1/18/01

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of:	)	
	)	
Consolidated Edison Company of New York, Inc.	)	Docket No. 50–247
(Indian Point Nuclear Station, Unit No. 2)	)	

AFFIDAVIT OF STEPHEN D. BROWN

I, Stephen D. Brown, being duly sworn, state as follows:

1. I have prepared this affidavit as an independent consultant.

2. I was recently asked to examine elements of a nondestructive examination (NDE) of the steam generators at the Indian Point 2 nuclear power plant conducted in the spring of 1997 utilizing a technique referred to as eddy current testing. Indian Point 2 is owned and operated by the Consolidated Edison Company of New York, Inc.

3. I did not participate in the Indian Point 2 steam generator inspections conducted in 1997 and 2000. I have recently participated in retrospective reviews of the 1997 examination on behalf of Consolidated Edison and Westinghouse.

4. My professional qualifications and experience are set forth in my curriculum vitae, which is attached as Exhibit 1. I have been involved in steam generator eddy current in excess of 50 plants over 26 years.

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5. Prior to preparing this affidavit I reviewed the following documents: 1) IP2 1997 Data Information Package provided by Westinghouse consisting of a) the Data Analysis Guidelines, b) copies of the Analysis Technique Sheets, c) drawings for rotating probe calibration standards, d) data analysts training information distributed in 1997 and e) rotating probe eddy current data from SG 21,23 and 24; 2) NRC Special Inspection Report – Indian Point Unit 2 Steam Generator Tube Failure – Report NO. 05000247/2000-010 dated August 31, 2000; 3) Proposed Steam Generator Tube Examination Program – 1997; 4) Transmittal of the Indian Point 2 Steam Generator Tube Failure Lessons Learned Report dated November 1, 2000; 5) Final Significance Determination for a Red Finding and Notice of Violation at Indian Point 2 (NRC Inspection Report 05000247/2000-010) dated November 29, 2000.

6. The purpose of this affidavit is to evaluate issues surrounding the 1997 Indian Point 2 steam generator NDE raised by the Nuclear Regulatory Commission in a November 20, 2000 document entitled Final Significance Determination for a Red Finding and Notice of Violation at Indian Point 2 - Report No. 05000247/2000-010. This is accomplished by reviewing Indian Point 2 plus-point rotating probe eddy current data acquired and analyzed during 1997 in the context of data quality issues and the statistical/probabilistic nature of the eddy current examination process.

7. The specific NRC finding, as applied to the 1997 Indian Point 2 steam generator examination, states as follows: "Significant ECT signal interference (noise) was encountered in the data obtained during the actual ECT of several low-row U-bend tubes. This significant noise level reduced the probability of identifying an existing PWSCC tube defect. However, the 1997 SG inspection program was not adjusted to compensate for

the adverse effects of the noise in detecting flaws, particularly when conditions that increased susceptibility to PWSCC existed."

8. In understanding events that transpired at Indian Point 2 during that time frame, it is important to note that this unit had extensively dented steam generators.

9. Based on industry experience with the Surry and Turkey Point nuclear plants, the nuclear industry was aware that extensively dented steam generators were susceptible to inner row U-bend PWSCC.

10. Rotating probe eddy current technology, used for inner row U-bend examination, was not introduced into the field until the 1987 timeframe well after the Surry and Turkey Point steam generator replacements.

11. Thus, there was no industry rotating probe eddy current data from extensively dented units with apex cracking that could be used for reference or application during the 1997 Indian Point 2 steam generator examination.

12. Other industry rotating probe eddy-current data from non-dented units did exist. However, there was no factual basis that could be applied to this data to determine its adequacy (or inadequacy) since no extensively dented U-bend apex reference data set existed for comparison.

13. The inner-row U-bend examination that was conducted at Indian Point 2 during 1997 was done using a plus-point rotating probe which was considered one of the best probes in the industry for detection.

14. The use of this probe was approved by the NRC.

15. My review of the Indian Point 2 1997 outage plus-point rotating probe eddy current data used data from steam generator 24. I used analysis software with phase

rotation settings identical to those used by the two primary and secondary production analysts that analyzed data from tube R2C5 (the tube that leaked during February 2000).

16. As a general observation, while the U-bend data was qualitatively noisy, the data was able to be analyzed using 1997 industry practices and technology and was not atypical of noisy data encountered in other plants contemporary with or prior to the 1997 timeframe.

17. The type of noise I observed in the 1997 Indian Point 2 U-bends would normally be classified as tube noise i.e., inherent with the condition of the tubing or steam generator secondary side.

18. There were no industry requirements or guidelines in effect during 1997 that addressed tube noise or data quality.

19. Data quality noise practices that did exist during the 1997 timeframe typically addressed electronic sources related to instrumentation, probe cabling, etc., Acceptance levels were often subjective and at the discretion of individual data analysts.

20. Extremes in U-bend tube noise levels are illustrated with the 300 kHz vertical channel strip chart data shown in Exhibits 2 and 3

21. Exhibit 2 shows vertical channel strip chart data from a tube (R2C74) with the highest noise level.

22. Exhibit 3 shows vertical channel strip chart data from a tube (R2C31) with the lowest noise level.

23. The ratio of the highest to lowest noise levels shown in Exhibits 2 and 3 is approximately 3 to 1.

24. I then compared eddy current data from tube R2C67 (which was plugged during 1997) with data from tube R2C5 (a tube with an unreported indication during 1997 that subsequently leaked during February 2000). This provides a context from which to assess the significance of the noise levels shown in the previous two exhibits.

25. Vertical strip chart data for the 1997 plugged tube R2C67 is shown in Exhibit 4. The noise level for this tube is comparable to the tube with the lowest noise level shown in Exhibit 3.

26. Exhibit 5 shows vertical strip chart data for the tube that leaked (R2C5) during February 2000. The noise in this tube is comparable to the highest noise level tube shown in Exhibit 2.

27. For the plugged tube R2C67 (Exhibit 4), the tube noise is relatively low in an absolute sense with the indication (signal) also exhibiting a relatively high signal-to-noise (S/N) ratio.

28. The opposite is true for R2C5 (Exhibit 5) which was the tube that leaked during February 2000. The tube had a higher absolute noise level with multiple indications (signals) exhibiting a lower (S/N).

29. A static Lissajous display for tube R2C67 with the only inner-row U-bend indication reported during the 1997 outage is shown in Exhibit 6.

30. The indication is seen as the large amplitude signal rising out of the strip chart data near the apex of the U-bend.

31. Isolation of one of these peaks in the Lissajous window shows an indication that met the Westinghouse analysis procedure reporting requirements in effect during 1997.

32. There was nothing unusual or unexpected about this indication. In my opinion, contrary to the NOV, finding this indication should not have resulted in any adjustments to the program then in progress at Indian Point 2 in 1997. Analysts often routinely deal with hundreds of indications as a part of their job and are not alarmed when an indication is first observed.

33. Exhibit 7 illustrates the static Lissajous display for indications in R2C5, which went unreported during 1997.

34. The right most strip chart shows a series of multiple peaks (noted as indications in the figure), which just barely exceed the local noise level.

35. Isolation of one of these peaks in the Lissajous window shows an indication that met the Westinghouse analysis procedure reporting requirements in effect during 1997.

36. A comparison of the eddy current graphics from Exhibits 6 and 7 shows the following.

37. The indications for the reported and unreported indications have comparable amplitudes i.e., 2.18 volts and 2.03 volts.

38. The strip chart data shows a much lower noise level for R2C67 than R2C5.

39. The indications in R2C5 are not nearly as prominent as those are in R2C67.

40. Exhibits 8 and 9 provide a visual representation of the dynamic aspects of U-bend tube noise and its relationship to detection as viewed in the Lissajous display.

41. Exhibit 8 shows a Lissajous display for R2C67 in which the screen persistence was maintained as the probe was pulled through the U-bend between the upper two supports. This display mode integrates the noise level throughout the U-bend.

42. The darker ellipsoidal region (noise ellipse) to the lower right of the Lissajous display, with its semi-major axis parallel to the horizontal axis, is the integrated noise level one observes as the probe is scanned through the U-bend.

43. The series of vectors (signal) directed to the upper left which arise out of the noise ellipse are indications associated with U-bend apex cracking. For this example, the flaw signals are clearly visible within the tube noise.

44. Exhibit 9 shows the dynamic tube noise for R2C5. As with the previous exhibit, an integrated Lissajous display is shown with the screen persistence maintained as the probe was pulled through the U-bend between the two upper support plates.

45. For this tube, the darkened ellipsoidal region (identified as the noise ellipse in the figure) near the center of the display with its semi-major axis located at an angle of approximately 75-degrees (left-handed coordinate system) is the integrated noise level.

46. The multiple signals directed towards the upper left are the signals of interest associated with apex U-bend cracking that were not reported. It should be noted that even though the integrated peak-to-peak signal-to-noise ratio is approximately unity, the signals of interest are discernable in the Lissajous display.

47. The conclusions drawn from reviewing the 1997 Indian Point 2 rating probe eddy current data are as follows; 1) The indication reported in R2C67 (the only tube reported with U-bend apex cracking) had a relatively high (S/N) ratio which increased detection probability. This was the first and only industry data point from which a conclusion could be drawn about data quality. Based on this single observation, there was no evidence that tube noise levels might be impacting detection; 2) The noise levels in the U-bend data were within other industry analysis experience prior to and contemporary

with the Indian Point 2 1997 timeframe. Thus, Indian Point 2 tube noise levels were not unique; 3) While the U-bend rotating probe data is noisy, this factor alone should not have prevented indications in R2C5 from being reported. The amplitude of the missed indication in R2C5 is comparable to the reported indication in R2C67 i.e., 2.31 volts versus 2.16 volts. However, the peak-to-peak noise level in R2C5 was higher by roughly a factor a four.

48. In order to have implemented an eddy current data quality or noise level requirement during the 1997 Indian Point 2 outage one significant item was necessary; a flaw signal data base from which to infer acceptable noise levels.

49. This database would be constructed from a set of eddy current signals obtained from tubes with denting assisted U-bend apex PWSCC.

50. Denoting the amplitudes of the eddy current signals as S_a, S_b, ... S_i, and defining an acceptable (S/N) ratio as $(S/N) > k$, where k is some number (usually assumed to be three), then the maximum acceptable noise level is given by $N < S_i/k$ where S_i is the amplitude (in volts) of the *smallest* signal required to be detected.

51. As mentioned previously, the type of data necessary to determine a maximum acceptable noise level did not exist prior to the 1997 Indian Point 2 steam generator examination since there was no rotating probe eddy current data from extensively dented units. Accordingly, it was not possible to realistically meet a data quality requirement. Any noise level that might have been chosen would have been selected on a somewhat ad hoc basis. It is again emphasized that based on the single indication reported in SG R2C67 during the 1997 outage there was no evidence of a data quality problem. The absence of rotating probe eddy current data from extensively dented

units would also have hampered and restricted the capabilities for analyst training on this type of flaw environment.

52. Basically what happened during the Indian Point 2 steam generator examination was that an indication in R2C5 went unreported which subsequently leaked during February 2000. In light of this event, it often goes unnoticed that the steam generation tube examination process is fundamentally statistical in nature. This is true for tube selection, data acquisition, and data analysis. For example, the minimum acceptable tube selection sample size, which is typically 20%, is based on sampling at least one degraded or defective tube at some confidence level. The success of this sampling scheme is dependent on the number of degraded or defective tubes being present in sufficient numbers, usually in excess of ten or so. Acceptable data acquisition technique performance is based on a cumulative 80% detection probability at a 90% confidence limit for discontinuities with depths in excess of 60% throughwall. Data analyst pass/fail criterion for the EPRI QDA program and many site-specific performance demonstrations is based on a cumulative 80% detection probability. The logical consequence of a statistically based i.e., imperfect, steam generator tube examination process is that defective tubes can be left in service. This is all that happened during the Indian Point 2 1997 steam generator examination.

53. The NRC has explicitly accepted a probabilistic approach to the steam generator examination process in its licensing of alternate repair criteria (ARC). Acceptance of a probabilistic approach recognizes that elements of the examination process are imperfect.

54. This imperfection was also inherent in the 1997 Indian Point 2 examination (and other plants) since the same examination process elements are present.

55. NDE related process elements typically include detection and sizing.

56. Imperfect detection is addressed using a detection probability function, an example of which is shown in Exhibit 10.

57. This exhibit shows that relatively deep cracks can inadvertently remain in service due to basic technique limitations or human factor effects.

58. I have kept track of industry-wide steam generator forced outages since PWR plants were first commercialized during late 1960.

59. While only a handful of tube ruptures have occurred, I have documented hundreds of leaker outages, which is what basically happened at Indian Point 2.

60. The cause of many of these leaker outages can be traced to the NDE process; in particular, human factor effects. However, for some reason, the historical regulatory reaction to eddy current examinations subsequently revealed to be imperfect pales in comparison with the response to the February 2000 Indian Point 2 tube leak event. I find no logical basis for this difference.

61. The foregoing statements are true and correct to the best of my knowledge and belief.

Stephen D. Brown

Stephen D. Brown

Sworn and subscribed to before me on this 18 day of January, 2001.

Frances M. Thurber

Notary Public

FRANCES M. THURBER
Commission # 1130906
Notary Public — California
San Diego County
My Comm. Expires Mar 23, 2001

My Commission expires: 03/23/2001

Exhibit 1

Curriculum Vitae

STEPHEN D. BROWN

SPECIALIZED PROFESSIONAL COMPETENCE

An expert in the development and application of nondestructive evaluation (NDE) techniques with more than twenty-five years of experience and extensive expertise from both practical and analytical viewpoints to the solution of NDE problems. Mr. Brown is a certified Level III and qualified data analyst (QDA) in accordance with the EPRI performance demonstration program.

Well-known industry consultant concerning all aspects of NDE of steam generator tubing. Mr. Brown has provided independent consulting services across the industry to vendors, utilities, and regulators. Actively involved in steam generator NDE since 1974 as Group Leader at Battelle Memorial Institute and later as Manager at the EPRI NDE Center. Experienced in the development of techniques to interpret all forms of steam generator tubing degradation. Knowledge and expertise is sought industry wide by vendors, foreign and domestic utilities, and the Electric Power Research Institute (EPRI). Prepared initial drafts (up through Rev. 5) of the "PWR Steam Generator ISI Guidelines", and was principal author of the "Steam Generator NDE Data Analyst Performance Demonstration Program" (i.e., EPRI QDA program) both of which are in use throughout the industry. Developed the statistical basis for steam generator tube sampling plans adopted by EPRI and the American Society for Mechanical Engineers (ASME).

EDUCATION AND PROFESSSIONAL BACKGROUND

- B.S. (Physics), The Ohio State University
- Degree, Electrical Engineer, The Ohio State University

Society/Committee Memberships:

- — Institute of Electrical and Electronic Engineers
- — American Society of Nondestructive Testing
- — EPRI ISI Guidelines Committee
- — ASME Task Group of Steam Generator Sample Plan Development
- — EPRI Steam Generator Degradation Specific Management Committee for the Development of Alternate Plugging Criteria

- Awards

  — *Achievement Award for Best Technical Paper* Published in Materials Evaluation, American Society of Nondestructive Testing

  — Westinghouse General Managers Quality Achievement Award 1986 for Outstanding Accomplishments in the Managerial Category

  — Patent #4,876,506, *Apparatus and Method for Inspecting the Profile of the Inner Wall of a Tube*, October 1989

SELECTED REPORTS, PUBLICATIONS, AND INVITED LECTURES

Depth Based Structural Analysis Methods for SG Circumferential Indications, Electric Power Research Institute, EPRI Report TR-107197 (co-author) (November 1997).

Development of Wavelet Analysis Methods for Crack Characterization, Presented at the EPRI 16th Annual Steam Generator NDE Workshop, EPRI Report TR-108858 (September 1997).

Inversion of Rotating Probe Eddy Current Data for Structural Integrity Applications, Presented at the EPRI Condition Monitoring and Operational Assessment Meeting, Colorado Springs, CO (February 1997).

Inversion of Rotating Probe Eddy Current Data for Improved Lateral Resolution, Presented at the EPRI 15th Annual Steam Generator NDE Workshop, EPRI Report TR-107161 (November 1996).

Steam Generator NDE Performance Demonstration Program, Electric Power Research Institute, EPRI Report RP-S530 (June 1993).

PWR Steam Generator Examination Guidelines Rev. 2, Electric Power Research Institute, EPRI Report NP-6201 (December 1988).

Nondestructive Evaluation Methods to Measure Inside Diameters of Steam Generator Tubing, Electric Power Research Institute, EPRI Report NP-5902 (July 1988).

Template Matching - An Approach for the Machine Sorting of Eddy Current Data, Materials Evaluation (November 1985).

Evaluation of Eddy-Current Procedures for Measuring Wear Scars in Preheat Steam Generators, Electric Power Research Institute, EPRI NP-3928 (April 1985).

Steam Generator U-Bend Eddy Current NDE, Electric Power Research Institute, EPRI

NP-3010 (April 1983).

Eddy-Current NDE for Intergranular Attack, Electric Power Research Institute, EPRI NP-2862 (February 1983).

Automatic Analysis of Eddy Current Signals, Proceedings, 5th International Conference on Inspection of Pressurized Components, The Institute of Mechanical Engineers, London (with G.J. Dau) (October 1982).

Field Experience with Multifrequency-Multiparameter Eddy Current Technology, Electric Power Research Institute, EPRI NP-2299 (March 1982).

Steam Generator Mock-up Facilities, Electric Power Research Institute, EPRI NP-1785 (co-author) (April 1981).

Evaluation of Multiparameter Eddy-Current Technology for Inspection of Steam Generator Tubing, Brookhaven National Labs, NUREG/CR-1958 (March 1981).

In-Service Evaluation of Multifrequency/Multiparameter Eddy-Current Technology for the Inspection of PWR Steam-Generator Tubing, Eddy-Current Characterization of Materials and Structures, ASTM STP 722, American Society for Testing and Materials, pp. 189-203 (1981).

Evaluation of Selected Signal Processing Methods for the Characterization of Steam Generator Eddy Current Signals, Brookhaven National Labs, NUREG/CR-1007 (co-author) (August 1979).

An Evaluation of Eddy Current Inspection Methods for PWR Steam Generator Tubing, Electric Power Research Institute, EPRI NP-636 (co-author) (October 1978).

Nondestructive Evaluation of Steam Turbine Rotors - An Analysis of the System and Techniques Utilized for Inservice Inspection, Electric Power Research Institute, EPRI NP-744 (co-author) (April 1978).

Evaluation of the Eddy-Current Method for the Inspection of Steam Generator Tubing - Denting, Brookhaven National Labs, NUREG-50743 (co-author) (September 1977).

Evaluation of the Eddy-Current Method for the Inspection of Steam Generator Tubing, Brookhaven National Labs, NUREG-40679 (co-author) (September 1976).

Steam Generator Reference Book, Chapter 26, Nondestructive Examination, Electric Power Research Institute, EPRI Report TR-103824.

Exhibit 2
Strip chart data showing visual representation of
tube noise extremes in SG 24 row 2 U-bends
- Highest noise level (R2C74) -

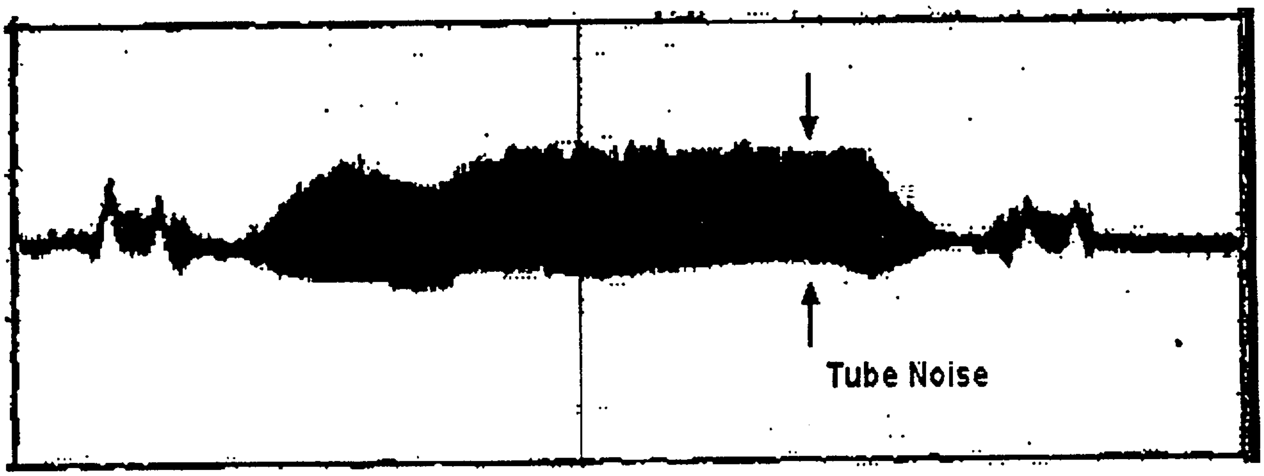

Exhibit 3
Strip chart data showing visual representation of
tube noise extremes in SG 24 row 2 U-bends
- Lowest noise level (R2C31) -

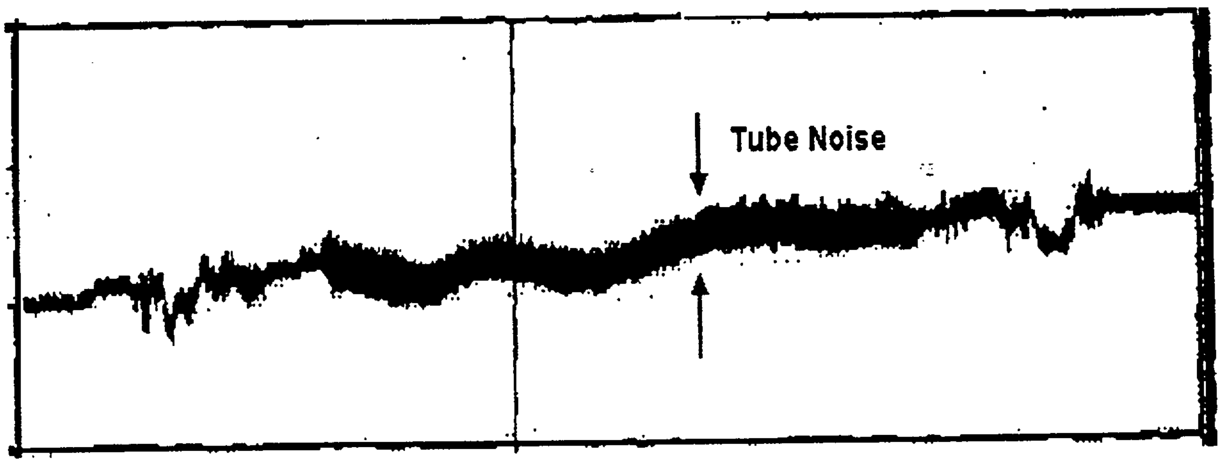

Exhibit 4
300 kHz vertical channel strip chart data showing noise levels in
SG 24 plugged tube (R2C67)
- Low noise level with high (S/N) indication -

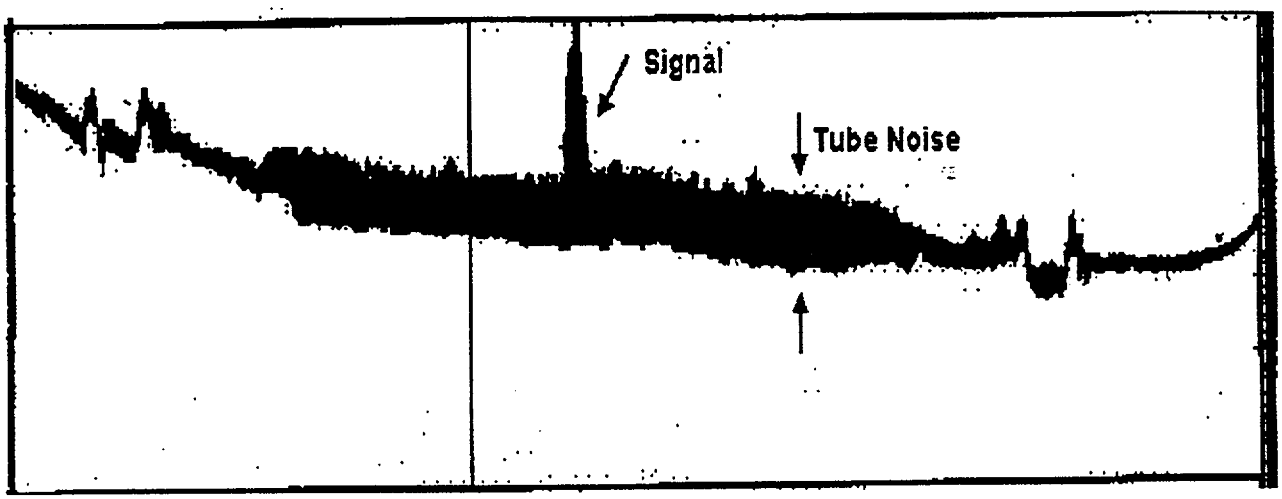

Exhibit 5
300 kHz vertical channel strip chart data showing noise levels in
SG 24 tube with unreported indications (R2C5)
– High noise level with low (S/N) indication -

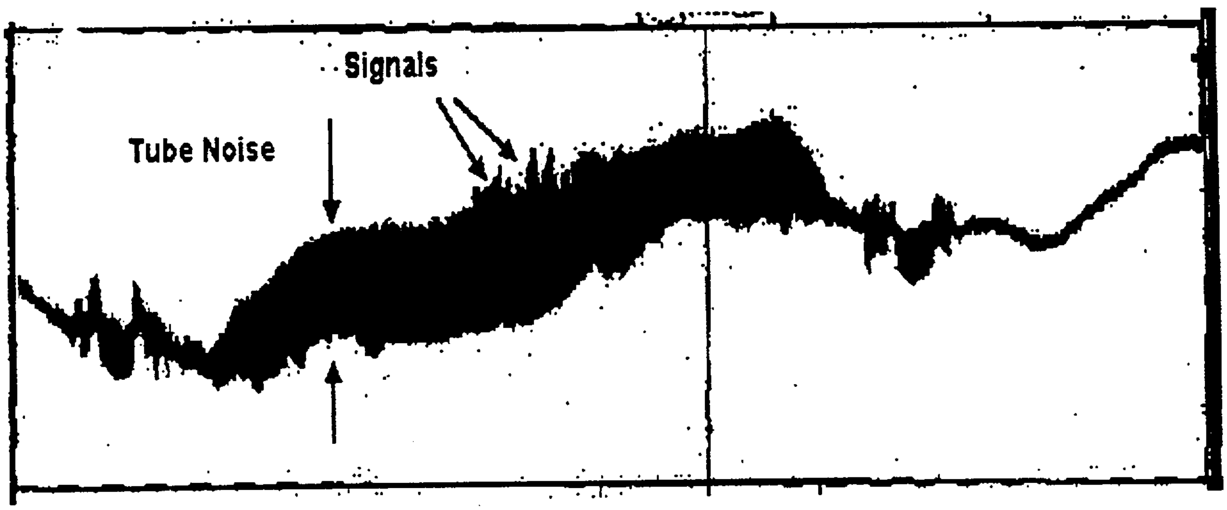

Exhibit 6

R2C67 plus point data for indication reported during 1997

- Lissajous display -

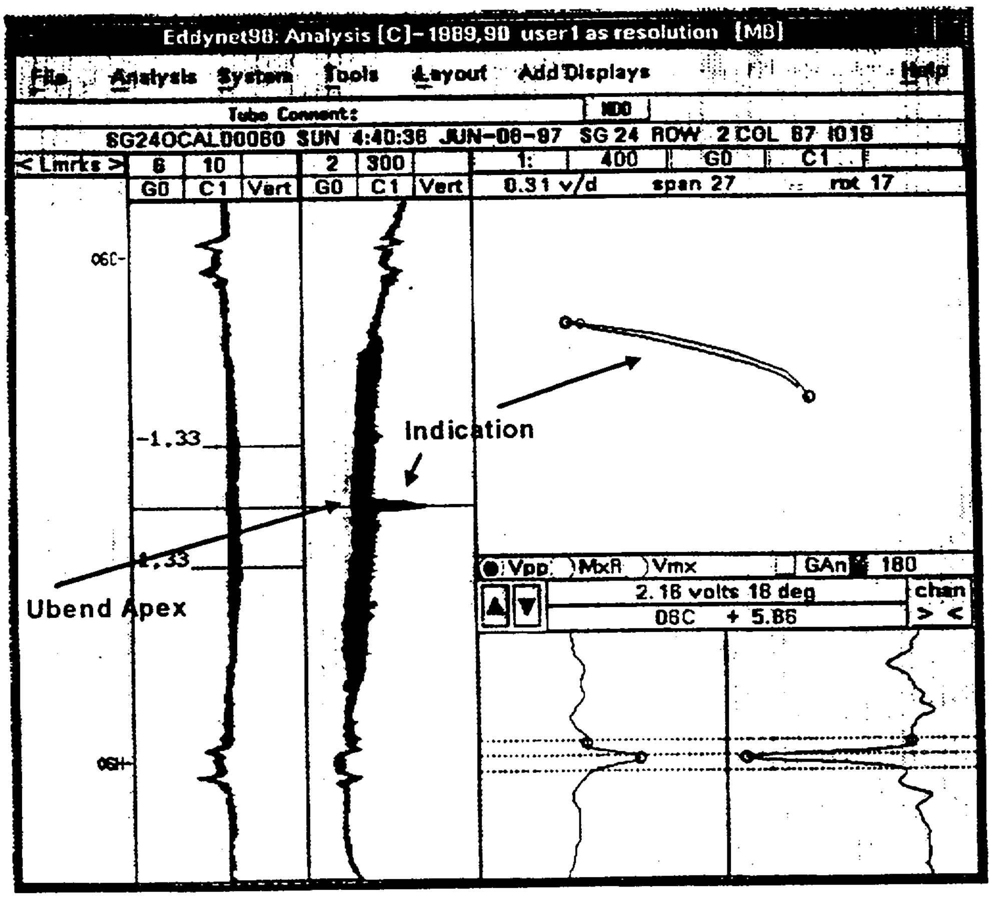

Exhibit 7

R2C5 plus point data for indication not reported during 1997

- Lissajous display -

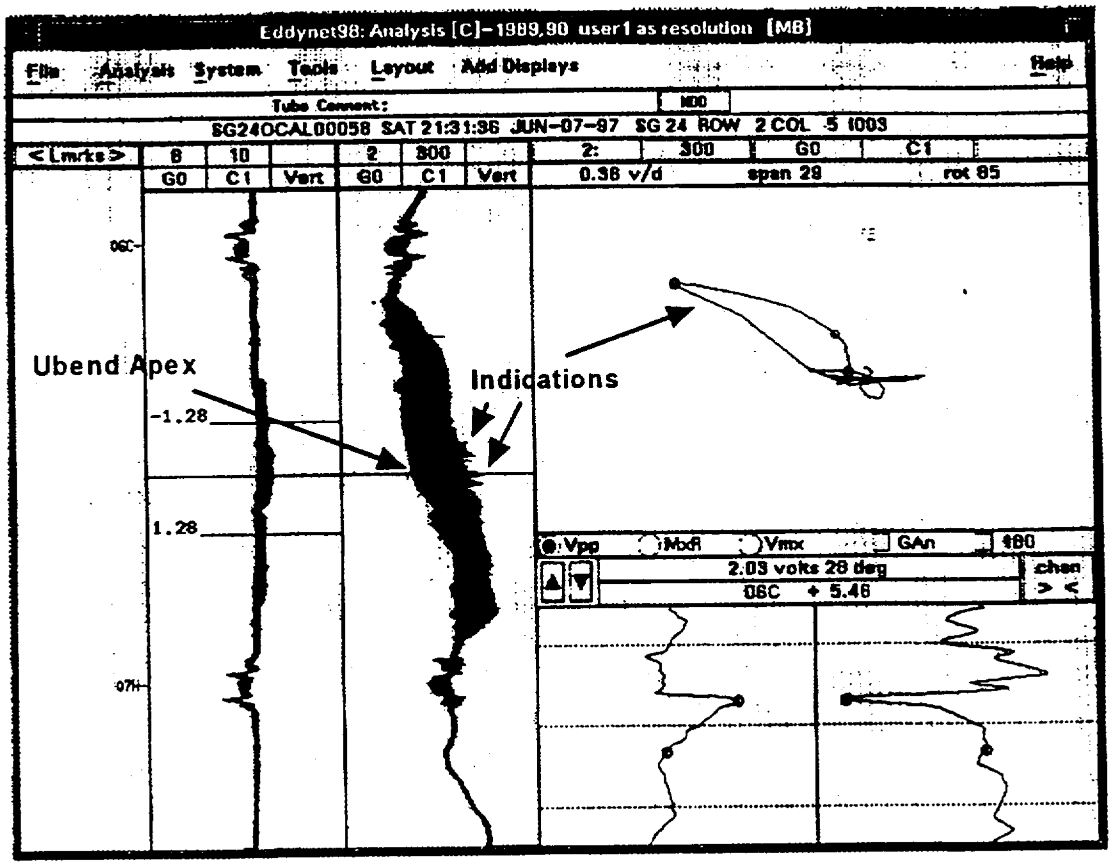

Exhibit 8

Lissajous display showing dynamic integrated noise levels in SG 24 plugged tube R2C67 as the plus-point probe is pulled through the U-bend

– Low noise level with high (S/N) indication -

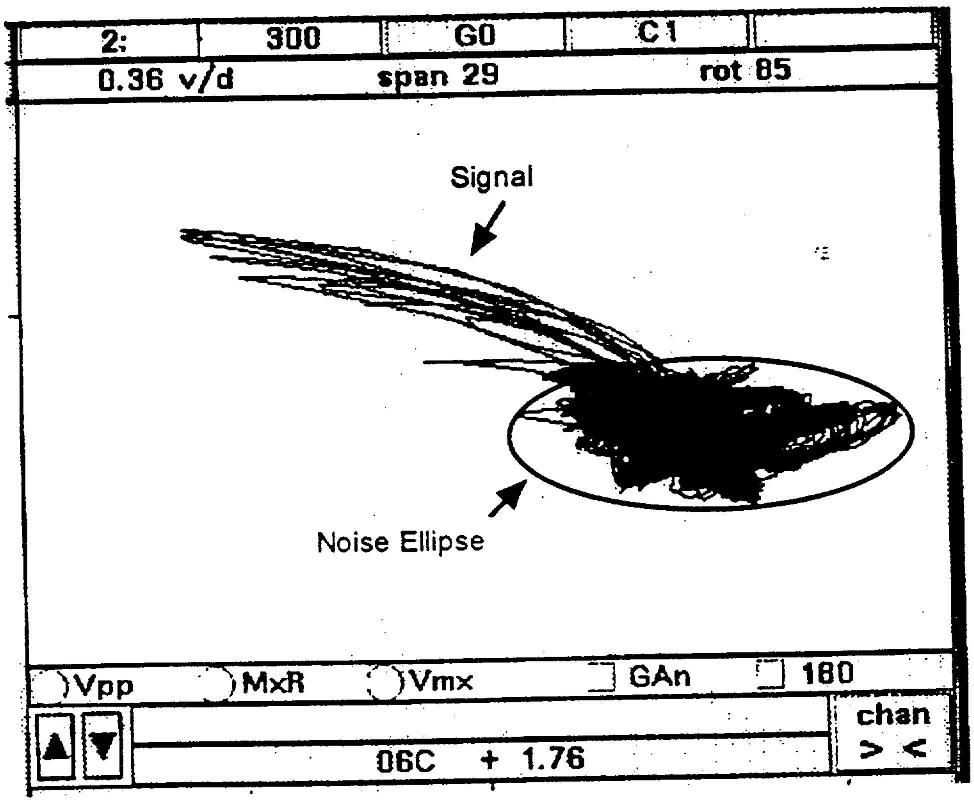

Exhibit 9
Lissajous display showing dynamic integrated noise levels in
SG 24 tube R2C5 as the plus point probe is pulled through the U-bend.
– Higher noise level with low (S/N) indication -

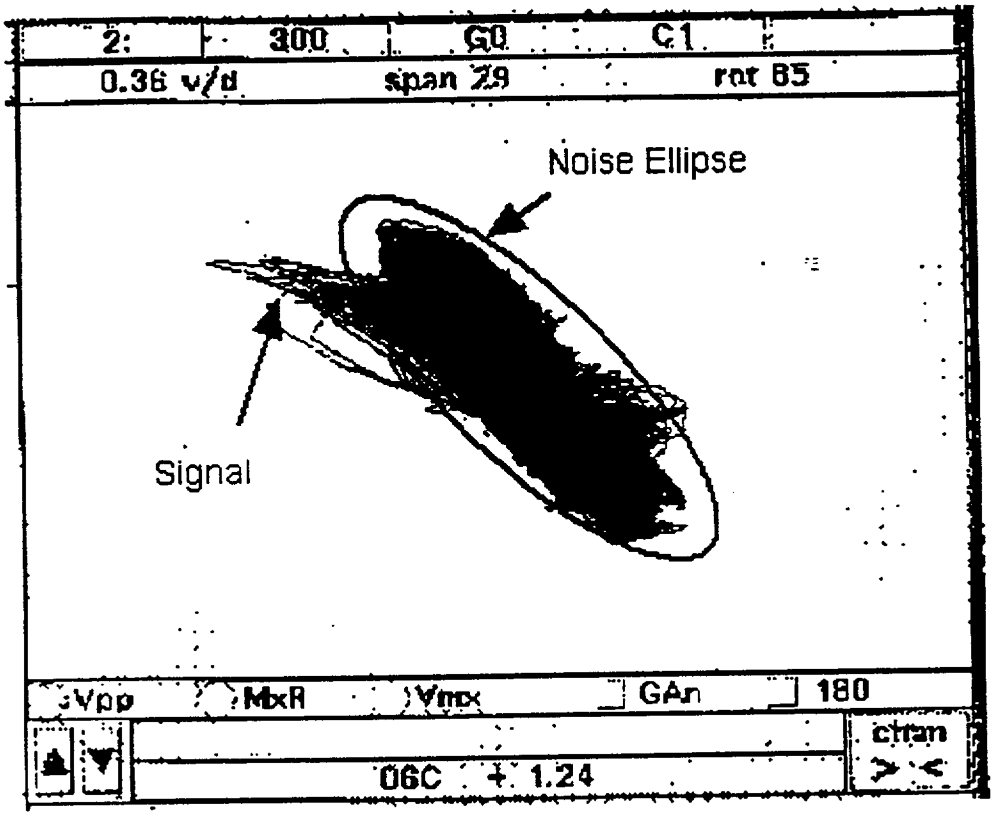

Exhibit 10

Probability of Detection Curve Illustrating Basic Technique and Human Factor Imperfections in the Detection Process