see it ranges  
24 from 38 KSI up to 66 KSI. This is different heats. There's  
25 a lot of different heats that will --

1 MR. MURPHY: Is this information you knew on a  
2 tube by tube basis?

3 MR. ESSELMAN: You know it on a tube by tube  
4 basis. You don't know where each individual tube goes,  
5 though. So you know the CMTRs for every row two tube. You  
6 don't know the location of any individual tube, though. But  
7 this is not a distribution. This is every data point for  
8 every row two tube.

9 If we take -- if you recall, we did stress  
10 analysis for low yield strength, medium yield strength, and  
11 the highest yeild strength. If you take that CMTR data and  
12 convert it into a distribution for the ID apex stress --  
13 again, this is the circumferential stress at the apex ID,  
14 which is the one that -- the ID tension is the one that's  
15 going to initiate cracking due to primary water stress  
16 cracking.

17 You can see that the distribution of stresses  
18 ranges from approximately 52,000 KSI up to 94 KSI. What's  
19 interesting, I guess I've looked at this and asked why are  
20 we seeing only seven tubes that have cracks in row two, and,  
21 in fact, if you look at this data, this would indicate that  
22 these tubes, that have the highest stress, are the most  
23 susceptible tubes. These would be the next susceptible, and  
24 then this collection of approximately 18 tubes, this is  
25 about either three or four tubes, and this is two or three

1 tubes, but then 18 tubes susceptible.

2 Again, if you took the ratio of this stress to  
3 this stress, which is approximately 1.2 or so, and the time  
4 to initiate that cracking is a fourth power relationship.  
5 So you would expect these tubes, wherever they are in the  
6 generator, to be most susceptible and they would be most  
7 likely to crack first, followed by these tubes.

8 There's a lot of tubes in row two that just aren't  
9 susceptible because their stresses in the apex are much,  
10 much lower. If you take the relationships, and I've done  
11 this for the row three tubes and I'll tell you the results,  
12 but this is the stress of the fourth relationship. This two  
13 down here would be expected to crack more than ten times or  
14 probably ten times in the amount of time it took for the  
15 first row two tube to crack.

16 So having seven flaws is not inconsistent with the  
17 way you would expect the row two behavior to progress.

18 MR. STROSNIDER: Just a question on this. This  
19 plot is -- this is applied stress.

20 MR. ESSELMAN: This is the stress -- this is the  
21 stress in the tube.

22 MR. STROSNIDER: Right. So this would give some  
23 indication of susceptibility based on stress in the tube.  
24 All right. Applied, residual, all the stresses in the tube.

25 But isn't the susceptibility also related to the

1 yield strength of the tube itself and couldn't there be some  
2 sort of normalized relationship here that might encompass  
3 more of those factors?

4 MR. ESSELMAN: Unique to the threshold. Below a  
5 certain threshold, related to yield stress, you will not get  
6 cracking -- this power to the fourth relationship applies to  
7 tubes that are all in or around the yield stress of the  
8 material.

9 This tube is higher by a percentage value than the  
10 yield stress than are these tubes. So this tube would be  
11 more susceptible, because it also is a higher percentage  
12 over the yeild stress. These tubes down here are a lower  
13 percentage.

14 MR. MURPHY: This data assumes all tubes see the  
15 same amount of hourglassing.

16 MR. ESSELMAN: Correct.

17 MR. MURPHY: When, of course, I mean, different  
18 tubes will -- the hourglassing probably varies from zero to  
19 4,800ths of an inch.

20 The data you have would suggest that there may be  
21 a huge time interval between the occurrence of cracks in the  
22 first seven tubes or whatever versus the rest of the  
23 population. But if one were to go through a Monte Carlo  
24 process, where one considers the likelihood that a given  
25 tube will be associated with a given amount of hourglassing,

1 one may have a distribution of flaws that perhaps doesn't  
2 have such an extreme tail and one might have a totally  
3 different picture of how quickly one encounters new cracks.

4 MR. ESSELMAN: Correct. Two points are important.  
5 Number one, again, across the stresses in the tubes across a  
6 flow slot, that's hourglassed approximately half an inch in  
7 the center, is relatively constant because of this threshold  
8 where the stress of the tube plateaus out.

9 So that the tubes in the hourglassing region are  
10 approximately -- have approximately equal stress. You are  
11 absolutely correct in that the tubes in the hard spots, and  
12 that's in between the flow slots, really have a very low leg  
13 displacement and there are about two tubes in each flow  
14 slot, and there are six flow slots, so that's about 12 tubes  
15 per generator that won't be seeing the U-bend displacement.

16 But I believe the rest of the tubes are similarly  
17 stressed.

18 MR. MURPHY: One thing we haven't talked about  
19 yet, and I hope to get there, is the differences in  
20 hourglassing from flow slot to flow slot, whether all flow  
21 slots are hourglassed and how much.

22 But it's not constant from flow slot to flow slot.  
23 Some may have zero.

24 MR. ESSELMAN: That's correct, and that would  
25 change this distribution and it would change the -- we've

1 treated every tube as having the maximum U-bend or the same  
2 leg displacement. So from that point of view, we've skewed  
3 this to have more cracks, more tubes susceptible than might  
4 actually be the case.

5 MR. MURPHY: But at the same time, you have to  
6 reckon with the fact -- I don't know what the current count  
7 is on U-bend indications, maybe seven or eight indications,  
8 so the statistics have to allow for the fact that --

9 MR. ESSELMAN: I offer as an indicator the  
10 behavior driven mostly by the wide variation in yield  
11 stress, which is also a somewhat unexpected variation in  
12 yield stress. I was surprised that it was so large in that  
13 variation in yield stress. There are other factors that we  
14 have to take in account. Variation in yield stress is very  
15 significant, though, in driving the behavior of the tubes.

16 We do the same thing in the row three tubes, the  
17 CMTR data that is shown here, which is roughly the -- it is  
18 roughly the same as the row two. Similarly, for the row  
19 three tubes, the same stress conditions are shown here and  
20 these are the ID apex stresses in the tubes that vary from  
21 42 to 66 KSI.

22 What's interesting is to take the row three tubes  
23 and overlay it on the row two tubes, which are shown here,  
24 and you can see the row two tubes have a large number of row  
25 two tubes that are more susceptible than row three tubes.

1           If you use the stress of the relationship, which  
2 is this tube is right around, at or near the yield stress,  
3 the strain or yield stress for that material is generally  
4 applicable to the stress of the fourth relationship.

5           The initiation time between this tube and this  
6 tube will be a factor of four. That is, the fourth power,  
7 this tube would be expected to initiate cracking four times  
8 longer than it took this tube to initiate cracking.

9           I think that that's a widespread and significant  
10 in terms of understanding the behavior of the row two tube  
11 and understanding why, in row three, there were zero defects  
12 which could very easily be because there are no defects  
13 because those cracks in row two have not initiated.

14           In similar fashion, and as I look at the data and  
15 analyze it, you have -- if you add up all these tubes,  
16 there's approximately -- the tubes that are more susceptible  
17 or as or more susceptible than the worst row three tubes, I  
18 did that, add them up, and I don't remember the number, but  
19 it's approximately 240 tubes, again, presuming a uniform  
20 susceptibility, uniform loading, I guess I think that having  
21 240 tubes initiate cracking in row two is inconsistent with  
22 having only seven defects, and I think that really, in the  
23 process, in row two, we're down in this region, and we -- at  
24 initiation, what we're seeing or detecting are cracks that  
25 are out in this region, and that, in fact, this would

1 indicate that the row three tubes would be would be lagging  
2 by quite a bit.

3 MR. MURPHY: Still, the assumption here is that  
4 you're seeing a uniform loading on all the tubes in terms of  
5 displacement. The conclusions one might draw from a chart  
6 like this would seem to be more clear if one had gone  
7 through, say, a Monte Carlo process in generating this  
8 curve, which accounts for the fact that not all flow slots  
9 are hourglassed, that different tubes will see different  
10 amounts of leg displacement, and you rack that all up and --

11 MR. ESSELMAN: But the effects -- but let me say,  
12 again, the effects, though, of those differences are  
13 secondary. The threshold for hourglassing that puts you on  
14 this plateau is around 100 mils, so that if you have a flow  
15 slot that had zero hourglassing impact, those tubes would be  
16 much less susceptible.

17 And in doing it in a Monte Carlo type analysis  
18 would be significant, if they were flow slots that we felt  
19 had zero. We are presuming that we are above the threshold  
20 in all the flow slots in this analysis, because if we had  
21 any flow slots at zero, that would be much, much lower  
22 stresses than ten or 15,000 psi off the chart.

23 I understand the point that you're making really  
24 clearly, but you have to look at the fact that we have  
25 relative independence across the flow slot and once you pass

1 about 100 mils, you're on a plateau and you're not  
2 increasing the stress incrementally.

3 That said, I will go back and look in more detail  
4 at particularly the higher strength tubes that might behave  
5 differently.

6 The conclusions that we've drawn clearly -- the  
7 work continues in process and is starting to understand all  
8 the subtleties that we're dealing with -- is that the  
9 ovality does appear by both test and analysis, but not by a  
10 significant role in the ID apex stress.

11 The cause of the cracking that we've seen in row  
12 two is linked to hourglassing in the top tube support plate.  
13 It provides a stress state that is very compatible with the  
14 occurrence of stress corrosion cracking. We've also seen  
15 that row three is much less susceptible than row two tubes,  
16 because of the stress state inside.

17 Thank you very much.

18 MR. ALLAN: It's now approaching 1:20. It's a  
19 good time to break for lunch. We will meet back about 2:15.  
20 For the visitors here, we have a cafeteria on the first  
21 floor of this building and there's locations across the  
22 street and next door for food.

23 If you do leave the building, report to security  
24 as far as your badge and you have to be escorted back up.

25 [Whereupon, at 1:20 p.m., the meeting was

1 recessed, to reconvene this same day at 2:15 p.m.]

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## AFTERNOON SESSION

[2:20 p.m.]

1  
2  
3 MR. ALLAN: We have one more presentation and then  
4 we'll open it up to question and answer from the NRC staff  
5 regarding the review of the IP-2 event with Con Ed.

6 We recognize that this may go beyond 4:00, but we  
7 plan on still having an opportunity to answer some  
8 questions. With that, I'll turn it over.

9 MR. PITTERLE: I'm going to address the planning  
10 and a little bit of the input data for the U-Bends on the  
11 condition monitoring and operational assessment. This is  
12 not the conclusions of the operations assessment, but rather  
13 more of a plan type approach we had taken.

14 Just some definitions that are pretty standard.  
15 Condition monitoring is looking at the last cycle evaluation  
16 of the indications found in the inspection against the  
17 performance criteria. The operational assessment is looking  
18 at the end of the next cycle and evaluating tube integrity  
19 against the performance criteria at the end of the next  
20 cycle.

21 A burst, because we'll be talking about ligament  
22 tearing and burst a little bit, burst is defined as a gross  
23 structural failure of the tube wall, unstable opening, crack  
24 extension, and is distinguished as different from just  
25 ligament tearing.

1 MR. MURPHY: Tom, you were just making the point  
2 that the failed tube configuration was not a burst.

3 MR. PITTERLE: I'll get into each of the specific  
4 tubes that might be in question.

5 MR. MURPHY: I was speaking of R2C5.

6 MR. PITTERLE: We don't believe that that was a  
7 burst. It was ligament tearing. But from the fundamentals,  
8 it doesn't really make much difference. It failed condition  
9 monitoring by leakage, but there are no indications that  
10 that reflected a burst of the tube, as contrasted with  
11 ligament tearing.

12 Arguably, if they're at that point in time, with  
13 two inches opening, would there have been any more burst  
14 pressure, we're not taking any position on.

15 It did fail condition monitoring just because of  
16 the leakage. The issue of that particular tube, whether  
17 it's a burst or ligament tearing is not particularly  
18 relevant.

19 The performance criterion, tube shall maintain  
20 structural integrity over the full range of operating  
21 conditions. The dominant criteria treating the U-bends are  
22 sludge pile is free span and for the Indian Point-2, in the  
23 margin of three against burst under normal steady-state full  
24 power operation is the dominant criteria. The margin of 1.4  
25 against steam line break is less restrictive than the three

1 delta P.

2 Then the primary to secondary accident induced  
3 leakage shall not exceed one gpm under steam line break  
4 conditions. That represents the sum of all leakage in the  
5 generator, not to exceed one gpm.

6 Those are the overall performance criteria that  
7 will be used.

8 The basic issues to be addressed show that the  
9 structurally significant degradation has been detected.  
10 That's, of course, with the 800 kilohertz probe. And that  
11 which is undetected will not grow to be structurally  
12 significant during the next operating cycle.

13 The three key inputs to that type of an analysis,  
14 probability of detection, growth rate, and, to a lesser  
15 extent, sizing of the indications in the outage that's been  
16 completed.

17 Complicating factors, we've had lots of discussion  
18 before between the 400 and 800 kilohertz probes, on the  
19 influence of the secondary side, deposits that resulted in  
20 low signal-to-noise ratios, and that does complicate some of  
21 the interpretation of the data.

22 We think we're covering that and I'll try to  
23 highlight a few things we're doing to address that.

24 The overall tube integrity considerations, the  
25 CMOA, condition monitoring operational assessment, must

1 address all degradation. Here I have highlighted what we  
2 believe to be the two, although we do need to look at all  
3 the degradation, but the two key elements are the low row  
4 U-bends PWSCC, the cracking mechanism for row two, column  
5 five, that led to the leakage, PWSCC at dented support  
6 plates is -- well, no indications, confirmed indications  
7 found in this particular outage.

8 The sludge pile, a lot of effort went into the  
9 inspection to look at, in considerable depth, the sludge  
10 pile assessment will be performed as a part of this effort.  
11 And there is the area above, if we call the sludge pile ten  
12 inches, above the sludge pile, those two, sludge pile and  
13 free span above the sludge pile are OD degradation, and then  
14 areas that have to be addressed in the tube sheet.

15 There is denting at the top of the tube sheet, can  
16 cause some indication in those dents. Crevice region ODSCC,  
17 the tubes in the Indian Point units are fully expanded for  
18 the first two and a half inches or so at the bottom of the  
19 tube sheet. They're not expanded the rest of the way in the  
20 tube sheet and you get deposits on the tubes and you can get  
21 OD cracking inside.

22 And then in the role transition, a couple inches  
23 from above the top of the tube -- the bottom of the tube  
24 sheet, there is a PWSCC indication. These will all be  
25 addressed in the final CMOA.

1           We focus more of this discussion today on the low  
2 row U-bends and then come back and more briefly address the  
3 other degradation mechanisms again.

4           We've, I think, pretty much covered these first  
5 couple topics, 2-5 would not have been called in 1997. We  
6 believe and very strongly believe that the improvements in  
7 going to the 800 kilohertz high frequency probe, we would  
8 not be leaving any indications of that size in service as a  
9 result of the 2000 inspection.

10           So the POD has been improved by probe,  
11 improvements in the analysis, guidelines and training. The  
12 high frequency probe, which improved the signal-to-noise  
13 ratio. Clear indication is one of the 2-4 type, row 2,  
14 column 4 indication, shown earlier. We can really begin to  
15 see a lot of the very small indications relatively clearly  
16 with the high frequency probe.

17           And a very important element, no indications found  
18 in rows three and four and all the indications have been in  
19 row two. We will discuss the PODs that we are planning to  
20 apply in the assessment for the U-bend and compare basically  
21 based on the extreme case of industry experience.

22           MR. MURPHY: I take it you're going to -- go  
23 ahead, go ahead.

24           MR. PITTERLE: This represents, in searching back  
25 through PODs that have been developed for PWSCC, this

1 represents kind of the range of PODs that have been found  
2 for a +Point coil. Now, applying this here specifically to  
3 the 800 kilohertz probe, I'm not trying to draw conclusions  
4 on the 400 kilohertz, where the issues of bad data come into  
5 play.

6 But as far as looking forward from this inspection  
7 on, showing what has been one of the better PODs found for  
8 +Point for PWSCC has been for denting at tube support  
9 plates. In this condition, the dents are relatively  
10 symmetric. The +Point probe tends to cancel out a lot of  
11 the denting effects and detection with the +Point probe is  
12 very good.

13 And we see that developed through a combination of  
14 pulled tubes and extensive laboratory testing is shown the  
15 +Point POD here, lost call rates for that particular exam  
16 were very, very low, a few percent, and it represents  
17 considerable effort in training, procedures, went into that  
18 program.

19 MR. MURPHY: Tom, you're not suggesting that these  
20 PODs here on this chart are representative of those in the  
21 U-bend, even with the +Point.

22 MR. PITTERLE: I believe that this POD is  
23 representative, the lower one, representing the lower band  
24 of indications of +Point detection is typical of what we can  
25 expect for the 800 kilohertz probe, not for the 400

1 kilohertz.

2 MR. MURPHY: I guess based on the information on  
3 the table, we wouldn't agree with that. It would seem to us  
4 that one is not going to detect a significant fraction of  
5 these until the max depth is on the order of 70 percent  
6 thruwall.

7 Be that as it may, there's no -- you don't have it  
8 with the surface deposits.

9 MR. PITTERLE: I agree we do not have a  
10 performance demonstration set, but I think I disagree with  
11 the first statement that if you look at the depths that we  
12 found, the average depth, this is average depth, the max  
13 depth shifts approximately 30 percent to the right, we found  
14 an indication in this range, two indications in this range.  
15 Let me get the numbers straight.

16 I don't have a full set of numbers, but there's  
17 two indications, one around 14, one about 20. A large group  
18 of indications found in this range of average depth.

19 MR. MURPHY: Those are square with the experience.  
20 The seven or eight U-bend indications found at Indian Point.

21 MR. PITTERLE: This is Indian Point.

22 MR. MURPHY: I'm talking about the U-bend  
23 indications.

24 MR. PITTERLE: Yes.

25 MR. MURPHY: Our assessment is these indications

1 don't become visible to the +Point until you have about a  
2 one volt response from the flaw and taking the +Point depth  
3 measurements at face value, the depths have to penetrate on  
4 the order of 60 to 70 percent thruwall before you get  
5 anything approaching a one volt response from the law.

6 So that would seem to be roughly the detection  
7 threshold for cracks in the U-bend.

8 MR. PITTERLE: I don't know the basis for that  
9 statement. We sized these indications and as I will go  
10 through a little bit, the sizing of the indications, when we  
11 do benchmark calculations, demonstrates that we are being  
12 pretty conservative with these indications.

13 And when we evaluate the data, 400 kilohertz data,  
14 which is the basis for sizing, because that's the one that's  
15 been developed, and the techniques that we're applying were  
16 developed for 400 kilohertz, there is a 14.4 average percent  
17 depth indication, a 23 percent average depth indication,  
18 large group between 38.9 to 45, 55, the 64.

19 MR. MURPHY: This is for axial dents, though.

20 MR. PITTERLE: The technique is derived from axial  
21 dents, but the sizes of these particular indications found  
22 in the U-bend.

23 MR. MURPHY: But I guess the question that arises  
24 is where is the evidence that this kind of information  
25 applies to cracks in the U-bend.

1 MR. PITTERLE: Don't have any direct indication, I  
2 concede, because there has not been an equivalent  
3 demonstration program. But the coils from the indications  
4 are riding the surface quite well, and certainly at the  
5 apex, where these indications are located, that the basic  
6 technique should be reasonable accurate.

7 We've increased the uncertainty by 25 percent to  
8 cover the differences between the support plates, the  
9 standard deviation. When we do the tube integrity, we  
10 increase the uncertainty by 25 percent.

11 But there's no good reason to expect that it's  
12 going to be radically different in the U-bend. We've looked  
13 at it for the same techniques, for example, against pulled  
14 tubes and role transitions. They work quite well. I agree  
15 there's going to be and we felt it also necessary to  
16 increase the uncertainty treatment for it, but I believe  
17 we're certainly of the right magnitude.

18 But increase in deviation, we're looking at maybe  
19 plus or minus ten percent average depth, a little bit more,  
20 12 percent. And there is nothing to indicate that these  
21 tubes are all -- that we found are all up here.

22 MR. MURPHY: Well, I explained how we came to our  
23 conclusion and I think to support a different conclusion is  
24 going to take a heck of a lot more supporting information  
25 than has thus far been presented.

1 MR. PITTERLE: Well, I don't think I understood  
2 how you came to a conclusion that all these indications are  
3 70 percent.

4 MR. MURPHY: It appears that that is the threshold  
5 at which flaws are being detected, that's correct.

6 MR. PITTERLE: But I don't see any data that says  
7 that.

8 MR. MURPHY: The decision was made not to pull  
9 tubes, so we don't have any supporting tube information,  
10 pulled tube information to help resolve this issue.

11 Certainly pulled tubes from Indian Point would be  
12 very helpful, but it was decided not to do that.

13 MR. PITTERLE: I think we'll need to certainly  
14 cover that one in more detail and I do believe that the  
15 sizing is reasonable, if I'm looking at 12 percentage  
16 average depth, that's a lot of difference in an average  
17 depth of the flaw, size in error, the large error that we've  
18 encompassed, and I cannot believe that something more sizing  
19 that 20 percent is 70 percent average depth. It just --

20 MR. MURPHY: Well, you're not sizing the U-bend  
21 flaws at 20 percent.

22 MR. PITTERLE: Yes.

23 MR. MURPHY: Okay. I see the source of our  
24 discrepancy then, because our profiling analysis, by our  
25 consultants, indicates that these depths, when they're being

1 detected, are on the order of 70 percent thruwall.

2 MR. PITTERLE: I think we'll need to sit down very  
3 carefully with the consultants and see how --

4 MR. MURPHY: I understand. Once you have a 70  
5 percent thruwall penetration that produces at least a one  
6 volt response, making it detectable, now, with the ability  
7 of hindsight, you can go in and you can pick out lower  
8 percentage thruwall components of the crack below the noise.  
9 You can dig those out.

10 But unless you have a segment of the crack that's  
11 producing at least a one volt signal, by which time it's  
12 about 70 percent thruwall, unless you have that situation,  
13 you're just not going to pick out a lesser crack from the  
14 noise. It's just not going to have the voltage amplitude.

15 MR. PITTERLE: I think we're different already at  
16 the voltage dependence on depth. These flaws that we're  
17 sizing at 23 percent, for example, is .86 volts. No reason,  
18 on an ID flaw, we believe that a one volt ID flaw is 70  
19 percent deep. It doesn't jive. The ID voltages are much  
20 higher than you can anticipate seeing an OD flaw.

21 But it's something I think we're going to have to  
22 come across the table in detail to --

23 MR. MURPHY: We've done a lot of profiling  
24 analyses on our end of the table and it may be that there  
25 are some -- a conciliation process that needs to be gone

1 through here. But we seem to be arriving at far different  
2 numbers.

3 MR. PITTERLE: I think the only way to reconcile  
4 that is some of the ways we've had to do it, sit down across  
5 the table and look at the data, because we seem to be quite  
6 a ways apart in sizing these indications and, agree, if you  
7 would, somehow conclude that these flaws are 70 percent  
8 average depth means every one was structurally unacceptable,  
9 they would have failed the in situ test.

10 MR. MURPHY: First, I was referring to max depth.  
11 We needed max depth penetrations on the order of 60 to 70  
12 percent thruwall to get a one volt response.

13 MR. PITTERLE: The max depth one is still not as  
14 bad as what you're addressing, but it's shifted about a  
15 factor of 30 percent to the right when you look at max  
16 depth. So max depth is about 50 percent detection at 40  
17 percent depth. But the average depth is far more important  
18 for these types of indications, where we've got a few, we're  
19 not going to get a lot of cumulative leakage, if we're going  
20 to have any problems, it's going to be a result of ligament  
21 tearing or burst.

22 Well, that is the max depth and indeed that does  
23 shift approximately 30 percent to the right compared to an  
24 average depth POD.

25 I'd like to address the other issue and one of the

1 questions previously given is in terms of growth rates and,  
2 again, that we have to establish the period that the largest  
3 undetected flaw will not grow to be structurally  
4 unacceptable, we need growth rate information as well as  
5 POD.

6 A determination of the growth rate, we are able,  
7 through the sizing techniques, to take nine indications  
8 found in five tubes back to the '97 data and evaluate at 400  
9 kilohertz, since the '97 data is limited to 400 kilohertz.  
10 Nine indications to work with between '97 and 2000.

11 We're using these, as I mentioned before, the  
12 +Point and sizing techniques developed under the PWSCC  
13 dented support plate program and believe that with the  
14 increase in the uncertainty, that we're applying, the 25  
15 percent, that they give us reasonable sizing and believe  
16 that, we don't have the details here, but doing a lot of  
17 benchmark testing by testing these against the in situ test,  
18 we cannot be very far off on the sizing.

19 Then from the cumulative distribution standpoint,  
20 it's a small sample. We've just adjusted the cumulative  
21 probability to reconcile the small sample.

22 And looking at what we derive from the Indian  
23 Point data, for example, the dented tube support plate  
24 growth rates, as a test of reasonableness.

25 This represents the database that we have. I

1 don't want to get into all the numbers. One point to make,  
2 and I'm not going to cover this in a whole lot of detail, in  
3 2-5, the one that led to the leakage, given that tube, at  
4 its end of life or at the time of the leakage and  
5 calculating what depth, average depth it had to be at that  
6 point in time to tear through, actually it's about 2.2  
7 inches long, would have been about 90 percent depth at the  
8 time of the leakage event, on an average depth basis.  
9 Locally, it may have been thruwall, but the average depth  
10 would be -- to tear through the rest of the uncorroded  
11 ligaments would have been about 90 percent.

12           Sizing of this, one has some range of estimates  
13 that we have on -- and I use -- just a point of explanation.  
14 I'm going to use the term burst effective link. What that  
15 means is in the flaw, there can be relatively long and  
16 shallow tails of the flaw that don't really have an effect  
17 on the structural character. So what is done in the tube  
18 integrity space is to search that flaw for the lowest burst  
19 pressure contribution of the flaw, which tends to be the  
20 deepest area of the section.

21           So in order to not let the tails influence average  
22 depths and so on in an inordinate or unacceptable manner,  
23 we're using the burst effective depths.

24           And to compare it with ligament tearing, the burst  
25 effect is in ligament tearing, lengths are about the same.

1           So we had two depths estimates for this tube in  
2 '97. Then using the lower of the two, the 73.8 average, on  
3 a growth per effective full power year, gives us about 11  
4 percent growth in that indication.

5           Then for the other indications that we sized,  
6 shown here, key elements, the average of that growth and  
7 average depth, order of three percent, with about the 11  
8 percent maximum growth rate.

9           These data have been used, as I will describe, to  
10 what we believe to be a conservative growth distribution.

11           This shows the data points or the cumulative  
12 distribution of those data points that I just showed you on  
13 the table. Then typical with growth data, there are some  
14 that will be negative due to size and uncertainty, and our  
15 intent here is to fit a lognormal distribution, which is one  
16 of the best shape functions for representing growth  
17 distributions, we wanted to get rid of the negative tail.

18           But yet what we're trying to do here, and I'll  
19 come back in a later viewgraph to discuss what sometimes is  
20 called tube growth, which has a more rigorous correction for  
21 the uncertainty. What we're trying to do here is just take  
22 out the negative tail, but bias it to the deeper part of the  
23 database.

24           So all we look for is to define an uncertainty for  
25 the NDE uncertainty that will take out the negative tail,

1 while forcing the distribution bias to the upper side of the  
2 database.

3           When you do that and you take, for example, this  
4 lognormal distribution, combine it with this uncertainty, we  
5 would predict this dotted line as a series of measurements  
6 that says, yes, this combination of uncertainties, this  
7 biased curve to the right, maximize the growth, makes a  
8 reasonable combination for the expected series of  
9 measurements.

10           So this is the way we've defined average depth  
11 growth, max depth growth and the length depth growth. I'm  
12 not going to go through all of the details of the other ones  
13 at this point in time.

14           This is basically the stars are the data we showed  
15 before and the curve. Just to compare with some other data  
16 and one of the more extensively developed sets of data for  
17 -- and most accurately sized, the PWSCC dented tube support  
18 plates, which is shown by the dotted line curve here.

19           The way we've bounded the Indian Point, we are  
20 predicting the growth to be larger and significantly larger  
21 when you consider this degree of the tail out here, and  
22 basically trying to force the data through the largest one  
23 that we've found to make sure that we are in this process  
24 biasing the data towards the larger side of the growth rate.

25           If this process for correcting for NDE

1       uncertainties is done more rigorously, what the general  
2       studies show is that the average growth rate, with or  
3       without uncertainties, basically should not be changing by  
4       the uncertainties.

5                But if you do this correction for ND  
6       uncertainties, forcing the generated curve to maintain the  
7       same average depth, then you end up with an uncertainty  
8       distribution, shown by the dotted line, combine it with this  
9       particular curve, which should be, say, so to speak, the  
10      best estimate of the true growth, and combine it with -- so  
11      we take this best estimate, combine it with the uncertainty,  
12      we get this prediction, which matches quite well, again, the  
13      measurement distribution.

14               The key difference here between what I showed in  
15      ~~the first one and this assessment and the traditional way of~~  
16      trying to define tube growth is the average growth rate is  
17      maintained.

18               The way we biased it was to let the average growth  
19      rate increase so that we kept biasing the growth to the  
20      larger side of the database. And given the small set of  
21      data, I think that appropriate conservatism would apply.

22               But it's pretty clear, this X curve here is what  
23      we're using, the best estimate of the tube growth would be a  
24      curve like this. We think we've built in conservatism into  
25      the growth distribution.

1 MR. STROSNIDER: Tom, what sort of assumption are  
2 you making on NDE uncertainty in those calculations?

3 MR. PITTERLE: The NDE uncertainty ends up to be  
4 pulled out. If you look at these kinds of studies in  
5 detail, they -- and the way these growths are defined, it's  
6 the same analysts doing both years at the same time.

7 When you do that, your uncertainties are a lot  
8 lower than they are in any absolute estimate. So I forget  
9 the magnitude that this curve entailed. Probably about, I'm  
10 guessing, because I can't remember the specific numbers, but  
11 maybe about a six percent standard deviation, that order of  
12 magnitude, but I don't want to be held to the number,  
13 because I don't have it here to check it.

14 But this is very frequently estimates of the true  
15 growth are used in a number of integrity assessments. We  
16 are not using that to maintain and mechanize the limited  
17 database. We're using the one biased to the larger side of  
18 the growth rates.

19 As I mentioned, just to show a couple examples and  
20 what was shown early on in sizing techniques is if you do go  
21 to a higher frequency, and this shows a comparison of the  
22 400 and 800 kilohertz sizing, or 269, as an example, and  
23 I'll show another example.

24 But the 800 kilohertz data would give you about 18  
25 percent, on an average, higher depth than obtained with the

1 400 kilohertz.

2           Since we are using correlations for the  
3 uncertainty developed on the 400, we believe that the  
4 combined use of the 400 and I will show, not today, but in  
5 the full operational assessment, that the benchmarking seems  
6 to be better with the 400 kilohertz when we compare it with  
7 predictions of, say, in situ tests, that the data for the  
8 400, given the uncertainties in the correlation we're  
9 applying, is the appropriate way to do the assessment.

10           We will still do the operational assessment both  
11 ways and both of them as a demonstration that we can still  
12 meet a recommended operating cycle, but the most reliable  
13 combination of sizing is the 400 kilohertz, based on  
14 expectations from the way that the techniques were defined,  
15 as well as some of the benchmarking that we will discuss in  
16 more detail at a later date.

17           This is one example. You see it's pretty much a  
18 general shift up rather than getting a strong difference.

19           This is another one showing the differences and  
20 later on in the presentation, I will compare these two.  
21 This is 271, which I will discuss later in the discussion of  
22 in situ testing, and we'll show the post-in situ profile and  
23 compare it with these two.

24           But, again, the differences show up typically on  
25 the average depth. For example, there is, in this case, an

1 11 percent difference in the average depth.

2 It doesn't say -- I'm not trying to say that if  
3 you went through an 800 kilohertz program, develop the  
4 correlation with truth, that, in the end, that one might end  
5 up at a slightly smaller standard deviation. That may  
6 happen, but the fact is we're using 400 kilohertz  
7 correlations and consistently then, when we apply those with  
8 the 400 kilohertz, the integral checks also show it to be  
9 better.

10 As you saw in Tom Esselman's presentation a little  
11 earlier, ovality is not a -- in fact, can be bigger in row  
12 three than row two, because the ball mandrill was pulled  
13 through to reduce ovality in the row two tubes and not in  
14 the row three.

15 ~~.....~~ Ovality is not a big issue between two and three.

16 Some of the conclusions from Tom's presentation,  
17 pull together, relevant to the operational assessment. I  
18 would like to go through in just a couple minutes.

19 As Tom described, the site measurements of  
20 displacements have been input to the plate model. You  
21 develop displacements by row and tubing fact. Determine  
22 most stresses at the apex due to the plate stresses. And a  
23 key part of that is if you notice this presentation, that at  
24 a displacement of about a tenth of an inch, you basically  
25 have saturated or leveled off the -- induced the stress from

1 the pinching or collapsed legs, whatever term we want to  
2 call the hourglass effect.

3           So the row three stresses are less than row two,  
4 as shown in Tom's presentation. The other key element is  
5 that the stress effects from these leg displacements, they  
6 are present in history, the denting is not changing  
7 significantly. The stress effects of the denting have been  
8 there, they're going to continue to be there without a  
9 significant change, and where the displacements are  
10 significant, that stress has already been built into  
11 whatever may be affecting the initiation rates, as well as  
12 growth rates.

13           There is not a significant change in denting  
14 anticipated and if, for example, as Tom's presentation said,  
15 a couple of tubes may have significantly different stresses.  
16 If those are driving it, we probably have seen some of the  
17 larger growth rates.

18           But the main point is that there is not going to  
19 be a big change in the future as a result, since denting is  
20 basically arrested. These effects have been in there for  
21 years. So our growth rates, the initiation rates we're  
22 seeing reflect those.

23           But again, a point relative to initiation and the  
24 operational assessment, is the number of new sites is not  
25 going to have any effect on the operational assessment.

1           We are going to be limited by the largest  
2 undetected indication, the new ones do not grow fast enough  
3 to be an issue in the operational cycle length that we're  
4 going to be talking about.

5           Whether or not we have exactly the same initiation  
6 rate is not important to the operating cycle just because  
7 they are not going to grow from initiation to a structural  
8 challenge in one cycle.

9           MR. STROSNIDER: Tom, I'd just like to make one  
10 comment. We didn't bring this up earlier, but I think it's a  
11 question that will come up, and that has to do with the  
12 impact of strain rate on the susceptibility.

13           You're making a point here that you think you've  
14 basically got a static situation and because I think there  
15 is a strain rate sensitivity, you're going to have to be  
16 looking for some information to support that.

17           MR. PITTERLE: It can be addressed in the details.

18           MR. STROSNIDER: Or assessing the strain rate  
19 effects, maybe some combination of the two.

20           MR. PITTERLE: Right. The industry experience, to  
21 our knowledge, and we have not made a complete review of all  
22 data, but we do not know of any indications in a row three  
23 tube anywhere in the industry. Row two is now plugged, as  
24 has been presented.

25           MR. MURPHY: I think you're right, industry data

1 is of interest with respect to row three and we could do a  
2 fairly --

3 MR. PITTERLE: Yes, that is --

4 MR. MURPHY: I think you guys at Westinghouse are  
5 probably in a better position to --

6 MR. PITTERLE: Well, we looked through our  
7 database. There are some we may not have done the  
8 inspections, and that's my only, at this point, reservation  
9 to not saying absolutely.

10 MR. MURPHY: I think certainly one might think  
11 that row three experience had the most heavily dented units  
12 in the past, like Surry, Turkey Point. San Onofre might be  
13 of particular interest.

14 But I noticed, I looked at one plugging map I  
15 think that was current at the time, the Surry Unit 2  
16 generator that was autopsied at PNL. That plugging map  
17 showed that all row ones, virtually all row twos, and the  
18 vast majority of row threes had been plugged at the time of  
19 the replacement activity around 1980.

20 And I think almost all that plugging in the inner  
21 three rows occurred within either the time the tube ruptured  
22 in 1976 at Surry to a year afterward. So there wouldn't  
23 have been much, at least for that particular generator, I  
24 don't know about others, but there wouldn't have been a  
25 whole lot of operating time accumulated for rows two or

1 three in an unplugged condition.

2 And if you plug it, perhaps it's less susceptible  
3 to PWSCC assessment that point.

4 MR. PITTERLE: Yes, I certainly would agree. At  
5 Surry, we did not look back at. We've been going backwards  
6 from time so far and the more recent inspection, the  
7 operating plants have not found. We did look at all their  
8 tube exam reports and nothing was found in row three in the  
9 tube exam reports.

10 What we've not done is the step that you've gone,  
11 and we'll do that to look at causes of plugging in row three  
12 before they replaced. That piece we have not gotten that  
13 far back in time yet in searching. But I agree that's  
14 something we will have to take a look at and we'll do that.

15 MR. SHARRON: Tom, for the ones you have looked  
16 at, though, have you ascertained that the hourglassing, if  
17 there was any, was as severe or more severe than what was  
18 seen at --

19 MR. PITTERLE: Most of the operating plants that  
20 we're looking at do not have any significant hourglassing.

21 MR. SHARRON: I'm having difficulty then trying to  
22 understand how you conclude that row three tubes are not a  
23 problem if they do not have the hourglassing that was seen  
24 at Indian Point 2. From a historical perspective, I mean, I  
25 understand the stress analysis that was done, but to sit

1 there and make the conclusion that says, gee, we haven't  
2 seen it at other plants, but other plants don't have the  
3 same problem that Indian Point does.

4 MR. PITTERLE: There is a tradeoff that,  
5 admittedly, I can't quantify between denting effects or  
6 displacement of the legs and temperature, but most of the  
7 other plants are operating at about 20 degree higher  
8 temperatures and no one has heat treated the row three tube  
9 yet.

10 So there is a tradeoff between the temperature  
11 effect driving, which is a strong effect on PWSCC, and the  
12 stresses from denting, and those two are unquantified  
13 compensating effects.

14 I'm not trying to make an absolute, as I'm going  
15 to show in a minute that really to establish an operating  
16 cycle, since there is nothing in row three, we're really  
17 going to establish the operating cycle extremely  
18 conservative by assuming that we will have row two in  
19 service. I don't know how to do it any more conservative  
20 than that. We'll go through that in a minute.

21 All right. Because of the issues of deposits and  
22 sizing, uncertainties in sizing, there's an extensive amount  
23 of benchmarking and the analysis methods. It's really a  
24 test of the methods and the data to support the adequacy of  
25 the data and the methods.

1           Trying to demonstrate that when we apply these  
2 techniques at the specified confidence level, at which we're  
3 using for an operational assessment the 95 percent  
4 probability, 95 percent confidence, that we will demonstrate  
5 that the methods are giving us conservative predictions of  
6 structural and leakage integrity.

7           And these provide a combination, dependent on  
8 which set we're looking at, of the sizing technique, the NDE  
9 uncertainty, material properties, and then we compare '97  
10 projections to 2000, also includes the growth rates.

11           We specifically tested the in situ tubes as high  
12 as we could, but the equipment to 5,500 trying to drive them  
13 to some kind of a leakage, if we could, and then that helps  
14 us a little bit in this comparison and I'm not prepared to  
15 go into extreme detail on this, but just to emphasize that  
16 this is what's being done.

17           We can take our '97 sizing and project forward to  
18 2000, as a check on the methods, how well did we predict  
19 that R2C5 should have a large leakage event, and the  
20 standard methods we would normally predict it's steam line  
21 break and, in fact, when we predict this tube at steam line  
22 break, we would have predicted something in excess of 100  
23 gpm, with the methods that we are projecting at our 95-95  
24 confidence level.

25           The other things we can do is compare projections

1 of the '97 data to what we have predicted any of the other  
2 ones that are -- they all satisfied the three delta P, but  
3 would we have predicted the weaker of the tubes, like those  
4 that had some leakage. And in general, we are predicting,  
5 in fact, more conservatively, the burst pressures of those  
6 tubes and leakage, than we found in the in situ test.

7 And we can compare, as another means, a little bit  
8 more indirect, take the '97 projections, compare it with  
9 burst pressures and leakage from the 2000 profiles, which,  
10 since the indications are a little bit larger, would be a  
11 little more reliable, and, again, we find that these  
12 projections are conservative to the 2000 profile.

13 Check the 2000 data, we have the in situ test and  
14 we compare for the 2000 profiles did we predict the weaker  
15 tubes of the in situ test and we'll show that we have done  
16 those rather conservatively.

17 MR. SHARRON: Is that based on -- when you do  
18 these look forward things, that's based on the growth rate  
19 data?

20 MR. PITTERLE: Yes. The growth rates that --

21 MR. SHARRON: Maybe I'm missing something here.  
22 Isn't there a circular argument here? Because you're --

23 MR. PITTERLE: There is a little bit in --

24 MR. SHARRON: You're predicting your growth rates  
25 based on comparing the 2000 data to the '97 data and then

1 you bias it a little bit conservatively to account for the  
2 fact you had some negative tails here, and then you apply it  
3 here and then you say, gee, it's conservative.

4 Well, of course, it would be. I'm trying to --

5 MR. PITTERLE: You're totally right in that  
6 element of the '97 to the 2000. It combines everything  
7 together, but the growth rates are going to be consistent  
8 with the data. However, we're using a distribution of the  
9 growth rates, not, for example, to predict the 2-5-2, not  
10 the 2-5 growth rate by itself.

11 So it does give an integral check of the  
12 methodology and the use of distributions and statistical,  
13 but I agree with you that it's not a completely independent  
14 check, because the growth rates are derived from that cycle.  
15 The difference is distribution versus tube specific growth  
16 rates and demonstration of the rest of the techniques  
17 combined.

18 MR. STROSNIDER: One thing, I think you said,  
19 though, Tom, I just want to understand, is that you're going  
20 to make this comparison at a 95-95 value, and I'm wondering  
21 if, for benchmarking, it shouldn't be best estimate. The  
22 95-95 seems to me that would be a non-conservative  
23 benchmark.

24 MR. PITTERLE: We are providing the nominal and  
25 the nominals will be, in general, on the slightly

1 non-conservative side. Now, too bad that we do predict the  
2 weakest tubes nominally, but it may not be totally right on  
3 or anything like that.

4 We do agree that these benchmarking tells us, for  
5 this analysis, we should use the 95-95 confidence, and we  
6 want to incorporate that.

7 MR. STROSNIDER: I need to think about that a  
8 little bit, because if you're telling me that you can go  
9 back and take the '97 data, run it through the model and  
10 predict the 2000 condition at 95-95, I mean, that's  
11 something that the -- that condition shouldn't be happening  
12 very often at 95-95, yet there it is, and it seems to me  
13 that that's probably not the best demonstration.

14 MR. PITTERLE: The more --

15 MR. STROSNIDER: If we're talking the upper 95.

16 MR. PITTERLE: We're talking the lower  
17 conventional 95 confidence. And I agree with you that there  
18 is, as Brian has addressed, a little bit of a circular part  
19 in the use of the growth rates derived from that data set.  
20 What it is basically saying is when you put it all together  
21 in the methods, the methods will give you the right  
22 projections, but it's not perhaps as strong as saying, all  
23 right, let's take the profiles from 2000.

24 MR. STROSNIDER: Okay.

25 MR. PITTERLE: And do we predict the weak links of

1 the tubes from the in situ. And we've even gone to  
2 calculating the ligament tearing pressures of each of the  
3 tubes individually and the probability distribution of that  
4 to support it.

5 That is basically independent of the more circular  
6 loops, which this part is demonstrating an integral  
7 methodology, use of distributions, and that provides it.  
8 But we will be providing both the nominal predictions and  
9 the lower 95, so that element of it can be evaluated, to see  
10 how we are doing on a nominal prediction versus the 95.

11 We'll show that the nominals are predicting the  
12 weakest links, but the nominals may give, say, a little  
13 higher burst pressure than we actually attain. It is doing  
14 a pretty good job of identifying the weaker element of the  
15 tube.

16 A lot of detail here that's not appropriate for  
17 today and I'm sure we'll have many discussions over it, but  
18 it is an important element given such questions as Emmett  
19 raised about the fact that the sizing techniques are not  
20 directly U-end at all.

21 FROM THE AUDIENCE: Can I ask a question for  
22 clarification? When you started the discussion, you  
23 mentioned that you took '97 data and projected the 2000.

24 MR. PITTERLE: Yes. I'll give the normal  
25 operating projection. I don't remember what that is, but

1 the reason I cited that is that's the normal calculation.  
2 The fact that it predicted it to be a big leakage event  
3 would say --

4 FROM THE AUDIENCE: It would be higher pressure.

5 MR. PITTERLE: Yes, it is. But we will show, I  
6 believe, and I don't remember the number exactly, but at the  
7 nominal, we have that projection done. I think we're  
8 predicting maybe ten, 20 gpm at nominal conditions. I don't  
9 remember the exact number.

10 The breakthrough is -- in the other calculation,  
11 the breakthrough is calculated at the nominal delta P. My  
12 main point was that's the standard techniques and are we  
13 predicting that this tube would not have made it? Yes, it  
14 would be clearly failing.

15 The nominal delta P calculation is included in the  
16 benchmark with its predicted leak rate, and I don't recall  
17 the exact number, but it's in the multiple gpm range.

18 The low row U-bend in situ tests, in situ testing,  
19 the total was ten tubes to as high as the equipment could go  
20 to support benchmarking. Tested all indications.

21 The three delta P criteria for condition  
22 monitoring is 4617 psi under hot temperature conditions.  
23 The tests are generally done at room temperature, I've  
24 converted them all to the hot, just because typically that's  
25 the condition we work with in most of the tube integrity

1 assessments.

2           The only one that did not directly exceed the  
3 three delta P criteria of the in situ tests was the row two  
4 C71 indication. This test was limited and the testing to  
5 hot condition was about 4206 psi by a progressively  
6 increasing leak rate. This was not like some of the other  
7 ones that failed above three delta P or leaked above three  
8 delta P, that had a sort of like an instantaneous change.

9           This is a rather progressive increase in leak rate  
10 from simulations of normal operating conditions on up to the  
11 point at which it reached two gpm at 4206 psi.

12           MR. SHARRON: Did you do any predictions for these  
13 tubes before you ran these tests?

14           MR. PITTERLE: Did we do any predictions?

15           MR. SHARRON: You said you had a predictive model  
16 that says I know growth rate and stuff and you obviously  
17 know where these things were in 1997. So if you applied  
18 that and then said, gee, if I run this pressure test, would  
19 I expect this tube to fail.

20           MR. PITTERLE: Yes. As I was saying, that if I  
21 take the '97 and project it forward, yes, we predict this  
22 tube to fail. We take the 271 2000 profile, we predict it  
23 to fail, and we have about a 95-95 it's predicted to fail  
24 and there's about a 50 percent probability of having  
25 significant leakage and ligament tearing at this condition.

1           So I think this test supports the profile of the  
2 271 tube fairly specifically. Again, these indications from  
3 '97 to 2000 are single indication projections using  
4 distributions, so it does give a growth check on the profile  
5 back in '97. There's a lot of detail to go into this in the  
6 benchmarking, but just to complete this discussion.

7           The two ways to now assess this tube -- well,  
8 three ways are actually applied to evaluate this tube after  
9 the test. We've done post-test NDE, which I'll show in the  
10 next viewgraph. There's also a leak rate measurement made  
11 after it reached peak pressure, come back down and measure  
12 the leak rate at a given pressure differential, because  
13 that's something that's relatively easy to calculate and  
14 back out a thruwall length and look at the plastic opening  
15 of that crack, for example, back at the peak pressure.

16           When we backed out the thruwall length based on  
17 the post-in situ, and that's about a .39 inch thruwall NDE  
18 would imply that it's less than .39 or there could be, as  
19 I'll show, from the NDE, two indications that may be  
20 thruwall at the time or two elements of the crack, not two  
21 indications, the parts of the crack that may be thruwall,  
22 contributing to this leakage.

23           But it's pretty clear from the NDE and this data  
24 that at the time this test was terminated, had not reached  
25 even the full ligament tearing elements of the deep section,

1 which is the order of a half an inch long, and the burst  
2 pressure, by all the number of different ways of evaluating  
3 it, would be more than 300 psi above the ligament tearing  
4 pressure.

5 We do conclude, in a lot more detail than this,  
6 that this indication would have met the 4617 burst pressure.

7 MR. MURPHY: 5173 for cold.

8 MR. PITTERLE: Cold, I remember the -- I'm not  
9 sure where that number is. The correction from hot to cold  
10 -- oh, that's greater than three delta P, the 5173. The  
11 U-bend, the hot to cold ratio is about 1.07. This test is  
12 -- I don't remember the exact number, I think 1.07 times  
13 that and that would be the room temperature three delta P.

14 This is a room temperature number and they were  
15 tested to that number, which is just somewhat greater than  
16 three delta P. That's the three NDE tubes that were tested  
17 to really look is there something that -- the purpose of  
18 this basically is to get the pressure up high, and this is  
19 sometimes used, for example, in tube exams, to open up  
20 indications, to make them more visible to NDE, and that was  
21 one of the purposes of trying to do this, to see if there  
22 are a broad degree of cracking in the U-bends, you'd expect  
23 that this pressurization would open it up to be able to see  
24 it within the NDE after you've expanded the tube, in fact,  
25 very close to plastic deformation at that point.

1 MR. MURPHY: This tube is an interesting benchmark  
2 for your leakage model, but the test for row two C69 I think  
3 was also interesting. I think that one appeared to be at a  
4 point of incipient burst at the three delta P number, just  
5 making it.

6 But you do -- you're treating that particular  
7 thing as a burst at three delta P.

8 MR. PITTERLE: It's above three delta P.

9 MR. MURPHY: When you're establishing the burst  
10 point -- what burst model are you using?

11 MR. PITTERLE: We're using the Westinghouse  
12 WCAP-1528 burst pressure. All the -- although there will be  
13 two tube integrity analyses, the WCAP-128 methods that  
14 you've reviewed and are familiar with, and also a  
15 multi-cycle analysis as a backup will be done.

16 Now, there was data years ago indicating that  
17 burst pressures for U-bends might be as much as 40 percent  
18 higher than for straight links of tubing, everything else  
19 being equal.

20 Are you factoring that somehow into your  
21 comparisons between the test data and the analytical  
22 predictions?

23 MR. PITTERLE: No. Only -- what we've done is to  
24 define an effective flow stress, the U-bend tube, that  
25 accounts for the strain hardening and it's based on fitting

1 burst pressure on the apex. On the apex, the -- or on the  
2 extrados, the burst pressure increase is not as high as,  
3 say, on the flanks. The flanks have the highest increase  
4 relative to a straight leg tube.

5 So the flow stress that we use has been based on a  
6 couple U-bend tests, the type of analysis Tom talked about,  
7 like the 50 percent increase in yield, and then fitting to  
8 burst tests of U-bend tubes, and trying to use that as  
9 basically a lower bound that fits all those combinations.

10 But indirectly, yes, but the effect of that burst  
11 increase on the extrados of the tube is small. The big  
12 increase is on the flanks and I think on the intrados, I'd  
13 have to go back and look at the data again, but the extrados  
14 does not have a large increase just because it's a U-bend.

15 I'm trying to remember the data in detail and it's  
16 been a while, but if that's a question, we can certainly get  
17 that data out. There's extensive --

18 MR. MURPHY: Yes. I think we ought to somehow  
19 reconcile this whole Westinghouse data. I think it dates  
20 back probably 20 years.

21 MR. PITTERLE: Well, not quite, but close to it.  
22 You're right, and I'm trying to remember the same data you  
23 are and I'd have to go back and refresh my memory, but  
24 certainly it's something we can bring along and discuss what  
25 the differences are around the tube.

1           But, again, the main point here is, not a pure  
2 statistically based test, to give an established confidence  
3 that there is not general cracking. The general objective  
4 here was to at least establish that it's not widely cracking  
5 in the tubes and this test and the following post-test NDE  
6 after the pressurization would open up the cracks, found no  
7 indications in the U-bend.

8           This is a little bit complicated, because there's  
9 three profiles given here. We cover them one at a time.  
10 The red here is the depth profile derived from 271 after the  
11 in situ test. That is shown basically implying that two  
12 sections of the tube had torn to thruwall. These depths,  
13 from an NDE sizing technique, are in the range that we would  
14 not conclude that those couple points in that area could be  
15 within uncertainties be thruwall.

16           But the main point of this to conclude from just  
17 the post in situ is that it clearly has not torn the deep  
18 length of the crack, thruwall, there's lots of remaining  
19 ligaments, so that the full ligamentary pressure or burst  
20 pressure of this indication has not been achieved at the  
21 time of the peak pressure test.

22           The other thing that's shown here are the 400  
23 kilohertz profiles and I showed you this one, where it's  
24 just the 400 and 800, I showed you that alone. And  
25 basically you can shift this alignment maybe a tenth of an

1 inch any way to line it up, because in the U-bend, there is  
2 a little bit of slippage, plus difficulty of locating the  
3 reference point for measurements.

4 I did some semi-arbitrary alignment within a tenth  
5 of an inch or so of these profiles, and I won't dispute  
6 somebody shifting them another tenth of an inch.

7 But the point is that where the indications seem  
8 to show some kind of spiking, this one or this for the 800  
9 kilohertz, this for the 400, appears to be where the  
10 ligaments tore thru wall from the result of the testing.

11 And even the predictions by both the -- there is  
12 another 800 kilohertz point right behind there and both  
13 profiles predicted a spike where the post-in situ also  
14 indicates that there is a deeper section of the indication.

15 And in general principals, the fact that the  
16 cracks are opened up after the in situ, signal-to-noise is  
17 better, at least the general ability to size, shape and so  
18 on may be expected to be somewhat better than the base data.

19 But the key point here is that it really tends to  
20 support the general shape of the profiles that we've  
21 developed from the sizing of the indication. The  
22 predictions from these two profiles to probability of  
23 leaking by ligament tearing we will show as part of the  
24 benchmarking and it is somewhere about 50 percent  
25 probability of ligament tearing of a large ligament at the

1 point of this test termination.

2 But a general support that the sizing is of a  
3 reasonable magnitude and shape from the profile.

4 Just to wrap up the discussion on the U-bends and  
5 then briefly address some of the other degradation  
6 mechanisms again. The low row U-bend operational assessment,  
7 clearly row two has been plugged, row three is now the  
8 limiting row, no indications found. As we talked about  
9 before, we know of no cracking in row three. We are  
10 continuing that review.

11 But although they're not dented, and we already  
12 covered this point, that they are operating at higher  
13 temperatures, maybe 20 degrees higher, which, for PWSCC, is  
14 - you'd generally expect, for example, growth to go up by 70  
15 percent or more with the 20 percent change.

16 These -- and none of the row three tubes have been  
17 heat treated. At least to some degree provide, without the  
18 denting effect, but a general consensus that maybe there is  
19 a distinct difference between row two and row three.

20 But the problems that we encountered to try and  
21 predict row three, with no indications, you can postulate a  
22 single indication, you can postulate some missed  
23 indications, we felt that the best way to treat the  
24 operational assessment is to be extremely conservative and  
25 let's evaluate how long we could have operated with row two.

1           With row two, we can make corrections for  
2 undetected indications, we can do it as though this was a  
3 postulated distribution of indications in row three, even  
4 use the row three flow strip, even though we're really  
5 evaluating row two.

6           So it's an extremely conservative way to approach  
7 the operational assessment to use row two rather than row  
8 three. Our best judgment, we don't really expect to find  
9 any. We could be arguing for a long period of time relative  
10 to not whether something in row three, but I think hopefully  
11 everybody would agree that row three is no where going to be  
12 as bad as row two.

13           MR. MURPHY: Let me understand something. You're  
14 proposing to assume that the condition of row three is  
15 identical to the condition of row two at the beginning, upon  
16 restart from the '97 outage. Is that the premise?

17           MR. PITTERLE: Row three we believe probably may  
18 not even be correct. All we're trying to do by this is to  
19 say that a very conservative way to evaluate row three is  
20 bound it by row two.

21           MR. MURPHY: Starting when, in 1997 or the current  
22 condition?

23           MR. PITTERLE: No, this is the --

24           MR. MURPHY: The current condition of row two.

25           MR. PITTERLE: We're taking the current condition

1 of the indications found in this inspection in row two,  
2 doing an operational assessment forward and see how long we  
3 could run if it was row two, as the clear bound of row  
4 three. I would hope that everybody would agree that that is  
5 about as conservative assumptions as you could do and it's  
6 relatively -- we expect to find nothing and that's -- we'd  
7 argue forever whether or not there was nothing.

8 But the most conservative way to do the assessment  
9 is to assume that basically we left row two in service, how  
10 long could we operate if we had left row two as a clear  
11 upper bound of row three.

12 MR. MURPHY: Row two minus the tubes with  
13 indications that you found.

14 MR. PITTERLE: They're plugged, yes. The plugging  
15 goal of row two is basically the form of the evaluation.  
16 That way, there's well established techniques to account for  
17 the undetected indications. Methodology is extremely well  
18 established and I hope everybody agrees bounds are anything  
19 you can do on row three. That's the intended purpose.

20 Take out the arguments about whether or not  
21 there's some possible cracking in row three or not and let's  
22 see how long we could have run with row two tubes left in  
23 service. That's the approach we're proposing to take.

24 I think it avoids a lot of debate.

25 MR. MURPHY: It doesn't totally avoid debate,

1 because now your detection threshold and POD and that kind  
2 of thing becomes extremely important.

3 MR. PITTERLE: The problem is you'd raise the same  
4 issue if you're at row three and there would be arguing  
5 about more qualitative manner what the potential missed  
6 indication was in row three. It doesn't totally get by the  
7 issues of POD, but it certainly says it's a -- well, I  
8 believe, by any measure of doing tube integrity analysis, a  
9 worse case bounding condition to assess growth rate.

10 If we took growth rate from everything we know,  
11 we'd say, yes, I can go easily through full cycle of  
12 operation, but there is nothing to indicate that we would  
13 expect indications. There's nothing in history to say that  
14 there would be indications.

15 We would sit there and debate forever whether that  
16 was a correct judgment. We're just trying to avoid that, if  
17 at all possible, by saying let's treat it as an upper bound  
18 and worst case scenario that we did not plug out row two and  
19 how long could we operate.

20 I don't know how to do this any more conservative  
21 than that. So we are taking credit, clearly, the high  
22 frequency probe POD is an essential element.

23 MR. SHARRON: You're assuming that any indication  
24 found in row two would have been plugged.

25 MR. PITTERLE: Right. It's plug and go, plug and

1 go of row two, yes, and certainly not leaving any or  
2 projecting to consider any indications left in service. The  
3 plug and go analysis of row two.

4 The POD corrections, we use the POD, we propose  
5 what we believe to be a lower bound POD for the 800  
6 kilohertz probe, corrected that in a generic letter approach  
7 to one over POD, minus one type indications left in service,  
8 to account for the potentially undetected indications.

9 The methods here are those of the WCAP that we  
10 reviewed as part of the PWSCC alternate repair criteria.

11 That's what we're calling the reference single  
12 cycle profile analysis, the WCAP methodology.

13 As an independent and backup and, to some extent, insight  
14 into the problem, we've done a multi-cycle analysis using  
15 EMECA technology and support to evaluate, as an independent  
16 check on this evaluation, and also one of the advantages of  
17 this technique or insight it gives us that it looks at the  
18 initiation prior to cycle detection, and we do find that the  
19 only way to fit with this methodology, the inspection  
20 results require that there be only a few indications  
21 initiated over time years back and growing to what we found  
22 in the current inspection.

23 These are obviously in much more detail in the  
24 operational assessment. Just to quickly try to wrap this up  
25 and address some of the other degradation mechanisms.

1 Dented tube support plates, CECCO results, number  
2 of calls, none were confirmed by +Point, but we do believe  
3 that, from everything we can see here, that no confirmed  
4 indications by +Point. They are repaired off the CECCO  
5 calls and this basically inspection has been previously  
6 reviewed by the NRC.

7 There's no indications confirmed. This does not  
8 look to be an issue for the next cycle.

9 MS. KAUFMANN: Tom, I sort of missed that second  
10 bullet. What is the basis for that statement, the CECCO  
11 qualification?

12 MR. PITTERLE: There were a number of NRC meetings  
13 before the CECCO was used for that inspection, describing  
14 what was going to be done and I believe there was a  
15 consensus to go ahead. The agreement was that rather than  
16 using +Point for confirmation, we would repair off of CECCO,  
17 because it wasn't exactly clear which probe might be more  
18 sensitive at the time.

19 The CECCO calls are repaired based on those prior  
20 discussions.

21 MS. KAUFMANN: I would just say qualification  
22 accepted by the NRC is something of an overstatement.

23 MR. PITTERLE: I agree. I'm sorry. I forgot all  
24 the ramifications of the word qualification in the  
25 statement. Reviewing at that point. You're right, that's a

1 strong statement.

2 The area above the sludge pile, basically  
3 inspected the CECCO, the bobbin probe, and the more  
4 extensive testing was done to look at 20 percent of the  
5 tubes in each steam generator, with the +Point up to just  
6 below the first support plate, and basically this indicated  
7 that basically the lack of finding any significant  
8 indications confirmed that CECCO was indeed over-calling in  
9 this region.

10 Then to further look at this region, to give a  
11 technique that had less influence of copper, 23 tubes were  
12 inspected with UT to reduce that copper effect and there is  
13 one tube that couldn't get the probe through the first  
14 support plate, but other than that, the test went through  
15 the first plate.

16 Two tubes were inspected after the in situ test  
17 and, again, basically found agreement with the CECCO call,  
18 with no additional indications identified.

19 In the area above the sludge pile, there were,  
20 again, five in situ tubes -- tubes in situ tested, all of  
21 which met the structural and leakage criteria.

22 At this point, I would like to divert just a  
23 little bit to clarify one point on in situ test  
24 requirements. I understand there has been some discussion  
25 and I need to straighten that out.

1           It has been stated that none of the tubes met the  
2 requirements for in situ testing and let me emphasize that  
3 the decision before we even made up the criteria was we were  
4 going to in situ test above all sludge pile indications.  
5 But in the first issue -- let me start at the beginning.

6           In the degradation assessment, the in situ test  
7 requirements are defined by a statistically developed curve  
8 of effective burst pressure -- burst effective length versus  
9 depth.

10           The first sets of data that we put out, and  
11 partially because of haste in review, did not use burst  
12 effective length and depth. By that criteria, one we'll  
13 talk about a little bit later, 3451, would not have required  
14 in situ tests. However, when burst effective length depths  
15 are put in as in the degradation assessment to be done, is  
16 the only tube that would have required in situ testing.

17           When the in situ test requirements are used with  
18 the data that the requirement was specified, the curve was  
19 specified, predicted the only tube that even came close to  
20 challenging the in situ test requirements.

21           MR. MURPHY: Was there a burst test for that, too?

22           MR. PITTERLE: I'm going to come into that one, I  
23 think, in the next viewgraph for some of the 3451. This is  
24 the area above the sludge pile and five tubes tested there  
25 with no leakage whatsoever.

1 MR. MURPHY: This one leaked.

2 MR. PITTERLE: Yes. The 3451, which we will get  
3 to here and we'll discuss in more detail. Basically, in  
4 this area, the original effort was detect with CECCO,  
5 confirm with +Point, found that we were getting basically a  
6 lower confirmation rate than the qualification, some sort of  
7 an implication maybe we were over-calling, but basically  
8 that was the base inspection.

9 We looked at this again in the extension of the  
10 overall inspection, 100 percent of the hot leg tubes were  
11 inspected with +Point from the tube hot, the 24 inches above  
12 the top of the tube.

13 Out of this, only a total of about six small indications  
14 were identified that had not been found by CECCO, and that's  
15 quite good to take two different probes and all you see with  
16 one or the other is about six small indications.

17 MS. KAUFMANN: Tom, do you mean the production  
18 CECCO? .

19 MR. PITTERLE: Yes. This is evaluated against the  
20 original CECCO call. If we went back and looked back, I  
21 don't know if you could say whether there was a signal. I  
22 don't know what that answer is.

23 But basically that's a small population when we're  
24 looking at 100 percent of all hot leg tubes to find one  
25 probe or the other. There is always a sensitivity of one

1 probe versus the other that's going to detect some of these  
2 small indications and the other one won't.

3 This is really -- I would argue it actually  
4 supports CECCO, but I'm not trying to make any point of one  
5 probe or the other, other than this certainly is a good  
6 over-check on the inspection, the detection in the sludge  
7 pile region. That's the main point.

8 Again, as I talked about before, we did the U-tech  
9 inspection of 23 tubes. That confirmed the CECCO call.

10 All of this was basically done, this additional  
11 testing was done to make sure that we had done everything  
12 practical, possible, debate between those two adjectives, to  
13 identify any of the indications in the first pass above the  
14 top of the tube sheet.

15 In addition, since we basically made the decision,  
16 we're going to basically in situ test everything in the  
17 sludge pile region just to make sure that we did not have  
18 sizing problems. Thirty-one tubes were in situ tested. All  
19 met the 9706 or the burst criteria, the leakage criteria,  
20 basically none leaked, steam line break.

21 The only one that leaked at all in the full test  
22 pressure of 5500 psi cold was 3451. And this, the peak test  
23 pressure reached was 4985 and I'm just going to -- I'm used  
24 to working with hot, it's 4591 psi into a hot condition.

25 Well, you talked about how close together one was,

1 it's at three delta P. You take the 4591, divide it by the  
2 4985, 4591 psi hot, divide it by the 1539 normal operating  
3 delta P, the burst margin is 2.98, bounds to three.

4 MR. MURPHY: Perhaps you can clarify something.  
5 Am I correct in recalling that this tube was detected by one  
6 of two analysts?

7 MR. ADANONIS: That's correct.

8 MR. MURPHY: Here we have a tube that, at this  
9 point in time, is marginal with respect to meeting NRC  
10 performance criteria and was only detected by one of two  
11 analysts? I believe that five -- only five of the eight  
12 actual indications were detected by both analysts and the  
13 review conducted by our consultant indicated that this  
14 indication certainly was one that should have been detected  
15 by both analysts.

16 I think as we indicated to you last week, I guess  
17 this is a source of concern for us and certainly I think we  
18 need to understand a little bit better why this type of  
19 indication, which includes one that was quite marginal in  
20 terms of its burst pressure capability, why there isn't  
21 better performance in the field in picking up this kind of  
22 indication.

23 MR. ADANONIS: And we are in the process of going  
24 back and pulling together those statistics and looking at  
25 these particular indications in detail to be in a position

1 to address that question. We have the same question.

2 MR. PITTERLE: The bottom line is that the tube  
3 and looking at that, it didn't even open up the length of  
4 the crack, it probably did not burst either, it's a ligament  
5 tear, but in either case, just met the three delta P  
6 criteria.

7 In the cold leg program, the initial inspection  
8 with CECCO and bobbin probe, then followed by 20 percent of  
9 one steam generator with +Point from the cold to just above  
10 the first tube support plate.

11 Inspected 20 percent of each of the other three  
12 steam generators to the tube end cold to 24 inches above the  
13 tube sheet, but, again, an over-check with +Point to assure  
14 that we've picked up any significant indications.

15 No crack-like indications were found in any of  
16 these inspections, were found to varying degrees of pits,  
17 and as a result of finding some pit-like indications, 23 and  
18 24 were expanded to 40 percent of the tubes.

19 And that, in fact, is all pit-like indications  
20 have been plugged and no cracking was found by any of this  
21 extended inspection on the cold leg.

22 The cold leg is basically pits and tend to be  
23 small, from all indications, negligible growth, but as a  
24 conservative element, they have been repaired. See really  
25 no anticipation of this being an issue in the operational

1 assessment.

2 MS. KAUFMANN: Tom, when you talked about the  
3 comparison between CECCO and +Point for the sludge pile, did  
4 you do a similar comparison for the cold leg inspection  
5 between +Point calls and CECCO calls?

6 MR. PITTERLE: I think the only difference was a  
7 couple pit calls.

8 MR. ADANONIS: There were a number of pits. I  
9 don't have the statistics with me, but there were pits  
10 identified with the bobbin or identified with the +Point.

11 MR. PITTERLE: The point is when you take a +Point  
12 to something like the pits, even if you inspect, say, new  
13 steam generator tubing, you get what's sometimes called a  
14 lap indication, you can see those with +Point, down to two  
15 or three percent depth. You see in some of these it may  
16 well be a manufacturing defect, there is no way of  
17 separating them in this vintage of a plant.

18 Tube sheet region, then the tube sheet burst is  
19 not an issue, the restraint of the tube sheet prevents the  
20 tube from bursting, so it's really just the -- not just, but  
21 is a leakage related question.

22 Again, CECCO and +Point correlation as far as  
23 confirmation with CECCO was similar to that of the  
24 qualification. There appears to be less of an influence of  
25 copper within the tube sheet crevice.

1 We found, after post-in situ testing, one  
2 indication that the pressurization above 5000 psi had opened  
3 up a crack, probably including some tearing, and identify  
4 the crack that had not been originally called.

5 Now, it may have gone from 40 to 70 percent or  
6 something as a result of the pressurization. We really don't  
7 clearly can't distinguish from that. But on the basis of  
8 that, the inspection was further expanded to include the  
9 tube sheet region, including the 100 percent of the hot leg  
10 with the +Point inspection and 20 percent of the cold.

11 Now, we have the CECCO and the +Point as, again,  
12 independent inspection techniques.

13 In situ tested five of these indications. They  
14 all met the leakage criteria, none of them leaked.

15 We don't anticipate that, given the combined  
16 inspection, that this is really an operational assessment  
17 issue.

18 Finally, to wrap this up, a couple general  
19 consideration comments, as I said, all pit indications are  
20 being plugged. You may be aware I didn't discuss -- I don't  
21 even recall if there was a pluggable indication, I don't  
22 think so, but AVB Wear has been around in these units for  
23 many, many years, it's not an operational assessment issue.

24 What growth we've evaluated has been consistent  
25 with the rest of the industry experience and Tom Esselman

1 described previously the evaluation being conducted for the  
2 support plates that indicates the plates will maintain  
3 adequate tube integrity over the next operating cycle, and  
4 then there's some additional loose part that is being closed  
5 out, but that's not really a tube integrity issue.

6 That summarizes, details, whichever way you look  
7 at it, of this presentation.

8 MR. SULLIVAN: Tom, I have a question about the  
9 pit indications.

10 MR. PITTERLE: Yes.

11 MR. SULLIVAN: The slide indicates that the sample  
12 in 2-3 and 2-4 was expanded to 40 percent due to pit  
13 indications.

14 MR. PITTERLE: Yes. Found a couple pits in the  
15 first part of the 20 percent sample and that led to  
16 following the EPRI guidelines to an expansion of the  
17 inspection.

18 MR. SULLIVAN: So the expansion was done based on  
19 EPRI guidelines, not based on tech specs.

20 MR. PITTERLE: I think that's correct.

21 MR. SULLIVAN: And what was it about the EPRI  
22 guidelines that allowed the sample to stop at 40 percent.

23 MR. PITTERLE: For volumetric type indications,  
24 it's different than, say, for example, cracks or plugging --  
25 I don't remember exactly. Do you remember, Don?

1 MR. ADANONIS: Yes. If you find -- well, any  
2 volumetric or any non-crack type indication would have been  
3 beyond the repair limit would have thrown us into a further  
4 expansion.

5 So if you -- if we would have had something beyond  
6 a pit beyond 28 percent depth, which is what we had in the  
7 first sample, threw us into the expansion. In the second  
8 expansion or in the expansion, we found no pits deeper than  
9 28 percent, which was our calculated repair limit.

10 MR. SULLIVAN: So you've got a qualified sizing  
11 technique.

12 MR. ADANONIS: There is an EPRI-qualified sizing  
13 technique, with a bobbin probe.

14 MR. PITTERLE: The reason that limit is 28, we  
15 didn't plug at that limit. The 28 percent is the result of  
16 the uncertainty in the EPRI sizing technique is very, very  
17 low. It would not support -- the growth rates are very  
18 small. The uncertainty is so large that if you back off  
19 from the structural limit at that NDE size and uncertainty,  
20 we would have repaired, if we had not decided to plug them  
21 all, at about 28 percent.

22 It's just a huge size in uncertainty.

23 MR. SULLIVAN: But you're relying on some sort of  
24 qualification for your decision on expansion.

25 MR. PITTERLE: Yes, the EPRI databank.

1 MR. SULLIVAN: How does that fit Indian Point?

2 MR. PITTERLE: From a pit standpoint, volumetric  
3 standpoint, should fit. Pitting should not be very --

4 MR. SULLIVAN: Were there ever any pulled tubes?

5 MR. HENRY: Yes. There are pulled tubes included  
6 in that data set.

7 MR. PITTERLE: As we said, all decision was made  
8 to repair all of them, even though the growth rates are  
9 close to nil, just to avoid the issue of size and accuracy  
10 for plugging. It was only used as a consideration in the  
11 expansion of the inspection.

12 Are there any other questions?

13 MR. BAUMSTARK: We can get into the question and  
14 answer.

15 MR. MURPHY: Last week, we sent you a set of very  
16 detailed questions and presumably we will be getting a  
17 detailed response to these written questions. The  
18 presentation we heard today, of course, was fairly high  
19 level compared to the detail involved in some of these  
20 questions.

21 However, there were a couple of, I think some of  
22 the most important of these questions have not really been  
23 addressed at all.

24 One, the thrust of the -- I think the most  
25 significant contributor that you've identified from the

1 standpoint of the cracking mechanism, the most significant  
2 contributor you've identified is leading to the U-bend  
3 cracks, the flow slot hourglassing phenomenon.

4 And of course, you have identified that the flow  
5 slot adjacent to the tube which failed, R2C5 in SG24, that  
6 that flow slot was hourglassed, 4800ths of an inch.

7 Of course, a number of other U-bend indications  
8 were found in the steam generators, and to what extent have  
9 you been able to confirm that flow slot hourglassing is also  
10 associated with these other U-bend cracks?

11 This would be pretty central, I would think, to  
12 support the notion that hourglassing is a necessary  
13 condition for these cracks.

14 MR. PITTERLE: Can I try to separate that from the  
15 operational assessment? It may be an influence on  
16 initiation.

17 MR. MURPHY: I think we heard that we can't get  
18 cracks, ID initiated cracks without the influence of -- at  
19 the apex without the existence of hourglassing. I think  
20 that was identified as a necessary condition for the kinds  
21 of cracks that we're seeing. So the question is have we, in  
22 fact, confirmed hourglassing associated with each of the  
23 U-bend cracks that have been identified.

24 MR. PITTERLE: I'm trying to understand if there  
25 is any concern relative to doing the operational assessment.

1 I understand that from a technical standpoint, of  
2 understanding what may have caused the cracking, but the  
3 influence of the --

4 MR. MURPHY: I think it does, Tom. I think it  
5 does. Of course, question was made in the context of a root  
6 cause analysis and the earlier discussions related to root  
7 cause or causal factors.

8 But I think that an operational assessment, in  
9 order to be credible, certainly needs to be consistent with  
10 what is known about the causal factors involved with the  
11 cracking.

12 So I think we need to understand the root cause of  
13 these cracks in order to have confidence in the operational  
14 assessment.

15 ESSELMAN: The cracks that were identified, the  
16 indications that were identified were all identified in the  
17 outer-most flow slots. That is, at the periphery or the  
18 second flow slot in. Only a single flow slot has been  
19 measured, though, and the measurement was made in steam  
20 generator 24 and it was made in a flow slot that, as we  
21 said, was visually difficult to determine, both because of  
22 the image that you get from the video cameras and because of  
23 the rough cut, flame cut.

24 But yet the location that the cracks occurred are  
25 where we expect the hourglassing to be most severe, which is

1 the outer most near the periphery. The indications appear in  
2 the center of the flow slots.

3 None of the indications have been at the regions  
4 away from where the hourglassing has occurred, and even  
5 though we haven't gone to the other flow slots and performed  
6 a measurement, the location of the other indications are  
7 consistent with the presence of hourglassing.

8 The other thing that we've learned is that  
9 hourglassing that exceeds approximately two-tenths of an  
10 inch in total leg to leg hourglassing, less than half of  
11 what was depicted.

12 Also would be sufficient to cause the level of  
13 stress that we saw in the tube that was analyzed with the  
14 flow slot that was measured.

15 So I believe what we have absent measurements of  
16 the other flow slots that would allow us to draw hard  
17 conclusions is consistency of indication locations and a low  
18 threshold that is very plausible relative to the extent of  
19 denting.

20 MR. MURPHY: You've performed visual inspections  
21 from each of the hillside ports in each of the four steam  
22 generators and apart from the flow slot we've been  
23 discussing in SG24, and I think one additional flow slot in  
24 SG23, has there been hourglassing identified in some of the  
25 other flow slots and are we able to confirm the existence of

1 hourglassing as being associated with each of the row two  
2 cracks that have been found?

3 ESSELMAN: The direct link, short of going in and  
4 measuring the other flow slots to say that there is  
5 sufficient hourglassing, is only through the consistent  
6 appearance of locations.

7 We also know that absent that mechanism, absent  
8 hourglassing, in that we've looked at the pressure stress  
9 and the effects of ovalization in those tubes, the other  
10 consistent path has also led us through the other potential  
11 contributors and none others have appeared as likely  
12 contributors.

13 So I think that we have identified a low  
14 threshold. We have, for instance, in the outer flow slot,  
15 measured hourglassing. I don't know that we know a  
16 mechanism why the second flow slot in would not also be  
17 hourglassed.

18 The occurrence of denting is a relatively uniform  
19 event in that we're seeing flow slot deformation in the  
20 lower tube support plates across the entire bundle.

21 I don't know that we know a mechanism why we would  
22 get hourglassing in the flow slot that was measured, for  
23 instance, and would not see it in the flow slot that's  
24 adjacent to it.

25 But I think that there is a -- and I think we

1 could develop this also, but the consistency of location of  
2 flaws within the flow slot, in the outer flow slots, it's  
3 consistent. Also, the mechanism that's caused the denting,  
4 what we know about -- in detail about the lower support  
5 plate denting, and that is that the denting effect clearly  
6 is uniformly occurring across the bundle.

7 I could lead you to not have a mechanism, not have  
8 an alternate mechanism nor have an alternate mechanism why  
9 you wouldn't have denting.

10 MR. PITTERLE: Could I just add that I don't  
11 believe we can show with absolute certainty that denting is  
12 100 percent requirement. There have been one or two other  
13 apex indications reported in other plants without  
14 substantial denting, most of whom are at the tangent points,  
15 which are a different causative stress. But it's not 100  
16 percent dependent on denting.

17 MR. MURPHY: I think before moving on to ovality,  
18 I guess I'm a little concerned about the lack of  
19 corroborating evidence of hourglassing as being associated  
20 with the occurrence of the known cracks in row two.

21 This is the operative theory about the main causal  
22 factor for the state of stress at the apex of the U-bends,  
23 at the ID, that basically drive the initiation and growth of  
24 the cracks.

25 There are a number of potential mechanisms to

1 explain cracking at the apex and the next one I'd like to  
2 explore a little bit is ovality and excessive ovality  
3 introduced by fabrication.

4 But before getting into that, given that there's more than  
5 one way to explain, hypothetically more than one way to  
6 explain the occurrence of ID cracks at the apex, I would  
7 think that there would be more of an effort to corroborate  
8 the particular theory that you've come up with as being the  
9 primary cause.

10 In the late 1970s, the Dole unit in Belgium  
11 experienced a rupture at the apex of a small radius U-bend.  
12 That plant did not have any significant denting reported or  
13 any reported hourglass effects.

14 The ultimate cause of the failure was determined  
15 to be the result of excessive ovality introduced during  
16 fabrication and this degree of excessive ovality was  
17 confirmed after the fact by running ball gauges through the  
18 U-bends to establish the diameters.

19 Also, in the past, at Indian Point, back in 1997,  
20 in your 1977 inspection report, dated July 29, you reported  
21 quite a number of restrictions in the U-bend, U-bends that  
22 reportedly restricted a six-ten-inch diameter bobbin quell.

23 In the root cause report, you also note that  
24 restrictions existed in the U-bend at and above the sixth  
25 support plate.

1           So I guess the general question is how -- what has  
2 been done to rule out fabrication induced ovality or  
3 excessive ovality relative to the allowed -- the drawing  
4 specifications on a lot of degrees of ovality during the  
5 fabrication?

6           MR. PITTERLE: I'd just comment that I think that  
7 Dole has to be put into almost a separate category. The  
8 bending process did not use the ball mandrill. As a  
9 consequence, those tubes were small radius tube bent without  
10 the ball mandrill to help reduce the ovality, much different  
11 animal than anything we're looking at.

12           MR. ESSELMAN: The other comment that I would  
13 make, and I guess I would like to not provide a final  
14 answer, and I'd like to go through it, but ovality,  
15 manufactured ovality was specified as limited to ten percent  
16 on the drawings. One of the features of ovality is that  
17 from an ID cracking point of view, that as you pressurize  
18 the tube, you do induce a compressive stress state into the  
19 ID surface. So that there's two things that you need to  
20 look at, and that is what may the residual stresses be,  
21 which I guess is -- I try never to talk about residual  
22 stresses that I hadn't thought about before without having  
23 some time to think about them, because they're very complex,  
24 but yet the operating stresses, absent any other driving  
25 force like U-bend cracking, would tend to give you a

1 compressive stress on the ID.

2           So in general, we've looked at ovality, we've  
3 considered ovality in the work that we've done, and we have  
4 not been able to attribute a feature to the initial  
5 manufacturing ovalization of a tube, especially absent the  
6 leg closing that would give you stresses that would be  
7 sufficient to induce cracking.

8           MR. MURPHY: Wasn't the Dole failure attributed to  
9 primary water cracking?

10          MR. ESSELMAN: Yes.

11          MR. MURPHY: There must have been tensile stress  
12 there on that. Tom, you referred to the ball mandrill  
13 process used for rows one and two at Indian Point. Until  
14 the root cause report was issued a couple of weeks ago, we  
15 had talked about, in earlier discussions with Con Ed, the  
16 fabrication methods that were employed on these U-bends.

17           And until the root cause report came out, the  
18 information consistently had been that at least that the  
19 Huntington tubes had not been fabricated with a ball  
20 mandrill.

21           I think early on in our discussions, in the  
22 initial weeks, I think the initial information we had was  
23 that perhaps there were two suppliers involved for the  
24 tubing in rows one, two and three, and that perhaps some had  
25 been fabricated with a ball mandrill and some hadn't.

1 But the story had been, right up until the root  
2 cause report, that a ball mandrill hadn't been used and when  
3 the root cause report did say that a ball mandrill had been  
4 used.

5 So my question is what was done and how confident  
6 are we that, in fact, a ball mandrill process was used  
7 during fabrication?

8 MR. PITTERLE: Part of preparing the root cause  
9 report was a rather detailed review. We've had many, many  
10 telecons with the Huntington Alloy people with regard to how  
11 those tubes were bent, because some details of the  
12 procedure, even to the point of whether they would make  
13 additional tubes the same way.

14 As a result of those discussions, it's been clear  
15 that they did use the ball mandrill, slightly different  
16 technique than, say, the tubes made by Westinghouse, where  
17 most of the cracking may have been at the tangent points,  
18 differences in how the ball mandrill is used in the process,  
19 but they were very explicit in the use of the ball mandrill  
20 to reduce the ovality of row one and two, and it was not  
21 used in row three.

22 MR. MURPHY: Was there a post-process inspection  
23 of these U-bends in terms of ovality measurements before  
24 they were installed?

25 MR. PITTERLE: I can't say that I've reviewed the

1 inspection records. That part we did not do. I would  
2 expect that there is a drawing requirement, but I cannot  
3 verify anything that was specifically done, because we did  
4 not review that. There generally is an ovality limit on the  
5 tubing that's supposed to be passed.

6 We have not tried to dig out those manufacturing  
7 records to confirm that at this point.

8 MR. MURPHY: Okay. I think I also alluded to your  
9 1997 inspection reports, talking about reported instances of  
10 U-bend restrictions. I know you've taken a look at that  
11 issue and I know you have some thoughts on that and perhaps  
12 before going on, you might briefly summarize your  
13 conclusions as to what those reported U-bend restrictions  
14 were all about.

15 MR. NEFF: The U-bend restrictions, when we  
16 investigated, we found that they were not intended to be  
17 tested through the U-bends. The reason why those low radius  
18 U-bends were tested was to get the straight legs inspected.

19 The probe, when it tries to jam up into the bend,  
20 naturally stops. The operators made messages on the tape  
21 that said that these tubes were restricted in the U-bend.

22 There were other cases where those tubes were  
23 restricted at other elevations, lower elevations. And that  
24 is the reason why they were plugged. But I didn't find any  
25 reference that stated or that showed that that probe was

1 caught in the U-bend proper, and I so stated in the letter  
2 that I wrote. But I also couldn't say where it stopped in  
3 the U-bend. It was just that the probe is too long,  
4 physically too long to negotiate the U-bend.

5 MR. MURPHY: Go ahead, Stephanie.

6 MS. KAUFMANN: I just want to make the general  
7 observation, start off by making the general observation  
8 that in the letter that we sent to you last Friday with the  
9 17 points on it, I realize those are very detailed questions  
10 and that you couldn't address all of them today.

11 So I'll be looking very much forward to seeing the  
12 written responses to these questions. But I just want to  
13 bring out probably in terms of my interactions and input on  
14 this whole event with IP-2 is that I noticed in your root  
15 cause analysis, I thought there could have been a much more  
16 candid and objective evaluation of the root cause and your  
17 overall steam generator management program and how the  
18 industry guidelines factor into that.

19 You know the staff has to look beyond just what's  
20 happened at IP-2 and consider the generic implications and  
21 we can do that, but it's best if we both do that. That's  
22 something I would really much like to see in your cause  
23 evaluation, specifically reliance on generically qualified  
24 techniques without perhaps a very close critical questioning  
25 attitude about whether those are applicable at one's plant.

1 That's an example.

2 MR. STROSNIDER: I'd like to just follow up on  
3 that and I think Stephanie characterized that issue very  
4 well. Basically, the root cause evaluation says there is an  
5 inability to detect because of noise and secondary  
6 contributing factor, the hourglassing and stress aspect.  
7 But I guess there's a lot more that could be said about  
8 that.

9 Why did this inability exist, why wasn't it  
10 corrected, what needs to be done to correct it, which is  
11 getting into corrective actions, but certainly, from your  
12 perspective, you need to take probably a deeper look to make  
13 sure that your corrective actions and your ongoing efforts  
14 are appropriate.

15 And from our perspective, we need to understand  
16 this and it's very important because we'll be looking at  
17 this not only for Indian Point, but for generic implications  
18 for the industry, and it's important that we focus on the  
19 right thing and that's one of the reasons for going into the  
20 detail that we're going into and trying to understand the a  
21 very complex area.

22 So I think in general, I'm glad Stephanie brought  
23 this up, there's perhaps a deeper, more probing look that  
24 could be taken at this and I think there are probably going  
25 to have to be more discussions in that regard.

1           So that's just a general comment. I think some of  
2 the specifics we've asked are going to help in that regard,  
3 some of the discussion today will certainly help. We've  
4 talked about what was the status of generic requirements in  
5 terms of qualifying the inspection. We talked a little bit  
6 about how you apply them at Indian Point. But I think we  
7 need to have a very good understanding of that to make sure  
8 that we really focus on the right corrective action for you  
9 and for the industry.

10           So I'm glad Stephanie brought that up and that's  
11 an important sort of general comment.

12           MR. ADANONIS: That is a good point. One of the  
13 facts is in 1997 was the first time that this plant, that  
14 these generators had been looked at with a +Point probe. So  
15 there wasn't even any basis for any kind of comparison as  
16 you see now going into the different requirements.

17           MR. BAUMSTARK: At the same time, we appreciate  
18 your comment on the rigor with which we approach this whole  
19 issue.

20           MR. PITTERLE: And I think we all agree that we  
21 need to proceed and follow this on a generic basis. I do  
22 hope, though, that we can separate the timing of the review  
23 of the operational assessment from the generic issues,  
24 because we do want to get everything we know about it on the  
25 table and done. We, speaking for Westinghouse and I'm sure

1 everybody else, will look at this and what should be done on  
2 a broader generic basis.

3 But we get the operational assessments and  
4 everything else pulled together, it gives us much better  
5 technical knowledge to then, on a timely basis, but extended  
6 basis, look at the generic issues. But I hope that they can  
7 be separated in the short term from the review of the  
8 operational assessment.

9 MR. STROSNIDER: I'd just comment. NRC is  
10 experienced in looking at plant-specific issues in parallel  
11 with their generic implications.

12 MR. PITTERLE: I understand.

13 MR. STROSNIDER: And that's what we'll be doing.  
14 But clearly there is a close coupling and we don't want to  
15 lose sight of that. We'll be looking at issues as we  
16 understand them along the way from both plant-specific and  
17 the generic perspective.

18 MR. SHARRON: I marked down here, from earlier, I  
19 just would just like to get a clarification. I'm not sure.  
20 You started, when you talked about the EPRI guidelines for  
21 changes in leak rate, I think you said that the latest  
22 guidelines or something basically reduced the -- they  
23 reduce, I guess, the threshold at which you would start  
24 increased monitoring or something.

25 MR. PARRY: Yes.

1 MR. SHARRON: The rest of my question is I didn't  
2 understand, when I look at the leak rates that you  
3 experienced, when you went from like I think it was one to  
4 1.5 to three gpm or something like that, how does that fit,  
5 in other words, from a lessons learned standpoint or a root  
6 cause? Does this change have any affect on how you would  
7 have managed your steam generator or what you would have  
8 done?

9 And, again, the question is hwy is that okay if  
10 there was no change?

11 MR. BAUMSTARK: The answer to your question, I  
12 think, is, would we take different action now if we had a  
13 3.5 gallon per day leak, and the basic answer to that is  
14 probably not, because you can't find a leak or it's been  
15 demonstrated because of utilities that have had leaks of ten  
16 gallons and less that they were never able to locate the  
17 locations of those leaks by shutting down and investigating  
18 the steam generators for a potential leak.

19 The industry standards, and correct me if I'm  
20 wrong, Gary, the industry standard is basically that there's  
21 a leak of less than ten gallons per day, you are probably  
22 not going to be able to find it.

23 In the history of our plant, we existed, I think,  
24 between 1983 and 1994, with a recorded leakage, I think it  
25 was 5.9 gallons per day, and we were never able to find that

1 leak.

2 Cycle after cycle after cycle, going into those  
3 generators.

4 MR. SHARRON: One of the questions that was raised  
5 was do we even know that this increase in leakage that  
6 occurred just prior to the failure was actually coming from  
7 the tube that failed or was it from something else.

8 MR. BAUMSTARK: And we don't know the answer to  
9 that question. We know, based on all the examinations that  
10 we've done, that we are plugging a number of tubes and we  
11 may well, in plugging those tubes, disguise what the real  
12 source of that 3.5 gallons per day was, as we believe we did  
13 in the 1993 timeframe because that leak, after one outage,  
14 was not there in the succeeding operational cycle, yet we  
15 could never find a distinct leak.

16 MR. PITTERLE: Of all the tubes tested, only row  
17 2, column 71 leaked under normal operating conditions. A  
18 lot less than the -- I think it was more like .1 gpm. But I  
19 think the answer is no, we cannot really assure that that is  
20 the contributor to the leakage. I think it's recognized in  
21 all the leakage monitoring documents, the EPRI, NRC,  
22 DG-1074, that leakage monitoring gives you defense-in-depth,  
23 it protects you against high percentage of potential flaws,  
24 but there are always going to be some flaw that can tear  
25 without preceding leakage. That may or may not have been

1 this case, but clearly it wasn't very much leakage, zero or  
2 very small leakage.

3 MR. MURPHY: There are many detailed questions  
4 here that I'm not -- time doesn't permit going through in  
5 detail, but a lot of them deal with the general issue of how  
6 it came to pass that the symptoms and precursors of the kind  
7 of failure that occurred at Indian Point in February this  
8 year, how these went unnoticed or no red flags got raised,  
9 years ago, that this was a problem that was building up on  
10 you from the early evidence of the hourglassing, to the  
11 finding of the an apex indication that the row two U-bend in  
12 1997, the fact that you clearly had very noisy data in the  
13 U-bend, and flaw detection was clearly a big challenge,  
14 whether there shouldn't have been much more careful  
15 attention and perhaps further action to ensure the integrity  
16 of the inner row U-bends.

17 So this will certainly be a subject of continuing  
18 discussion with you and among ourselves and with the  
19 regions.

20 MR. STROSNIDER: And I think most of those issues  
21 that Emmett sort of listed there are captured in the letter  
22 that we sent you last week and we'll be looking for your  
23 perspective on those issues when we provide that answer.

24 Today was helpful, but I think there's probably  
25 some more detail, some more information that you might be

1 able to provide to help us understand that.

2 MR. SHARRON: Let me just close, if I could. You  
3 presented us with a lot of information, some of it's new.  
4 We obviously have to go back and review it. I think you've  
5 heard there's a number of areas where I guess we feel that  
6 in terms of the 17 questions we asked under root cause, we  
7 would need some more information. And so obviously we'll  
8 look forward to getting the answers to those questions and  
9 basically I would encourage you that when you go through  
10 these questions and reflect on what we've heard here,  
11 there's a transcript, so obviously you can go back and get  
12 some more detail on that.

13 But to the extent you can address those in the  
14 written response, I think that would help us and we're  
15 always available for clarifications or anything with a  
16 phone, if you need them, with regard to the questions.

17 With that, I guess I'll turn it back over to Jeff.  
18 I'm sorry.

19 MR. BAUMSTARK: Can I say something?

20 MR. SHARRON: Sure.

21 MR. BAUMSTARK: Unless you just want to close out.  
22 Again, Con Edison and specifically those of us at Indian  
23 Point, we appreciate the opportunity to come down here and  
24 discuss our steam generators in this particular forum. As  
25 you know, we're working very hard right now on our condition

1 monitoring operational assessment report.

2 One of the reasons we built that into the  
3 presentation today was we believe it answers a number of the  
4 questions that were not answered as part of our root cause  
5 analysis.

6 This assessment, in our minds and clearly in your  
7 minds, it needs to be the same way, will determine the  
8 readiness of our generators for safe operation and I  
9 certainly want to emphasize safe operation. We need to  
10 determine, first ourselves, and then have you concur that  
11 these generators are safe to operate, and then based on the  
12 operational assessment, what type of operational cycle that  
13 assessment will define.

14 Again, we appreciate the opportunity to come down  
15 here today and present this.

16 MR. ALLAN: I just want to make one other comment.  
17 We had stated in the April 28 about the topics for  
18 discussion for this meeting, that we were kind of expecting  
19 that all the information that we heard today would be --  
20 we'd also receive in the form of writing, and also everybody  
21 is concerned about timing of when we'll receive responses.

22 Would you just keep us up to date on when you  
23 expect to submit documents to us, so that we can have an  
24 idea, as well as inform the public, because I get calls all  
25 the time of when is this going to be submitted.

1           With that, that concludes the technical meeting  
2 between Con Ed and NRC and we're going to go now to question  
3 and answer session with the public. We appreciate your  
4 time.

5                     [Whereupon, at 4:30 p.m., the meeting was  
6 concluded.]

REPORTER'S CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

NAME OF PROCEEDING: NRC AND CONSOLIDATED EDISON  
TECHNICAL MEETING REGARDING IP2  
STEAM GENERATOR

PLACE OF PROCEEDING: ROCKVILLE, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

B. Charles Hopchas

B. Charles Hopchas

Official Reporter

Ann Riley & Associates, Ltd.

**Indian Point Unit 2  
Low Row U-Bend Examinations**

**Jimmy Mark and Andy Neff**

**Con Edison**

**May 3, 2000**

# Technique Qualification for 1997 Row 2 and 3 U-Bend Examinations

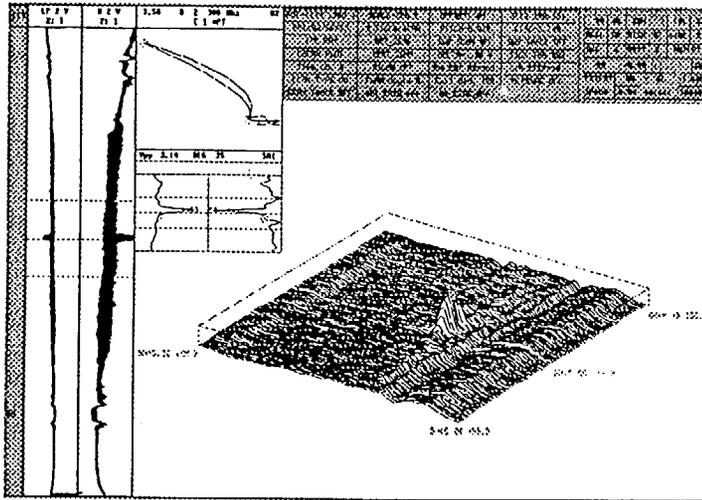
- Performed in accordance with the then current Rev. 4 of the EPRI PWR SG NDE Guidelines
- Midrange +Point probe
  - Qualification documentation ETSS 96511 - 150, 300 & 400 kHz
  - Twenty-six sample data set
    - Two pulled tubes (~40% TW)
    - Twenty-four EDM samples (27% to 100% TW)
    - All 26 flaws detected
    - 91.5% POD at a 90% CL
- No requirement for site-specific technique qualification
- First utilization of midrange +Point at Indian Point Unit 2

## 1997 Row 2 and 3 U-Bend Examinations

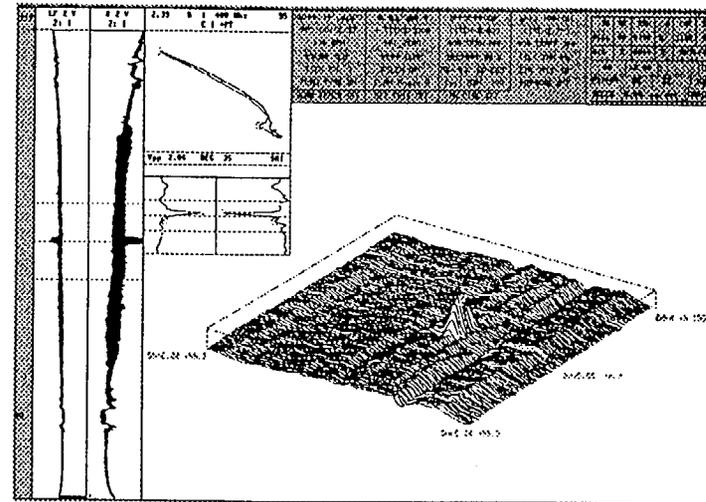
- Site Specific Performance Demonstration (SSPD) in accordance with EPRI PWR SG NDE Guidelines, Rev. 4
  - Practical examination utilized industry degraded U-bend +Point data
  - U-bend cracking not observed previously at Indian Point 2
- Calibration setup within industry variance
- Data quality requirements
  - No quantitative industry standards exist
  - Being incorporated into Rev. 6, EPRI Guidelines, March 2001
- +Point noise level similar to other MA Alloy 600 SGs
- PWSCC identified in the U-bend region of one tube; SG24, R2C67
  - Provided confidence in detection capability

# SG 24, R2C67 - 1997 Midrange +Point Data

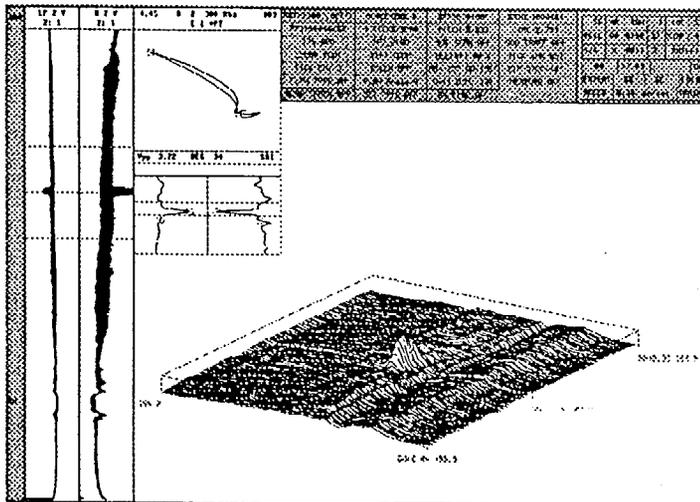
300 kHz 1997 Setup



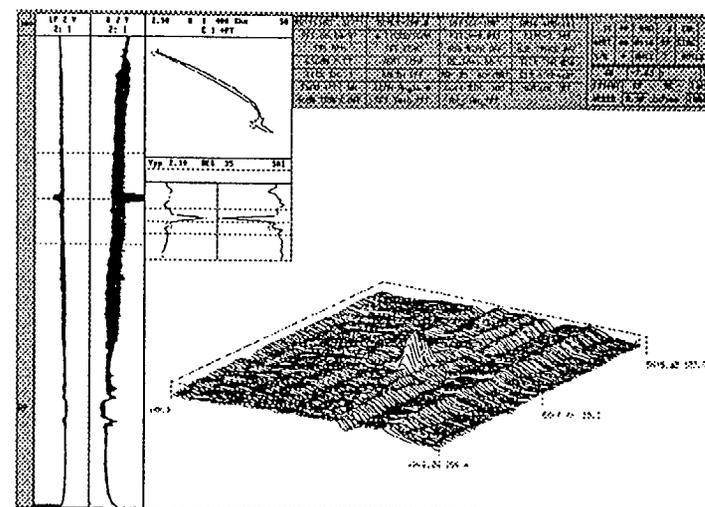
400 kHz 1997 Setup



300 kHz 2000 Setup

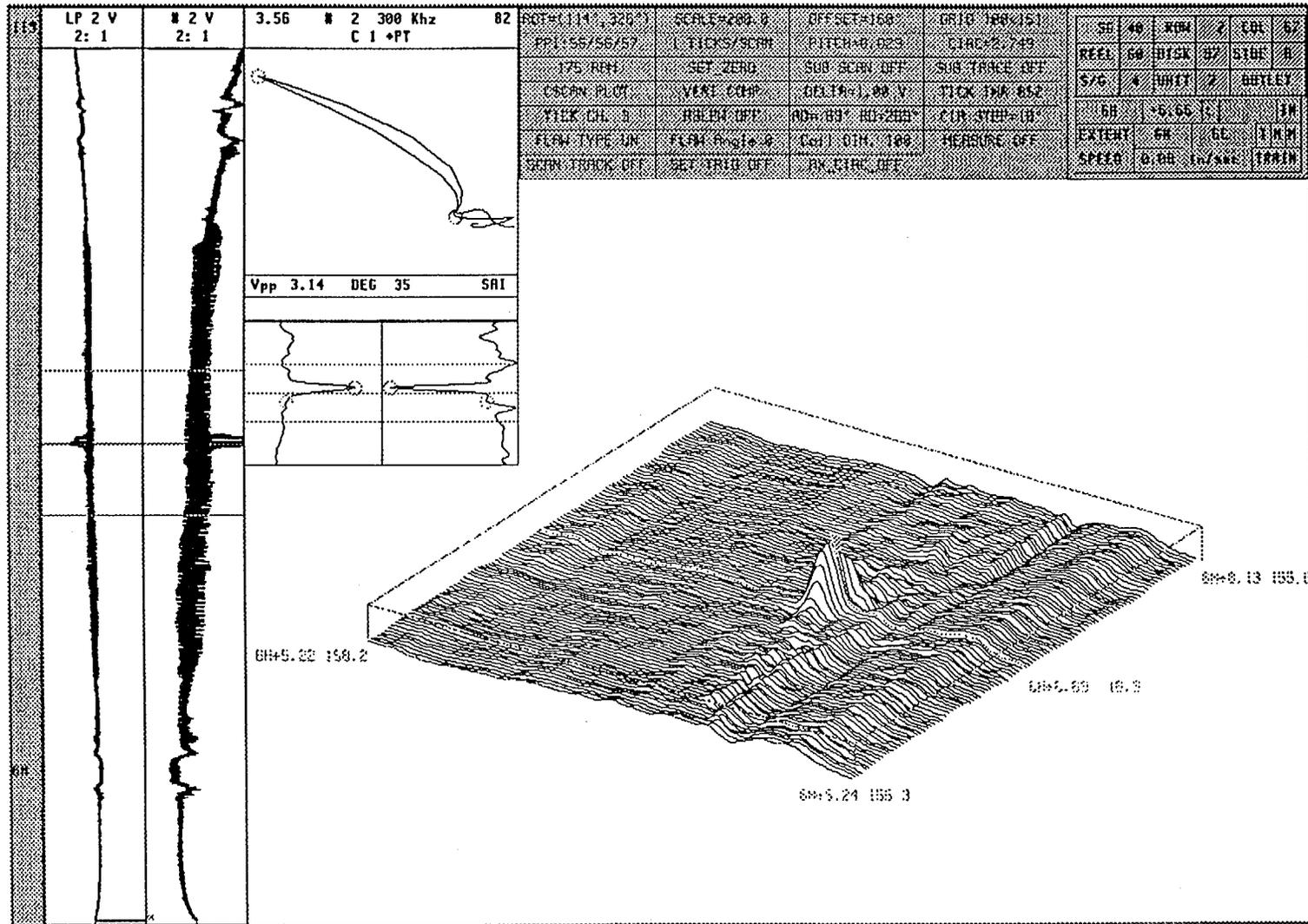


400 kHz 2000 Setup



# SG 24, R2C67 - 1997

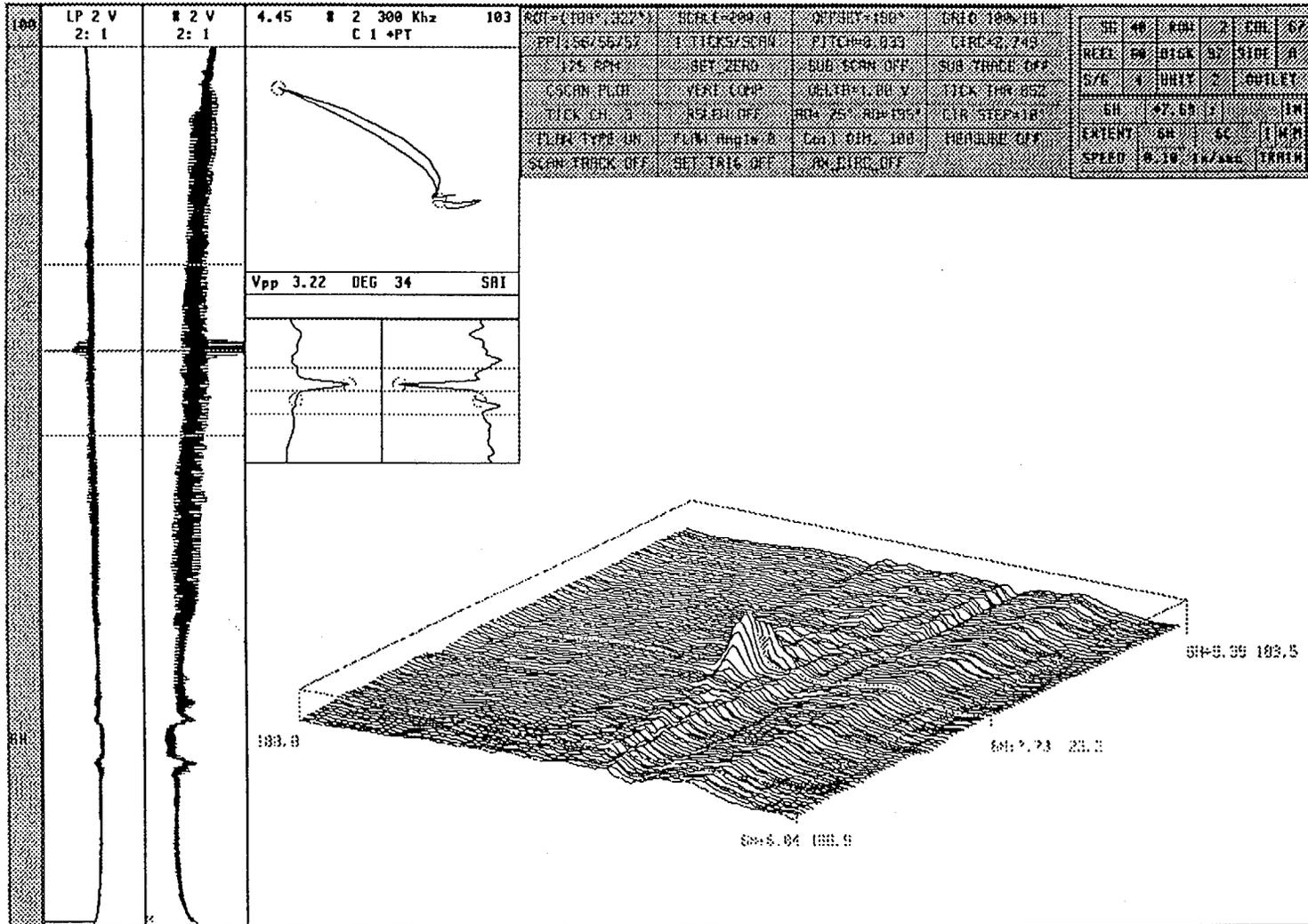
## 300 kHz Midrange +Point 1997 Setup





# SG 24, R2C67 - 1997

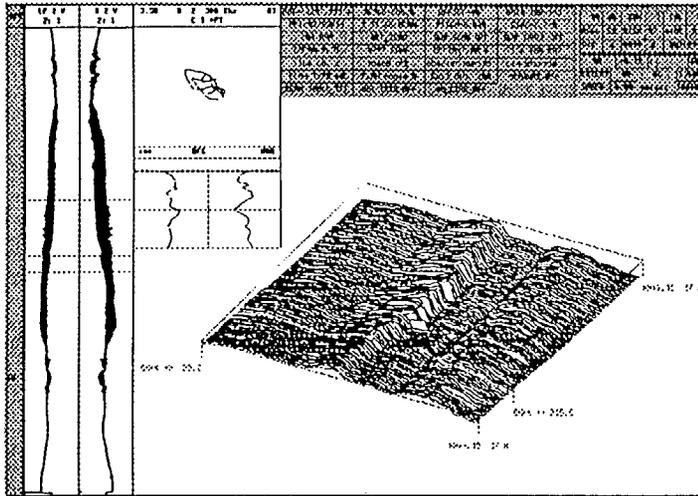
## 300 kHz Midrange +Point 2000 Setup



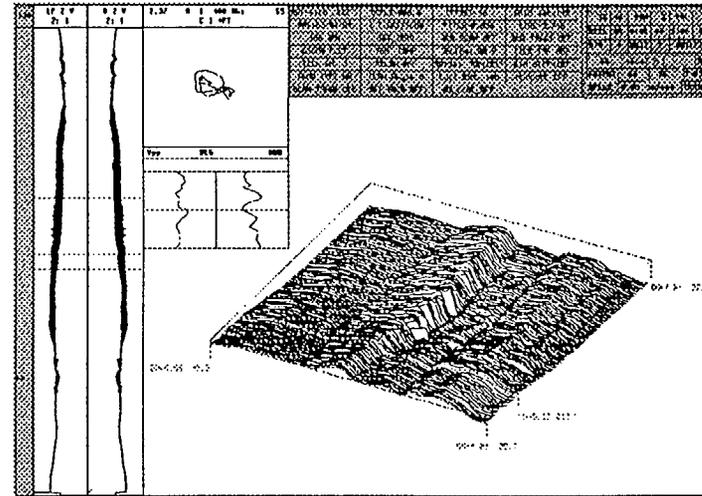


# SG 24, R2C5 - 1997 Midrange +Point Data

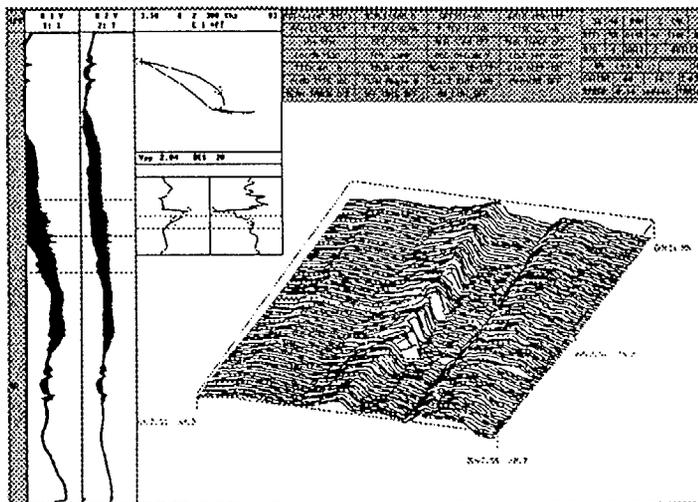
300 kHz 1997 Setup



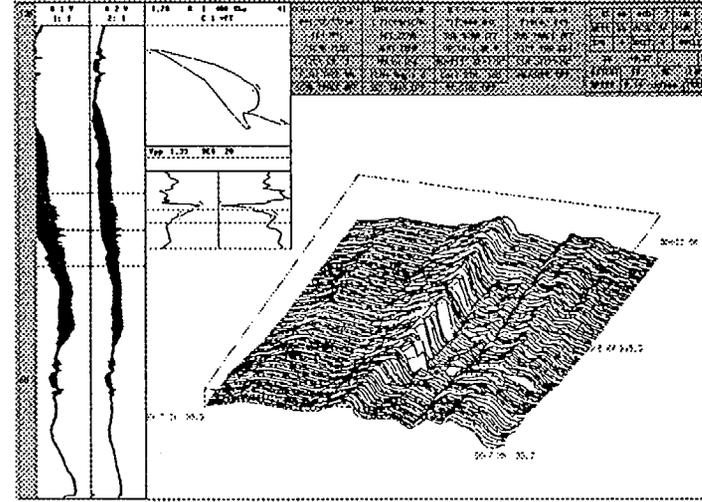
400 kHz 1997 Setup



300 kHz 2000 Setup

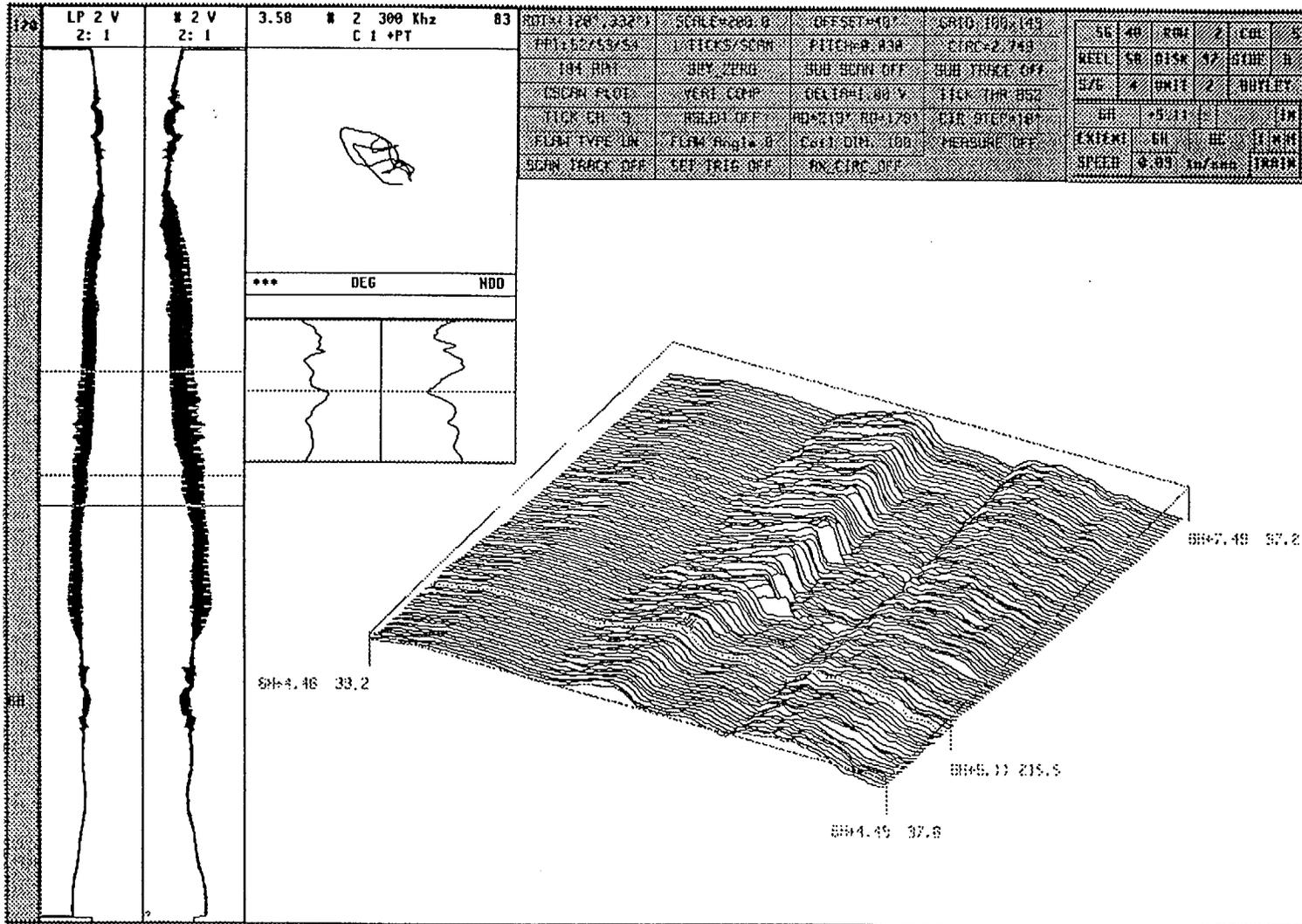


400 kHz 2000 Setup



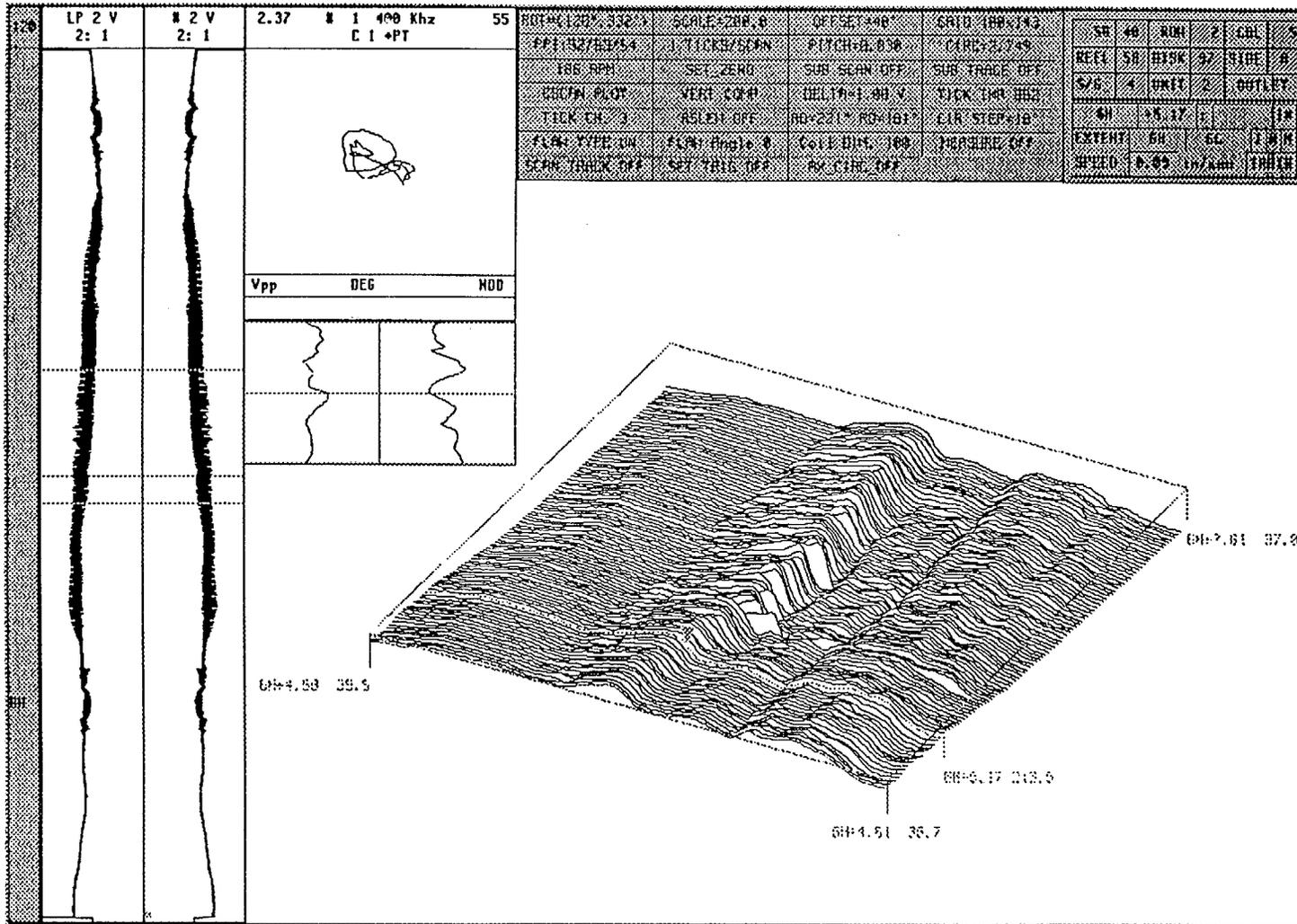
# SG 24, R2C5 - 1997

## 300 kHz Midrange +Point 1997 Setup



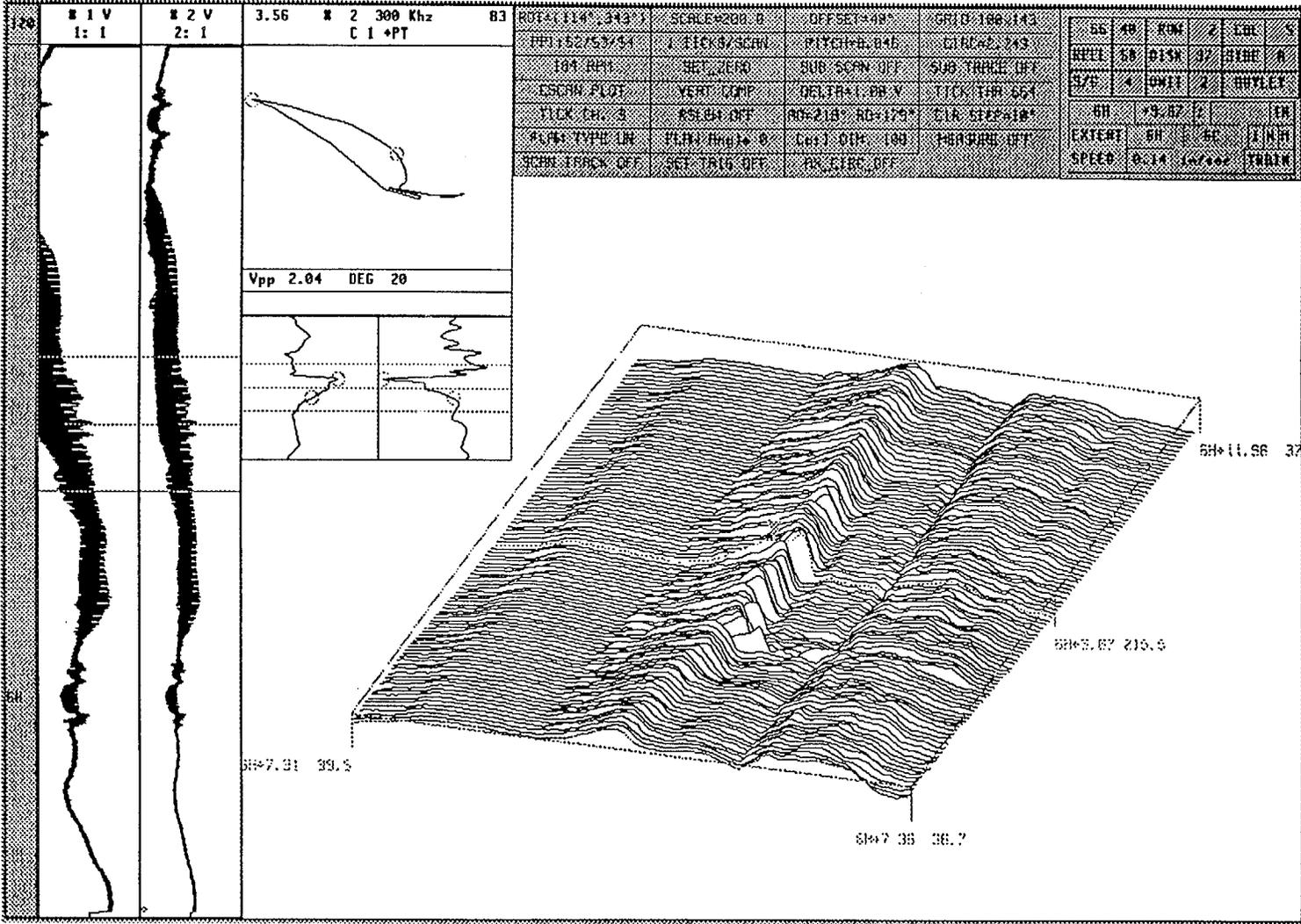
# SG 24, R2C5 - 1997

## 400 kHz Midrange +Point 1997 Setup



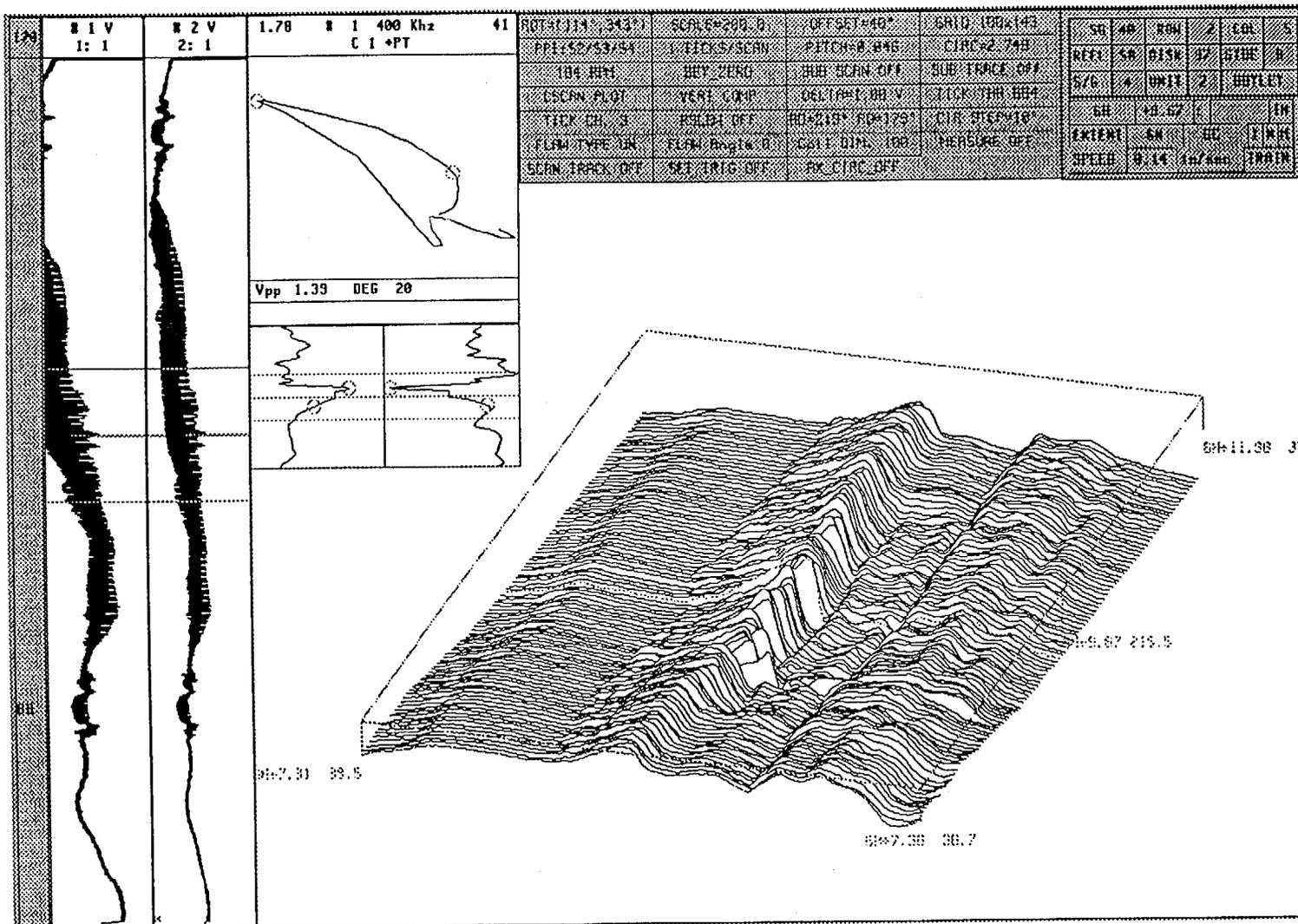
# SG 24, R2C5 - 1997

## 300 kHz Midrange +Point 2000 Setup



# SG 24, R2C5 - 1997

## 400 kHz Midrange +Point 2000 Setup



# 2000 Row 2, 3, and 4 U-Bend Examinations Midrange +Point

- SSPD in accordance with Rev. 5 of the EPRI NDE Guidelines
  - Written training supplement developed
    - “IP2 Spring 2000 Outage U-bend +Point Analysis Training”
    - Setup with 20% ID EDM notch visible at 6 to 10°
    - Requirements for data quality
- All row 2, 3 and 4 U-bends inspected with midrange +Point
  - PWSCC identified in three U-bends
    - SG 21; R2C87
    - SG 24; R2C69 and R2C72
- Data quality criteria evolved as inspections progressed
- Independent review of all low row U-bend data (Tertiary review)
  - Senior analysts performed primary, secondary and resolution
  - Specific training administered
  - Revealed no new indications
  - 457 of 863 U-bends classified as BDA due to low S/N ratios

# Assessment of High Frequency +Point Options

- Site test of midrange +Point at 750 kHz and 800 kHz high frequency +Point
  - Prototype 800 kHz +Point probe manufactured
  - Retested two tubes with PWSCC identified by midrange +Point
    - SG 24; R2C69 and R2C72
  - High frequency probe showed better S/N ratios
- Decision to reinspect with the 800 kHz high frequency probe

# High Frequency Probe Qualification

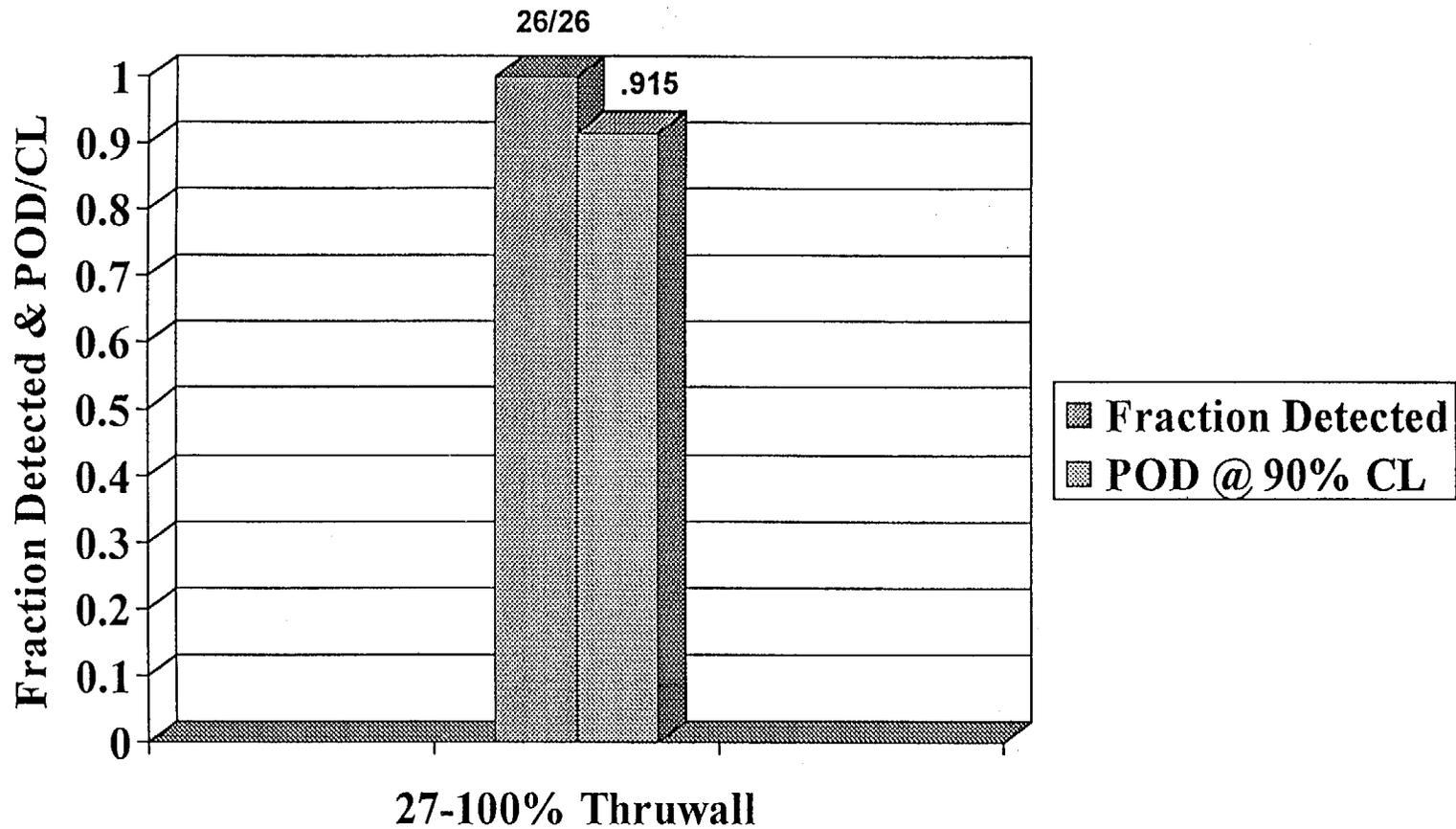
- 800 kHz high frequency +Point qualified per EPRI Rev. 5
- Qualification documentation
  - EPRI ETSSs 99997.1 (800 kHz) and 99997.2 (1000 kHz)
  - Twenty-six sample data set
    - Two pulled tubes with service-related degradation (~40% TW)
    - Twenty-four EDM samples (27% to 100% TW)
    - All 26 ID flaws detected
    - 91.5% POD at a 90% CL
    - Deposit simulation with Cu foil had no effect on detectability
- High frequency probe was site qualified

# High Frequency +Point ETSS 99997.1 Qualification Data Set for U-Bend PWSCC

Type	Depth (% Thruwall)
Pulled Tube	40
Pulled Tube	40
Lab EDM	62
Lab EDM	62
Lab EDM	42
Lab EDM	42
Lab EDM	40
Lab EDM	100
Lab EDM	100
Lab EDM	44
Lab EDM	60
Lab EDM	60
Lab EDM	50

Type	Depth (% Thruwall)
Lab EDM	54
Lab EDM	40
Lab EDM	58
Lab EDM	55
Lab EDM	44
Lab EDM	44
Lab EDM	45
Lab EDM	32
Lab EDM	27
Lab EDM	41

# High Frequency +Point ETSS 99997.1 Technique Performance



# 2000 U-Bend Examinations

## 800 kHz High Frequency +Point

- First industry application of the 800 kHz high frequency +Point
  - All row 2 and 3 U-bends
  - Row 4 U-bends classified as BDA with midrange +Point
- Applied data quality requirements developed for midrange +Point
- High frequency +Point identified PWSCC in four U-bends classified as BDA or RST with the midrange +Point:
  - SG 23; R2C85
  - SG 24; R2C4, R2C71 and R2C74
- Five tubes remained classified as BDA with 800 kHz +Point
  - All BDA tubes plugged

# Data Quality Results

## Midrange Vs High Frequency +Point

Row	Midrange Independent Review Results (Number of Tubes)		High Frequency Results (Number of Tubes)	
	Acceptable Data	Low S/N Data	Acceptable Data	Low S/N Data
<b>SG 21</b>				
2	40	32	71	1
3	32	57	88	1
4	41	46	46	0
Totals	113	135	205	2
<b>SG 22</b>				
2	16	19	35	0
3	31	43	74	0
4	38	36	36	0
Totals	85	98	145	0
<b>SG 23</b>				
2	7	38	44	1
3	23	49	72	0
4	30	60	60	0
Totals	60	147	176	1
<b>SG 24</b>				
2	28	28	54	2
3	37	48	85	0
4	83	1	1	0
Totals	148	77	140	2
<b>Overall Totals</b>	406	457	666	5
<b>Percent Bad Data</b>		(53%)		(0.8%)

## 2000 U-Bend Examination Results Midrange Vs High Frequency

Steam Generator	Tube	Midrange Coil	High Frequency Coil
21	R2C87	SAI	SAI
23	R2C85	BDA	SAI
24	R2C4	BDA	SAI
24	R2C69	SAI	SAI
24	R2C71	RST*	SAI
24	R2C72	SAI	SAI
24	R2C74	BDA	SAI

\* Reported restricted at 6H and UB

# Conclusions

## Low Row U-Bend Examination Programs

- 1997, 2R13 examination program met industry guidelines
  - Revision 4 of the EPRI PWR Steam Generator NDE Guidelines
    - Industry qualified technique
    - Site-specific performance demonstration
    - Calibration setups within industry variance
    - U-bend +Point data quality similar to industry (Alloy 600 MA)
- 2000, 2R14 examination program met industry requirements
  - Revision 5 of the EPRI PWR Steam Generator NDE Guidelines
    - Site qualified technique
    - Site-specific performance demonstration
    - Calibration setups within industry variance
    - New data quality requirements

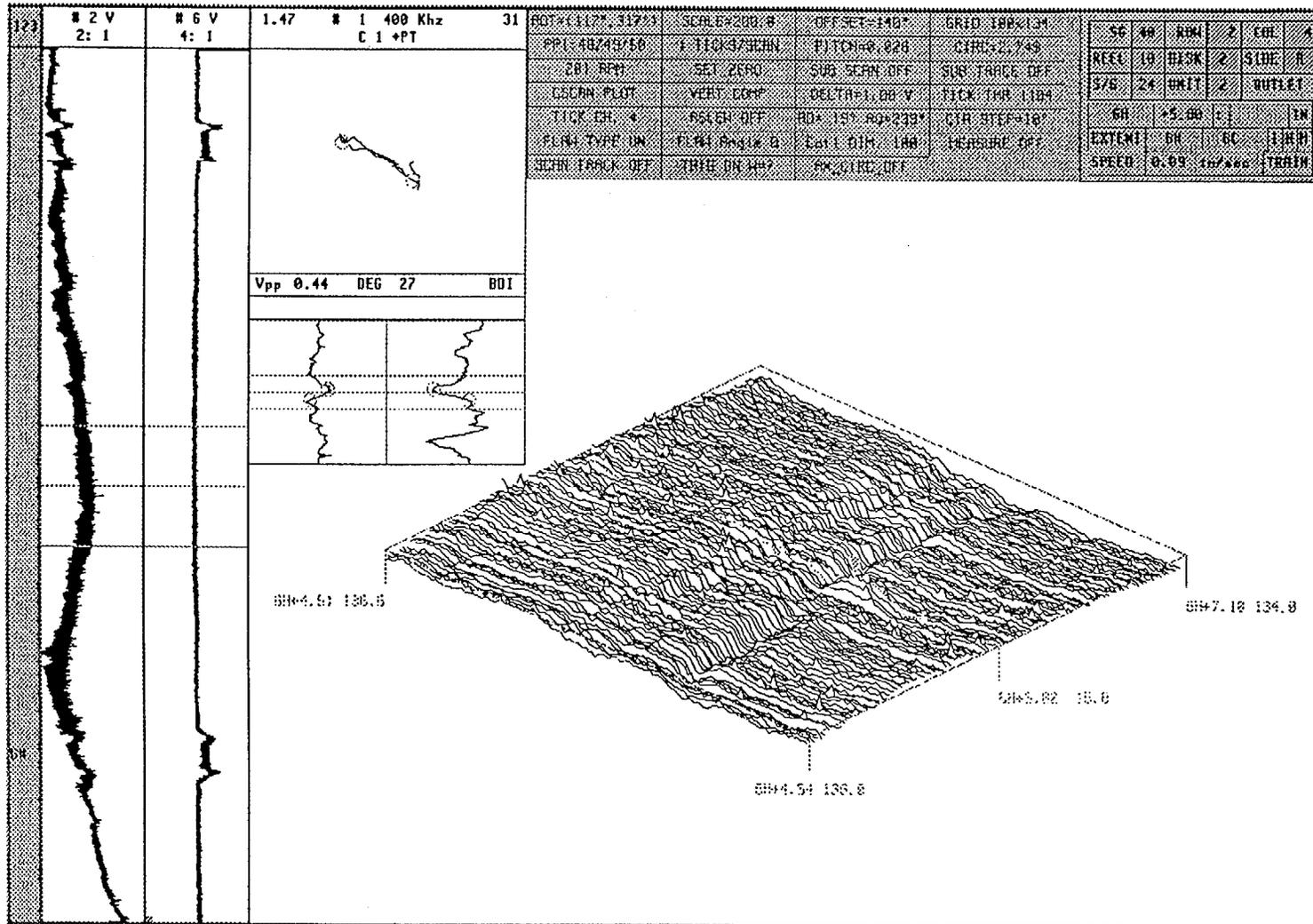
## **Conclusions (Cont'd)**

### **Low Row U-Bend Examination Programs**

- When lessons-learned are considered, use of high frequency +Point provided the most significant improvement to POD
  - Setup rotations and 300 kHz versus 400 kHz midrange data provided minimal improvement
- The high frequency probe is site validated for use at Indian Point Unit 2
- Technology being transferred to other utilities and vendors

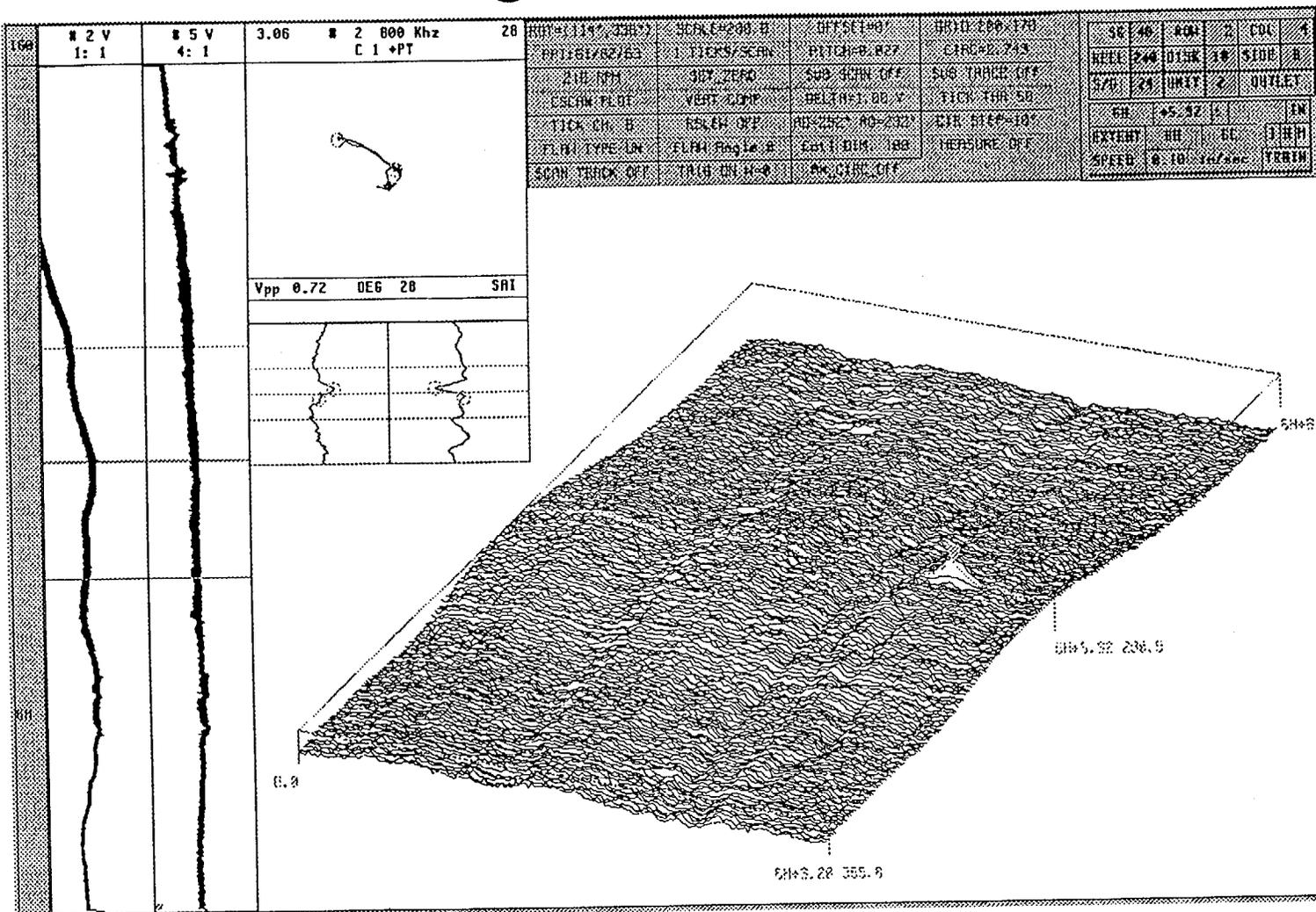
# SG 24, R2C4 - 2000

## 400 kHz Midrange +Point



# SG 24, R2C4 - 2000

## 800 kHz High Frequency +Point



# **ROOT CAUSE ANALYSIS REPORT OVERVIEW**

**J. O. PARRY  
PROJECT MANAGER**

**May 3, 2000**

# **AGENDA**

---

- **OVERVIEW OF EVENT**
- **PRIMARY TO SECONDARY LEAKAGE**
- **TUBE RESTRICTION HISTORY**
- **OTHER ISSUES**
- **ROW 2 - 1997 VIEWPOINT**
- **DOMINION ENGINEERING REVIEW**

# **OVERVIEW**

**February 15, 2000**

---

- **Primary/Secondary leakage @ 1915 hrs. 3.5 GPD**
- **1929 hrs. 75-100 gpm, plant shutdown**
- **R2C5 in SG24 leaking at U-bend (2/27/00)**
- **Welch-Allyn video probe used, shows large axial indication in the U-bend (2/28/00)**
- **Attempted +Point analysis of R2C5, probe caught in U-bend, obtained partial data from crack tip, location on extrados of tube**

# OVERVIEW

February 15, 2000 (cont.)

---

- **R2C5 bobbin tested, 1.7-1.8” long located at apex (3/1/00)**
- **+Point obtained by gluing coil “shoe” down**
  - Located on Extrados
  - Axial indication
  - Length between 2 to 2-1/2”
- **Secondary side inspections and analysis begin concurrently**

# OVERVIEW

Analysis of leaking tube begins 2/28/2000

---

- Reviewed 1997 data for R2C5, 20/20 hindsight, Identified possible indication at U-bend apex
  - Concluded indication Axial PWSCC based on phase angle
  - Analyzed the program to determine any weaknesses
  - Analysis identified low signal-to-noise (S/N) ratio
  - Sources of noise identified
    - OD deposits mask flaw signal
    - Probe rotational speed variations possibly due to ovalization
  - Examined data analysis setup and techniques used in 1997
    - Noise rejection criteria developed
    - Determined that 400kHz has slightly better Signal/Noise ratio
    - 1997 data would be classified as BDA with 2000 criteria

# OVERVIEW

Training initiated incorporating lessons learned

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- **2000 utilized EPRI rev 5 guidelines for ID phase setup**
- **Instructions for poor S/N data rejection**
- **Program of retesting noisy data until acceptable or plugged is instituted**
- **Training administered to analysts**
  - **Separate training sessions**
- **Lessons learned evolved during U-bend inspection**

# OVERVIEW

Initial Inspection starts

---

- **Inspection scope - 100% of U-bend in rows 2, 3 and 4**
- **Examined initial scope**
- **3 PWSCC axial cracks located on the extrados of the U-bend apex found in row 2**
- **No indications found in any row 3 or row 4**
- **Extensive retesting conducted on noisy tubes, many still unacceptable**
- **First analysis of U-bends complete**

# OVERVIEW

## Independent analysis begins

---

- **Updated training program - second phase**
- **Senior analysts used, new to project**
- **Primary/Secondary and Resolution teams**
- **Analyzed all 2000 U-bend midrange +Point data**
- **No new indications reported; 3 row 2 indications reconfirmed**
- **Result - 53% of inspected tubes still unacceptable due to low S/N at this point**

# OVERVIEW

Higher inspection frequencies to enhance PWSCC detection  
are investigated

---

- **Mid range (MR) +Point at 750kHz**
- **New high frequency (HF) plus point:  
0.075" diameter @ 800kHz - 1MHz**
- **Used both techniques to examine known  
PWSCC**
- **HF +point is chosen best**
- **Qualification is formalized (3/20/00)**

# OVERVIEW

Production testing with HF +pt begins

---

- Retest rows 2 and 3, and low S/N tubes in row 4 with HF probe
- 4 new PWSCC flaws discovered in previously noisy tubes
- No new indications found in Initial Program NDD tubes
- No indications in rows 3 or 4 U-bends

# OVERVIEW

Production testing with HF +pt begins (cont.)

---

- **452 tubes recovered from original BDA calls**
  - Data quality much better on HF
  - 5 tubes remain bad data, are plugged
- **Insitu pressure tests all SAI Ubends**
  - 7 tubes tested
  - Exceeded requirement for Insitu test
  - 3 Ubends leaked - met burst criteria
- **All row 2 tubes are plugged at the conclusion of U-bend inspections**

# **OVERVIEW**

## **Concurrent Activities**

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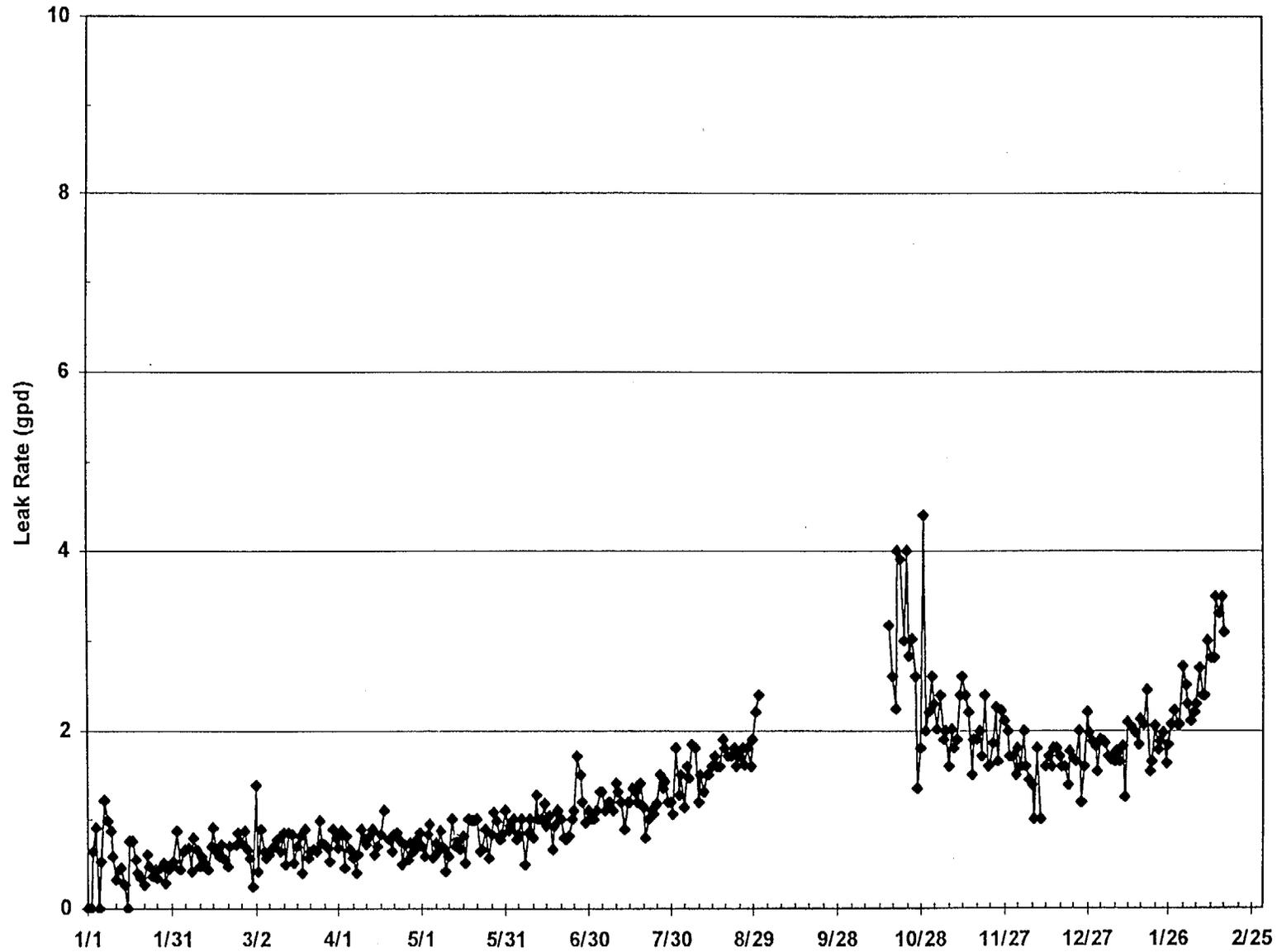
- **Secondary side pressure tests on each SG**
- **Secondary side component inspection and evaluation**
- **Install hillside ports**
- **Investigate and measure hour-glassing**
- **Sludge Lancing/Fosar**

# **PRIMARY TO SECONDARY LEAKAGE**

---

- **Prior to February 15, 2000**
  - **Nitrogen 16 radiation monitor in service**
  - **Alarm points**
    - **10 gallons/day**
    - **25 gallons/day**
    - **150 gallons/day**
    - **Recorder out of service**
  - **Common alarm in Control Room**
    - **Accident assessment panel**
    - **Operator responds locally for common alarms**
  - **Local alarm also**
  - **Leak rate trend for 1999-2000 is attached**

# Indian Point 2- Primary to Secondary Leak Rate Calculated from Condenser Off Gas



# PRIMARY TO SECONDARY LEAKAGE

---

- **Chemistry routine checks N-16 radiation monitor 1/shift**
- **Air ejector radiation monitor R-45**
  - **Rad monitor provides overall trending**
  - **Chemistry samples pathway – calculates overall leak rate**
    - **IPCA 110, primary to secondary leak rate calculation**
  - **7:15 PM on 2/15/00 chemistry rounds, leak rate = 3.4 GPD per N-16**

# **PRIMARY TO SECONDARY LEAKAGE**

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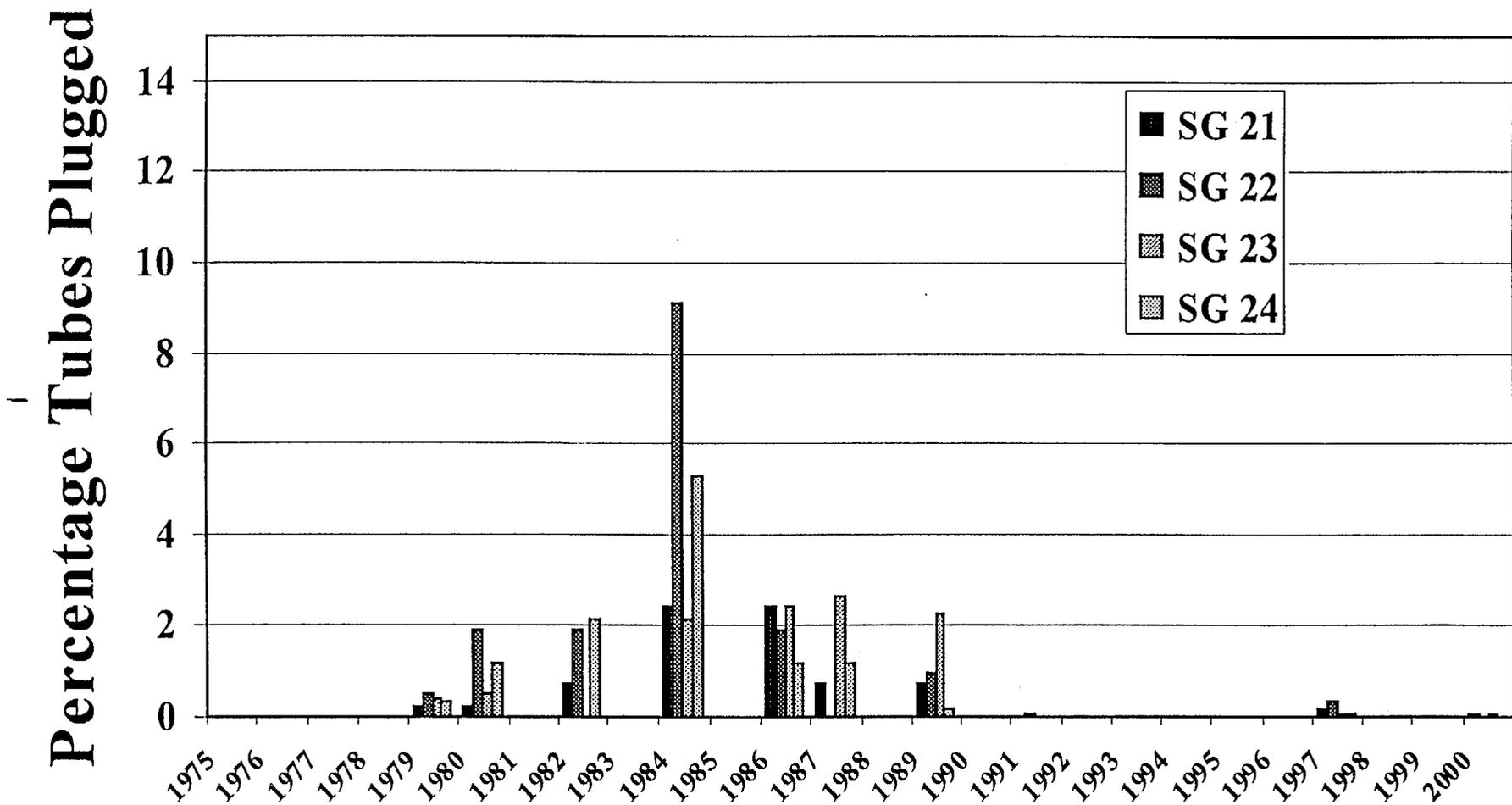
- **Proposed 2000 Primary to Secondary Leak limits**
  - **Base administrative limits on new EPRI guidelines, February 2000**

# **TUBE RESTRICTION HISTORY**

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- **Frequency of plugging due to 610 probe restrictions has not significantly increased**
- **2000 - 2 tubes plugged due to 610 probe restriction**
- **Data from 1997 & 2000 allows improved tracking**

# Tubes Plugged For 0.610" Probe Dent Restrictions



# COMPARISON OF TUBE/TUBE SUPPORT PLATE RESTRICTIONS FROM 1997 - 2000 STEAM GENERATOR 23

Location	Restriction Size		
	Smaller	No Change	Larger
TSP			
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%

- **13.94% of the intersections became more restricted**
- **70.19% did not change**
- **15.87% of the intersections became less restricted**
- **No history to compare**

# OTHER ISSUES

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- **Susceptibility of ALLOY 600**
  - PWSCC is a function of material, stress, environment
- **Material Anneal Temps - 1850 F**
- **Environment, T-hot - 590 F**
- **Primary Water Chemistry**
- **Stress - Evaluated separately by ALTRAN & Westinghouse**

# OTHER ISSUES

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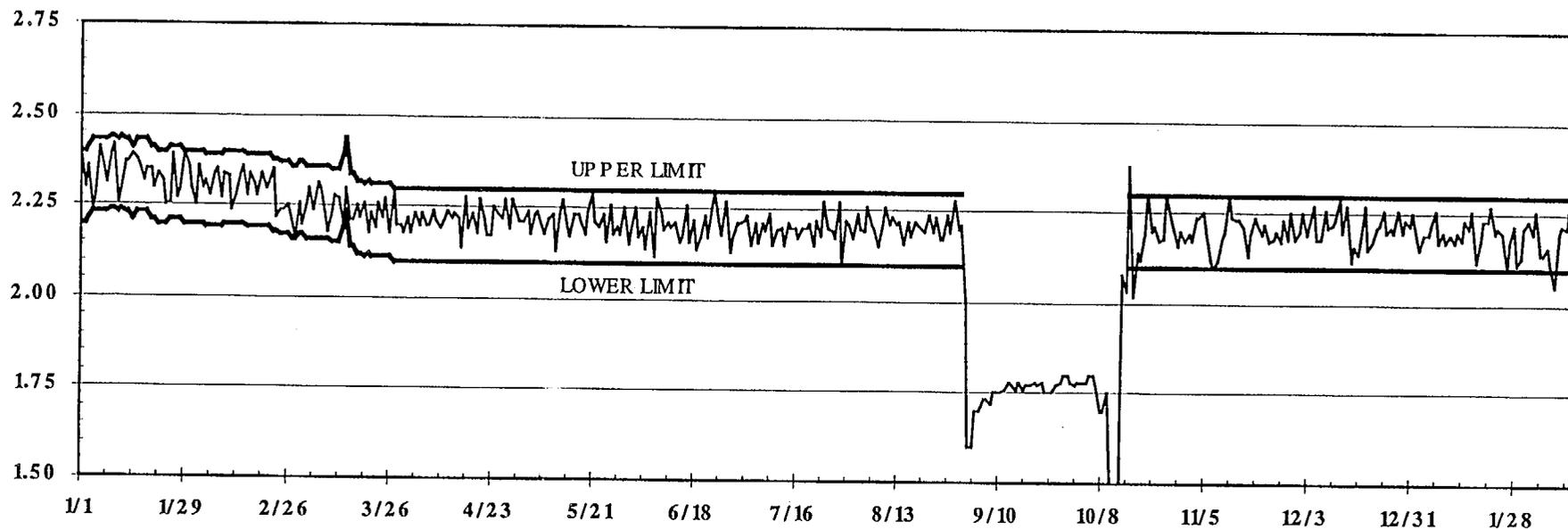
- **Primary Water Chemistry**
  - Followed industry guidelines
  - Boron/Lithium curve
  - Hydrogen concentrations
  - Assessed as not an issue

# OTHER ISSUES

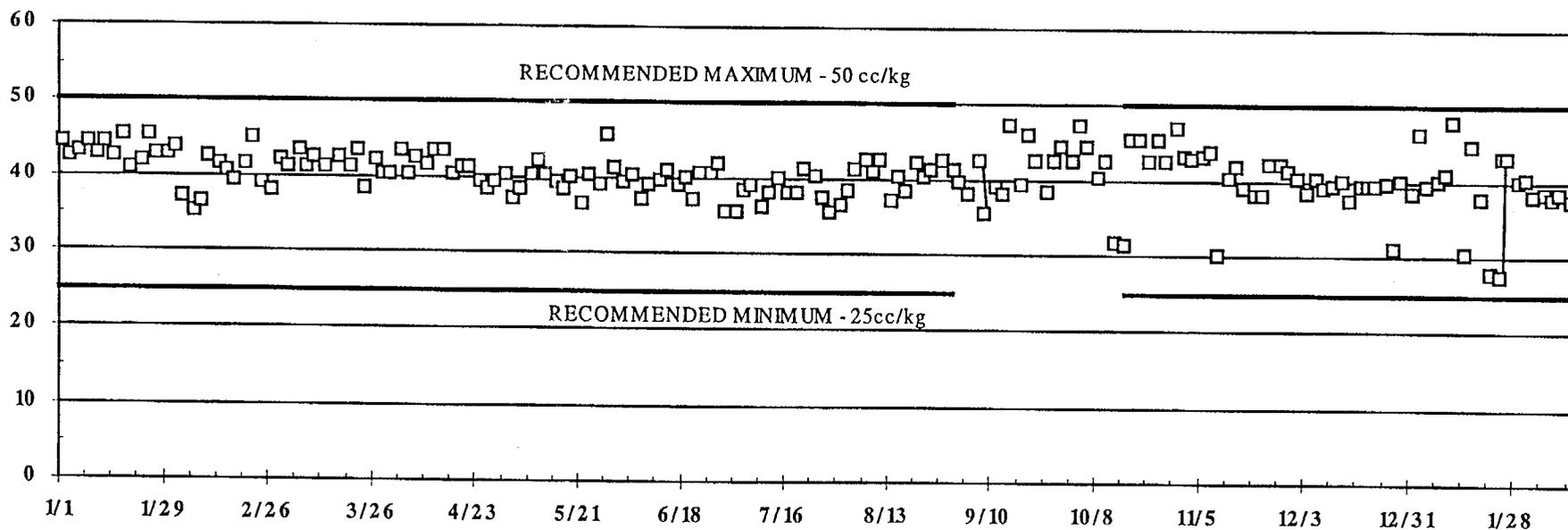
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- **ODSCC potential for ROW 2 U-bend apex consideration**
  - This was a consideration to plug ROW 2 and examine ROW 3 & 4
  - High frequency detection verified for ODSCC at top of tube sheet
  - Verified OD flaw detection on U-bend samples

# REACTOR COOLANT LITHIUM



# REACTOR COOLANT DISSOLVED HYDROGEN



# **ROW 2 - 1997 VIEWPOINT**

---

- **1997 Visual inspection of top support plate**
  - **Visual inspection performed on 22 & 23 steam generators**
    - **No cracking in 6<sup>TH</sup> support plate flowslot in 22 or 23 SG**
    - **No observable hourglassing**

# **ROW 2 - 1997 VIEWPOINT**

---

- **Inspection program consistent with industry standards**
- **Quality of data issue in EDDY CURRENT**
  - **+Point probe used for ROW 2 & 3 in 1997**
    - **Best probe available for U-bend**
  - **Program detected one PWSCC indication in R2/C67 in 24 SG**
  - **No indication detected in ROW 3 in 1997**

# **DEI REVIEW**

## **U-BEND PWSCC PREDICTIONS**

---

- **DEI was tasked to prepare tube degradation predictions for IP2 in 1995 and 1997.**
  - **Included U-bend PWSCC**
- **In 2000, DEI was asked to update 1997 predictions based on re-analysis of 1997 data.**

# **DEI REVIEW**

## **1995 U-BEND PWSCC PREDICTIONS**

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- **No U-bend cracks were detected through 1995.**
- **Predictions performed using industry data for time of first detection for Huntington tubes, and assumed rate of increase based on industry experience with PWSCC (Weibull slope of 3).**
- **No Cracks Predicted for 1997 or 2000.**
- **Main factors for low rate of PWSCC:**
  - **Low temperature**
  - **Huntington tubes**

# **DEI REVIEW**

## **1997 U-BEND PWSCC PREDICTIONS**

---

- **Single U-Bend PWSCC flaw detected in 1997.**
- **Predictions developed based on plant specific starting point (1 flaw) and rate of increase of roll transition PWSCC in Huntington tubes (Weibull slope of 4) (known to be consistent with U-bend slopes).**
- **Predicted 1 new flaw during next operating cycle.**

# **DEI REVIEW**

## **EVALUATION of IP 2 U-BEND PWSCC EXPERIENCE**

---

- **Rate of increase of U-Bend PWSCC at IP2 assessed using re-evaluation of 1997 data and mid range +Point results from 2000 (i.e. consistent inspection sensitivity)**
- **Assumes 3 flaws in 1997**
  - **5 cumulative flaws in 2000**
- **Above data give Weibull slope of 4.7**

# **DEI REVIEW**

## **EVALUATION of IP 2 U-BEND PWSCC EXPERIENCE (Cont.)**

---

- **Weibull slope of 4.7 is consistent with industry experience, and indicates that IP2 would experience about 8 new Row 2 flaws in the next fuel cycle (624 EFPD) if not preventively plugged, using high frequency probe**
- **Industry data:**
  - **EPRI report NP-7493 (1991) Figures 3-6, 7 & 8: Weibull slopes of 4.5, 4.4, and 4.2 for row 1 and 2 U-bends.**
  - **EPRI report TR-104030 (1994) Table 5-1: PWSCC median slope for row 1 and 2 U-bends about 4.4.**

# **DEI REVIEW**

## **EVALUATION of IP 2 U-BEND PWSCC EXPERIENCE (Cont.)**

---

- **Observed Weibull slope of 4.7 is within bounds used in analysis in 1997 (Weibull slopes assumed to range between 2 and 6, median of 4).**

# **DEI REVIEW**

## **Comment Regarding SCC Statistics**

---

- **SCC typically exhibits large scatter, with small numbers of early failures, and increasing numbers as time progresses.**
- **This pattern often modeled using Weibull statistics, with Weibull slopes in range of 2 to 6 commonly seen.**
- **Applying these slopes to IP2 indicates that moderate increases in numbers of new PWSCC flaws at Row 2 would be seen in future cycles, if tubes were not preventively plugged.**

# **DEI REVIEW**

## **Potential for Row 3 U-Bend PWSCC**

---

- **No known cases of row 3 U-bend PWSCC leaks in industry.**
- **No detected PWSCC in IP2 row 3 U-bends.**
- **Crack initiation in row 3 expected to be significantly later than in row 2 based on lower stresses and lower cold work.**
- **Crack growth rate expected to be lower than in row 2 based on lower stresses and lower cold work.**

# **DEI REVIEW**

**Potential for Row 3 U-Bend PWSCC (cont.)**

---

- **Conclusion: Very low likelihood of large flaws developing during next inspection interval based on:**
  - **Low potential for crack initiation**
  - **Low growth rate**
  - **Modified operating interval**

Indian Point 2  
Condition Monitoring  
Operational Assessment  
Plan

Tom Pitterle

Westinghouse Electric Company

# Definitions

- Condition Monitoring (Backwards Looking)
  - Evaluation of indications found this inspection against performance criteria
- Operational Assessment
  - Evaluation against performance criteria at the end of the next operating period
- Burst
  - Gross structural failure of tube wall---unstable opening displacement
  - Not ligament tearing

# Performance Criteria

- Steam generator tubing shall retain structural integrity over full range of operating conditions
  - Margin of 3 against burst under normal steady state full power operation
  - Margin of 1.4 against burst under SLB
- Primary to secondary accident induced leakage not to exceed 1 gpm. under SLB

# Issues

- Show that all structurally significant degradation has been detected and that which is undetected will not grow to be structurally significant during the next operating cycle
  - Probability of Detection (POD)
  - Growth Rate
  - NDE Sizing
- Complicating Factors
  - Secondary side scale deposits (copper) result in low signal to noise ratios making NDE data more difficult to interpret

# Tube Integrity Considerations

- *Low row U-bends (PWSCC)*
- Dented tube support plate intersections (primarily PWSCC but also potential for ODSCC)
- *Sludge pile (within 10" TTS)--(ODSCC)*
- Area just above sludge pile (ODSCC)
- Tubesheet region
  - Dents at TTS (primarily PWSCC but also potential for ODSCC)
  - Crevice region (ODSCC)
  - Roll transition (PWSCC)

# Low Row U-Bends

- R2C5 leaked in service
  - Would not have been “called”
  - Improvements in NDE would not leave an indication of this size in service in 2000 inspection
- POD
  - Improvements in analyst guidelines & training
  - High frequency probe has improved data quality & detection
    - Enhanced S/N ratio
    - Found additional smaller indications
    - No indications in rows 3 & 4
  - POD compared to other industry experience
    - PWSCC in symmetrical and axial dents

Figure 5-1. Comparisons of +Point Average Depth  
PODs

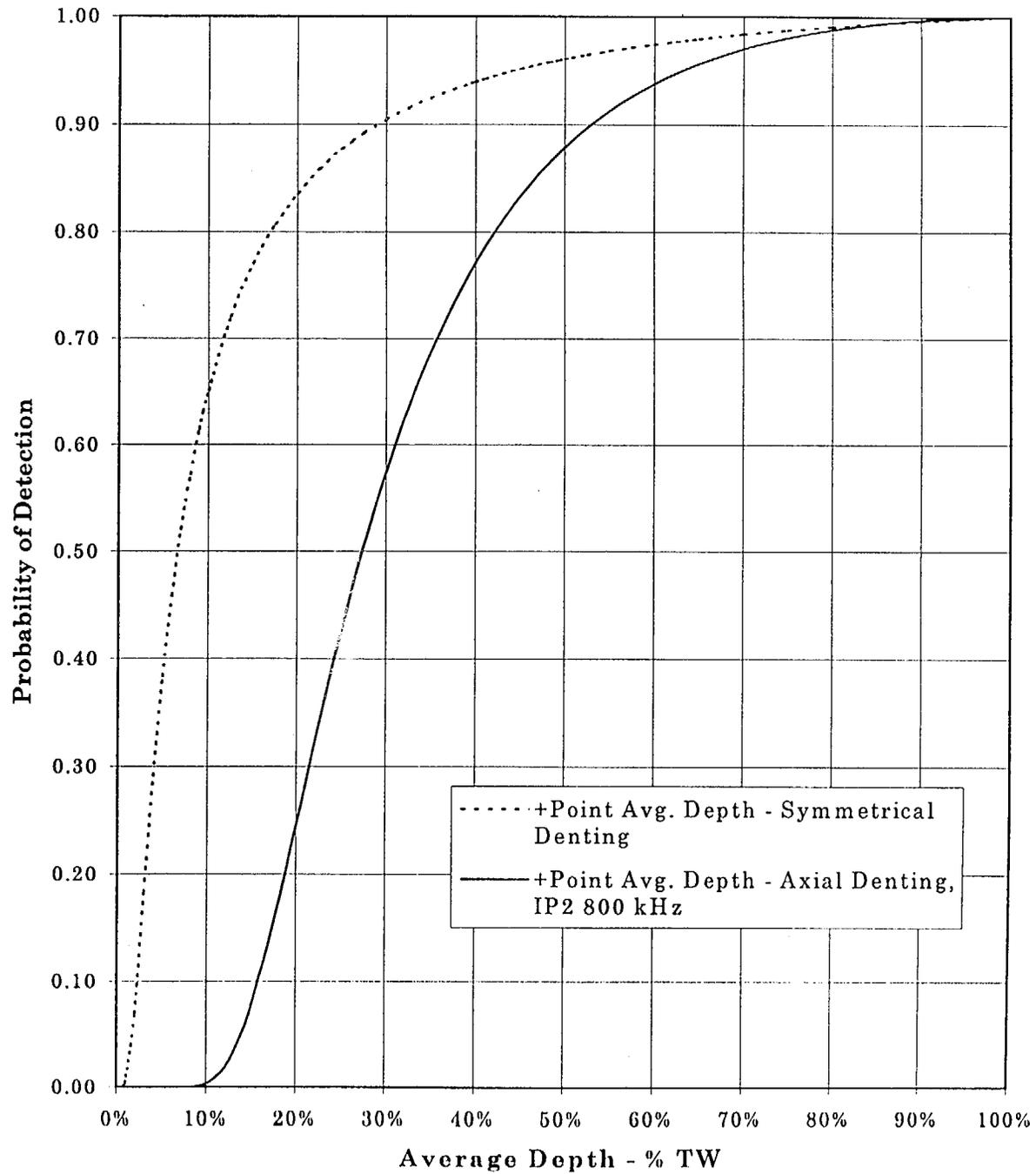
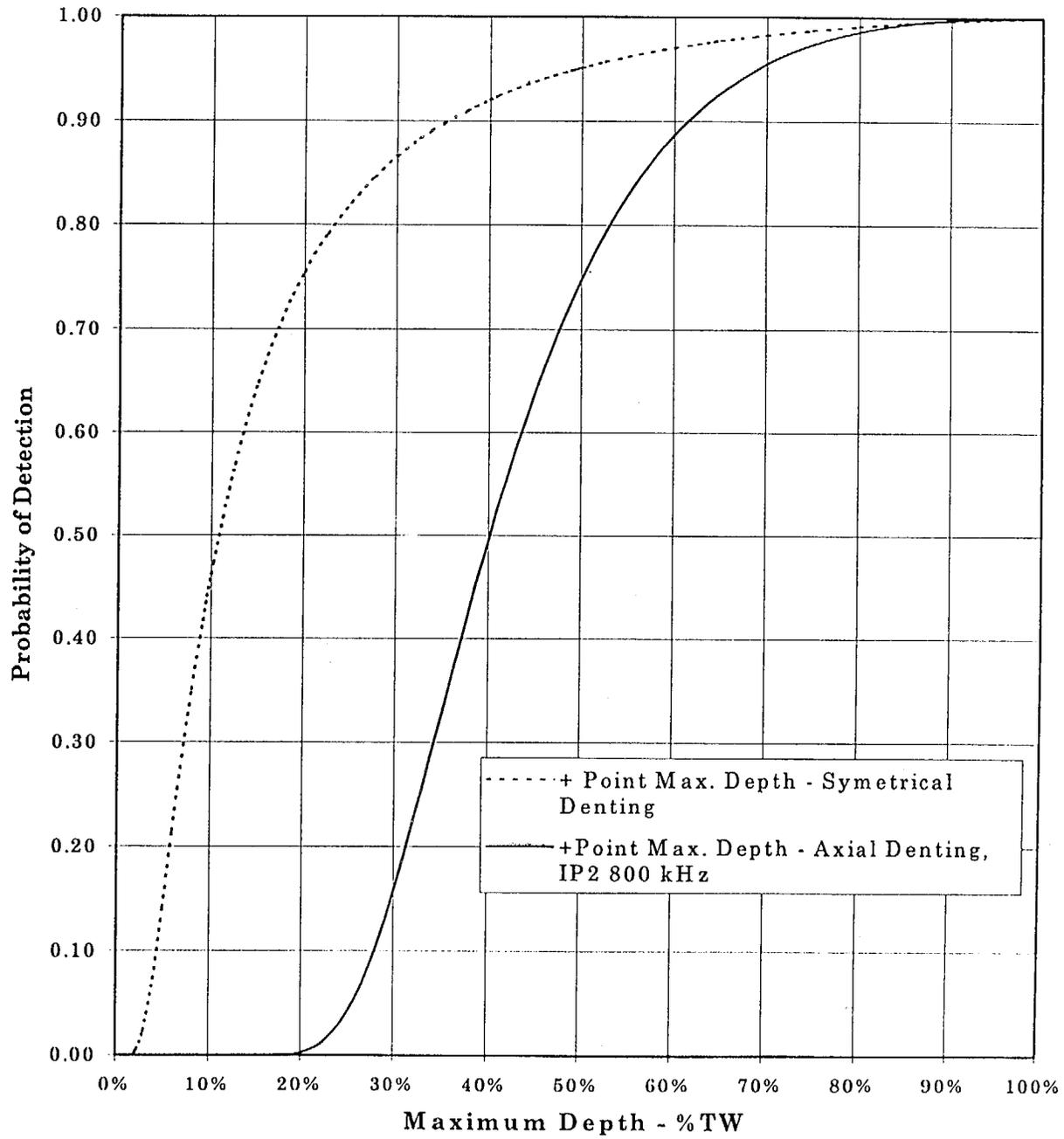


Figure 5-2. Comparisons of + Point Maximum Depth  
PODs

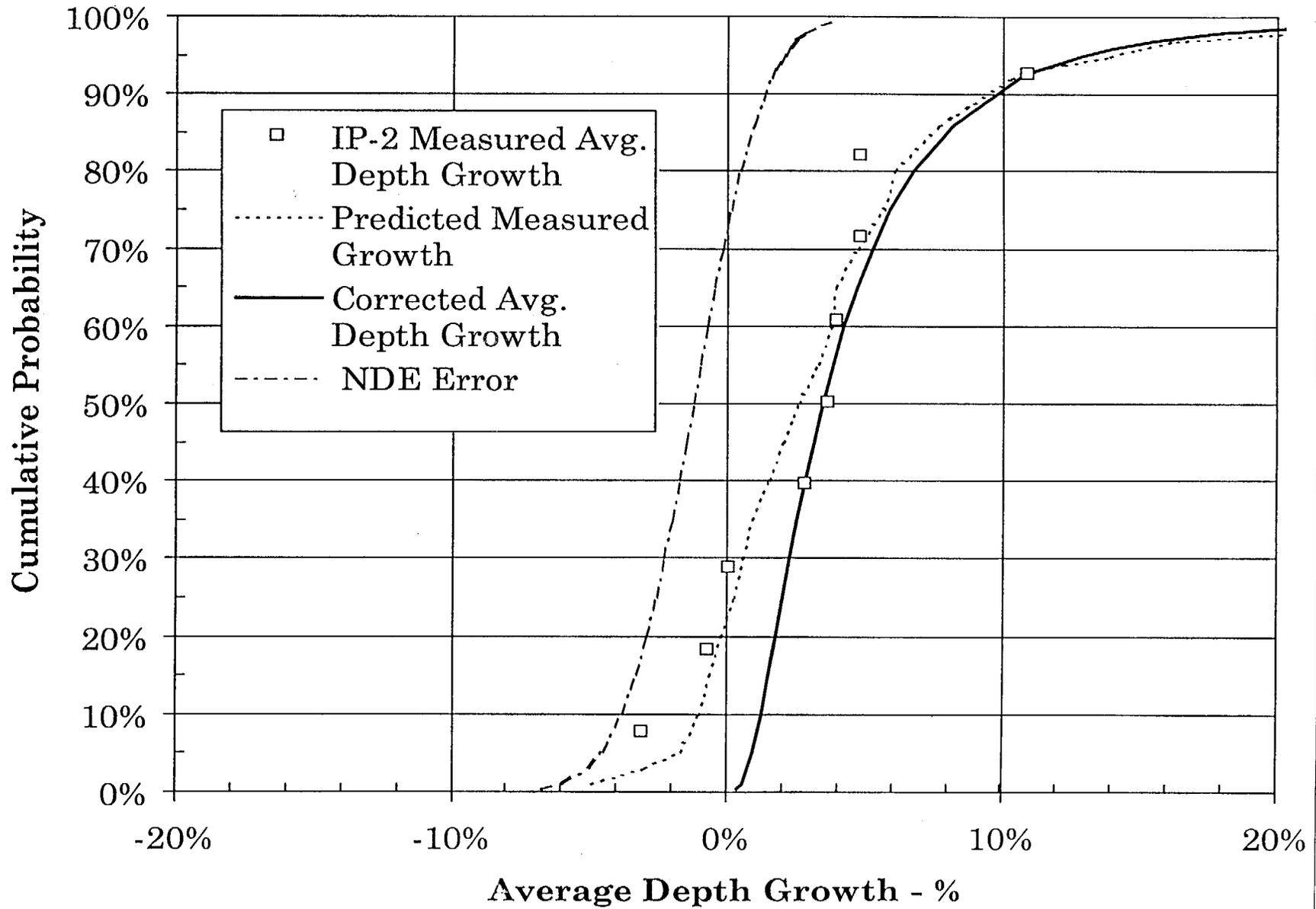


# Low Row U-Bends

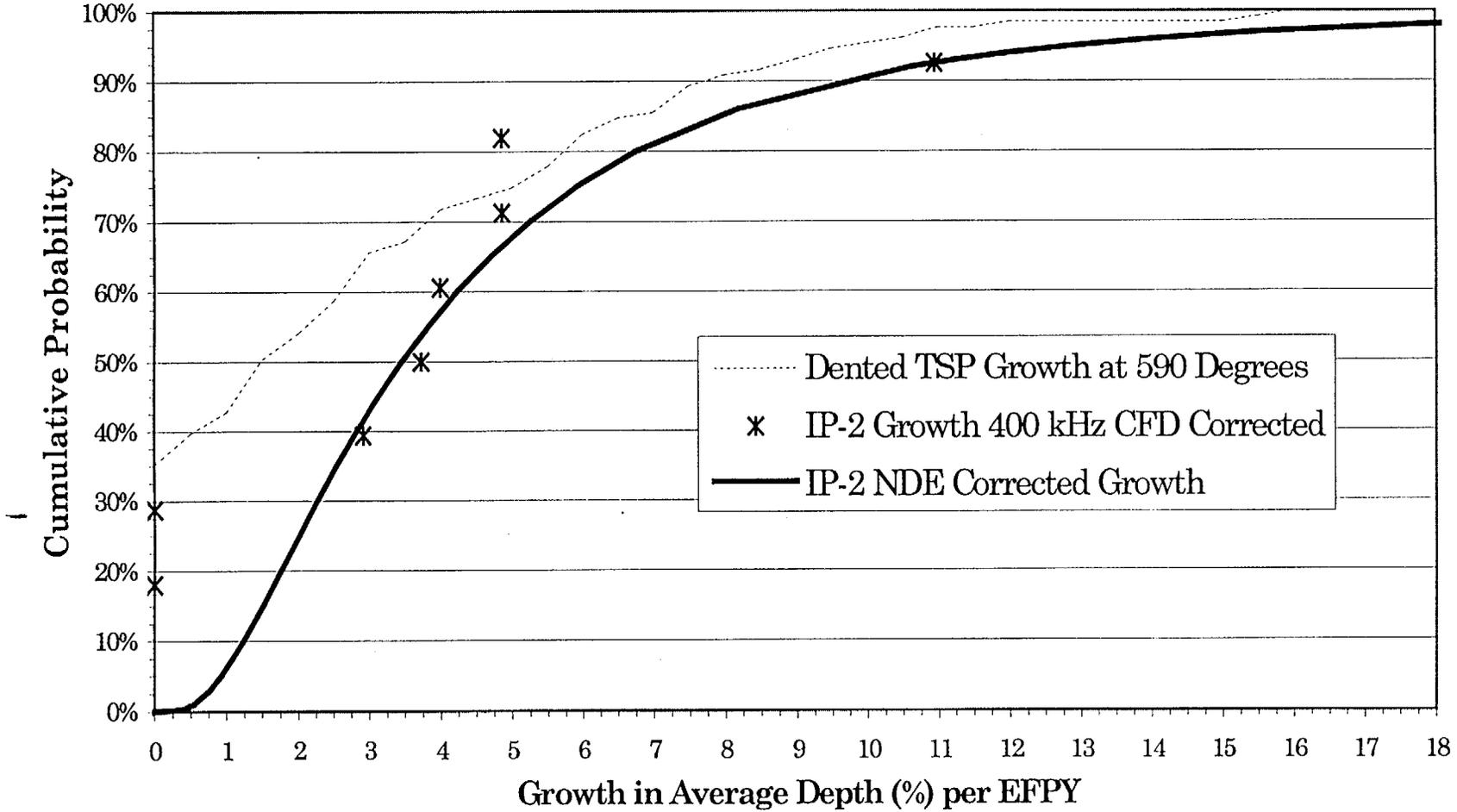
- Growth Rate
  - Establish operating period such that the largest “undetected” flaw will not grow to be structurally significant during next operating period
  - Combination of POD and growth rate determines operating period
- Determination of growth rate
  - Derive estimate from 9 indications in 5 tubes
    - Comparison of 400 KHz data
      - Must compare like data between 1997 & 2000
      - +Point sizing techniques based on 300-400 kHz techniques and uncertainties (std. dev. increased by 25%) from PWSCC at dented TSP intersections as used for PWSCC ARC (WCAP-15128)
      - 400 KHz sizing data more consistent with in-situ test results
    - Data adjusted for small sample size
  - Comparison to historical data from dented TSPs and other industry data



**Figure 5-3. Indian Point-2 U-bend Average Depth Growth Data and Distribution**



**Figure 5-5.**  
**Comparison of Indian Point-2 and Dented TSP PWSCC Growth at 590°F**  
**Burst Effective Average Depth (%)**



**Figure 5-8. Comparison of Indian Point-2 Best Estimate "True" Growth with Distribution for Operational Assessment**

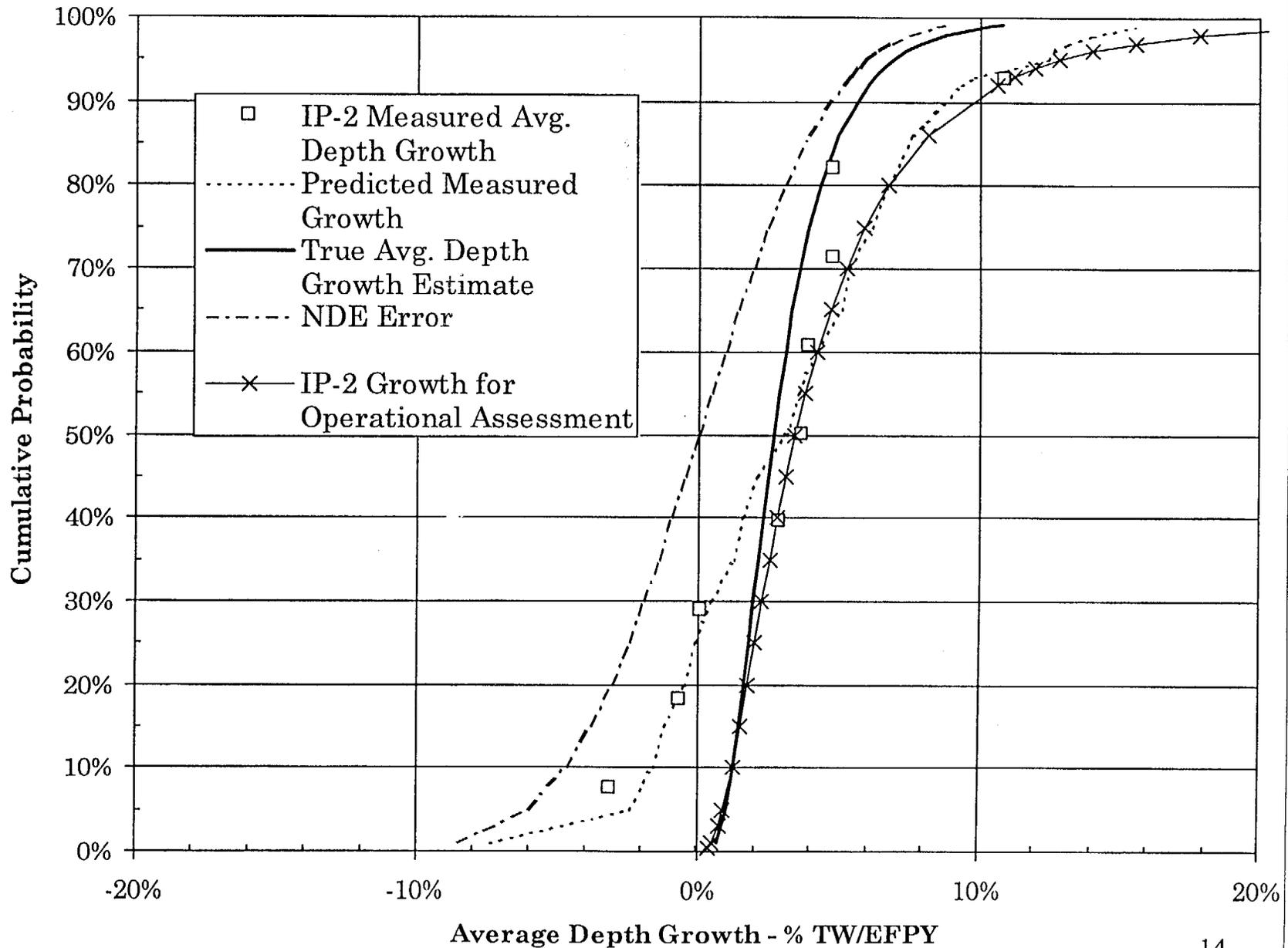


Figure 3-4. Indian Point-2: Comparison of SG 4 R2C69 400 and 800 kHz Depth Profiles

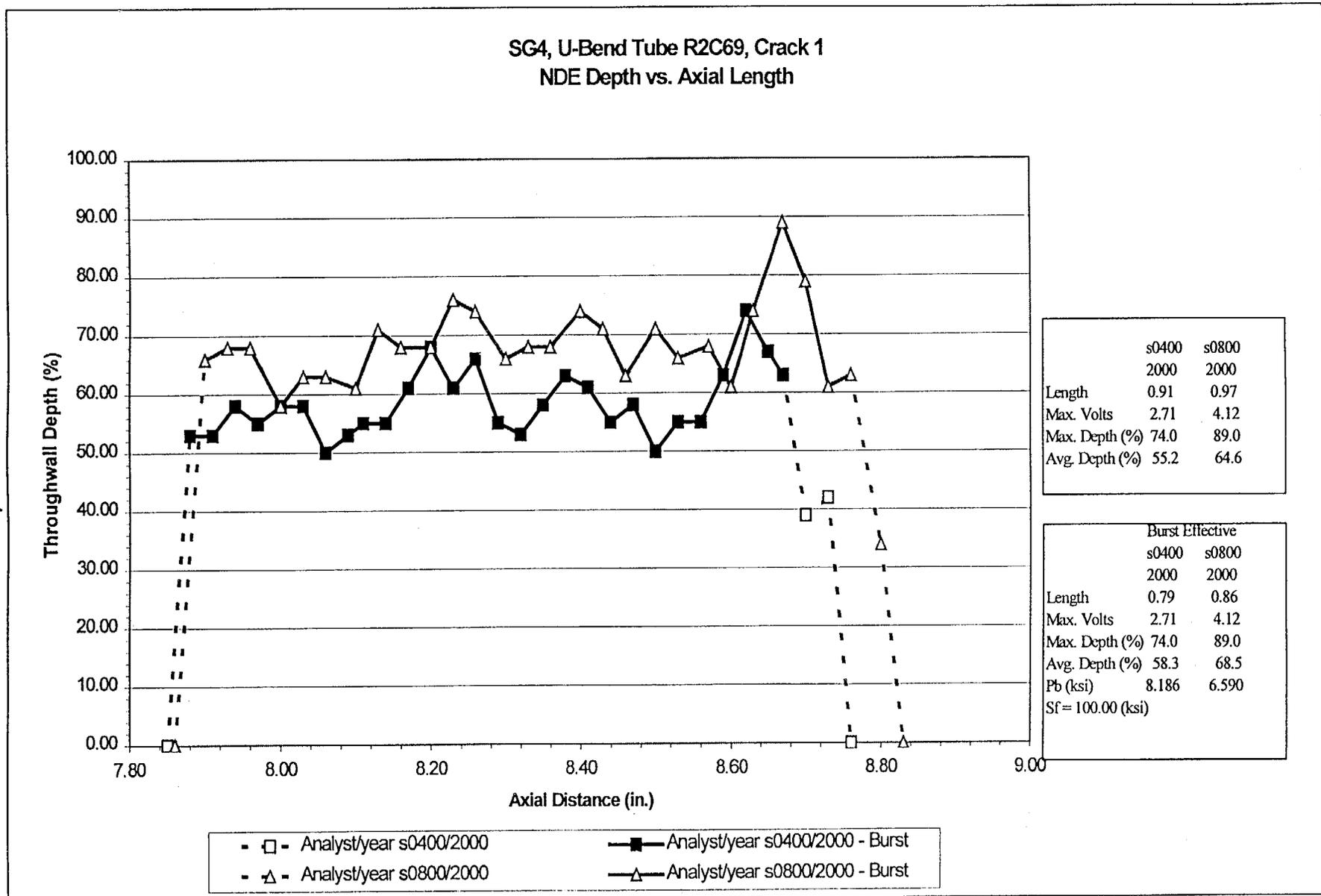
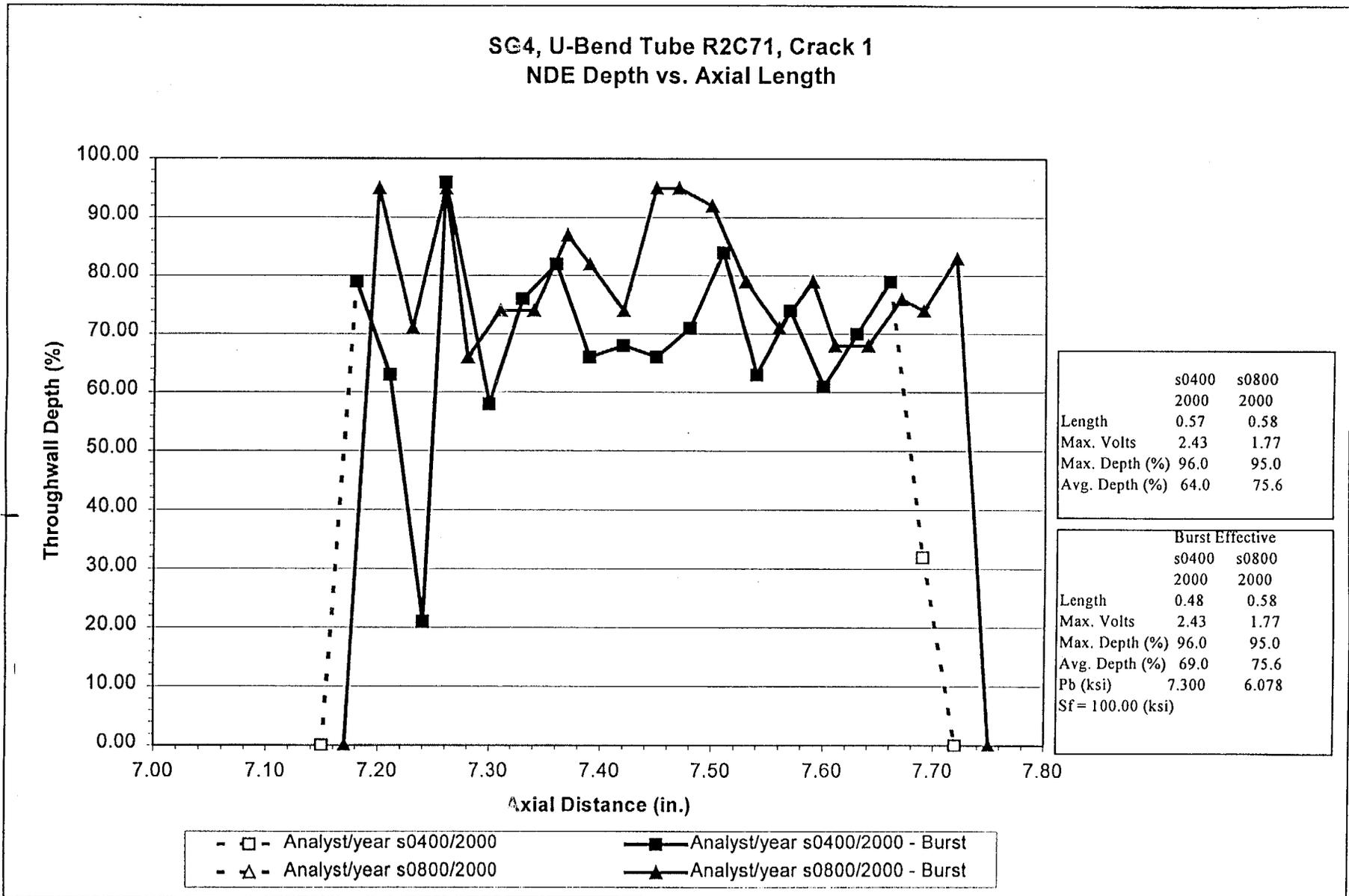


Figure 3-5. Indian Point-2: Comparison of SG 4 R2C71 400 and 800 kHz Depth Profiles



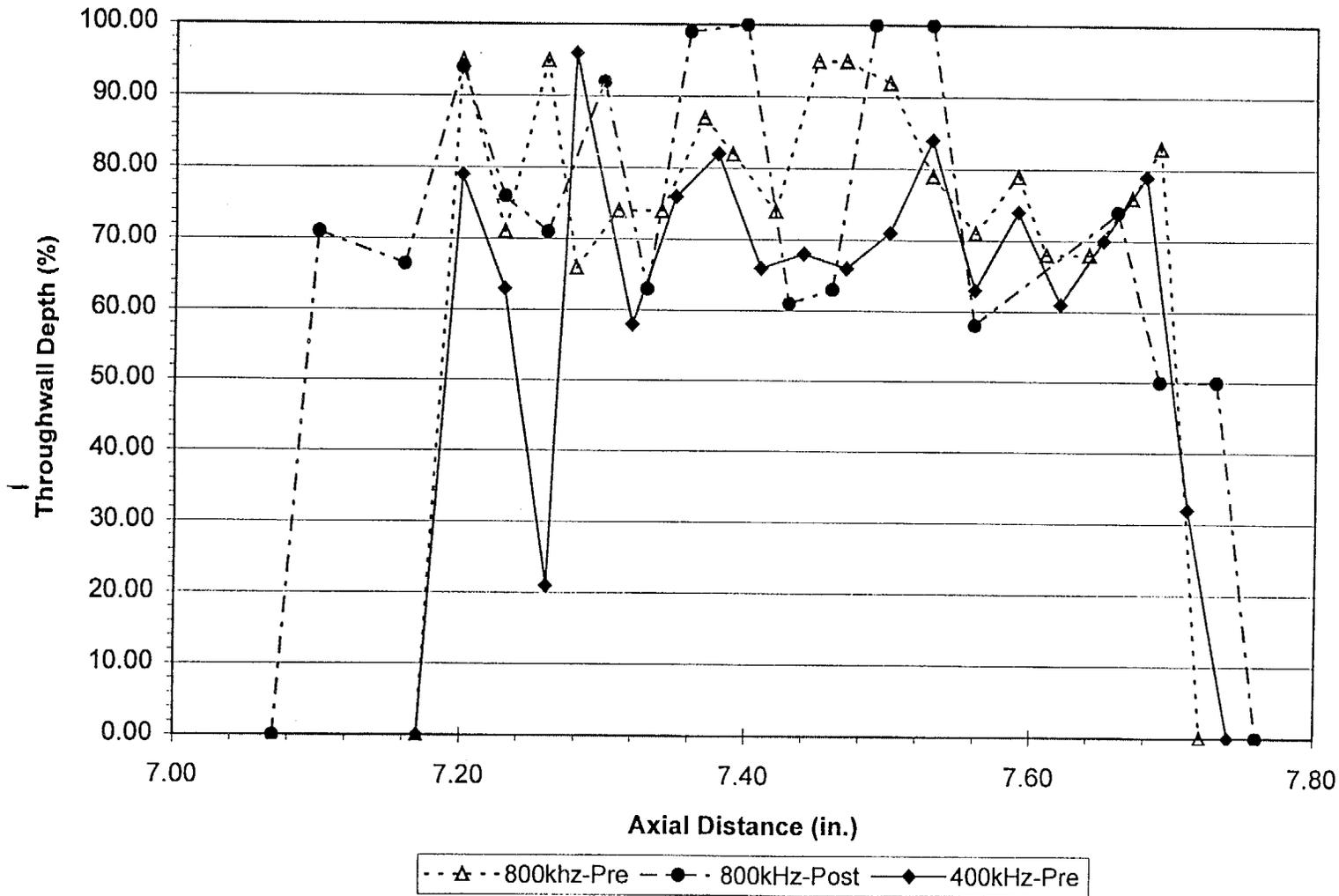
# Low Row U-Bends

- Ovality has little or beneficial effect, particularly row 3 compared to row 2
- Effect of leg displacement on operating stresses
  - Site measurements of displacements input to plate model
  - Plate model determines displacements by row
  - Determine stresses at apex due to plate displacement
  - Row 3 stresses less than row 2, etc.
  - Stress effects from leg displacement present in the past and not changing significantly with time
- Industry Experience
  - Industry data suggests row 3 is not a concern
  - Row 2 is now plugged at Indian Point-2

# Benchmarking of Analysis Methods and Data

- Benchmarking Analyses performed to support adequacy of data and methods
  - Demonstrate the methods provide conservative predictions of structural and leakage integrity at specified confidence
  - Provide integral test of NDE sizing technique, NDE uncertainty, and material properties
- Compare 1997 projections to 2000 data
  - R2C5 leakage
  - In situ tests
  - Comparisons with burst pressures and leakage from year 2000 profiles
- Compare analyses using year 2000 profiles with in situ test for burst pressure and leakage thresholds

**Figure 8-3**  
**SG 4, U-Bend Tube R2C71, Crack Depth Profiles**  
**Comparison of Pre and Post In Situ**  
**NDE Depth vs. Axial Length**



# Low Row U-Bend In Situ Tests

- In-Situ testing--total 10 tubes
  - Tested to as high a pressure as possible to demonstrate margin (5500 psi.)
  - Test results used to benchmark tube integrity analysis methods
- Tested all indications
  - Test results met NEI-97-06 Criteria ( $3\Delta P_{NO} = 4617$  psi, hot)
- R2C71 in situ test
  - Test limited to 4206 psi (hot) by progressively increasing leakage
  - NDE and post peak pressure leak rates show short TW (<0.39")
  - Indication has not reached full ligament tearing of deep section ( $\approx 0.5$ "") and burst pressure would be about 300 psi above tearing
- Tested 3 NDD tubes to  $>3\Delta P_{NO}$  (5173psi)
  - 2 Row 2 tubes, 1 Row 3 tube
  - No leaks & no indications in post test NDE

# Low Row U-Bend Operational Assessment

- Row 3 is now the limiting row
  - No Indian Point-2 indications found in row 3
  - Industry experience for Model 44/51 is no cracking in row 3
    - Higher operating temperature plants with no row 3 heat treated tubes
- Operating period very conservatively calculated by assuming indications found in row 2 were found in row 3
  - High frequency probe POD
  - POD correction per NRC GL 95-05 applied to account for potential undetected indications
- Analysis methods employed
  - Reference analysis is single cycle profile analysis as applied for PWSCC ARC at dented TSP intersections (WCAP-15128 Rev. 2)
  - Multi-cycle analysis methodology as independent check and guide to crack initiation history

# Dented TSP Intersections

- Cecco results
- Qualification accepted by NRC
- No Cecco indications confirmed as flaws by  
+Point inspection

# Area Above Sludge Pile

- Inspected with CECCO/bobbin probe
- 20% of tubes in each steam generator inspected with +Pt. to just below 1st TSP
  - Confirmed CECCO overcalls in this region
- 23 tubes in one steam generator inspected through 1st TSP with UTEC
  - UT inspection lessened influence of copper
  - 1 tube could not be inspected through 1st TSP
  - 2 tubes inspected after in-situ test
  - Confirmed CECCO calls
- 5 tubes in-situ tested in this region
  - All met NEI-97-06 structural and leakage criteria

# Sludge Pile

- Detect with Cecco/confirm with + Point
  - Confirmation rate lower than qualification data
- Inspected 100% of hot leg tubes with + Point from TEH to 24” above top of tubesheet
  - Found a total of 6 small indications not found by CECCO
- UTEC inspection of 23 tubes in 1 steam generator
  - Confirmed CECCO calls
- 31 tubes in-situ tested in this region
  - All met NEI-97-06 structural and leakage criteria
  - R34C51: peak test pressure = 4985 psi = 4591 psi hot
  - Burst margin =  $4591/1539(\Delta P_{NO}) = 2.98 = 3\Delta P_{NO}$  burst margin

# Cold Leg Program

- Initial inspection with CECCO/bobbin probe
- Inspected 20% of 1 steam generator with +Pt from TEC to just below 1st TSP
- Inspected 20% of each of the other 3 steam generators with +Pt from TEC to 24" above top of tubesheet
- No crack-like indications found
- S/G 23 & 24 expanded to 40% due to pit indications
  - All pit indications plugged

# Tubesheet Region

- Within tubesheet, burst prevented by tubesheet constraint
- Cecco/+ Point correlation similar to qualification
- Less of an influence of copper
- However---one indication within crevice did grow larger (crack opening and probable tearing) after an in situ test
  - to 5000 psi for another indication
- Tubesheet region included in 100% H/L +PT. inspection and 20% C/L inspection
- In-situ tested 5 indications
  - All met NEI-97-06 leakage criteria

# Other Tube Degradation Considerations

- Plugging all pits
- AVB wear is well understood
  - Growth rate consistent with industry experience
- Support plate condition
  - Analysis shows plates maintain tube integrity support function
- Wear due to loose parts also being evaluated

# **Indian Point Unit 2**

## **U-Bend PWSCC Susceptibility Investigation**

**Status Report  
May 3, 2000**

Altran Corporation  
451 D Street  
Boston, MA 02210  
(617) 204-1000  
Fax (617) 204-1011

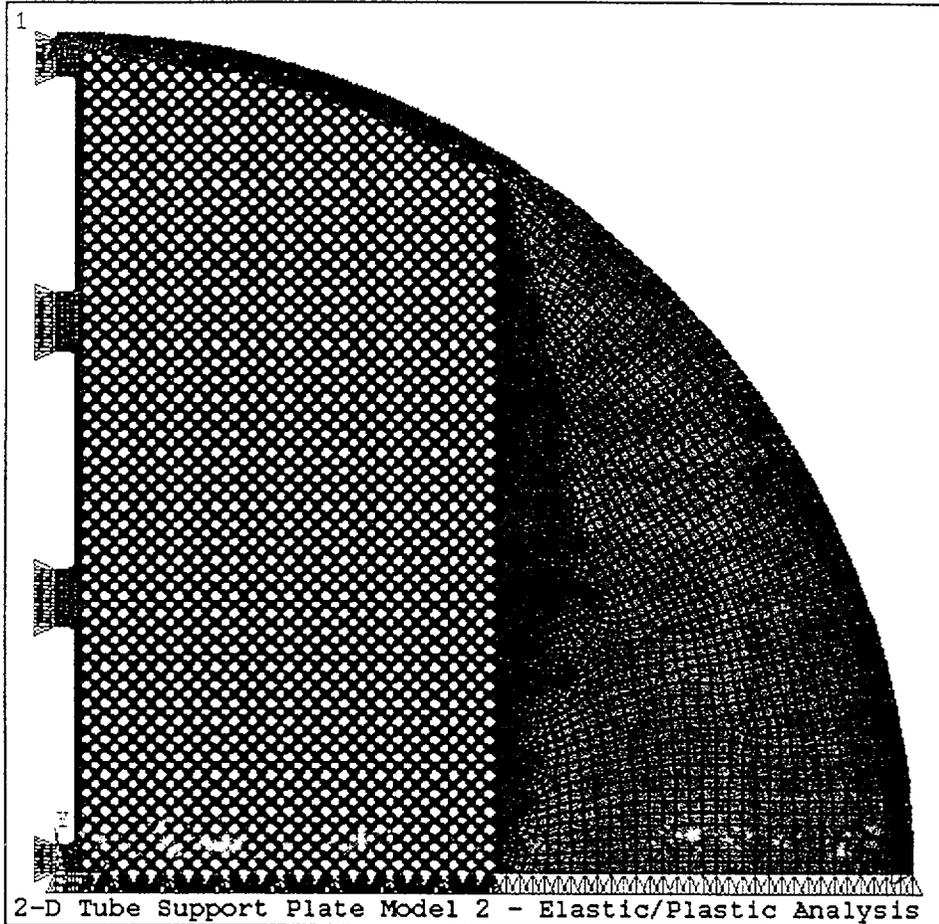
**altran**

# U-Bend Tube Investigations

- Purpose: Determine Relative Susceptibility of Small Radius U-Bends to PWSCC
- Approach:
  - Determine tube displacements for specified amount of hour-glassing
  - Determine stresses in U-bends due to TSP deformation and other operating conditions
  - Determine the residual stresses
  - Assess time to initiate cracking due to PWSCC
  - Estimate life expectancy of Row 3 tubes relative to Row 2 tubes
- Analyses and tests performed
  - Tests performed on Row 2 and Row 3 tubes provided by EPRI
  - Stress Analyses performed for Row 2 and higher rows of tubes

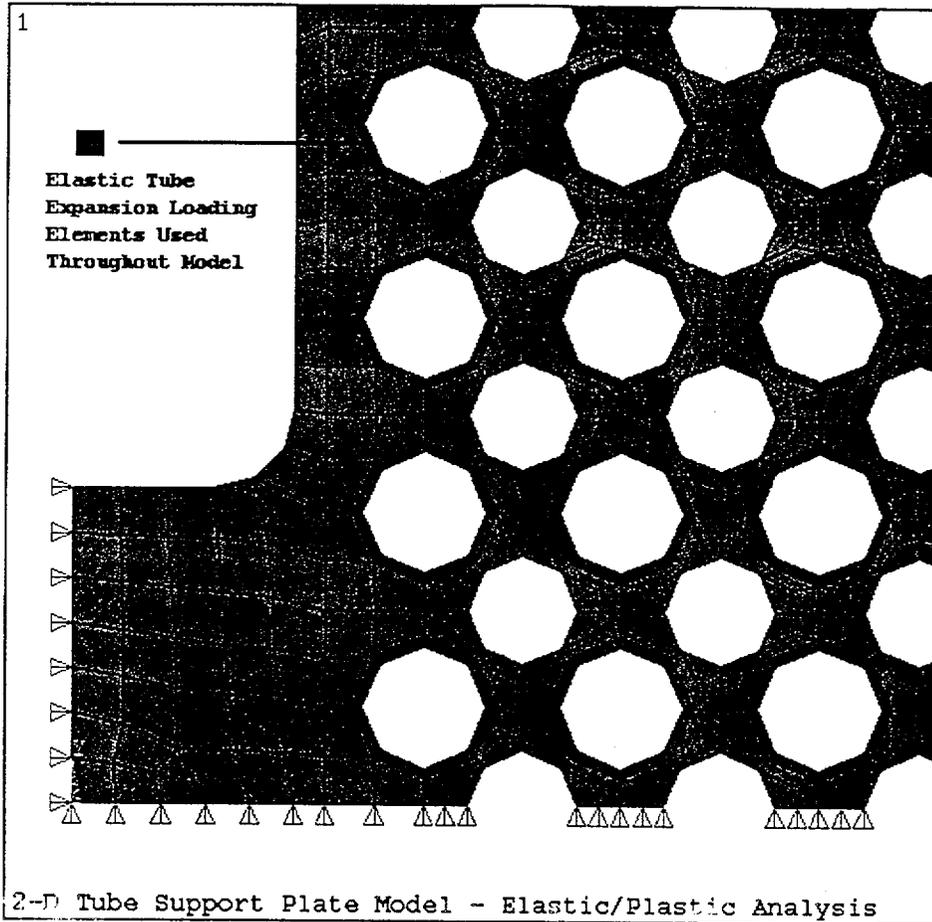
## **Tube Support Plate Motion**

- Analysis Objective: Quantify the movement of Row 2 and 3 tubes for a given amount of hour-glassing
- Analysis Assumptions
  - 3-D Elastic/Plastic Finite Element Model
  - Model consisted of a Quarter Plate
  - Applied corrosion packing loads inside tube holes simulated by thermally expanding elements inside the tube hole
- Corrosion packing load causes in-plane compression in the TSP and hour-glassing at the flow slot
- Analyses performed represent the measured total hour-glassing at flow slot of 476 mils.
  - Row 2 tube displaces approx. 63% to 97% of the flow slot deformation
  - Row 3 tubes displace approx. 63% to 92% of the flow slot deformation

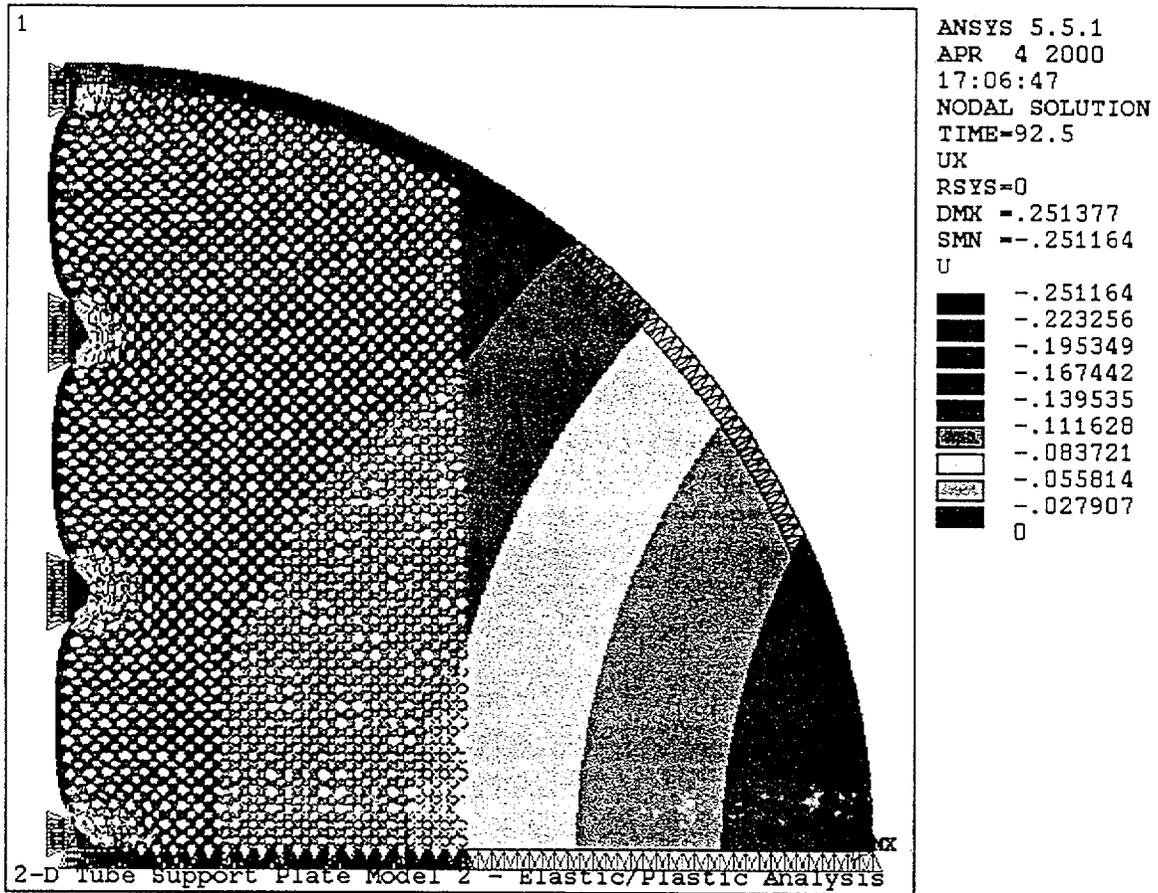


ANSYS 5.5.1  
APR 5 2000  
11:34:16  
ELEMENTS  
MAT NUM  
U

## Tube Support Plate Finite Element Model



## **Tube Support Plate Flow Slot/Hole Region Finite Element Plot**



**Full Quarter TSP Model – Shown with Exaggerated Displacements at Flow Slots**

X-Displ. Normalized to R1C7 of Outer Slot				
Column No.	Row 1	Row 2	Row 3	Row 4
3	67	63	63	63
4	85	81	76	73
5	93	90	85	80
6	98	94	90	85
7	100	97	92	87
8	100	97	92	87
9	99	96	91	86
10	96	93	88	83
11	91	88	83	78
12	83	79	74	71
13	67	63	62	63

**X-Displacement for the Tubes at Outer Slot from  
the Quarter Model;  
(Values Normalized In Percentage to the  
Maximum Displacement of Tube R1C7)**

## U-Bend Tube Investigations

- Stress Analysis Objectives: Quantify Row 2 and 3 tube stresses due to TSP #6 hour glassing
- 3-D Elastic/Plastic Finite Element Model
- Effects include:
  - Temperature and Pressure
  - 0.003” of tube wall thinning and thickening (all rows the same)
  - Residual Stresses (determined from testing)
  - Imposed U-bend leg displacement due to hour glassing
  - Strain hardening in U-bend increases yield strength by approximately 50%
- Analysis performed with 0.238” one side hour glassing
- Range of yield strength data from IP2 Generator tube CMTR, adjusted for strain hardening and operating temperatures.

## **As-Bent Ovality and Thinning**

- Row 2 and 3 U-Tubes were located in the EPRI archives.
- Similar geometry to IP2 tubes – 7/8” tubes with 0.050” walls
- Performed material composition and mechanical property testing
- As-received tubes used for ovality measurements, wall thinning measurements, and measurement of yield stress in bend versus straight run

## As-Received U-Tube Samples

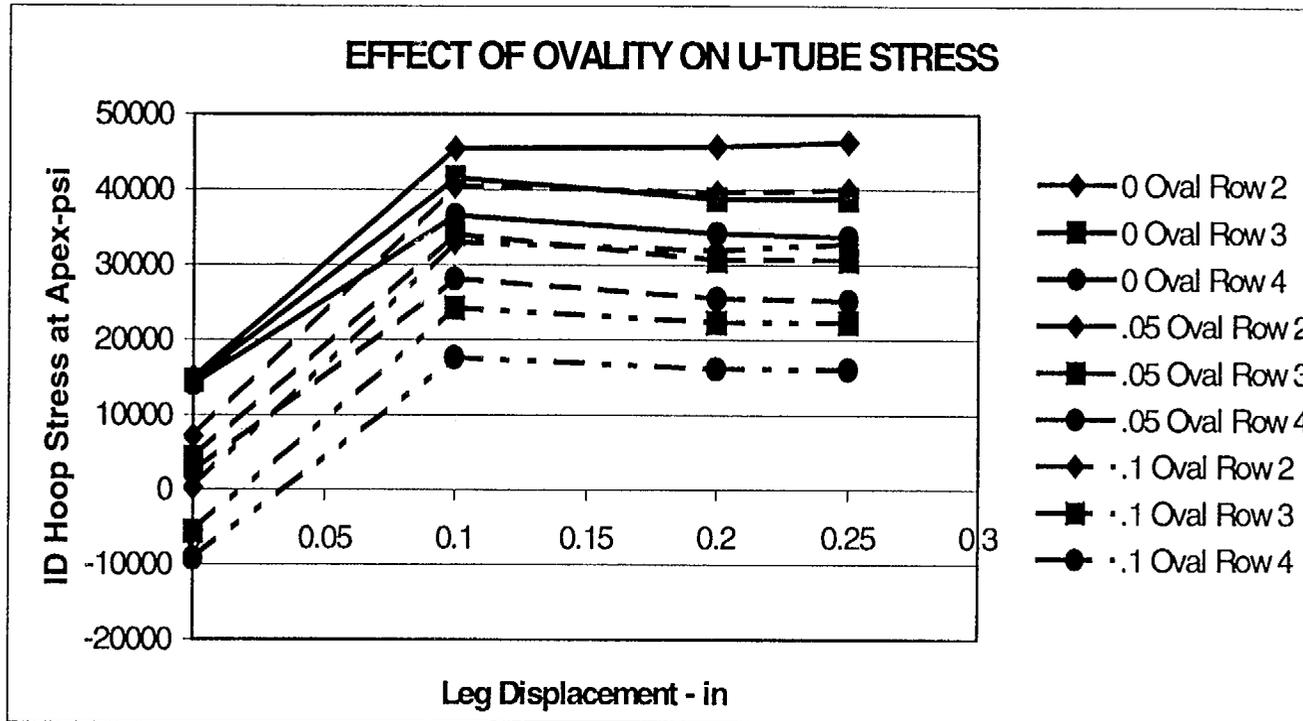
<b>Sample Number</b>	<b>Tube Row</b>	<b>Wall Thinning (in.)</b>	<b>Percent Ovality</b>
00603-1	2	0.003	4.99
00603-2	2	0.003	5.48
00603-6	2	0.004	2.28
00603-3	3	0.004	5.30
00603-4	3	0.004	5.65
00603-5	3	0.002	4.99

## Ovality Investigation

- Purpose: Investigate effect of as-manufactured ovality and U-tube leg displacements on apex stresses.
- Elastic-Plastic finite element model with ovality for Rows 2, 3 and 4
- Ovality: 0, 0.05, and 0.10

$$\text{Ovality} = \frac{(\text{Flank Dia.} - \text{Extrados/Intrados Dia.})}{\text{StraightLegDia.}}$$

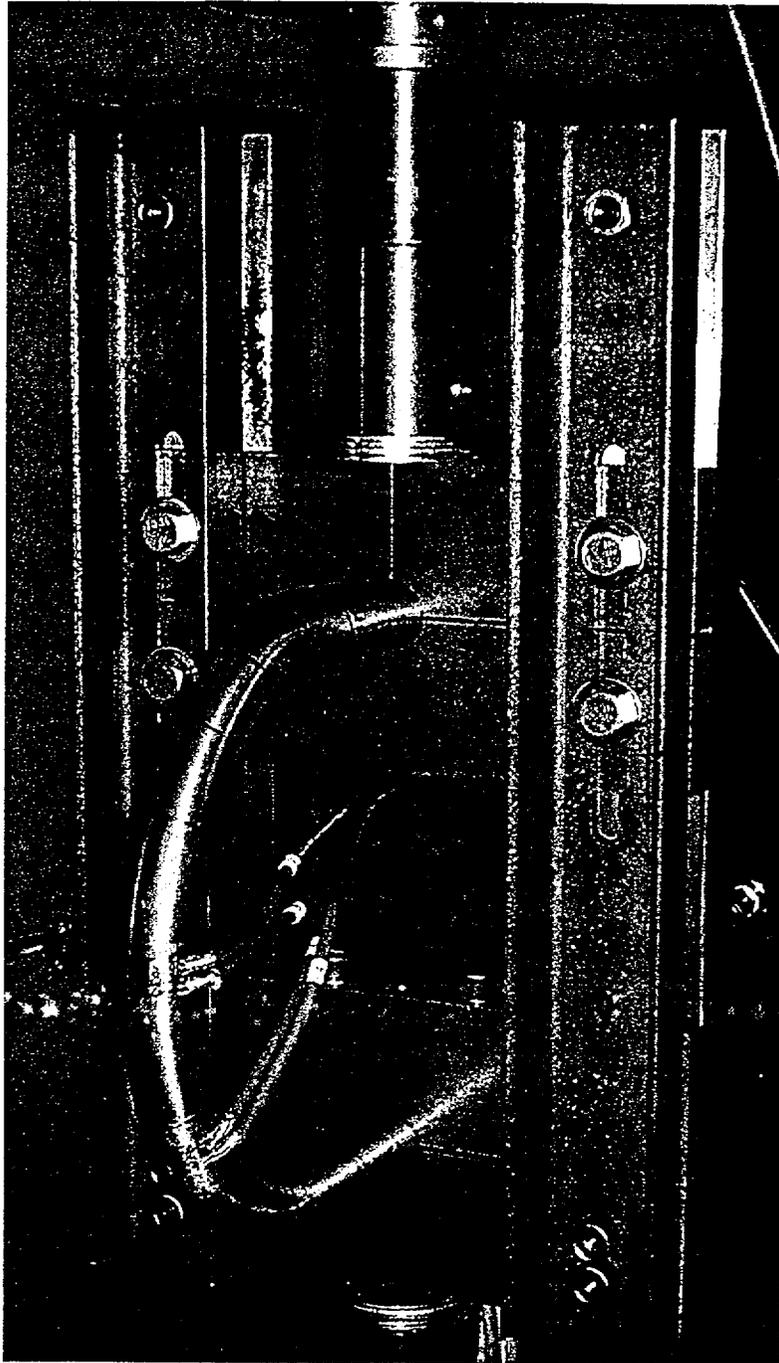
- Lateral displacement of one leg: 0.”, 0.1” , 0.2” and 0.25”
- A U-bend analysis model with a circular cross section will result in conservative ID hoop stress values at the apex.



**Comparison of ID Hoop Stress of the Extrados at the Apex  
(Analysis performed with yield stress of 40 ksi)**

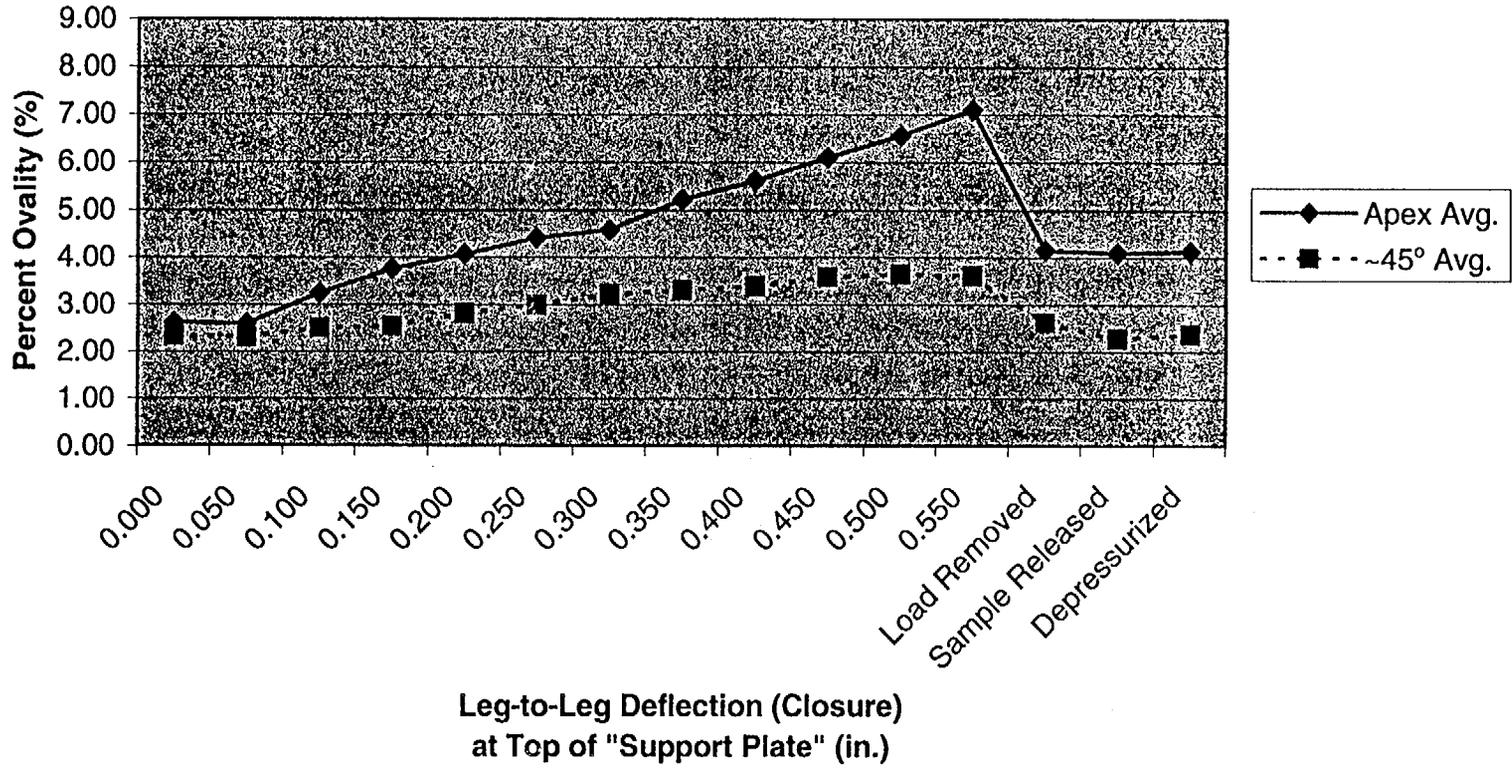
## **U-Bend Leg Displacement Test**

- Fixture designed to apply boundary conditions that allow almost no rotation to simulate the support plate hour-glassing.
- Incremental displacement applied while internally pressurized
- Ovalization, Strain, and Displacement measured

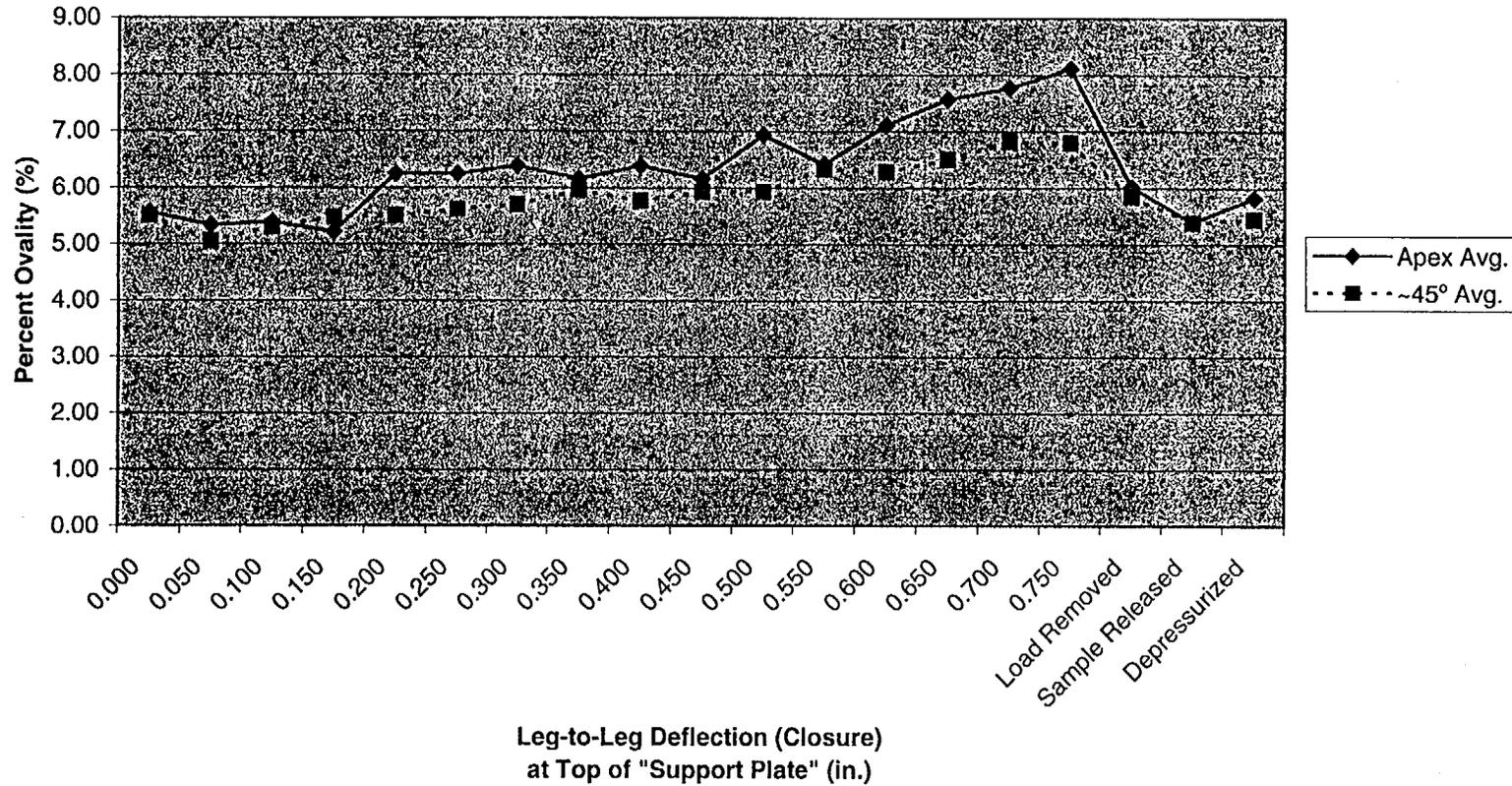


**Sample 00603-6 in Test Fixture  
Prior to Testing**

U-Bend Deflection Test  
Sample 00603-6  
Row 2 U-Bend

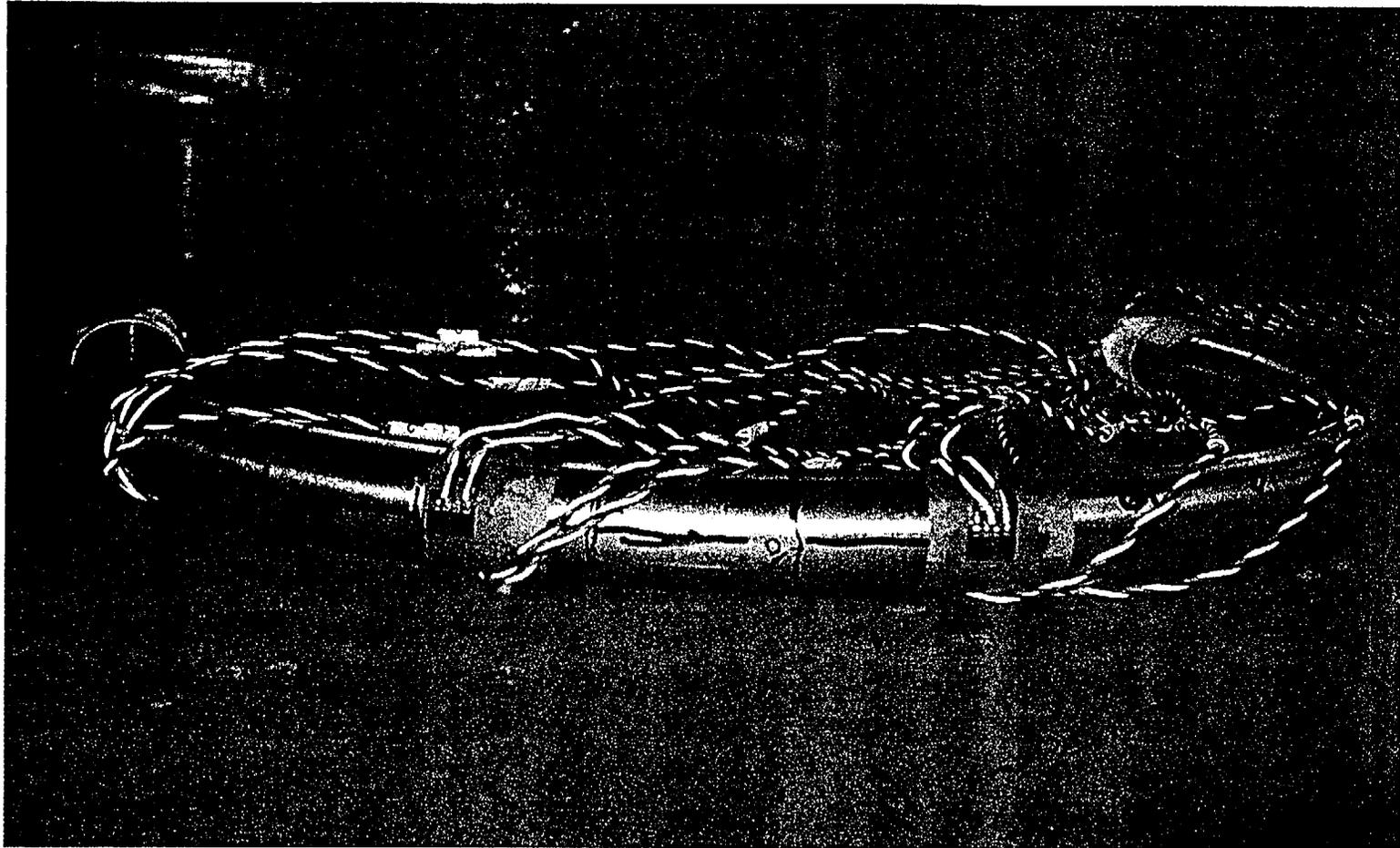


U-Bend Deflection Test  
Sample 00603-5  
Row 3 U-Bend

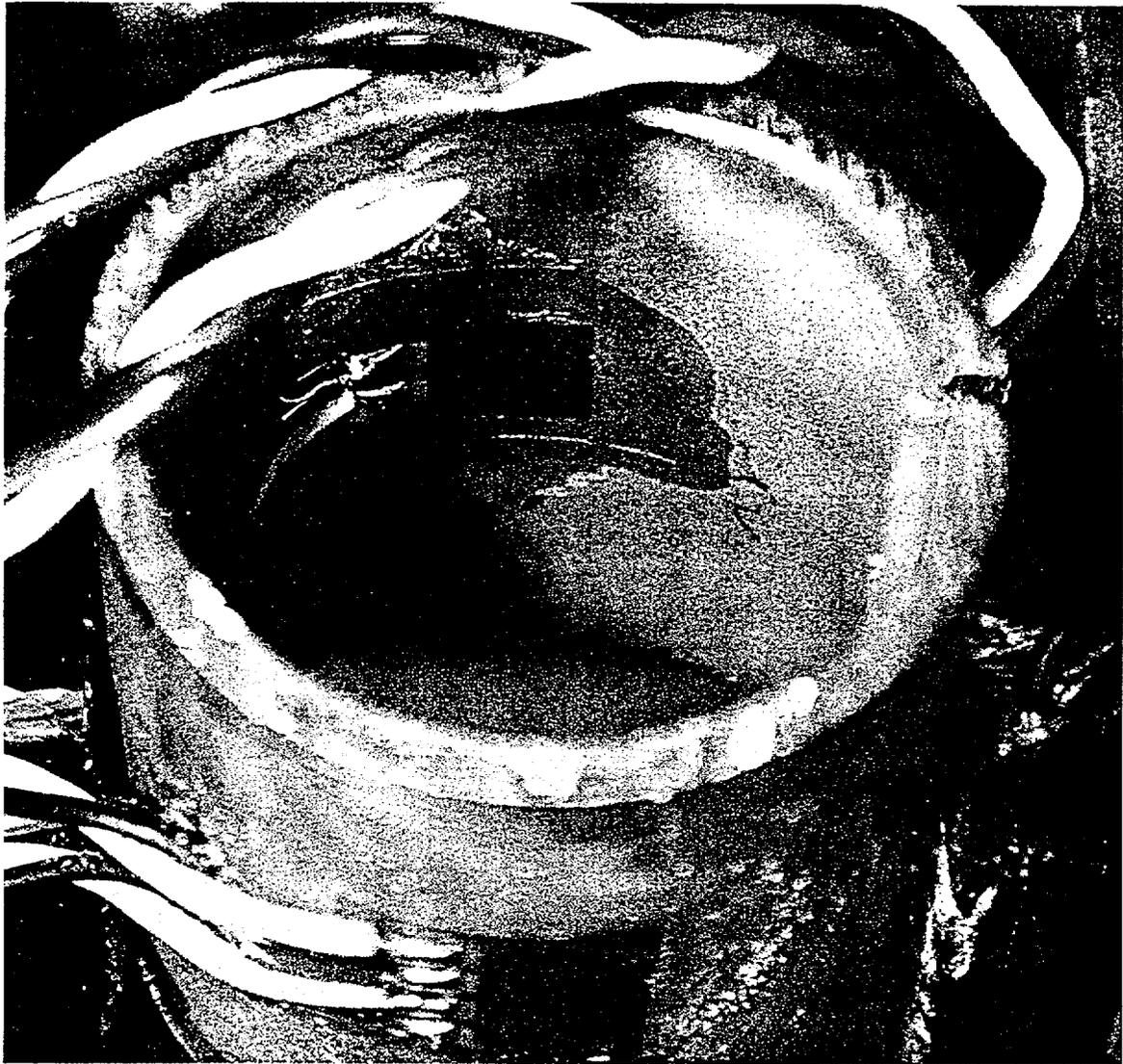


## Residual Stresses

- Tests to determine the residual stress were performed.
- OD strain gages were applied to a Row 2 and a Row 3 tube and the “restraint” initially relieved by cutting the tubes circumferentially.
- ID gages then applied and the tubes were cut axially



**Strain Gages Attached to Extrados  
For Residual Stress Measurement  
Sample 00603-4**

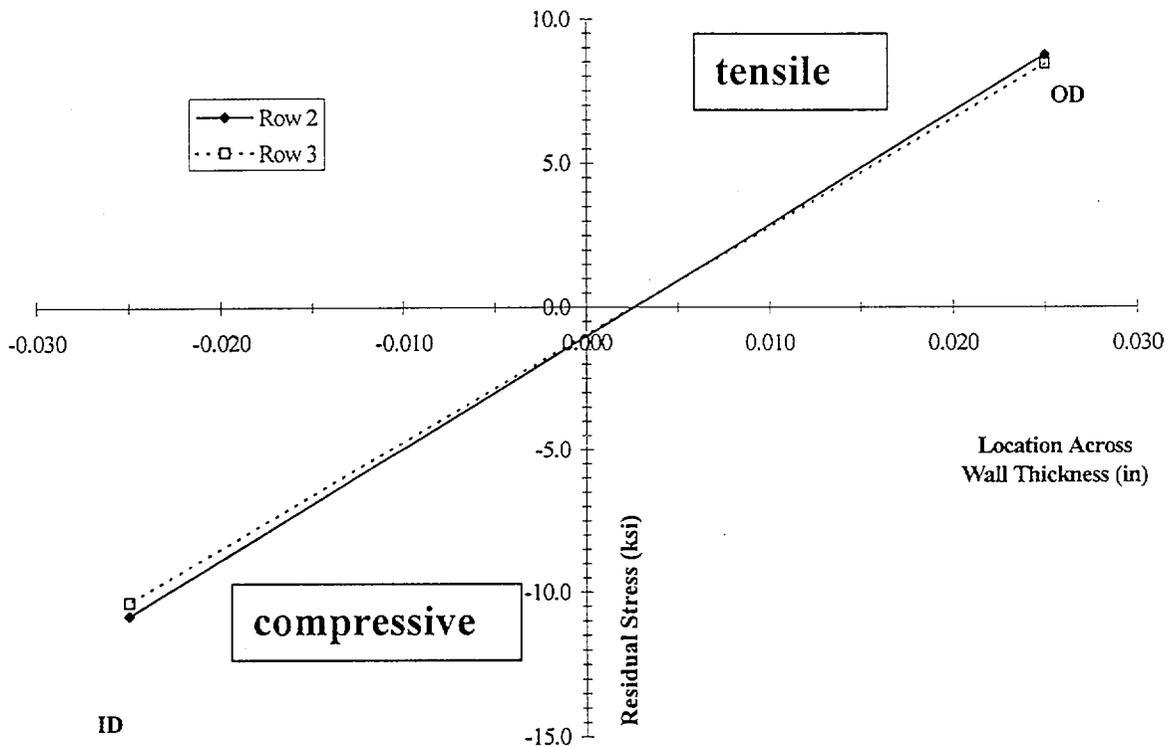


**Strain Gage Attached to I.D.  
For Residual Stress Measurement  
Sample 00603-4**

## Average Released (Measured) Hoop Strain in Rows 2 and 3 Samples at the Apex

Sample	Average Total ID Hoop Strain (in/in)	Average Total OD Hoop Strain (in/in)
Row 2	0.00038	-0.00030
Row 3	0.00036	-0.00029

U bend Residual Stress Distribution



## Equivalent U-Bend Elastic Residual Stress Distribution

## Stress Strain Properties of the Tubes

- Row 2 and Row 3 tube yield stress will be higher than nominal due to strain hardening. Yield strength adjustment determined from elongation induced during bending (Row 2 strain hardening is greater than Row 3).
- Testing showed an increase in yield strength at the tube U-bends of approximately 50% due to strain hardening
- CMTR records from IP2 provided a range of yield strengths in the generator for the various rows
- The analysis model incorporated CMTR data adjusted for strain hardening and operating temperature

## Finite Element Analysis

- Analysis was performed with ANSYS.
- Pressure, temperature, residual stress, and leg displacement included
- Yield strengths shown below were utilized in the analysis – these are corrected for temperature and strain hardening.

		Row 2	Row 3
<b>0.2% Yield Stress (psi) – Mil. Test Cert. Values Adjusted for Design Temp.</b>	<b>Lower Yield</b>	44,100	40,300
	<b>Average Yield</b>	61,000	58,800
	<b>Higher Yield</b>	86,000	82,700

# Stress Analysis Results

<b>SUMMARY OF APEX HOOP STRESSES</b>				
<b><u>AT CENTER OF FLOW SLOT</u></b>				
<b>Apex Hoop Stress (psi)</b>				
<b>Loading Condition</b>	<b>Row 2</b>		<b>Row 3</b>	
	<b>I.D.</b>	<b>O.D.</b>	<b>I.D.</b>	<b>O.D.</b>
<b>Equivalent Elastic Fabrication Residuals</b>	<b>-10,800</b>	<b>8,700</b>	<b>-10,400</b>	<b>8,400</b>
<b>Differential Pressure Plus Thermal Expansion</b>	<b>15,427</b>	<b>8,929</b>	<b>15,009</b>	<b>9,629</b>
<b>Total Loading – Lower Yield Strength</b>	<b>50,845</b>	<b>-35,169</b>	<b>40,743</b>	<b>-13,934</b>
<b>Total Loading - Average Yield Strength</b>	<b>68,496</b>	<b>-48,952</b>	<b>52,711</b>	<b>-30,172</b>
<b>Total Loading – Higher Yield Strength</b>	<b>92,378</b>	<b>-64,060</b>	<b>65,439</b>	<b>-37,204</b>

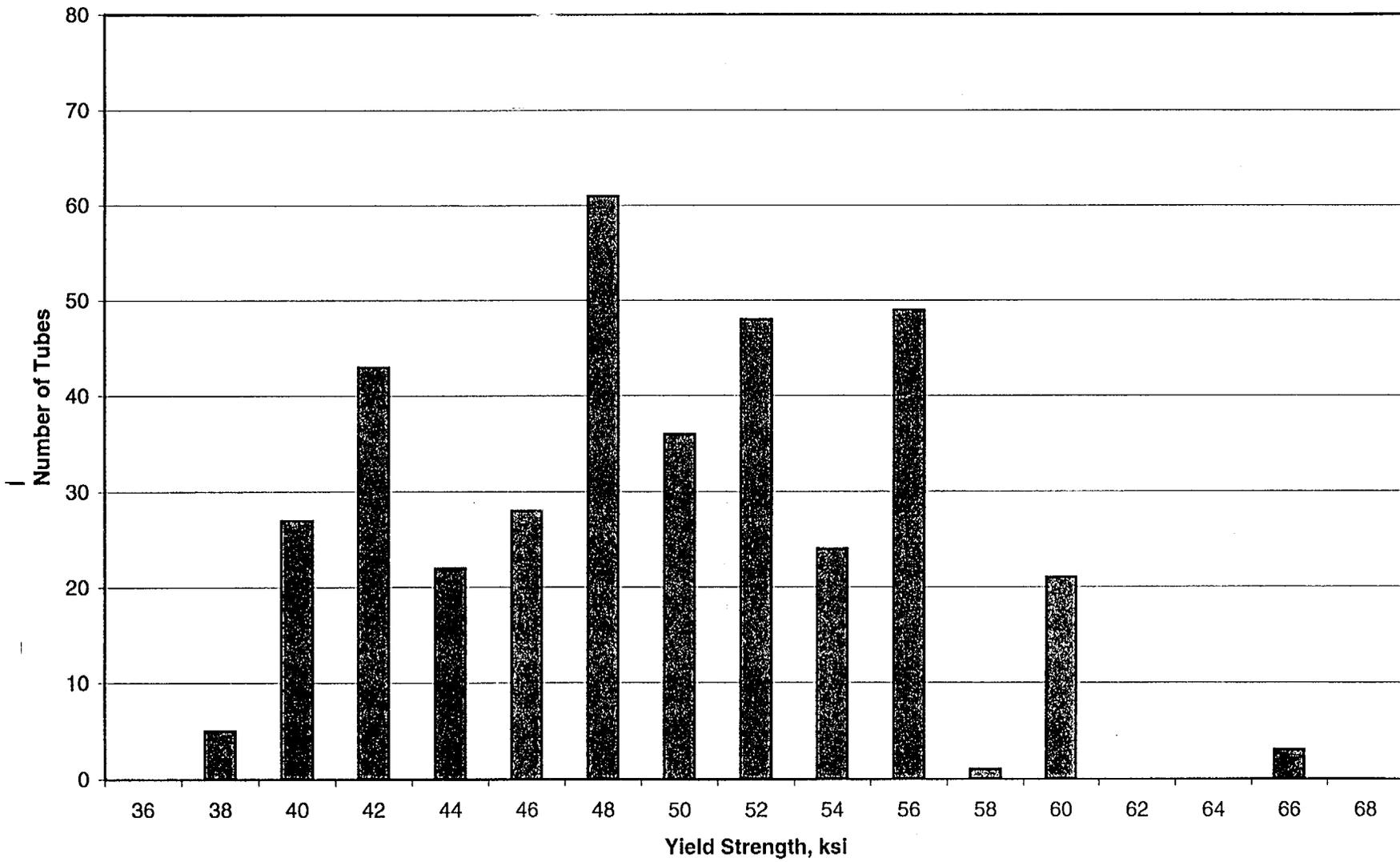
## Crack Initiation

- Time to crack initiation is proportional to the applied stress raised to the 4<sup>th</sup> power.
- Time to crack initiation in Tube i will be proportionally longer than in Tube j by the following:

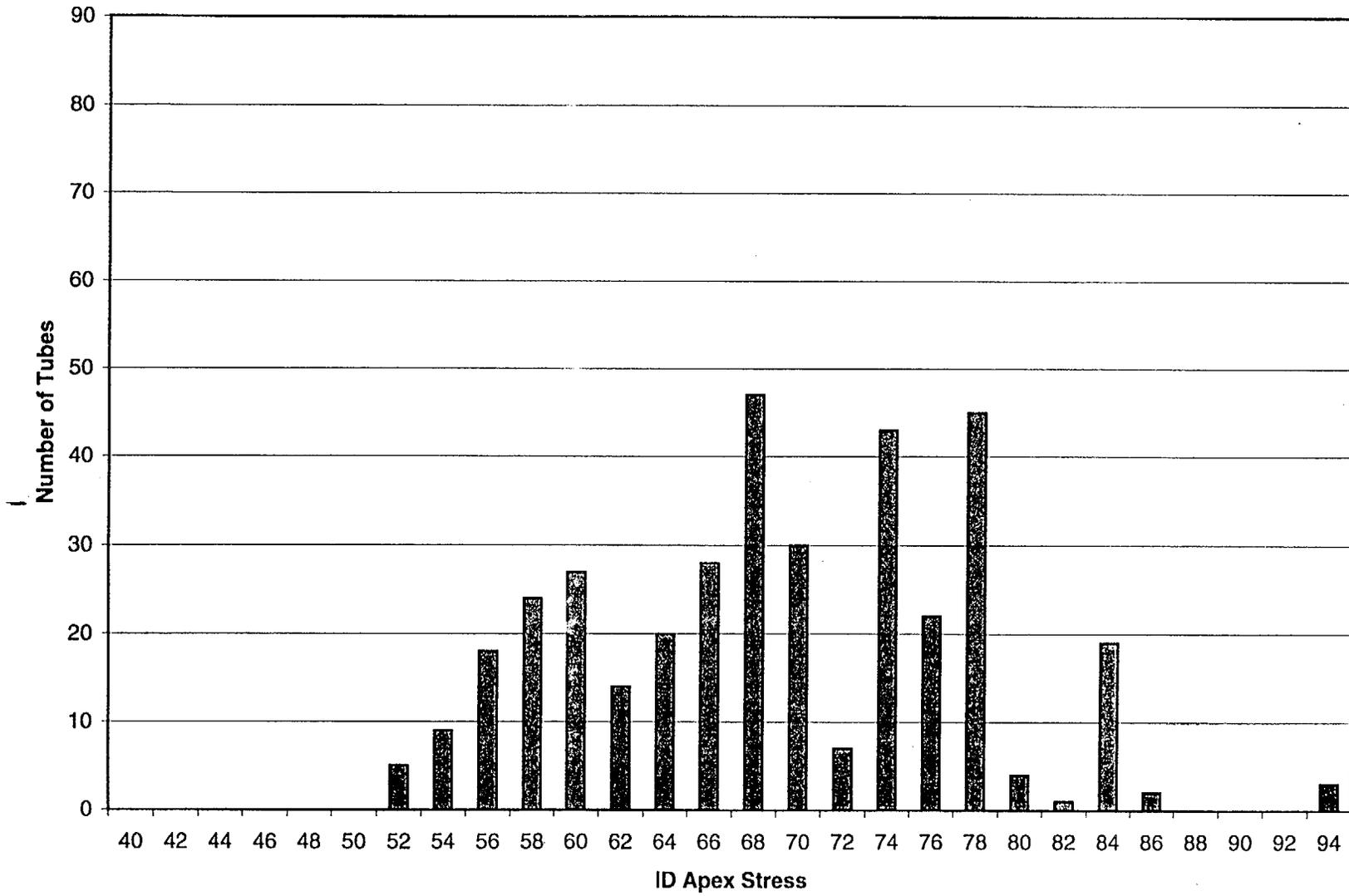
$$t_j = t_i \left[ \frac{\sigma_i}{\sigma_j} \right]^4$$

- Cracks will initiate at different times in different Row 2 tubes
- Cracks will initiate at different time in Row 3 tubes compared to Row 2 and other Row 3 tubes

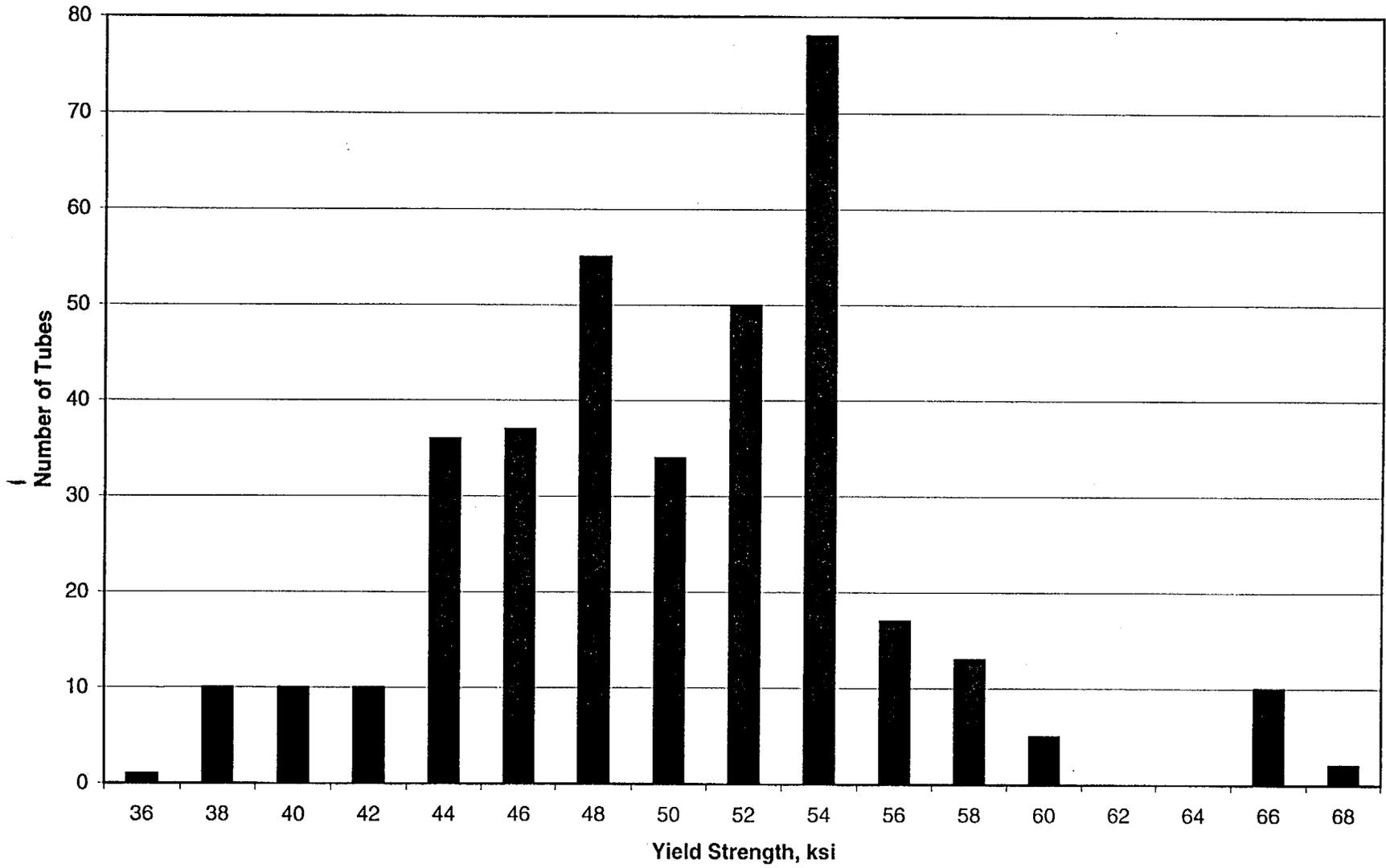
IP2 SG Tube CMTR Yield Strength Distribution - Row 2



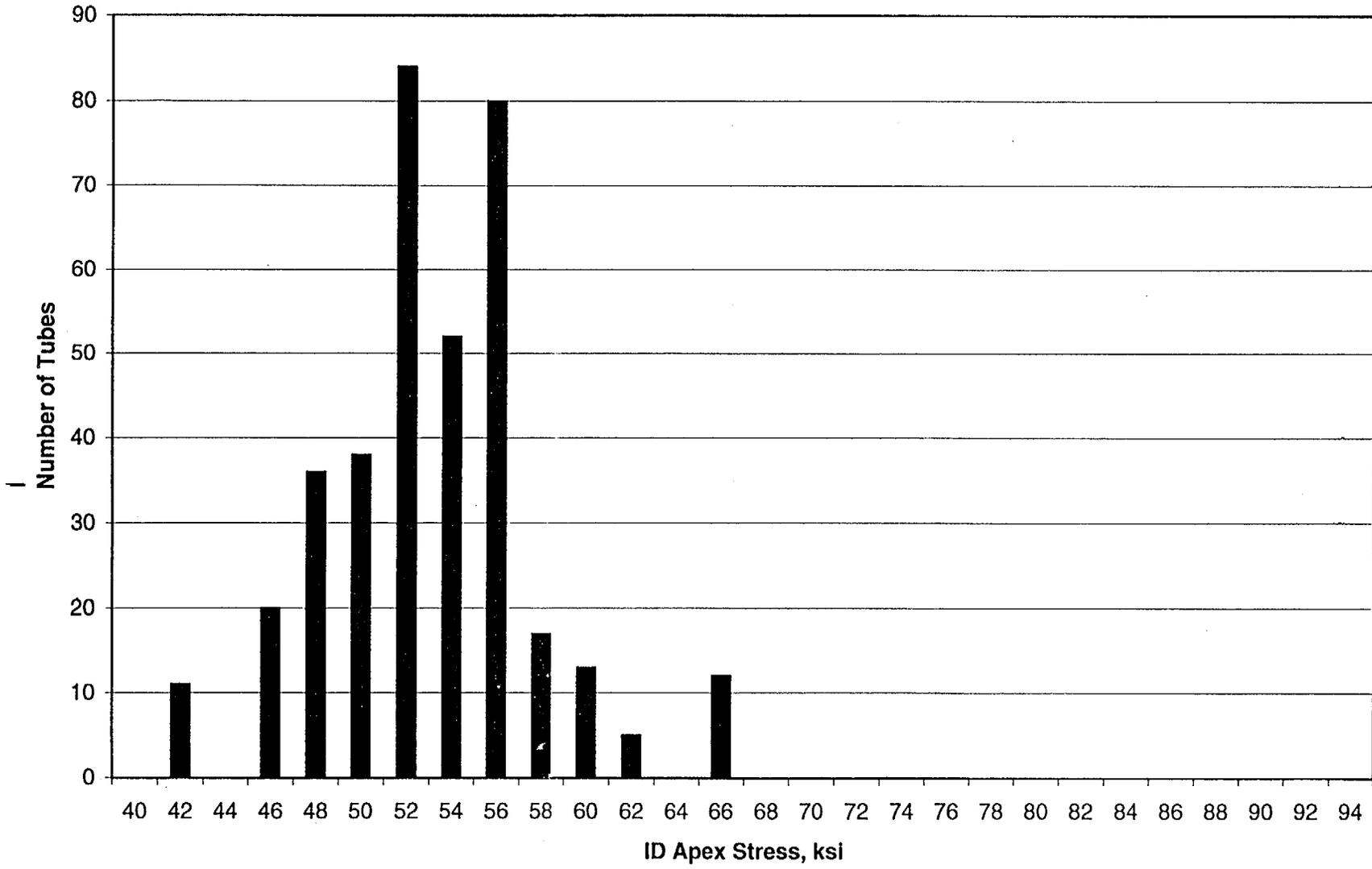
Distribution of ID Apex Stress - Row 2



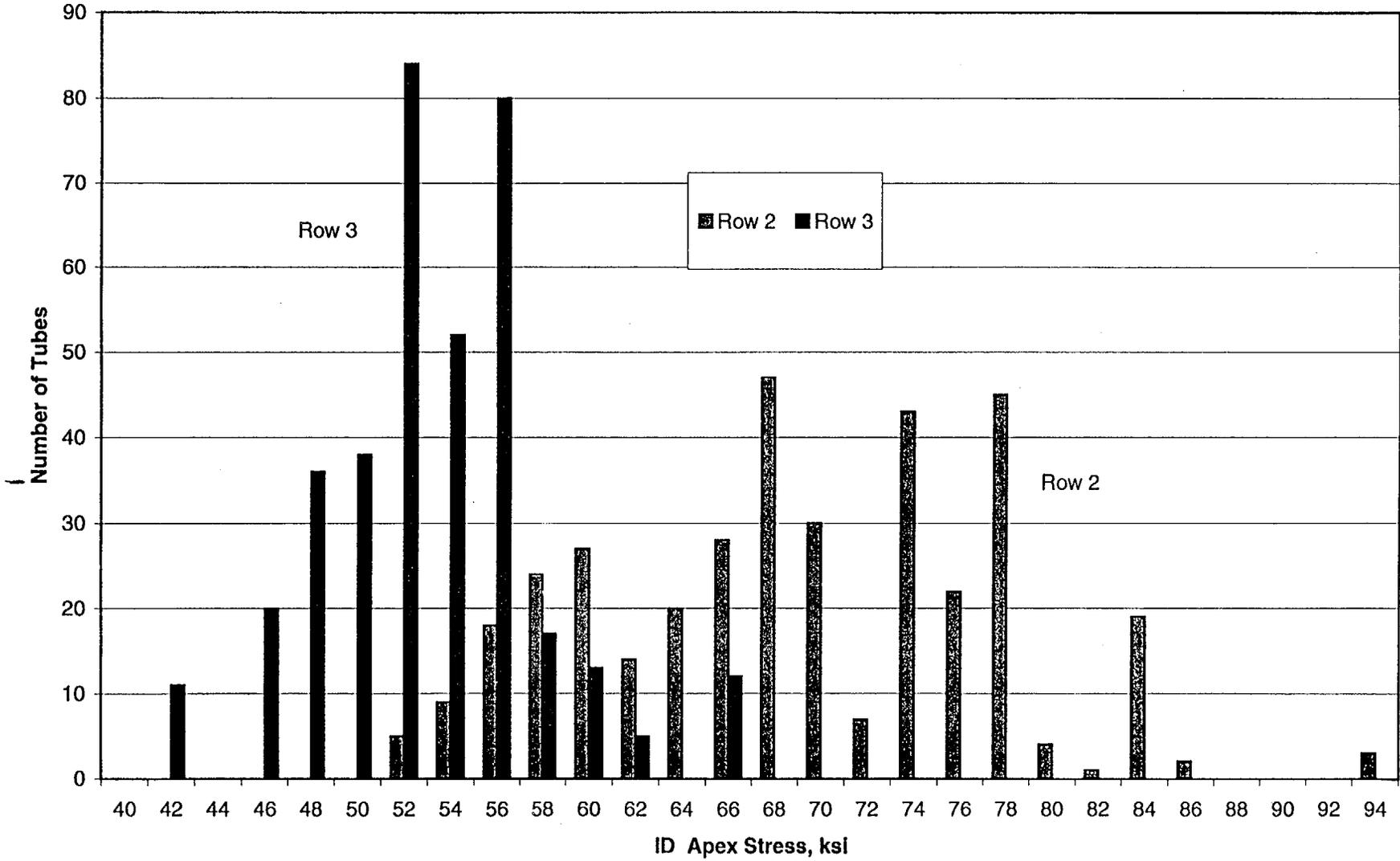
IP2 SG Tube CMTR Yield Strength Distribution - Row 3



Distribution of ID Apex Stress - Row 3



Distribution of ID Apex Stress for Row 2 and Row 3



## Conclusions

- Ovality appears by test and analysis to not play a significant role in the ID apex stresses
- Cause of cracking linked to hour-glassing in the top TSP
- Row 3 much less susceptible to PWSCC than Row 2 tubes