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Subject: Arkansas Nuclear One - Unit 2
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2P99 Steam Generator Tubing Inspection Probability of Detection Improvement
(TAC NO. MA8418)

Gentlemen:

On March 9, 2000 (2CAN030003), Entergy Operations submitted a proposed license change to allow risk-informed operation for the remainder of the 14th operational cycle for Arkansas Nuclear One, Unit 2 (ANO-2). Supplemental information in support of the proposed change was submitted on April 11, 2000 (2CAN040005) April 28, 2000 (2CAN040006), and May 30, 2000. The attached discussion details the improvements on the probability of detection observed during the 2P99 steam generator tubing inspection.

Should you have questions concerning the information provided, please contact me.

Very truly yours,

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JDV/jjd
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A001

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2P99 Probability of Detection Improvement

During the 2P99 steam generator (SG) inspection at Arkansas Nuclear One, Unit 2 (ANO-2), an increased number of eggcrate flaws were detected over that which was predicted. A detailed study of the 2P99 results indicated that this increased number of indications is due to an improved probability of detection (POD) by the bobbin eddy current. It is believed that the primary contributor to the improved POD was the use of different calibration standards for the 2P99 inspection that resulted in an improved voltage response by the bobbin probe.

Entergy Operations has implemented numerous improvements in the eddy current program at ANO since stress corrosion cracking (SCC) of the steam generators was first detected in the early 1990s. These improvements have resulted in continued improved probability of detection (POD) of defects in the ANO-2 SGs. As in the past, improvements were incorporated into the program for the 2P99 inspection. Between the January 1999 outage (2R13) and the November 1999 outage (2P99), an extensive Site Specific Performance Demonstration (SSPD) was conducted to evaluate the POD of the inspection techniques used at ANO-2. The overall result of the SSPD was the ability to quantify the POD based on pulled tube comparisons, and to identify specific areas for improvements during the 2P99 inspection. Based on previous experience and the results of the SSPD, the following changes were incorporated into the eddy current program for 2P99:

- **Training of the Analysts**

Based on the results of the previous outage (2R13), special emphasis was placed on low amplitude indications at the lower hot leg eggcrates since these could potentially challenge the structural integrity limit. Small amplitude examples from 2R13, as well as a range of other indications that were representative of flaws previously detected in the ANO-2 SGs, were used in the training and testing of the analysts prior to the inspections. The analysts were trained to make conservative calls from the bobbin exam at the lower hot leg eggcrates for dispositioning by rotating pancake coil (RPC).

- **Localized Testing**

The 2P99 inspection was focused on the area of interest, namely the lower hot leg eggcrates. In a general inspection, a given analyst would be responsible for analyzing the full length tube bobbin data in addition to all the other testing that would be performed (such as top of tubesheet RPC, sleeve and U-bend analysis).

- **Resolution Effect**

  This effect was identified in 2R13 as a corrective action to an indication called in the outage prior to 2R13 by a production analyst, but allowed to remain in service by a resolution analyst. It was determined during 2R13 that the resolution process was actually degrading the bobbin analysis POD. After the initial 2R13 inspection and analysis, all indications called by either production analyst were tested with RPC, even if resolution dispositioned them as clean tubes. The result was that additional flaws were identified and removed from service. However, the production analysis had already been completed during 2R13 prior to taking this step. The production analysts were informed prior to 2P99 that all indications identified by either analyst, no matter how insignificant, would be tested with RPC and would not go through the bobbin resolution process.

- **Data Quality**

  In addition, an observation was made concerning the quality of the data acquired during the 2P99 inspection. During previous outages, problems were experienced with noise during the initial stages of the inspection. During 2P99, no startup problems were experienced. The data quality was considered good from the initial setup throughout the inspection.

  During the last three outages, a "data cop" was utilized to monitor the quality of the data as it was being acquired. The data cop is an analyst who reviews the data quality online to catch problems with noise, probe failures/wear, and any other concerns that could affect the quality of the data. Fewer retests were also required in 2P99, indicating better quality data on the initial acquisition than in previous outages.

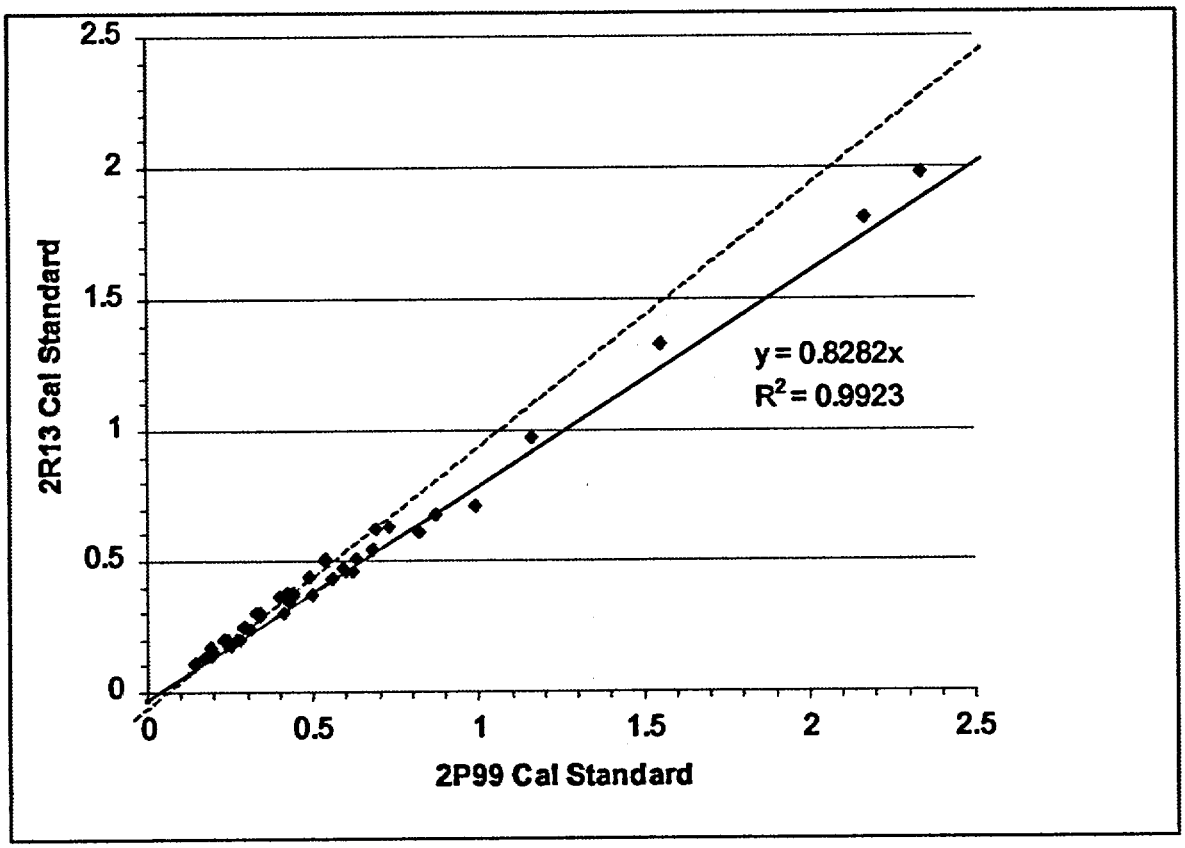
2P99 Inspection Results

During the inspection, a larger than expected number of indications were detected at the eggcrates. Investigations were conducted to better understand the cause for the increased number. It was initially believed that the focused inspection and training was the primary contributor to the numbers, but increased growth rate and initiation of new flaws could not be ruled out without further investigation.

During the outage, an online review of the previous outage data for each tube containing a flaw in 2P99 was performed. The review determined that no significant growth was occurring and that there was no apparent increase in the growth rate over previous intervals. It was also identified that for many of the 2P99 indications, flaw precursor signals were present in the previous outage, indicating no significant increase in initiation of new flaws.

Toward the latter part of the 2P99 inspection, it was noted the bobbin signal amplitude, measured in volts, was on average larger than in previous outages. A review of the probes, cables, equipment, and calibration standards was performed to determine the reason for the increase. During the 2P99 outage, different calibration standards were used for the bobbin analysis. A review was performed to evaluate the possible effect that the new standards had on the process. During the outage, one of the old calibration standards used during 2R13 was tested at one of the SG platforms with the same setup and configuration used during 2P99. Both the old and the new standards were tested with the same probe. A set of tubes that contained 12 distorted support indications (DSIs) were compared and the difference in voltages identified. Following the outage, a set of 42 tubes in SG "B" were analyzed using calibration setups from both standards. This data is shown in Figure 1. Additional indications were analyzed using the old standards as well as the new standards, with results comparable to that seen in Figure 1.

FIGURE 1



Post Outage Evaluations

The number of indications detected in 2P99 was higher than previously seen or predicted for the outage. An increase of this nature can be attributed to one or a combination of the following:

- Improvements in detection,
- Higher than expected growth rate,
- Increase in initiation rate of flaws.

These had each been evaluated during the outage, but follow-up work was performed. The results are as follows:

- **Improvements in Detection**

  In addition to those items previously discussed, the change in the calibration standard resulted in an improvement to the signal characteristics. As demonstrated during the ANO-2 SSPD, for signals below 0.5 volt, a small increase in the voltage response can result in a significant increase in the POD.

  For a given voltage response in the 0.20 volt range, an increase of approximately 0.1 volt was calculated based on a regression of the data from Figure 1. The net effect would be an increase in probability of detection from approximately 50% to 70%.

- **Higher than expected growth rate**

  Increased growth rate can be an obvious reason for an increased number of indications. Entergy Operations has performed extensive growth rate studies to evaluate the ongoing conditions of the ANO-2 SGs. The initial look back performed during the outage did not identify any significant change in growth rate.

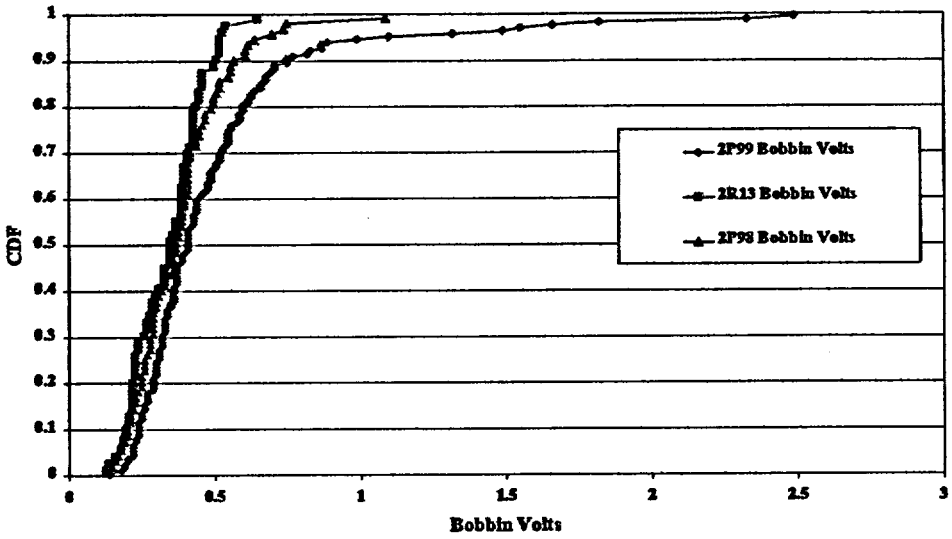
  In previous operational assessments, growth rates calculated from Palo Verde were used to bound those found at ANO-2. To validate this, a growth rate evaluation was performed following 2R12 (1997). The study utilized three outages and was based on bobbin sizing methodologies. The end result of the study was a mean growth rate of 6.89% TW/EFPY. This growth rate distribution bounds the results of several growth rate studies for plants of similar design.

  To reconfirm this, a second growth rate evaluation was performed using the most recent three outages (2P98, 2R13 and 2P99). The results of the study were once again consistent with those performed throughout the industry and the previous ANO-2 studies. The average growth rate was 6.533 % TW/EFPY, which is near that of the previous study. This data indicates no change in overall growth for the ANO-2 eggcrate flaws over the last several intervals.

Figure 2 shows the distribution of the bobbin voltages for the past three outages. The 2P99 results are clearly larger than those measured for the other outages. This is indicative of either a change in the inspection technique that resulted in a higher voltage, or larger flaws being detected on average. The extreme values are of obvious importance. Of those few indications exceeding 1 volt, some did exhibit an increase in amplitude. One of those indications also had a length and depth that resulted in the indication being in-situ pressure tested. That indication successfully met 3ΔP. The remaining indications over 1 volt were generally short cracks which were not structurally significant.

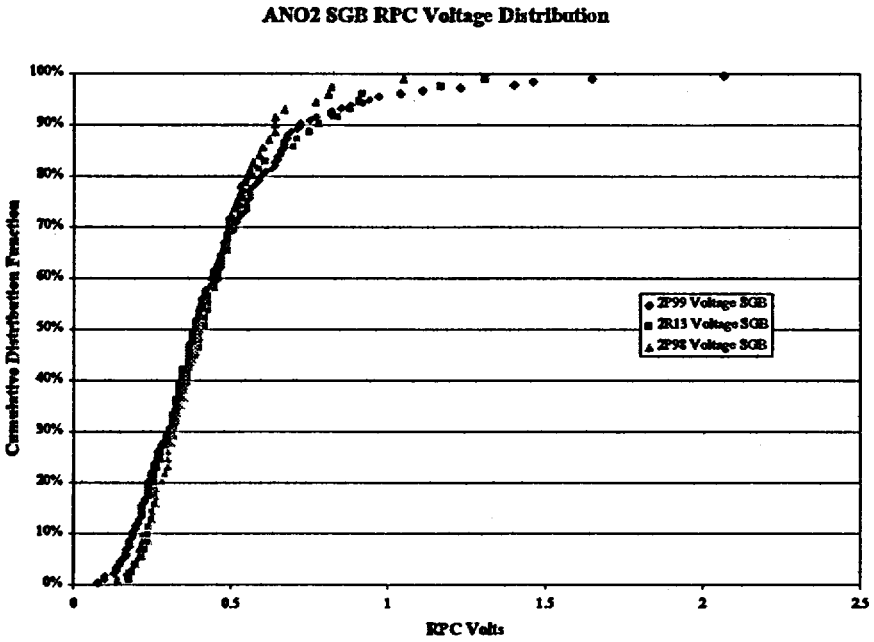
FIGURE 2

ANO-2 Cumulative Distribution Function for P1 Channel Bobbin Voltage



To ensure no significant growth was occurring, the RPC data for the flaws in the past three outages was reviewed. Figure 3 shows the voltage distribution from confirmed flaws for these outages. These results show 2P99 is generally comparable to the other outages, but does confirm the extreme value amplitudes shown by the bobbin coil. Once again, flaws at the upper end of this specific distribution are not structurally significant based on the length and depth of the flaws and in-situ pressure testing results.

FIGURE 3



In addition, the depths and lengths of the flaws based on RPC were reviewed. This is shown in Figures 4 and 5, respectively. RPC sizing, while not qualified, was validated as conservative against pulled tubes. These distributions do not support an increase in flaw size, indicating the flaw population is generally behaving in the same manner. Thus, the most recent growth rate and initiation rate are consistent with previous operating intervals.

FIGURE 4

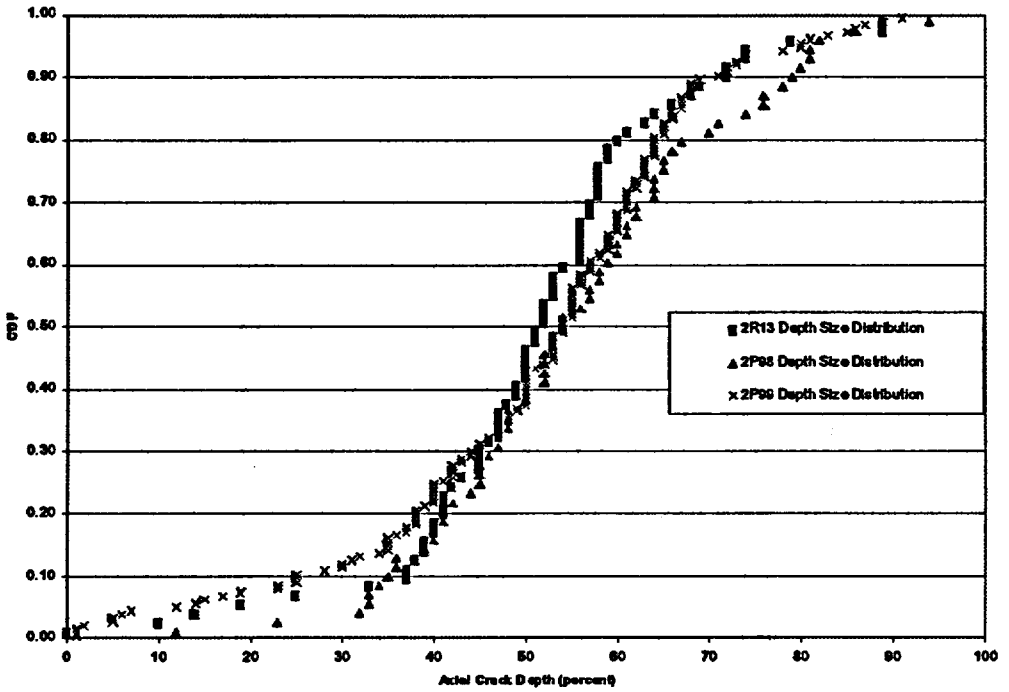
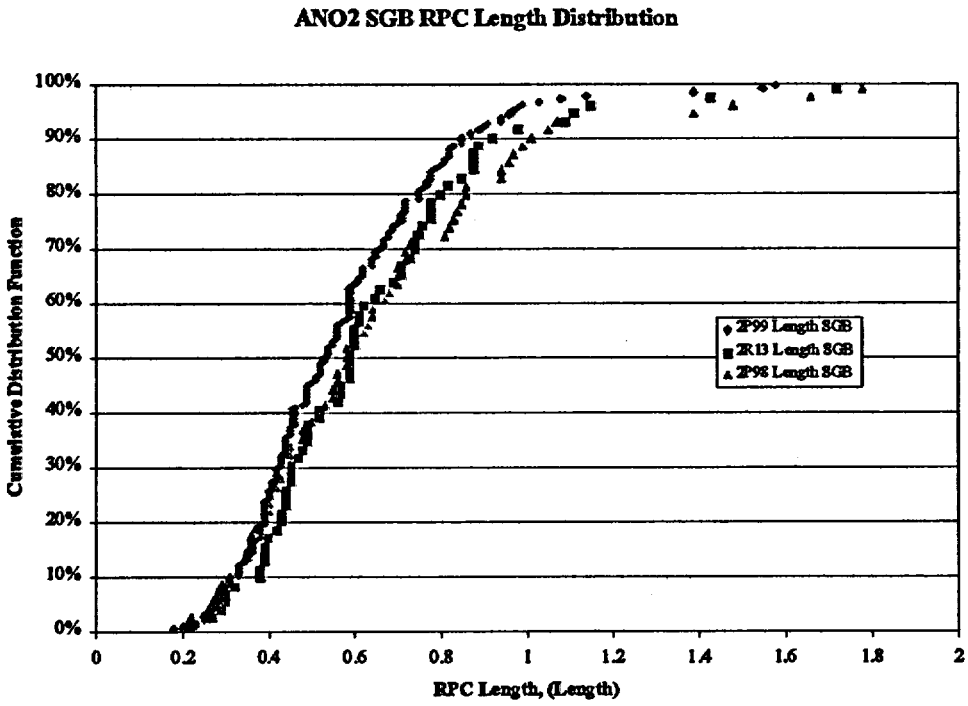
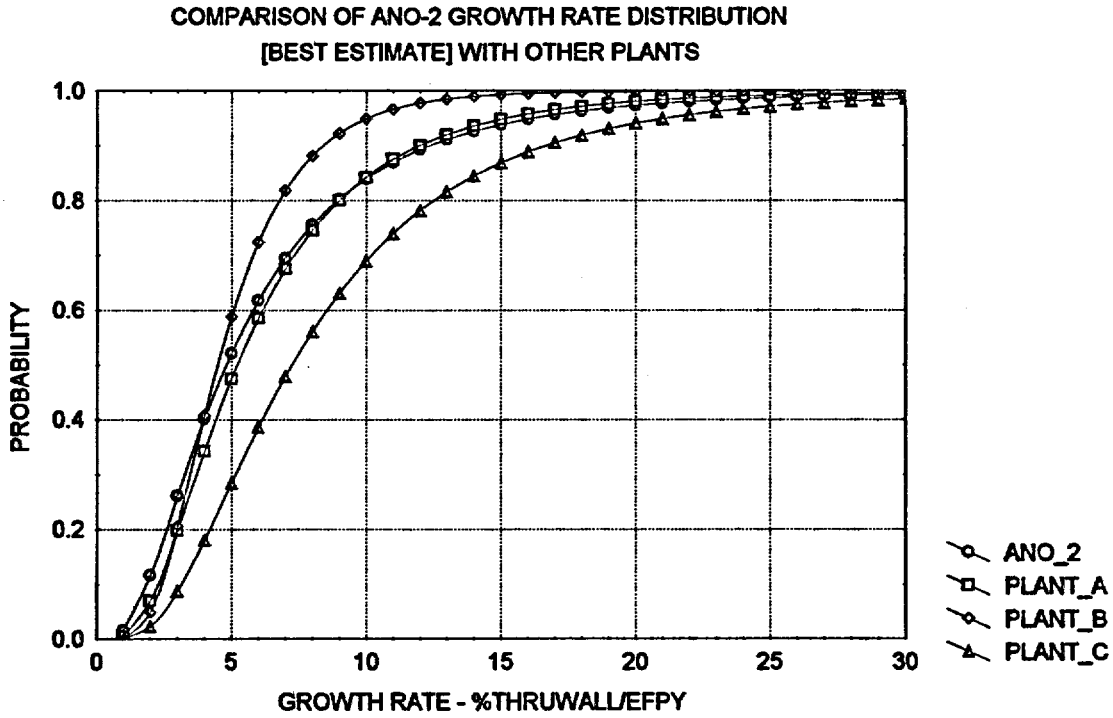

Cumulative Distribution Function of Crack Depth for Axial Cracks at the 61H - 63H for ANO-2
CDF
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
10
20
30
40
50
60
70
80
90
100
Axial Crack Depth (percent)
2R13 Depth Size Distribution
2P98 Depth Size Distribution
2P99 Depth Size Distribution

FIGURE 5



Finally, the ANO-2 data was compared to that of other CE plants, as shown in Figure 6. This figure shows the ANO-2 data is generally consistent with the growth observed at similar plants with axial outer diameter stress corrosion cracking (ODSCC).

FIGURE 6



This confirms that the axial ODSCC degradation at the ANO-2 eggcrates has not changed and the growth rate is comparable to that observed in previous operating intervals over the last several years.

- **Increase in Initiation of Flaws**

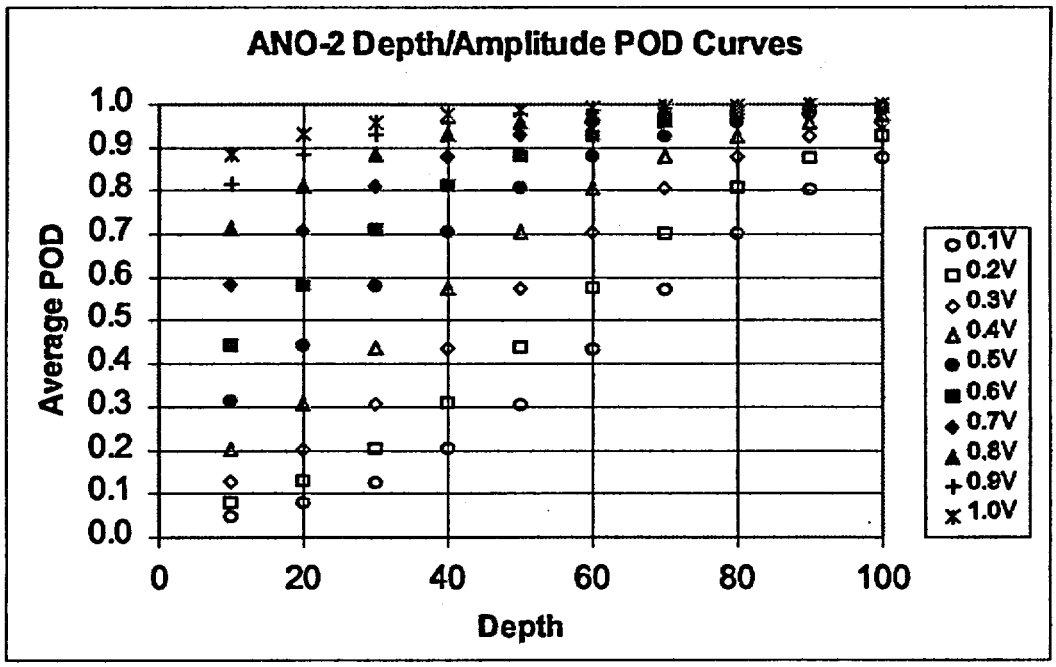
  A review of the flaws detected in 2P99 was performed to determine whether signals were present in the previous outage. This provides a basis for assessing the initiation of new flaws. Of the 185 indications identified in 2P99, signals were present in 173 of those in 2R13. If a significant change in the initiation of new flaws were the reason for the increased number detected, there would be considerably more flaws without precursor signals in the previous outage. This once again highlights that the improvements in 2P99 resulted in a more sensitive inspection and a detection of more flaws.

Discussion of Bi-variate POD

Historically, POD curves have been based on maximum depth as measured by the bobbin coil probe. POD is also a strong function of signal amplitude, measured in volts. This single parameter is often used as a simple measure of signal-to-noise ratio, which

controls POD. As part of the ANO-2 SSPD performed in 1998, the effect of voltage on POD was evaluated. One key aspect is that the POD is really a function of both voltage and depth. This is shown in Figure 7. Flaws that are deep enough to challenge structural limits have a good POD regardless of their amplitude. Thus, any improvement in the signal amplitude results in a direct improvement in the POD and the overall sensitivity of a given inspection.

FIGURE 7



Summary

Several parameters exist to confirm that a significant improvement in the ANO-2 SG tubing inspection occurred during 2P99. These are as follows:

1. The number of indications detected was significantly higher than in previous outages.

2. While the distribution of bobbin voltages increased, the voltage, length, and depth distributions of RPC data showed no difference between the last three outages, indicating no real change in flaw growth rate.

3. Growth rates for the last two operating intervals were compared to previous studies at ANO-2 and with those of other CE plants. The result was that the eggcrate flaws in ANO-2 are growing at a rate comparable to those observed in previous intervals over the last several years, and comparable to other CE plants.

4. A review of previous data for flaws detected in 2P99 indicates the initiation rate of new flaws has not changed significantly. In addition, a multi-cycle probabilistic model was developed to independently assess the initiation of new flaws. That model confirmed the results observed in the field and showed a good correlation between the number of expected flaws and the number of detected flaws over the last four outages.

In conclusion, POD improvements during 2P99 resulted in a more sensitive inspection than in previous outages, as evidenced by the increased number of flaws detected and removed from service. No change in growth rate has been observed for axial ODSCC at the ANO-2 SG eggcrate supports, nor has the initiation rate for new flaws changed.