ATTACHMENT A

INVESTIGATION OF AN ULTRASONIC INDICATION IN THE INDIAN POINT UNIT 2 REACTOR PRESSURE VESSEL

Consolidated Edison Company of New York, Inc.

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Summary

An ultrasonic indication was found during an inservice inspection of the Indian Point Unit 2 Reactor Vessel that initially could not be characterized as allowable per the ASME Code Section XI Criteria.

The indication was initially sized per Standard ASME Section XI ultrasonic testing methods as 2.03" deep and 1.96" long. Improved ultrasonic techniques more appropriate for sizing were then applied to more accurately size the indication and analyses were made to determine if standard ASME Section XI ultrasonic sizing techniques exaggerate the dimensions of reflectors located at or near the outside surface.

These improved techniques and analyses have resulted in assessing the dimension of the vessel indication as a surface indication 0.26" deep by 0.85" long. The indication is of an allowable size per ASME Section XI, and does not require repair or augmented inspections.

The following sequence of examinations and analyses resulted in the above conclusion.

The indication was initially sized during vessel detection phase inspections using standard ASME Code Section XI pulse echo ultrasonic techniques as 2.03" deep and 1.96" long. Corrections for the spread of the sound beam were applied to the initial depth sizing. These corrections established the through wall dimension as 1.2" and located the indication 0.25" from the O.D. surface with a length of 1.96".

More accurate sizing techniques were then employed to characterize the indication dimensions.

An ultrasonic pitch catch technique using a 45° sending transducer and a 45° receiving transducer was then used. The pitch catch technique anticipates an interruption in the receiving signal by a planar reflector. This technique showed that the indication depth is less than 1" because no loss of signal could be detected by the receiving transducer.

A delta technique was then used to more accurately size the vessel indication. This technique used a 45° sound beam transmitted to the indication and a 0° receiving transducer to receive the signal from the indication. Time of flight information was used to measure the through wall distance from the vessel inside surface to the reflector surface. This technique showed the indication depth to be less than 0.3".

The 0° transducer of the delta array was also used in the pulse echo mode. This showed the indication to be of no detectable width and that there were no detectable wall thickness varations in the vicinity of the indication.

Mockups were then constructed with various reflectors to demonstrate the pitch catch and delta techniques and to determine if ASME Section XI ultrasonic sizing techniques exaggerated the vessel indication size.

The mockups demonstrated that the pitch catch techniques are valid techniques for detecting planar indications on the order of 1". This supported the conclusions that the initial sizing of the vessel indication was exaggerated and that it is actually less than 1".

The mockups also demonstrated that the delta technique, using time of flight information based on total metal path distance, correlates to various depth notches when the mockup wall thickness is known. A review of comparable examination results from the vessel inspections indicates that the vessel reflector is 0.24" deep.

The mockups also demonstrated that when the delta technique results are analyzed using time of flight information based on distance between indications from the reflector upper and lower extremes, the time of flight information correlates with reflector depth independent of a known wall thickness. A review of comparable examination data from the vessel inspections using this measurement indicates that the vessel reflector is 0.18" deep.

An analysis of the exaggeration factors of standard ASME Section XI sizing techniques was also made. This analysis showed that at high amplitude responses the depth of small notches is exaggerated by these techniques by a factor of 7.79 times. This exaggeration in depth is caused in part by the difference between the flat block normally used to calibrate ultrasonic equipment and the curved vessel. The decreased sound impingement on the curved vessel increases amplitude responses as compared to the same reflector on a flat calibration block. This supports the conclusion that the original 2.03" sizing using standard ASME Section XI techniques resulted from a reflector 0.26" deep.

An analysis was also made of the length exaggeration of the standard ASME Section XI techniques. This analysis showed that the length of notches at high amplitude responses was exaggerated by a constant 1.109". A review of the vessel examination data indicates that the original 1.96" length sizing as indicated from standard ASME sizing techniques was obtained from a reflector whose length was 0.85".

The above investigations support the conclusion that the vessel indication is 0.26" deep by 0.85" long and is within the criteria allowable of ASME Section XI.

I VESSEL EXAMINATIONS

Ultrasonic (UT) examinations were performed and associated data collected and evaluated on the Indian Point Unit 2 Reactor Pressure Vessel as part of the ASME Section XI required 10 year in-service inspection program. During this 10 year UT examination 49 indications were detected, 48 of which were evaluated to the ASME BPV Code Section XI Indication Evaluation Standards and were found to be acceptable. One of the 49 indications identified during the detection phase with the 60° angle beam was initially sized as 2.03 inches in depth from the OD surface and 1.96 inches in length, without any corrections applied. This indication was preliminarily determined to exceed the Section XI Evaluation Standards using standard ASME Section XI detection techniques. The indication was detected at vessel location 345° and 236 inch elevation below the flange. This location is near the intersection between a lower shell course longitudinal seam and middle to lower shell course circumferential girth weld. Specifically, the indication is centered 3.5 inches below the girth seam and is contained in the longitudinal weld. The indication was investigated further using techniques appropriate for sizing and characterization.

Prior to performing investigations with alternative techniques suitable for accurate sizing and characterization, various corrections were applied to determine the most accurate size that could be predicted from the detection phase examination data. This consisted of:

- Beam spread reduction based on a total spread of 4.63 degrees in the vertical plane, as measured on side drilled holes in the calibration standard, established the 2a dimension as 1.2", and the lower extreme point(s) as 0.25" from the OD surface.

- The actual beam angle determined on the side drilled holes in the calibration standard was 56.36° for the nominal 60° transducer. This information, when applied to the indication established the 2a dimension as 1.2 inches, and predicted it to be located at the OD surface.

- Each of the 45° and 60° detection phase transducers oriented perpendicular to the longitudinal weld placed the indication at or near the OD surface of the vessel in the same region. However, the indication location projected by nominal beam angles were separated by 2.6". The largest separation between locations was shown by the 60° clockwise and counter clockwise oriented transducers. The data from the counter clockwise transducer located the indication at 343.98° versus the clockwise oriented 60° transducer which located the indication at 345.54°. Further evaluations of the data using the actual angles determined on the calibration standard reduced the separation between the 60° transducers to approximately 1.6". The difference between these locations necessitated that the indications be initially considered as multiple indications rather than a single indication.

- The 2 percent notch (0.18 inch depth) in the calibration standard was sized with the 60° detection transducer to determine the beam characteristics on a corner type reflector (planar reflector located at the OD surface). A beam angle of 60° was initially assumed for this calculation and the resulting size was determined to be between 1.54 to 1.68 inches in depth (at 14db drop points). Using the actual angle of 56.36° the apparent notch depth dimension was determined to be .94 to 1.08 inches. This was determined by correcting for that portion of the sound beam that apparently reflected from the OD surface (greater than 1/2 Vee path) and projecting that portion into the total through-wall dimensions. This demonstrated that amplitude based Section XI sizing methods greatly magnify a small reflector at the OD surface and could not be relied upon for true sizing information.

- The 0° detection phase transducer data showed no evidence of a flaw reflector nor a loss of back reflection. These results indicate that the angle beam reflector is small and at or near the outside surface.

Based on standard ASME Code sizing and characterization techniques and using a 56.36 degree angle, the data showed that the indication could have a depth of up to 1.2 inches and a length of up to 1.96 inches.However, because the ASME sizing techniques greatly magnify a reflector located at the OD surface, the initial information could not be relied upon for true reflector sizing.

Alternative techniques were developed and applied to the indication in the vessel. The alternative techniques utilized a transducer array containing two opposing 45°, 2.25 MHz, 1.5 inch diameter transducers one skip distance apart, and a 0°, 2.25 MHz, 1.5 inch diameter transducer located 1/2 way between the two 45° transducers . The 45° transducers and the 0° are designed such that the projected sound beams intersected at the OD surface of the vessel. A high resolution, 5 MHz, 0.5 x 1 inch rectangular transducer was also placed on the array.

The transducer system enables:

- the use of the delta technique in two opposing directions using the 45° transducers as transmitters and the 2.25 MHz, 1.5 inch diameter, 0° transducer as a receiver.

- the use of the pitch-catch technique using the opposing 45° transducers to respectively transmit and receive the sound beam.

- the use of the pulse-echo technique for each transducer.

- Increased resolution of small reflectors and of reflectors close to the OD surface.

These alternative techniques were applied to the vessel and the data utilized to more accurately determine the size and the characteristics of the indication. The delta technique indicated the maximum depth of the reflector to be 0.3" from the OD surface. This is in agreement with an analytical model using 45° shear wave sound beam transit time to the reflector and a 0° longitudinal wave transit time from the reflector to the 0° transducer. The pitch-catch technique showed no shadowing (loss of signal amplitude) effect that could be related to a large planar defect interupting the sound beam. Characterization of the reflector showed:

1) the indication was a single indication rather than multiple indications

2) the reflector produced a higher amplitude signal with the counter clockwise oriented transducer than with the clockwise oriented transducers indicating a preferential reflector orientation other than perpendicular.

3) the 0° transducers could not discern any evidence of a reflector or geometric condition, indicating no substantial reflector width.

4) the opposing 45° transducers operating in the pulse-echo mode, found the indication simultaneously at the same location without moving the inspection tool, indicating only one reflector.

II MOCKUPS FOR EVALUATION OF UT TECHNIQUES

The alternative techniques required demonstration for "proof of principle"; therefore further mockups with various reflector geometries were fabricated to analyze the results of the evaluation tests performed in the vessel. Two mockups were fabricated to facilitate these qualification evaluations. The first mockup (IPP-1T) was fabricated from a reactor vessel nozzle dropout. The mockup was curved and the I.D. surface contained production cladding. The second mockup (IPP-2T) also a clad nozzle dropout was fabricated to verify the results of the previously performed evaluation testing and to provide data to develop criteria for more accurate sizing information.

A. Objectives of Program

The objectives of the mockup testing program were:

1. To develop a size and type of artificial reflector that would produce ultrasonic responses similar to those obtained from the vessel indication.

Generally, the artificial reflectors selected for these tests are oriented in a planar direction so as to represent a worst case through wall planar reflector.

2. To develop a means of correcting for the oversizing of reflectors that results from the application of Section XI sizing methodology.

3. To determine a conservative thorough-wall (planar depth) dimension, within which the corrected data from the reactor vessel reflector could be bounded.

B. Mockup IPP-1T

The reactor vessel mockup designated IPP-1T was constructed during mid-August, 1984. The mockup contains the following types of reflectors (as shown in Figure 1):

- one 30° and one 45° vee type notche, each 0.25" deep
- two 1.0" long flat bottom notches 0.249" and 0.179" deep
- three 3.0" long flat bottom notches ranging in depth from 0.385" to 0.997".
- one concave reflector 0.25" deep

These reflectors are oriented perpendicular to the direction of weld clad deposit and are located on the side of the block opposite the cladding (the OD surface).

The IPP-1T mockup was constructed from a production reactor vessel nozzle dropout consisting of two base metal plates welded together at the center. The weld geometry is a double J bevel weld oriented perpendicular to the clad beads. This weld joint geometry and orientation is typical of the geometry and orientation of the vessel weld in the area of the subject indication. The three 2 inch long flat bottom notches ranging in size from 0.385 inches to 0.997 inches deep were located in the IPP-1T mockup centered in the weld on the outside diameter. The location of the notches simulate the location of the reflector in the Indian Point 2 reactor vessel.

The vessel mockup IPP-1T was chosen because it was sufficiently large to support introduction of the desired type and number of reflectors and because it was clad using multi-wire clad which simulated the cladding on the Indian Point vessel. During the week of August 27, while developing a plan for additional testing, it was determined that the IPP-1T vessel mockup curvature corresponded to a Westinghouse designed 3 loop vessel with a 78" nominal radius. The IPP-2T mockup (see C below) has a nominal radius of 86.5 inches, which simulates the Indian Point Unit No. 2 4-loop design. Because of the larger than expected exaggeration of reflector lengths, it was found that there was insufficient separation of reflectors on IPP-1T to permit adequate assessment of length oversizing.

C. <u>Mockup IPP-2T</u>

Subsequent to fabrication of the IPP-1T mockup, another production clad vessel section from a 4 loop vessel corresponding to the Indian Point Unit 2 design was located. This section has been constructed to include the following reflectors (as shown in Figure 2):

Flat Bottom Notches

- 1.0" long - 0.1", 0.18" 0.3" and 0.5" deep

- 2.0" long - 1.5" and 1.85" to 2.0" deep

- 0.5" long - 0.18" deep

Side Drilled Holes

- 0.375" diameter at 1/4T, 1/2T and 3/4T
- 0.125" from the OD surface

Side Drilled Notch

- 0.25" x 0.75", 0.125" from OD surface

Vee Notch

- 1.0" long - 0.25" deep, 90° included angle

IPP-2T is the same curvature, clad type, and material as the Indian Point Unit No. 2 vessel. The mockup is fabricated from a reactor vessel nozzle dropout from a 4-loop vessel. The dropout was removed after cladding, hence the clad deposition method is representative of the Indian Point Unit No. 2 vessel. The thickness of the block was that of the upper shell portion of the vessel and therefore had to be machined to 9", the nominal thickness of the vessel lower shell course.

III RESULTS OF MOCKUP TESTING RELATED TO VESSEL EXAMINATIONS

A series of evaluations were performed on the mockups to evaluate and quantify the techniques used on the Indian Point Unit No. 2 vessel. Included in these mockup tests were evaluations of acoustic properties which could influence the accuracy of the results. Specifically these tests included attenuation differences between the calibration standard and the vessel, effects of weld on location and sizing, effects of curvature and cladding, and use of various types of reflector geometries representative of both planar and geometric type of indications. The entire ultrasonic test system used in performing the examination on the vessel was used in performing these mockup evaluations. The results of the evaluations and description of the tests performed follow.

A. Amplitude Analysis

The initial sizing of the vessel reflector using amplitude-based Section XI sizing methods revealed an overall size of 2.03 inches in total depth and 1.96" in length. The 2a dimension was later sized to 1.2 inches by using actual measured angle versus the nominal 60° angle. Because of the inaccuracy associated with amplitude-based sizing methods, evaluation of the oversizing was performed to determine the exaggeration in both depth and length dimensions. These tests were performed using the same transducers and instrumentation as used in the detection and sizing of the indication in the vessel under the same conditions, i.e., water path, 45° and 60° angles, and the same transducer holder (plate). These tests were performed on the notches and side drilled holes in the mockups. Results from mockup IPP-2T were used to compute the exaggeration factor because the clad and geometry on mockup IPP-2T is more typical of the clad and geometry of the vessel. Table 1 lists the results of these tests. The results are sub-divided into 4 categories based on amplitude:

1) Table 1-A - Indications with amplitude less than 100% DAC,

2) Table 1-B -Indications with amplitude between 100% DAC and 100% DAC + 10dB,

3) Table 1-C - Indications with amplitude between greater than 100% DAC + 10db and 100% DAC + 20dB,

4) Table 1-D - Indications with amplitude greater than 100% DAC + 20dB.

Each reflector was scanned from two directions where allowed by access; direction A is clockwise and direction B is counter clockwise. The transducer angles are identified as follows:

TR - 20 = 0° transducer
TR - 22 = 45° transducer
TR - 24 = 45° transducer
TR - 25 = 60° transducer
TR - 27 = 60° transducer

The predicted length and depth refer to the 1 and 2a dimensions and are uncorrected for true angle and portion of the sound beam projected to be beyond the OD surface of the material. Therefore these should be related to the original indication length (1 = 1.96") and depth (2a = 2.03"). Two types of factors were used to determine the amount of exaggeration, the percentage of predicted depth over the actual depth; and, for length, the amount of oversize or undersize.

The results show that the projected size in both dimensions varies with amplitude response from the reflector and with the actual size of the indication. When considering the amplitude response from the notches, it is significant to only consider the range of 10dB to 20dB above DAC because this range relates to the 100% DAC + 15dB indication detected by transducer TR-27 in the vessel.

Table 2 represents the results obtained with the pulse echo angle beam transducers on mockup IPP-1T. These results were not used to determine the amount of sizing exaggeration due to the curvature and attenuation differences between the mockup and the vessel and due to the lack of adequate separation between reflectors to resolve length. However, these results consistently demonstrate the exaggeration of Section XI amplitude-based sizing methods on depth and length. The results from both mockups demonstrate the type of amplitudes observed from small corner reflectors at the OD.

Exaggeration Factor for Depth (2a): The depth exaggeration is influenced by the corner effect, wherein the reflector is at or near another surface, resulting in a "capture" and return of the sound beam. Therefore, a much larger portion of the sound beam is reflected than would be from a subsurface reflector such as a side drilled hole. The reflected energy is greatest over the range of impingement angles from 35 to 55°. On curved material such as the mockups and the vessel, while the entry angle is 56.36°, the impingement angle to a corner reflector becomes 51° or less. This results in an impingement angle in the range of greatest amplitude reflection. This also results in reflection energies over the entire sound beam increasing the exaggeration factor. This demonstrates that the exaggeration factor is caused in part by the use of a flat block for calibration of ultrasonic test equipment. When transforming the ultrasonic energy calibrated on a flat block into a curved vessel or curved block the decreased angle of impingement caused by the curved surface increases amplitude responses as compared to the same reflector on the flat block.

The exaggeration in 2a was therefore determined as a percentage. The statistical mean ($\bar{X}$) and standard deviation (σ_N) were computed for those indications detected by 60° transducers and producing amplitudes, in the range of 10 to 20dB above DAC. These were determined to be:

$$\bar{X} = 7.79 \text{ or } 779\%$$
$$\sigma_N = 3.34 \text{ or } 334\%$$

Exaggeration factor for Length (l): Tests performed on mockup IPP-1T showed that a 1.5" separation between reflectors (See Figure 1) was not sufficient to resolve the end of one notch and the beginning of the adjacent notch. This is a significant demonstration of the inherent oversizing of code required sizing methods. Therefore testing to determine the extent of length exaggeration was confined to mockup IPP-2T. The analysis to determine length exaggeration was limited to the angle beam data from both 60° transducers in both directions (A and B) and only for indications with amplitudes in the range from 10 to 20dB above DAC.

The factor considered for exaggeration in length was a constant (K) which therefore did not depend on the actual length of the reflector. This is considered to be more valid than the percentage factor, because the sound beam has a finite size for each amplitude level and therefore this constant size is what determines the exaggeration factor. Since K varies with amplitude, the mean ($\bar{X}$) and standard deviation (σ_N) are used to determine the K to be used for predicting the vessel indication length. These were determined to be:

$$\bar{X} = 1.747 \text{ inches}$$
$$\sigma_N = .638 \text{ inches}$$
$$K = 1.109 \text{ inches}$$

Effect of Test System Gain on Sizing: Two notch reflectors in IPP-2T were sized with a 60° and a 45° transducer varying the test system gain. The results of this test are shown in Table 3. The oversizing factor is clearly shown to be amplitude dependent and in general agrees with the data shown previously using amplitude based sizing methods. For purposes of comparison with the 2a and l dimensions taken from the entire population, it is important to compare the 50% DAC levels in the range of 10 to 20 dB above DAC.

B. Results of Delta Analysis

In the delta technique, a reflector insonified by means of transverse waves at an angle emits edge waves which can be received by a second transducer, usually a straight beam unit positioned over the reflector. This technique is a variation of what has been recently referred to as diffraction sizing methods where reflector size is determined directly by measurement of transit time and, as such, is considered more desirable than an amplitude - based technique.

In order to develop delta information from the reflector in the Indian Point 2 vessel, a transducer array was developed which consisted of two opposing 1 1/2 inch diameter, 2.25 MHZ, 45° transducers one skip distance apart and a 1 1/2 inch diameter, 2.25 MHZ, 0° transducer located half way between the two angle beam transducers. The 45° transducers and the 0° transducer were arranged such that the projected sound beams essentially intersected at the vessl OD surface. In this configuration, delta information could be developed with either 45° transducer as a transmitter and the 0° transducer as a receiver.

A mathematical model was developed for the delta arrangement based on an 8.9 inch vessel thickness. This model assumed shear waves at a velocity of 0.127 inches/ microsecond are introduced into the vessel, travel to and insonify the reflector, and longitudinal edge waves at a velocity of 0.231 inches/ microsecond are emitted and return to the receiving 0° transducer. The model predicted an essentially linear relationship between delta transit time for reflector depths in the range 0.1 inches to 2.0 inches as measured from the vessel OD surface. The model further predicted an indication at the vessel outside diameter surface would appear at a delta transit time of 133.4 microseconds.

When the delta technique was applied for investigation of the reflector in the vessel, the two 45° angle beam transducers and the straight beam transducer placed on the delta array were the identical transducers used on the detection phase transducer array (TR20/0°, TR22/45° CCW, TR24/45° CW).

The reflector was initially verified using TR22 (45°/CCW) operated in the pulse-echo mode. With the array in that location, the system was switched to the delta mode, i.e. with TR22 transmitting and TR20 receiving an indication was noted at a transit time of 131.6 microseconds. Without moving the array, the system was switched to the delta mode with the TR24 transmitting and TR20 receiving. A delta signal was noted in this configuration at 131.0 microseconds. As the area was investigated with the delta arrangement, delta indications were consistently detected at transit times between 131.0 to 133.6 microseconds. These results indicate:

- The source of the indications noted during the detection phase is a single reflector in the lower shell longitudinal weld on the 345° vessel axis location.

- The maximum depth of the reflector, based on delta transit time information, is 0.24 inches.

The delta transducer array and all associated ultrasonic equipment used during the Indian Point Unit 2 reflector investigation were returned to the immersion calibration facility where all test system parameters were re-established for the purposes of mockup testing.

A second mathematical model was developed based upon the thickness of the mockups. This model also predicted essentially a linear relationship between delta transit time for reflector depths in the range 0.1 inches to 2.0 inches as measured from the vessel OD surface. The model further predicted an indication at the mockup outside diameter surface would appear at a delta transit time of 134.9 microseconds. The delta arrangement was then applied to perform multiple examinations of a series of reflectors ranging from 0.1 inches to 2.0 inches deep in the IPP-1T and IPP-2T mockups.

The multiple examinations on the mockup reflectors were intended to demonstrate the overall relationship between the delta technique and notch depth. Numerous readings from varous block reflectors was taken and the sizing of the reflectors as determined by the delta technique was correlated with actual reflector depth. Results of these studies are described below:

- The delta technique has been demonstrated to provide information which can be related to reflector depth as measured from the OD surface in agreement with the mathematical model developed for the mockups.

- As a general observation, delta results from reflectors at or near the OD surface display two indications. The spacing between these two indications for any one reflector remains essentially constant and can be related to reflector depth. These indications represent the upper and lower extremes of the reflector.

- For notch depths equal to or smaller than 0.1 inches, the transit time difference between the two indications is small and therefore difficult to discriminate.

- Notches greater than 0.18 inches deep result in two indications which become more clearly separated as notch depth increases through the range.

Data from the delta investigation of the reflector in the Indian Point Unit 2 reactor vessel were reviewed again in light of the findings of the mockup testing. A second indication, preceding the primary indication by 1.8 microseconds was observed during several scans over the reflector in the reactor vessel. This observation indicates a vessel reflector depth of 0.18 inches.

C. Results of "Pitch-Catch" Investigations

The transducer array plate used to perform supplementary investigations on the Indian Point 2 reactor vessel and on mock-up blocks IPP-1T and IPP-2T, included two 1 1/2-inch diameter, 2.25 MHz, 45° transducers, which could be operated independently in the pulse-echo mode or in tandem in the "pitch-catch" mode. When operating in the "pitch-catch" mode, either transducer could act as a transmitter with the other acting as a receiver. The spacing and orientation of the transducers was such that the transmitted sound wave travelled through 15 inches of water at an angle which produced a refracted 45° shear wave sound beam in the component being examined. If there are no reflectors which redirect or interupt the transmission of the sound wave, the sound reflects off the back surface and returns on a path that reaches the receiving transducer. Therefore, if there are no significant discontinuities in the path of the sound wave, the receiving transducer detects a reflection from the OD surface. If, on the other hand, a significant discontinuity is in the path of the sound wave, all or some of the sound energy is blocked from the receiving transducer causing a loss of, or reduction in amplitude. This effect would occur each time the area containing the significant discontinuity was scanned. The above effect is referred to as the "shadowing" effect.

To perform "pitch-catch" investigations on the Indian Point 2 reactor vessel, a 15% to 90% full screen height indication was established from the OD surface while scanning plate areas that had not produced indications during the inservice inspection. The fluctuation in amplitude was random and was most likely due to surface irregularities such as the clad surface or the clad base metal interface. When scanning the area containing the reflector, no consistent change in the OD surface indication was noted. Therefore, the reflector was not of sufficient size or orientation to interrupt the reflected signal to the extent that the amount of energy reaching the receiving transducer was significantly reduced. If, the reflector had been planar and of the dimensions initially predicted during the inservice inspection, it was expected that a complete loss or a consistent reduction in amplitude of the OD surface indication would have been noted.

To substantiate the initial observations, the "pitch-catch" technique was utilized during tests on the IPP-1T mock-up block. When scanning over the 0.385 inch deep, 90° flat-bottom notch, no observable effect was noted on the OD indication. However, when scanning over the 0.985 inch and 0.997 inch deep 90° flat-bottom notches, a consistent and repeatable reduction in the amplitude of the OD surface indication was noted.

To further qualify the "pitch-catch" technique, additional tests were performed on the IPP-2T mock-up block. The test system was calibrated to the same gain as was used at Indian Point 2. The screen presentation was expanded to display primarily the area where reflector indications and the OD surface indication would occur.

The areas of the block containing notches E (1.85 inch through-wall depth), D (1.5 inch through-wall depth), C (0.5 inch through-wall depth), and B (0.3 inch through-wall depth) were scanned so that the "pitch-catch" sound beam intersected the notches. Variations in the O.D. signals caused by non-notch parameters (surface roughness, clad, etc.) were again noted. These variations were representative of those noted during the vessel investigations. However, when passing over notches C, D, and E, a consistent and repeatable decrease in amplitude of the O.D. signal was observed. In the cases of notches E and D, the O.D. signal decreased to between 0% and 5% full screen height. When passing over notch C, the O.D. signal dropped to a lesser extent. The extent of decrease in signal from notch B could not be readily differentiated from the normal fluctuations observed during scanning.

The test results obtained from the "pitch-catch" evaluations support the observation that a planar reflector with a through-wall dimension greater than 1 inch would have caused a repeatable and consistent reduction in the O.D.

signal. Since no such reduction was noted when scanning over the reflector in the Indian Point 2 vessel, it is logical to conclude that the reflector has a through-wall dimension less than 1 inch.

D. Results of Acoustic Similarity Evaluations

During the demonstration of techniques performed for the NRC and their consultants at Westinghouse Waltz Mill facilities, it was realized that a much higher response was obtained from the notches in IPP-1T than on the calibration standard (approximately 30 dB). This observation suggests that the gain required on the calibration standard side drilled holes could have resulted in an over sensitive examination. To further investigate the attenuation differences and the effects of weld material versus plate material, tests were performed to compare IPP-1T, IPP-2T, the 9 inch calibration standard and the vessel. The 9 inch calibration standard (IPP-RV-70) was the standard ASME Section XI block used to calibrate the ultrasonic test system used for the vessel detection phase examinations.

Attenuation Evaluation: The side drilled holes were tested in all three blocks. The results are shown in Table 5. These results demonstrate that IPP-1T is approximately 5 to 12 dB less attenuative than IPP-2T and the 9" thick calibration standard. Additionally, the pitch catch transducer arrangement was utilized to determine attenuation differences between the vessel and IPP-2T. This was done by examining IPP-2T using the same criteria as used in the vessel exam, (fluctuations in amplitude between 15 and 90% FSH as displayed on the CRT), then noting the difference in gain used between the IPP-2T test and the vessel. No changes in gain were noted; therefore IPP-2T, the calibration standard, and the vessel have the same relative attenuation.

Effects of Welds on Acoustic Properties: Mockup IPP-1T is a welded dropout which has three notches (see Figure 1) A, B, and C contained in the weld. The notch placement corresponds to the reported location of the indication in the vessel lower shell longitudinal seam weld. The mockup was then tested with pitch-catch, delta and angle beam pulse-echo techniques. Results of the notch amplitudes using the pulse-echo angle beam tests are shown in Table 2. These data showed no discernible effects from the weld material versus the parent material.

IV CONCLUSIONS

Based on extensive ultrasonic testing on mockup reflectors and analyses of exaggeration factors the indication is a surface indication having a through-wall dimension (2a) of 0.26" and a length (l) of 0.85". The a/l ratio is 0.31 and the a/t ratio is 0.03 or 3%. The indication is an allowable indication when compared to the maximum allowable 3.48% per ASME Section XI IWB-3510.1. The shape and orientation of the indication could not be specifically established from these ultrasonic tests.

The above conclusion is based on the following results which were demonstrated by the vessel examinations and mockup tests:

1. ASME, Section XI sizing techniques were demonstrated to oversize both depth and length of reflectors at higher reflector amplitudes for reflectors at the outside (O.D.) surface.

   Amplitude sizing studies indicate depth oversizing by 7.79 times. This shows that the initial depth sizing of up to 2.03" was obtained from an indication whose depth was 0.26".

   Amplitude sizing studies also show length exaggeration of reflectors by a constant 1.109". This shows that the initial length sizing of 1.96" was obtained from an indication whose length is 0.85".

2. The delta technique based on time interval spacing between indications representing the upper and lower extremes of the reflector shows that the indication is 0.18" deep.

3. The delta technique based on total metal path showed the reflector depth to be 0.24 inches. Although generally corroborative of the other delta technique measurement, this method is less accurate because of vessel wall thickness, cladding effects and beam angle variations.

4. The pitch catch technique showed that the indication could not be as large as 1" in depth.

5. The consistent results obtained from the amplitude analyses, and delta and pitch-catch evaluations confirm the oversizing factors inherent in ASME Section XI sizing techniques.

TABLE 1

EFFECT OF AMPLITUDE VARIATIONS ON ACTUAL SIZE VERSUS PREDICTED SIZE (IPP-2T)

NOTCH	DIRECTION	TRANSDUCER	ACTUAL DEPTH	PREDICTED(1) DEPTH/ ACTUAL DEPTH	ACTUAL LENGTH	PREDICTED LENGTH/ ACTUAL LENGTH	OVER (+) OR UNDER (-) (IN)
TABLE 1-A Indications with amplitude less than 100% DAC							
A	B	TR-25	0.1"	4.0	1.0"	0.414	-0.586"
A	B	TR-27	0.1"	5.0	1.0"	0.461	-0.539"
G	A	TR-27	0.18"	2.28	0.5"	0.618	-0.191"
TABLE 1-B Indications with amplitude between 100% DAC and 100% DAC + 10dB							
A	A	TR-25	0.1"	20.0	1.0"	1.333	+0.333"
A	A	TR-27	0.1"	10.4	1.0"	1.064	+0.064"
A	B	TR-22	0.1"	8.2	1.0"	1.809	+0.809"
A	B	TR-24	0.1"	8.5	1.0"	2.041	+1.041"
B	B	TR-25	0.3"	4.5	1.0"	1.306	+0.306"
B	B	TR-27	0.3"	3.03	1.0"	1.794	+0.794"
C	B	TR-25	0.5"	2.85	1.0"	1.087	+0.087"
C	B	TR-27	0.5"	2.85	1.0"	1.03	+0.03"
F	A	TR-22	0.25"	2.52	1.0"	0.719	-0.281"
F	A	TR-24	0.25"	2.2	1.0"	1.741	+0.741"
F	A	TR-25	0.25"	4.04	1.0"	1.509	+0.509"
F	A	TR-27	0.25"	2.64	1.0"	0.76	-0.24"
G	A	TR-22	0.18"	2.89	0.5"	2.478	+0.739"
G	A	TR-24	0.18"	3.00	0.5"	2.466	+0.733"
G	A	TR-25	0.18"	4.89	0.5"	1.65	+0.325"
H	A	TR-22	0.18"	4.33	1.0"	0.91	-0.099"
H	A	TR-24	0.18"	5.28	1.0"	1.743	+0.743"
H	A	TR-25	0.18"	4.44	1.0"	1.287	+0.287"
H	A	TR-27	0.18"	4.28	1.0"	1.39	+0.39"
J(2)	A	TR-22	0.13"	5.85	3.0"	1.11	+0.328"
J(2)	A	TR-24	0.13"	7.31	3.0"	1.20	+0.607"
J(2)	A	TR-25	0.13"	8.31	3.0"	0.413	-1.75"
[illegible](2)	A	TR-27	0.13"	7.31	3.0"	1.07	-0.215"

(1) Corrected for curvature

(2) Portions of notch depth = 1.85"

(3) Side-drilled reflector. Edge of block may influence length measurements

TABLE 1 (CONTINUED)

NOTCH	DIRECTION	TRANSDUCER	ACTUAL DEPTH	PREDICTED[1] DEPTH/ ACTUAL DEPTH	ACTUAL LENGTH	PREDICTED LENGTH/ ACTUAL LENGTH	OVER (+) OR UNDER (-) (IN)
[redacted]E 1-C Indications w/ amplitude between greater than 100% DAC + 10dB and 100% DAC + 20dB							
A	A	TR-22	0.1"	16.6	1.0"	1.549	+0.549"
A	A	TR-24	0.1"	15.7	1.0"	1.488	+0.488"
B	A	TR-22	0.3"	7.33	1.0"	3.25	+2.25"
B	A	TR-24	0.3"	7.6	1.0"	3.223	+2.223"
B	A	TR-25	0.3"	13.57	1.0"	3.12	+2.12"
B	A	TR-27	0.3"	6.13	1.0"	1.789	+0.789"
C	A	TR-22	0.5"	3.74	1.0"	2.901	+1.901"
C	A	TR-24	0.5"	3.64	1.0"	3.467	+2.467"
C	A	TR-25	0.5"	5.48	1.0"	3.687	+2.687"
C	A	TR-27	0.5"	5.98	1.0"	2.608	+1.608"
C	B	TR-22	0.5"	2.6	1.0"	2.004	+1.004"
C	B	TR-24	0.5"	2.34	1.0"	2.027	+1.027"
D	A	TR-22	1.5"	1.99	2.0"	2.22	+2.439"
D	A	TR-24	1.5"	1.54	2.0"	2.17	+2.343"
[redacted]	A	TR-27	1.5"	1.83	2.0"	2.425	+2.85"
[redacted]	B	TR-22	1.5"	1.09	2.0"	1.852	+1.704"
D	B	TR-24	1.5"	1.61	2.0"	1.4295	+1.859"
D	B	TR-25	1.5"	1.2	2.0"	1.99	+1.98"
D	B	TR-27	1.5"	1.65	2.0"	1.559	+1.118"
E	A	TR-22	2.0"[3]	2.89	2.0"	2.064	+2.128"
E	A	TR-24	2.0"[3]	2.89	2.0"	2.39	+2.78"
E	B	TR-22	2.0"[3]	0.985	2.0"	1.56	+1.127"
E	B	TR-24	2.0"[3]	0.965	2.0"	1.527	+1.053"
E	B	TR-25	2.0"[3]	0.88	2.0"	1.728	+1.456"
E	B	TR-27	2.0"[3]	1.015	2.0"	1.858	+1.716"
K[2]	A	TR-22	0.75"	1.95	3.0"	1.016	+0.048"
K[2]	A	TR-24	0.75"	2.52	3.0"	0.996	-0.001"
K[2]	A	TR-27	0.75"	2.33	3.0"	1.383	+1.15"

(1) Corrected for curvature

(2) Portions of notch depth = 1.85"

(3[redacted]e-drilled reflector. Edge of block may influence length measurements

TABLE 1 (CONTINUED)

NOTCH	DIRECTION	TRANSDUCER	ACTUAL DEPTH	PREDICTED(1) DEPTH/ ACTUAL DEPTH	ACTUAL LENGTH	PREDICTED LENGTH/ ACTUAL LENGTH	OVER (+) OR UNDER (-) (IN)
TABLE 1-D Indications with amplitude greater than 100% DAC + 20dB							
B	B	TR-22	0.3"	5.97	1.0"	2.355	+1.355"
B	B	TR-24	0.3"	5.33	1.0"	2.13	+1.13"
D	A	TR-25	1.5"	2.67	2.0"	2.563	+3.126"
E	A	TR-25	2.0"(3)	1.35	2.0"	2.404	+2.807"
E	A	TR-27	2.0"(3)	2.13	2.0"	2.442	+2.883"
K(2)	A	TR-25	0.75"	2.93	3.0"	1.505	+1.516"

(1) Corrected for curvature

(2) Portions of notch depth = 1.85"

(3) Side-drilled reflector. Edge of block may influence length measurements

TABLE 2

MOCKUP IPP-1T
EFFECTS OF AMPLITUDE AND WELD
MATERIAL ON ACTUAL SIZE VERSUS PREDICTED SIZE

		TR-22		TR-24		TR-25		TR-27	
eflector	Actual Depth(1)	Ampl.	"2a"(1)	Ampl.	"2a"(1)	Ampl.	"2a"(1)	Ampl.	"2a"
A(2)	.385	+19	1.45"	--	--	+27dB	2.45"	+30	3.77
B(2)	.985	+28	1.75"	+31	2.29"	+32	3.15"	+32	4.51
C(2)	.997	+28	1.93"	+31	2.38"	+28	3.07"	+31	4.5"
A	.385	+28	1.50"	+23	1.56"	+27	2.56"	+26	2.62
B	.985	+33	1.63"	+20	2.21"	+26	2.73"	+33	3.28
C	.997	+27	1.65"	+24	2.04"	+33	2.64"	+36	3.32
D	.250	+19	1.32"	+18	1.69"	+5	1.71"	+6	0.87
E	.250	+17	1.08"	+5	0.51"	+14	2.23"	+21	1.76
F	.249	+28	1.45"	+19	1.25"	+18	2.09"	+26	1.78
G	.180	+25	1.07"	+7	0.71"	+14	1.13"	+24	1.99
H	.248	+13	1.06"	+10	0.94"	+11	1.11"	+10	1.55

(1) Corrected for curvature

(2) Counterclockwise scan direction

Note: Reflectors A, B, and C are located in the weld

TABLE 3

EFFECT OF TEST SYSTEM GAIN ON SIZING

(Mockup IPP-2T)

		LENGTH (1)						DEPTH (2a)					
	Inst. Rec.	20% DAC Size		50% DAC Size		100% DAC Size		20% DAC Size		50% DAC Size		100% DAC Size	
ch	Gain	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.	Actual	Pred.
ATA OBTAINED WITH TR-27													
	20dB	1.0"	2.084"	1.0"	1.92"	1.0"	1.75"	0.3"	4.15"	0.3"	1.66"	0.3"	1.55"
	14dB	1.0"	2.005"	1.0"	1.68"	1.0"	1.435"	0.3"	4.13"	0.3"	1.59"	0.3"	1.46"
	8dB	1.0"	1.991"	1.0"	1.439"	1.0"	1.05"	0.3"	2.35"	0.3"	1.39"	0.3"	0.95"
	2dB	1.0"	1.379"	1.0"	0.892"	1.0"	0.415"	0.3"	1.57"	0.3"	0.98"	0.3"	0.68"
ATA [illegible]INED WITH TR-22													
	[illegible]B	2.0"	*	2.0"	5.006	2.0"	2.36"	1.5"	2.41"	1.5"	1.55"	1.5"	1.38"
	14dB	2.0"	5.35"	2.0"	2.413"	2.0"	1.09"	1.5"	1.56"	1.5"	1.11"	1.5"	0.64"
	8dB	2.0"	4.135"	2.0"	1.112"	2.0"	0.671"	1.5"	1.44"	1.5"	0.65"	1.5"	0.36"
	2dB	2.0"	2.83"	2.0"	0.646"	2.0"	*	1.5"	1.14"	1.5"	0.35"	1.5"	*
ATA OBTAINED WITH TR-27													
	20dB	2.0"	3.258"	2.0"	3.109"	2.0"	2.914"	1.5"	3.57"	1.5"	3.32"	1.5"	3.09"
	14dB	2.0"	4.094"	2.0"	3.034"	2.0"	2.862"	1.5"	2.04"	1.5"	1.84"	1.5"	1.60"
	8dB	2.0"	4.049"	2.0"	2.1"	2.0"	*	1.5"	1.95"	1.5"	1.72"	1.5"	1.50"
	2dB	2.0"	3.9"	2.0"	1.956"	2.0"	1.59"	1.5"	1.62"	1.5"	1.48"	1.5"	1.29"

ata not obtained

TABLE 4

BEAM ANGLES - IN DEGREES

FLAT/CURVED

	TR-22			TR-24		
Reflector	- 50%	Peak	+ 50%	- 50%	Peak	+ 50%
IPP-RV-70						
1/4T	35.28	43.76	48.60	32.98 (2)	48 (2)	47.55 (2)
1/2T	40.26	43.36	45.86	40.25	42.68	45.38
3/4T	42.0	43.8	46.33	41.30	43.61	45.71
AVG.	39.18	43.64	46.93	40.78	43.15	45.55
B.S. (3)	-4.46		+3.29	-2.37		+2.40
B.S. TOT.		7.75			4.77	
IPP-2T (1)						
1/4T	38.01	41.49	50.56	38.69	43.17	48.11
1/2T	38.60	40.88	42.26	37.50	42.18	46.16
3/4T	34.64	43.92	46.26	37.72	43.50	45.68
AVG.	37.08	42.10	46.65	37.97	42.95	46.65
B.S. (3)	5.02		4.45	-4.98		+3.70
B.S. TOT.		9.57			8.68	

(1) Corrected for curvature

(2) Data not used - considered not to be valid

(3) Beam spread

TABLE 4 (CONTINUED)

BEAM ANGLES - IN DEGREES

FLAT/CURVED

Reflector	TR-25 - 50%	TR-25 Peak	TR-25 + 50%	TR-27 - 50%	TR-27 Peak	TR-27 + 50%
IPP-RV-70						
1/4T	49.67	54.46	58.2	52.85	56.43	59.10
1/2T	53.49	55.56	57.67	53.27	55.01	57.81
3/4T	53.70	55.50	58.86	56.03	57.66	59.13
AVG.	52.28	55.17	58.24	54.05	56.37	58.68
B.S.(3)	-2.89	5.96	+3.07	-2.32	4.63	+2.31
B.S. TOT.		5.96			4.63	
IPP-2T(1)						
1/4T	47.76	53.05	64.56	47.08	53.45	60.83
1/2T	54.60	58.02	61.48	53.44	56.51	59.65
3/4T	51.57	56.41	62.14	51.64	56.08	59.98
AVG.	51.57	56.41	62.14	51.64	56.08	59.98
B.S.(3)	-4.84		+5.73	-4.44		+3.90
B.S. TOT.		10.57			8.34	

(1) Corrected for curvature

(2) Data not used - considered not to be valid

(3) Beam Spread

TABLE 5

ACOUSTIC COMPARISON - IPP-RV-70 VERSUS IPP-2T

	TR-22		TR-24		TR-25		TR-27	
	IPP-RV-70	IPP-2T	IPP-RV-70	IPP-2T	IPP-RV-70	IPP-2T	IPP-RV-70	IPP-2T
1. Preamp Gain	25.5	25.5	20.5	20.5	29.5	29.5	30.5	30.5
2. Receiver Gain	20dB	22.dB	20dB	18dB	20dB	15dB	20dB	16dB
3. 1/4T Hole Response (% FSH)	80	80	80	80	80	80	80	80
4. 1/2T Hole Response (% FSH)	50	38	50	42	55	55	38	90[1]
5. [illegible]/4T Hole Response (% FSH)	32	38	30	22	26	21	27	30[2]
6. Cal Block Notch (% FSH)	65		60		26		18	

(1) Double peak - 1st peak = 70% FSH; 2nd peak = 90% FSH

(2) Double peak - 1st peak = 25% FSH; 2nd peak = 30% FSH

RESULTS FROM IPP-1T(3)

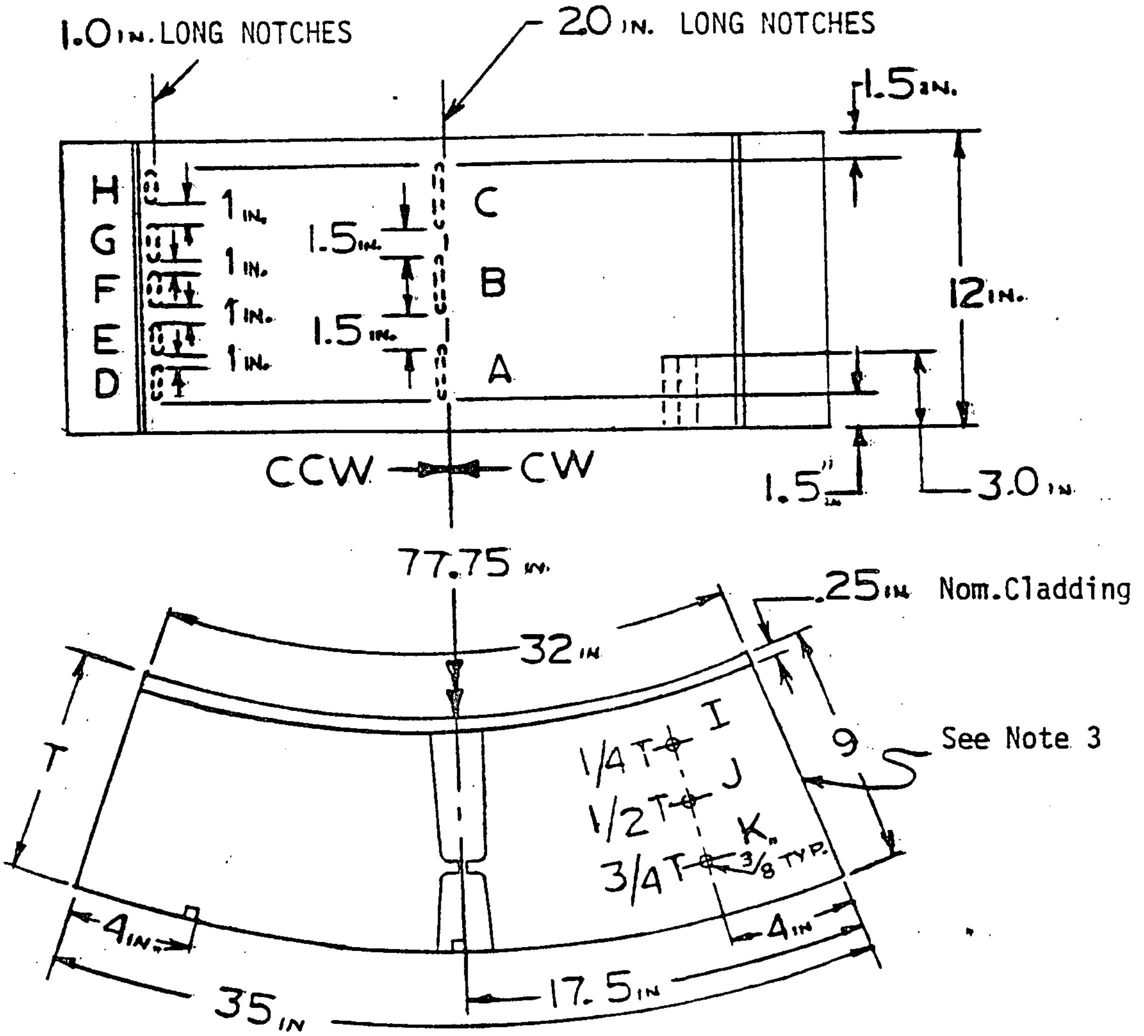
	TR-22	TR-24
1/4 T Hole (% FSH)	100% + 6dB	100% + 6dB
1/2 T Hole (% FSH)	100% + 5dB	100% + 5dB
% FSH	88%	88%

(3) Preamp and receiver gains remained the same as those used for TR-22 and TR-24 on IPP-2T

SKETCH SHEET
WESTINGHOUSE FORM 2444D

WESTINGHOUSE ELECTRIC CORPORATION

Illustrative Only



NOTCH	DEPTH	TYPE	AS BUILT
A	.280	90° Flat Bottom	.385
B	.5	90° Flat Bottom	.985
C	1.0	90° Flat Bottom	.997
D	.250	30° Vee	.250
E	.250	45° Vee	.250
F	.250	90° Flat Bottom	.249
G	.180	90° Flat Bottom	.179
H	.250	Concave	.248
I	3.0	3/8" Dia. Drill	
J	3.0	3/8" Dia. Drill	
K	3.0	3/8" Dia. Drill	

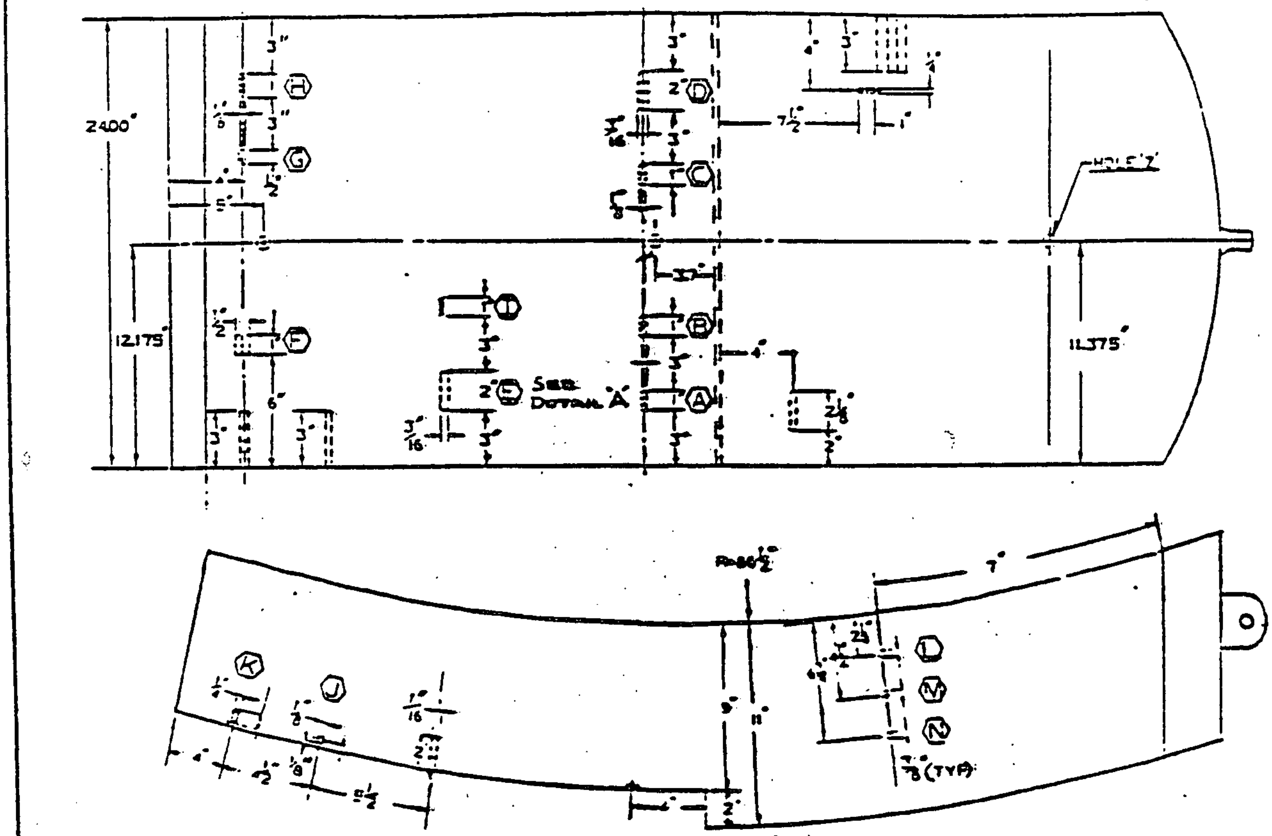
NOTES:
1. Material - SA533 Gr.B.CL 1
2. Tolerance on Dimensions = .032 unless otherwise specified
3. Stamp using metal stamp, Block No., Mat'l Type, Ht. No.
4. Test Block/Not for Calibration

IPP-1T

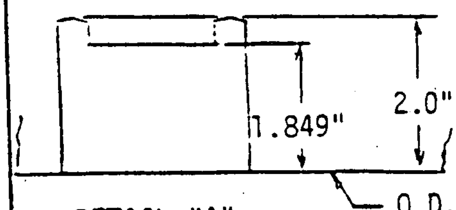
Figure 1

WESTINGHOUSE ELECTRIC CORPORATION

Illustrative Only



TARGET	DEPTH	TYPE	AS BUILT
A	.100"	1/8" x 1.00"	.112"
B	.300"	1/8" x 1.0"	.305"
C	.500"	1/8" x 1.0"	.501"
D	1.5"	3/16" x 2.0"	1.499"
E	2.0"	3/16" x 2.0"	1.849"
F		V-Notch 90°	
G	.180"	1/8" x 1/2"	.180"
H	.180"	1/8" x 1/0"	.181"
I	.250"	Tack Weld (Fillet) 1.0" Lg.	
J	3.00"	1/8" Dia. Hole	1.8"
K	3.00"	1/4" x 3/4" Slot	3.00"
L	3.00"	3/8" Dia. Hole	3.00"
M	3.00"	3/8" Dia. Hole	3.00"
N	3.00"	3/8" Dia. Hole	3.00"



DETAIL "A"
Deotr of Notch

IPP-2T

FIGURE 2

ATTACHMENT B

RESPONSE TO OUTSTANDING QUESTIONS CONTAINED IN
NRC's REQUEST FOR ADDITIONAL INFORMATION DATED AUGUST 16, 1984

Consolidated Edison Company of New York, Inc.
Indian Point Unit No. 2
Docket No. 50-247
September 1984

QUESTION I A:

Additional artificial reflectors should be introduced into the reactor vessel mockup to simulate cracks at various depths from the outside diameter (OD) of the vessel. The licensee should determine the maximum size of a crack that would produce an ultrasonic response similar to that observed during the actual vessel examination with normal scanning and the evaluation examinations with the pitch-catch and delta techniques.

The artificial reflectors should have a length and orientation that is the same as the actual flaw indication. The depth of the artificial reflectors should include the allowable flaw size based on the IWB-3000 of Section XI, 1/2", 1", 1 1/2", and 2".

RESPONSE TO QUESTION I A

Two mock-ups of the reactor vessel have been manufactured into which additional artificial reflectors have been introduced. The reflectors have various sizes and geometric shapes, and have been placed at varying depths from the OD surface. The purpose of these mockups is to demonstrate the principles of the ultrasonic techniques used on the vessel, prove the accuracy of the techniques used from which the indication characterization and sizes were concluded, and to further refine our estimates of the actual indication dimensions.

The reactor vessel mockup designated IPP-1T contains the following types of reflectors (see Figure 1 of Attachment A):

- one 30° and one 45° vee type notch each 0.25" deep

- two 1.0" long flat bottom notches 0.249" and 0.179" deep

- three 3.0" long flat bottom notches ranging in depth from 0.385" to 0.997".

- one concave reflector 0.25" deep

These reflectors are oriented perpendicular to the direction of weld clad deposit and are located on the side of the block opposite the cladding (the OD surface). These conditions simulate the location of the ultrasonic indication in the vessel.

A second reactor vessel mock-up, designated IPP-2T, includes the following additional notch reflectors and side drilled hole reflectors.

Flat Bottom Notches

- 1.0" long - 0.1", 0.18", 0.3" and 0.5" deep
- 2.0" long - 1.5" and 1.85" to 2.0" deep
- 0.5" long - 0.18" deep

Side Drilled Holes

- 0.375" diameter at 1/4T, 1/2T and 3/4T
- 0.125" from the OD surface

Side Drilled Notch

- 0.25" x 0.75", 0.125" from OD surface

Vee Notch

- 1.0" long - 0.25" deep, 90° included angle

Tests on these reflectors have been completed. A description of the tests accomplished, the results and conclusions are presented in Attachment A. From the testing and evaluations described in Attachment A the maximum size flaw that would produce a response similar to that observed during the actual vessel examination has been determined to be 0.85 inches long with a maximum depth of 0.24 inches based primarily on the delta technique and supported by the other techniques employed.

The allowable Code indications as determined from ASME Section XI depend on the aspect ratio, a/L, and also vessel wall thickness. Revising either a or L or the wall thickness has the effect of changing the allowable indication. In addition to 1/2", 1", 1 1/2" and 2" deep nominal reflectors in the mockups, the vessel mockup IPP-2T includes a typical code allowable notch 0.3" deep x 1" long associated with the 9" nominal vessel wall thickness. Other reflectors smaller than and larger than 0.3" deep are also included.

QUESTION I B:

The location of the flaw indication is important in the fracture mechanics evaluation. An artificial reflector should be introduced on the weld fusion line with the same orientation and apparent characteristics of the flaw indication. The licensee should demonstrate that the examination technique was capable of accurately locating the flaw indication within the weld.

RESPONSE TO QUESTION I B

Information regarding potential effects of weld proximity on the ability to locate indications was obtained from the mockup IPP-1T. This mockup was constructed from a production reactor vessel nozzle dropout consisting of two base metal plates welded together at the center. The weld geometry is a double J bevel weld oriented perpendicular to the clad beads. This weld joint geometry and orientation is typical of the geometry and orientation of the vessel weld in the area of the subject indication. Three 2 inch long flat bottom notches ranging in size from 0.385 inches to 0.997 inches deep were located in the IPP-1T mockup centered in the weld on the outside diameter. The proximity of the weld produced no discernible effects on the ability of the ultrasonic test system to locate or size the reflectors accurately. The tests also confirmed that there are no significant acoustic differences between the weld and base metal materials that influence the capability to locate or size the indication.

In addition, the results of the evaluation of the indication in the vessel also demonstrated that there are no significant differences between weld and base material that would effect either location or sizing. During the detection phase of the vessel examination, the reflector was detected and located within the longitudinal weld by two pulse-echo beam angles from two opposite directions; specifically, opposing 45 and 60 degree transducers oriented perpendicular to the vessel longitudinal seam containing the indication. Subsequent evaluation phase examinations used a transducer arrangement with opposing 45° transducers located one skip distance apart with a 0° transducer centered between the 45 degree transducers. These three transducers were applied as follows: a delta (45° to 0°) technique; 0° and 45° pulse-echo techniques; and a 45° to 45° pitch-catch technique. The coincident point for the pitch-catch, the delta, and the pulse-echo techniques were at the same point on the outside diameter (OD) surface of the reactor pressure vessel (RPV). After removal and reinstallation of the vessel inspection tool, the reflection was detected from two opposite directions with the pulse-echo 45° transducers at the same location as that found in the detection examination phase. Also during the evaluation phase, the position and size of the reflector was established to be the same using the opposing delta transducer arrangements. Both of these techniques located the indication at the same position in the vessel with opposing transducers without moving the inspection tool or the transducers.

The indication, therefore, has been repeatedly identified at the same location on the vessel during all of the evaluation examinations with the angle beams traveling through substantially different of weld metal and base material sound path distances. These data confirm the accuracy of the reflector location and also confirm that there are no significant acoustic differences between the weld and base metal materials that influence the location or sizing of the indication.

In certain materials, the influence of weld material and microstructure on ultrasonic properties differs from that of base materials of the same component, even though the composition of the material is essentially the same. These effects are most noticeable in stainless steel welds where the microstructure is similar to a casting rather than the wrought or forged base materials. The influence of the weld in such cases may affect ultrasonic properties such as differences in attenuation, beam redirection, sound beam scattering, and shifts in the beam velocity. Historically, the effects on the ultrasonic properties of carbon steel welds in carbon steel plates, as in the Indian Point Unit 2 vessel, have not demonstrated a comparable influence on locating or sizing reflectors. This is due to manufacturing processes such as "pre" and "post" welding heat treatment and annealing which result in grain refinement of the weld microstructure, causing it to be similar to the base material.

In summary, the vessel detection and evaluation examinations, together with the IPP-1T mockup testing, has demonstrated that the weld proximity has no affect on the ability to accurately locate and size the indication.

QUESTION I C:

Large variations in the ultrasonic response (15% to 90% of Full Screen Height) were observed with the delta technique. The licensee should address the technical basis for concluding that the estimated depth of the flaw indication is accurate considering the relatively large fluctuations in the ultrasonic response observed in the region adjacent to the flaw indication. Literature indicates that the 60° transducer is the optimum angle when using the delta technique. The licensee should discuss the reason that the 60° transducers were not used during the evaluation examination to investigate reflectors with "crack-like" properties.

RESPONSE TO QUESTION I C

The basis for determining that the estimated depth of the indication is accurate results from the ultrasonic techniques utilized during the evaluation phase. Two techniques were employed during the evaluation phase for sizing the reflector in the vessel, the 45° to 45° pitch-catch technique and the delta technique. The large variations in ultrasonic response (amplitude) referred to in your questions were observed with the pitch-catch technique. The delta technique uses sound beam transit time for the location and sizing of reflectors and is therefore independent of amplitude considerations.

The pitch-catch technique was primarily used as an indicator of depth to confirm the quantitative data obtained by other techniques.

The sizing information from the pitch catch technique was anticipated to result from a "shadowing effect" in which the reflector would interfere with the sound beam causing a loss of amplitude of the O.D. surface indication. In the evaluation process, amplitude variations were observed to fall within the range observed on clean plate material in an area away from the reflector. The amplitude variations occurring in the plate were between 15 to 90% full screen height, as were the variations in amplitude observed at the reflector location. Constant and repeatable variations were observed in the amplitude of the O.D. surface indication in the vessel mockup IPP-1T on a 1" depth notch indicating that the shadowing effect is observable on that size discontinuity. This was later confirmed on the .5, 1.5 and 1.85 inch deep notches in mockup IPP-2T. This test indicated that the reflector in the vessel is less than 1 inch in depth.

The delta technique utilizes a 45 degree angle beam to insonify the reflector. Longitudinal waves then radiate from the top of the reflector to a zero degree transducer placed above the reflector. The measured transit time of the sound beam represents quantitative information that is directly translated to the reflector maximum depth from the OD surface. The observed minimum transit time of 131 microseconds for a sound path consisting of a shear wave to the reflector top and a longitudinal wave from the reflector top to the vessel inside surface was correlated to the data gathered under the same conditions on notches in the vessel mockup IPP-1T and mockup IPP-2T. Since sound beam transit time is the quantitative measurement for sizing, the technique is independent of amplitude.

In summary, the delta technique is the sizing technique utilized for quantitatively determining the depth of the reflector in the vessel and the pitch catch is only used to generally confirm the results. With the delta technique, a 45° transducer was used as insonifing sound beam. In principle, it is not significant what angle is used for this purpose but from an application standpoint, a 45° beam is the least sensitive to beam redirection, has a shorter beam length and smaller beam spread resulting in more accurate sizing than a 60° angle.

QUESTION I D:

The licensee should determine the variations in acoustical properties in the basic calibration block, and the mockup, and correlate this information with the properties of the actual vessel, if available. The licensee should provide a discussion of the actual inspection variables, including the differences in acoustical properties, that could influence the characterization and dimensions of the flaw indication.

RESPONSE TO QUESTION I D

Differences in acoustic properties between the calibration block and the reactor vessel can have an impact on the size and type of indications that become candidates for sizing and on the eventual size that is determined in accordance with specified methodology of the applicable ASME Code. Other factors which may influence characterizations of indications are: effects of weld on location and sizing, uncertainty bounds for sizing, effects of curvature and cladding, and reflector geometry.

Preliminary observation during studies of reflectors in the flat basic calibration block IPP-RV-70 and the IPP-1T mockup suggested that a difference in at least one of the acoustic properties--attenuation--may have existed between the calibration block and the vessel. Reflector amplitudes from notches of identical size were significantly higher, i.e., on the order of 30dB, from the mockup than from those in the basic calibration block.

To further investigate the attenuation differences and the effects of weld material versus plate material, tests were performed to compare mockup IPP-1T, mockup IPP-2T, the calibration standard IPP-RV-70 and the vessel. These tests were performed using the same ultrasonic system used in the vessel examinations.

Attenuation Evaluation: The side drilled holes were tested in all three blocks. The results demonstrate that IPP-1T is approximately 5 to 12dB less attenuative than IPP-2T and the 9" thick calibration standard IPP-RV-70.

After performing attenuation comparisons using the side drilled holes in the various blocks, the pitch catch transducer arrangement was utilized to determine attenuation differences between the vessel and IPP-2T. This was done by examining IPP-2T using the same criterion as used in the vessel examination, (fluctuations in amplitude between 15 and 90% FSH as displayed on the CRT), then noting the difference in gain used between the IPP-2T test and the vessel. No changes in gain were noted, therefore IPP-2T, the calibration standard, and the vessel have the same relative attenuation.

Effects of Welds on Acoustic Properties: Mockup IPP-1T is a welded dropout which has three notches A, B, and C contained in the weld. The notch placement corresponds to the reported location of the indication in the vessel lower shell longitudinal seam weld. The mockup was then tested with pitch-catch, delta and angle beam pulse-echo techniques. Results of the notch amplitudes using the pulse-echo angle beam tests show no discernible effects from the weld material versus the parent material.

Other Effects: The mockup IPP-1T whose curvature and cladding differ somewhat from that of the Indian Point Unit No. 2 vessel, and mockup IPP-2T whose curvature and clad are representative of the vessel were tested with the same techniques used in the vessel. These effects are therefore considered in the mockup evaluations. The results from these evaluations show consistent data with a range of variations. These variations are taken into account in the final assessment of the size of the indications. Numerous test runs were performed in two directions towards the reflectors (where possible) and these data were used to determine an uncertainty bound for the data. The varied geometry of the reflector population in the mockups permitted the evaluation of the ability of the test technique to detect and size the reflectors. The effects of these variables were included in the technique evaluation data and hence the final sizing and location of the reflector in the vessel.

QUESTION I E:

The licensee should document the beam spread characteristics of the actual transducers used to detect the flaw indication for future reference.

RESPONSE TO QUESTION I E

Vertical beam profile data for all transducers used during the Indian Point Unit 2 reactor vessel examinations were developed during calibration of the ultrasonic system. Information, such as signal amplitude, transit time at 100%, 50% and 20% amplitude readings and transducer travel distances at 100%, 50% and 20% amplitude readings is recorded for each transducer. This detailed information has been documented as part of the calibration data package associated with the examinations and tests already completed. The same transducers that were used for the vessel detection and evaluation phases were used for additional examinations on two vessel mockups. Additional measurements have been made on a series of notches in these mockups to further define the beam size from OD corner reflectors and determine the effect of vessel curvature. The results of these efforts have been documented for future reference. In addition to the above described beam description information, radio frequency (rf) waveforms have been documented and all critical dimensions required to duplicate the examinations have been recorded.

The above documentation will assure that information obtained from future examinations may be readily correlated with past examinations.

QUESTION I F:

Although the straight beam examination of the flaw indication did not produce consistent results with respect to the depth, the licensee should investigate other longitudinal wave transducers to determine the capability of identifying flaws from grinding. Since the Westinghouse inspection tool is capable of indexing and recording data at 1/4" increments, straight beam transducers with other frequency or beam spread characteristics may produce an interpretable response from grinding.

REPONSE TO QUESTION I F

Two different longitudinal wave transducers of different frequencies and sizes were utilized to investigate indications and determine thickness variations of the reactor vessel. During the detection phase a 2.25 MHz, 1.5" diameter, 0° transducer was used in the reflector region. During the evaluation phase a 5 MHz, 1/2" x 1" rectangular, 0° transducer was used in addition to the 2.25 MHz, 1.5" diameter, 0° transducer. Neither of these transducers produced apparent indications of a discrete reflector or of obvious thickness variations.

Video tapes of the 0° examinations on the vessel were reviewed several times for potentially more subtle quantitative information. No unique characteristics in the screen pattern which could be directly correlated to a flaw were noted.

Additionally, 0° examinations have been performed on mockup IPP-1T. The position of the back surface indication shifted when scanning over the 0.25" deep concave indentation. Definite indications were also noted from the tops of all five of the flat-bottom notches including the 0.179" deep notch. No unique screen pattern variations were present when scanning over either the 30° and 45° vee notches. These overall results in both vessel and the mockup demonstrate:

- The 0° examinations performed on the vessel are capable of discerning variations in wall thickness of at least .18 inches.

- Vee type geometries could not be detected nor resolved with the 0° transducer.

- Reflectors angled beyond 30° could not be resolved using the 0° transducers.

Based on the results of these 0° data and associated conclusions, the indication is most likely to be smaller than .18 in depth or is not of a geometrical configuration that causes sound to return to the transducer.

In conjunction with the beam examinations conducted to date, the above data suggest that the reflector is most likely less than 0.3" in depth with a geometrical configuration that does not reflect back to a 0° transducer.

QUESTION I G:

The flaw indication probably will require monitoring during subsequent ISI. Other types of transducers and techniques could be used to evaluate and dimension the indication. The licensee should identify the optimum technique and transducer combination during the laboratory investigation to permit monitoring the flaw indication in the future.

RESPONSE TO QUESTION I G

In light of the findings and conclusions of the examination and evaluation program which demonstrate that the indication is allowable per ASME Section XI criteria, the scheduling, techniques and equipment applied for future examinations are expected to be consistent with ASME Section XI requirements.

QUESTION II A:

The licensee should determine whether the fabrication records indicate that repairs were performed in the immediate vicinity of the flaw indication.

RESPONSE TO QUESTION II A

A review of vessel fabrication records was conducted at various facilities by Consolidated Edison, Combustion Engineering and Westinghouse representatives. The records of the post hydro shop ultrasonic test indicate that a manually controlled water wheel transducer was used to conduct 0° Longitudinal and 45° shear wave angle examinations. These transducers were calibrated on a 3% notch placed in a 9" calibration block. A Westinghouse trip report dated May 8, 1967 also indicates that ultrasonic tests were conducted on the reactor vessel lower shell in a "shear mode calibrated to a .24" deep buttress notch ground in the shell O.D." The specific location on the shell O.D. is not identified in the report. No other records supporting this observation were discovered either at Combustion Engineering or Consolidated Edison. The shop UT records also did not record the vessel indication detected during the latest vessel ISI examinations. This is not unusual since the instrumentation utilized for current vessel examination is more precise, automated, computerized and complex.

The original radiographic technique and radiographs were also reviewed. The radiographic technique utilized 7" x 17" type AA film. The film was placed on the vessel inside surface with the source located outside the vessel. Two number 100 penetrameters were placed adjacent to the weld on the outside surface. A double film technique with single film viewing was utilized. The reader sheets associated with the radiographs indicated NAD (no apparent defects). However, a review of the radiographs indicated that there may be marginally detectable density variations present in the radiographs in the area of the reflector. Imagery enhancement of the original fabrication radiographs identified linear indications in the area of interest. (see answer to II B).

The fabrication documentation does not record other probable sources of indications from weld repairs or fabrication alignment bars in the reflector region, although shop photographs show fabrication alignment bars were used on the vessel. Photographs of the reactor vessel taken during the field installation indicate a variation of light shadings potentially related to shallow grinding or localized painting on the outside vessel surface coincidental with the location of the reflector.

The above information suggests the possibility that surface indications were identified subsequent to radiography and a grinding operation initiated to remove them. Such surface grinding operations were usual at the time that the Indian Point Unit No. 2 reactor vessel was fabricated. The ultrasonic indication may be the result of an incomplete grinding operation to remove those surface indications. However ultrasonic examinations could not detect any wall thickness variations indicative of grinding.

A second potential explanation for the vessel reflector is that it is due to the placement of a 0.24" deep buttress notch in the O.D. surface of the vessel for calibration of ultrasonic test equipment during shop examinations. The notch was not removed but instead painted locally. Such a notch is consistent with ultrasonic examanination results. However the results of the radiographic image enhancement, if valid, make it unlikely that the linear indications noted in the enhancement are coincidentally located at the same location as the calibration notch.

QUESTION II B:

The licensee should attempt to enhance the original fabrication radiographs to determine whether additional information can be obtained in the immediate vicinity of the flaw indication.

RESPONSE TO QUESTION II B

Image enhancement of the original fabrication radiographs was performed by EPRI's Nuclear Systems and Materials Department in Palo Alto, California. According to an EPRI memorandum, the enhanced radiographic image shows three shallow linear indications in the area of interest. Assuming that the radiographic source was aligned to the linear indication, the image width suggests that the depth is substantially less than 10 millimeters. Depth sizing of these indications is accomplished by comparative methods. The time available to respond did not permit a detailed study and therefore no more refined statement of depth could be made. Such a detailed study would be expected to reduce the maximum potential depth of the indications reported here.

QUESTION IV A:

The licensee should provide a summary table defining the location, characteristics, and dimensions of the approximately 49 "relevant" ultrasonic indications.

RESPONSE TO QUESTION IV A

Attached is Table 1 and Sketches IPP-1-1100 and IPP-1-1100A which together identify the 49 valid (relevant) vessel indications. Forth-eight of the 49 valid indications were evaluated in accordance with ASME Code Section XI criteria and were found acceptable upon initial evaluation. The single reflector identified in welds 3 and 12 required further evaluation to determine its acceptability in accordance with the code and is the subject of the questions and associated responses contained in this report. The dimensions shown in Table 1 for the indication identified in welds 3 and 12 are the final dimensions determined as a result of this investigation.

TABLE I

INDIAN POINT UNIT II

SUMMARY OF ASME CODE SECTION XI ACCEPTABLE VESSEL INDICATIONS

LOCATION	EXAMINATION ANGLE					DIMENSIONS		CHARACTERISTICS	ACCEPTABLE PER CODE PARAGRAPH
Weld #	0°	45°s	60°s	6°L	Size (inches)	Aspect Ratio a/l	% Wall Thickness a/t		
1		X				.158	.030	Subsurface	IWB 3511
		X				.8	.028	Surface	IWB 3511
2		X				*	*	Spot - Subsurface	IWB 3511
		X				*	*	Spot - Subsurface	IWB 3511
		X				.125	.0074	Subsurface	IWB 3511
			X			*	*	Spot - Subsurface	IWB 3511
			X			.326	.0184	Subsurface	IWB 3511
3	X				(.63 x .75)			Mid-Plate***	IWB 3510
	X				(.85 x 1.86)			Mid-Plate***	IWB 3510
	X				(.42 x .84)			Mid-Plate***	IWB 3510
	X				(1.4 x 2.17)			Mid-Plate***	IWB 3510
					(.93 x .54)			Mid-Plate***	IWB 3510
		X				.20	.017	Subsurface	IWB 3510
		X				.28	.031	Subsurface	IWB 3510
			X			*	*	Subsurface	IWB 3510
		X	X			.31	.03	Surface**	IWB 3510
12	X				(.81 x 1.42)			Mid-Plate***	IWB 3510
	X				(.77 x 63)			Mid-Plate***	IWB 3510
		X	X			.31	.03	Surface**	IWB 3510

*Spot Indication - No meaningful dimension

**Same Reflector

***Lamination

TABLE [illegible]ONTINUED)

INDIAN POINT UNIT II

SUMMARY OF ASME CODE SECTION XI ACCEPTABLE VESSEL INDICATIONS

LOCATION	EXAMINATION ANGLE					DIMENSIONS		CHARACTERISTICS	ACCEPTABLE PER CODE PARAGRAPH
Weld #	0°	45°s	60°s	6°L	Size (inches)	Aspect Ratio a/l	% Wall Thickness a/t		
13	X				(.95 x .90)			Mid-Plate***	IWB 3510
11	X				(.77 x .5)			Mid-Plate***	IWB 3510
	X				(1.2 x 2.5)			Mid-Plate***	IWB 3510
	X				(.7 x .8)			Mid-Plate***	IWB 3510
	X				(.5 x 1.06)			Mid-Plate***	IWB 3510
	X				(.8 x .7)			Mid-Plate***	IWB 3510
	X				(.8 x .8)			Mid-Plate***	IWB 3510
	X				(1.2 x .7)			Mid-Plate***	IWB 3510
		X				.137	.014	Subsurface	IWB 3510
8		X				.188	.0078	Subsurface	IWB 3511
9	X				(.6 x .78)			Mid-Plate***	IWB 3510
10			X			.32	.017	Subsurface	IWB 3510
Lower Head	X				(Spot)			Mid-Plate***	IWB 3511
	X				(.6 x .46)			Mid-Plate***	IWB 3511
	X				(.84 x .48)			Mid-Plate***	IWB 3511
	X				(1.3 x .7)			Mid-Plate***	IWB 3511
	X				(1.3 x 1.8)			Mid-Plate***	IWB 3511
		X				.09	.010	Subsurface	IWB 3511
		X				*	*	Spot Subsurface	IWB 3511

*Spot Indication - No meaningful dimension

***[illegible]

TABLE 1 (CONTINUED)

INDIAN POINT UNIT II

SUMMARY OF ASME CODE SECTION XI ACCEPTABLE VESSEL INDICATIONS

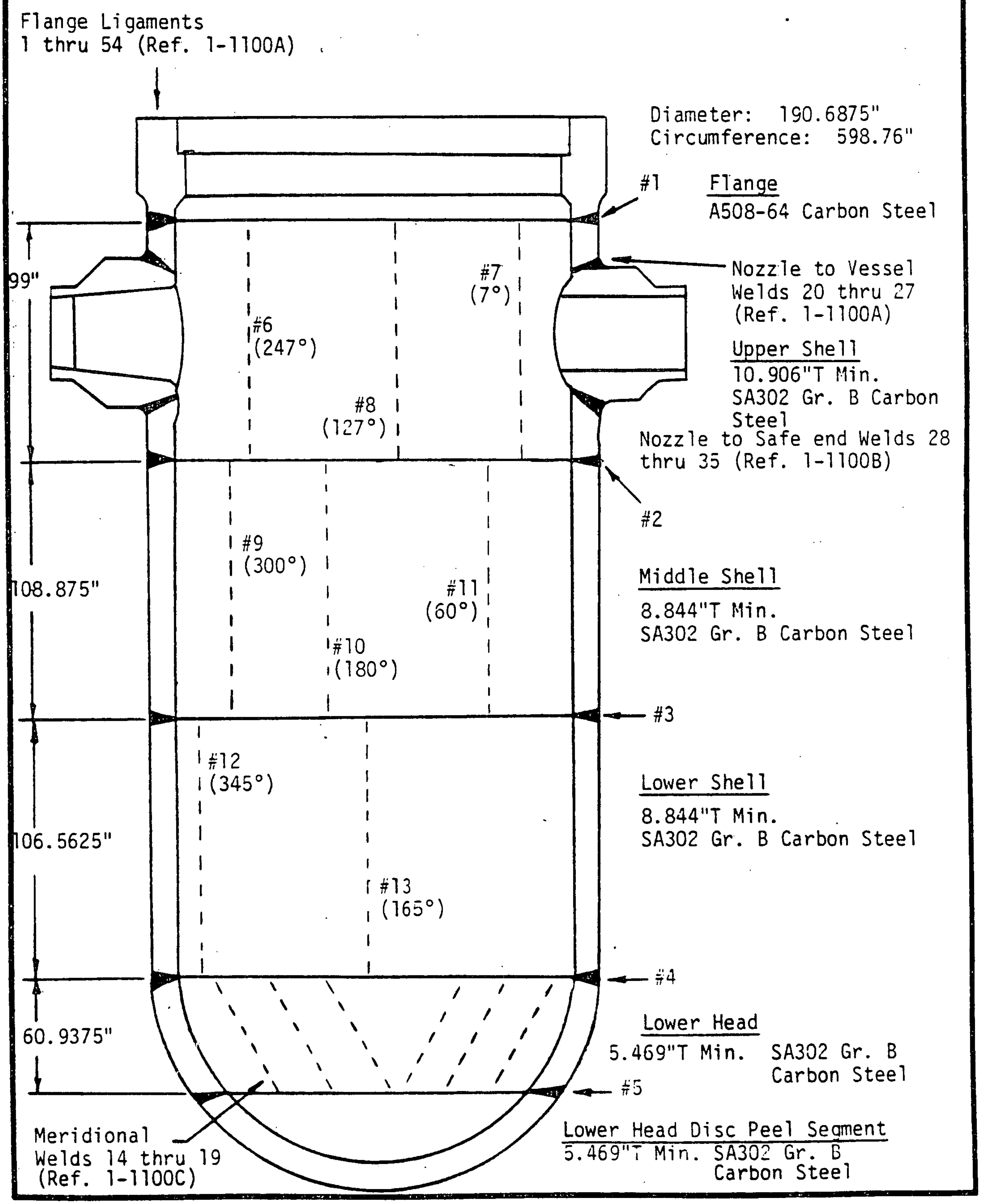
LOCATION	EXAMINATION ANGLE					DIMENSIONS		CHARACTERISTICS	ACCEPTABLE PER CODE PARAGRAPH
Weld #	0°	45°s	60°s	6°L	Size (inches)	Aspect Ratio a/l	% Wall Thickness a/t		
Lower Head		X				*	*	Spot Subsurface	IWB 3511
		X				.35	.030	Subsurface	IWB 3511
			X			.106	.008	Subsurface	IWB 3511
			X			.116	.015	Subsurface	IWB 3511
			X			*	*	Spot Subsurface	IWB 3511
			X			.175	.024	Subsurface	IWB 3511
26 Nozzle				X		1.64	.042	Subsurface	IWB 3512
				X		1.78	.042	Subsurface	IWB 3512
22 Nozzle				X		2.10	.056	Subsurface	IWB 3512
28 Nozzle				X		*	*	Spot Subsurface	IWB 3512
				X		1.89	.057	Subsurface	IWB 3512
				X		.97	.045	Subsurface	IWB 3512

*Spot Indication - No meaningful dimension

Illustrative Only

IPP-1-1100
Rev. 2: 2-84

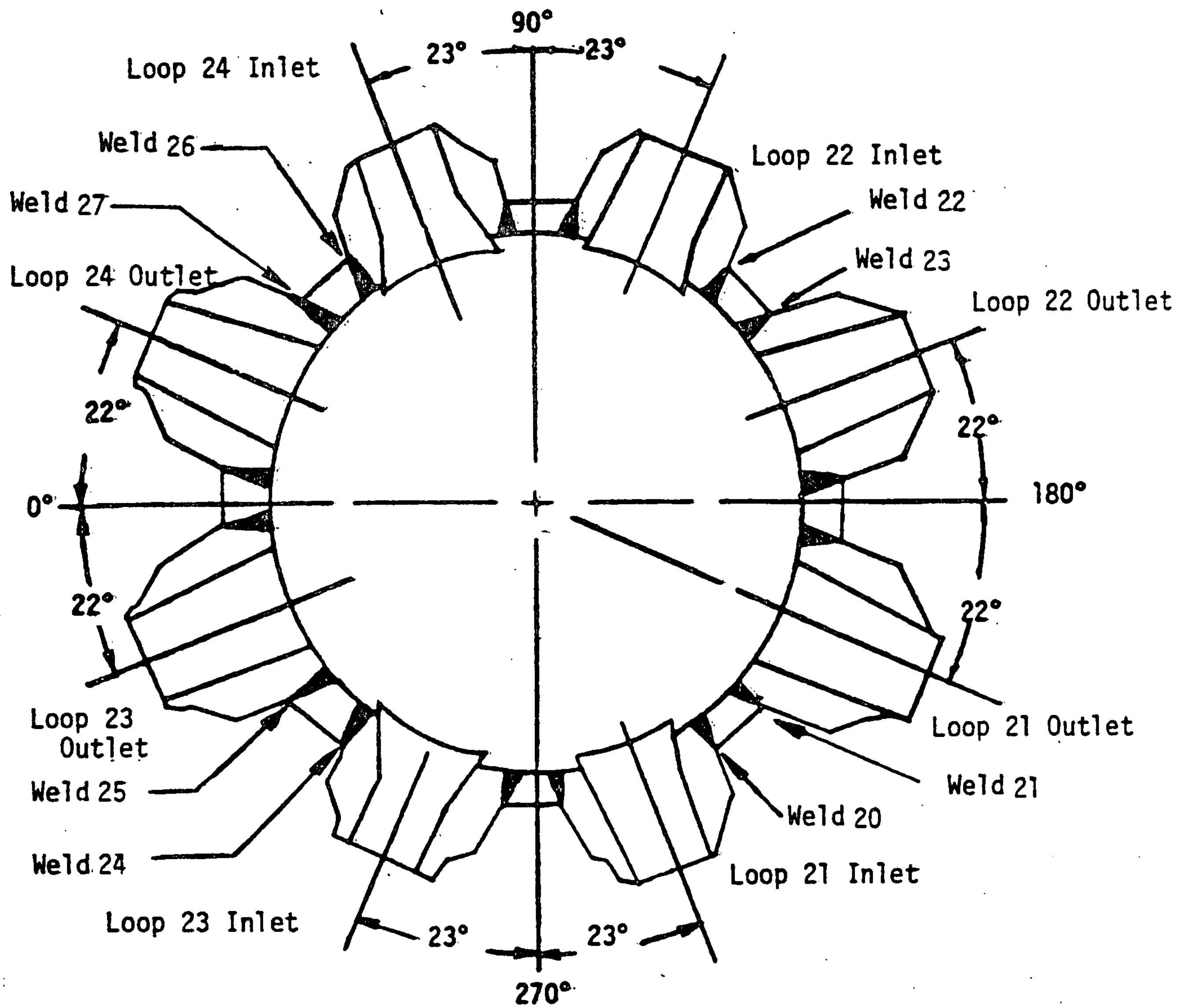
REACTOR VESSEL



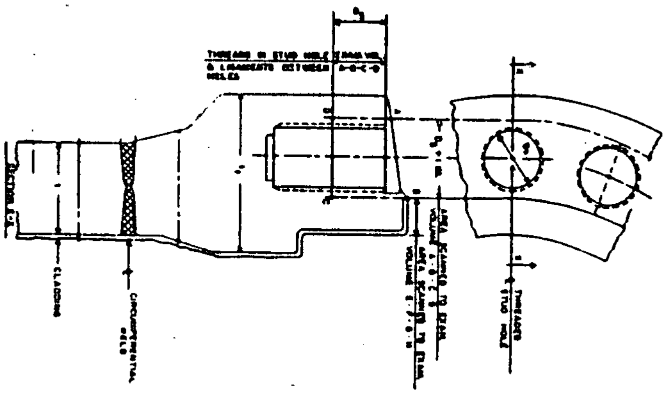
Illustrative Only

IPP-I-1100A
Rev. 2: 2-84

NOZZLE TO VESSEL WELDS



Vessel Flange Ligaments



Note: Stud hole 1 at 270° thru Stud Hole 54 at 263.4°

QUESTION IV B:

The licensee should review the inspection data from all "relevant" and "non-relevant" indications again. The licensee should verify that no reflectors exist in the vessel with "crack-like" properties or with ultrasonic characteristics similar to O.D. grinding.

RESPONSE TO QUESTION IV B

All examination reflectors were initially investigated and recorded by a Westinghouse certified Level II examiner. The data were then independently reviewed by a Westinghouse certified Level III examiner in the field. Indications which were determined to be valid (relevant) were further reviewed by additional qualified Westinghouse home office personnel. Subsequently, all the examination data from valid (relevant) and non-valid (non-relevant) indications were again reviewed during the week of August 20, 1984. Based on these multiple reviews, it is concluded that none of the other recorded reflectors have characteristics similar to the subject reflector.

ATTACHMENT C

RESPONSE TO OUTSTANDING ISSUES CONTAINED IN AN NRC MEMORANDUM DATED AUGUST 28, 1984

Consolidated Edison Company of New York, Inc.

Indian Point Unit No. 2

Docket N. 50-247

September 1984

QUESTION 1:

Based on the preliminary demonstration of the notches in the curved blocks and review of video tapes of the data taken on the indication in the IP-2 reactor vessel, it appears that the reported indication is about 0.3 inch deep. However, the staff believes it prudent that the delta technique be demonstrated in the same manner as the indication was found in the vessel on a test block containing the real crack to verify its sizing capability.

RESPONSE TO QUESTION 1

There are no known blocks which represent the vessel size, curvature, and clad type and condition, that also contains "real cracks" or; in which "real cracks" could readily be induced. However to verify the delta technique sizing capability, extensive additional testing was conducted on test blocks containing representative reflectors in the vessel mockups and the preponderence of accumulated data verifies the sizing capability of the technique as reported in Attachment A.

QUESTION 2:

The licensee should establish the uncertainty bound for depth sizing determined by the delta technique using the information obtained from various notch depths in the curved block.

RESPONSE TO QUESTION 2:

To determine a conclusive uncertainty bound for any technique which contains potential operator and system variables, a large number of data points and a significant period of time is required to accumulate data and analyze the results. With small sample sizes even the most accurate technique can give unwarranted indications of variation in data. However within the short period of time available for these mockup exams the uncertainty range of the delta technique was reviewed based on test results on the reflectors in a IPP-2T mockup. These tests were performed from both sides of the reflector (where possible) with both of the delta arrangmenets (TR 22 to TR 20 and TR 24 to TR 20). Several oprators performed the examinations with the UT test system used in performing the vessel examination. Data from transit time measurements based on total metal path were reviewed. The uncertainty range was approximated to be on the order of ± 2 microseconds, which translates to a measuring tolerance of ± 0.2 inches over a reflector depth range from 0.1 to 2.0 inches. Data from delta measurements was also reviewed in terms of the time interval spacing between indications representing the upper and lower extremes of the reflectors. The uncertainty range was approximate to be on the order of ± 1.5 microseconds for these measurements which translates to a measuring tolerance of ± 0.15 inches.

Because of time constraints, insufficient data points were taken and a complete statistical analysis of these results has not been accomplished. Therefore the uncertainty ranges discussed above are considered inconclusive and have not been factored into the overall test conclusions.

QUESTION 3:

The licensee should establish the acoustic property relationship among the vessel, the curved block and the flat calibration block.

RESPONSE TO QUESTION 3

See response to Question I D, Attachment 2.

QUESTION 4:

On reviewing the video tapes of the delta technique signal of the indication on the vessel, a second smaller pulse approximately 18 microseconds later in time after the primary pulse was observed. The significance of this secondary pulse and its relation to the depth of the indication should be pursued.

RESPONSE TO QUESTION 4

Delta technique data from both the vessel and the IPP-2T mockup consistantly show a second smaller pulse approximately 30 microseconds later in time after the primary pulse is observed. No pulse has been observed at 18 microseconds. The 18 microsecond measurement was made based on a screen calibration of 3.3 microseconds per major screen division; however, the particular display from which the measurement was made was calibrated at 5.0 microseconds per major screen division. This secondary pulse has not been utilized for characterizing the vessel indication on mockup reflectors since it has been demonstrated that the primary signal from the delta technique is an accurate reliable indicator of reflector depth. It is postulated that the second pulse at 30 microseconds is a shear wave diffraction signal which travels in the shortest path (0°) to the ID clad surface. Due to the roughness of the ID surface, the signal mode converts to longtidudinal wave and is therefore received by the 0° transducer. However, this secondary pulse has not been a factor in the examination and test conclusions, and the specific explanation for this pulse has not been theoretically or practically pursued in depth.

ATTACHMENT D

RESPONSE TO FRACTURE MECHANICS RELATED
QUESTIONS CONTAINED IN NRC's SEPTEMBER 19, 1984
REQUEST FOR ADDITIONAL INFORMATION

Consolidated Edison Company of New York, Inc.
Indian Point Unit No. 2
Docket No. 50-247
September, 1984

QUESTION 1:

The events analyzed in determining the ASME Code allowable flaw indication should include the Turkey Point Unit 4 LTOP event which occurred on November 28 and 29, 1981. Based upon the frequency of this type of event in all operating PWRs, the licensee should determine whether the event is considered upset or emergency and faulted. In analyzing this event for the IP-2 vessel, the pressures and temperatures to be considered should be those which would occur if the event were terminated by lifting of the IP-2 Pressurizer Safety Valve. If the Turkey Point set of events had occurred at IP-2, without operator action to terminate the transient, how much time would it take for the pressure to reach the Pressurizer Safety Valve set point?

RESPONSE TO QUESTION 1:

The transient which occurred at Turkey Point Unit 4 is a single event, and has not been classified as a design condition. Therefore, there is no licensing requirement to demonstrate acceptability of the Indian Point Unit No. 2 indication relative to the criteria of Section XI for such a transient.

The Turkey Point LTOP event can be classified as a low probability event based on two independent approaches. Using a systems approach, such an event would require multiple failure combined with no operator action. A second approach, based on experience, reveals one incident in over 350 reactor years of service. In either approach, the probability is lowered further by overpressure mitigation systems. Both demonstrate that the probability of such an event is no greater than 10^{-4} per reactor year.

Technical Specifications, submitted by letter dated February 14, 1983, require that the Indian Point Unit No. 2 low temperature over pressure protection system (LTOPS) be operable whenever the Reactor Coolant System temperature is below 310°F. Those specifications permit the inoperability of the LTOPS providing that other conditions identified in the specification are satisfied. Those conditions include limitations applicable to both heat and masss addition events. Protection against such transients is accomplished by: (1)restricting the number charging and safety injection pumps that can be energized to that which can be accommodated by the PORV's or the gas space in the pressurizer, (2) providing administrative controls on starting of a reactor coolant pump when the primary water temperature is less than the secondary water temperature, or (3) providing vent area from the RCS to containment for those situations requiring relieving capacity in excess of that available through the PORV's or where the available pressurizer gas space is insufficient to preclude postulated transients from exceeding the 10 CFR 50, Appendix G limits. For those transients involving operator action to terminate the cause of pressurization, it is assumed in the analysis that no operator action takes place for ten minutes following the start of the transient. This is consistent with the design basis of the LTOPS.

An NRC staff Safety Evaluation (SE) for the Indian Point Unit No. 2 LTOPS was transmitted by letter dated April 24, 1984. The staff concluded that the IP-2 LTOPS will meet GDC 15 and 31 and implements the guidelines of NUREG-0224. The system is therefore an adequate solution to the problems of LTOP transients. The technical specifications submitted, as previously discussed, are awaiting issuance. Nevertheless, current operating practice is in conformance with the specifications as submitted.

Current plant operating procedures call for the introduction of nitrogen into the pressurizer in preparation for start-up. As pressurizer temperature is raised a steam bubble begins to form. With increasing reactor coolant pressure the nitrogen gas enters into solution and is vented off at the volume control tank. In this manner the steam bubble displaces the nitrogen gas. The equivalent procedure is followed in preparation for bringing the plant to cold shutdown. Similarily during hydrostatic tests, nitrogen gas is introduced into the pressurizer and maintained in the reactor coolant system for the duration of the test, precluding operation in a water solid condition.

In addition, there are apparent differences in the design of Turkey Point IV and Indian Point Unit No. 2 which prevent such an event at Indian Point. The Turkey Point event appears to have been caused by the starting of a reactor coolant pump with no other reactor coolant pumps running while both trains of the LTOPS were inoperable and the reactor coolant system was water-solid. An apparent design feature that automatically isolated letdown under the conditions that existed without terminating mass addition, appears to have increased the severity of the transient. The IP-2 RHR loop has no automatic isolating capability that could result in terminating RHR flow under conditions indicative of the Turkey Point event. These operating procedures together with the proposed Technical Specifications substantially reduce the already low probability of a Turkey Point IV type overpressure event occurring at Indian Point Unit No. 2.

The extensive investigation of the indication, the evaluation of the ultrasonic techniques employed to support it's sizing and location, the acceptability of the indication with respect to the allowable flaw indication standards of ASME Section XI, the fracture mechanics analyses indicating the acceptability of an indication assumed to be larger than the actual indication, and the extremely low probability of a Turkey Point IV type event occurring at Indian Point Unit No. 2, support our conclusion that the Indian Point Unit No. 2 reactor vessel can be safely returned to service as scheduled. No further evaluations are planned.

QUESTION 2:

If the flaw indication were located in the adjacent HAZ or base metal (Plate B 2003-1), what would be the ASME Code allowable flaw indication during normal, upset, test, emergency and faulted conditions?

RESPONSE TO QUESTION 2:

As previously stated, the indication is located in the weld material, not the adjacent HAZ or base metal, nevertheless, the allowable stress intensity factors for the complete range of possible materials are listed below:

Normal/Upset/Test

Allowable K_1, weld 3-042A	= 63.2 ksi/in
Allowable K_1, plate B2003-1	= 63.2 ksi/in
Allowable K_1, plate B2003-2	= 63.2 ksi/in

Emergency/Faulted - Small Steam Break

Allowable K_1, weld 3-042A	= 141.4 ksi/in
Allowable K_1, plate B2003-1	= 114.5 ksi/in
Allowable K_1, plate B2003-2	= 141.4 ksi/in

These allowable stress intensity factors can be compared to the calculated stress intensity factors in WCAP-10651 to assess the code allowable flaw indication in the adjacent HAZ or base metal.

QUESTION 3:

Compare the end-of-life RT_{NDT} and ASME Code allowable flaw indication using the amount of increase in RT_{NDT} predicted by the "Guthrie" formula in Comission Report SECY 82-465 and the model in Draft Regulatory Guide 1.99 Rev. 2 (Attachment 2).

RESPONSE TO QUESTION 3:

The draft regulatory guide revision has not even been officially issued for comment at this stage, much less adopted, so it would be completely inappropriate to use it for evaluations of this type. It appears that there are some serious problems with the manner in which it treats weld materials, so its applicability would be questionable at best. Nonetheless, calculations were made using the equations for informational purposes. These calculations do not constitute an endorsement of the proposed curves.

The end-of-life RT_{NDT} using fast fluence at the indication and ASME code allowable stress intensity factors for the "Guthrie" formula and the model in Draft Regulatory Guide 1.99 Rev. 2 are:

Guthrie formula:	RT_{NDT} = 79°F
	Normal/Upset/Test allowable K_I=63.2ksi/in
	Emergency/Faulted allowable K_I=141.4 ksi/in
Draft Regulatory	RT_{NDT} = 131.8°F
Guide 1.99 Rev. 2:	Normal/Upset/Test allowable K_I=63.2ksi/in
	Emergency/Faulted allowable K_I=141.4 ksi/in

QUESTION 4:

Indicate the references and heat numbers, and lot numbers for the weld wire and flux for each weld chemistry in Table 3-1.

RESPONSE TO QUESTION 4:

The weld in question has the same-weld wire and flux as one of the core region welds in the H.B. Robinson Unit 2 reactor vessel, specifically, weld wire Heat W5214 and Linde 1092 flux with addition of nickel 200 wire. This weld wire/flux combination has been investigated thoroughly by both Carolina Power and Light and EPRI, and the two most complete available references are:

a. "Robinson Unit 2 Reactor Vessel: Pressurized Thermal Shock Analysis for Small Break LOCA", EPRI report EPRI-NP3573-SR, August 1984.

b. Letter NLS-84-191, Carolina Power and Light to H. Denton, June 29, 1984, Docket No. 50-261-License No. DPR-23.

The specific lot numbers for the flux for results provided in Table 3-1 are listed below:

Indian Point Unit 3	Linde 1092 Lot 3692
Unit 3	3692
Unit 3	3692
Unit 3	3692
Millstone Unit 1	3617
H.B. Robinson Unit 2	3692
Unit 2	3692
Unit 2	3692
Unit 2	3692

QUESTION 5:

Indicate the heat number and lot number for the weld wire and flux for the weld in Table 3-2.

RESPONSE TO QUESTION 5:

The flux lot number for the actual weld in Indian Point Unit 2 is 3576. The weld wire is heat W5214, the flux is Linde 1092, and an extra wire was added with Nickel 200.

QUESTION 6:

Figure 3-2 indicates that the current fast neutron exposure at the inside surface - 345° Azimuthal Angle is 1.5×10^{18} n/cm^2. Consolidated Edison has reported to the staff in a telecon that after completing the sixth fuel cycle using a low leakage core, the current fast neutron exposure at the inside surface - 345° Azimuthal Angle is 1.77×10^{18} n/cm^2. Explain the difference in these estimates and use the more accurate number in the analysis.

RESPONSE TO QUESTION 6:

The value of 1.5×10^{18} n/cm^2 represents the reactor vessel inside surface fluence (at the 345° Azimunthal angle location of the indication) for 5.33 EFPYs (Effective Full Power Years). The value of 1.77×10^{18} n/cm^2 provided the staff in a recent telephone conversation was for 6.32 EFPYs (at the completion of Cycle 6 operation) at the same location. The value of 1.7×10^{18} n/cm^2 used in the analysis is the most appropriate value as it represents end-of-life fluence at the tip of the indication analyzed (18.2 cm from the inside vessel surface).

QUESTION 7:

This question was asked in a September 18, 1984 telephone conversation between NRC, Con Edison and Westinghouse personnel but not transmitted. What is the stress relief temperature and duration for the Indian Point Unit No. 2 vessel.

RESPONSE TO QUESTION 7:

The entire vessel was heat treated at 1150 ±25 F for 13 hours on August 31, 1968. Heating and cooling rates above 600 F were limited to 100F/hour.