INDIAN POINT UNIT 2

REACTOR VESSEL SPECIAL INSPECTION

OCTOBER 1987

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1.0 INTRODUCTION

Plant Technical Specification provisions Section 4.2.G, Item 7.2, Reactor Vessel Special Inspection, specify that:

- o Examinations of the Indian Point Unit 2 reactor vessel be performed in an area approximately 236 inches below the vessel flange at 345 degrees azimuth.

- o Inspection results be forwarded for NRC review and approval 15 days prior to plant start-up.

In response to those provisions, an examination of the reactor vessel was performed during the current refueling outage. This report identifies the inspections performed and the results of the inspections.

Ultrasonic examinations were performed during the current refueling outage in the location of an ultrasonic indication, which was previously detected during the 1984 refueling outage.

The examinations covered an area on the order of 6 x 6 inches centered on the ultrasonic indication in the lower shell longitudinal weld seam located at vessel azimuth 345 degrees. The indication is near the intersection of the longitudinal weld seam and the intermediate-to-lower shell girth weld. The girth weld is located 236 inches below the reactor vessel flange. The indication is located at about 239.5 inches below the flange.

The 1987 reactor vessel ultrasonic examination program included the following:

- o Standard ASME Code Section XI ultrasonic examination and sizing techniques were used for the vessel examination. These techniques were identical to those utilized during examinations of the vessel in 1984. The ASME Code Section XI ultrasonic examinations are the primary basis for concluding that the ultrasonic indication, which was previously detected, has remained unchanged.

- Special ultrasonic examinations beyond those specified in the ASME Code XI were also utilized. These examinations included techniques known as delta and pitch-catch techniques. These were also previously utilized during the 1984 examinations.

- Additional state-of-the-art examination techniques and equipment were utilized in an attempt to better characterize the indication. Focused immersion transducers were applied to enhance the data collected with conventional transducers. Focused transducers were not used during the vessel examinations conducted in 1984.

- The techniques and equipment applied for the field examinations were demonstrated offsite prior to field use. The demonstration was accomplished on both the standard calibration block used for vessel examinations, and an additional special demonstration block containing simulated surface-connected flaws.

- A multi-channel, high speed digitizing, recording and display system was utilized to record and map ultrasonic examination results. This additional data analysis system was used to supplement data collected with conventional recording mechanisms.

- Ultrasonic data was collected and analyzed by the Synthetic Aperture Focusing Technique (SAFT). This technique was not used during the 1984 examinations.

- Scan increments for each individual examination technique were 0.1 inch with the exception of data collected for Synthetic Aperture Focusing Technique evaluation where 0.05 inch increments were used. These scan increments resulted in the accumulation of significantly more data points as compared to scan increments of 0.5 inch which are typically used for vessel examinations.

2.0 BACKGROUND

During the 1984, first interval, third period, inservice ultrasonic examination of the Indian Point Unit 2 reactor vessel, an ultrasonic reflector was identified in the lower shell longitudinal weld (weld #12) at 345 degrees vessel azimuth which required additional investigation.

The reflector was detected by 45 degree and 60 degree shear wave angle beam scans in the clockwise and counter clockwise directions with the peak amplitude location at 239.5 inches from the top of the vessel flange, figure 2-1. The indication was initially sized in accordance with standard ASME XI ultrasonic testing methods as 2.03 inches deep and 1.96 inches long. Improved ultrasonic techniques were then applied to gain more accurate sizing information. Further analyses were made to determine the extent to which ASME XI, fifty percent (50%) DAC sizing techniques exaggerated the dimensions of reflectors at, or near, the vessel outside surface.

Corrections were applied to the initial depth sizing to compensate for beam spread and angle. These corrections established a through-wall dimension of 1.2 inches, a length of 1.96 inches, and located the reflector 0.25 inch from the outside surface.

Alternative techniques were developed and applied to further aid in analysis of the vessel indication. The alternative techniques were implemented using a transducer array configured with two opposing 45 degree, 2.25 MHz, 1.5 inch diameter shear wave transducers one skip distance apart, and a 0 degree, 2.25 MHz, 1.5 inch diameter shear wave transducer located midway between the two 45 degree transducers. The 45 degree and 0 degree transducers were arranged such that the projected sound beams intersected at the outside surface of the vessel. A high resolution 5.0 MHz, 0 degree longitudinal wave transducer was also placed on the array. This transducer array plate provided for the capability to perform a 45 degree shear wave pitch-catch or diminishing echo study of the area of interest, interrogation with delta techniques, and high resolution 5.0 MHz scans of the area of interest.

Pitch-catch interrogation of the area of interest was performed looking for an interruption in the transmitted signal due to a reflector of significant size. This technique showed the indication depth was certainly less than 1 inch as no loss of signal directly attributable to the reflector was noted during the scans.

Delta techniques were then applied to more accurately establish the maximum depth of the reflector. This technique utilized the 45 degree shear wave transducers as transmitters and the 0 degree transducer as a receiver. Time of flight information was used to measure the reflector location with respect to the outside diameter surface. Analysis of this data with respect to the delta model developed for the particular geometry of the shell section predicted a maximum depth on the order of 0.3 inch from the vessel outside diameter surface.

Finally, standard ASME XI amplitude drop sizing studies were conducted on a series of notches in a mock-up which simulated the thickness and curvature of the vessel lower shell course. These studies clearly showed the tendency for such sizing methods to consistently oversize the depth of reflectors having dimensions smaller than the sound of beam width by factors in excess of seven to one (7 to 1).

The conclusion of this program was that the actual dimensions of the reflector in the lower shell longitudinal weld of the Indian Point Unit 2 reactor vessel were exaggerated significantly by the ASME XI amplitude-based sizing methodologies.

3.0 EXAMINATION EQUIPMENT AND TECHNIQUES

3.1 ASME Section XI Ultrasonic Examinations

The 1984 Section XI ultrasonic examinations were repeated on the reactor vessel during the current refueling outage. These examinations included 45 degree and 60 degree shear wave interrogation in the clockwise and counter clockwise directions and a 0 degree longitudinal wave scan. Transducers used for this phase of testing were 2.25 MHz, 1.5 inch diameter units mounted on a standard "Ten Year Array Plate", as illustrated in figure 3-1. Transducers identified as TR20, TR22, TR24, TR25, and TR27, were mounted for this analysis. With the exception of TR27, all transducers were identical to those used for the 1984 examinations. Initial measurements were made using the vessel inspection tool in a manual or "jog" mode to repeat the measurements made in 1984. Data were then digitized and recorded for off-line analysis at scan increments of 0.1 inch allowing for archival storage of all raw data and more accurate measurements of parameters such as time-of-flight, location, etc. These results were compared to those collected during the 1984 vessel examinations in terms of ASME Code Section XI amplitude drop sizing. The data recording system also offered the capability for signal processing and conditioning which allowed the analyst to identify features of the recorded signals, which might otherwise go unnoticed.

3.2 State-of-the-Art Examinations

The use of focused transducers has been demonstrated successful in retaining satisfactory signal-to-noise ratios with good flaw detection and sizing capabilities. The transducers used in this evaluation were 1.0 MHz, 0 degree longitudinal wave, 45 degree and 60 degree shear wave focused units, and a 2.0 MHz, 45 degree longitudinal wave focused unit, all with focal lengths corresponding to the outer vessel wall. These transducers have permanent lenses affixed with compound curvature in order to minimize the effects of aberrations due to the curvature of the vessel inside diameter surface. These transducers were characterized in terms of their focal spot size and focal lengths and they were selected to minimize the effect of beam spreading and beam distortion on the ability to size and characterize the reflector. A summary of the characteristics for the focused transducers is provided in table 3-1.

The focused transducer array illustrated in figure 3-2 was developed based upon the physical size of the transducers and waterpaths required to achieve the proper focal depths. The focused search units were used in the pulse-echo mode and in a delta arrangement. The reflector was interrogated in both circumferential directions. All scans were performed on increments of 0.1 inch. Data were digitized and recorded for off-line analysis. This allowed for archival storage of all raw data and accurate measurement of parameters such as time of flight, location, etc. The data recording system also offered the capability for signal processing and conditioning which allowed the analyst to identify features of the recorded signals, which might otherwise go unnoticed.

3.3 Special Ultrasonic Examinations

During the 1984 and 1987 evaluations, alternative ultrasonic techniques were applied to aid in analysis of the vessel indication. The alternative techniques utilized a transducer array, as illustrated in figure 3-3, containing two opposing 45 degree shear wave, 2.25 MHz, 1.5 inch diameter transducers, one skip distance apart, and a 0 degree, 2.25 MHz, 1.5 inch diameter transducer located midway between the two 45 degree transducers. The 45 degree and 0 degree transducers are configured such that the projected sound beams intersect at the outside surface of the vessel. A high resolution, 0 degree longitudinal wave, 5.0 MHz, 0.5 inch x 1 inch rectangular transducer was also placed on the array. The following examinations were performed:

- o A delta technique of two opposing directions using the 45 degree shear wave transducers as transmitters (TR22 and TR24) and the 0 degree transducer (TR20) as a receiver.

- o A pitch-catch technique using the 45 degree shear wave transducers to respectively transmit (TR22) and receive (TR24) the sound beam, a diminishing echo technique.

- o A pulse echo technique for one of the 45 degree shear wave transducers (TR22).

- o High frequency 5.0 MHz, 0 degree longitudinal wave interrogation of the area of interest.

All scans were performed at increments of 0.1 inch. Data were digitized and recorded for off-line analysis allowing for archival storage of all raw data and accurate measurement of parameters such as time-of-flight, location, etc. The data recording system also offered the capability for signal processing and conditioning which allowed the analyst to identify features of the recorded signals.

3.4 Synthetic Aperture Focused Transducer (SAFT)

SAFT data was collected with the intent of evaluating the use of the SAFT processing system on thick walled, clad vessels and of characterizing the indication. As a result of the demonstrations at the Westinghouse Waltz Mill site and concurrent laboratory tests at Battelle Northwest Laboratories (BNW) prior to the site effort it was determined that a Synthetic Aperture Focusing Technique transducer with the following characteristics would be used for the vessel examination. The transducer was 2.25 MHz, with a focal length of 3.0 inches, and a bandwidth approaching fifty (50%) percent. The transducer was mounted to the Westinghouse ten year plate in slot 29, see figure 3-1. Data was acquired using three scan configurations at increments of 0.05 inch. A 45 degree longitudinal wave clockwise scan and a 45 degree longitudinal counter clockwise scan were performed with the array plate oriented as shown in figure 3-4. A 45 degree shear wave counter clockwise scan was performed with the array plate oriented as shown in figure 3-5.

4.0 DEMONSTRATION AND CALIBRATION OF EQUIPMENT TECHNIQUES

This part of the program was conducted to provide a quantitative assessment of system repeatability, and a statistical verification of sizing techniques assuming a surface-connected planar flaw for the three series of examinations: (1) Standard ASME Code Section XI examinations, (2) state-of-the-art examinations with focused transducers, and (3) special examinations with delta and pitch-catch techniques. The program was based on the use of simulated surface-connected planar reflectors and encompassed the following activities.

4.1 System Repeatability and Statistical Verification of Sizing Techniques

System repeatability and statistical verification of the standard ASME Code XI techniques, pitch-catch and delta techniques, and focused transducer techniques were demonstrated by repetitive calibrations on the side-drilled holes in the calibration block used for the vessel examinations, illustrated in figure 4-1, and examinations of the simulated flaws in the special demonstration block, illustrated in figure 4-2. The UT system is defined as transducer array plate mounted on the inservice inspection tool; the ultrasonic instrumentation; and the multi-channel, high speed digitizing, recording, and display system.

The statistical verification of sizing techniques was performed on a sample matrix that included artificial flaw sizes chosen in the region encompassed by depths of 0.11 to 1.0 inch and lengths of 0.75 to 1.50 inches. A clustering of artificial flaws (outer diameter notches) with depths of 0.11 to 0.5 inch and lengths of 0.75 to 1.0 inch was chosen to increase the amount of data points around the reflector size predicted in 1984.

The data for each sizing technique were evaluated through linear regression analysis performed on each depth measurement as a function of depth and corresponding length, and on each length measurement as a function of length and corresponding depth.

This analysis resulted in a quantitative evaluation of each sizing technique such that the data obtained during the examination would be accurately assessed within a 95% confidence level.

4.1.1 Statistical Verification of Standard ASME Code Section XI Examinations

The standard ASME Code Section XI examinations consisted of the techniques described in Section 3.1. Each of the 12 artificial flaws was scanned repeatedly with each transducer. The total number of scans was 220, with a scan increment of 0.1 inch.

4.1.2 Statistical Verification of State-of-the-Art Examinations

The state-of-the-art examinations consisted of the techniques described in Section 3.2. Each of the 12 artificial flaws were scanned repeatedly with each transducer/transducer configuration. The total number of scans was 290, with a scan increment of 0.1 inch. In addition to using the focused transducers for amplitude based length sizing of the artificial flaws, special emphasis was placed on detecting and distinguishing diffraction tips to improve depth sizing capabilities over normal Code techniques.

4.1.3 Statistical Verification of Special Examinations

The special examinations consisted of the techniques described in Section 3.3. For the delta technique, each of the 12 artificial flaws was scanned repeatedly with each transducer combination for a total of 110 scans, with a scan increment of 0.1 inch. For the pitch-catch techniques, 10 artifical flaws were scanned repeatedly for a total of 50 scans.

5.0 ULTRASONIC EXAMINATION DATA RECORDING AND DISPLAY SYSTEM

5.1 System Overview

The ultrasonic examination data recording and display system used for the Indian Point Unit 2 reactor vessel indication analysis was the Dynacon Ultrasonic Data Recording and Processing System (UDRPS).

5.2 System Functional Description

A block diagram of the UDRPS system is included in figure 5.1. Functionally, the system is comprised of five (5) subsystems:

- o Data Acquisition
- o Data Display
- o Central Processing Unit
- o Operator Interface
- o Storage Peripherals

5.2.1 Data Acquisition

The data acquisition subsystem consists of a Front End and Array Processor (FE/AP). The FE digitizes the entire A-scan at up to 32 MHz resolution. Digitization starts at the system trigger pulse, which also triggers the ultrasonic instrument, and continues for as long as required. The FE provides digital gates to accept the proper portion of the incoming data stream as the test requires. The front end also provides preliminary processing of the data stream to improve signal-to-noise ratio.

The Array Processor (AP) is a programmable pipeline processor that allows a variety of processing algorithms to be applied to the data in real time. The AP is primarily used to automatically detect and locate flaws based on one or more features of the data, e.g. signal-to-noise ratio, amplitude, target motion, amplitude cross-section, etc.. The AP normally operates on several A-scans at a time.

5.2.2 Data Display

Data is displayed via a Ramtek 9465 Display Processor on a color display terminal having 1024x1280 pixel resolution. The Ramtek provides fast image generation and very flexible image processing capabilities. Available features include:

- o Color or gray level manipulation
- o Windowing
- o Annotation
- o Pan, zoom, scroll
- o Arithmetical or logical functions to manipulate image
- o Combining/comparing images
- o Designating and operating certain areas of images
- o Performing coordinate transforms

A joystick is used to interact with the imaged data to identify and extract specific features. Position measurements, dimensions between specific features in the image and the data value at a specific point can be obtained.

An Off Line Analysis mode allows the recall of data from disk, and provides displays in a variety of formats for analysis. Included are:

- o Transducer characterization
- o A-Scan presentation, plan, end, side and perspective views of individuals or groups of A-Scans
- o B-Scan presentation, full color, gray scale or thresholded
- o C-Scan presentation, single or multi-layer presentation, color coded by amplitude or depth, full color, gray scale or thresholded
- o Automatic detection maps as orthogonal or 3-D views
- o Image combination (projection, averaging)
- o Plate geometry overlays
- o Pan, zoom, scroll
- o Color table manipulation
- o Position and dimension measurements

The Color Graphics Hard Copier is a Seiko D-Scan CH5301 that generates A-size color hard copies.

5.2.3 Central Processing Unit (CPU)

The CPU provides overall system control and management. It buffers data to disk and controls real time display during data acquisition. It retrieves data from disk and performs high speed data processing during display and analysis. The CPU is a Hewlett Packard A-900 minicomputer.

5.2.4 Operator Interface

The system can boot up and be menu driven locally from the control terminal or from the host computer. System status and diagnostics are provided during operation as a message on the control terminal screen. Such messages will include:

- Name and status of any inoperative system component
- Identity of critical test parameters set beyond system limits
- Calibration standards or plate not present
- Remaining data storage capacity
- Total data stored

In addition, a system test mode is included that utilizes extensive diagnostic software. It includes the ability to check the status and operability of each major system component by exercising its functions. The test software also provides an integrated system selftest.

5.2.5 Storage Peripherals

System data storage is subdivided into four general categories. They are scratch, hard copy, semi-permanent and archival data base storage.

Scratch data is data that has only a very short term value. For example, data acquired during automatic normalization is of no value after the peak position is determined and fed back to the motion controller. Scratch data space is provided on the system disk. This disk also contains system software and the accumulated library of automatic scanning and calibration procedures.

Hardcopy data is comprised of several sheets of paper for each component. Each sheet is uniquely identified with the component that it represents.

Semipermanent storage is provided on Winchester disk. Archival data base storage is on optical disk.

All local data storage units are linked to the CPU using IEE 488. The CPU is able to transmit data from a local storage devise to a remote host computer via one of the open I/O ports provided and one of the optional external interfaces.

6.0 RESULTS OF EXAMINATIONS

6.1 ASME Code Section XI Examinations

The data from the Section XI amplitude based sizing techniques taken in 1984 and 1987, are shown in table 6-1. A comparison between the 1984 and 1987 results in terms of peak amplitude, length, and through-wall dimensions indicates these data are well within the range of variation expected for dB drop data. The data clearly shows that the indication is unchanged from the 1984 examinations.

Figure 6-1 represents a typical blockmap display using the UDRPS system. This display was created using the recorded data for the 45 degree shear wave examination in the counter clockwise direction (TR22). The top view provides a look at the data in a plane parallel to the inner and outer diameter surfaces. The side view displays the data in a plane parallel to a radial cross-section of the vessel, and the end view displays the data in a plane parallel to an axial cross-section of the vessel. Length sizing results using 50% DAC sizing with UDRPS analysis software is shown in the top view. In this display the left region of the top and side views represents the plate material at a vessel azimuth less than 345 degrees.

The results from the Section XI amplitude based sizing techniques using UDRPS analysis software are shown in table 6-2. These results were extracted from recorded examination data. The examinations were performed at approximately 20 dB (10 times) above the ASME Code Section XI sensitivities and this would account for the apparent variations with the manual 50% DAC sizing results shown in table 6-1.

Figures 6-2 and 6-3 represent B-scan displays for a single scan line. Figure 6-2 displays recorded examination data for the 45 degree shear wave examination in the counter clockwise direction at 241.3 inches below the vessel flange, whereas figure 6-3 displays the 45 degree shear wave examination data for the clockwise scanning direction at 241.2 inches below the vessel flange. The peak location of the indication in figure 6-2 is measured at 8.434 inches below the inner diameter surface or approximately

0.44 inch from the outer diameter surface (measured thickness of component using 2.25 MHz, 0° longitudinal wave transducer is 8.87 inches). A satellite response is located adjacent to the primary indication at approximately 2.5 μsec difference. The peak location of the indication in figure 6-3 is measured at 9.10 inches below the inner diameter surface. This indicates that the reflector was detected after the sound beam reflection from the backwall. Therefore this examination locates the reflector approximately 0.23 inch from the outer diameter surface (9.10 - 8.87 inches).

6.2 State-of-the-Art Examinations

Examinations with focused transducers were performed with the focused array plate in the normal and the 180 degree positions. Information from the 45 degree longitudinal, 45 degree shear, and 60 degree shear wave focused transducers was obtained in both the clockwise and counter clockwise scanning directions.

Figures 6-4 and 6-5 represent the blockmap and a single scan line B-scan (239.1 inches below the vessel flange), respectively, for the 45 degree longitudinal wave focused transducer scanning in the clockwise direction. Figures 6-6 and 6-7 represent similar displays, except the scan line is at 241.3 inches below the vessel flange, for the same transducer scanning in the counter clockwise direction. Figure 6-4 shows that the measured linear extent of the indication using half maximum amplitude points is from 238.69 to 240.29 inches from the vessel flange. Using the successive dB drop technique[1], the measured length is 3.1 inches over a linear extent of approximately 238.6 to 241.7 inches from the vessel flange. It also shows the position of the backwall with respect to the depth location of the indication. The indication is consistently located after the backwall clearly indicating that this reflector was detected outside (i.e. after) the sound beam was reflected off the backwall. No responses were noted near and before the backwall. Figure 6-5 shows the reflector image at 239.1 inches from the vessel flange. The

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1 Saglio, R., and A. C. Prot, "Ultrasonic Focusing Techniques," Nondestructive Testing, Academic Press Inc. (London) Ltd., Vol. 8, 1985, pp. 61-140.

plotted peak amplitude depth location is 9.19 inches or approximately 0.32 inch past the backwall. With a 45 degree reflection angle at the backwall, this peak response would be located 0.31 inch from the backwall. The position of the backwall can be clearly seen in this display as evidenced by the vertical line of low amplitude signals. Figure 6-6, as previously stated, represents the blockmap display for the 45 degree longitudinal wave transducer scanning in the counter clockwise direction. The linear extent of the indication, determined by the half maximum amplitude points, is from 238.45 to 239.05 inches and from 239.45 to 241.35 inches, from the vessel flange. The signal amplitude falls below the half maximum amplitude value between the two points. Using the successive dB drop technique, the measured length is 3.2 inches over a linear extent of approximately 238.3 to 241.5 inches from the vessel flange. In direct contrast to the images of figure 6-4, the indication is consistently before the backwall position as shown in figure 6-6. This clearly shows that the indication was detected prior to any sound beam interaction with the backwall. No strong responses were noted after the backwall. Additionally, in this figure there is a low amplitude indication approximately 6.43 inches below the inner diameter surface. This indication was used to establish the position of the backwall in the 45 degree shear and 60 degree shear wave examinations since these signals provide a clearer benchmark than the backwall signals. Figure 6-7 shows a B-scan image for the scan line at 241.3 inches from the vessel flange using the 45 degree longitudinal wave transducer scanning in the counter clockwise direction. The peak response from the reflector is at a depth location of 8.61 inches or approximately 0.26 inch before the outer diameter surface.

Similar displays for the 45 degree shear wave focused transducer in both scanning directions are shown in figures 6-8, 6-9, 6-10, and 6-11. The blockmap in figure 6-8 displays the 45 degree shear wave data for the clockwise scanning direction. The linear extent of the indication using half maximum amplitude points is from 238.45 to 240.65 inches and 240.95 to 241.25 inches from the vessel flange. Additionally the indication is consistently imaged after the backwall position. This is more clearly shown in figure 6-9 which shows the B-scan image at 241.3 inches below the vessel flange. The peak response is located at 9.37 inches or 0.50 inch after the backwall. This corresponds with a reflector within the component 0.50 inch before the backwall with a 45 degree sound beam reflection at the backwall. Figure 6-10 shows the blockmap for the same transducer scanning counter clockwise. The indication has a linear extent from 238.79 to 241.99 inches from the vessel flange and is consistently before the backwall position. An average depth location of this indication is 8.47 inches from the inner diameter surface or 0.40 inch before the outer diameter surface. The benchmark indication as seen with the 45 degree longitudinal wave transducer is observed at a depth location of 6.37 inches from the inner diameter surface. The B-scan display for the scan line at 239.1 inches below the vessel flange is shown in figure 6-11. The peak amplitude response is 0.43 inch from the backwall position. Additionally in this display several images of the same reflector are observed. Image B is approximately 9 μsec from image A and appears at the same position as the backwall. Image C is approximately 8 μsec from image B, not in the same A-scan as either image A or B and appears deeper than the backwall. These secondary images represent the sound beam interacting with both the reflector and the backwall.

Focused 60 degree shear wave transducer data is displayed in figures 6-12 and 6-13, and figures 6-14 and 6-15, for the clockwise and counter clockwise scans, respectively. For the clockwise scans the blockmap display in figure 6-12 shows the linear extent of the indication using the half maximum amplitude points to be from 239.24 to 241.04 inches and from 241.44 to 241.84 inches below the vessel flange. The indication is also located consistently after the position of the backwall indicating detection after the sound beam has reflected at the backwall. A corresponding B-scan at 241.2 inches below the vessel flange, figure 6-13, shows two images with a doublet spacing of 3.5 μsec. The first image is located at 9.032 inches depth and the second is at 9.168 inches, both after the backwall. Figures 6-14 shows the linear extent of the indication from the vessel flange using half maximum amplitude points to be from 238.53 to 239.63 inches and from 240.03 to 241.53 inches with a depth location consistently before the backwall position. This counter clockwise scan is consistent with similar scans using the 45 degree longitudinal wave and 45 degree shear wave transducers. The B-scan at 241.2 inches from the vessel flange, figure 6-15, shows a single image of the indication of interest at a depth location of 8.147 inches.

Table 6-3 summarizes the results of the length sizing using half maximum amplitude and successive dB drop techniques. In terms of depth sizing, no signals indicative of planar flaw diffraction peaks were observed throughout the focused transducer data. Additionally no responses indicative of corner reflections which would be expected from surface-connected flaws were observed. The 0 degree longitudinal wave examination yielded no significant information in terms of locating the indication. The focused delta techniques consisting of 45 degree shear wave/0 degree longitudinal wave examinations and 45 degree longitudinal wave/0 degree longitudinal wave examinations in both circumferential directions provided information as to the presence of the reflector but yielded essentially no ultrasonic features for use in establishing depth from the backwall or in estimating the through-wall size of the reflector. This is primarily due to the resolution capability of the focused transducers. The unfocused delta techniques provided more conclusive results and are described in the next section.

6.3 Special Examination

The results of the delta technique are shown in table 6-4 which includes data from the two delta transducer configurations (TR22/TR20 and TR24/TR20) as well as the 45 degree shear wave pulse-echo technique (TR22) in the counter clockwise direction. The delta technique in the counter clockwise direction; i.e. TR22/TR20, provided a number of instances where multiple signals were observed. The maximum signal in this configuration occurred at a depth before the backwall, with relatively weak signals occurring at positions near the backwall and at positions after the backwall. The delta technique in the clockwise direction, i.e., TR24/TR20, typically resulted in only one weak peak occurring near the position of the backwall. The pulse echo technique while providing information as to the estimated depth of the reflector also yielded a trailing satellite pulse in some instances.

No loss of back reflection was observed using the pitch-catch shadowing technique.

Figure 6-16 shows a B-scan view at 240.5 inches below the vessel flange using the delta configuration TR22/TR20 for the counter clockwise direction. Two responses are noted. These responses are separated in time by 4 μsec. The highest amplitude response, image A, is emanating directly from a reflector within the component whereas image B is positioned after the backwall position indicating sound beam interaction between the reflector and the backwall.

Additional 0 degree longitudinal wave examinations using a 5.0 MHz, 0.5 inch x 1 inch transducer were performed in an effort to obtain better resolution near the backwall surface. These examinations were performed twice, at high and low sensitivities. Direct reflection from the reflector or a significant loss in back reflection was not observed at the position of the indication. A multitude of responses were observed in the plate material on the clockwise side of the weld caused by small, randomly scattered plate segregates, and in the weld itself.

6.4 Synthetic Aperture Focusing Technique

SAFT was evaluated on a demonstration block (IPP-2T), which contained a number of artificial notches with varying depths and lengths. Analysis of the Waltz Mill data revealed:

- o Processing data along both the sweep axis and the increment axis did not produce a highly correlated resultant image. Primarily, adjacent data points did not align well from one sweep to the next because of occasional offsets of up to 0.06 inch. Processing along the sweep axis produced the more favorable results. As a result, the type of data processing for the Indian Point Unit 2 data was line SAFT and aperture-limited 3-D SAFT.

- o In an effort to limit the number of different transducer configurations and maintain a high degree of resolution, a 2.25 MHz transducer was used in the 45 degree shear wave mode. Analysis of the Waltz Mill data indicated the cladded surface severely impaired the weaker tip-diffracted echo; however, the higher amplitude corner-reflected echo correlated well and produced a distinct corner trap image.

- Laboratory tests on a 3 inch thick, multi-wire cladded block containing a sawcut performed at BNW during the Waltz Mill data analysis revealed that the same transducer using the 45 degree longitudinal wave mode would generate a higher amplitude and a more coherent tip-diffracted echo.

- The theoretical SAFT resolution in steel is 0.191 inch for the shear wave mode and 0.351 inch for the longitudinal wave mode. The resolution realized under actual field conditions is not expected to be as good because of the effects of the cladding.

During SAFT data collection on the Indian Point Unit 2 vessel, data was acquired using three scan configurations. The SAFT transducer was mounted in slot 29 of the Westinghouse ten-year plate (figure 3-1). When the plate was normal to the vessel wall the SAFT transducer produced a 45 degree refracted shear wave in the vessel (figure 3-5). When the plate was tilted 10.8 degrees a 45 degree refracted longitudinal wave was produced in the vessel (figure 3-4). The shear wave scan yielded a higher resolution image and the longitudinal scan enhanced the capability to detect tip-diffracted echoes. The following describes the three scans in which data were collected:

- Scan 1 was a 45 degree longitudinal wave scan with the transducer pointing in the clockwise direction.

- Scans 2 and 3 were with the transducer pointing in the counter-clockwise direction. Scan 2 was a 45 degree longitudinal wave insonification and Scan 3 was a 45 degree shear wave scan.

The 3-D SAFT-processed 45 degree shear wave data shows the indication is clearly before the far surface. No corner trap signal at the far surface was observed. The 3-D SAFT-processed 45 degree longitudinal wave data shows no images characteristic of tip diffracted indications normally observed with planar type reflectors. The 45 degree longitudinal wave scans also locate the reflector before the far surface.

Additionally the 45 degree shear wave images indicate that the reflector does not have uniform through-wall height over its length and the remaining ligament from the reflector to the far surface is not uniform.

7.0 DISCUSSION OF RESULTS

Integration of the results from the four series of examinations: 1) ASME Code Section XI, 2) State-of-the-Art, 3) Special and, 4) Synthetic Aperture Focusing Technique clearly indicates the presence of an embedded reflector with some degree of orientation. The possibility of it being a surface-connected planar reflector is eliminated by its observed ultrasonic characteristics. There is no evidence of a strong corner signal which is expected of a surface-connected reflector. Figure 7-1 shows the expected image of a surface-connected reflector using a 45 degree focused longitudinal wave transducer. This image is of notch C, 0.5 inch deep x 1 inch long, in the special demonstration block, IPP-2T. It demonstrates that the intensity of the corner reflection is much higher than secondary peaks such as the notch tip. Additionally throughout the entire vessel data set there is no evidence of signals from diffraction peaks. The inverse relationship of the intensity of the multiple peaks in the delta technique is also evidence that a surface-connected reflector does not exist. Figure 7-2 shows the unfocused 45 degree shear wave/0 degree longitudinal wave delta technique on notch C in the block, IPP-2T. The corner signal is greater in amplitude than the tip diffracted signal. This is an inverse to the image obtained from the reactor vessel, figure 6-16, where the strongest signal is emanating from a reflector before the outer diameter surface.

The data fits the model presented in figure 7-3. This model depicts a small embedded weld inclusion with its major depth axis at an angle (ϕ) with respect to a radial line from the vessel centerline. This offset angle is toward the clockwise direction.

Ultrasonic examinations performed from the counter clockwise direction would be expected to yield the following characteristics:

- For a pulse-echo technique, the maximum response would be observed from direct specular reflection without interaction with the backwall since a large cross-section of the reflector is lying essentially perpendicular to a counter clockwise direction ultrasonic beam. The reflector would be located within the component; i.e., the depth location would be before the backwall. Very weak secondary signals would be observed after reflection from the backwall as illustrated in figure 7-4A.

- For a delta technique, the maximum response directed toward the 0° receiver transducer would be from the reflector itself without interaction with the backwall. Weaker signals would be observed from interaction with the backwall as illustrated in figure 7-5.

- For a pulse-echo or a delta technique no diffraction peaks would be observed due to the lack of sharp extremities and to the physical size of the reflector.

- For a pulse echo technique, trailing satellite pulses due to conversion of some ultrasonic energy into surface waves which traverse along a reflector's circumference may be observed depending upon the surface roughness of the reflector.

Ultrasonic examinations performed from the clockwise direction would be expected to yield the following characteristics:

- For a pulse-echo technique, the maximum response would be observed after interaction with the backwall since the cross-section of the reflector perpendicular to the ultrasonic beam for direct reflection is small but relatively larger to an ultrasonic beam after reflection from the backwall. The reflector would be located after the component backwall, i.e., the depth location would be greater than the backwall. Very weak signals would be observed from a direct specular reflection as illustrated in figure 7-4B.

- For a pulse-echo technique, no diffraction peaks would be observed due to the lack of sharp extremities and to the physical size of the reflector.

- For a pulse-echo technique trailing satellite pulses could be observed depending upon the surface roughness of the reflector.

- For a delta technique, the maximum response would be observed after interaction with backwall because of the small, cross-sectional area of the reflector with respect to the direct ultrasonic beam.

For a 0° longitudinal wave examination, the following characteristics would be observed:

- The reflector would be difficult to detect due to its orientation, size, and shape. A majority of the sound energy striking the reflector would be scattered away from the receiver transducer.

- Evidence of a loss of backwall reflection due to the scattering of the sound energy away from the receiver transducer would be difficult because of normal fluctuations of the backwall reflections caused by the cladding and the small physical size of the reflector.

- Spurious reflectors within the weld and base material located at depths before the reflector may mask detection.

7.1 ASME Code Section XI, State-of-the-Art, and Special Ultrasonic Examinations

The ultrasonic data for the ASME Code Section XI, State-of-the-art, and Special examinations supports the model presented in figure 7-3. For the pulse-echo examinations performed in the counter clockwise direction, the maximum signal response is consistently at a depth located before the backwall. This is demonstrated by the data presented in figures 6-1, 6-2, 6-6, 6-7, 6-10, 6-11, 6-14, and 6-15. Figure 6-11 clearly displays three images created by the focused 45 degree shear wave recorded data. The alignment of these images demonstrates the validity of the model. Image A is a direct specular reflection. Image B is a sound beam path consisting of a reflection from the backwall to the reflector and back to the transducer by a direct path. Image C is a sound beam path consisting of a reflection from the backwall to the reflector and back the same path to the transducer. For the delta examinations in the counter clockwise direction, the maximum signal response is from the reflector itself without interaction with the backwall with weak secondary responses after interaction with the backwall. This is demonstrated by the typical data presented in figure 6-16. For the pulse-echo examinations in the clockwise direction, the maximum signal response is consistently located at a depth after the backwall. This means that the reflector was detected after reflection from the backwall. This is demonstrated in figures 6-3, 6-4, 6-5, 6-8, 6-9, 6-12, and 6-13. For the delta examinations in this same direction, the maximum response was obtained after sound beam interaction with the backwall, specifically as shown in figure 7-5b. This data is shown in table 6-4.

The 0° longitudinal wave examinations comprising the 2.25 MHz, 1.5 inch diameter conventional ASME Code Section XI transducer, the 1.0 MHz, focused transducer, and the 5.0 MHz, 0.5 x 1 inch transducer resulted in no evidence of the embedded reflector. This is not unusual for a small, oriented, embedded reflector near the outside diameter surface. Additionally the presence of insignificant weld inclusions, specifically near 6.4 inches below the inner diameter surface and above the indication, and small randomly scattered plate segregates in the clockwise plate may have prevented detection of this indication.

7.2 Synthetic Aperture Focusing Technique

Three types of indications could have potentially existed in the area that SAFT data was acquired:

- Case 1 - Volumetric. Slag or porosity with a high degree of spherical or cylindrical size.

- Case 2 - Flat. Lack of fusion or inclusion (the width dimension being small relative to the height or length dimension).

- Case 3 - Crack. Diffuse reflector, probably surface connected.

All of the images analyzed conveyed a single message -- the indication was above the far surface and not surface-connected. The 45 degree shear wave image of the corner trap of a 0.3 inch deep notch shows the indication center is around the far surface. The 3-D SAFT processed 45 degree shear wave data acquired from the Indian Point Unit 2 reactor pressure vessel clearly shows the indication is before the far surface. If the indication were a crack, it would most likely be surface-connected, thus presenting a corner trap echo that would be oriented similar to that shown in the notch data. If it were a crack and not surface connected, the tip-diffracted echo should appear if it is within the system resolution. The 3-D SAFT-processed 45 degree longitudinal wave images do not contain any tip indications.

If the indication were volumetric with significant acoustic cross section, the normal beam scans would be expected to show an indication. Finally, if the indication were flat and of a proper orientation, a mirror image should be seen projected below the far surface and possibly an indication resulting from beam redirection or mode conversion effects would be projected on the far surface.

The SAFT 45 degree shear wave data file did not sample far enough to see the mirror echo, if it exists, and a corner trap echo is not evident. The geometry of the indication may be such that the beam redirection/mode conversion effects are reduced and therefore may not be distinguishable from the background noise. The 45 degree longitudinal wave scans support the shear wave scans in that the indication is seen before the far surface.

Based upon careful review of the SAFT data, the reflector does not present a geometry which exhibits tip signals or a strong corner trap echo. The reflector appears before the back surface although the remaining ligament and through-wall height cannot be established by the SAFT data alone, since it was based almost entirely on the one scan of the 45 degree shear wave transducer in the pulse-echo mode. The size cannot be estimated with very much accuracy since the SAFT performance was based on notches and clearly this indication does not image like a notch. The 45 degree shear wave image shows that the defect does not have uniform through-wall height over its length and this is also manifested in the size of the remaining ligament in that it is not uniform across the defect. The indication has an image center that is located on average about 0.4 inch above the far surface. The SAFT data shows the indication has a continuous length of 1.9 inches and an intermittent length of 2.4 inches.

7.3 Determination of Reflector Size

The reflector size and location was determined utilizing a combination of techniques. Figure 7-6 provides a summary of the linear extent of the reflector for the various techniques used. This figure is provided to show the relative consistency and concentration of the reflector over a linear extent from approximately 238.15 to 242 inches from the vessel flange. The lengths for the ASME Code examinations using UDRPS analysis were obtained using 50% DAC sizing (table 6-2), whereas for the focused transducers the lengths were determined using half maximum amplitude and successive dB drop techniques (table 6-3). The length can be determined in three different perspectives: 1) the average length obtained by averaging the lengths of all techniques assuming ASME Code Section XI proximity rules; 2) the maximum length obtained with any one technique; and 3) the maximum bounding length for all techniques, obtained by taking the minimum and maximum positions below the vessel flange. These lengths are as follows:

- Average length = 2.4 inches (data from tables 6-1, 6-2, 6-3, and section 7.2)

- Maximum length = 3.3 inches (data from tables 6-1, 6-2, 6-3, and section 7.2)

- Maximum bounding length = 3.9 inches (data from figure 7-6)

The ligament between the reflector and the backwall was calculated using the results of the delta techniques and the pulse-echo techniques in both scanning directions. The equations for the delta techniques are provided in figure 7-5 for the various approximated sound paths. With the time spacings indicated on table 6-4 for the various paths the ligament dimension was calculated. These calculated values are given in table 7-1 for each scan line where appropriate signals are observed. The minimum ligament as determined by the delta techniques is 0.23 inch. The ligaments determined by using the depth locations of the indication from the various pulse-echo techniques and the known backwall are given in table 7-2. Because of mode conversions and reflections at angles from the backwall differing from the incident angles, the distances from the backwall for the clockwise scans are not considered as accurate as the counter clockwise scans. The minimum ligament as determined by the pulse-echo data is 0.26 inch. Therefore, the most conservative ligament dimension is 0.23 inch.

In terms of reflector through-wall size, the absence of a significant loss of backwall response using the pitch-catch technique qualitatively confirms the fact that the cross-section of the reflector is less than 1 inch. This is the minimum size in which a loss in backwall was observed during the Waltz Mill statistical verification investigation. The lack of a response with the three different 0 degree longitudinal wave techniques (2.25 MHz unfocused, 1.0 MHz focused, and 5 MHz unfocused) also suggests a reflector with a small cross-section. The estimated reflector through-wall size was calculated using the doublet spacing observed in the 45° shear wave pulse-echo technique noted in table 6-4. This technique, commonly referred to as the satellite pulse observation technique (SPOT),[2] relies on the observations of a trailing satellite pulse which is generated by a portion of the incidence sound beam transforming into a surface wave. This surface wave transverses around the circumference of a reflector and is directed back to the receiver transducer. This received response, which is synchronous with the maximum specular response, is typically weaker and travels slightly later in time than the primary, specularly reflected signal. By observing the difference in time, calculations can be made to determine the effective reflector diameter. Alternately a correlation to the reflector size can be applied using the difference in sweep length provided a relationship on actual flaw sizes has been established. Therefore a conservative estimate of the reflector

2. Gruber, G. J., Hendrix, G. J., and Schick, W. R., "Characterization of Flaws in Piping Welds Using Satellite Pulses," Material Evaluation, April 1984, pp. 426 - 432.

through-wall dimension is 0.37 inch. Figure 7-7 shows a relationship established using side-drilled holes and real volumetric flaws.[3] This relationship is provided in the linear regression equation provided in the lower right hand corner.

A typical display of the doublet is shown in figure 6-2. In this figure the doublet spacing is 2.5 μsec. Using the results in table 6-4, the estimated reflector diameter using this technique is calculated for the different scan lines. Table 7-3 provides the results of these calculations. The maximum reflector effective diameter is 0.37 inch.

In addition, the ligament calculations using unfocused delta configuration data (figure 7-1) was used to establish a through-wall dimension. Using the maximum ligament and the minimum ligament, the difference is 0.21 inch (0.44-0.23 inch).

7.4 Statistical Verification of Sizing Techniques

The statistical verification of sizing techniques which was performed at Waltz Mill involved the use of artificial flaws simulating surface-connected planar reflectors (notches). These machined notches have smooth surfaces perpendicular to the outer diameter surface, a uniform depth across their length and a flat top surface. The reflector in the Indian Point Unit 2 reactor vessel was determined to be subsurface (at least 0.23 inch from the backwall), not oriented perpendicular to the outer diameter surface, and considered an inclusion with some degree of asymmetry in its physical shape. Since these are two different types of reflectors a direct comparison of results of the Waltz Mill examinations and the vessel examinations is not applicable although some general comparisons can be made.

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3. Kim, C. C., Jusino, A., Rishel, R. D., and Shannon, R. E., <u>Development of an Ultrasonic Inspection for the D1G Pressurizer and Steam Generators</u>, Westinghouse Electric Corporation, WCAP-10933, May 1985.

Surface-connected planar reflectors are appropriately characterized using tip diffraction principles (pulse-echo, delta) whereby time-of-flight information for responses emanating from extremities or tips is used to determine the through-wall depth. This was the technique used in the statistical verification program performed at Waltz Mill. Embedded weld inclusions of the type in the vessel cannot be appropriately characterized by such a technique due to the absence of sharp extremities and their physical size. These types of reflectors are more appropriately characterized using satellite pulse techniques which were not part of the statistical verification program.

In terms of length assessment, the statistical verification program was comprised of amplitude-based sizing methodologies, such as 50% DAC and half maximum amplitude, and an amplitude-independent sizing methodology, successive dB drop. Amplitude-based sizing methodologies are reflector geometry dependent such that surface-connected planar reflectors and embedded reflectors will yield different accuracies. The successive dB drop technique is the only length sizing methodology where the results of the statistical verification program and the results of the vessel examinations may be compared. The successive dB drop technique used with the focused 45 degree longitudinal wave transducer relies on observing the points where the length increments with successive dB drops are a function of the beam width. The statistical verification program, though, only considered reflectors up to a maximum length of 2.0 inches based on the examination results of 1984 (figure 7-8). The successive dB drop and the half maximum amplitude techniques, though, are appropriate in sizing reflectors such as that found in the vessel and have been applied extensively in the field.

In terms of determining the ligament between the reflector and the backwall, the unfocused delta technique data and the pulse-echo technique data were used. The delta technique evaluation for surface-connected planar reflectors and embedded reflectors is different in that different reflection paths are being utilized and measured. For surface-connected planar reflectors the two responses necessary to determine the through-wall size or in a different sense, the ligament between the top extremity and the backwall are emanating from the corner between the reflector and the backwall, and the top extremity. The path difference between the two responses is composed of both a shear wave component and a longitudinal wave component. A composite velocity multiplied by the time of flight difference between the paths is used to estimate the through-wall size. For the vessel reflector, the ligament size between the reflector (inclusion) and the backwall was determined using the direct response from the reflector and secondary responses after interaction with the backwall (figure 7-5). Both path differences (paths 1-2 and paths 1-3 in figure 7-5) are comprised of only one wave mode, either shear or longitudinal. Therefore for the vessel reflector, the delta technique-determined ligament is dependent on a single velocity whereas for a surface-connected planar reflector as used in the statistical verification program a similar measurement is dependent on two velocities, a different statistical condition.

The pulse-echo tip diffraction results from the statistical verification program may be used if interpreted in a manner different than originally intended. Tip diffraction using pulse-echo techniques is essentially a methodology based on determining the difference in position between the corner reflector and the tip reflector and classifying this difference as the through-wall size or the ligament. This same situation is evident for the vessel reflector where the difference in position between the reflector and the backwall is necessary to determine the ligament. For the 45 degree longitudinal wave focused transducer and reflectors of less than 0.5 inch the ligament, i.e., the through-wall depth, is shown to be undersized with respect to the actual (figure 7-9). Therefore the actual ligament or through-wall would be greater. Similar information for the 45 degree shear wave and 60 degree shear wave focused transducers are shown in figures 7-10 and 7-11. The 45 degree shear wave focused transducer data indicates a slight oversizing of the ligament with respect to the actual but the absence of data points below 0.5 inch due to the inability to resolve tip signals necessitates a cautious interpretation of this trend. The 60 degree shear wave focused transducer data (figure 7-11) are similar to the 45 degree shear wave focused transducer data, but indicate a poorer technique for resolution of tip reflectors near the backwall surface. No data points are present for reflectors of less than 1 inch from the backwall surface due to the inability to resolve tip signals. The absence of data points in this region prevents determining the accuracy of the measurements for the ligament.

The statistical verification program results are therefore not directly applicable to the vessel examination results; however the following general conclusions can be made of the program:

- o Conventional ASME Code Section XI sizing methodologies based on 50% DAC techniques tend to oversize the length of surface-connected planar reflectors. In terms of depth, these same techniques tend to oversize small surface-connected planar reflectors but undersize large surface-connected planar reflectors.

- o Half maximum amplitude and successive dB drop length sizing techniques using focused transducers improve length measurement capabilities for surface-connected planar reflectors.

- o Tip diffraction depth sizing using pulse-echo focused transducers and the unfocused delta technique is a good methodology for determining the through-wall size of surface-connected planar reflectors.

It is believed that further statistical sizing technique analyses related to subsurface reflectors is unnecessary at this time. The methodologies applied to characterize the vessel reflector, i.e., half maximum amplitude and successive dB drop for length sizing, time of flight for ligament measurement, and trailing satellite pulse for depth, have all been demonstrated and used in field situations to characterize embedded reflectors. Additionally the use of state-of-the-art techniques and transducers with the automated data recording and analysis system represents one of the most complex and comprehensive inspection programs for reactor vessel examinations. And finally, the bounding of the reflector size using the most practical ultrasonic examination results is conservative.

7.5 Evaluation of Nondestructive Examination Results

The reflector is located near the outside surface of the reactor vessel and is conservatively characterized as embedded with a length (l) of 3.9 inches and through-wall dimension (2a) of 0.37 inch. The ligament between the reflector and the vessel outside diameter surface (S) is 0.23 inch.

Comparison with the standards of IWB-3500, ASME Section XI 1980 Edition with Addenda through Winter 1981, shows that the reflector is acceptable:

$a = 0.185$ in.
$l = 3.9$ in.
$t = 8.625$ in.
$y = S/a > 1$, therefore

$a/l = 0.047$
$a/t = 2.1\%$

The limit on acceptable a/t is 2.4%.

8.0 FRACTURE MECHANICS ANALYSIS

A fracture mechanics analysis (WCAP-10651) was completed and submitted by letter dated September 7, 1984. Additional information was submitted by letter dated September 21, 1984. These analyses were based on the initial 1984 sizing in accordance with standard ASME XI amplitude based sizing techniques after corrections were made for beam spread and beam angle. The initial ASME amplitude based sizing characterized the reflector as 2.03 inches deep and 1.96 inches long. After beam spread and angle correction, the reflector was sized at 1.96 inches long with a through-wall dimension of 1.2 inches located 0.25 inch from the outside diameter surface. The fracture mechanics analysis assumed an a/l ratio of 0.5 per ASME Section XI requirements and therefore an actual flaw indication of 1.45 inches deep and 2.9 inches long was analyzed. These analyses and submittals concluded that the indication was acceptable and without significance from an operating or safety standpoint.

The same type of amplitude based sizing techniques were used during the current 1987 examinations. Based on these techniques, it was shown that the indication remains unchanged. Since the analyses accomplished in 1984 were based on end of plant life conditions the conclusions reached in 1984 continue to remain valid.

Based on new ultrasonic techniques the indication has been sized as a result of the 1987 exams as 3.9 inches long with a maximum effective diameter of 0.37 inch and a ligament dimension of 0.23 inch. Although this is an embedded reflector even if it were considered a surface reflector with its length different (3.9 inches vs. 2.9 inches), and its depth different (0.6 inch vs. 1.45 inches), the 1984 analysis conclusions would still be applicable because the length of the flaw indication analyzed in 1984 was comparable to the length found during the 1987 examinations, although the 1984 assumed depth was significantly greater as compared to 1987 determined depth. Therefore the 1984 analysis is a conservative treatment of the 1987 flaw size results and the 1984 conclusions continue to remain valid and consistent with the 1987 size determinations.

Although the conclusions of the 1984 analysis continue to remain valid it is noted that the 1987 examinations have demonstrated that the indication is of Code allowable size for subsurface indications per Table IWB-3510-1 of ASME Section XI. An evaluation analysis and re-examinations per paragraph IWB-3122.4, (a) and (b) Acceptance by Evaluation, are therefore not required for determination of acceptability.

Although not required for determination of acceptability, additional fracture analyses work has been performed in 1987 to determine how large the indication could be and still be acceptable pursuant to the flaw evaluation criteria of IWB-3600. Figure 8-1 shows that <u>any</u> indication which can be characterized as embedded and within the chart limits is acceptable per the criteria of IWB-3600. For the embedded reflector characterized in this examination, the distance from the surface and the half width as defined in figure 8-1 are 0.05 and 0.02, respectively, based on S = 0.23 inch, 2a = 0.37 inch and l = 3.9 inches. This point is shown in figure 8-1. Although the indication has been determined to be embedded, if it were considered as outside surface connected, figure 8-2 shows how large it could be to remain within the IWB-3600 criteria. For example, a flaw .86 inches deep by 8.6 inches long is acceptable, as is a flaw of 1.6 inches deep by 4 inches long.

The vessel indication clearly has been shown to be much smaller than such sizes.

9.0 CONCLUSIONS

The variety of ultrasonic examination techniques utilized together with the fracture mechanics analyses performed support the conclusions that the indication is a subsurface welding inclusion such as slag or localized lack of fusion etc. that has existed, unchanged, since vessel fabrication and will remain unchanged throughout the plant operating lifetime.

Evaluation of the nondestructive examination results show that the indication is conservatively bounded by a length (1) of 3.9 inches, a through-wall dimension (2a) of 0.37 inch and a ligament distance of 0.23 inch. Such an indication is acceptable for continued operation per the ASME XI Code with no need for repair, replacement, further evaluation by analysis, or further augmented examinations.

The examinations and evaluations discussed herein support the conclusions reached in 1984, the indication is Code allowable per ASME Section XI and is without significance from an operating and safety standpoint.

TABLE 3-1

CHARACTERISTICS OF FOCUSED TRANSDUCERS

TRANSDUCER*	FREQUENCY	FOCUSING DEPTH	BEAM DIAMETER IN INCIDENCE PLANE**	BEAM DIAMETER IN THE PLANE PERPENDICULAR TO THE INCIDENCE PLANE**
0°L	1.0 MHz	226 mm (8.9 in.)	11.5 mm (0.45 in.)	10.5 mm (0.41 in.)
45°L	2.0 MHz	226 mm (8.9 in.)	10.9 mm (0.43 in.)	8.7 mm (0.34 in.)
45°S	1.0 MHz	216 mm (8.5 in.)	9 mm (0.35 in.)	10 mm (0.39 in.)
60°S	1.0 MHz	219 mm (8.6 in.)	15.8 mm (0.62 in.)	13.7 mm (0.53 in.)

*Transducers fabricated by Intercontrole.

**Beam diameter at 6 dB drop points, experimental value.

TABLE 6-1
INDIAN POINT UNIT 2 REACTOR VESSEL INDICATION AT
345 DEGREE VESSEL AZIMUTH

ASME Section XI Manual Results Comparison
Length and Through-Wall Measurements at 50% DAC
1984 vs. 1987

TRANSDUCER	EXAMINATION YEAR	PEAK AMPLITUDE	DEPTH (in.)	LENGTH (in.)
TR22	1984	100% DAC + 5 dB	0.42	1.10
	1987	100% DAC + 2 dB	0.39	0.88
TR24	1984	100% DAC	0.62	1.64
	1987	100% DAC	0.62	0.83
TR25	1984	63% DAC	0.21	0.37
	1987	30% DAC	Spot	Spot
TR27	1984	100% DAC + 15 dB	2.03	1.96
	1987	100% DAC + 13 dB	1.88	1.97

TABLE 6-2

INDIAN POINT UNIT 2 REACTOR VESSEL INDICATION AT
345 DEGREE VESSEL AZIMUTH

ASME Section XI Sizing Using Automated Data
Recording and Processing System

(Length and Through-Wall Measurements Taken Between 50% DAC Points)

TRANSDUCER	EXAMINATION YEAR	DEPTH (in.)	LENGTH (in.)
TR22	1987	0.50	2.3
TR24	1987	0.55	2.0
TR25	1987	Spot	Spot
TR27	1987	1.47	1.9

TABLE 6-3

INDIAN POINT UNIT 2 REACTOR VESSEL INDICATION AT
345 DEGREE VESSEL AZIMUTH

State-of-the-Art Examinations -- Focused Transducers
(Length Sizing Using Half Maximum Amplitude Method
and Successive dB Drop Method)

TRANSDUCER	SCAN DIRECTION	LINEAR EXTENT BELOW FLANGE, INCLUSIVE (IN.)	LENGTH (IN.)	TECHNICAL
45°L	CW	240.29 thru 238.69	1.7	Half maximum amplitude
45°L	CCW	241.35 thru 239.45	2.0	Half maximum amplitude
		239.05 thru 238.45	0.7	
45°S	CW	241.25 thru 240.95	0.4	Half maximum amplitude
		240.65 thru 238.45	2.3	
		238.15	0.1	
45°S	CCW	241.99 thru 238.79	3.3	Half maximum amplitude
60°S	CW	241.84 thru 241.44	0.5	Half maximum amplitude
		241.04 thru 239.24	1.9	
60°S	CCW	241.53 thru 240.03	1.6	Half maximum amplitude
		239.63 thru 238.53	1.2	

TABLE 6-3 (Cont'd.)
INDIAN POINT UNIT 2 REACTOR VESSEL INDICATION AT
345 DEGREE VESSEL AZIMUTH

State-of-the-Art Examinations -- Focused Transducers
(Length Sizing Using Half Maximum Amplitude Method
and Successive dB Drop Method)

TRANSDUCER	SCAN DIRECTION	LINEAR EXTENT BELOW FLANGE, INCLUSIVE (IN.)	LENGTH (IN.)	TECHNICAL
45°L	CW	241.7 to 238.6	3.1	Successive dB drop
45°L	CCW	241.5 to 238.3	3.2	Successive dB drop

TABLE 6-4

INDIAN POINT UNIT 2 REACTOR VESSEL INDICATION AT

345 DEGREE VESSEL AZIMUTH

Special Examinations - Delta Technique Results

DISTANCE BELOW FLANGE (IN.)	TRANSDUCER CONFIGURATION	NO. OF MULTIPLE SIGNALS OBSERVED	TIME DIFFER-ENCE 1-2 (μsec)	TIME DIFFER-ENCE 2-3 (μsec)	TIME DIFFER-ENCE 1-3 (μsec)	DEPTH LOCA-TION (IN.)	AMPLITUDE (COLOR LEVEL)	OBSERVED DOUBLET SPACING (μsec)	COMMENTS
241.4	TR22/TR20	3	2.0	3.0	5.0	--	--	--	
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	0	--	--	--	8.46	--	--	
241.3	TR22/TR20	3	2.0	2.5	4.5	--	--	--	
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	1	--	--	--	8.55	102	2.5	
241.2	TR22/TR20	2	--	3.0	--	--	--	--	
	TR24/TR20	1	--	3.5	--	--	--	--	
	TR22	1	--	--	--	8.53	110	3.0	
241.1	TR22/TR20	2	--	2.5	--	--	--	--	
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	1	--	--	--	8.41	94	3.5	

TABLE 6-4 (Cont'd.)

INDIAN POINT UNIT 2 REACTOR VESSEL INDICATION AT

345 DEGREE VESSEL AZIMUTH

Special Examinations - Delta Technique Results

DISTANCE BELOW FLANGE (IN.)	TRANSDUCER CONFIGURATION	NO. OF MULTIPLE SIGNALS OBSERVED	TIME DIFFER-ENCE 1-2 (μsec)	TIME DIFFER-ENCE 2-3 (μsec)	TIME DIFFER-ENCE 1-3 (μsec)	DEPTH LOCA-TION (IN.)	AMPLITUDE (COLOR LEVEL)	OBSERVED DOUBLET SPACING (μsec)	COMMENTS
241.0	TR22/TR20	2	--	2.5	--	--	--	--	
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	1	--	--	--	8.34	128	3.0	
240.9	TR22/TR20	0	--	--	--	--	--	--	Responses are poor.
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	1	--	--	--	8.41	161	3.0	
240.7	TR22/TR20	0	--	--	--	--	--	--	Responses are poor.
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	1	--	--	--	8.41	149	2.0	
240.6	TR22/TR20	1	--	--	3.5	--	--	--	
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	1	--	--	--	8.41	147	1.5	

TABLE 6-4 (Cont'd.)

INDIAN POINT UNIT 2 REACTOR VESSEL INDICATION AT

345 DEGREE VESSEL AZIMUTH

Special Examinations - Delta Technique Results

DISTANCE BELOW FLANGE (IN.)	TRANSDUCER CONFIGURATION	NO. OF MULTIPLE SIGNALS OBSERVED	TIME DIFFER-ENCE 1-2 (μsec)	TIME DIFFER-ENCE 2-3 (μsec)	TIME DIFFER-ENCE 1-3 (μsec)	DEPTH LOCA-TION (IN.)	AMPLITUDE (COLOR LEVEL)	OBSERVED DOUBLET SPACING (μsec)	COMMENTS
240.5	TR22/TR20	1	--	--	4.0	--	--	--	
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	0	--	--	--	8.41	140	--	
240.4	TR22/TR20	1	--	--	4.0	--	--	--	
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	0	--	--	--	8.36	124	--	
240.3	TR22/TR20	1	--	--	4.0	--	--	--	
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	0	--	--	--	8.41	117	--	
240.2	TR22/TR20	1	--	--	4.0	--	--	--	
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	1	--	--	--	8.36	110	2.5	

TABLE 6-4 (Cont'd.)

INDIAN POINT UNIT 2 REACTOR VESSEL INDICATION AT

345 DEGREE VESSEL AZIMUTH

Special Examinations - Delta Technique Results

DISTANCE BELOW FLANGE (IN.)	TRANSDUCER CONFIGURATION	NO. OF MULTIPLE SIGNALS OBSERVED	TIME DIFFERENCE 1-2 (μsec)	TIME DIFFERENCE 2-3 (μsec)	TIME DIFFERENCE 1-3 (μsec)	DEPTH LOCATION (IN.)	AMPLITUDE (COLOR LEVEL)	OBSERVED DOUBLE T SPACING (μsec)	COMMENTS
240.1	TR22/TR20	1	--	--	4.0	--	--	--	
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	1	--	--	--	8.36	114	2.5	
240.0	TR22/TR20	1	--	--	4.0	--	--	--	
	TR24/TR20	0	--	--	--	--	--	--	Only peak 3 observed.
	TR22	0	--	--	--	8.29	151	--	
239.9	TR22/TR20	1	--	--	3.5	--	--	--	
	TR24/TR20	1	--	1.5	--	--	--	--	Only peak 2 observed.
	TR22	1	--	--	--	8.29	182	4.5	
239.8	TR22/TR20	0	--	--	--	--	--	--	
	TR24/TR20	1	--	1.5	--	--	--	--	Only peak 2 observed.
	TR22	1	--	--	--	8.29	219	6.0	

TABLE 6-4 (Cont'd.)

INDIAN POINT UNIT 2 REACTOR VESSEL INDICATION AT

345 DEGREE VESSEL AZIMUTH

Special Examinations - Delta Technique Results

DISTANCE BELOW FLANGE (IN.)	TRANSDUCER CONFIGURATION	NO. OF MULTIPLE SIGNALS OBSERVED	TIME DIFFERENCE 1-2 (μsec)	TIME DIFFERENCE 2-3 (μsec)	TIME DIFFERENCE 1-3 (μsec)	DEPTH LOCATION (IN.)	AMPLITUDE (COLOR LEVEL)	OBSERVED DOUBLET SPACING (μsec)	COMMENTS
239.7	TR22/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR24/TR20	0	--	--	--	--	--	--	Only a faint peak 2
	TR22	1	--	--	--	8.29	245	6.0	observed.
239.6	TR22/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR24/TR20	0	--	--	--	--	--	--	Only a faint peak 2
	TR22	0	--	--	--	8.24	252	--	observed.
239.5	TR22/TR20	0	--	--	--	--	--	--	Only peak 1 observed.
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	1	--	--	--	8.24	253	3.5	
239.4	TR22/TR20	0	--	--	--	--	--	--	Only peak 1 observed.
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed.
	TR22	0	--	--	--	8.22	238	--	

TABLE 6-4 (Cont'd.)

INDIAN POINT UNIT 2 REACTOR VESSEL INDICATION AT

345 DEGREE VESSEL AZIMUTH

Special Examinations - Delta Technique Results

DISTANCE BELOW FLANGE (IN.)	TRANSDUCER CONFIGURATION	NO. OF MULTIPLE SIGNALS OBSERVED	TIME DIFFERENCE 1-2 (μsec)	TIME DIFFERENCE 2-3 (μsec)	TIME DIFFERENCE 1-3 (μsec)	DEPTH LOCATION (IN.)	AMPLITUDE (COLOR LEVEL)	OBSERVED DOUBLET SPACING (μsec)	COMMENTS
239.3	TR22/TR20	0	--	--	--	--	--	--	Only peak 1 observed.
	TR24/TR20	0	--	--	--	--	--	--	Only peak 2 observed (faint).
	TR22	0	--	--	--	8.19	171	--	
239.2	TR22/TR20	0	--	--	--	--	--	--	Very faint signals -- not measurable.
	TR24/TR20	0	--	--	--	--	--	--	Very faint signals -- not measurable.
	TR22	1	--	--	--	8.22	100	2.0	
239.1	TR22/TR20	0	--	--	--	--	--	--	Very faint signals -- not measurable.
	TR24/TR20	0	--	--	--	--	--	--	Very faint signals -- not measurable.
	TR22	1	--	--	--	8.24	62	2.0	

TABLE 6-4 (Cont'd.)

INDIAN POINT UNIT 2 REACTOR VESSEL INDICATION AT

345 DEGREE VESSEL AZIMUTH

Special Examinations - Delta Technique Results

DISTANCE BELOW FLANGE (IN.)	TRANSDUCER CONFIGURATION	NO. OF MULTIPLE SIGNALS OBSERVED	TIME DIFFER-ENCE 1-2 (μsec)	TIME DIFFER-ENCE 2-3 (μsec)	TIME DIFFER-ENCE 1-3 (μsec)	DEPTH LOCA-TION (IN.)	AMPLITUDE (COLOR LEVEL)	OBSERVED DOUBLET SPACING (μsec)	COMMENTS
239.0 - 238.4	TR22/TR20	0	--	--	--	--	--	--	Very faint signals -- not measurable.
	TR24/TR20	0	--	--	--	--	--	--	Very faint signals -- not measurable.
	TR22	0	--	--	--	--	--	--	Very faint signals -- not measurable.

TABLE 7-1
LIGAMENT CALCULATIONS USING UNFOCUSED
DELTA CONFIGURATION DATA

DISTANCE BELOW FLANGE (in.)	TRANSDUCER CONFIGURATION	S1 (In.)	S2 (In.)
241.4	TR22/TR20	0.23	0.44
	TR24/TR20	-	-
241.3	TR22/TR20	0.23	0.40
	TR24/TR20	-	-
241.2	TR22/TR20	-	-
	TR24/TR20	-	-
241.1	TR22/TR20	-	-
	TR24/TR20	-	-
241.1	TR22/TR20	-	-
	TR24/TR20	-	-
240.9	TR22/TR20	-	-
	TR24/TR20	-	-
240.7	TR22/TR20	-	-
	TR24/TR20	-	-
240.6	TR22/TR20	-	0.31
	TR24/TR20	-	-

TABLE 7-1 (Cont'd.)

LIGAMENT CALCULATIONS USING UNFOCUSED

DELTA CONFIGURATION DATA

DISTANCE BELOW FLANGE (in.)	TRANSDUCER CONFIGURATION	S1 (In.)	S2 (In.)
240.5	TR22/TR20	-	0.35
	TR24/TR20	-	-
240.4	TR22/TR20	-	0.35
	TR24/TR20	-	-
240.3	TR22/TR20	-	0.35
	TR24/TR20	-	-
240.2	TR22/TR20	-	0.35
	TR24/TR20	-	-
240.1	TR22/TR20	-	0.35
	TR24/TR20	-	-
240.0	TR22/TR20	-	0.35
	TR24/TR20	-	-
239.9	TR22/TR20	-	0.31
	TR24/TR20	-	-
239.8	TR22/TR20	-	-
238.4	TR24/TR20	-	-

TABLE 7-2
LIGAMENT CALCULATIONS USING PULSE-ECHO
TECHNIQUE DATA

TRANSDUCER	SCAN DIRECTION	SCAN LINE BELOW VESSEL FLANGE (IN.)	DISTANCE FROM BACKWALL (IN.)
Focused 45°L	CW	239.1	0.32*
Focused 45°L	CCW	241.3	0.26
Focused 45°S	CW	241.3	0.50*
Focused 45°S	CCW	239.1	0.43
Focused 60°S	CW	241.2	0.20*
Focused 60°S	CCW	241.2	0.72
SAFT 45°S	CCW	--	0.4 (center of image, on average)

*Because of mode conversions and/or reflections at angles from the backwall differing from the incident angles, the distances from the backwall for the clockwise scans are not considered as accurate as the counter clockwise scans.

TABLE 7-3

ESTIMATED FLAW DIAMETER USING

SATELLITE PULSE OBSERVATION TECHNIQUE

DISTANCE BELOW FLANGE (IN.)	OBSERVED DOUBLET SPACING (μsec)	CALCULATED SWEEP DOUBLET* (mm)	ESTIMATED FLAW EFFECTIVE DIAMETER (mm)	ESTIMATED FLAW EFFECTIVE DIAMETER (IN.)
241.4	-	-	-	-
241.3	2.5	4.0	3.9	0.15
241.2	3.0	4.8	4.7	0.19
241.1	3.5	5.6	5.5	0.22
241.0	3.0	4.8	4.7	0.19
240.9	3.0	4.8	4.7	0.19
240.7	2.0	3.2	3.1	0.12
240.6	1.5	2.4	2.3	0.09
240.5	-	-	-	-
240.4	-	-	-	-
240.3	-	-	-	-
240.2	2.5	4.0	3.9	0.15
240.1	2.5	4.0	3.9	0.15
240.0	-	-	-	-
239.9	4.5	7.1	6.9	0.27
239.8	6.0	9.5	9.3	0.37
239.7	6.0	9.5	9.3	0.37
239.6	-	-	-	-
239.5	3.5	5.6	5.5	0.22
239.4	-	-	-	-
239.3	-	-	-	-
239.2	2.0	3.2	3.1	0.12
239.1	2.0	3.2	3.1	0.12
239.0-238.4	-	-	-	-

*(Observed doublet spacing /2) x shear velocity x 25.4

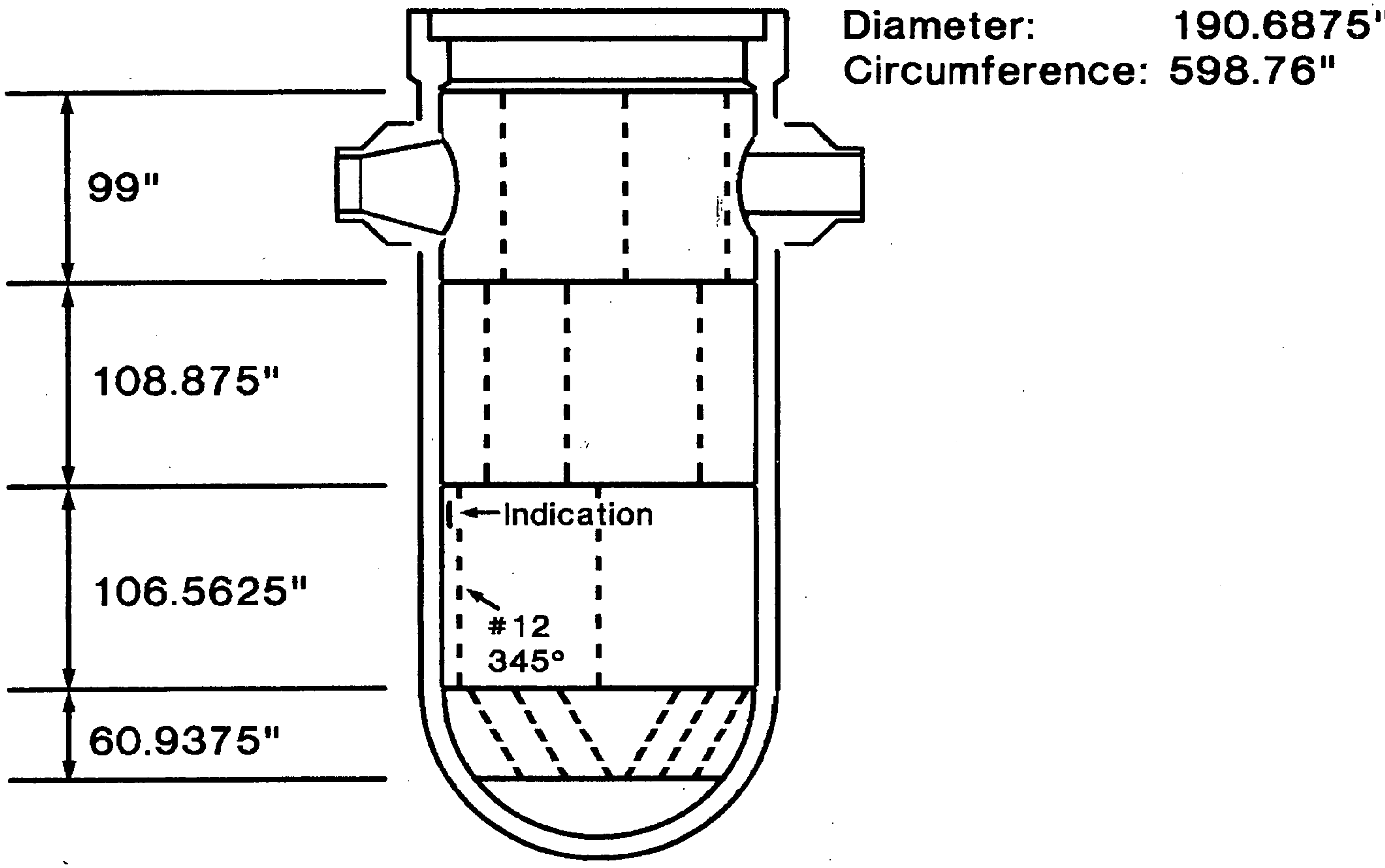


Figure 2—1: Indian Point Unit 2 Reactor Vessel

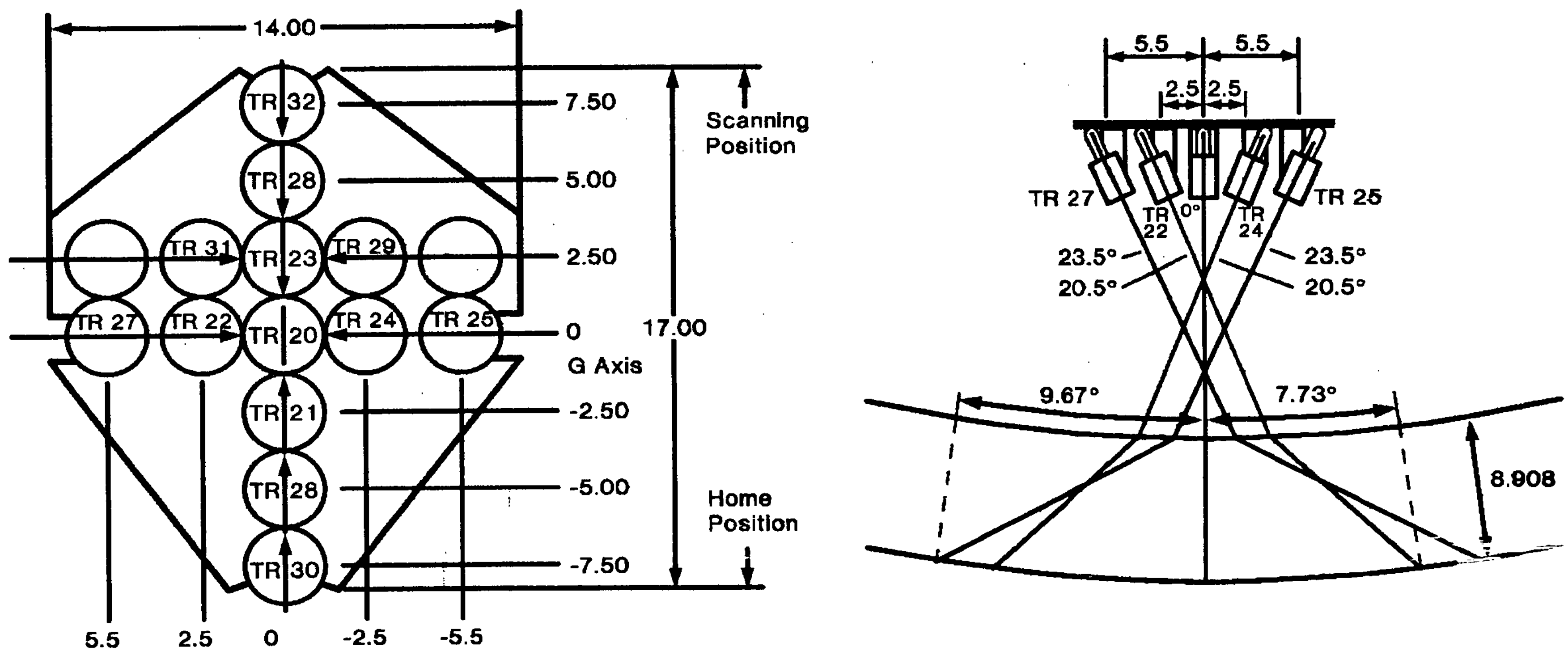
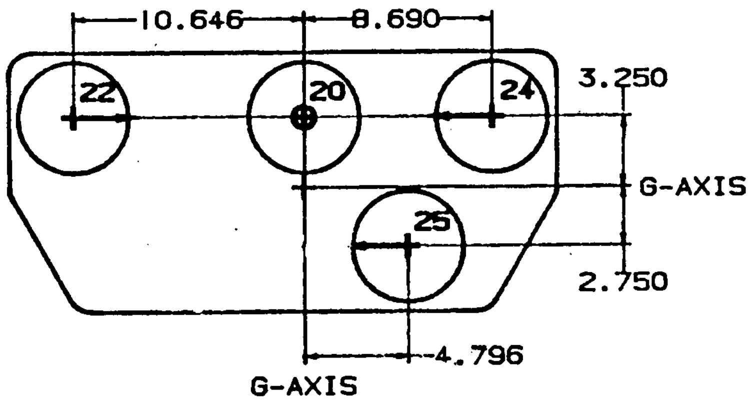


Figure 3–1: Indian Point Unit 2 Ten Year Examination Plate



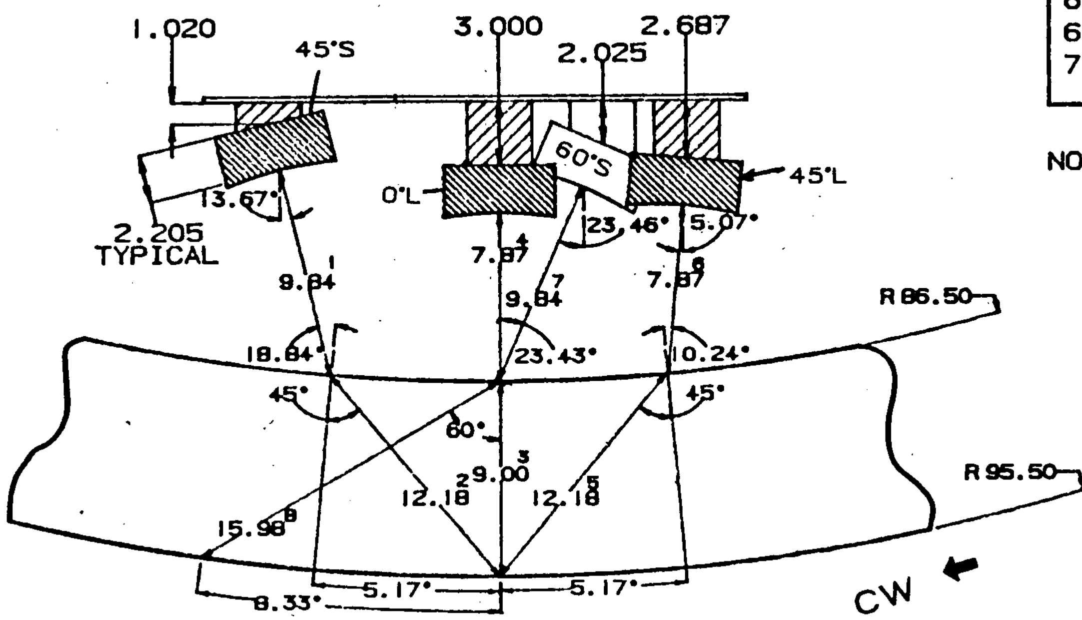
TIME OF FLIGHT DATA

SHEAR VELOCITY = .125 In/μsec
LONG VELOCITY = .230 In/μsec
WATER VELOCITY = .05755 In/μsec

PATH	MODE	TIME (μsec)
1-2-2-1	L-S-S-L	537
1-2-3-4	L-S-L-L	444
1-2-3-4	L-S-S-L	477
1-2-5-6	L-S-L-L	458
6-5-5-6	L-L-L-L	379
6-5-3-4	L-L-L-L	366
6-5-3-4	L-L-S-L	398
7-8-8-7	L-S-S-L	598

NOTES:

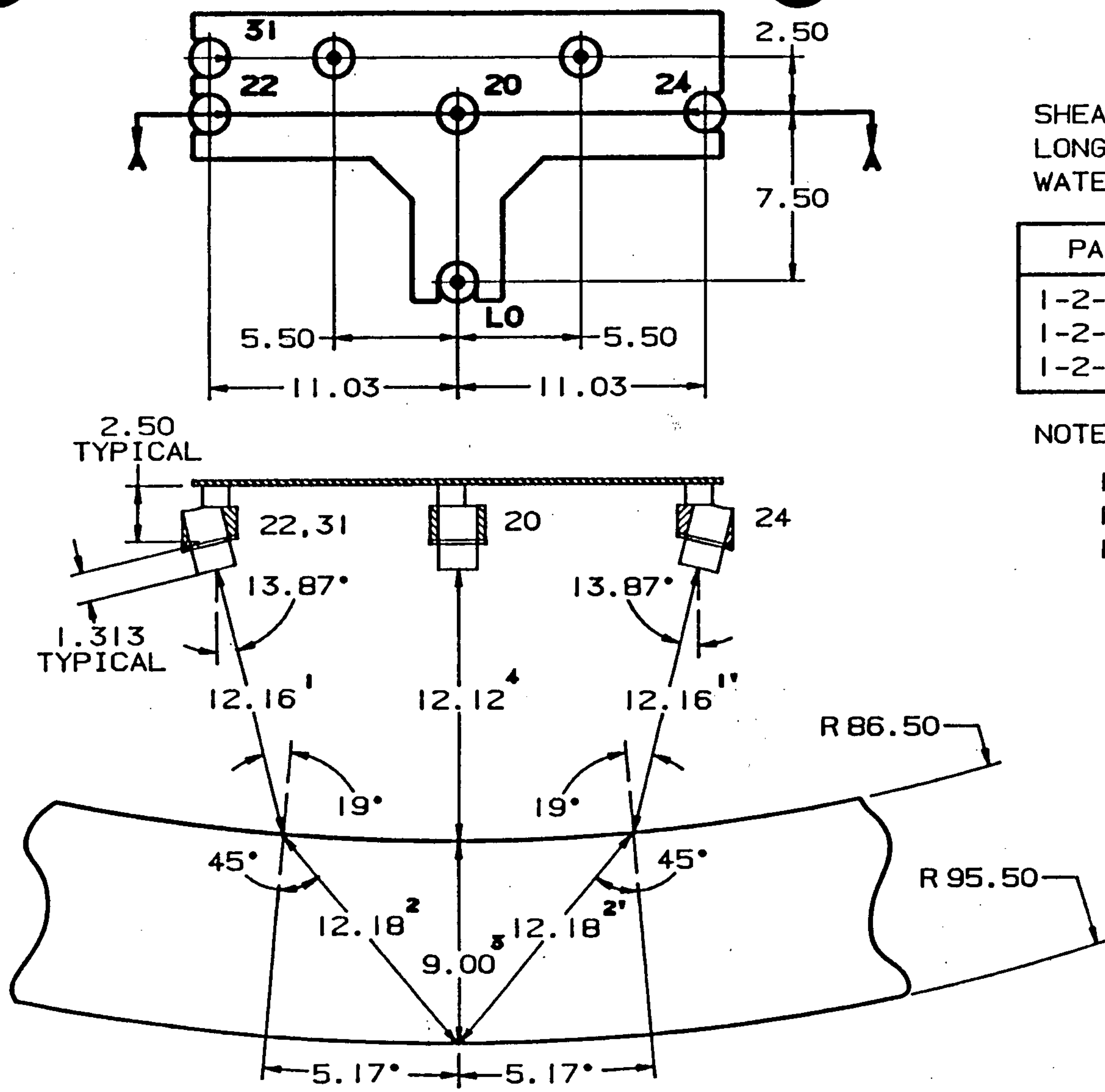
TR 22 IS A 45° SHEAR WAVE
TR 24 IS A 45° LONG. WAVE
TR 20 IS A 0° LONG. WAVE
TR 25 IS A 60° SHEAR WAVE



SECTIONAL VIEW

SHOWN WITH 4-LOOP ULTRASONIC BEAM PATTERN
(CIRCUMFERENTIAL VIEW)

Figure 3—2: Westinghouse RV—ISI Focused Array Plate



SECTION A-A
SHOWN WITH 4-LOOP ULTRASONIC BEAM PATTERN
(CIRCUMFERENTIAL VIEW)

TIME OF FLIGHT DATA

SHEAR VELOCITY = .125 in/μsec
LONG VELOCITY = .230 in/μsec
WATER VELOCITY = .05755 in/μsec

PATH	MODE	TIME (μsec)
1-2-3-4	L-S-L-L	558
1-2-3-4	L-S-S-L	591
1-2-2-1	L-S-S-L	617

NOTE: BY SYMETRY,

PATH 1-2-3-4 = 4-3-2-1
PATH 1-2-2-1 = 1-2-2'-1'
PATH 1-2-3-4 = 1'-2'-3-4

Figure 3-3: Westinghouse RV-ISI Delta Array Plate

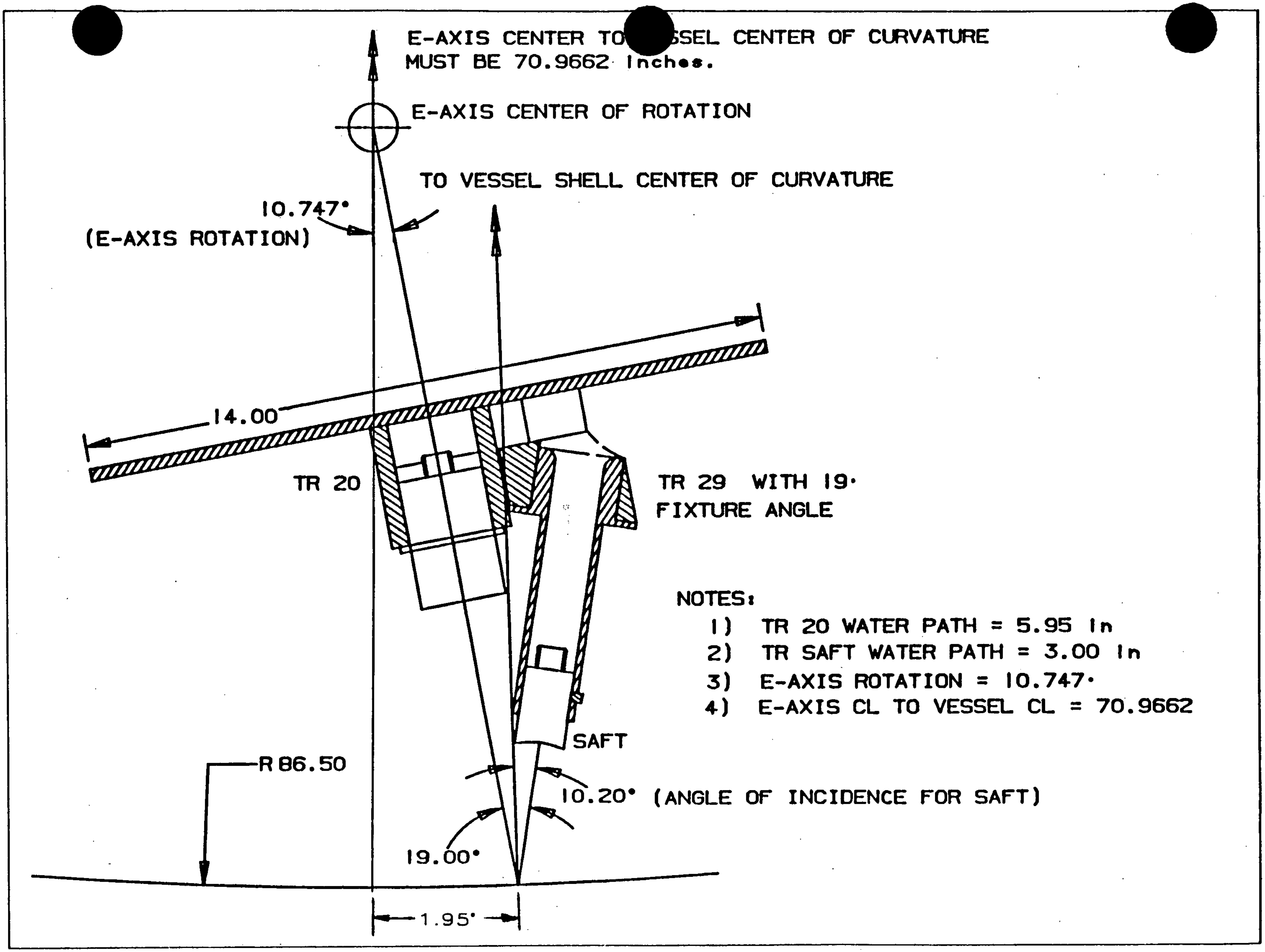


Figure 3—4: 45° Longitudinal Transducer Assembly and Test Setup

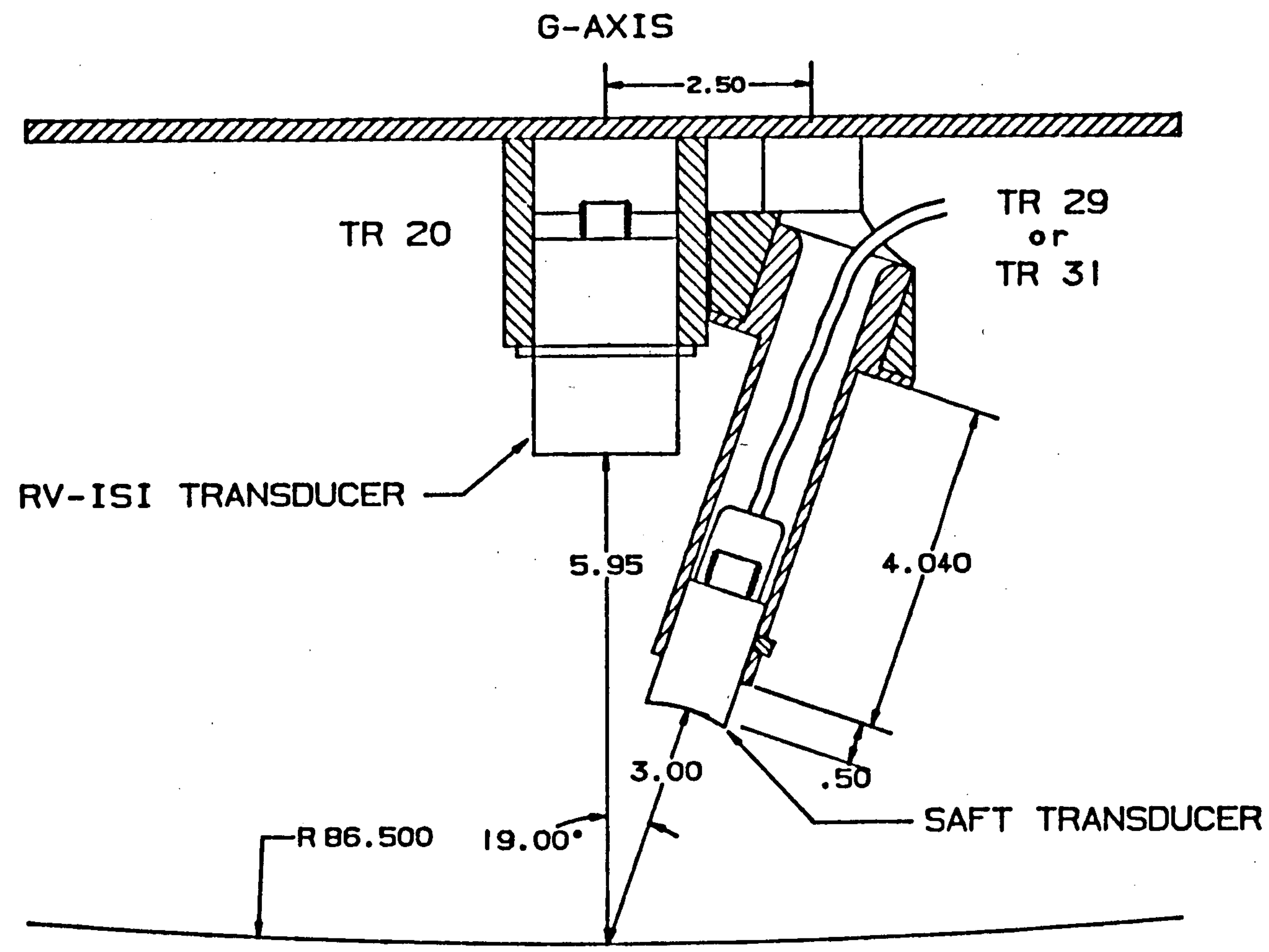


Figure 3–5: 45° Shear Transducer Assembly and Test Setup

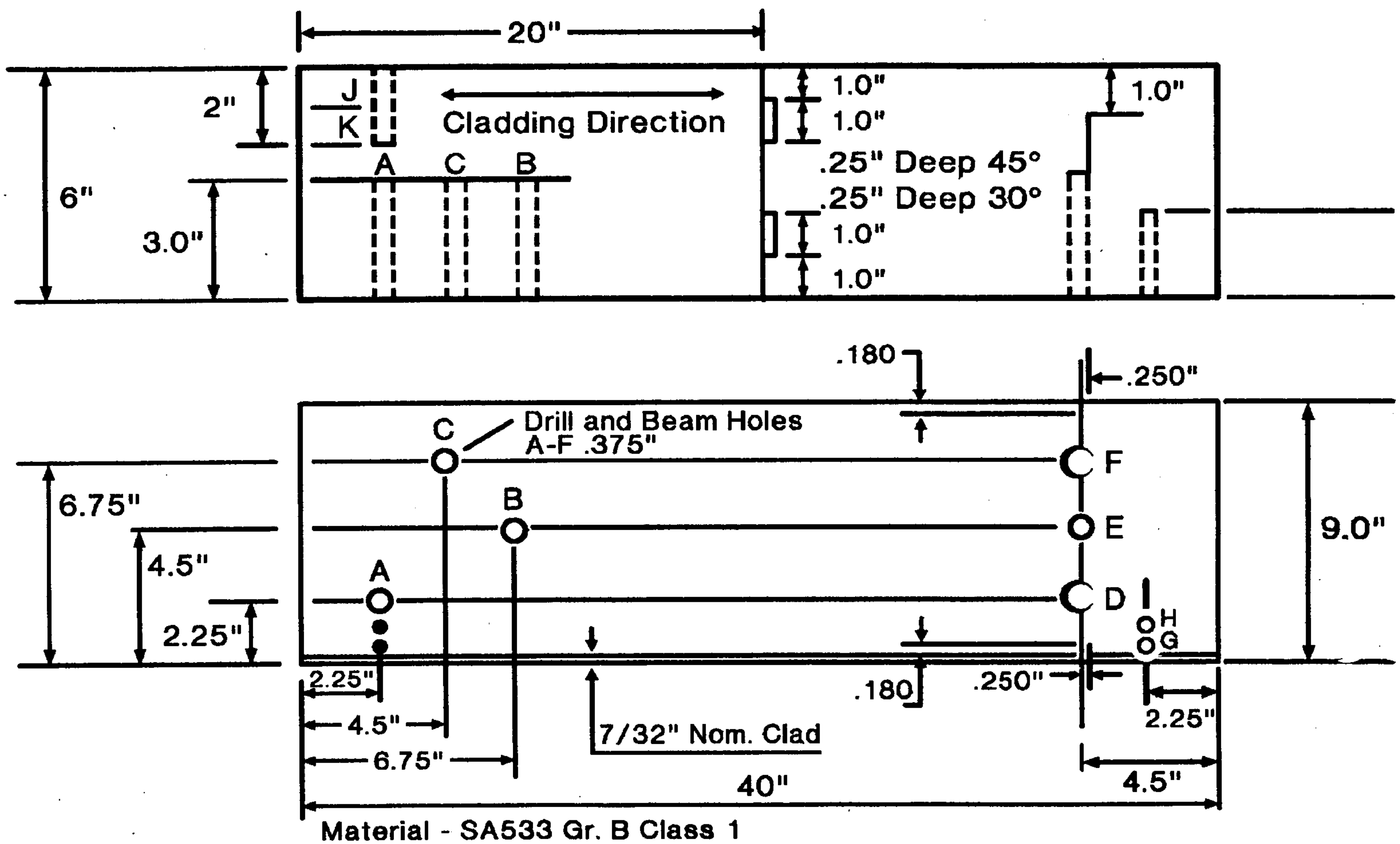
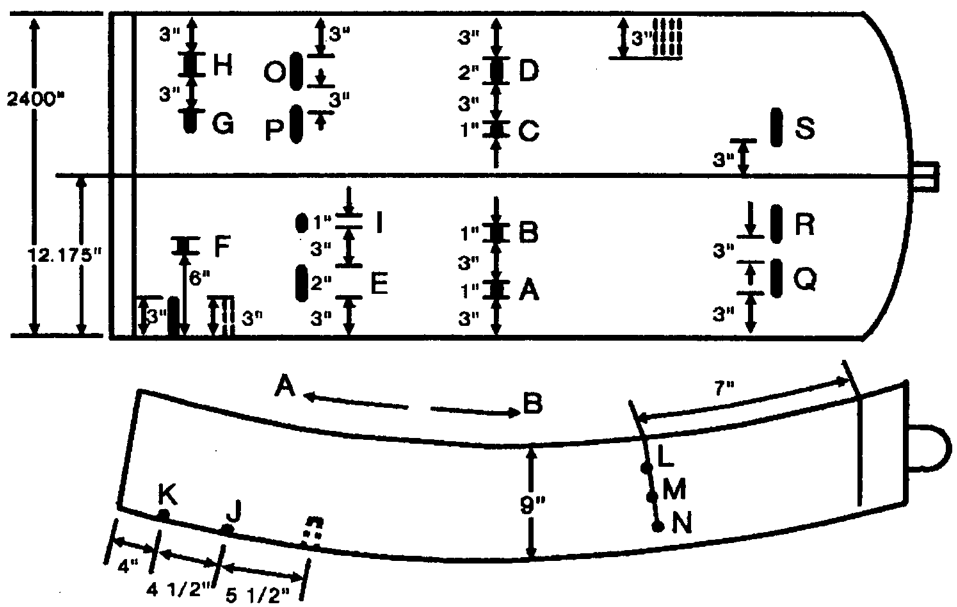


Figure 4-1: Basic 9" Reactor Vessel Calibration Block, IPP-RV-70



Target	Depth	Type	As Built
A	0.100"	1/8" x 1.00"	0.112"
B	0.300"	1/8" x 1.00"	0.305"
C	0.500"	1/8" x 2.00"	0.501"
D	1.5"	3/16" x 2.00"	1.499"
E	2.0"	3/16" x 2.00"	1.849"
F		V-Notch 90°	
G	0.180"	1/8" x 0.50"	0.180"
H	0.180"	1/8" x 1.00"	0.181"
I	0.250"	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"
O	0.180"	1/8" x 0.75"	
P	0.500"	1/8" x 0.75"	
Q	1.00"	1/8" x 1.00"	
R	0.180"	1/8" x 1.50"	
S	0.500"	1/8" x 1.50"	

Figure 4—2: Special Demonstration Block, IPP—2T—REV.1

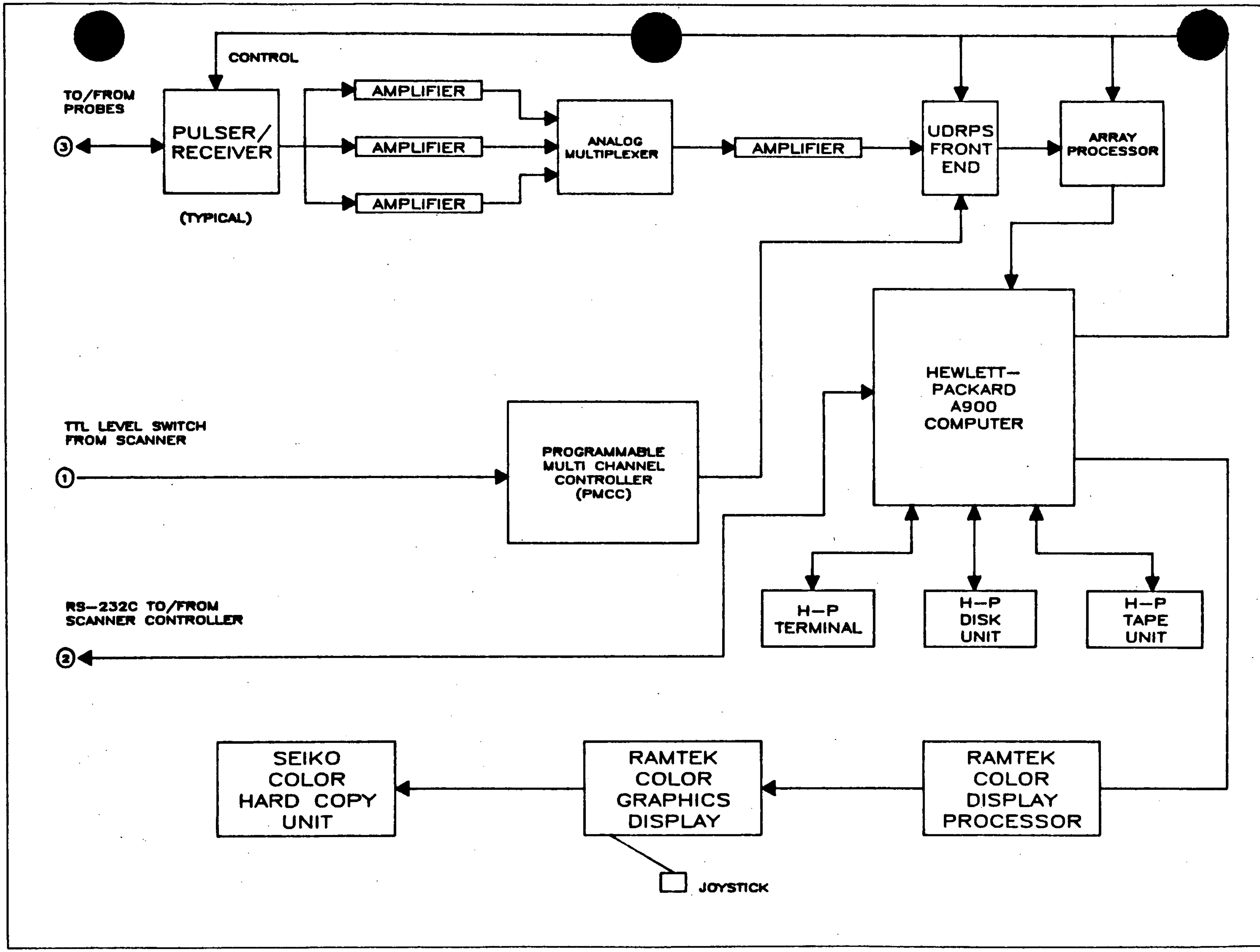


Figure 5-1: Equipment Arrangement (One of Two Identical Systems Shown)

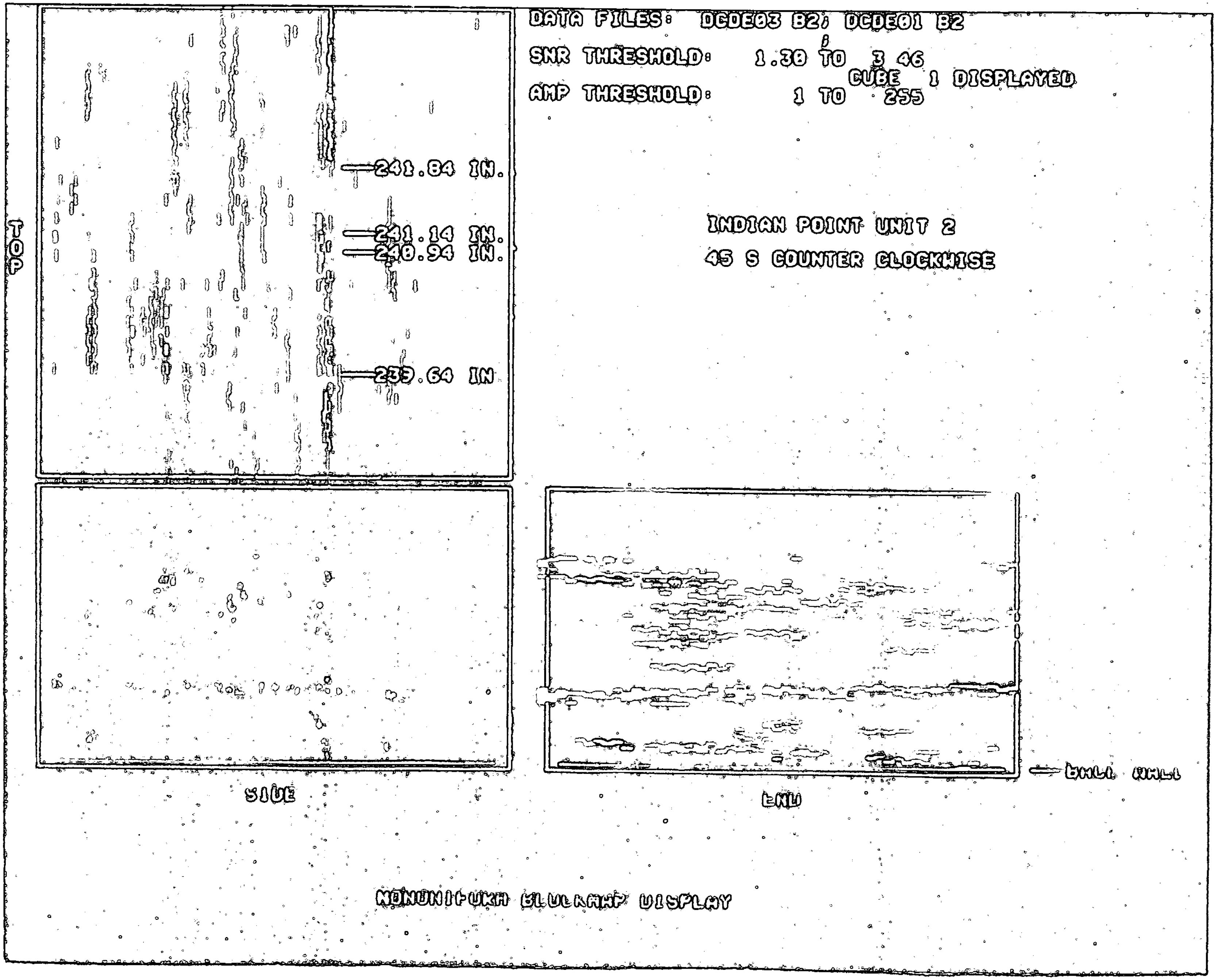


Figure 6—1: Indian Point Unit 2, Weld 12, Blockmap Display— ASME Code Section XI, 45°S CCW

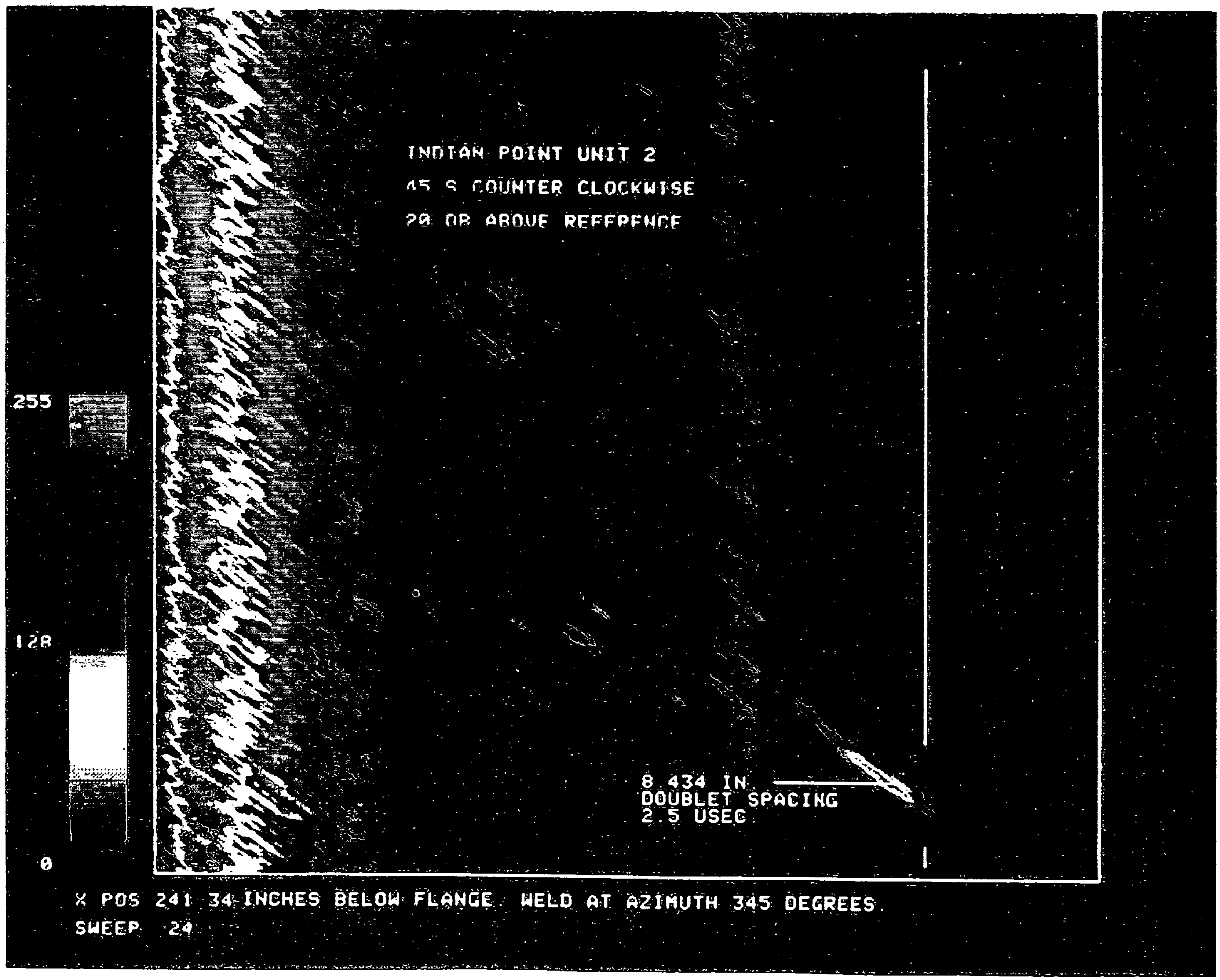


Figure 6—2: Indian Point Unit 2, Weld 12, ASME Code Section XI 45°S CCW

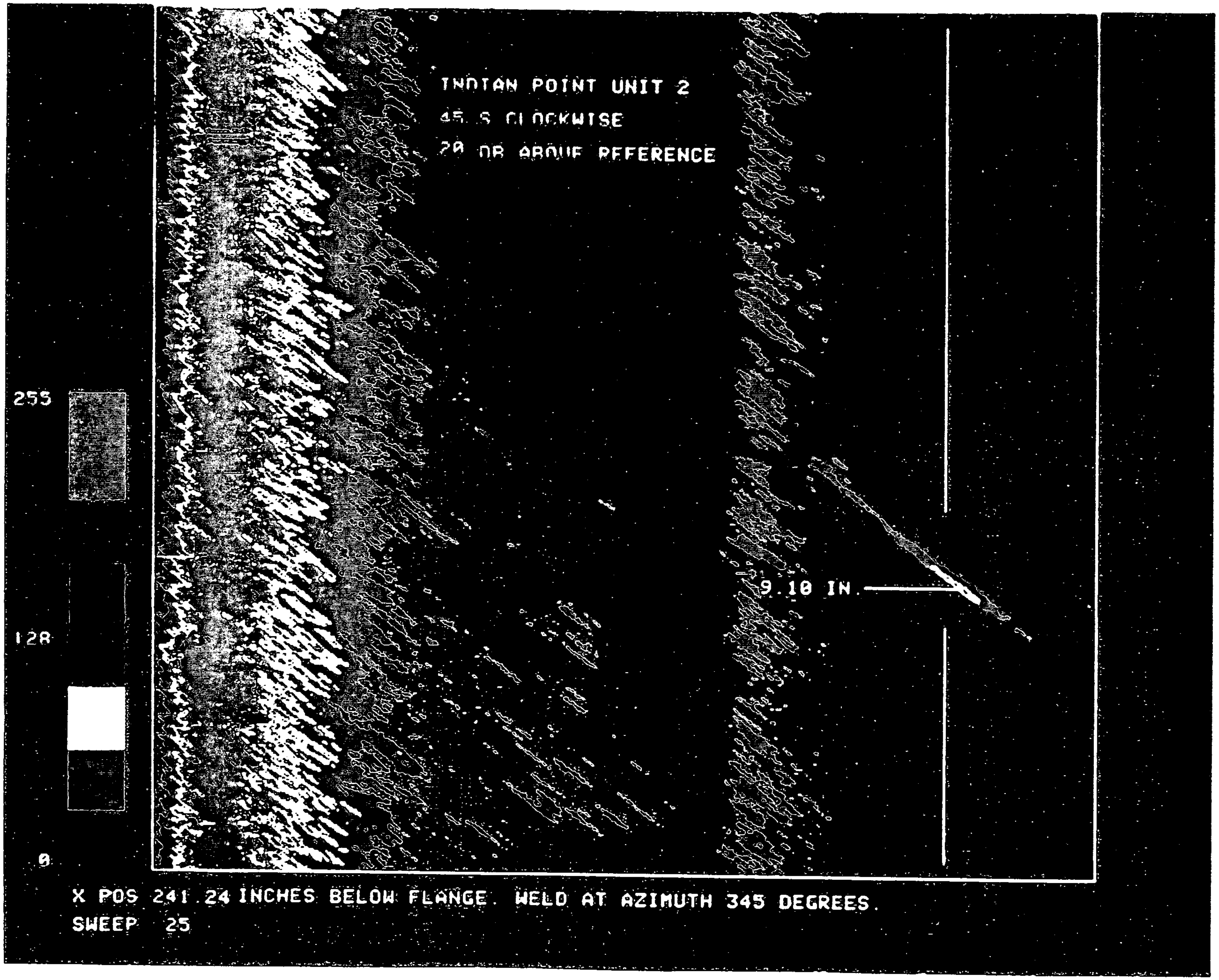


Figure 6—3: Indian Point Unit 2, Weld 12, ASME Code Section XI 45°S CW

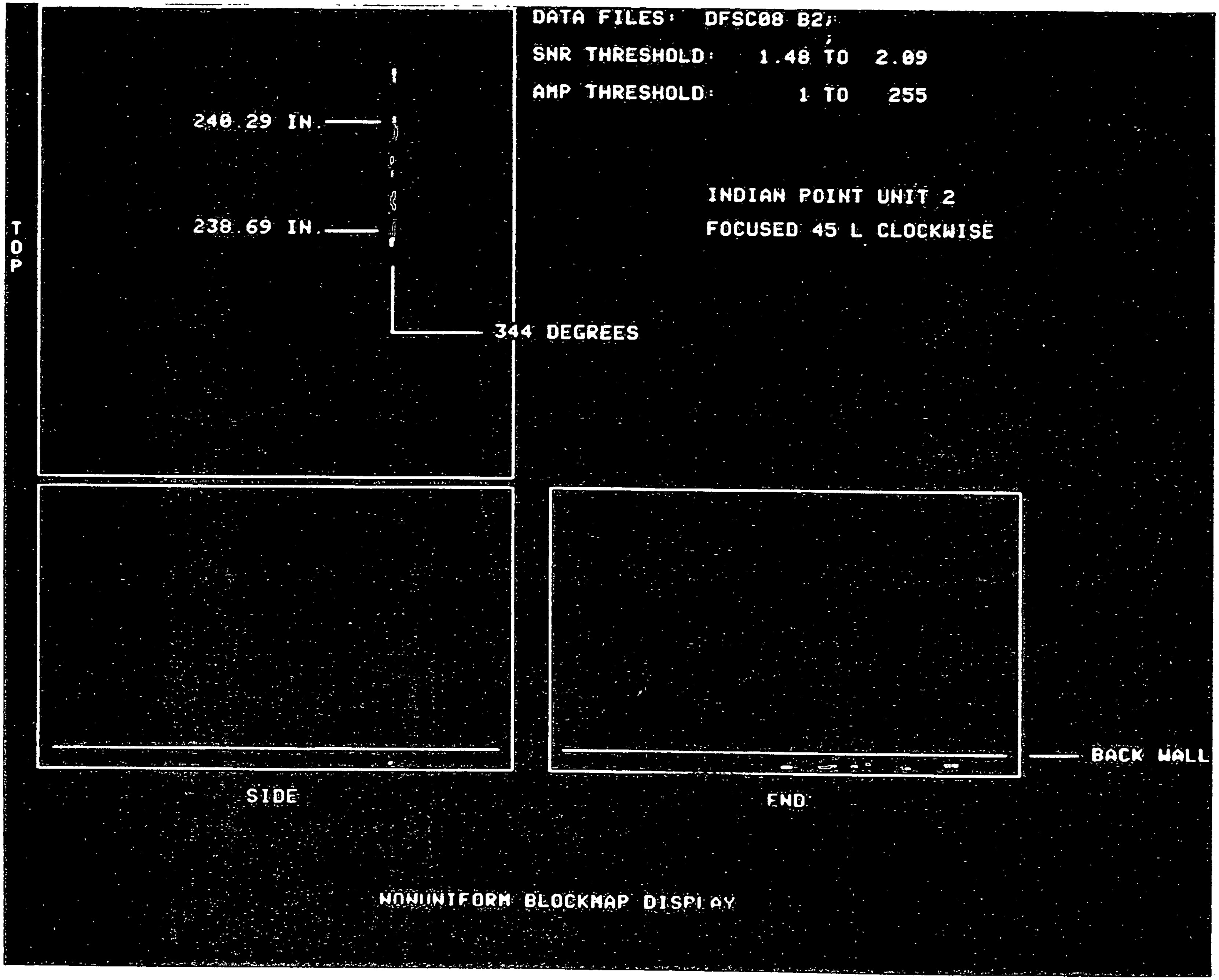


Figure 6–4: Indian Point Unit 2, Weld 12, Blockmap Display— Focused 45°L CW

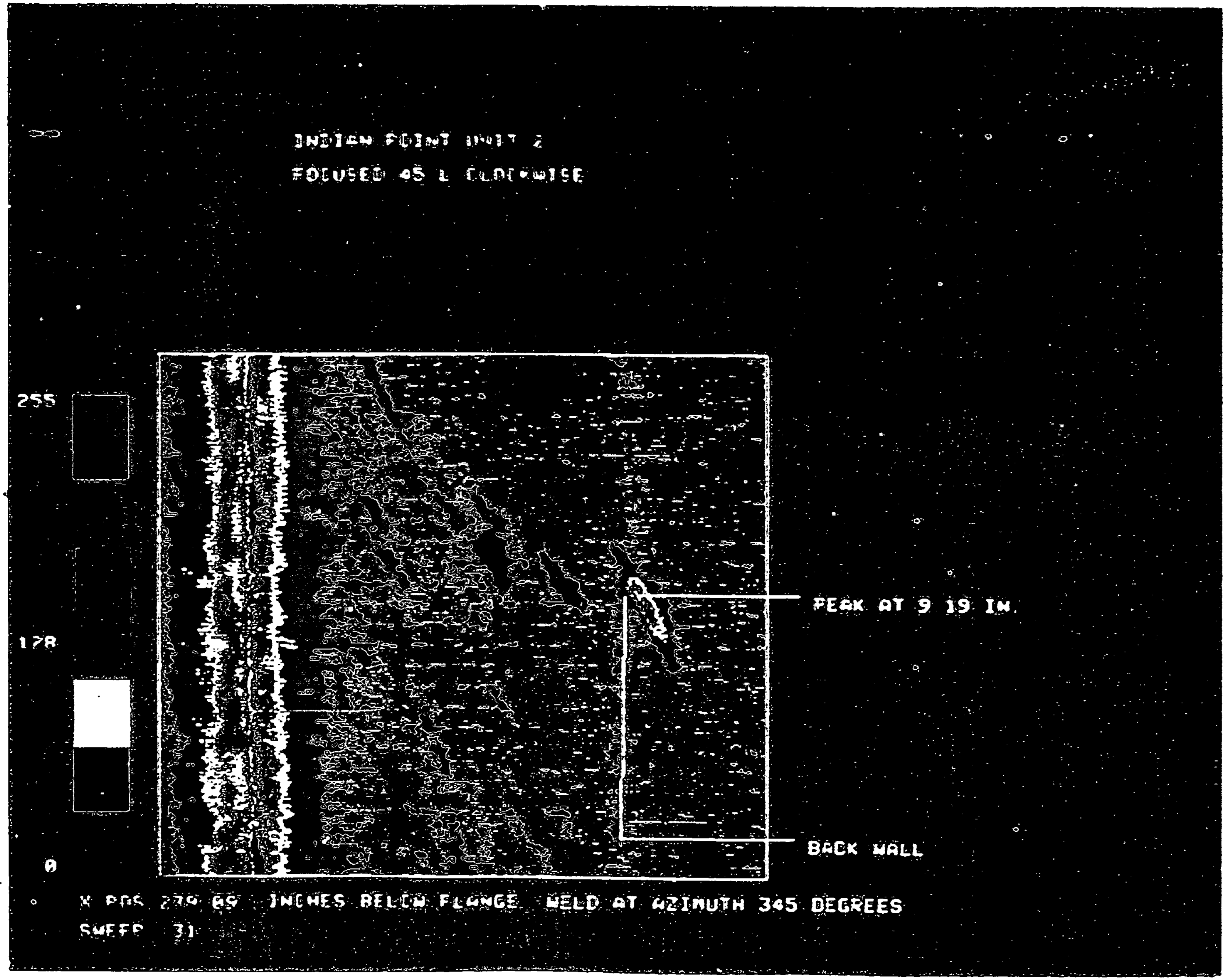


Figure 6—5: Indian Point Unit 2, Weld 12, Focused 45°L CW

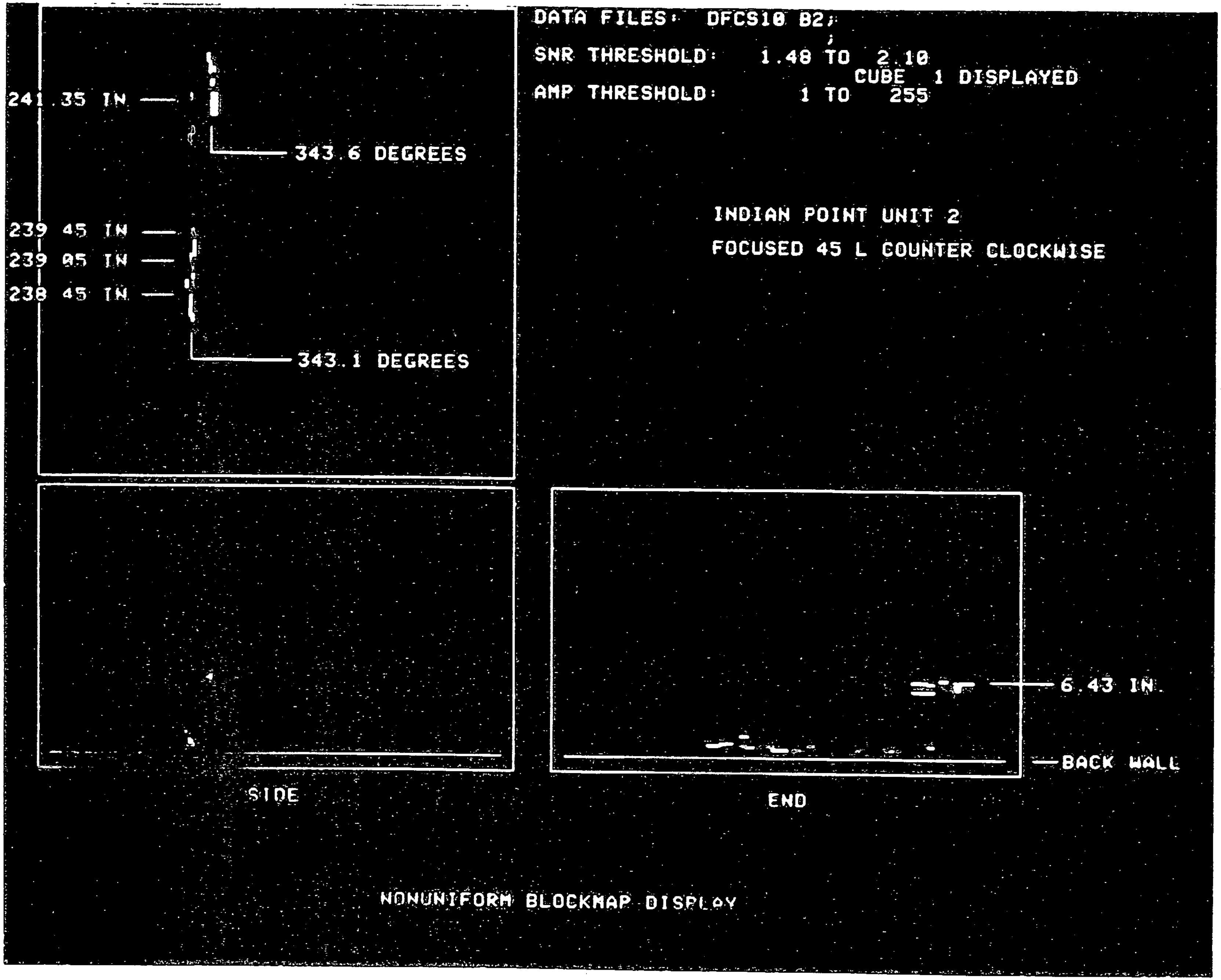


Figure 6—6: Indian Point Unit 2, Weld 12, Blockmap Display— Focused 45°L CCW

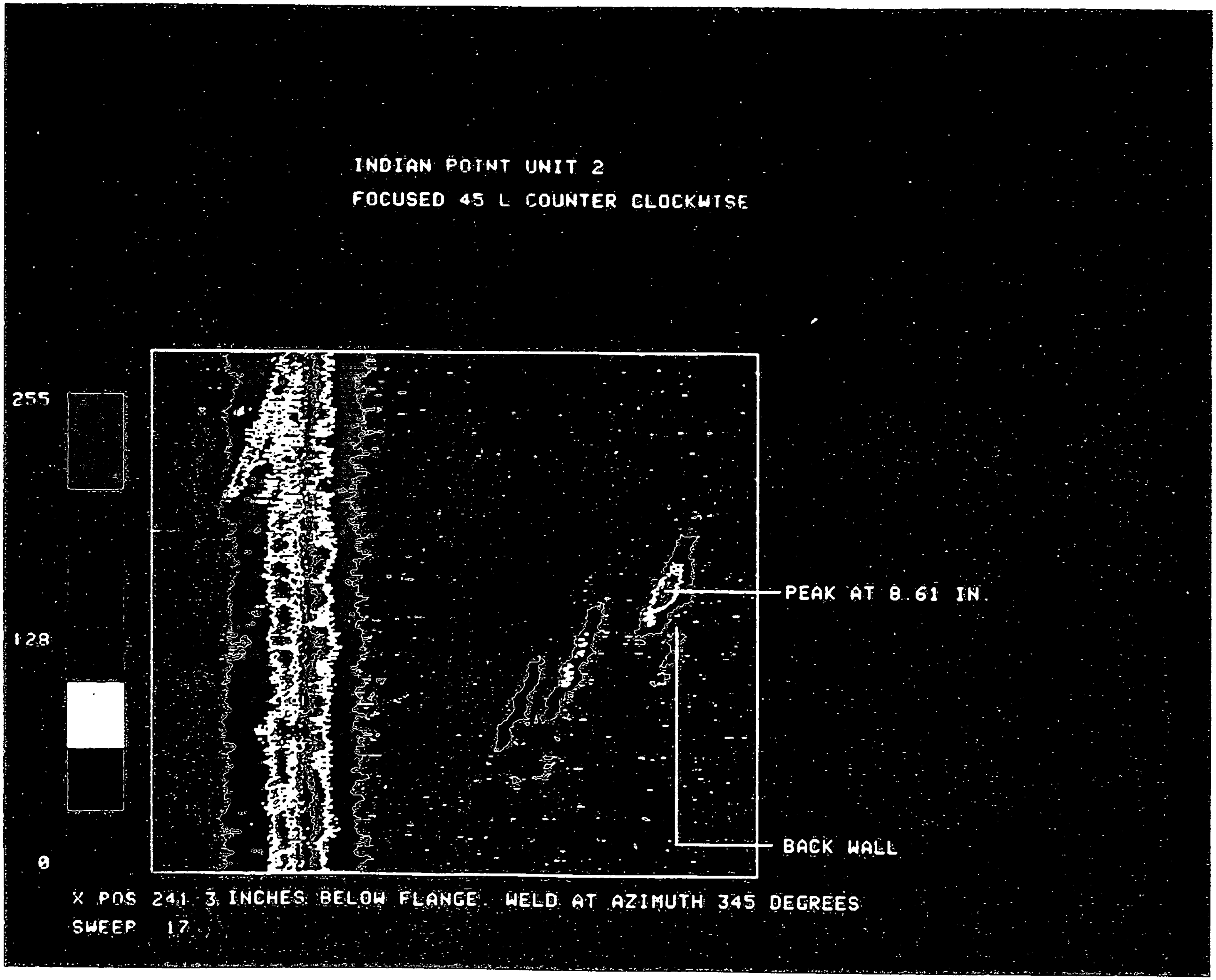


Figure 6—7: Indian Point Unit 2, Weld 12, Focused 45°L CCW

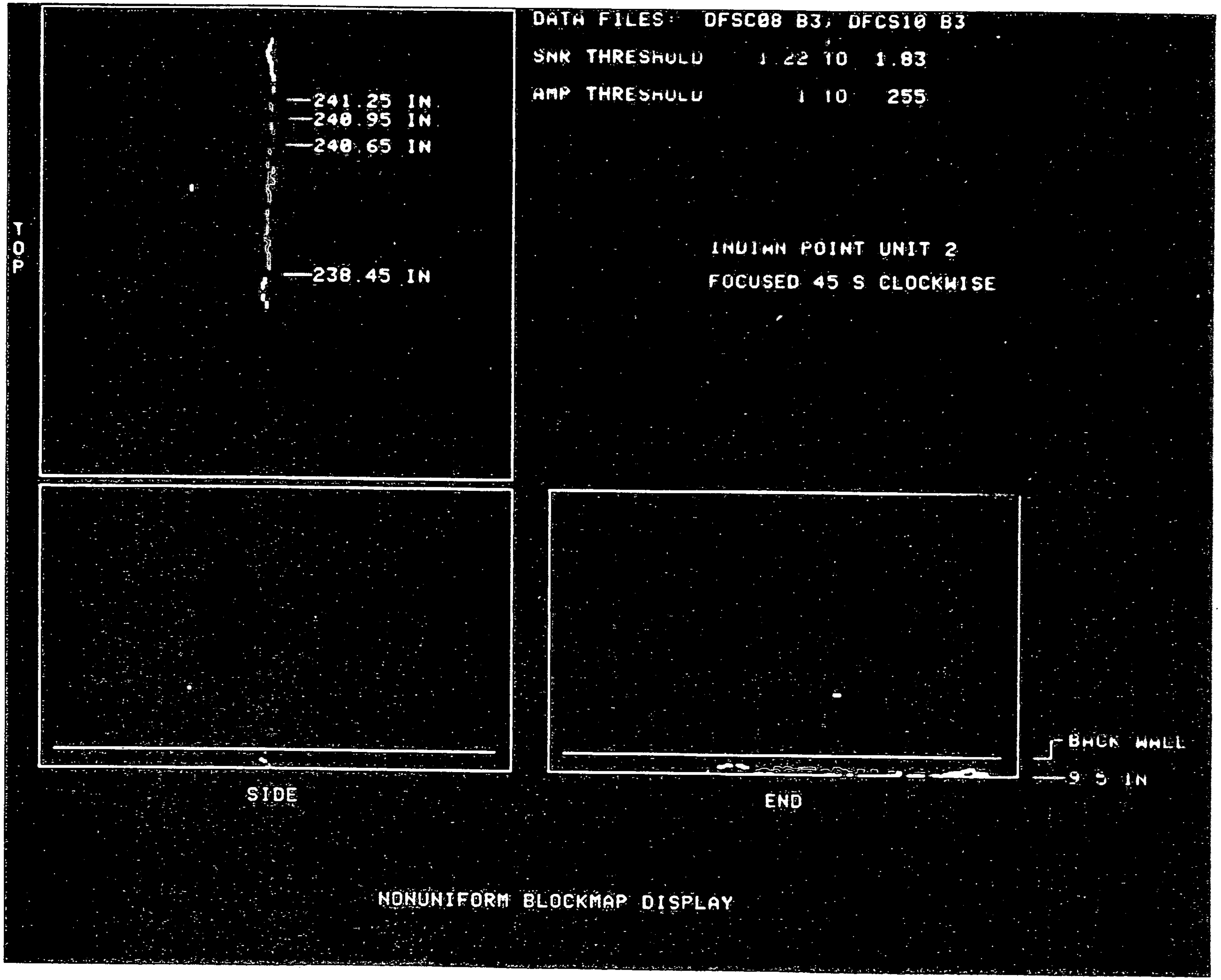


Figure 6—8: Indian Point Unit 2, Weld 12, Blockmap Display— Focused 45°S CW

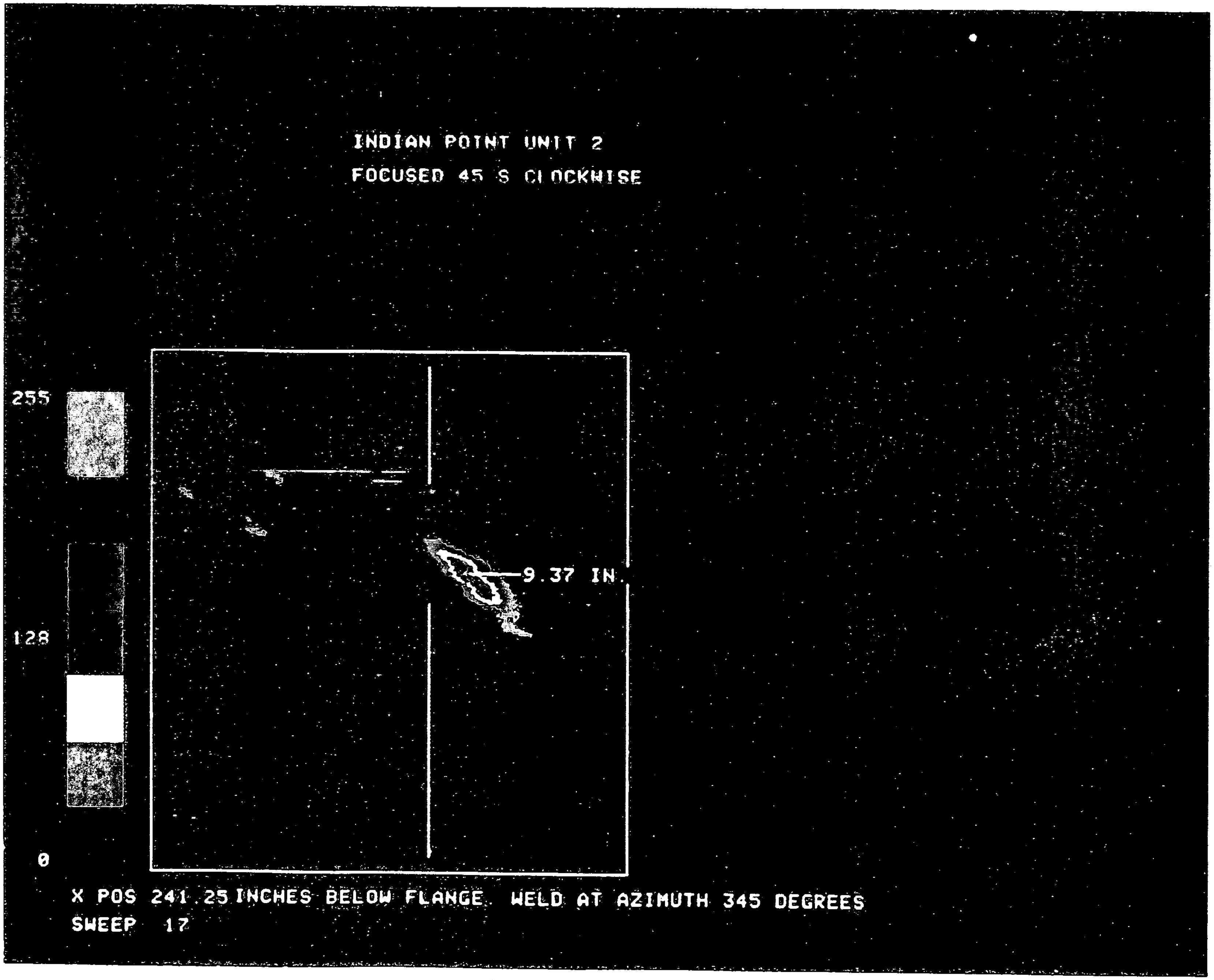


Figure 6–9: Indian Point Unit 2, Weld 12, Focused 45°S CW

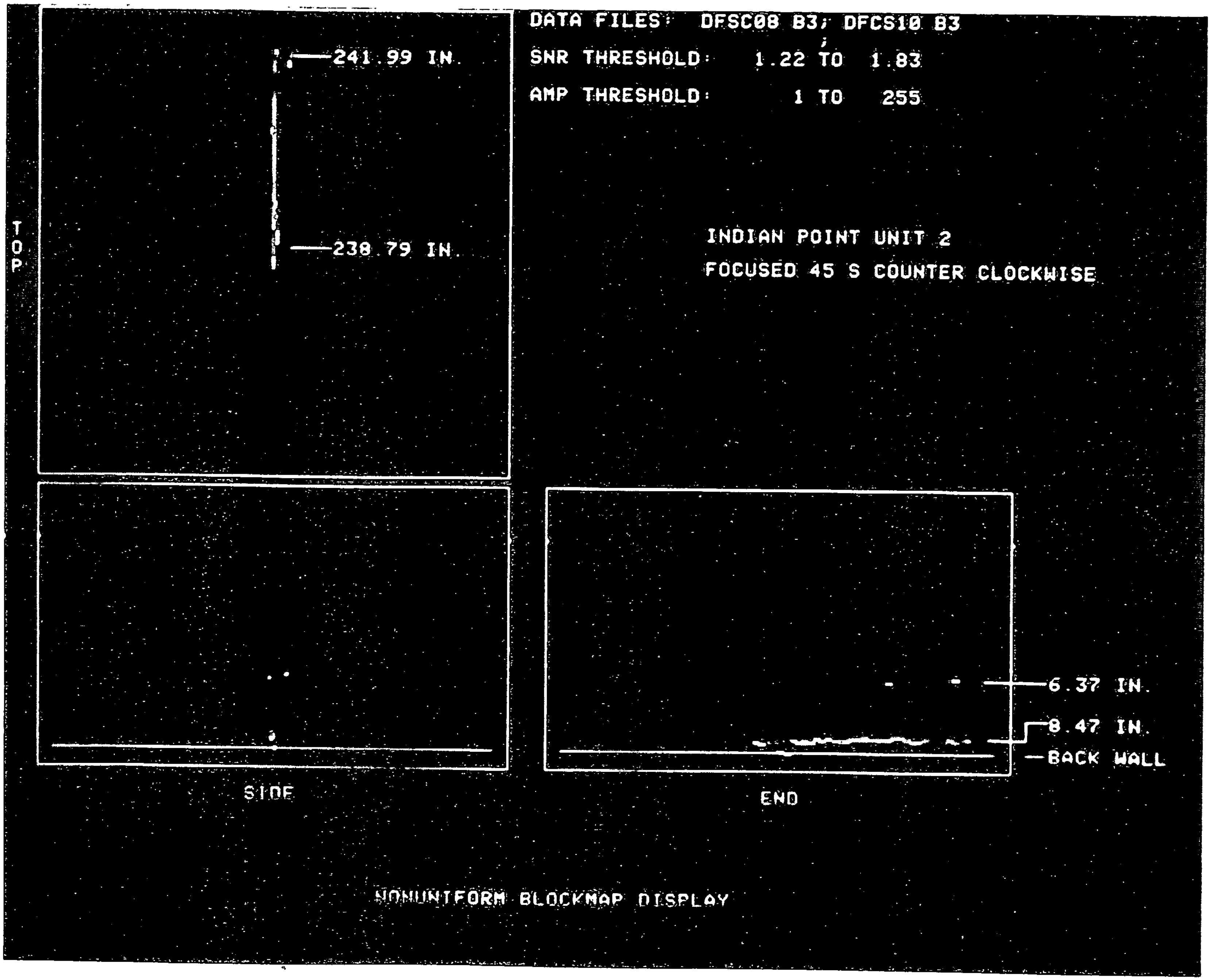


Figure 6—10: Indian Point Unit 2, Weld 12, Blockmap Display— Focused 45°S CCW

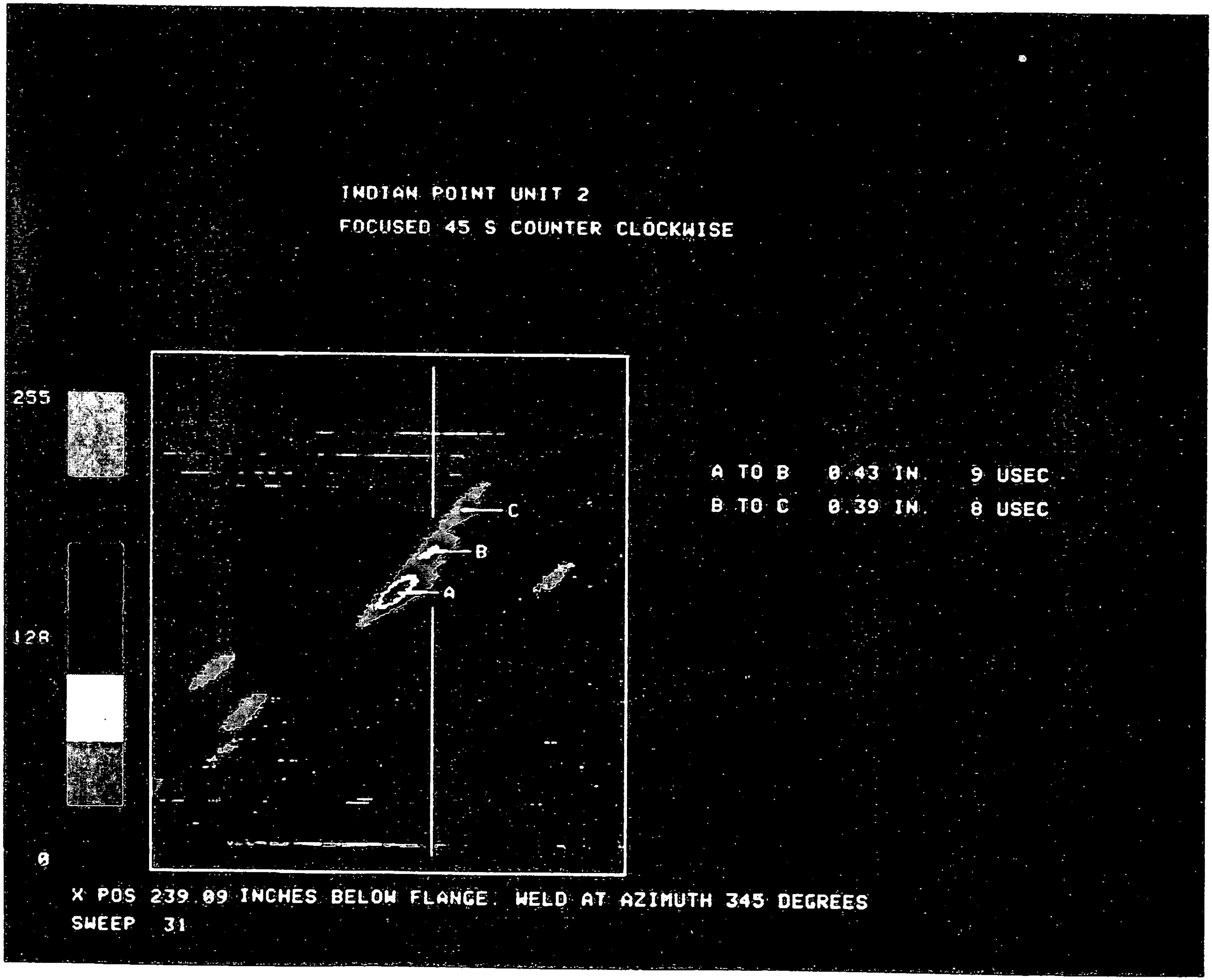


Figure 6—11: Indian Point Unit 2, Weld 12, Focused 45°S CCW

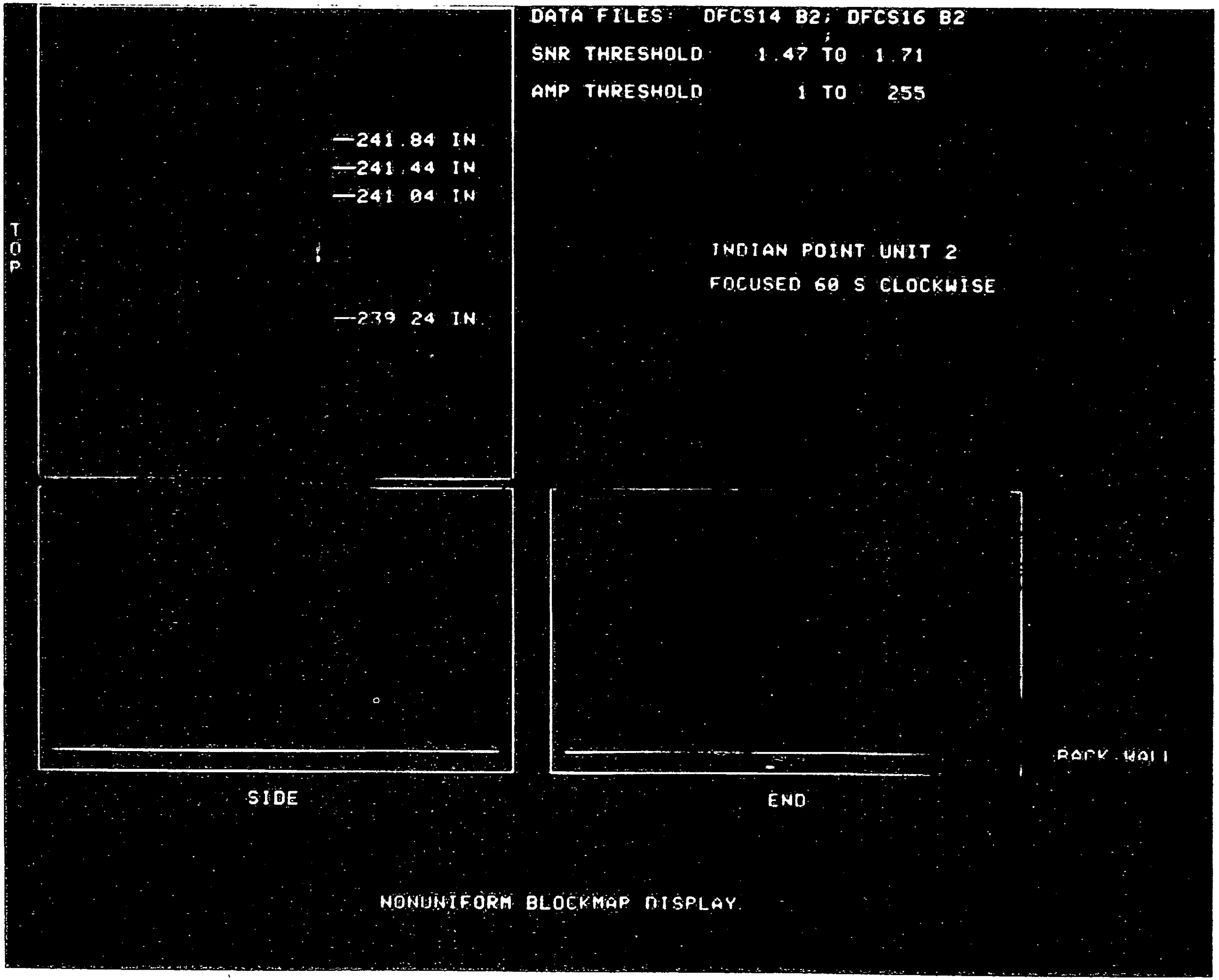


Figure 6—12: Indian Point Unit 2, Weld 12, Blockmap Display— Focused 60°S CW

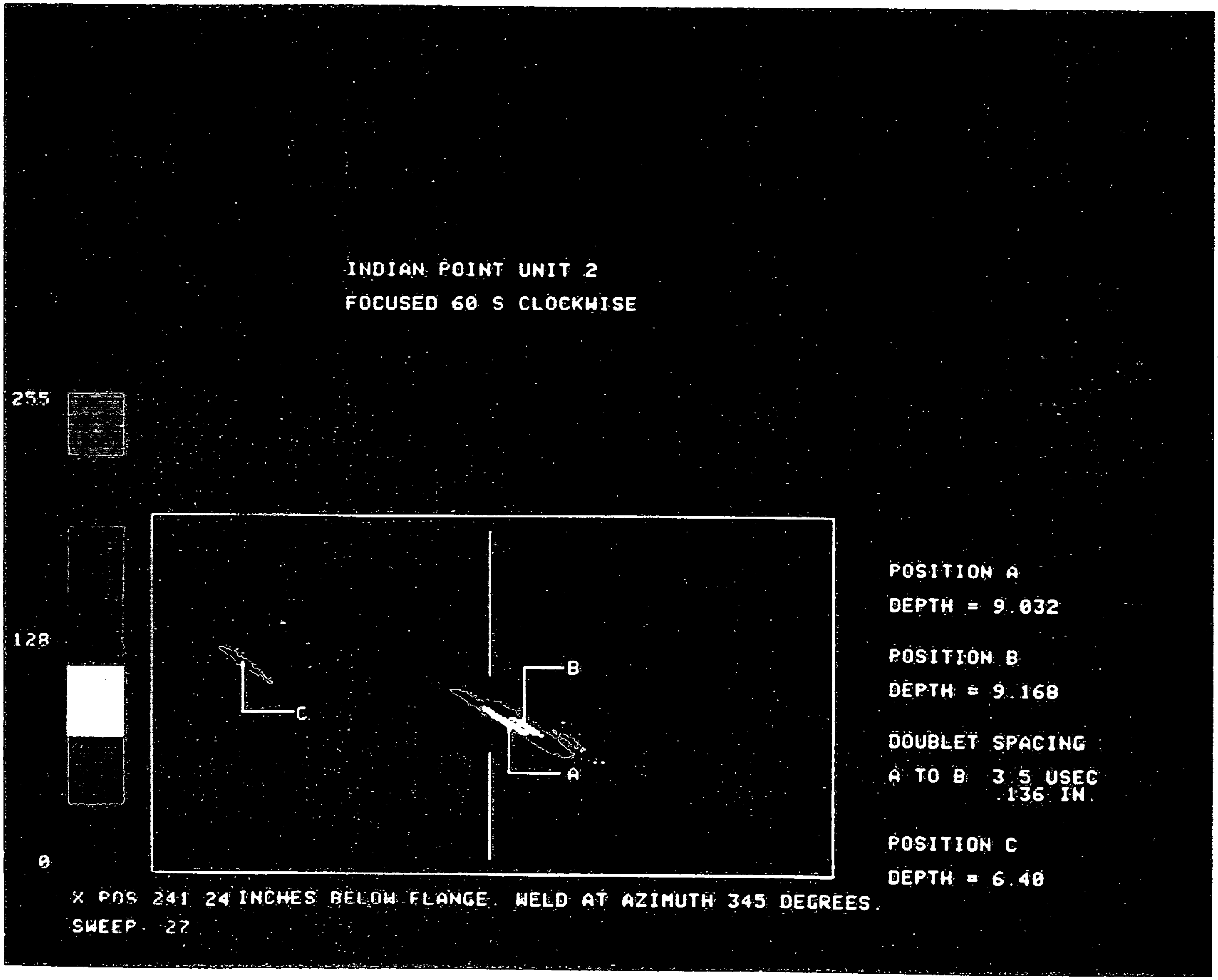


Figure 6—13: Indian Point Unit 2, Weld 12, Focused 60°S CW

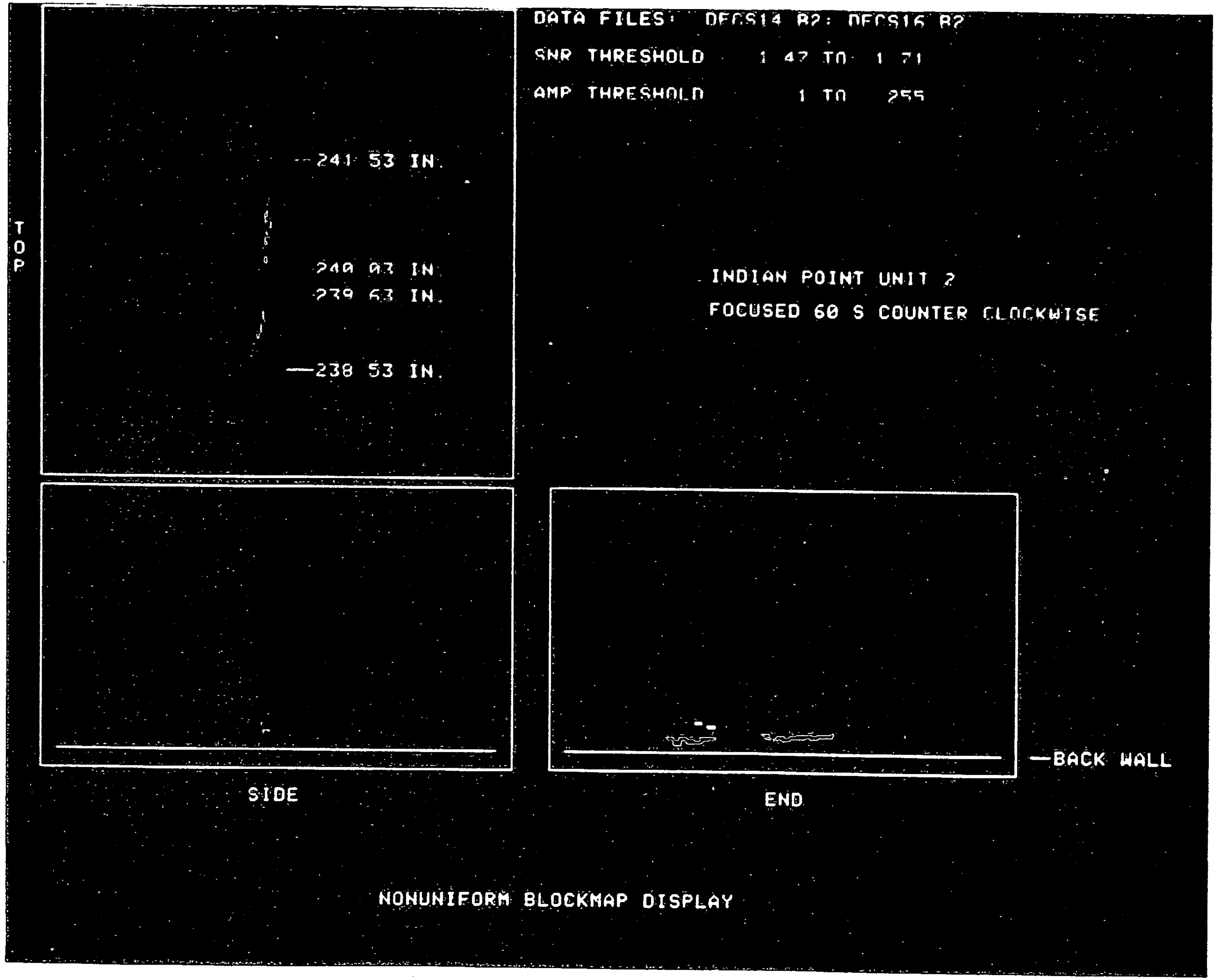


Figure 6–14: Indian Point Unit 2, Weld 12, Blockmap Display– Focused 60°S CCW

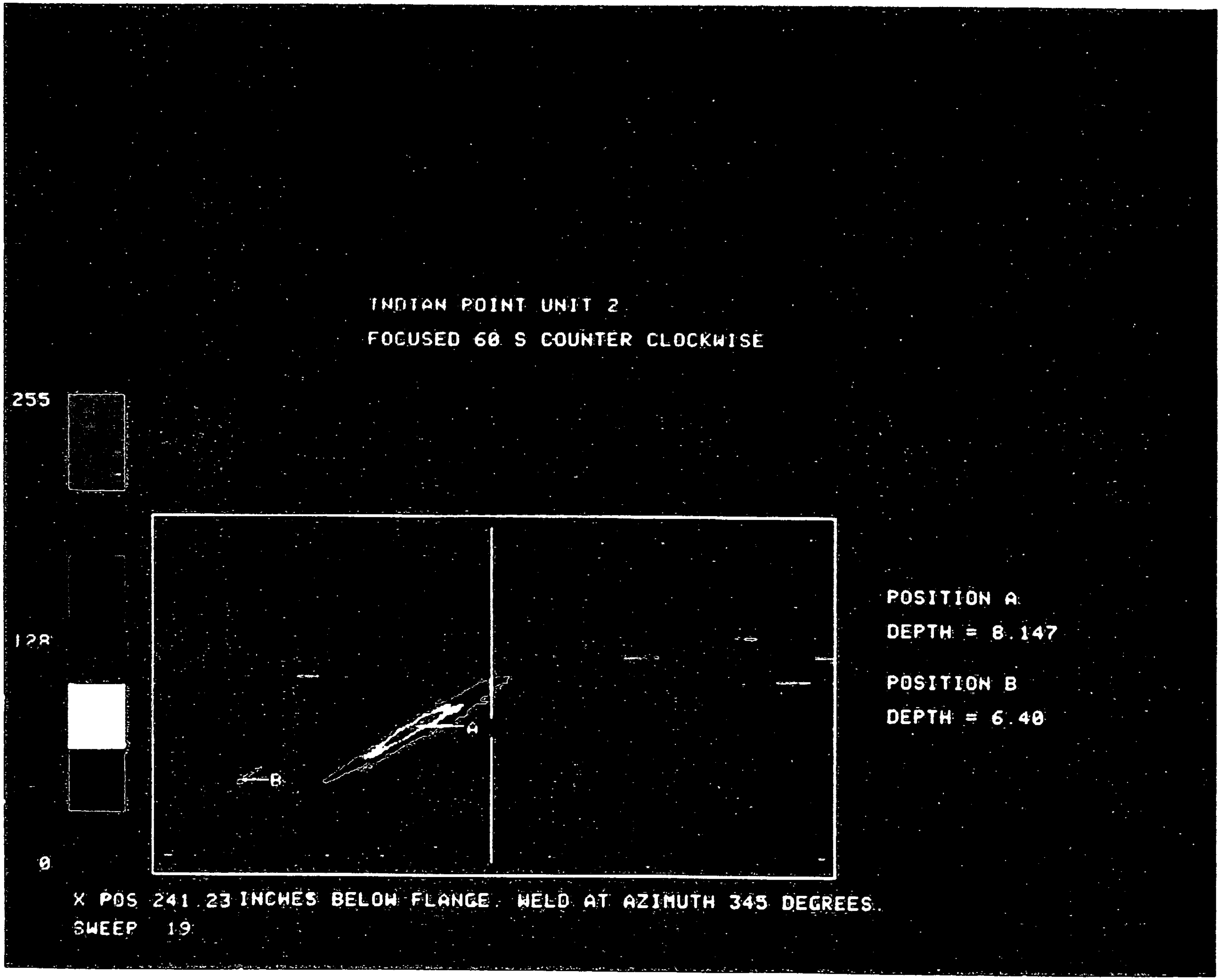


Figure 6–15: Indian Point Unit 2, Weld 12, Focused 60°S CCW

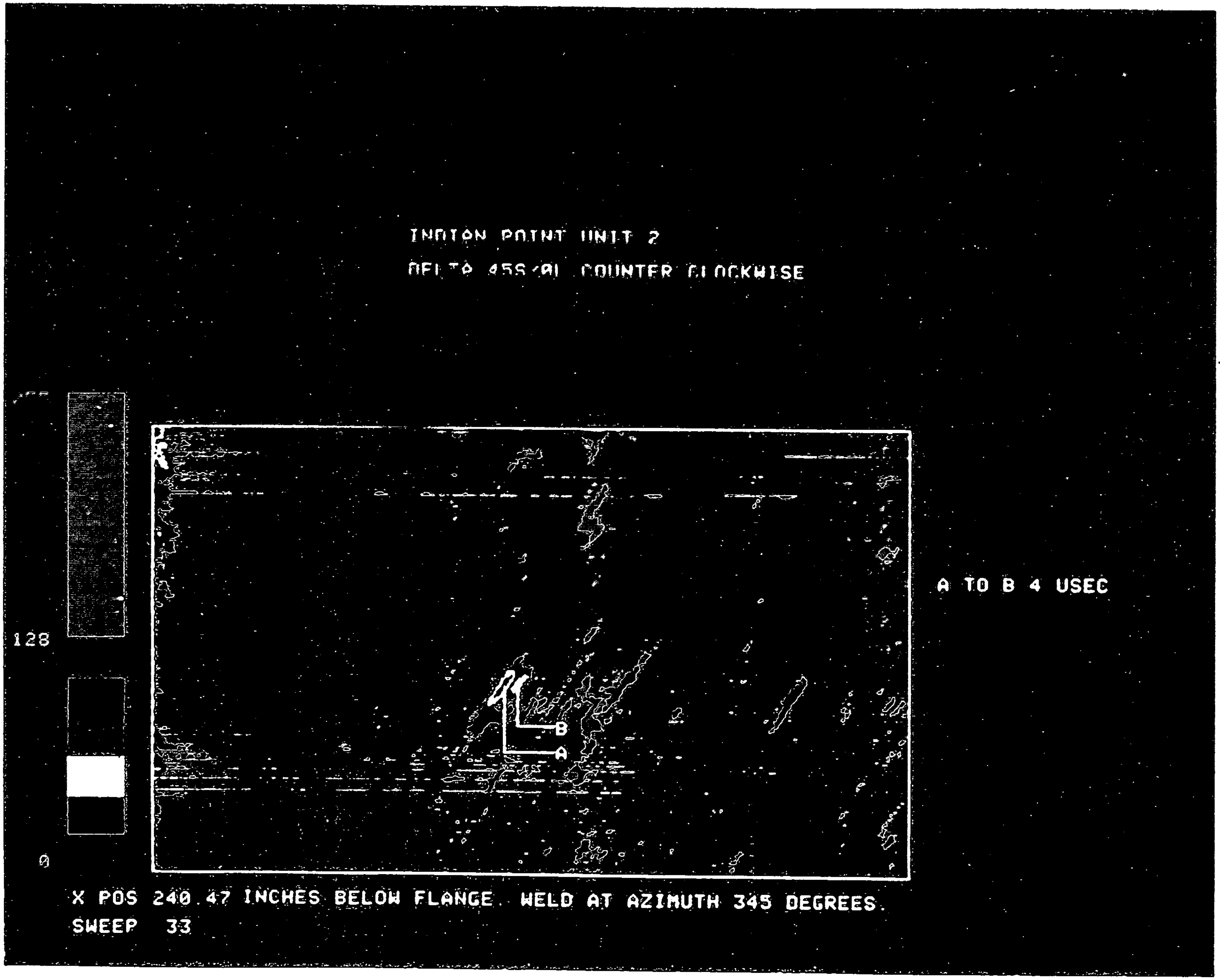


Figure 6—16: Indian Point Unit 2, Weld 12, 45°S/0°L Delta CCW

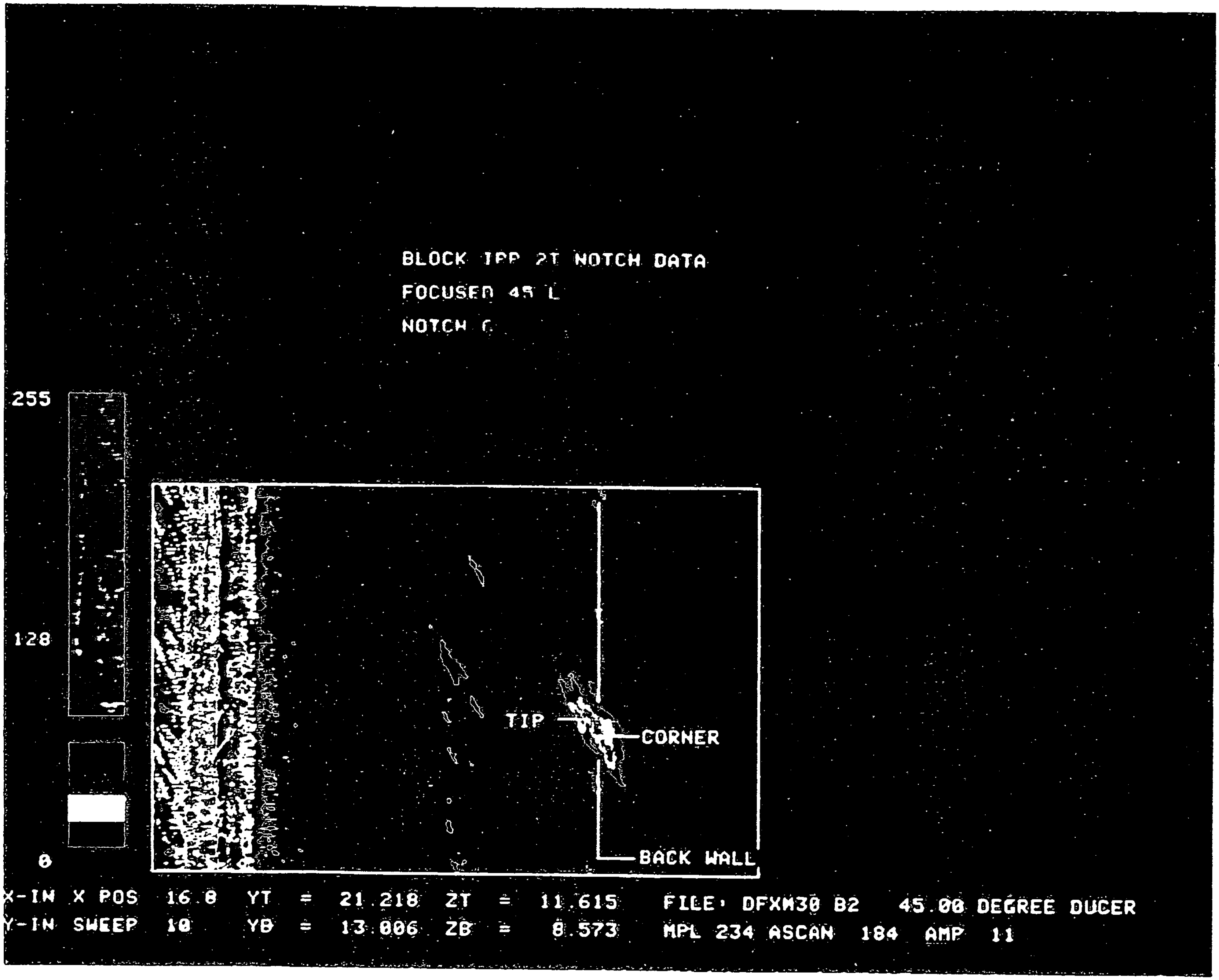


Figure 7-1: IPP-2T Block, Notch C- Focused 45°L

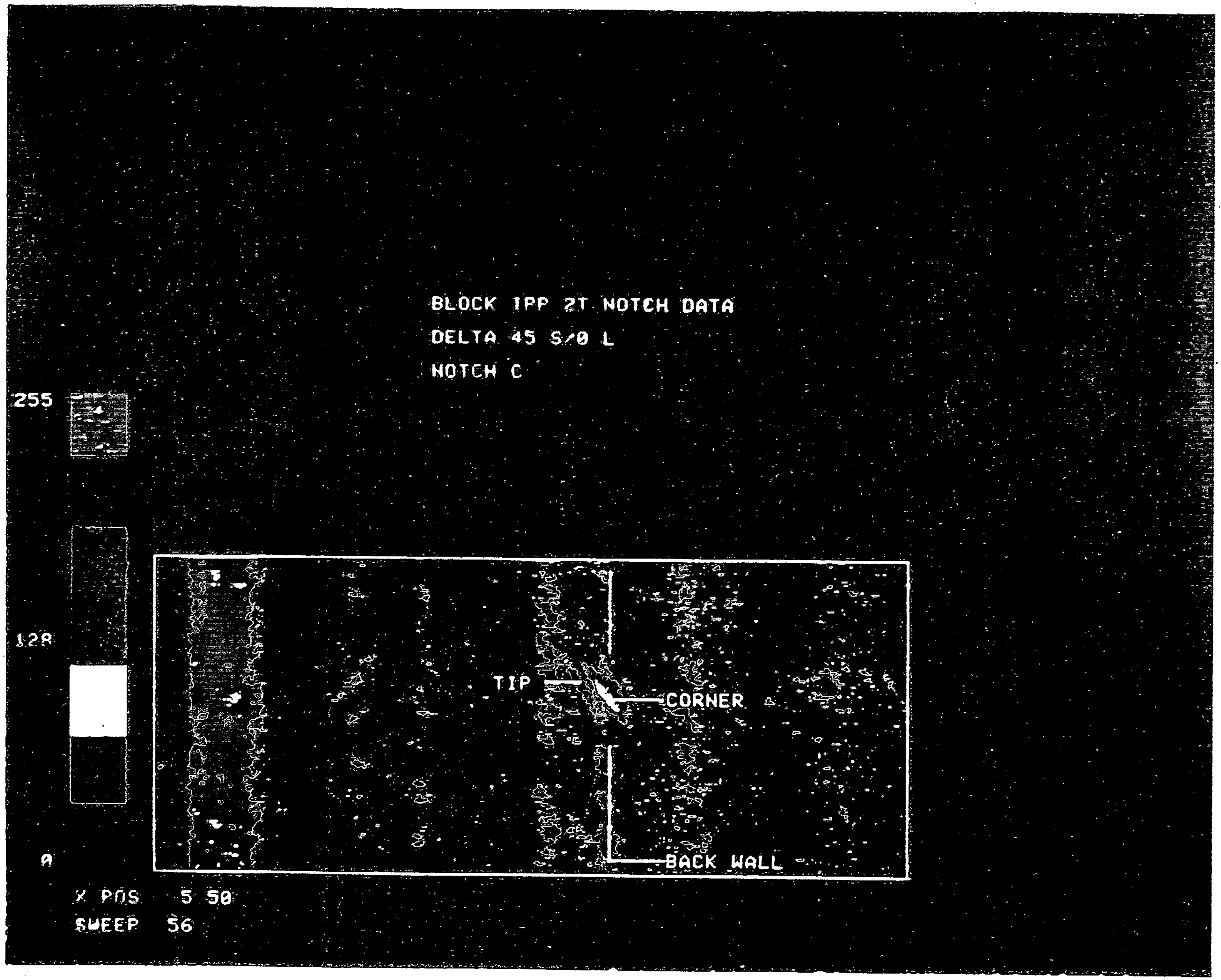


Figure 7–2: IPP2–T Block, Notch C– 45°S/0°L Delta

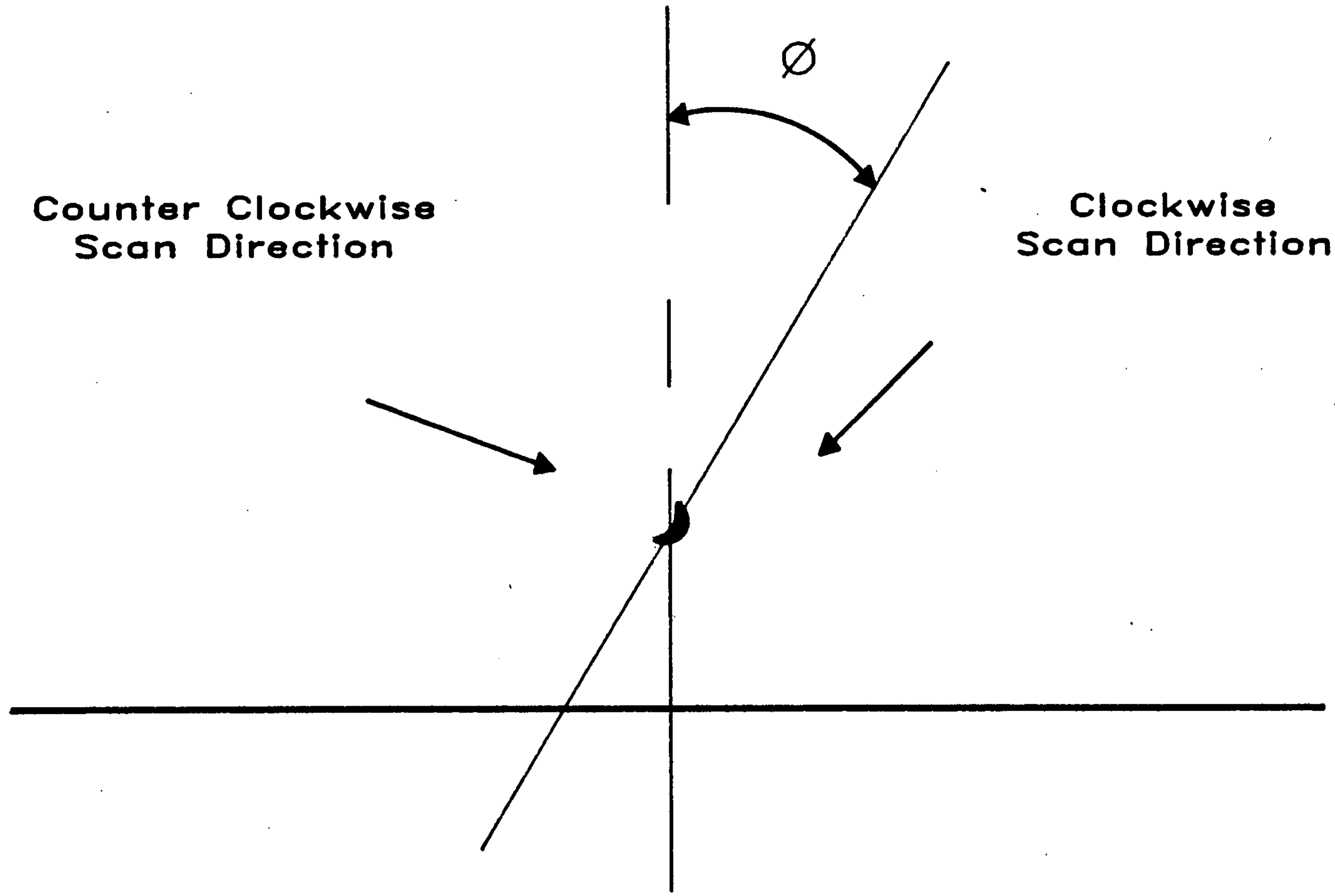
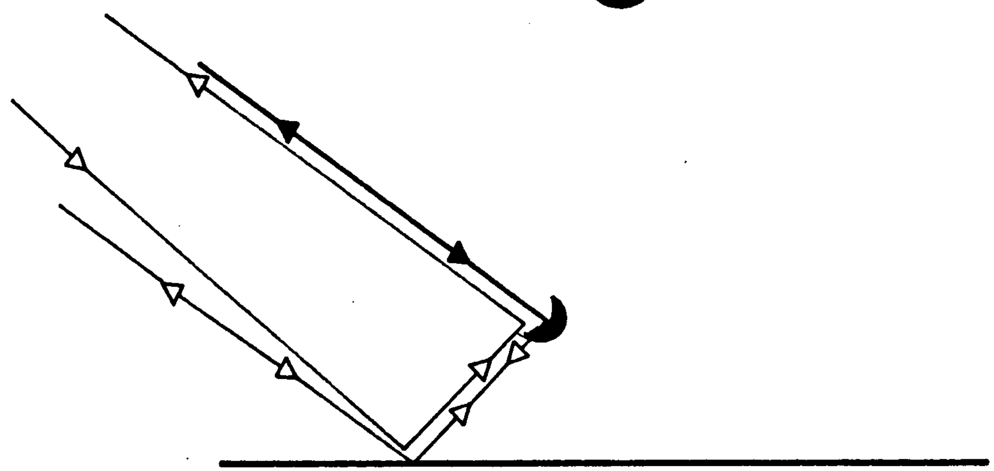
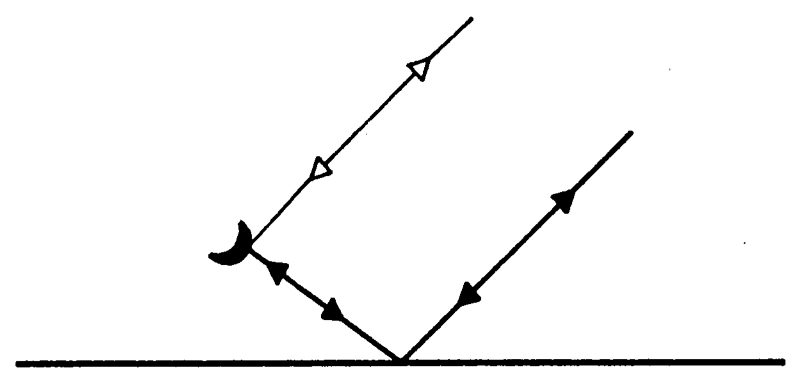


Figure 7—3: Model of the Indian Point Unit 2 Reactor Vessel Indication

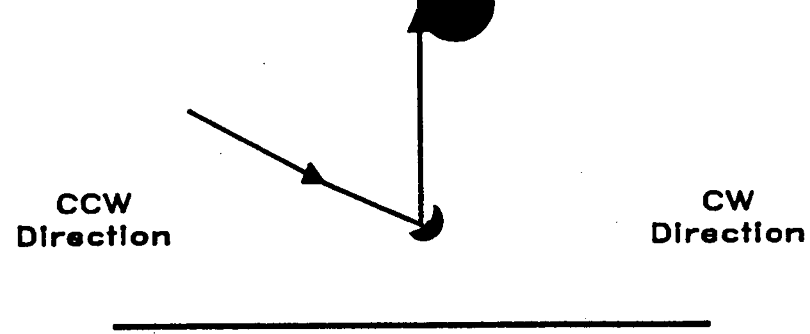


A — Counter Clockwise Scan Direction

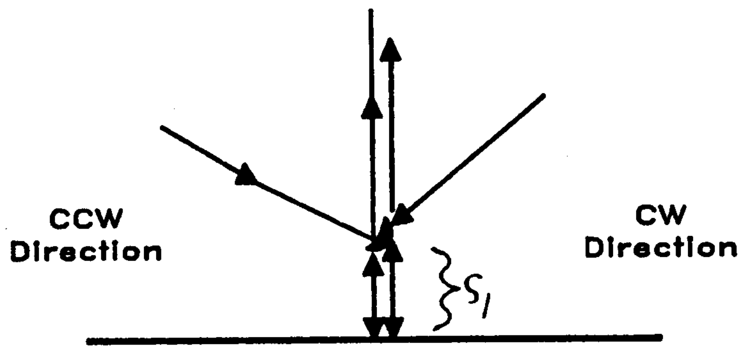


B — Clockwise Scan Direction

Figure 7—4: Model of Reflector, Pulse Echo Technique



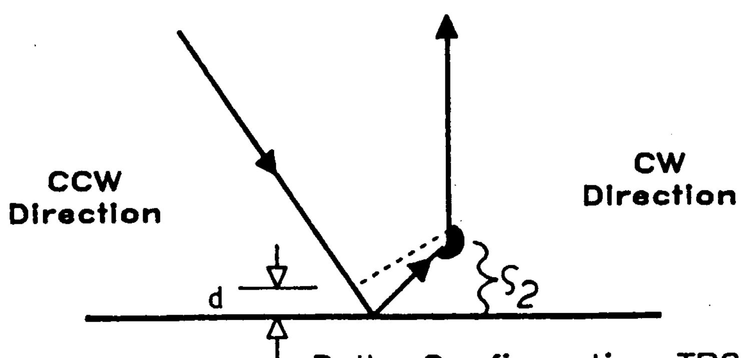
Delta Configuration TR22/TR20, Counter Clockwise Direction
PATH 1



$$\varsigma_1 \cong \frac{\Delta t_{2-1}}{2} U_L$$

where $U_L = 0.23$ in/usec

Delta Configuration, Both Directions
PATH 2



$$\varsigma_2 \cong \Delta t_{3-1} \; U_\varsigma \cos 45^\circ - d$$

where $U_\varsigma = 0.125$ in/usec
$d \cong 0$ for a large radius

Delta Configuration TR22/TR20, Counter Clockwise Directions
PATH 3

Figure 7-5: Model of Reflector, Delta Configuration

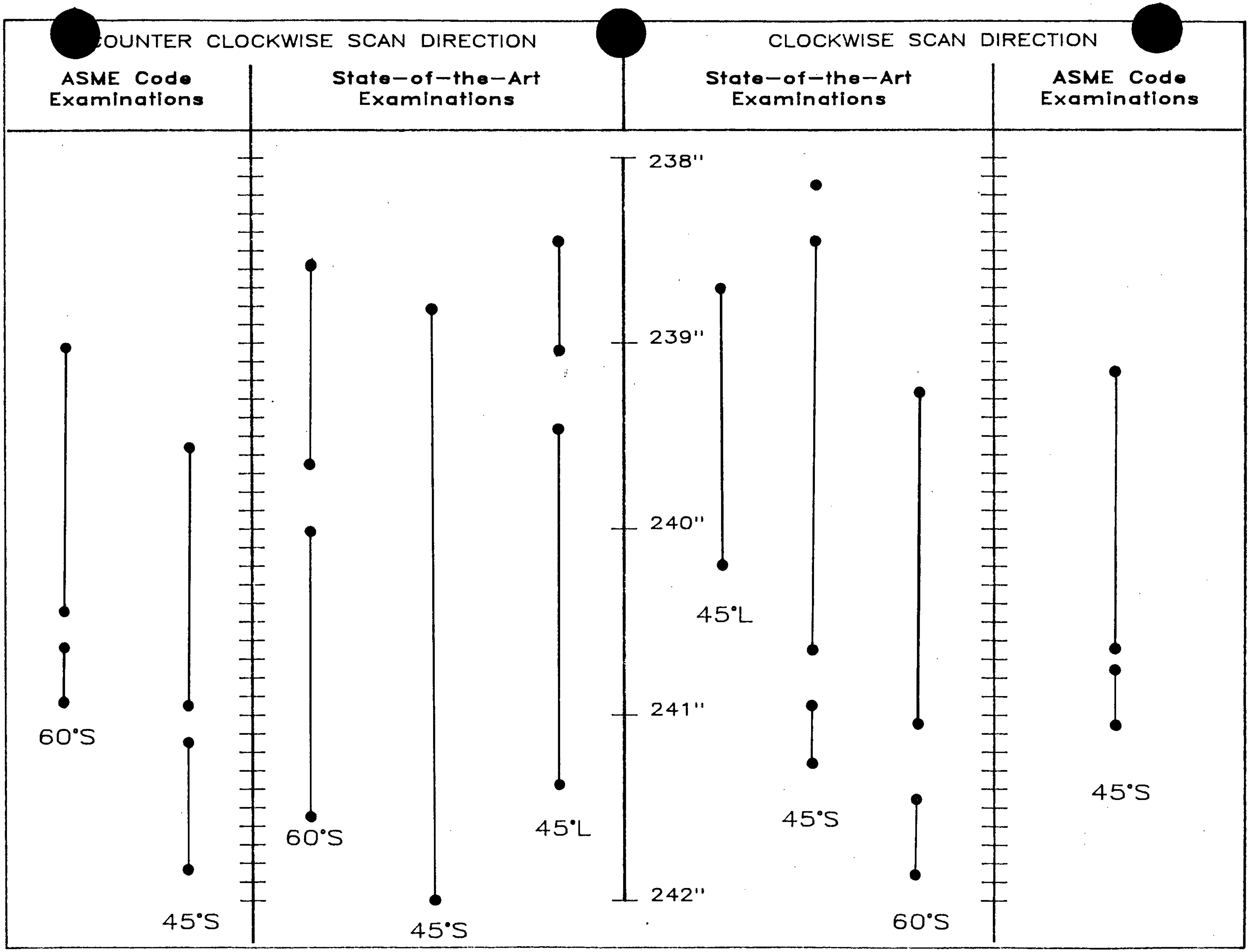


Figure 7-6: Comparison of Linear Extent of Examinations as Determined Using ASME Code Examinations and State-of-the-Art Examinations

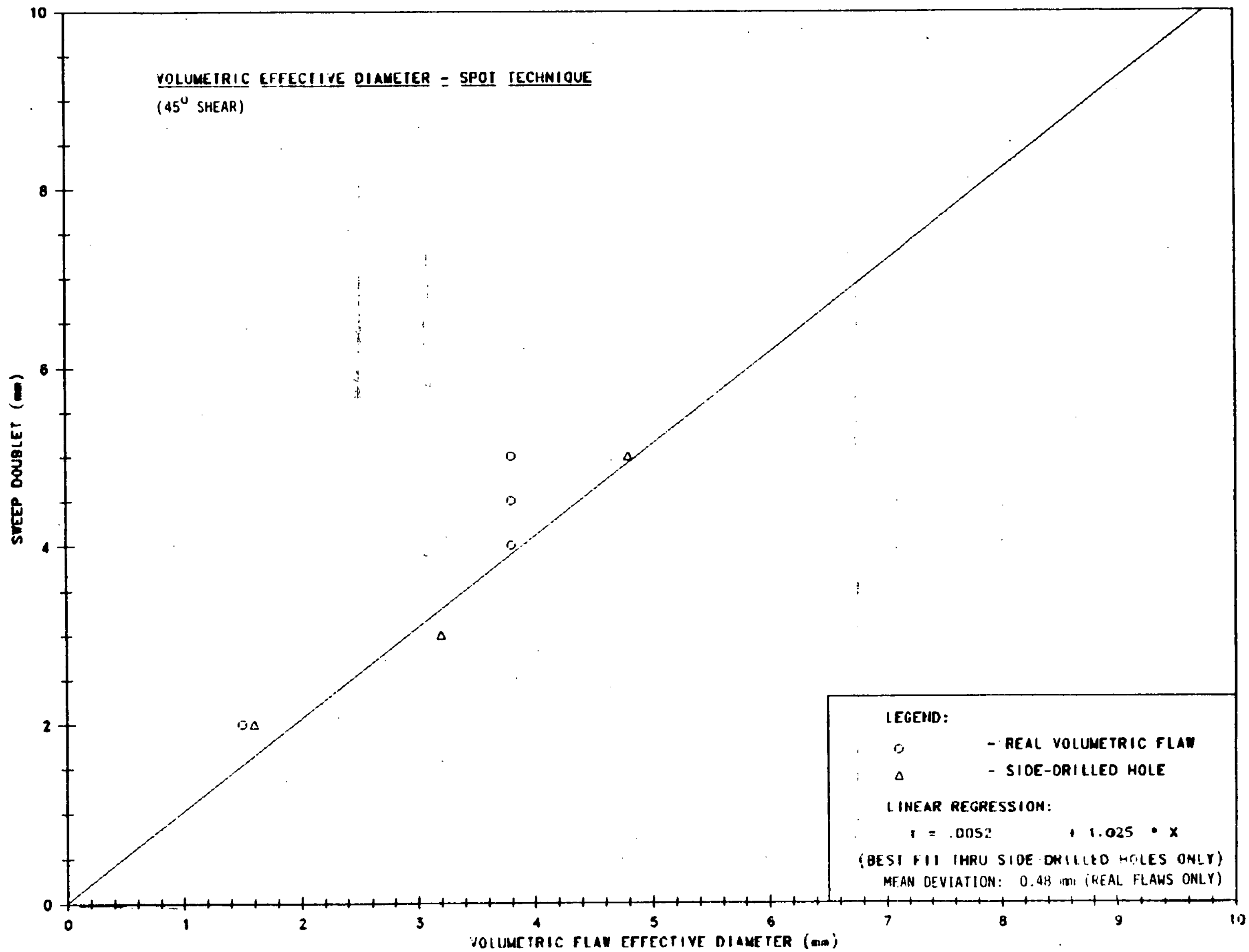


Figure 7–7: Volumetric Effective Diameter, SPOT Technique

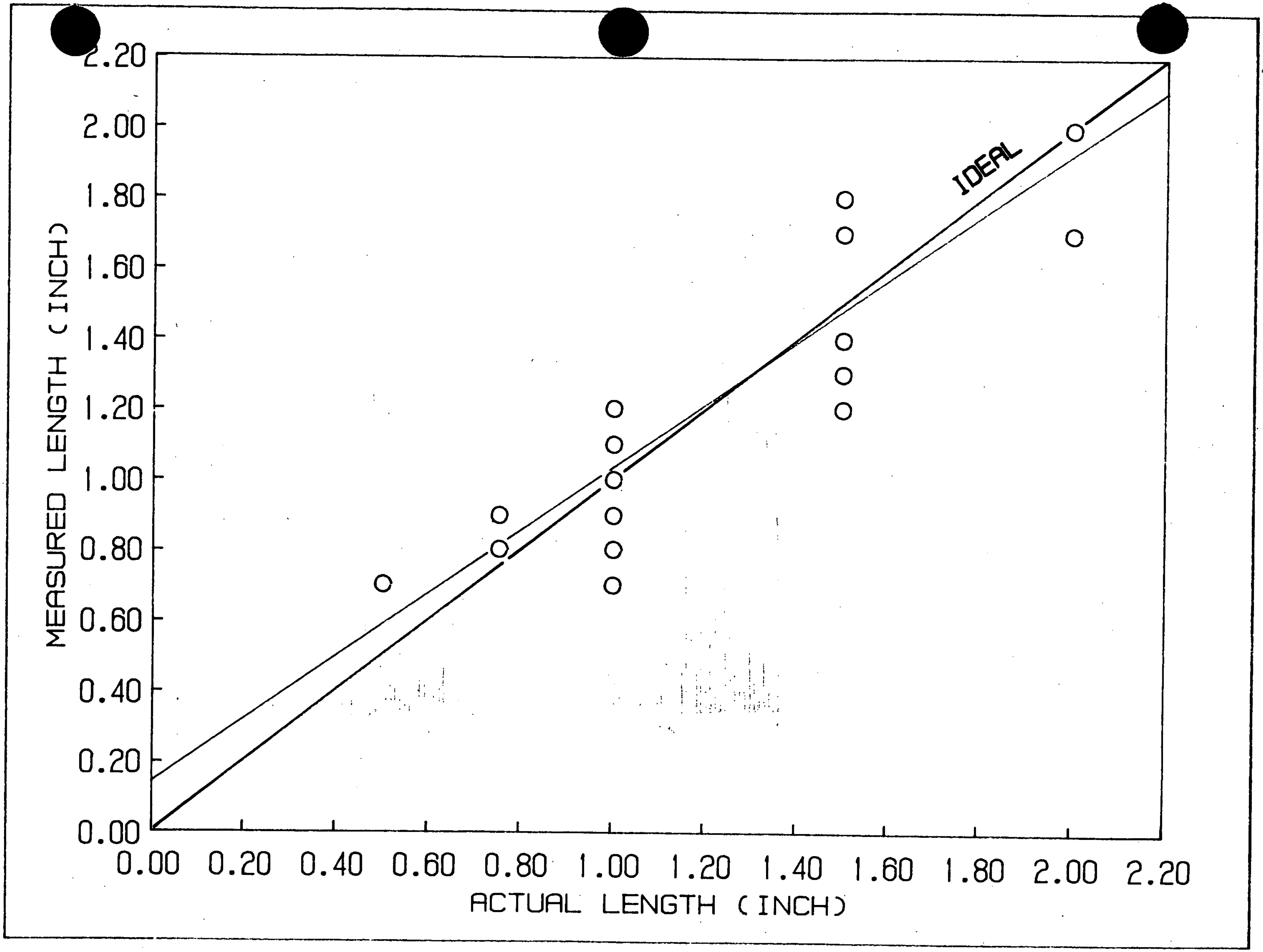


Figure 7—8: Length Sizing (Successive dB Drop Method) 45° Longituinal Wave Focused Transducer

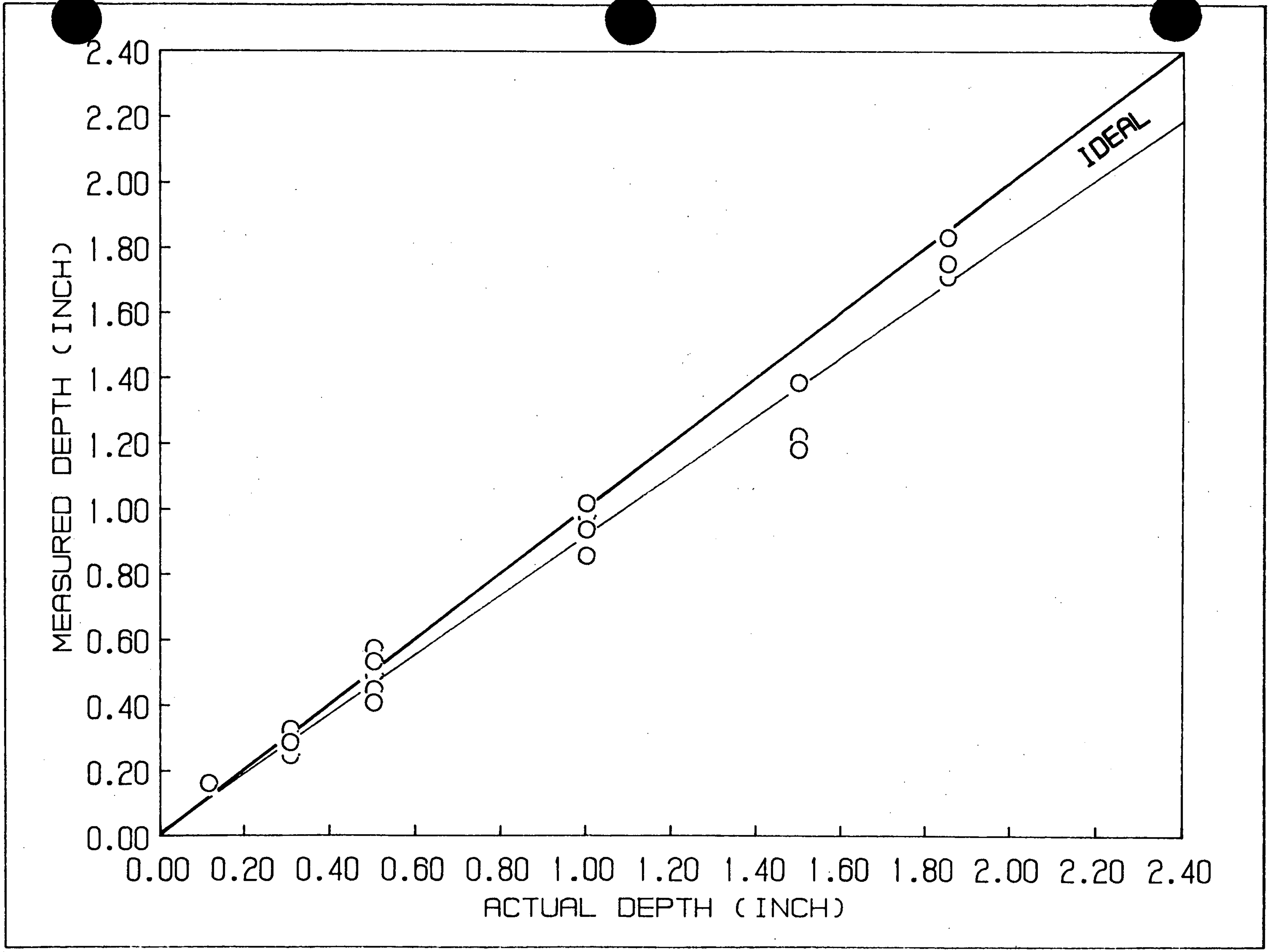


Figure 7—9: Depth Sizing (Tip Diffraction) 45° Longitudinal Wave Focused Transducer

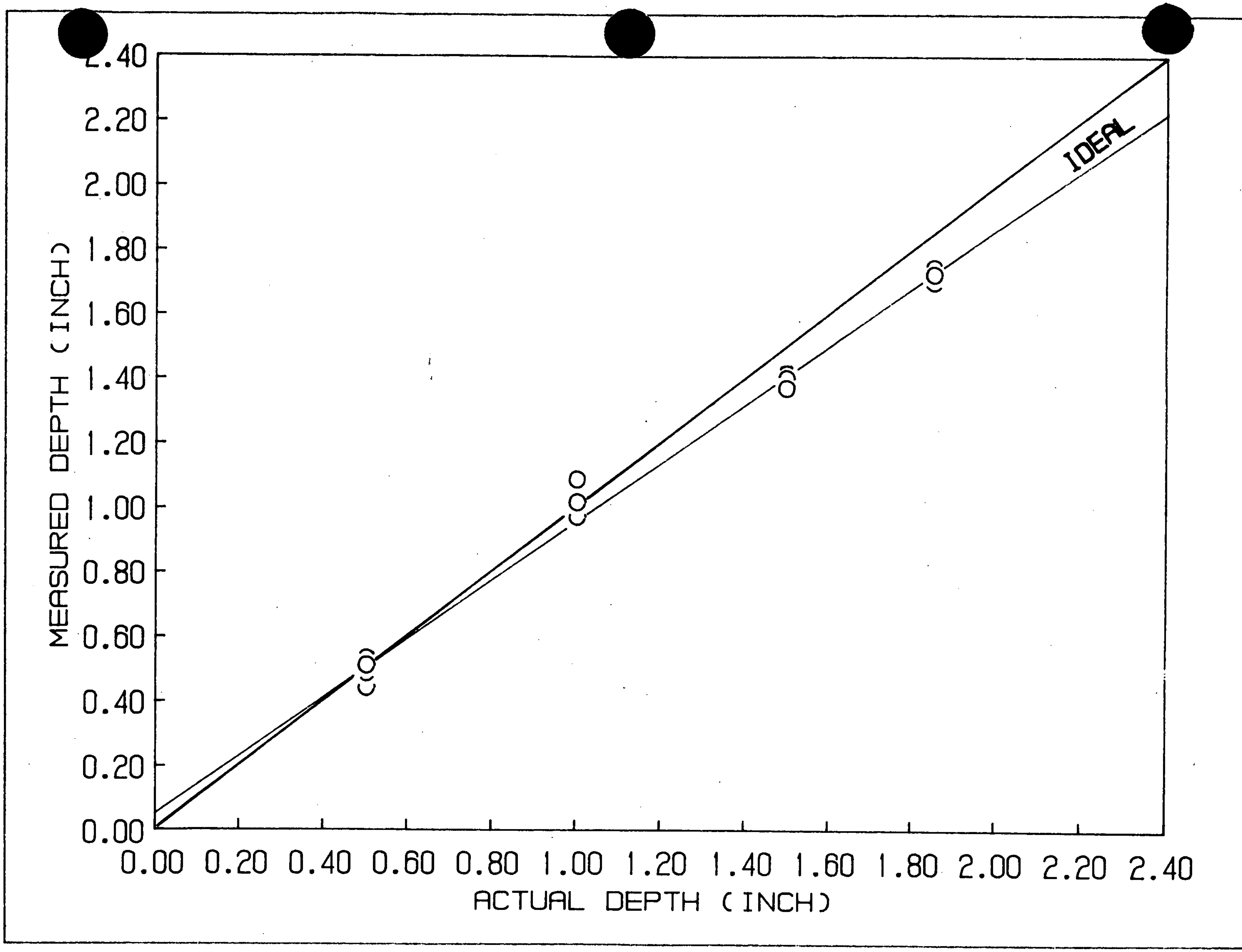


Figure 7–10: Depth Sizing (Tip Diffraction) 45° Shear Wave Focused Transducer

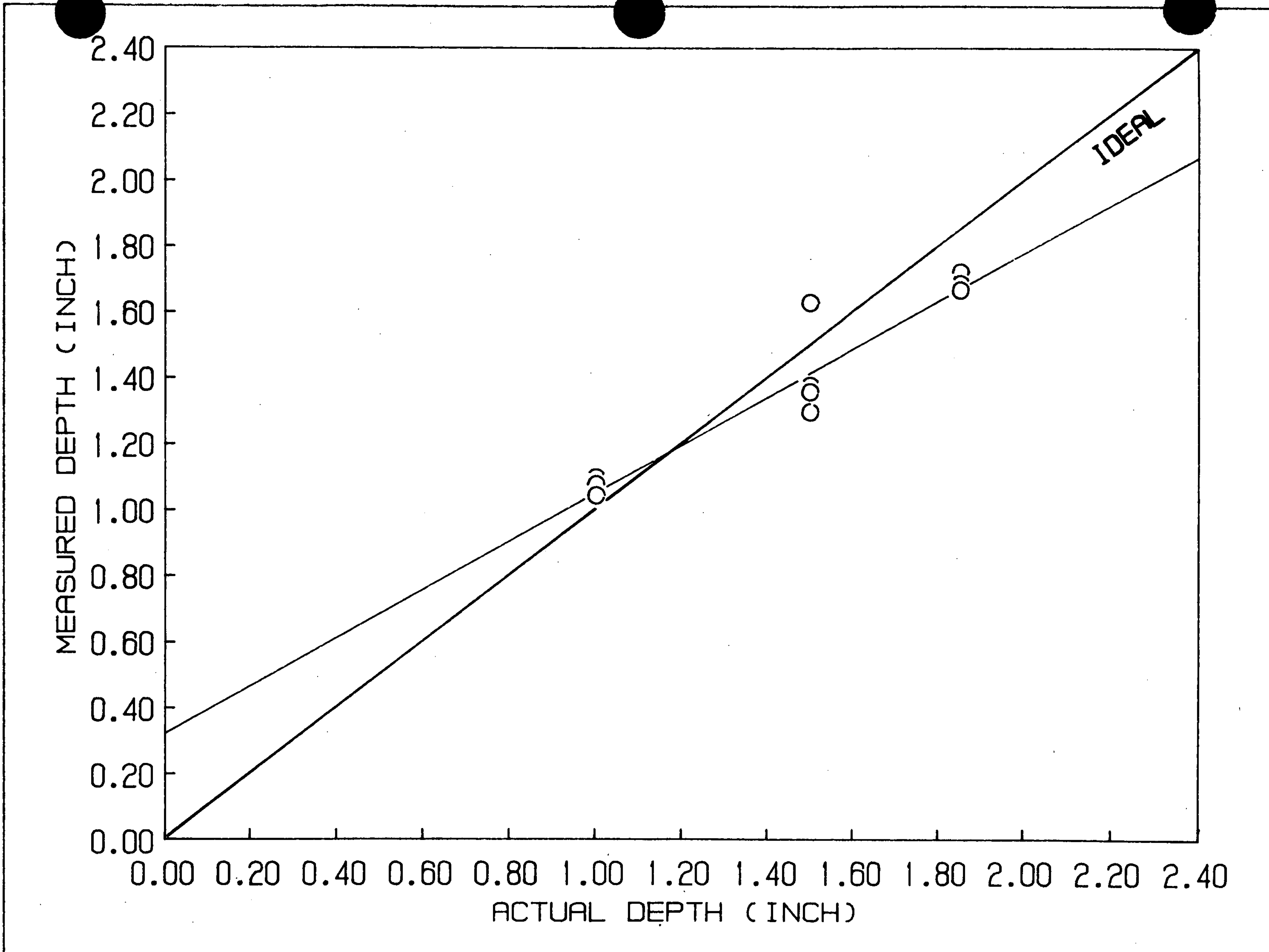


Figure 7—11: Depth Sizing (Tip Diffraction) 60° Shear Wave Focused Transducer

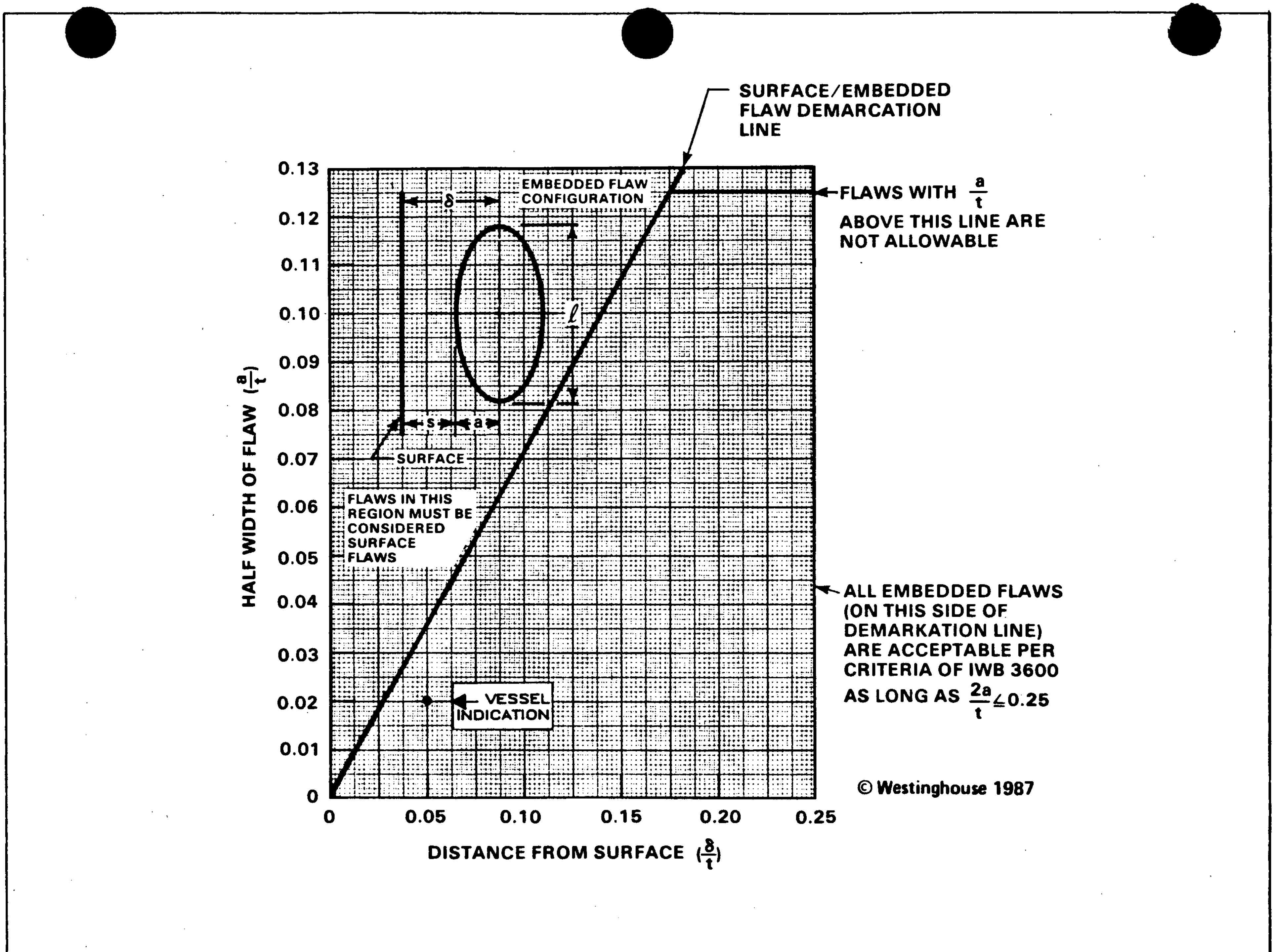
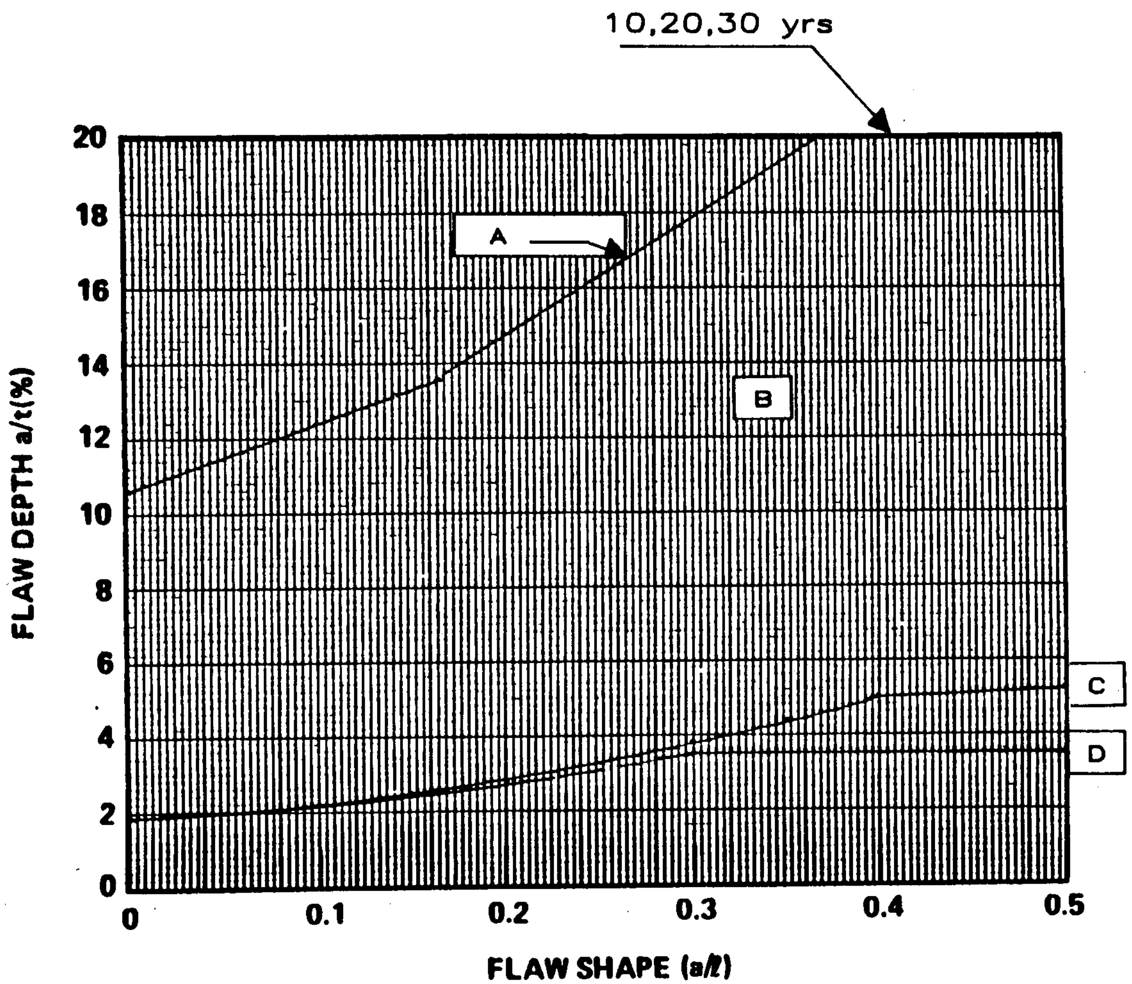


Figure 8—1: Embedded Flaw Evaluation for the Circumferential and Longitudinal Indications in the Reactor Vessel Beltline Region



LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

Figure 8-2: Flaw Evaluation Chart for Longitudinal Outside Surface Flaws in the Beltline Region