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REVIEW OF FLAW INDICATION DATA FOR INDIAN POINT 2 REACTOR PRESSURE VESSEL

SUMMARY REPORT
SwRI Project 17-5023

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I. INTRODUCTION

On August 14-16, 1984, Southwest Research Institute (SwRI) participated as a consultant in the meeting at Pittsburgh, Pennsylvania, between the Nuclear Regulatory Commission (NRC) and Consolidated Edison and their contractors. This meeting was held to review portions of the 1984 Inservice Examination conducted by Westinghouse on the Indian Point Unit 2 reactor pressure vessel.

SwRI was asked by C. Y. Cheng of the NRC to perform an independent review of data presented by Consolidated Edison. At the end of the meeting SwRI was requested to report the results of their review and conclusions relative to the data presented.

II. MEETING TOPICS

A. Flaw Sizing per ASME Section XI 1974 with Addenda Through Summer 1975 and Regulatory Guide 1.150

After initial review of the plotted data for the four search units utilized during the examination (transducer nos. TR 22, 24, 25, and 27), it was concluded by K. V. Cook and the author that the preliminary sizing analysis should be based on data taken with transducer number TR 27 (60 degrees) since that transducer generated the highest amplitude response to the indication. The response was approximately 560 percent of the distance-amplitude correction (DAC) curve. C. Y. Cheng requested that Consolidated Edison provide calibration and examination data as well as beam angle measurement, beam spread correction, and instrument linearity data for transducer TR 27. Westinghouse stated the automated detection data was not used for sizing and would be of no use for this exercise and that they would, instead, provide the data gathered manually from the instrument screens used for evaluation and sizing.

After preliminary review of this data the author concurred that the sizing mathematics performed by Westinghouse to arrive at the original 2.03 inches through-wall dimension appeared proper. However, it was noted that Westinghouse had used the 60-degree nominal beam angle for plotting the flaw and for determining the through-wall dimension instead of the 56.36-degree measured angle from their data. When using the 56.36-degree measured angle, the position of the indication relative to the wall of the vessel and the through-wall dimension becomes approximately 1.22 inches. This reduction in apparent through-wall dimension is due to the fact that the straight line plotting places part of the reflector beyond the vessel outside surface. This is obviously impossible and indicates that a portion of the data is obtained from the sound beam bouncing off the outside surface. This is not an uncommon response. It was also noted that the same sizing technique using the actual angle was performed by John Fox from Combustion Engineering (independent consultant to Consolidated Edison). He had also arrived at the 1.22 through-wall dimension. Westinghouse had, on the other hand, chosen to apply a beam spread correction of approximately

2.3 degrees to the original data, while still assuming a 60-degree beam angle. By this process they reduced the size of the indication from 2.03 inches to approximately 1.45 inches.

B. Demonstration of the Effect of Beam Spread on Notch Sizing

Consolidated Edison and their consultants had additionally performed a sizing exercise on a 2 percent notch in a calibration block. This sizing exercise was performed in the same manner as the sizing of the indication in the vessel. Assuming a 60-degree angle, the apparent size of the notch when using the assumed 60-degree beam angle and Section XI sizing procedures was 1.54 inches through-wall. This information was used to demonstrate that sizing the 2 percent notch (0.18 inch actual depth) using ASME procedures resulted in an extreme exaggeration of the notch depth and that this same exaggeration could be assumed to take place in code-sizing of the reactor vessel indication. K. V. Cook and the author checked the sizing calculations and determined that, with the given parameters, the sizing exercise had been correctly performed mathematically. However, again the assumed 60-degree angle was used. When a 56.36-degree beam angle and 50 percent of DAC points were used, it was determined that the Section XI apparent size of the indication contained in the wall of the block was only 0.6 inch and located at the outer surface. This information would lead one to believe that while the sizing of the machined notch was exaggerated, the degree of error was a factor of 3 rather than a factor of 8-1/2. It was also noted that the amplitude of the 2 percent machined reflector was extremely low compared to the 560 percent of DAC response of the vessel flaw.

C. 45-Degree Pitch-Catch and Delta Technique Evaluation

After preliminary sizing of the flaw using the angle beam vessel examination data in accordance with ASME criteria, Westinghouse performed an evaluation of the indication using a delta head technique.

The delta head technique consisted of using two 45-degree search units aimed at each other in a pitch-catch mode and a 0-degree search unit located midway between the two 45-degree search units and directed straight down into the material such that a tip-generated wave from the indication could be captured. The purpose of this evaluation technique was to determine how much the 45-degree transmitted beam could be shadowed by the flaw. Additionally, the technique used information gathered by the 0-degree search unit from the flaw to possibly determine the location of the tip of the flaw within the reactor vessel wall. This information was explained by Westinghouse during a review of the video tape record of the pitch-catch examination by W. T. Clayton and K. V. Cook. Unfortunately, when Westinghouse took the pitch-catch data during the vessel examination, they were recording and observing only the instrument attached to the receiving transducer, and the only response that could be reviewed was the received ultrasonic beam. There was no way of monitoring the pulse-echo beam from the 45-degree transmitting search unit. Therefore, it could not be confirmed that reduction of the received signal amplitude was necessarily due to interruption of the transmitted sound beam by the flaw.

The unresolved question is whether the low amplitude of the through-transmitted sound beam was due to interruption by a flaw or if it was due to normal variations caused by the cladding. As it was, the received signal amplitude varied between approximately 15 and 90 percent of full screen height (FSH). However, it was impossible to determine if this was a normally varying pattern during the scans across the cladding or if the lowering of the received signal (from 90 to 15 percent FSH) was in conjunction with passing across the flaw. It was determined that unless a pitch-catch experiment could show that total loss of signal would occur with a relatively large (1 inch) indication, the pitch-catch experiment may be inconclusive because of the limited amount of data that was taken during the vessel examination.

Westinghouse then presented information on the delta sizing technique, which consisted of a video tape showing the indication found with the 0-degree search unit in the area of the flaw and a time measurement to that signal. Westinghouse contended that the time of flight for the 45-degree beam to travel to the far wall, convert to the longitudinal mode, and travel to the 0-degree transducer would be 133 microseconds. When Westinghouse measured the time of flight to the signal that was received they measured approximately 131 microseconds. This 131 microseconds, according to Westinghouse, would indicate that a reflector not greater than 0.3 inch deep was the source of the signal.

Westinghouse demonstrated the method of making that determination and at that time no conclusions were drawn by the NRC staff or their consultants.

This presentation on the part of Westinghouse concluded the Wednesday portion of the meeting. On Wednesday evening, John Geiske from Sandia Laboratories arrived as an additional consultant for the NRC and was briefed by K. V. Cook and the author on the information previously presented by Westinghouse and Consolidated Edison.

On Thursday morning, as the meeting convened, John Geiske requested to review the Westinghouse data on the delta technique flaw measurement evaluation. At the conclusion of that review he felt that even though the mathematics as presented by Westinghouse worked out properly, there were other questions relative to additional signals observed that had gone unanswered. After the presentations, Westinghouse performed some demonstrations on the flat calibration block used for the vessel examination and a curved block which was reportedly a dropout from a vessel with production cladding. The flat block used for the calibration was a piece of material that met the ASME requirements for a reactor vessel calibration block and was clad by Westinghouse using a procedure similar to the one used to clad the Indian Point vessel.

The initial demonstration was performed on the flat calibration block. This demonstration was intended to duplicate the sizing of the 2 percent notch previously performed and the results presented previously. Additionally, a comparison to a notch in the curved block was performed. The results of this demonstration were that the apparent sizing data taken on the 2 percent notch that Westinghouse had presented early in the meeting seemed to be proper. But the comparison between the notch on the curved calibration block with the notch on the flat calibration block indicated a significantly higher sensitivity or higher response from the notch in the curved block than from the notch in the flat calibration block.

On Friday morning, additional demonstrations were performed by Westinghouse on the curved demonstration block. These were for the purpose of demonstrating the pitch-catch technique, the shadowing effect that could be expected when passing across an indication approximately 1 inch in depth, and the time-of-flight measurement using the delta configuration on a 0.38-inch deep notch and a 1-inch deep notch. The demonstration of the pitch-catch technique showed that the received signal dropped to approximately 10 percent FSH as the beam passed across the 1-inch deep notch after having been normalized at approximately 50 to 80 percent FSH.

It was felt that because of the results of this demonstration, the pitch-catch data from the vessel examination could not be used to confirm that the indication was significantly less than 1 inch deep. This determination was based on the observed signal loss to approximately 15 percent FSH noted during the flaw evaluation in the vessel, which was similar to the reduction noted from the 1-inch deep notch.

During the demonstration of the delta technique, the author observed that the time-of-flight measurement performed on the 0.38-inch deep notch in the block was very similar to the time-of-flight measurement on the indication performed in the vessel. The author also concluded that the time-of-flight information gathered from the 1-inch deep notch was not similar to the time-of-flight information gathered on the indication in the vessel. The difference was as expected from reflectors of different depths. Preliminarily, the consultants agreed that if the technique was performing as presented by Westinghouse relative to the tip of the reflector producing this time-of-flight information, then the flaw in the vessel seemed to be more like the 0.38-inch deep notch than the 1-inch deep notch. This evaluation was very preliminary in nature and Westinghouse should continue to try to develop more conclusive evidence of the validity of the delta sizing technique prior to final acceptance of the 0.3-inch indication depth.

III. SOUTHWEST RESEARCH INSTITUTE COMMENTS

At the conclusion of the Westinghouse demonstration, C. Y. Cheng requested that each of the consultants address a certain portion of the demonstration and evaluation of the indications and leave a handwritten report of his evaluation with him. The author's comments are summarized on the following pages.

A. <u>Sizing of the Indication Data Taken With Transducer TR 27 Using the Rules of 1974 S75, Section XI</u>

For this effort the data taken with transducer TR 27 (60 degrees) was chosen as that which would probably yield the larger or more conservative size. Westinghouse had presented preliminary sizing information using data collected with TR 27 which indicated that the Section XI through-wall size at 50 percent DAC was 2.03 inches. They then applied a beam spread correction of 2.3 degrees to the above size and obtained a total through-wall dimension of 1.45 inches. The indication length at 50 percent DAC was determined to be approximately 2 inches. No attempt was made to modify the indication length by a beam spread correction.

Upon review of the TR 27 calibration data it was determined that the actual angle was approximately 56 degrees, which could have an effect on the through-wall dimension. This determination was based on using the beam transit time reflector depth, and surface distance from beam entry point to reflector location.

The actual measured angle of 56.36 degrees was accepted instead of 60 degrees. This angle (calculated with data taken on a flat calibration block) was later confirmed by performing a similar test on a block with a curvature reported by Westinghouse to match the curvature of the reactor pressure vessel (RPV) wall.

Once the review of the calibration data was completed, the sizing data was reduced and size calculations were made using the 56.36-degree measured angle.

The top of the indication at 50 percent DAC was determined to be approximately 1.22 inches from the outside surface. The lower edge at 50 percent DAC fell outside the vessel wall by approximately 3/4 inch, which apparently was due to the sound beam being reflected from the outside surface before impinging on the flaw or due to a reflection at a shallower angle. The through-wall size was, therefore, determined to be 1.22 inches based on the data provided.

The length of approximately 2 inches reported by Westinghouse seems to be correct and is not under question.

B. <u>Attempt to Size the 2 Percent Notch in the 9-Inch Flat Calibration Block Used for Examination of the Indian Point 2 RPV</u>

This sizing was also in accordance with Section IX 1974-S75.

Westinghouse also performed a sizing exercise on the 2 percent surface notch in the flat calibration block. A beam angle of 60 degrees was assumed for this effort and the resultant apparent size was determined to be 1.54 inches. When the 56.36-degree actual angle was used by NRC consultants the Section XI size became approximately 0.6 inch. This change, as in the case of the vessel sizing, was due to the difference in beam angle used for sizing calculations. Again, as in the case of the vessel, a large portion of the apparent size of 1.54 inches fell outside the block when using the actual angle.

As previously mentioned, the data reviewed was for transducer TR 27. Additional information may be obtained by performing a similar review for the other three transducers that located the indication. It is felt, however, that no larger flaw size would be obtained during such a review.

C. Calculation of the Beam Spread Data Used for Size Modification to the Section XI Size

The 2.3-degree half-angle beam spread was confirmed by calculations using the calibration data, but such a correction is not allowed by Section XI and was therefore not used for the ensuing sizing evaluation.

IV. CONCLUSIONS

Based on the data reviewed and the demonstrations by Westinghouse, SwRI has reached the following conclusions:

1. The data made available for review indicates that by using Section XI sizing techniques the indication has a length of approximately 2 inches and a through-wall dimension of approximately 1.22 inches, and is located at or near the outside surface of the vessel wall.

2. The demonstration of the pitch-catch evaluation technique used by Westinghouse was inconclusive. The lack of pulse-echo data during the vessel examination results in the inability to determine whether the signal reduction to 15 percent FSH was due to shadowing by the flaw or was normal cladding variation. When compared to the demonstration on a 1-inch deep notch which yielded a reduction to 10 percent FSH, it was not possible to conclude that the flaw was shown to be significantly less than 1 inch through-wall.

3. While the demonstrations of the evaluation techniques offer conflicting suggestions of the true vessel flaw size and comparison of the data is inconclusive, we estimate that the flaw is at least 0.3 inch deep but probably no more than 1 inch deep. These estimates are based, in part, on the limited length of the flaw, the common aspect ratio of fatigue cracks (we are not necessarily suggesting that this is a fatigue crack), the omnidirectional reflective characteristics of the flaw, the possibility that the examinations could have been conducted at an erroneously high sensitivity, and the fact that the observed tip-diffracted signal may have emanated from the tip or a point near the tip. Further, we estimate that the flaw is probably in the 0.3 to 0.5 inch depth range; but additional examinations and/or evaluations are needed to conclusively show that it is not as deep as 1 inch.

4. The delta technique used by Westinghouse demonstrated that a similar time of flight could be obtained from a 0.38-inch deep saw-cut notch as from the flaw in the vessel. It is our belief, however, that the diffracted tip wave could be originating at other than the uppermost tip of a flaw that may be inclined instead of being perpendicular to the surface. Considering that no other evaluation method applied supported the postulated 0.3-inch through-wall dimension, it is difficult to develop a high degree of confidence that this single measurement provides an accurate measurement of the flaw depth.

V. RECOMMENDATIONS

SwRI feels that the 0.3-inch dimension measured with the delta technique could be better supported if the following steps were taken:

1. Re-examine the vessel flaw using the pitch-catch technique in order to assure that pulse-echo data is taken simultaneously such that accurate flaw-received signal response correlation can be obtained. Also, the use of smaller transducers to reduce the through-transmitted beam size should be considered.

2. Compare the pitch-catch data with various notch depths from 0.3 to 1.5 inch in the curved block. Confidence in the results will be enhanced if multiple notches at each incremental depth are evaluated so that the effects of the cladding can be better quantified.

3. Perform additional studies on actual cracks in similar thickness test blocks. Since Consolidated Edison feels that the response from the crack of over 500 percent DAC is caused from an inclined face, a similarly inclined crack should also be considered.