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Review of Indian Point

On Thursday, March 9, I reviewed the eddy-current inspection at the Indian Point 2 power plant. The prior inspection, in 1997 had been done with probes and procedures designed to detect od defects, rather than the id defects that are present in the u-bends. In addition, the phase setting used by the utility, which is critical for id defect detection, was an old one specified for pancake probes, which is not adequate for the plus-point probe. The EPRI probe qualification for the plus-point used a correct setting in 1997 and uses the correct one at the present time. In reviewing the data, it was obvious that the phase setting was too low in 1997. This was one contributing factor to the indication being missed. The correct phase setting was already being used at this inspection when we visited the plant.

Among our observations was that the noise decreased as the frequency increased, and that the signal from the defect increased. This is expected for id defects, with artifacts on the od that generate noise. Simply increasing the frequency and reducing the probe size will limit the eddy-current signal on the outside of the tube while increasing the concentration of eddy-currents on the inside wall of the tube. This is the well known "skin-effect", and has been employed for years in general eddy-current testing. However, in the steam-generator tube-testing business, most of the defects and problems have been on the exterior of the tube, where they are much harder to detect.

Another observation was that the guidelines were very poor. I made a number of specific recommendations for the improvement of the guidelines. In general, most utilities have poor guidelines that do not fulfill their purpose of insuring an uniform and repeatable inspection. The utilities should spend more effort on their guidelines so the time spent training a large number of analysts is not wasted. It should be noted that most utilities have poor guidelines until NRC "suggests" upgrades. The utility has not documented the training that the analysts are given. This is particularly important in this case, since they are being trained at different times.

I made a number of specific recommendations to the utility to improve the test in three areas of the generator, the u-bends, the sludge pile region, and the tube support region. They are as follows:

Recommendations for U-bend inspection improvement, in decreasing order of importance.

1. Use a smaller, high-frequency plus-point probe. I talked with the manufacturer of the plus-point probe, and "negotiated" a 0.075-inch long probe that would work to 1 MHz. The utility had ordered this probe, had EPRI test it, and applied it to the steam-generators. The results were excellent, as will be discussed later.

2. Increase the frequency of the present midrange plus-point probe. Zetec has said that these probes can be operated as high as 500 kHz. Gary Henry of EPRI has tested the probes to 750 kHz.

3. Use a 400 kHz-100 kHz mix to reduce the effects of od noise. Both the utility and I have checked this out and determined that more development will be needed to get any

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significant improvement in this. However, it allows the possibility of analyzing the data previously acquired, including the 1997 inspection. A method that utilizes the greater phase rotation with frequency for od artifacts may give the needed improvements. Also, using more frequencies may improve this type of mixing. At least a limited amount of data should be acquired in this region using the new probe, operated over a broad frequency range (300 kHz to 1 MHz). This type of mixing will require the addition of copper and ferrite to the od of the tubing calibration standard.

4. Analyze the 400 kHz data in addition to the 300 kHz data that the guidelines now require. I believe that the utility is now doing this.

5. Use the correct phase setting for the different frequencies. The utility is now doing this for the present analysis. This is also being applied at the "look-back" of the 1997 data. An increased phase setting may be required for the best analysis of the higher frequency data.

Improve the sludge pile inspection

Try the mixing techniques and additional frequencies as outlined in section 3 above. This improvement will not be as easy to achieve, nor the results as spectacular as the inspection for id defects. However, the present inspection appears to me to have a region of low-sensitivity near the top of the sludge pile region. There also may be a similar region above the tubes that have significant deposits. While we have not had a tube rupture in this region as of yet, we should be aware of the problems that the deposits are causing, and their potential for masking flaws.

Improve the support plate detection

Try mixing techniques and additional frequencies as outlined in section 3 above. I do not feel that this region is as critical or as susceptible to tube rupture due to the presence of the support plates. In addition, the new smaller, high-frequency probe should do a very good job of detecting id defects at dented support plates.

Improve the Guidelines Training and Testing

The guidelines need to be a more readable document, with figures interspersed in the text, rather than gathered at the end. The history of these generators from the eddy-current prospective is too brief. Due to the increased probability of part of the support plate falling between the tubes, loose part inspection should be emphasized. The ACTS sheets do not match the figures in the present guidelines. A written procedure is needed for the bad data rejection calls that are being made. The figure and table captions should contain all the information needed to explain them. Written documentation should be provided for the training and testing. The utility should make more of an effort to prepare good guidelines and training. This would save money in the long run. Also, the good guidelines and well documented training will allow the utility and the NRC to tell the

type of inspection that was done at prior outages. The test is designed to insure that an analyst will achieve a certain probability of detecting defects in the field. During the testing, the utility does not grade off for false positive calls, so the analyst can call everything and increase his chance of passing. However, there is an analyst feedback at the end of each day. If an analyst makes a lot of false calls, which dumps extra work on the resolution analyst, he will be sent home. A method of testing the analyst under actual field conditions is needed.

High-frequency, smaller probe development.

The high-frequency 0.075-inch probe should reduce the effects of od deposits in two different ways. The amplitude of the signal should decrease as frequency increases and the predominant phase of the noise signal should rotate. If this noise signal can be made to be horizontal with respect to the phase setting of the defect signals, then a much greater signal-to-vertical-noise ratio can be achieved.

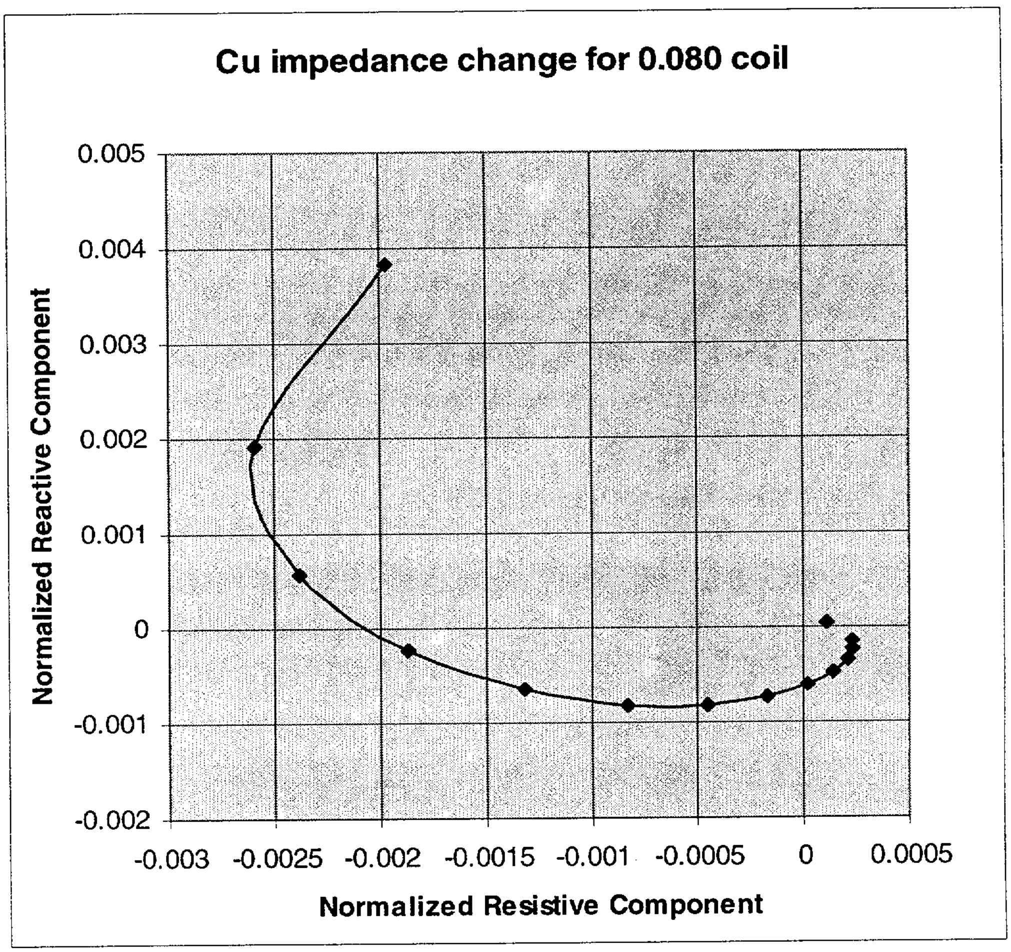

Figure 1 Impedance change due to the addition of a copper cladding on the tube at different frequencies.

In Figure 1 the computed the normalized impedance change for a 0.080 pancake probe between no copper and an infinite thickness of copper on the outside of the Inconel tubing is shown. The frequency is increased form 300 kHz to 2 MHz in 100 kHz steps, with a jump from 1.5 MHz to 2 MHz for the last two steps. The amplitude of the impedance change at 1.0 MHz is 17.5% of that at 300 kHz, and the phase has been shifted about 90 degrees. This "noise signal" does not give a straight vector from zero thickness to infinite thickness, but will produce a "fish-hook" shaped vector. Due to edge effects and other

geometry variations, the signal can have a number of variations. However, this does give an estimate of the effect. The noise measurements show a predominate signal with smaller variations at other angles. While this gives a rough indication of what may be done, better estimates will come from combined computations and measurements. The VIC-3D program can give fairly good computations for the signals produced by notches of different depths. Notches of 20% id and 100% deep notch have been run. Provides a phase setting and a better amplitude setting for the test and shows how the phase can be adjusted to reduce the noise. The computations for the 100% notch have not converged properly yet, but they give an approximate reading of its effect. The computations of the copper and lift-off are very accurate. In Figure 2 we show the computations for the 0.080-

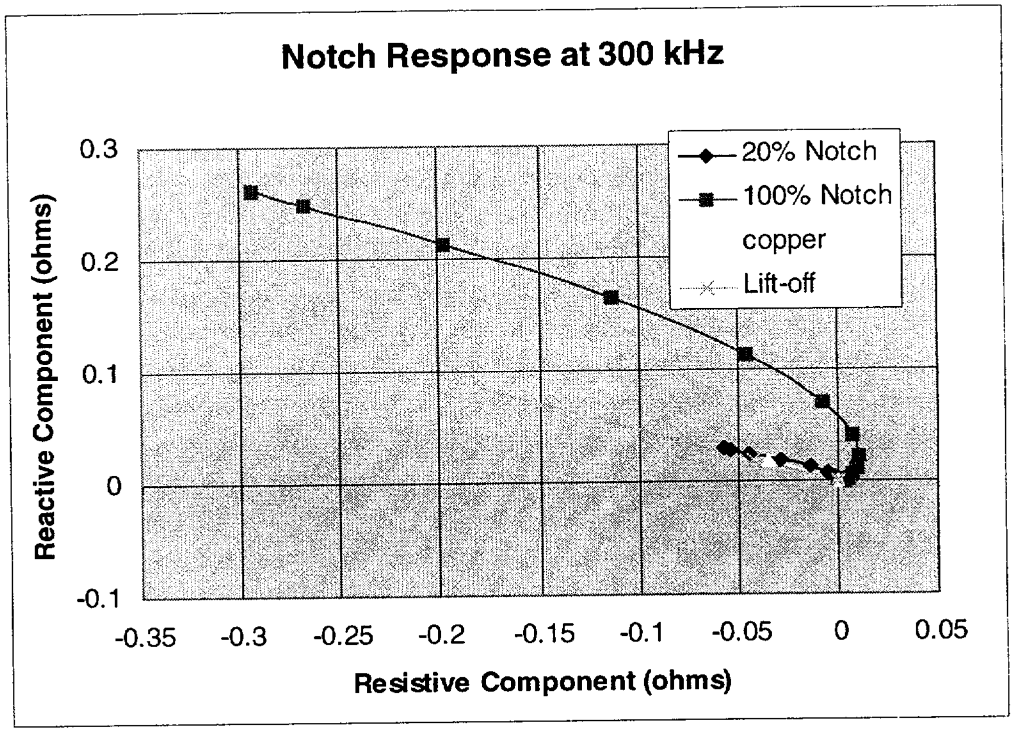

Figure 2 Response of a 0.080-inch probe to notches, copper and lift-off at 300 kHz.

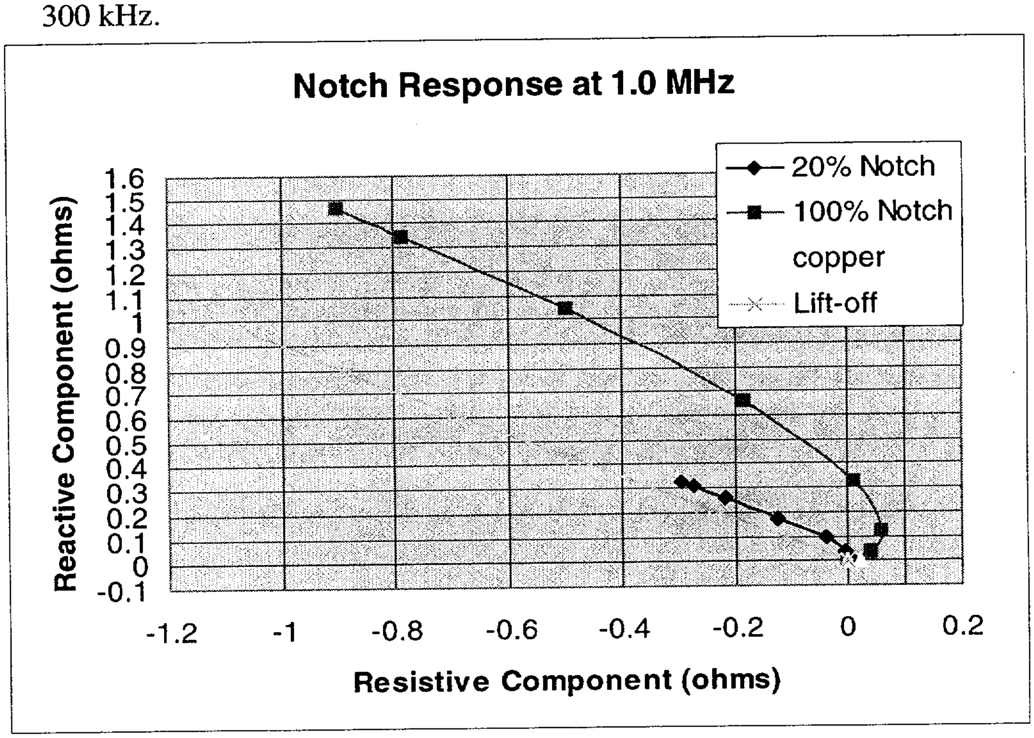

Figure 3 Response of the probe at 1 MHz.

inch probe at 300 kHz. (The modeling has not been done for the plus-point probe, but the media effects will be somewhat similar.) Note that the phase orientation of the 20% notch, the copper coating and the lift-off signal all have about the same phase shift. ODSCC defect signals in the generator have amplitudes of about 10% of the notch amplitude, but the same phase. Therefore, as can clearly be seen, the defects are impossible to separate from the noise.

By contrast, at 1 MHz the phases and amplitudes are much more favorable. In Figure 3 we show similar plots made at the higher frequency. There is more separation of the 20% notch and the lift-off. Also, the copper signal has rotated around until it is almost horizontal. This considerably reduces the effects of the noise signals on the detection of the defects. There is more phase spread between the 20% and 100% notches, which allows a more accurate sizing.

In Figure 4 we show a scan of the midrange plus-point, using the present phase setting. The indication is barely visible, and was not called in 1997. In figure 5 we show a scan of the same tube using the small, high-frequency plus-point, that has been calibrated in a similar manner. The improvement in the signal-to-noise ratio makes this defect very easy to detect. The reduction in noise will also allow more accurate profiling of the cracks. The signal-to-noise

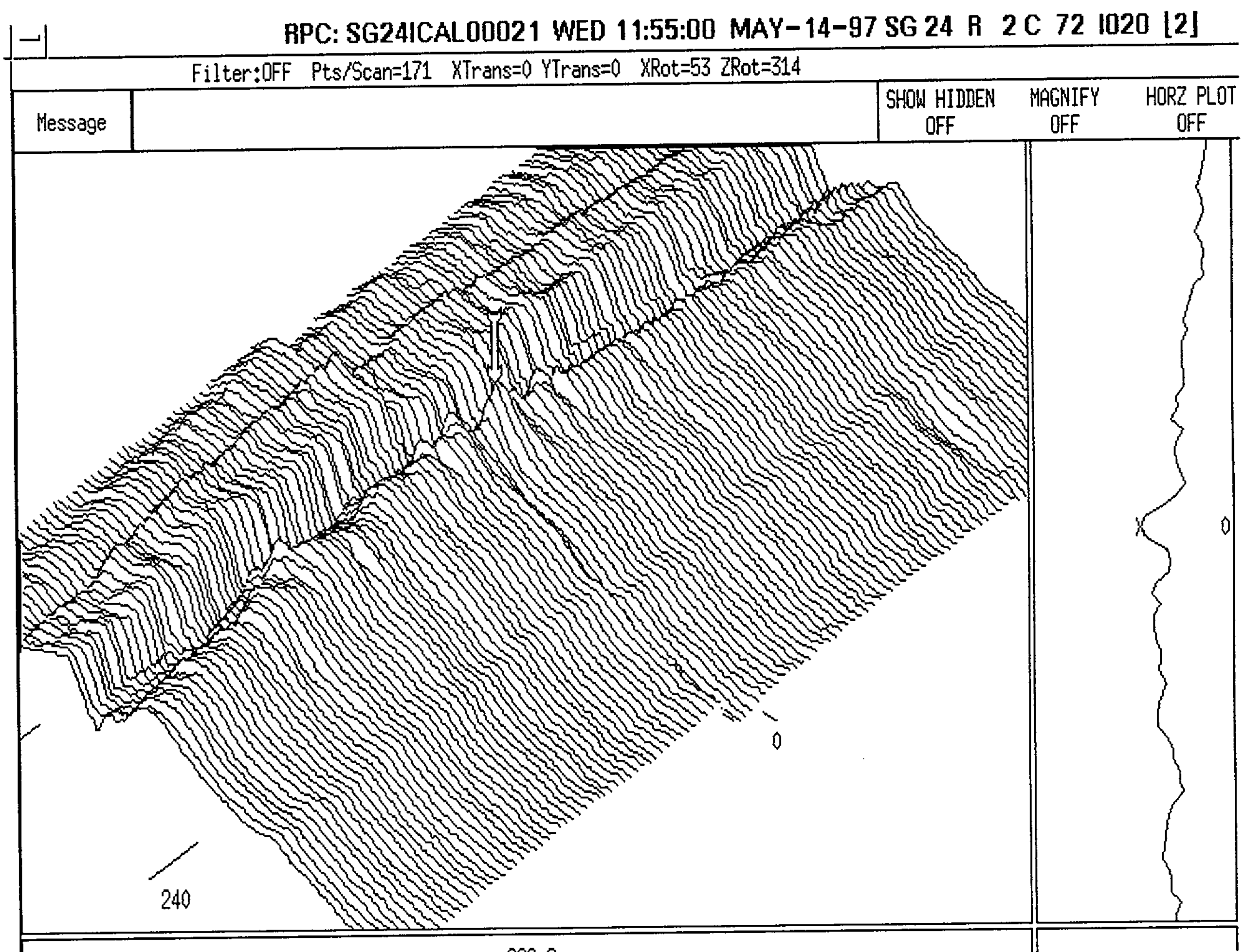

Figure 4 Plot of 1997 scan of tube 2-72 of steam generator 24 made at 400 kHz made with midrange plus-point.

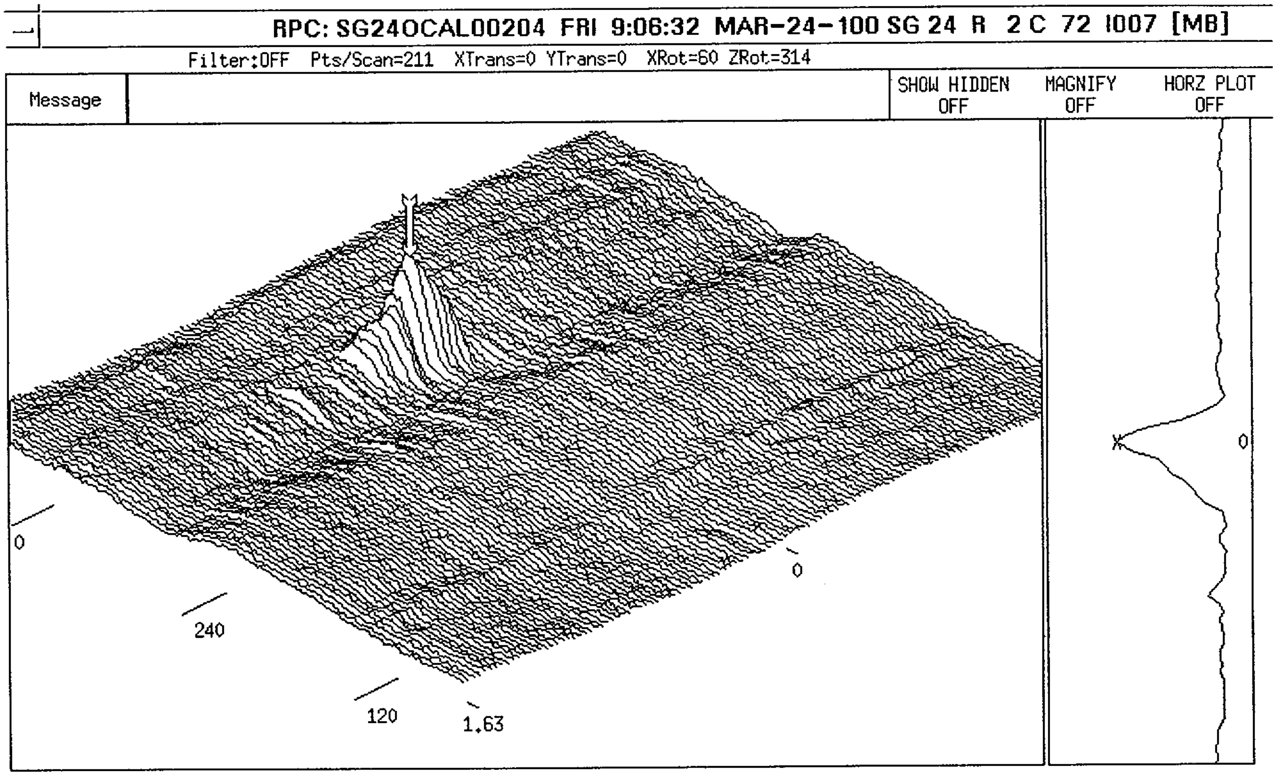

Figure 5 Plot of the smaller, high-frequency plus-point probe at 800 kHz made at this outage. All voltage settings are calibrated at 20 volts on the 100% defect at each frequency.

improvement is partially the result of the probe being made smaller also. The new probe has less noise at the 300 and 400 kHz frequencies than the old mid-range probe has.

Measurements will be made on the defects using the new probe and the old probe. The noise will be read from the tube scans at 100 kHz, 300 kHz and 400 kHz for the old probe and at all of the frequencies for the new probe. The measured defect voltages will be compared with the measured notch voltages for the measured defect depths. A more accurate estimate of the ratio between the actual defect voltage and the calibration voltage for the different defect depths will be obtained. It is expected that the defect voltages will be about 10% of the notch voltages for PWSCC cracks of this type. This voltage will be compared to the residual noise voltage in the tubes and an estimate of the threshold of detection for this probe for the u-bend inspection will be made.

The amplitude and phase of the standard notches will be measured at each frequency. These values will be compared to the calculated values. The proper phase setting at each frequency will be determined. This may result in a different calibration phase for the new probe. Setting the phase at too low a value will result in the more shallow defects being missed.