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Supp. 1

Review of P-scan Computer-Based Ultrasonic Inservice Inspection System

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Abstract

This Supplement reviews the P-scan system, a computer-based ultrasonic system used for inservice inspection of piping and other components in nuclear power plants. The Supplement was prepared using the methodology described in detail in Appendix A of NUREG/CR-5985, and is based on one month of using the system in a laboratory. This Supplement describes and characterizes: computer system, ultrasonic components, and mechanical components; scanning, detection, digitizing, imaging, data interpretation, operator interaction, data handling, and record-keeping. It includes a general description, a review checklist, and detailed results of all tests performed.

Contents

Figures

Tables

Executive Summary

This Review of the P-scan computer-based ultrasonic inservice inspection system is intended to assist NRC Inspectors in evaluating the use of P-scan equipment during inservice inspection (ISI) of nuclear power plants. It is expected that the P-scan equipment and operators have been duly qualified to perform the inspection and that the NRC Inspector is familiar with computer-based ultrasonic inspection to the extent described in the base volume of NUREG/CR-5985.

The Review was prepared using the methodology described in Appendix A of NUREG/CR-5985. A P-scan system was rented for a month and a series of test blocks were scanned. Images were produced using various P-scan options. The test blocks and images were chosen to highlight both the methods of image presentation and key aspects of system operation. The test blocks were not designed to test the flaw detection or evaluation capabilities of the equipment, as these capabilities are established through qualification processes. Rather, the test blocks are designed so that studying the images and other data in this Review will aid the Inspector to interpret P-scan data acquired during an ISI. Thus, the blocks were scanned at different speeds and from different directions, and images were produced using various display options such as color, scale, and data presentation.

As part of the review process, P-scan experts from Siemens Nuclear Power Services, Inc., provided hands-on training and assistance with scanning and image interpretation of the test blocks. Their advice was sought by telephone during preparation of the Supplement. The Supplement was also reviewed by the manufacturers of the system (Force Institutes of Denmark) to ensure that PNL had not misunderstood any aspects of system operation or misinterpreted the results. All comments from the document review were addressed and either cited as additional information or incorporated into revisions.

The Review begins with an overview of the results, then passes to a physical description of the P-scan system. Operator training, system setup, and documentation are reviewed briefly. A detailed section on image interpretation follows, laying the groundwork for the rest of the Review. Next are detailed results on the mechanical operation of the system, such as speed and resolution limits. Detailed results of ultrasonic measurements include the dynamic range , images of specified test blocks, and frequency characteristics. Data processing is discussed, followed by specifics of image presentation. Next, specifics of digitization, data acquisition, and data types are presented, followed by a discussion of processing options and data storage. A review checklist provides a concise framework for evaluation of proper P-scan use. A Glossary gives special P-scan terminology and special P-scan uses of standard terminology.

Some major observations are as follows. P-scan stored data consists of images rather than raw ultrasonic data, resulting in very small data sets but limiting the possibilities of reprocessing the data. The dynamic range of the P-scan is large because a logarithmic amplifier is used; there is no use of gain settings during data acquisition, so that data of all amplitudes is kept and the evaluation of indications according to amplitude is performed primarily during post-processing. The components of a P-scan data set are three views: top, side, and end; the terms "side" and "end" are relative to the weld, rather than to the component. P-scan terminology uses the word "transducer" to mean "position transducer" or "encoder" rather than "ultrasonic transducer," which is called "probe." Scanner motion parameters are not recorded automatically in the data set, and the Inspector should ascertain that these have been recorded by some other means. A feature called "Image Processing" permanently changes the data set used, and should never be applied to the original data set. Blank lines may occur in the data set, even though full coverage was achieved; it is thus important always to verify correct scanner operation. This Review does not contain any conclusions or recommendations, as the purpose of this characterization is simply to provide a technical basis in order to enhance the NRC Inspector's ability to evaluate the proper use of the P-scan in the field.

Preface

This document helps NRC staff to understand the operation of the reviewed computer-based ultrasonic testing system. It is expected that the reader will be familiar with the material presented in the base volume of NUREG/CR-5985, *Evaluation of Computer-Based Ultrasonic Inspection Systems*.

This work originated with a joint request from the Office of Nuclear Reactor Regulation (NRR) and Region I, submitted to the Office of Nuclear Regulatory Research (RES) in 1988. In this request it was noted that ultrasonic inservice inspection (UT/ISI) is the primary volumetric method used to confirm the integrity of piping, vessels, and other nuclear safety related components at operating plants, and that effective UT/ISI is therefore critical to assuring plant safety. The request asked for support in the evaluation of licensee nondestructive inspection activities utilizing computer-based ultrasonic testing (UT) systems. The reasons cited are that the computer-based technology is developing rapidly and is in common use; that a firm technical basis for NRC staff activity in this area is needed; and that a working knowledge of some computer-based UT/ISI systems will enhance NRC ability to evaluate licensee activities. It further stated that development of a Regulatory Guide or other document providing guidelines for the proper application of computer-based UT would be helpful, and that it is necessary to stay abreast of industry activities and maintain the ability to independently evaluate the technology in use.

On this basis, RES asked the Pacific Northwest Laboratory (PNL) to prepare a Form 189 Proposal, of which a draft was submitted in early 1989. In the proposal, PNL acknowledged the needs cited above, adding that the data from computer-based UT/ISI systems are often not presented in a traditional format, and that NRC staff need to understand how the systems operate, how to judge that they are being used correctly in field ISI, how to interpret results, and the limitations of system performance. They need to be able to independently assess the data produced by computer-based UT/ISI systems. The program provided for conducting reviews of systems, developing guidance for NRC staff, and providing training to enhance NRC staff's understanding of computer-based UT/ISI systems.

The purpose of NUREG/CR-5985 and its Supplements is thus to facilitate NRC staff ability to review and audit the use of computer-based UT equipment in ISIs, and to help them become familiar with the varying capabilities, philosophies, and operating principles that underlie the systems. These systems are highly sophisticated and widely varied. Specific systems have been reviewed in order to develop a paradigm for reviewing the systems and developing a basis for guidelines for incorporation into the Inspection Manual. While the specific systems reviewed are of interest in their own right, it is recognized that they evolve dramatically over a two to three year period, and the emphasis of the present series of reviews is therefore to develop a sound foundation for reviewing and auditing the use of computer-based UT systems in ISI.

Acknowledgements

This work is supported by the US Nuclear Regulatory Commission under Contract DE-AC06-76RL0 1830; NRC FIN L1100; Dr. Joseph Muscara, Mr. Allen Hiser, and Mr. Craig Hrabal, NRC program monitors; Mr. Richard Kurtz PNL program manager.

Particular thanks go to Ed Sadler of Siemens Nuclear Power Services, Chattanooga, Tennessee, and Joel Harrison of Ebasco Services, Inc., Searcy, Arkansas, for their help in understanding the P-scan system and in preparation of images for this document. Thanks also to Steen Neergaard of FORCE Institutes for reviewing a previous draft and providing helpful comments.

Trademarks

Introduction

General Description

P-scan (short for Projection Image Scanning Technique) is a computerized ultrasonic pipe-scanning system consisting of four modules: the PSP-3 processor (PC-compatible system controller and ultrasonic instrument), an electronic scanner control unit, an electro-mechanical scanner module, and the post-processing software. The operating system and programs reside in read-only memory chips in the PSP-3; the post-processing software is run on a separate PC-compatible computer system. The operator sets ultrasonic inspection parameters through the PSP-3, and physical inspection parameters through the scanner control unit. Data is stored on 3½ in. floppy disks.

P-scan system features include the following.

- P-scan data-taking has three loosely coupled functions: motion control, position sensing, and data recording. These three are not tightly interdependent.
- There is no minimum threshold set for signal recording.
- The final data set consists of maximum-amplitude projections onto each of the three viewing planes (top, side, and end).
- In P-scan images, the terms "side" and "end" refer to the weld, not the pipe: for a circumferential weld, "SIDE VIEW" refers to a view from the end of the pipe, and "END VIEW" refers to a view from the side of the pipe.
- "Transducer" is used in P-scan terminology only for position transducers (generally called "encoders" in the U.S.). The word used for ultrasonic transducer is "probe." Throughout this Supplement, "probe" is used to mean ultrasonic probe, and the word "transducer" is not used.
- Scanner control is performed by hardware settings on the front panel of the scanner controller.
- The system always records all data in gates within its dynamic range (over 100 dB).
- Gating levels are set during interpretation, rather than during scanning.

The remainder of this report contains a detailed review of the P-scan system, a review checklist, a glossary of P-scan terminology, and an index. The detailed review contains numerous figures and images, and covers general system information, image interpretation, mechanical and ultrasonic operation, data acquisition, data processing, data storage, and imaging characteristics.

1.0 System Description

1.1 System Name: P-scan

Short for Projection Image Scanning Technique

1.2 Date: August 4, 1992 - September 1, 1992

1.3 Manufacturer

FORCE Institutes - The Danish Welding Institute
Park Allé 345
DK-2605 Brondby, Denmark
Telephone: 45 43 96 88 00
Fax: 45 43 96 26 36
Telex: 3 33 88 svc dk

1.4 Supplier

Siemens Nuclear Power Services, Inc.
5959 Shallowford Road, Suite 531
Chattanooga, TN 37421
(615) 499-0961

Note: Some photographs and scans were done on a system supplied by:
EBASCO Services, Inc.
211 N. Rand St., Suite 1200
Searcy, Arkansas 72143
(501) 279-9399

1.5 Items Received

PSP-3 processor - #325
Weld Scanner Control Unit WSC2S - #1003
386 computer, color monitor, keyboard, mouse, pad, HP PaintJet color printer - #3001575237
Scanning unit ICB-1 - #168
Remote control RCU-1 - #407
Scanning arms
Scanner tracks
Probes
Tools
Manuals
Cords/cables
Power supplies
SuperSAFT software upon special request

A total of 11 boxes were shipped by Burlington Express. All of them fit onto one pallet. Ed Sadler, Siemens, assisted us from August 4 to August 21.

1.6 Components

1.6.1 P-scan System

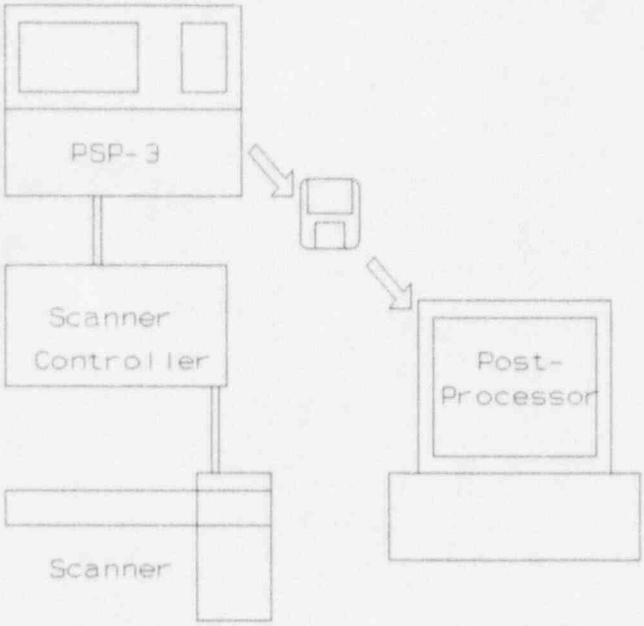

Figure 1.1 Block diagram of P-scan system

The P-scan system consists of 4 major units: the PSP-3 processor, the scanner control unit, the scanner, and the post processing software. Figure 1.1 shows a block diagram of the P-scan system.

Figure 1.2 shows a photograph of the system set up at PNL. The PSP-3 processor is the black instrument in the center. The scanner control unit is at the right. The scanner is in the background, below the scanner operator's hand. The post-processing software runs on the stand-alone PC computer at left, with attached color printer. Data is transferred from the PSP-3 to the PC on 3½ in. floppy diskettes. The PSP-3 operator takes notes on a paper pad during scanning and online evaluation.

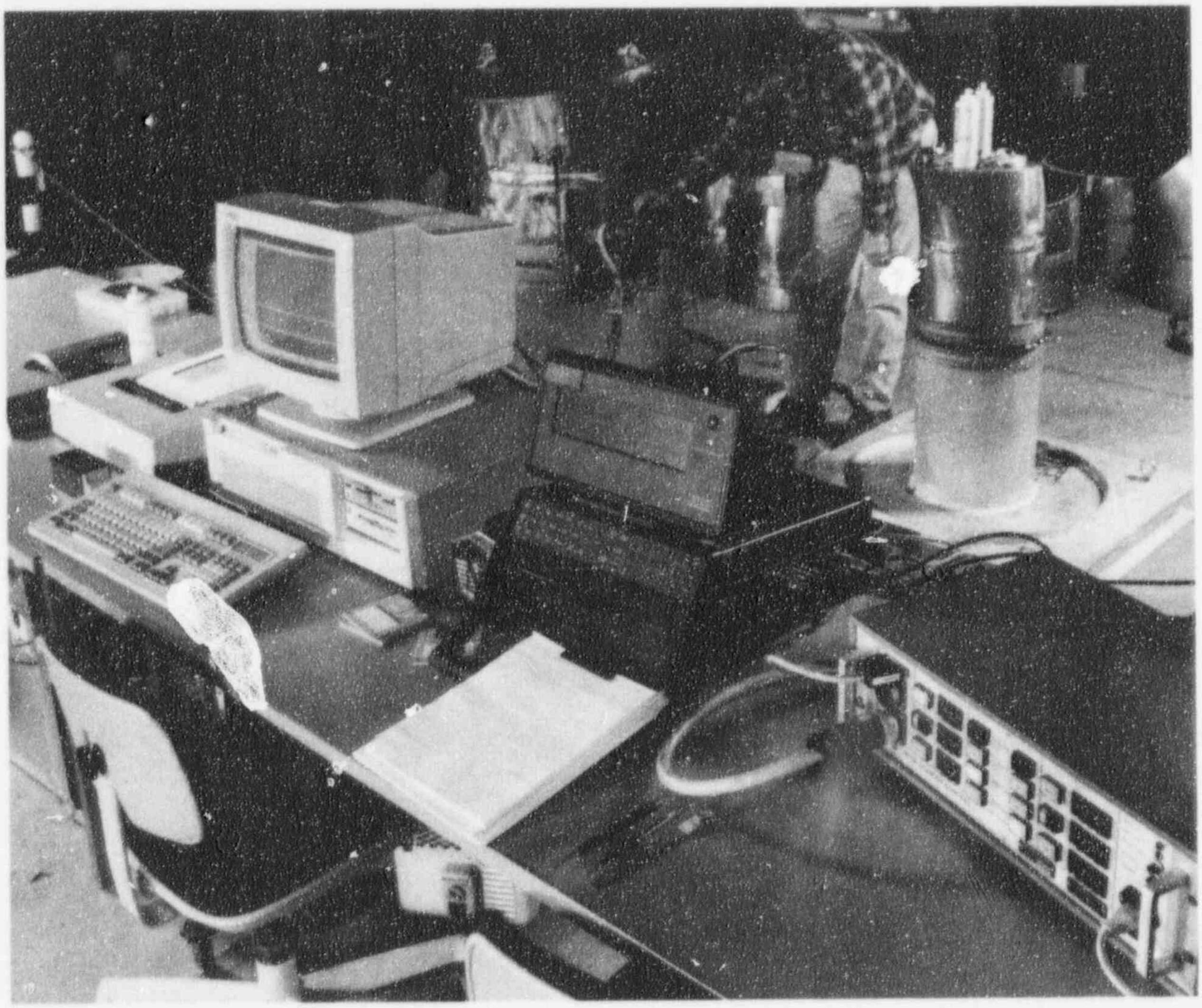

Figure 1.2 P-scan system set up at PNL, showing post-processor (left), PSP-3 (center), scanner control unit (right), and scanner (background)

1.6.2 PSP-3

The PSP-3 processor (Figure 1.3), is the system controller and ultrasonic instrument, with three main modes of operation: P-scan weld inspection, T-scan corrosion mapping, and A-scan recording. The PSP-3 with a manual or automated scanner forms a complete inspection system with means for scanning, text and image print-out, data storage on disk, and analysis on a small monochrome monitor.

The PSP-3 is a portable instrument with an LCD screen, color-coded keyboard, two 3½-in. floppy disk drives (bottom left and center) and a built-in printer (bottom right). Cables to the ultrasonic probes are attached on the right side of the instrument (see Figure 1.2).

Program control (including ultrasonic instrument control) is performed through 12 dedicated "menu" keys and the 10 F-keys, which access menus shown in the lower left-hand corner of the screen. The placement of the 10 menu items corresponds to the placement of the F-keys. The 10 numeric keys also serve as alphabetic entry keys, by

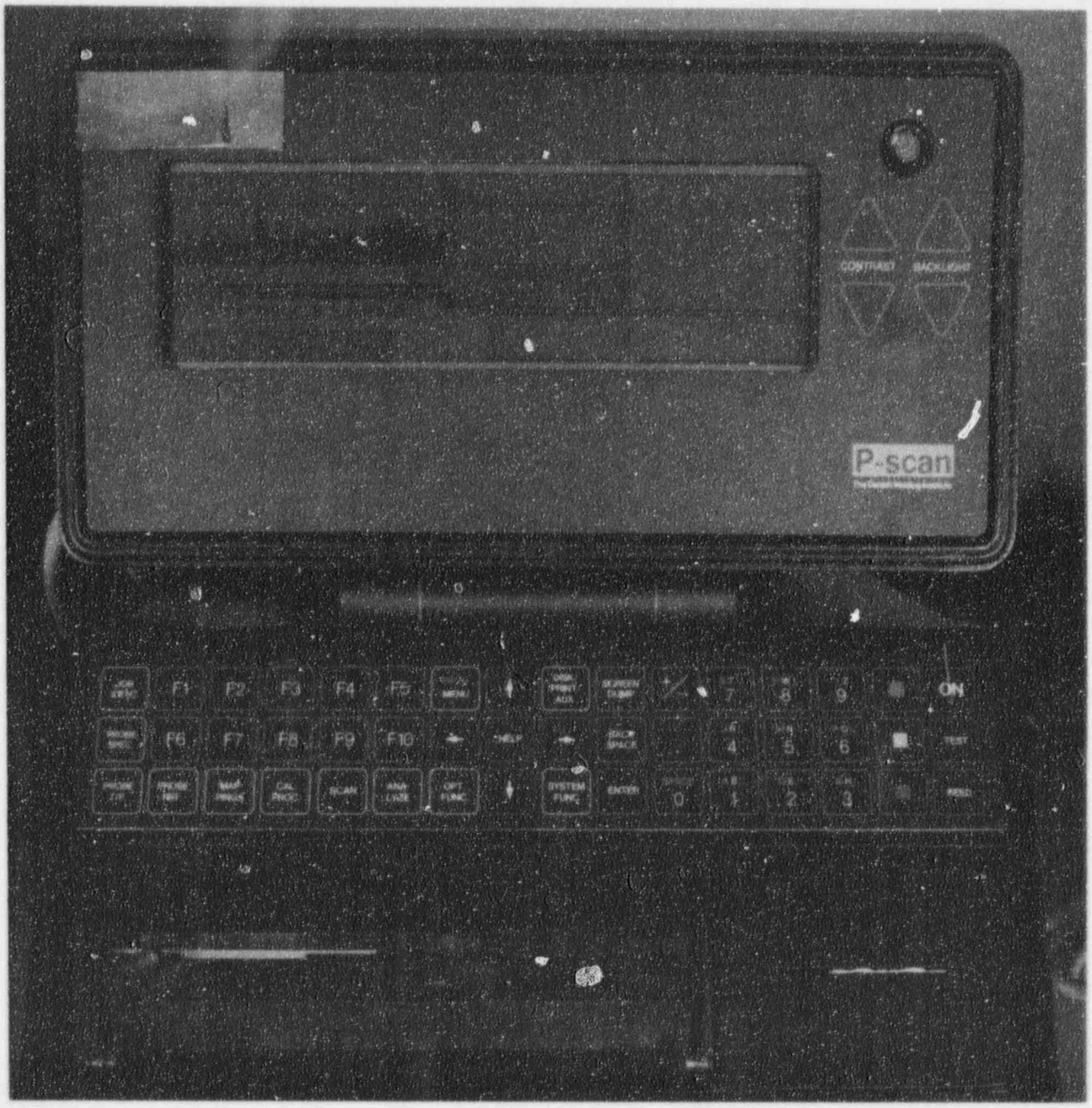

Figure 1.3 PSP-3 system controller and ultrasonic instrument: screen, keyboard, 3-1/2 inch floppy disk drives, 2-1/4 inch strip printer (lower right)

preceding each key with one of the three colored-square keys at the right.

1.6.3 Scanner Control Unit

The Scanner Control Unit (Figure 1.4) controls the movement of the scanner. The front panel is divided into five sections. At left are the cable connections for the PSP-3

Figure 1.3 PSP-3 system controller and ultrasonic instrument: screen, keyboard, 3-1/2 inch floppy disk drives, 2-1/4 inch strip printer (lower right)

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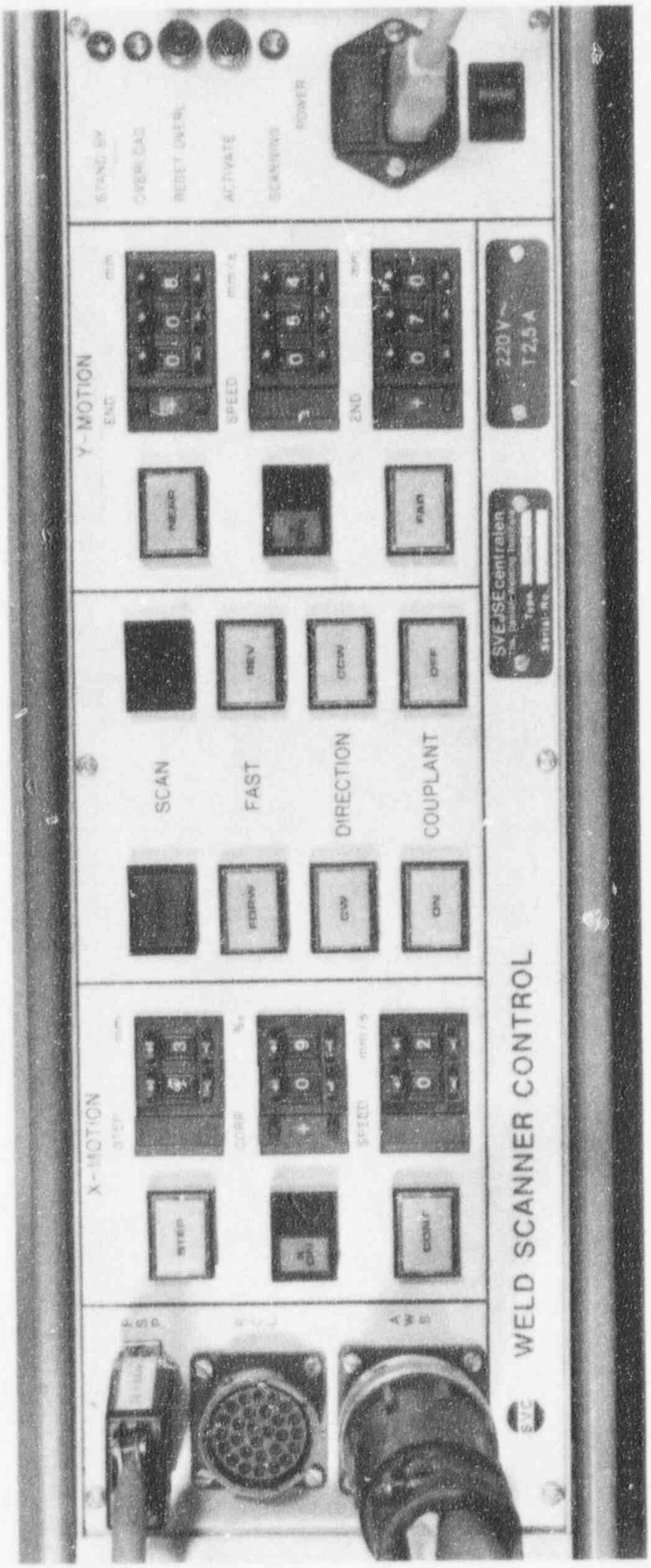


Figure 1.4 P-scan Scanner Control Unit

system controller (top), the optional hand-held Remote Control Unit (center), and the Automatic Weld Scanner (bottom).

The second section contains the controls for the X-axis (the magnetic wheels). Either STEP or CONTinuous is selected with the top or bottom pushbutton. The center pair of pushbuttons turns the X-axis ON or OFF. The size of the step, if STEP is selected, is set by the rotary pushbutton switch set beside STEP, and likewise for SPEED if CONT is selected. A percentage correction factor can be set on the center switch set.

The third, center, section controls overall operation. SCAN START and SCAN STOP are at top left and right. Jogging in the X-axis is performed with FAST FORW and FAST REV. The inspection direction is set to clockwise or counterclockwise with the DIRECTION switches, which also control the polarity of encoder data. The last pair of switches controls couplant flow.

The fourth section contains controls for the Y-axis (scanner arm). The rotary switch sets at top and bottom right control the extent of the scan; pressing the NEAR or FAR button moves the probe to the respective end of the scan (changing the DIRECTION from CW to CCW also affects the scanner response to these switches). At center left is the Y-axis on/off switch. At center right is the Y-axis speed control.

The right-hand front panel section contains general controls and power. The STANDBY light indicates that one of the operators (PSP-3 or scanner) has interrupted the scan. The OVERLOAD light indicates that an axis has been stopped by mechanical interference. The RESET OVERLoad switch recovers from the OVERLOAD condition. The ACTIVATE switch enables the scan control unit. During scanning the SCANNING light is lit. At the bottom are the power cord and on-off switch.

1.6.4 Remote Control Unit

A hand-held remote control unit (RCU, Figure 1.5) plugs into a socket on the scanner control unit. X-axis positions are read from the LCD displays at the top. The RESET button allows relative readings. All other functions are similar to those on the scanner control

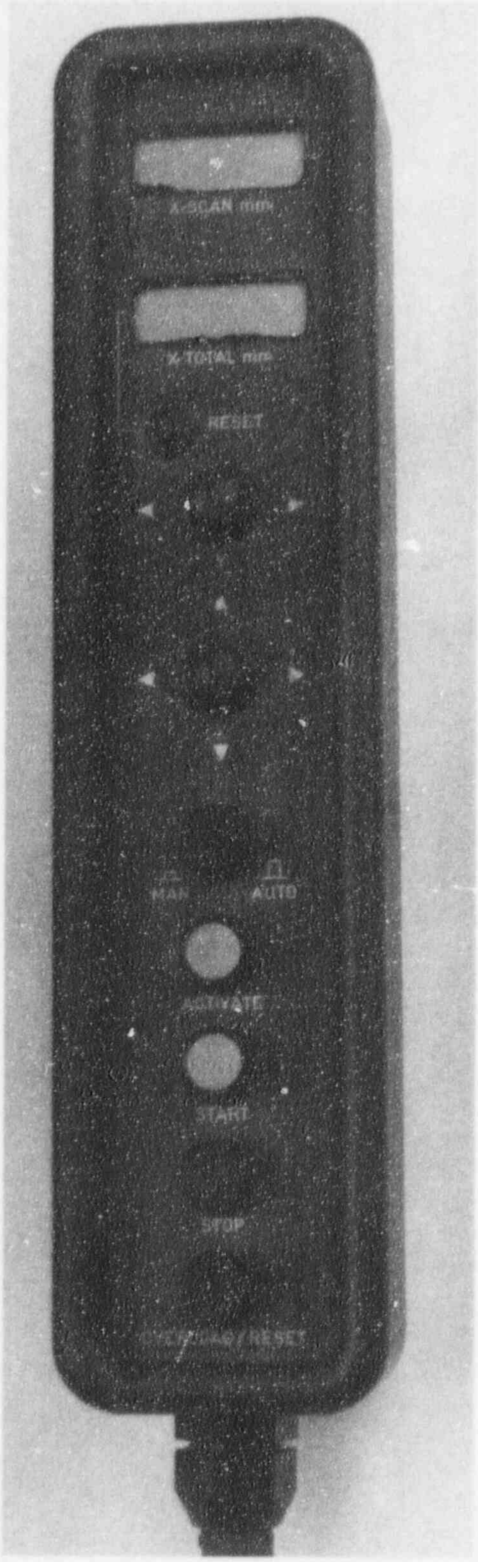


Figure 1.5 P-scan Remote Control Unit (RCU)

unit front panel. The Y and X buttons allow motion of the Y and X axes by pressing sideways on the appropriate button. The STANDBY switch and indicator (MAN, AUTO) lights up when the STANDBY light on the front panel is lit; the MAN/AUTO settings refer to steering settings for the AWS-5 scanner, which was not present on the reviewed system. The ACTIVATE, START, and STOP buttons are the same as on the front panel. The OVERLOAD/RESET button combines the functions of the OVERLOAD indicator and RESET OVERLoad button.

1.6.5 Scanner

The scanner (Figures 1.6 and 1.7) drives the probe about the surface to be inspected and transmits positional information to the PSP-3. It has magnetic wheels, and is capable of operation in any position. The wheels ride on a ferromagnetic steel track fastened around the pipe to be inspected; they can also ride directly on any ferromagnetic surface.

Figure 1.6 shows two dual-element probes fastened to spring mounts on either side of a weld. The probe cables ride in a guide that moves with the Y-axis motion. The entire assembly moves on the X-axis magnetic wheels. The chain holds the steel track, on which the wheels ride, tightly around the part, and guides the wheels to prevent the unit from skewing or walking away from the weld. Even on ferromagnetic pipe, it is advisable to use a chain to guide the wheels.

Figure 1.7 shows the X-axis encoder wheel at the bottom of the scanner. The wheel is riding on the pipe rather than on the ferritic steel band, so that there is no diameter difference between the encoder and the pipe. The encoder can also be mounted on the other side of the scanner if appropriate.

The probe cables are separate from the control cable.

1.6.6 Post-processor

The post-processing software is used on a PC computer (see Figure 1.2). It can perform further processing, on a full-size color monitor, of data transferred by 3½-in. floppy disk from the PSP-3. Images and data can be printed in black-and-white or color. PC-PROG and SuperSAFT are two post-processing tools available.

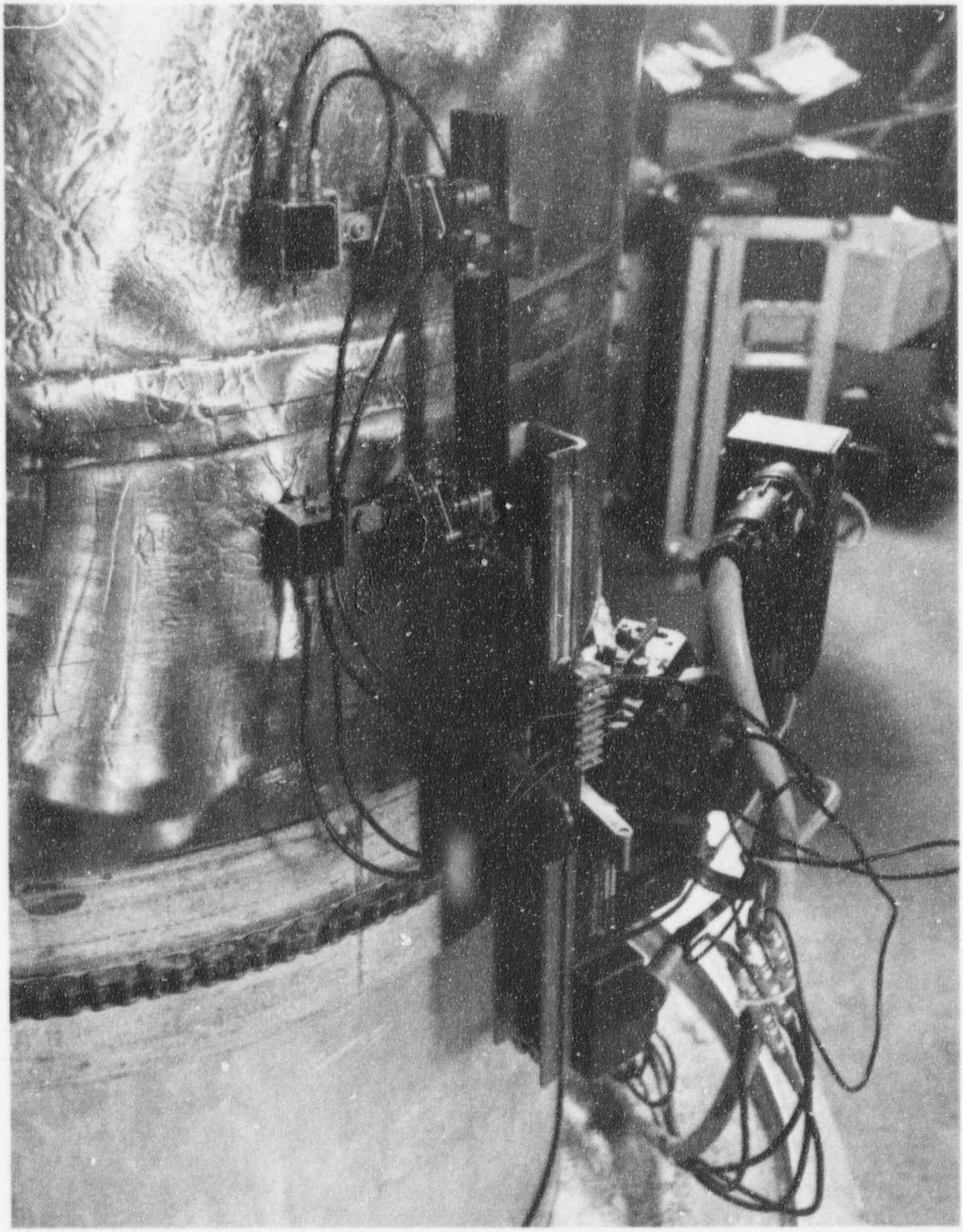


Figure 1.6 P-scan scanner, from probe side

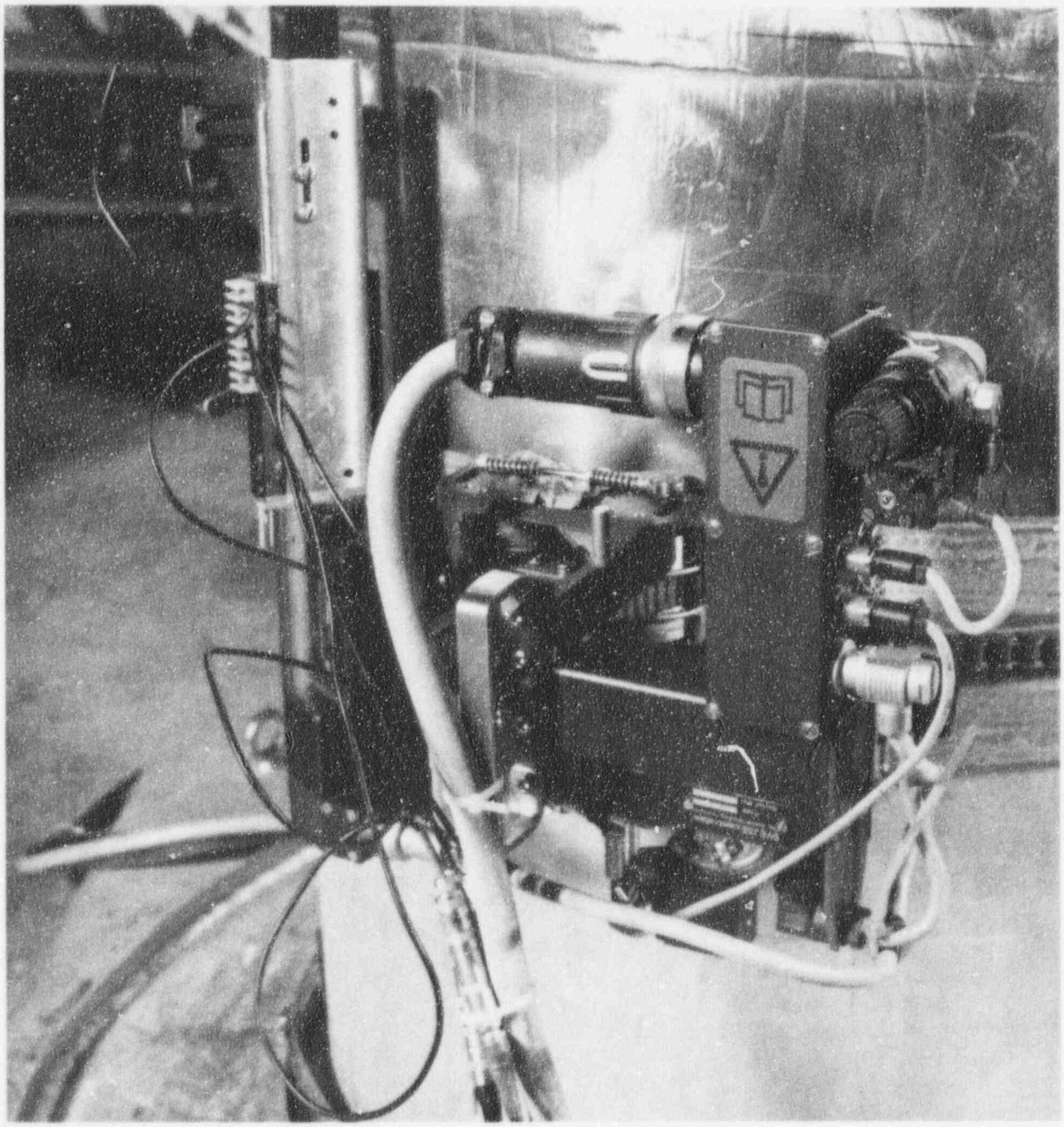


Figure 1.7 P-scan scanner, from cable side

PC-PROG is a display, evaluation and documentation program. SuperSAFT is a line SAFT processing program that uses A-scan data. There are some operations, such as Image Processing, that can be done on the PSP-3 but not on the Post-Processor.

1.6.7 Changeability

Identify which system components are fixed and which can be changed.

[B] Software
[B] Computer
[B] Ultrasonic instrument
[O] Mechanical scanner
[O] Other (explain) Post-processor computer (any PC-compatible computer, 286 or higher)

B = Built-in and fixed
O = Optional (possibly built-in, but can be changed)

1.7 Operating Platform

What is the operating platform of the system?

1.7.1 Type of Computer

IBM PC compatible.

1.7.2 Operating System

MS-DOS or equivalent

1.7.3 Multitasking

Yes [ ] No [X]

1.7.4 Windowing

Yes [ ] No [X]

1.7.5 Display

Type, size, and resolution of display(s)

The PSP-3 unit uses a liquid crystal display measuring approximately 2.5 in. x 8 in. (6.35 cm x 20.32 cm). The post-processing computer can use any color PC monitor. We used a 14-in. (36-cm) SuperVGA monitor.

1.7.6 Hard-copy Device

Type, size, and resolution of hardcopy device(s)

The PSP-3 unit uses an integrated printer that produces actual size screen-dumps as well as error messages.

The post-processing computer can use any compatible printer. We used an HP-PaintJet.

1.7.7 Pointing Device

The PSP-3 has no pointing device. The post-processing computer uses a mouse.

1.8 Audible Noise Level

The system is extremely quiet. Operators are able to converse in a whisper with the system operating.

2.0 Training

2.1 Operator Training

Operator training is provided by Force Institutes in Denmark. They recommend that the system be operated only by UT Level II personnel certified in accordance with SNT-TC-1A or equivalent. They recommend that interpretation and evaluation of results be performed only by UT Level III personnel certified in accordance with SNT-TC-1A or equivalent.

3.0 Set-up

3.1 Parameter Set-up

How does the operator set up the scanning parameters prior to scanning?

Scanning parameters are entered in two places: the PSP-3 processor and the scanner control unit front panel.

The PSP-3 has a set of entry pages that are accessed by function keys, arrow keys, and specialized keys. Moving between pages is possible in some cases by arrow keys and in other cases only by specialized keys. The scanner control front panel has pushbuttons and rotary controls.

4.0 Documentation

4.1 User's Manual

Is a manual, explaining the overall operation of the system and indicating any other support documentation, provided with the system?

Yes [X] No [ ]

A set of extremely detailed operation manuals are provided, and are intended to be used by trained operators of the system. The manuals are not intended for use as self-teaching tools. The manuals have a table of contents but no index.

4.2 Support Documentation

What detailed descriptions are available to the sophisticated user who wishes to go beyond the straightforward applications of the system?

[ ] Software logic description
  [ ] Functional description
  [ ] Flow chart
  [ ] Layered logic presentation
  [ ] Other
[ ] Electronic block diagram
[ ] Cable configuration
[ ] Mechanical configuration
[X] Other

P-scan Advanced User's Class and manual (manual only available with the class). None of the above was checked because they are proprietary and are usually not available to the user.

5.0 Image Interpretation

5.1 P-scan Axis Definition

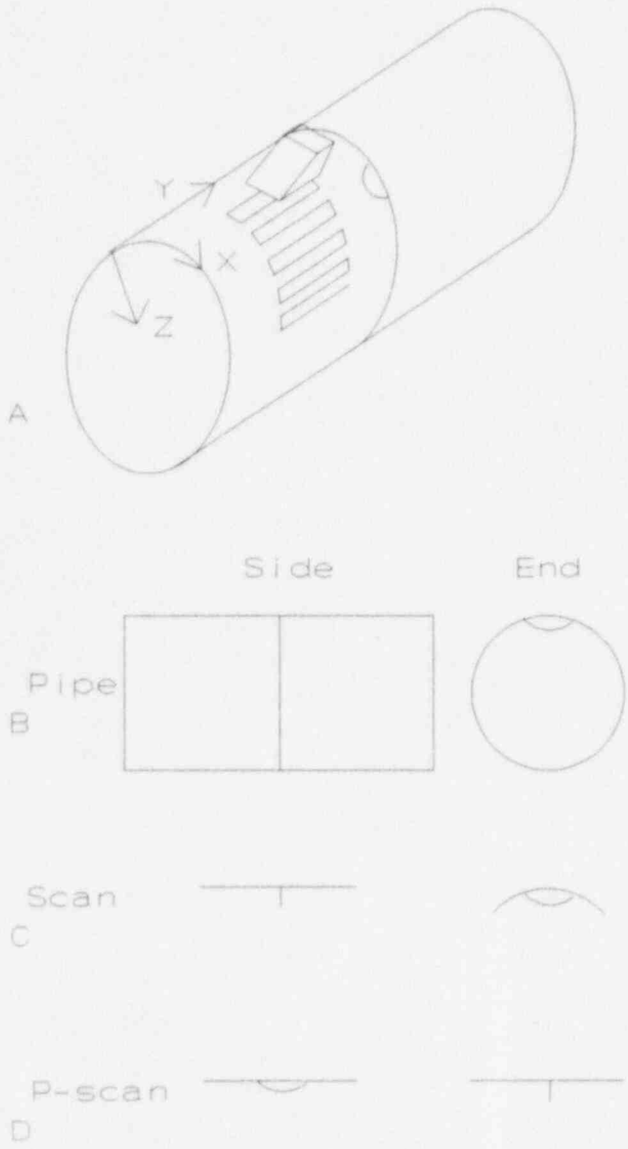


Figure 5.1 P-scan axis definition

Figure 5.1 diagrams the P-scan axis and view definitions. Figure 5.1A shows the typical orientation of the X, Y, and Z axes for inspection of a circumferential weld. Typically the weld centerline will be taken as Y=0. X=0 is preferably at a known reference point. Z increases toward the center of the pipe. A circular saw cut is shown in the outer surface of the weld zone.

Figures 5.1B-D show the meaning of "Side view" and "End view" in P-scan terminology. Figure 5.1B shows side and end views of the same pipe shown in Figure 5.1A. Figure 5.1C shows the side and end views of the circular saw cut. Figure 5.1D shows the P-scan side and end views of indications from the saw cut. Note that the terms are reversed from what might be expected; this is because the words "side" and "end" refer not to the pipe, but to the weld itself.

5.2 P-scan Axis Display

Figure 5.2 is a diagrammatic presentation of a P-scan image. Figures 5.2A, B, and D diagram the axis orientations for P-scan presentations. P-scan uses a rectangular coordinate system (in the case of a pipe, treating the outer surface as though it were a plane), presented with the Z-axis down (larger positive Z means greater depth into the part). The X- and Y-axes may begin at any number, positive, negative, or zero; the Z-axis normally begins at 0 or a positive number (a negative Z value indicates data above the surface of the part). The Top View (A) is a C-scan view, showing the stepping (magnetic-wheel crawler) axis (X) across and the scanning axis (Y arm) up, looking at the outside of the part, with the positive Z-axis pointing into the paper. The Side View (B) is a B-scan end view, showing the stepping axis (X) across and the depth axis (Z) down, with the scanning axis pointing into the paper. Figure 5.2C shows an ultrasonic amplitude presentation called an Echo View, aligned with the side view. The End View (D) is a B-scan side view, showing the scanning axis (Y) across and the depth axis (Z) down, with the stepping axis pointing into the paper. Figure 5.2E is an Echo View aligned with the End View. A screen display will show views A, B, and C or A, D, and E; a printed display may show the screen display or all five views.

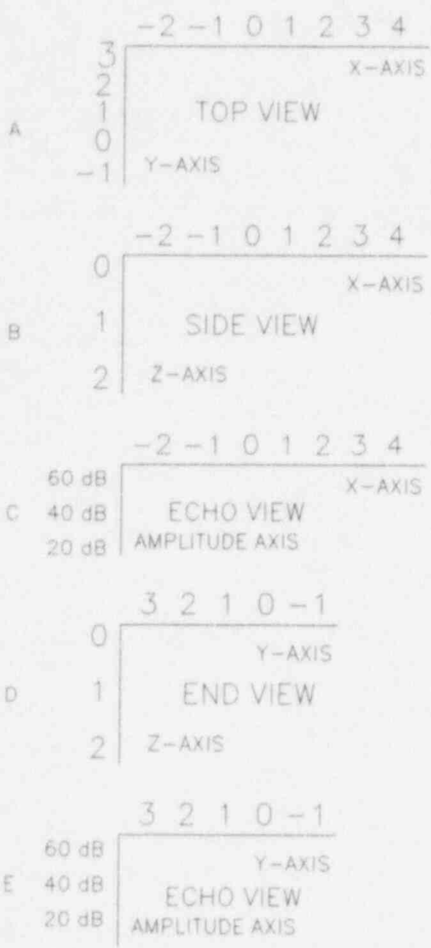


Figure 5.2 P-scan axis presentation

5.3 Imaging Modes

There are two types of imaging: P-scan and T-scan. P-scan is an amplitude presentation and T-scan is a thickness presentation. For either type, there are two modes: Imaging and A-scan. Imaging mode provides projected data, whereas A-scan provides full RF or video data. Most images for weld inspection are P-scan Imaging; erosion/corrosion inspection uses T-scan Imaging. A-scan mode is used only for evaluation, as it generates large data sets.

5.4 P-scan Imaging Mode

Figure 5.3 shows a P-scan image of test block UT-RPT-CIRC-1 (see Section 7.3 for notes on the geometry of the block). It has been reproduced at 90% of actual size to allow a vertical orientation on the page (scales for other images range from 55% to 100%).

5.4.1 Top of Image

At upper left, the print is identified as a P-scan image, as distinct from A-scan or T-scan. The small numbers (0.000, 4.808, 4.98, 5.117, 5.205) printed vertically above the image are X-axis ranges for indications. The numbers "0.00 in" and "5.51 in" above the image (far left and right respectively) indicate the X-axis (crawler axis) values at the left and right edges of the image, and also indicate that the dimensions are in inches rather than millimeters. The three other numbers "X 0.926," "Y 0.417," and "Z 2.334" above the image give the X, Y, and Z axis coordinates of the location marked by the cross-hairs.

5.4.2 Top View Identification

At the left side, "TOP VIEW" indicates that the view is in the plane (or a flattened representation of the cylinder, sphere, or other surface) on which the probe travels. "Top 5.00 in" means that the Y-axis (scanner axis) extent of the TOP VIEW is 5.00 in. (12.7 cm), but it does not indicate the lower and upper bounds for Y-axis values. In this presentation, colors are assigned to images. Im1 has a red block beside it, indicating that Image 1 is represented by red areas on the image; Im2 is yellow; Im3 is green; and Im4 is dark blue. Any image portion in which the signal amplitude is below the "Lower" value indicated in the ECHO VIEW (see below) is shown in background color (gray in this image). In this file, Images 1-4 represent time gates 1-4, which were set at four intervals through the block, gate 1 starting slightly below the near surface and continuing to a depth of about 1.5 in. (4 cm), gates 2 and 3 following at greater depths, and gate 4 ending just past the far surface. The gate settings are shown diagrammatically in Figure 5.4 (the Probes and Gates diagram is further explained in Section 5.5); the exact settings are given in Table 4.31, as determined by a data print-out of the scan parameters (scan parameter printouts are detailed and explained in Section 15.2).

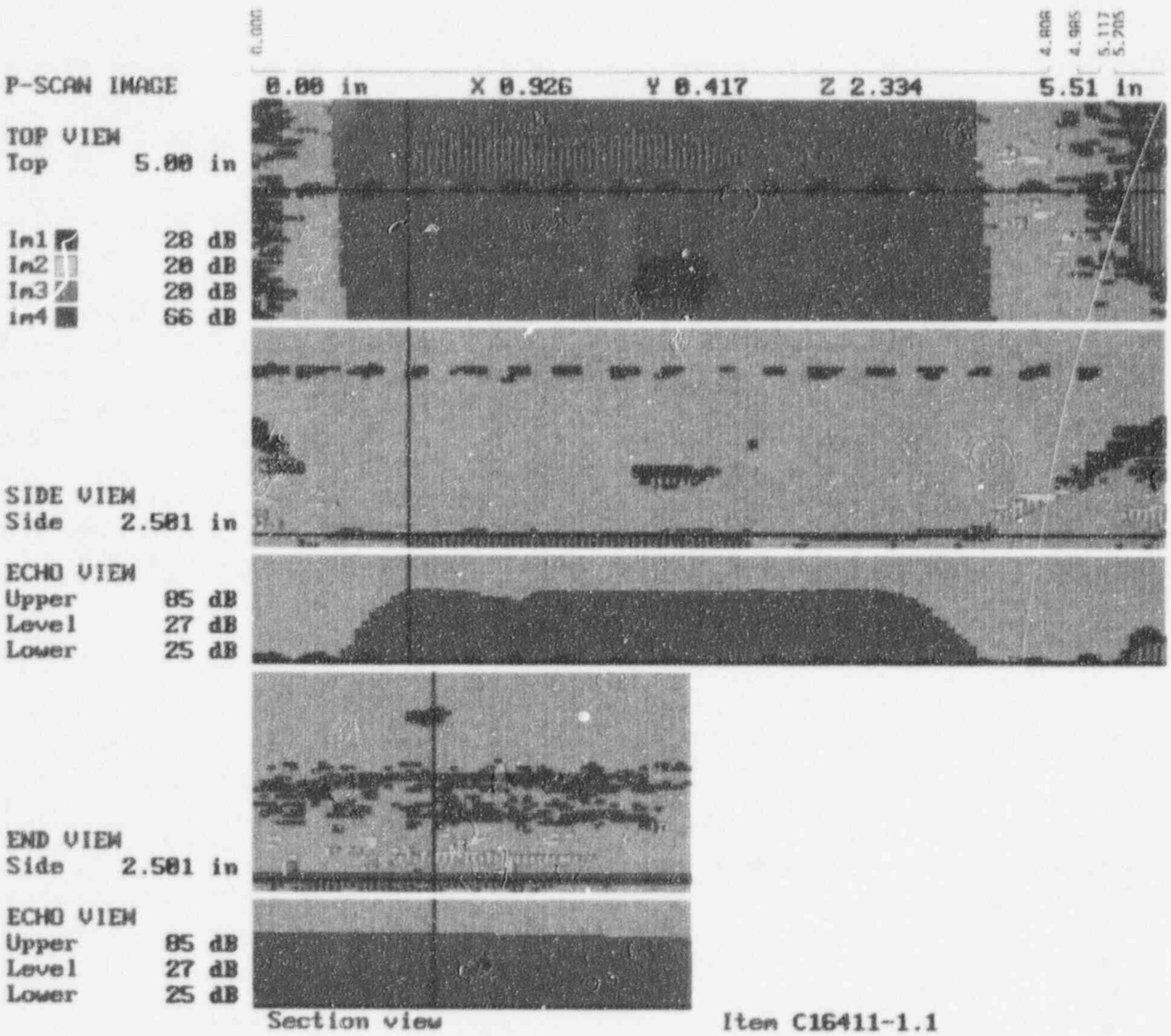


Figure 5.3 Typical P-scan image, image-coded mode

Images 1, 2, 3, 4 can also be used to represent data from four different probes or four different files, or any combination of gates, probes, and files.

In the P-scan image of 5.3, the numbers 28 dB, 20 dB, 20 dB, and 66 dB indicate the relative signal strength in decibels in each gate at the point indicated by the cross-hairs (without regard to depth). Lighter colors are obscured by darker colors, so it is not always possible to see all information from a single printout; this problem can be overcome by turning some images off and making several printouts, one for each gate if desired.

5.4.3 Side View

The legend "SIDE VIEW" indicates a projection on a plane that includes the X-axis and the Z-axis (as if the bottom edge of the TOP VIEW were tilted out of the paper 90 degrees); this is often called a B-scan end view. It is a view from the side of the weld. "Side 2.501 in" indicates the extent in depth of the SIDE VIEW, but it does not indicate the lower and upper bounds for Z-axis values. The cross-hairs indicate the X and Z coordinates printed above the TOP VIEW.

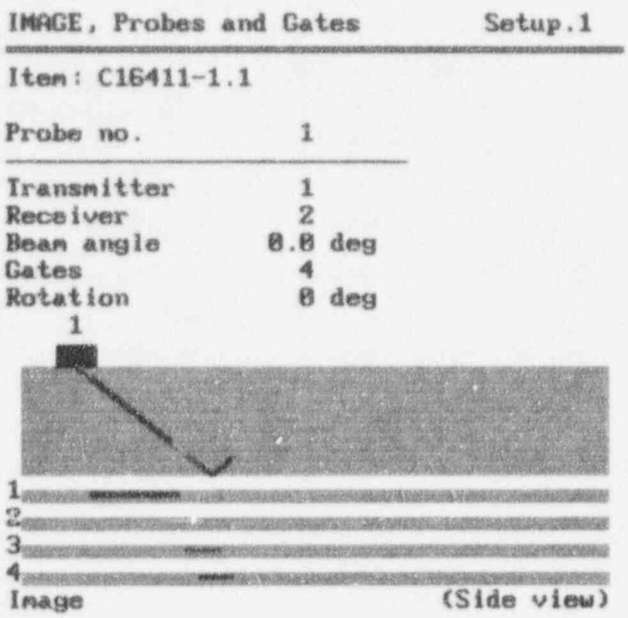


Figure 5.4 Gate settings for Figure 5.3. The angled line indicates time, not an angle-beam inspection.

Table 5.1 Exact gate settings for Figure 5.3

GATE 1 START	10%
GATE 1 RANGE	65%
GATE 2 START	70%
GATE 2 RANGE	25%
GATE 3 START	80%
GATE 3 RANGE	25%
GATE 4 START	90%
GATE 4 RANGE	25%

5.4.4 Echo View

The legend "ECHO VIEW" just below SIDE VIEW indicates a display of the signal strengths. The type of ECHO VIEW provided is indicated by the legend at bottom left: "Section view" in this case (compare to Figure 5.8, in which the legend at the bottom is "Projection view"). For each scan line (X-axis position), the value of the signal in each gate at the Y-axis cross-hair position is shown as a vertical bar. "Upper 85 dB" means that a signal reaching the top of the image has a relative strength of 85 decibels. "Level 27 dB" is the setting of the horizontal cross-hair. "Lower 25 dB" is the lowest signal that is displayed on the SIDE or TOP views, and represents the strength of a signal that just shows at the bottom of the ECHO VIEW.

The difference between "Section view" and "Projection view" is that the section view shows the amplitude data from a single cross-section, and is used to look at the amplitude profile of that cross-section; the projection view shows the maximum amplitude along the projected direction, and is suited to viewing indications that do not lie in a single plane parallel to either the X-axis or the Y-axis. If large echoes are present due to geometrical objects such as a weld root, the projection view is not likely to be useful, as the large geometric echoes will mask the indications. There is no way to limit the projection to a subvolume, except by rescanning over the desired subvolume.

5.4.5 End View

The legend "END VIEW" indicates a projection on a plane that includes the Y-axis and the Z-axis (as if the left end of the SIDE VIEW were rotated out of the paper 90 degrees); this is often called a B-scan. It is a view from the end of the weld. "Side 2.501 in" indicates that the vertical dimension of the image is 2.501 in. (6.352 cm) (see preceding discussion under SIDE VIEW). The cross-hairs indicate the Y and Z coordinates printed above the TOP VIEW.

The legend "ECHO VIEW" just below "END VIEW" is similar to the other "ECHO VIEW," with the Y-axis substituted for the X-axis. This is again a "Section view" (compare the legend at the bottom to Figure 5.8, in which it is "Projection view"). The scan used for the Section view is marked by the vertical X-axis cross-hair in the SIDE VIEW or TOP VIEW.

5.4.6 Projections and Sections

The TOP VIEW, SIDE VIEW, and END VIEW are all composite projections, i.e. the projected data for the entire inspected volume is shown in each view. The ECHO VIEWs, as mentioned, can be selected as either composite projections or sections. The legend at the bottom of each image ("Projection view" or "Section view") refers to the ECHO VIEWs.

5.4.7 Amplitude Color Coding

Figure 5.5 shows another P-scan presentation of the same data as Figure 5.3. This image, however, is color-coded by the ultrasonic signal strength rather than by image number. Thus there are no colored blocks beside the legends "Img 1," "Img 2," "Img 3," and "Img 4." There are four "Level" legends below the Image legends, and eight colored blocks between the Level number and the level amplitude in decibels. Thus Level 1 is shown by white and represents 90 dB and above, Level 2 is shown in yellow and represents some range of amplitudes between Level 1 and Level 3 (probably 81-89), Level 3 is orange and represents amplitudes from 72 dB up to the lower end of Level 2 (probably 72-80), Level 4 is red, Level 5 is brown at 54 dB and above, Level 6 is dark purple, Level 7 is green at 36 dB and above, and Level 8 is dark blue, and represents from 35 dB (just less than Level 7) down to the "Lower" value of 25 dB; any amplitude less than 25 dB is shown in background color (light blue in this image).

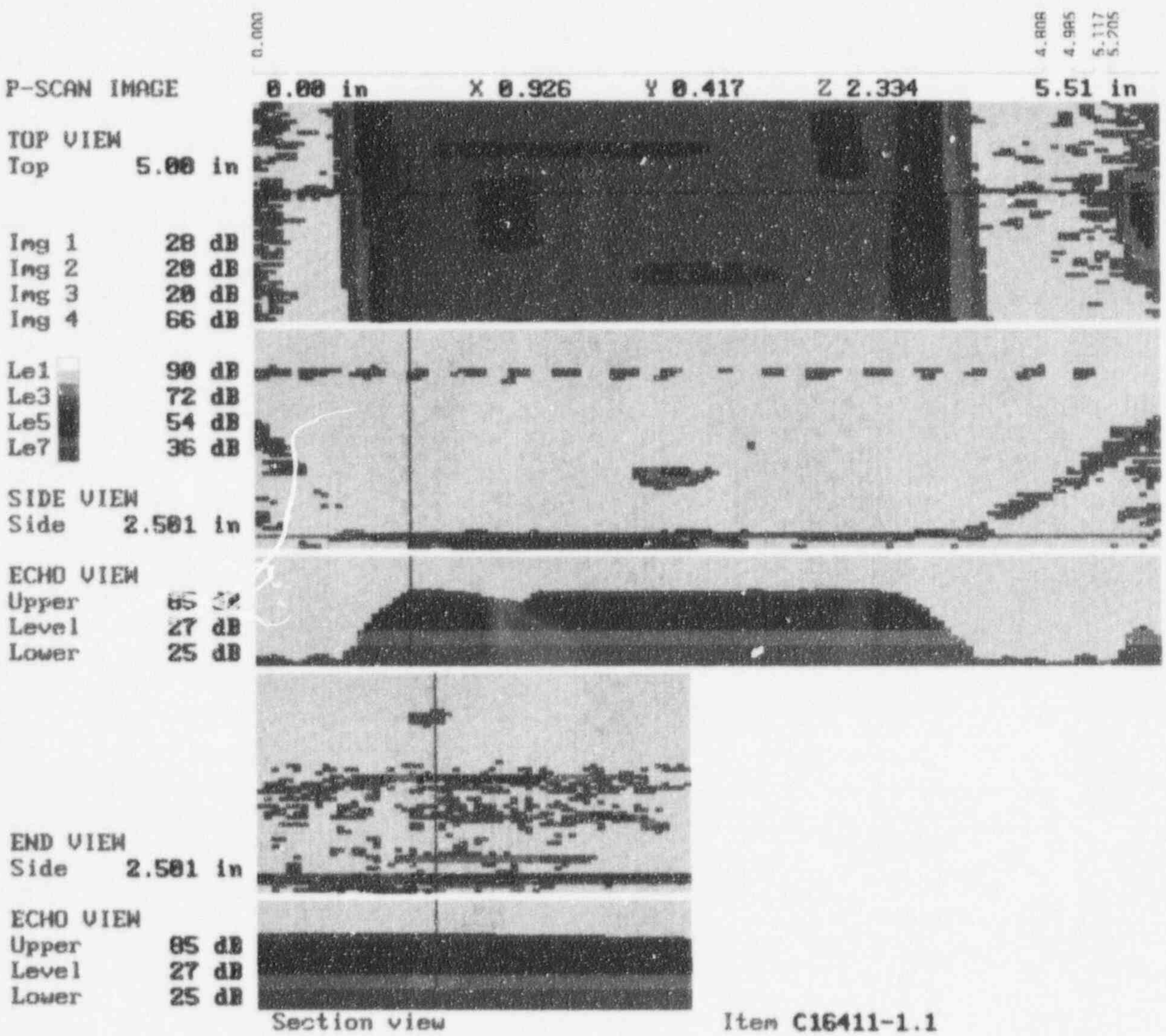


Figure 5.5 Typical P-scan image, level-coded mode

LEVEL, Scale and Range Setup.1

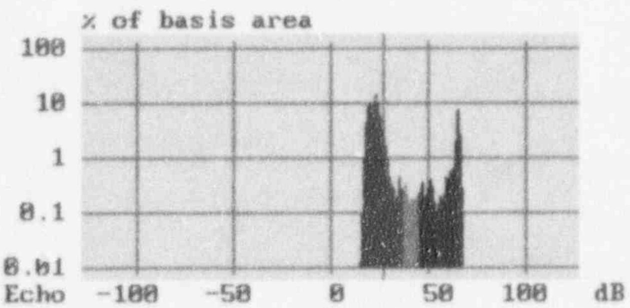
Item: C16411-1.1 Images: 1 2 3 4

Color	Scale	Echo	Ampl dB	Range	Area %
LEV 1		>	90	......	0.0
LEV 2		>	81	9	0.0
LEV 3		>	72	9	0.0
LEV 4		>	63	9	11.8
LEV 5		>	54	9	3.3
LEV 6		>	45	9	2.2
LEV 7		>	36	9	2.0
LEV 8		>	27	9	4.7
BGIMG		≤	27	......	76.1
LEVEL			27	......	76.1
Basis area			30000 of 30000		100.0

Max value	67 dB
Mean value	30 dB
Min value	15 dB
Deviation	15 dB

LEVEL, Scale and Range Setup.2

Item: C16411-1.1 Images: 1 2 3 4



Display level 27 dB [76.1 %]

Max value	67 dB
Mean value	30 dB
Min value	15 dB
Deviation	15 dB

Figure 5.6 Level display and analysis

5.4.8 Amplitude Color Definition

To ascertain the exact decibel range of each level, it is necessary to refer to the HELP screen on which the levels are displayed (upper portion of Figure 5.6). The ranges are not necessarily equal, as the operator can set them to arbitrary amplitudes, as long as they are in decreasing order.

5.4.9 Amplitude by Area

The lower portion of Figure 5.6 shows an analysis of echo strength in terms of reflective area; this kind of display is more often used with T-scan, for analyzing percentage of area below nominal thickness. No measurements were made to verify this analysis.

5.4.10 Section View Example

Figure 5.7 (shown also in Figure 9.5) shows ECHO VIEW Section views in which some objects are singled out from the rest. The amplitude profiles of four objects are shown in the two ECHO VIEWs. The objects shown are those lying along either of the cross-hairs in the TOP VIEW. The SIDE VIEW ECHO VIEW shows three objects: half of a hole at the left (the other half was cut off because the scan was not extended far enough on that side), another hole toward the right, and the back-wall echo from the sloping edge of the block at the far right. The END VIEW ECHO VIEW shows one hole, plus some of the echo from the adjacent hole (the bulge at the lower right). Note that even though the ECHO VIEWs are sections, the END VIEW and SIDE VIEW themselves are composite projections, not sections.

5.4.11 Loss of Couplant

Because the system records data at all levels, it is easy to see loss of couplant in a P-scan image. Figure 5.8 shows (deliberate) loss of couplant in the center of the image. The salient symptom is the disappearance, in the Top View, of the blue squares from the affected area.

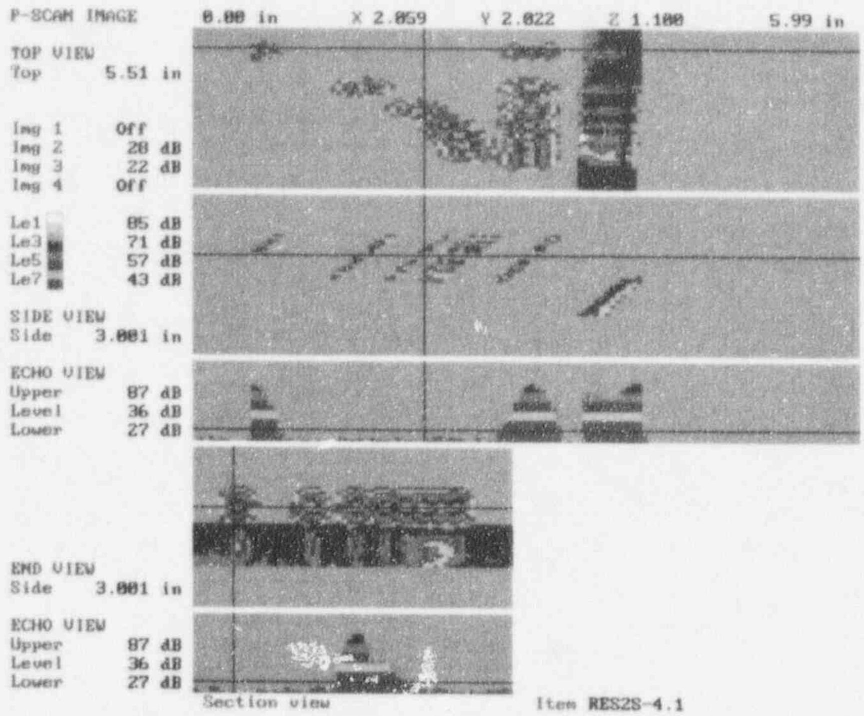


Figure 5.7 Use of ECHO VIEW

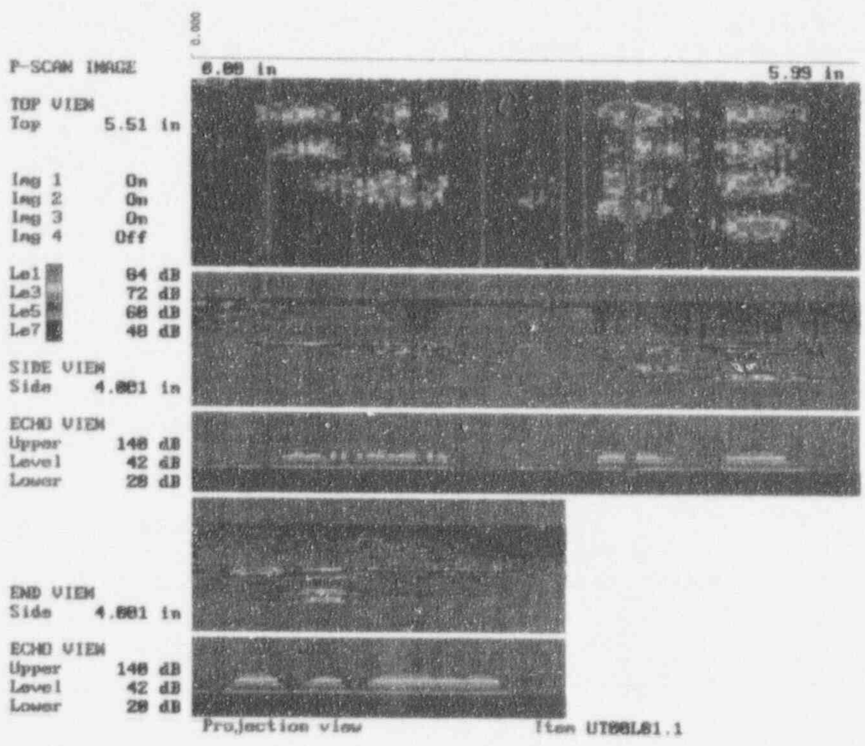


Figure 5.8 P-scan image showing loss of couplant (low amplitude in the ECHO VIEW presentation of the SIDE VIEW, center of the image)

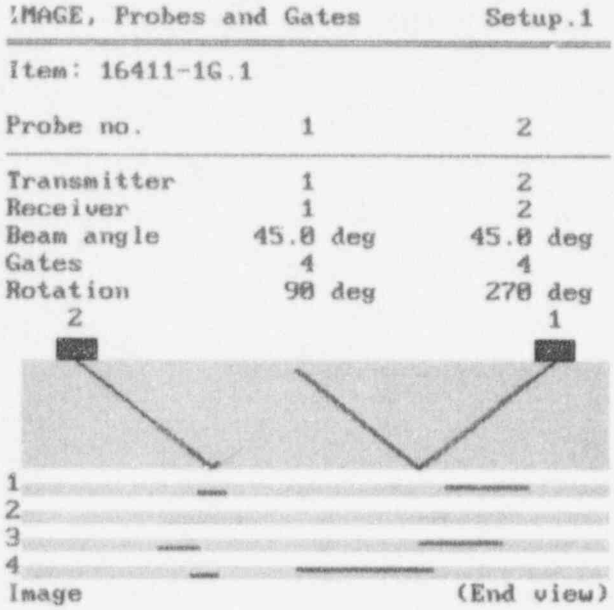


Figure 5.9 Probes and Gates display

5.5 Probes and Gates

Figure 5.9 shows a special presentation for visualizing the path of the sonic beam and the inspection volume assigned to each gate. The setup shown is for a housing containing two probes in a single housing, used to scan across a weld and inspect from both sides. Probe 1, on the right, is gated to acquire data not only through the part on the first echo, but also for any secondary echo almost as far as the front surface. Probe 2, on the left, is gated to acquire data from the middle of the part to the back surface, and secondary echoes close to the back surface. The four horizontal bars underneath the probes give the colors and times of each gate, with time 0 starting directly under the center of the respective probe and progressing toward the left for Probe 1 and toward the right for Probe 2. The part of each beam nearest the probe is black, meaning that no data is acquired, which corresponds to the lack of a colored horizontal bar below the probe for times close to 0. Lighter colors are overlaid by darker ones, so the bars below are necessary to properly visualize the gates.

Note that the angle of the beam path does not represent the ultrasonic beam angle; for example, Figure 5.4 shows the Probes and Gates presentation for a normal-beam probe, and the displayed angle of the beam path is the same as for the 45-degree probe shown in Figure 5.9. The angle is used merely to permit a visual correlation between the horizontally displayed gate settings at the bottom, with the vertically displayed thickness of the part.

5.6 T-scan Images

T-scan, or Thickness scanning, provides the same kinds of images as P-scan, but with the emphasis on time of flight instead of amplitude. T-scan images ignore amplitude, so there is no ECHO VIEW provided. Color coding is in terms of thickness instead of echo amplitude. In the SIDE VIEW and END VIEW, there is control over the Upper and Lower limits of thickness shown, so that either coarse or fine gradations of thickness can be presented. The choice of Projection or Section now applies to the Side and End views: in Projection mode, the thinnest section along the projection is shown; in Section mode, the backwall profiles along the X and Y cursors are shown. Figures 7.5 through 7.8 in Section 7.2.2 show T-scan images.

5.7 A-scan Images

More sophisticated image presentations are available using A-scan data, i.e. data in which the original ultrasonic RF or rectified data has been conserved for presentation and for further analysis by SuperSAFT. This report does not emphasize the A-scan capabilities, as they do not seem to be in wide use in the field, are intended for use only in unusual circumstances, and demand large amounts of storage space compared to the amount required for normal inspection data. A-scan data can be presented in at least three formats, illustrated in Figures 5.10 - 5.14: Individual A-scan, Composite A-scan, and B-scan. The Individual presentation is a conventional time-based RF or video A-scan presentation. The Composite presentation shows the scanning axis vertical and the time axis horizontal, with color-coded amplitude, like a conventional B-scan image, but rotated 90 degrees. The B-scan presentation shows the scan axis horizontal and the depth axis vertical, and includes a beam centerline display.

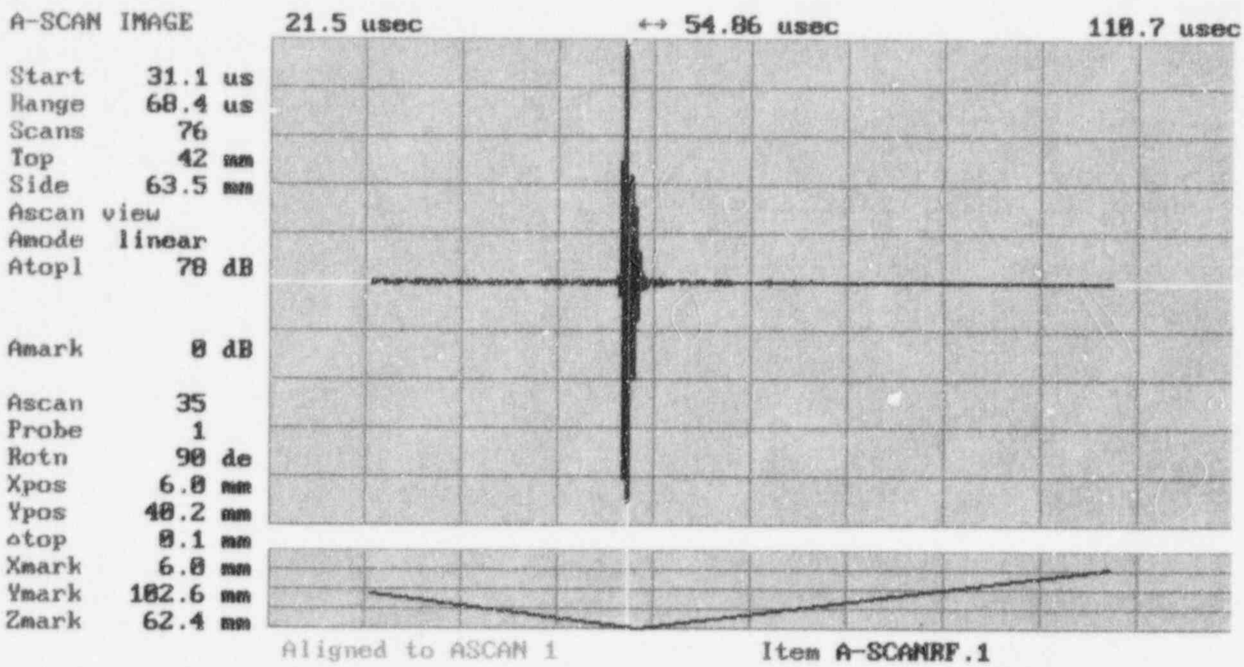


Figure 5.10 Individual A-scan image, RF mode

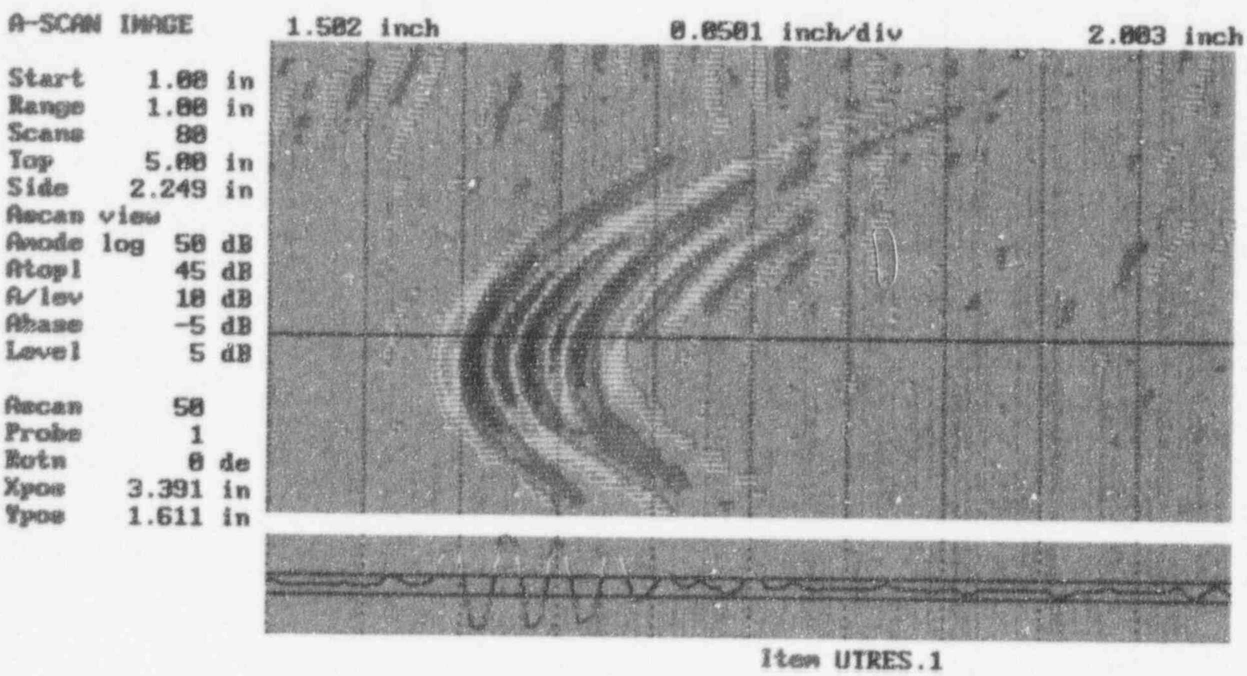


Figure 5.11 Composite A-scan presentation of scan of a spherical object

Figure 5.10 shows an Individual A-scan presentation of a single digitized RF signal. In this format, the bottom portion of the image shows a ray-tracing diagram of the beam.

Figure 5.11 shows a Composite A-scan presentation of an RF mode scan across a spherical target. The horizontal scale represents time, but can be labeled in either time or distance; here the units are inches. The vertical direction is along the scan axis (Y-axis) and contains one pixel for each scan. The graph labels are not sufficient to determine the scale in the vertical direction. For this information, it is necessary to examine a "Dataset" image, as shown in Table 5.2, which indicates that an A-scan was taken every 0.020 in. (0.051 cm) (F5 TRIGGER MODE = Y POSITION; F7 POSITION INCREMENT = 0.020 in.).

Table 5.2 Exact gate settings of Figure 5.11

```
Dataset   PROBE 1: A-SCAN REC PAR.
==================================
F1 ATYPE ASCAN TYPE>    RF
F2 ASTRT A-SCAN START    1.002 inch
F3 ASRNG A-SCAN RANGE    1.002 inch
F4 RECRT REC. RATE>     32 MHz
F5 TRIGM TRIG. MODE>    Y POSITION
F6 Y-STA Y START POS.    0.646 inch
F7 P-INC POSIS. INC.     0.020 inch
F8 A-NUM NUM. A-SCANS       80
F9       FIRST A-SCAN        1
F0       LAST A-SCAN        80
```

Metric equivalents: 1.002 inch = 2.545 cm, .646 inch = 1.641 cm, .020 inch = .051 cm

Note that there are 80 A-scans, from 1 to 80. It is then simple to calculate that the vertical axis represents 80x.020 = 1.60 in. (80x.051 = 4.08 cm). The A-scan shown in time-amplitude format in the strip at the bottom of the image is A-scan number 50. Since the sphere diameter is 0.25 in. (0.64 cm), and the pattern is about 1-in. (2.5-cm) wide, it is seen that this pattern is not a simple picture of the spherical target, but is a hyperbola caused by scanning the probe across the target. SAFT analysis would present this as a portion of a circle with a 0.25-in. (0.64-cm) diameter. The color scale is logarithmic, as indicated by the notation "Amode log 50 dB." The color scale is shown implicitly by the coloring of the time-domain trace at the bottom of the image. It can be explicitly determined from a "Level, Scale and Range" diagram similar to the upper portion of Figure 5.6.

Figure 5.12 shows three presentations of a Composite A-scan image. The first has a logarithmic amplitude color scale. The second is the same data, presented with a linear color scale. Much of the background is lost, but the highest-amplitude portion is clearly visible. The third presentation has the same color scale as the second, but the data have been "aligned" to the 38th scan, thereby removing the skewing effect of the angle beam.

Figure 5.13 shows the high-amplitude data from the bottom presentation of Figure 5.12 at an expanded horizontal scale. In the upper portion, the scale is expanded by a factor of about 6, and in the lower portion, by about 30. In the bottom portion, it takes three or four horizontal pixels to represent one actual data point (at a sampling rate of 32 MHz); the image appears to be interpolated between data points.

Figure 5.14, 5.14 shows a B-scan presentation of data from an A-scan file. The data set was acquired in A-scan mode, and thus contains full RF data. The presentation is in B-scan format. The indications are visible as a red and yellow cluster at the bottom center of the upper portion. The designated A-scan is shown in the lower portion. The sound-beam path is shown as an angled green line in the upper portion. Unlike the "Probes and Gates" image, such as Figure 5.9, the angle of the sound beam in Figure 5.14, 5.14 displays the true inspection angle.

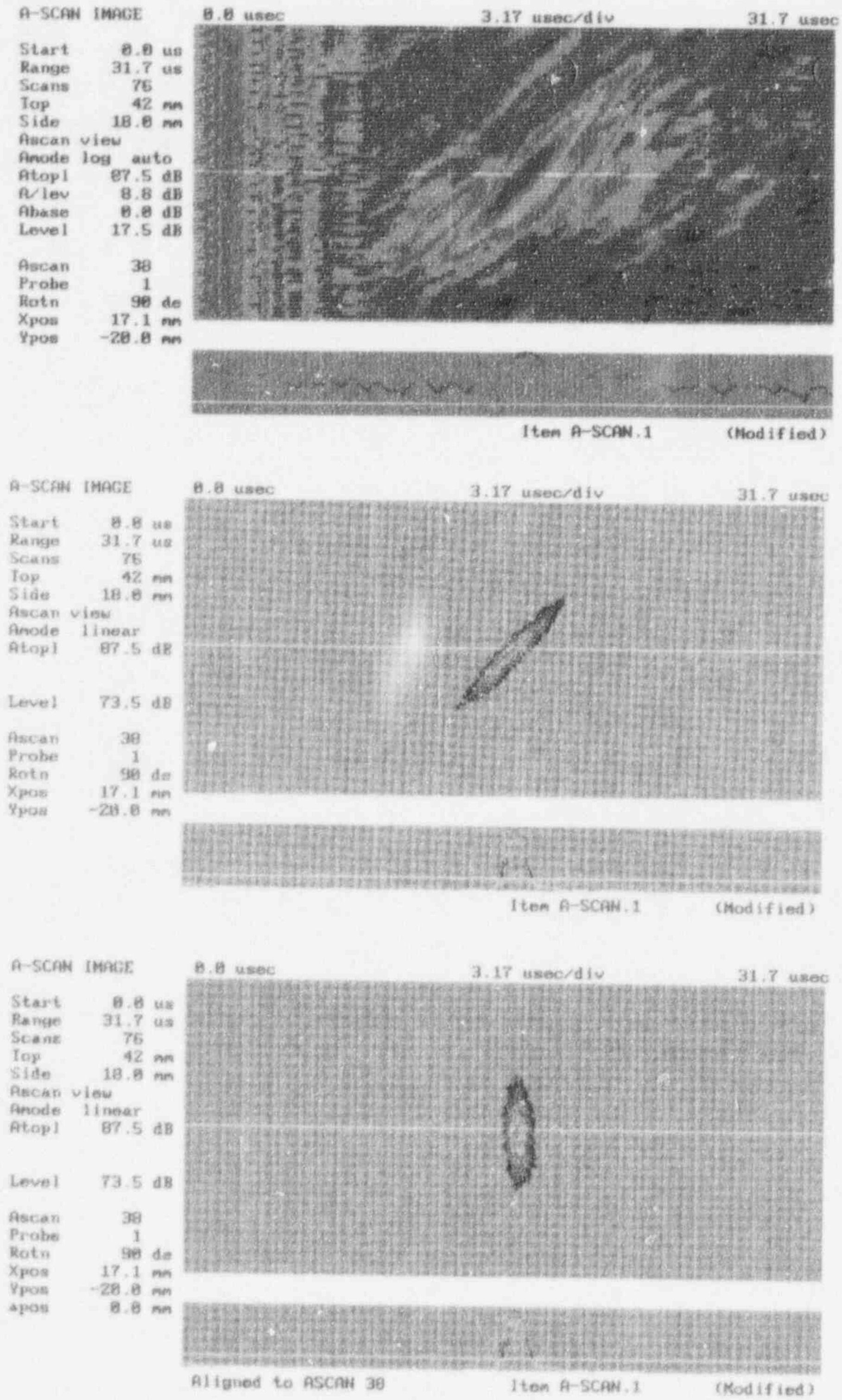


Figure 5.12 Three Composite A-scan presentations: Logarithmic (top), Linear (middle and bottom), Aligned (bottom)

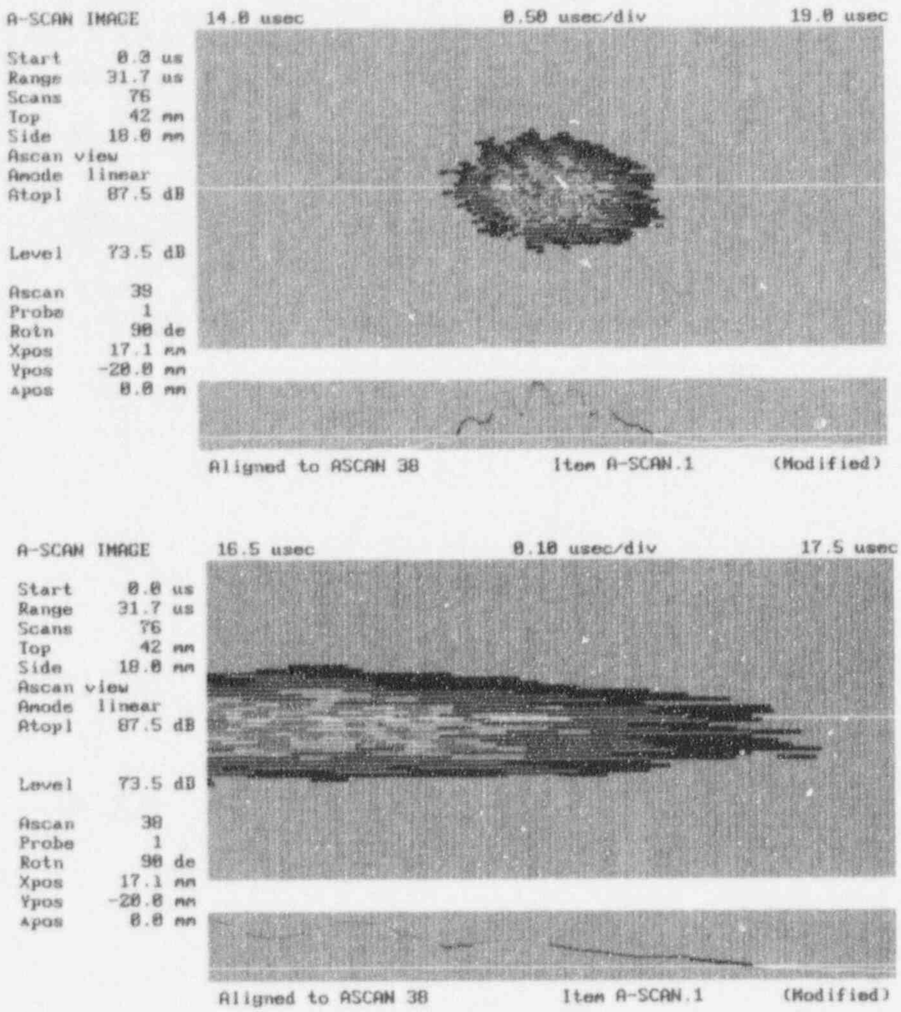


Figure 5.13 Two Composite A-scan presentations of Figure 5.12 data. The horizontal scale is expanded by a factor of about 6 (upper) and 30 (lower).

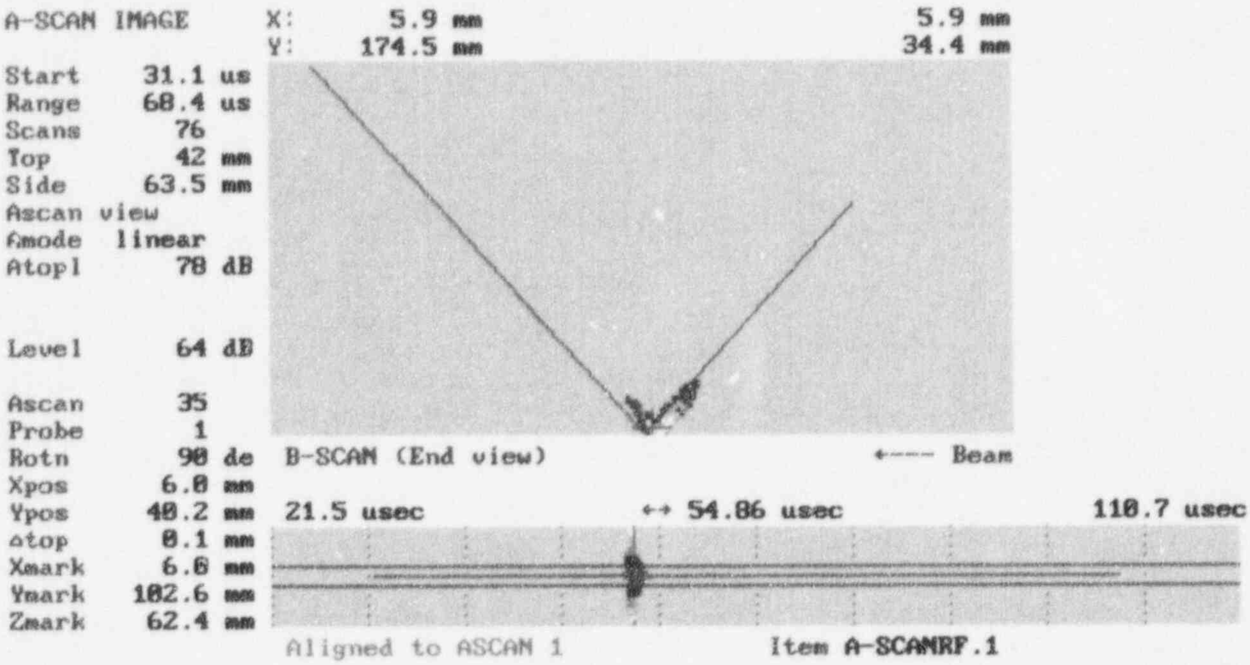


Figure 5.14 B-scan (end view) presentation of data and sound-beam from an A-scan file

6.0 Scanner/Mechanical Measurements

6.1 Mechanical Resolution

6.1.1 Step Size

Does the operator have the ability to enter the step size?

6.1.1.1 X- and Y-axis Together:

Yes [ ] No [X]

6.1.1.2 Y-axis Independently:

Yes [ ] No [X]

Y-axis is 90 degrees to the weld, and is the data collection axis, or stroke axis. It does not use step size; it uses speed in mm/sec.

6.1.1.3 X-axis Independently:

Yes [X] No [ ]

The X-axis is parallel with the weld. Units are mm. X is the increment axis.

6.1.1.4 Multi-axis: (describe)

Yes [ ] No [X]

6.1.2 Step Size Method

Is the step size set by software or hardware? Are values entered from the keyboard or are values entered by moving jumpers or controls?

6.1.2.1 X-axis:

Software [ ] Hardware [X]

6.1.2.2 Y-axis:

Software [ ] Hardware [X]

6.1.2.3 Multi-axis: (describe)

Software [ ] Hardware [ ] N/A

Step sizes for both axes are set by rotary switches on the Weld Scanner Control Unit (WSC-2). The control unit communicates with the scanner and the PSP-3 views the axis positional values via the scanner encoders.

6.1.3 Step Size Values

What are the possible values for step sizes? (e.g. increments of 5, etc.)

6.1.3.1 X-axis:

Step sizes of 0.2 mm (0.008 in.) up to 9.9 mm (0.390 in.) in forward direction in increments of 0.1 mm (0.0039 in.). Step sizes are always set in millimeters.

6.1.3.2 Y-axis:

N/A

6.1.3.3 Multi-axis:

N/A

6.1.4 Step Size Limits

6.1.4.1 X-axis:

	Operator Entry	Software	Scanner
Smallest:	0.1 mm	n/a	0.2 mm
Largest:	9.9 mm	n/a	9.9 mm

The operator can enter 0.1 mm, but the scanner will not move. Software entries have no effect. Inch equivalents: 0.1 mm = 0.0039 in., 0.2 mm = 0.0079 in., 9.9 mm = 0.390 in. (actual settings are always in mm).

6.1.4.2 Y-axis: N/A

6.1.4.3 Multi-axis: N/A

6.1.5 Encoder Bits

How many bits do the encoder counters have?

The encoder readings are transmitted to the PSP-3 as analog readings, -10 to +10 Volts, and are digitized to 12-bit accuracy by a 14-bit digitizer in the PSP-3. The Y-axis scale depends on the length of arm used (maximum range -3.2 meters to +3.2 meters). The scale was about 20 mV/mm on our unit. The X-axis scale is about 40 mV/mm. The values roll over when 10 Volts is reached; the software keeps track of how many rollovers have occurred, allowing a maximum range of -830 meters to +830 meters (far greater than cable length would actually allow).

6.1.6 Encoder Distance

What scan distance is associated with each encoder count?

In metric mode the smallest count is 0.1 mm (0.0039 in.). In inch mode the smallest count is 0.0039 in. (0.1 mm), which rounds to either 0.004 or 0.003 in. depending on the conversion from metric units and the accumulated difference between inches and millimeters.

6.1.7 Pulse Synchronization

What determines the pulse time?

In P-scan imaging mode (the normal data-taking mode for weld inspections) the pulser fires as often as it can, and the encoder value is read. As long as the encoder values remain within one pixel (as determined by the PART LENGTH and TOP PIXELS parameters), the data for that pixel is updated with the time and amplitude of the largest peak encountered within that pixel. The pulse repetition rate may be expressly limited by the operator if so desired; normally it is limited by the data processing rates of the computer.

The pulsing for A-scan mode can be selected to occur at uniform time intervals or at uniform distance intervals.

The scanner control unit and PSP-3 do not communicate with each other about positional information. The PSP-3 reads from encoders at calculated moments (as mentioned above). The operator should record the increments as "Notebook" parameters, which are computer file values that are printed but do not affect operation or analysis.

6.1.8 Positional Accuracy

Accuracy of Positional Information: Determine the accuracy of the ultrasonic path length over a 5 in. x 5 in. (12.7 cm x 12.7 cm) square by using accurate ultrasonic time-of-flight measurements.

It was not feasible to perform the test over the full 5 in. by 5 in. (12.7 cm x 12.7 cm) region desired, as the resulting data files would have been too large for the data acquisition program.

A series of scans were made within a 1 in. by 1 in. (2.54 cm x 2.54 cm) region, unidirectionally. The encoder data was taken from the P-scan encoder data line, and the ultrasonic data was acquired synchronously by a separate, high-precision ultrasonic phase measurement system. The data comprised a rectangle of 0.96 in. by 0.82 in. (2.44 cm by 2.08 cm). The target was a 45 degree face, and the probe was a 1 MHz, 45 degree shear wave probe, KB-Aerotech S/N A24335, operated at 1 MHz. The Y-axis was measured on 100 excursions and the X-axis was measured 100 times at each point during one excursion. The data showed two kinds of aberrations: drift and jitter. The drift was a long-term excursion making one swing over the inch (2.5 cm) of travel, and the jitter consisted of short-term oscillations, making about 29 oscillations over 1 in. (2.5 cm) of travel. The total aberration was calculated to be 0.005 in. (0.13 mm) on each axis, of which 0.004 in. (0.1 mm) was due to drift and 0.001 in. (0.025 mm) was due to jitter. Figures 6.1 through 6.4 show the data for the Y-axis; the data for the X-axis is similar.

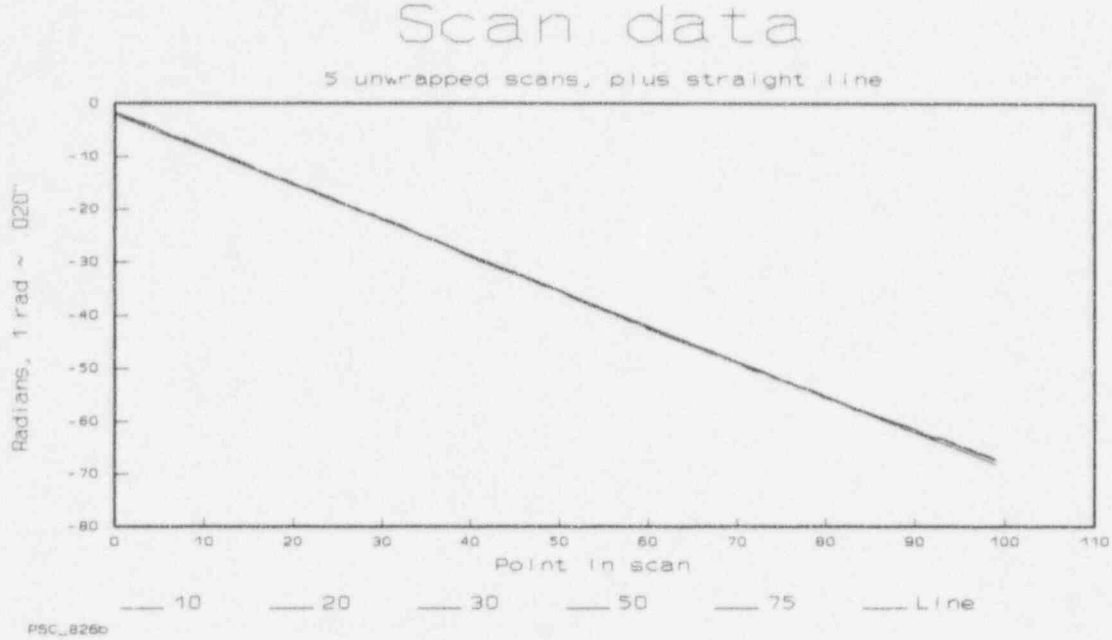


Figure 6.1 Time-of-flight data for P-scan scanner

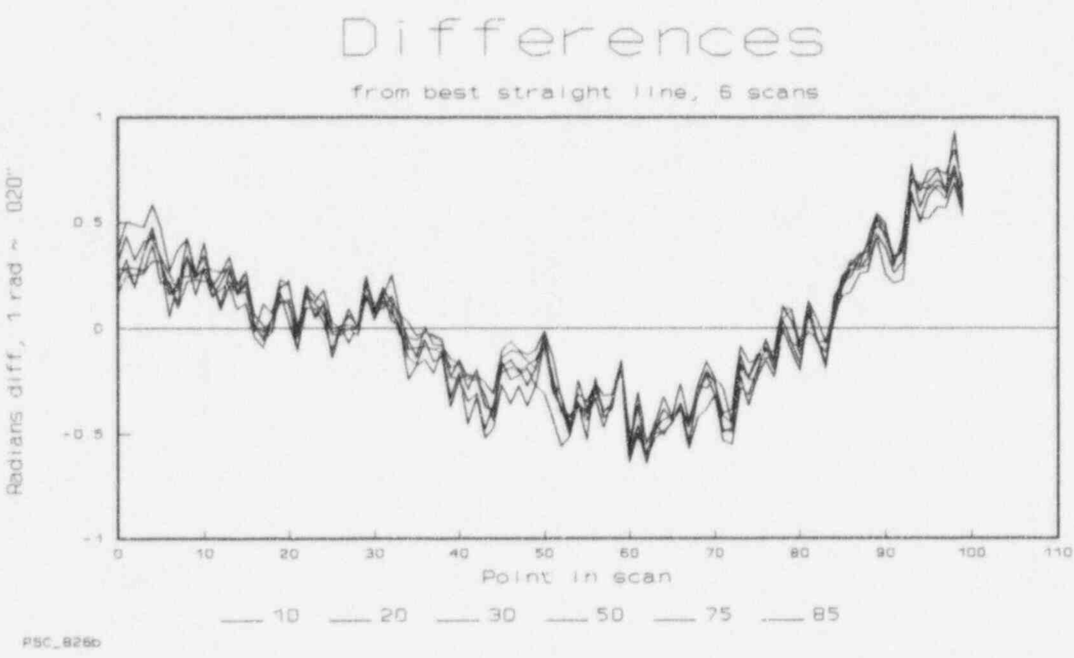


Figure 6.2 P-scan time-of-flight data: difference between data and best-fit straight line through data points

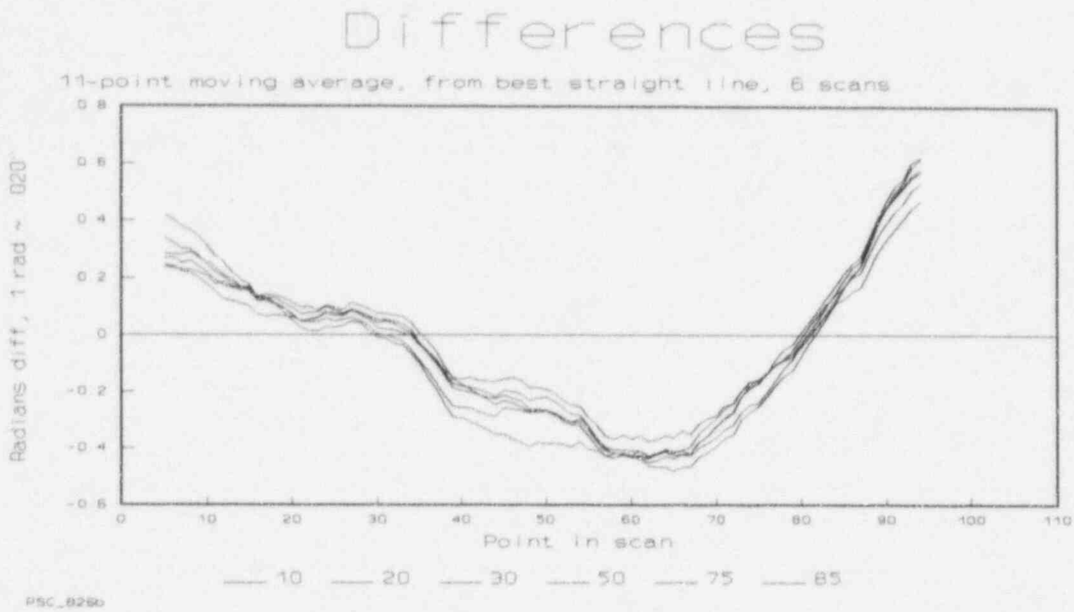


Figure 6.3 P-scan time-of-flight data: 11-point moving average of difference from straight line

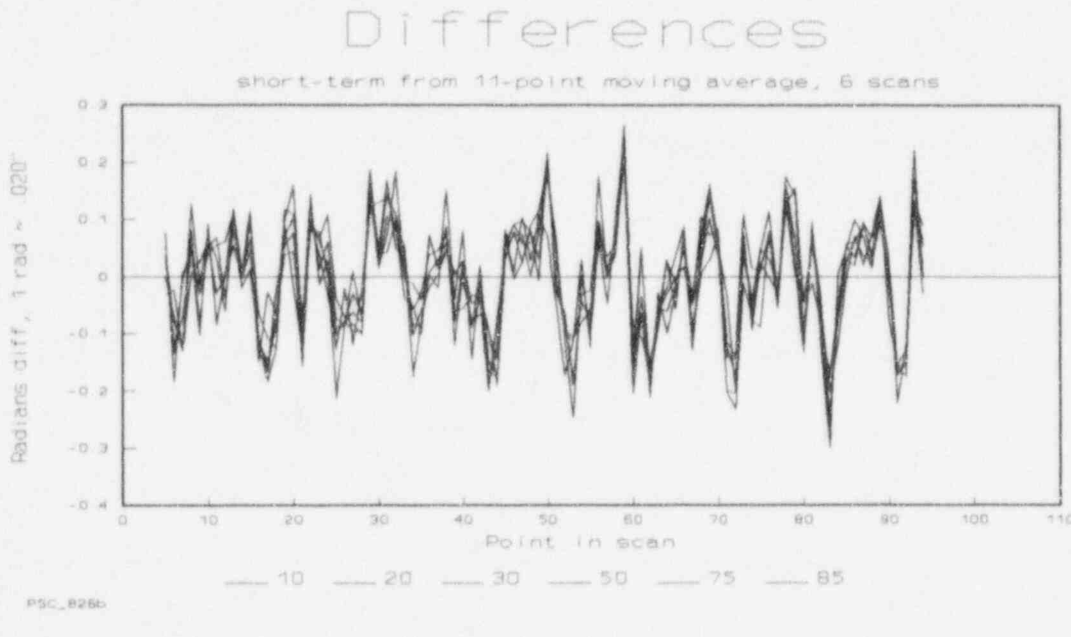


Figure 6.4 P-scan time-of-flight data: short-term noise, by subtraction of average difference from original difference

6.1.9 Positional Repeatability

Test for positional repeatability by starting the probe at a given distance from a reflector and recording the starting point on an oscilloscope display (a storage scope would be useful). Then, have the probe travel a path that should take it back to the starting marker. Perform the repeatability test at the default speed and at the fastest speed. Do this using (simultaneously or separately) all degrees of freedom that can legitimately be used during an inspection scan. Include a scan of an inclined surface with the scan moving to and from the surface by at least 1 rotation of the encoder. Record amplitude and time of ultrasonic signal before and after the excursion. Record amount of motion needed to restore original signal. Or, explain observations.

6.1.9.1 Repeatability

The amount of motion required to restore the original signal was zero as far as we could tell on an oscilloscope display.

There is more play than slippage. The scanner was able to travel several strokes in both the X and Y directions and then arrive close to the starting point without any considerable amount of drift. It was difficult to match the original X and Y coordinates read from the PSP-3 display with those after travel was completed. The thousandths of an inch (hundredths of a millimeter) were hard to match. Lightly tapping the Y-arm would cause fluctuations in the position readings.

6.1.9.2 Inclined Surface Scan

Include a scan of an inclined surface with the scanner moving to and from the surface by at least 1 rotation of the encoder.

Since there was no inclined surface available with sufficient travel, the scan was done in two portions. All scans were taken from left to right. The scans were done in T-scan mode. Figure 6.5 shows the result of the scans; the upper portion is the first set, and represents a little over one-half turn of the encoder. The encoder was rotated one-half turn and re-zeroed before the lower set was taken. Each color represents 0.3 in. (7.6 mm) of travel. The irregularities in the borders between colors are about one-third the length of the color band, or 0.1 in. (2.5 mm). This represents a combined effect due to probe fixture movement, positioning error, and encoder error.

6.2 Assurance of Positional Readings

6.2.1 Encoder Type

[ ] Linear
[X] Rotary
[ ] None

The manual states that the X encoder is an optical type with a resolution of 1/16 mm (0.0025 in.) and the Y encoder is an infinite resolution encoder. The Y encoder is a multi-turn potentiometer presumably with the same specifications as the MWS-2 manual scanner (i.e. infinite resolution, linearity of ± 0.25%). For the scanning axis (the Y-axis) a potentiometer is driven by a toothed belt. For the increment axis (the X-axis) an encoder is driven by a wheel resting on the part's surface. Data from both axes are transmitted to the scanner control unit as analog DC voltages.

6.2.2 Relative/Absolute

Are the position encoders relative or absolute?

X-axis:
Relative [X] Absolute [ ]

X-axis is relative (slippage is possible because a positional wheel encoder is used)

Y-axis:
Relative [ ] Absolute [X]

Y-axis is absolute - both a potentiometer and a servo motor are tied directly to a belt drive.

6.2.3 Encoder Location

Where are the encoders attached?

[ ] Motor
[X] Motion Axis

X-encoder is on a rubber friction wheel which can slip.

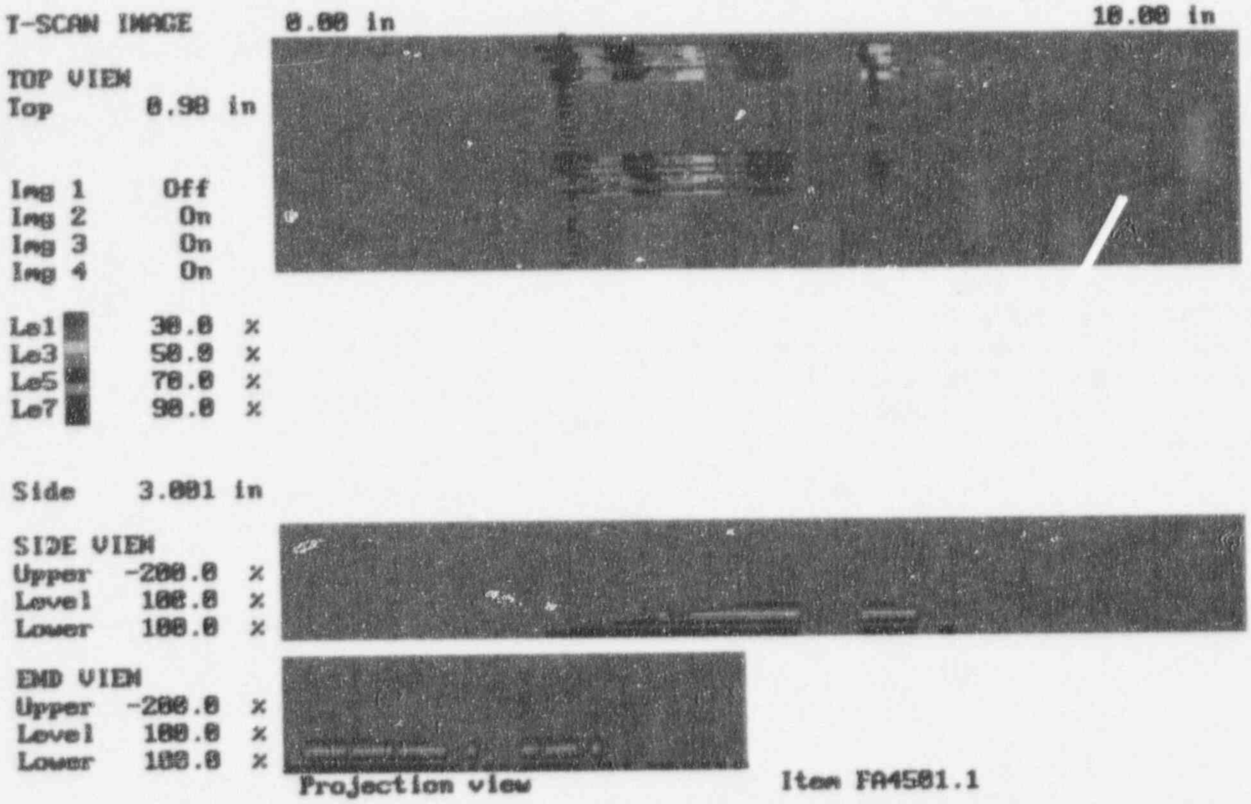


Figure 6.5 T-scan of inclined plane

The Y-axis is driven by a toothed belt which cannot slip and has a zero adjustment using a special calibration tool.

6.2.4 Drive Type

[ ] Stepper Motors
[X] Servo Motors
[ ] Hydraulics
[ ] Other (describe)

Both X- and Y-axes use DC servo motors, although the X movement is normally stepwise.

6.2.5 Position Feedback

[X] Open Loop
[ ] Closed Loop

Position at end of section must be manually verified. If the operator is considered to be included in the loop, the system is then a closed loop since the encoders always provide the actual position. Part coverage can be verified by viewing the image which is based on the encoder data. There is no feedback logic. There is no "go to" function provided by the system. In other words, the operator can't enter a specific (X,Y) point and command the system to position the probe there.

6.2.6 Backlash

How is backlash taken care of? If appropriate, record amount of backlash.

There is no provision for backlash.

For the X-axis: the system has an encoder wheel that is free-rolling and separate from the servo motor.

For the Y-axis: backlash is possible. By manually jiggling the scanning head in the Y-direction, backlash of approximately 0.004 in. (0.1 mm) was observed. Encoder backlash is not the relevant limiting factor. The backlash is mostly due to play in the fixturing. There is no option for unidirectional scanning. In stepping/scanning mode, data is always taken in the sequence: scan forward, step, scan backward, step.
We performed a test to measure the amount of backlash present and came up with the unreasonably large figure of 0.09 in. (2.3 mm). Upon further analysis, we came to the conclusion that the large amount of backlash was due primarily to the probe's skewing off normal due to play in the gimbal: the movement of the end of the beam was thus 0.09 in. (2.3 mm), but the movement of the center of pivot of the fixture may have been far smaller. An engineer at FORCE Institutes stated that the measured value is larger than the typical value for the scanner.

6.3 Mechanical Limits

6.3.1 Travel per Scan

What is the amount of travel that can be done in one scan? Determine this by operating the pipe and/or flat scanner through a series of test runs.

X-axis travel is limited only by the length of the control cable (25 meters). Y-axis travel is determined by the length of the Y-arm, which is available in lengths from 245 mm to 490 mm (10 in. to 19 in.). The minimum excursion of each scan line is 10 mm (0.4 in.), and the maximum is 100 mm (4 in.) less than the length of the Y-arm (145 mm to 390 mm, or 6 in. to 15 in.).

6.3.2 Travel Constraints

What limits the travel? (e.g. scanner structure, etc.)

The Y-axis travel is limited by the Y-arm length.
The X-axis travel is limited by the length of the control cable.

6.4 Speed Limits of Scan

6.4.1 Speed Setting

Does the operator have the ability to set the speed of the scans?

Yes [X] No [ ]

The operator is able to enter the speed in the Y-direction only, for stepping mode scans, and in both X and Y axes for continuous mode scans.

6.4.2 Speed Limits

What are the slowest and fastest speeds that the operator can enter?

6.4.2.1 X-axis:

Indexing speed is fixed. Continuous speed is variable from 1-25 mm/s (0.04-1.0 in./s) in increments of 1 mm/s (0.04 in./s; actual value is always in mm/s).

6.4.2.2 Y-axis:

Speed for Y-direction is approximately 5-250 mm/sec (0.2-9.8 in./s).

6.4.2.3 Multi-axis:

N/A

6.4.3 Speed Constraints

What limits the speed of the scans? (e.g. software or hardware)

Both the software and the hardware. The operator is able to enter a very high speed that will not work because of other factors such as repetition rate and sampling rate. The motors' maximum speed is about 250 mm/s. The maximum speed is far greater than the 6 in./s (152 mm/s) maximum permitted by ASME Section XI code. It is the responsibility of the operator to ensure that this speed is not exceeded, by not setting too high a speed on the scanner control unit.

6.4.4 Sampling Considerations

Is the default speed too slow, or can the speed be set too fast, for proper sampling?

6.4.4.1 Too Slow:

Yes [ ] No [X]

This is left up to operator discretion based on surface condition, couplant, etc.

Note: Y-speed can be adjusted at any time during a scan.

Note: Y-axis near and far positioning (start and end points for the stroke) can be adjusted at any time during a scan.

6.4.4.2 Too Fast:

Yes [X] No [ ]

In certain modes, the speed can be set to exceed the ultrasonic sampling rate (this potential problem may not occur in the new scanner controlled directly by the PSP-3). Figure 6.6 shows the result of setting the sampling rate too low for the scanning speed. The checkerboard effect shows the missing data elements. This scan corresponds to a factor of 20 to 70 less than the rate that the system would set automatically.

6.5 Scan Repetition

6.5.1 Scan Repetition Possibility

Does the possibility exist to repeat a scan for indication characterization?

Yes [X] No [ ]

6.5.2 Scan Repetition Method

How is a scan repeated? (e.g. using an absolute home)

Using a menu choice called subvolume which allows the user to select X, Y, and Z positions within the full volume. This gives a higher resolution scan than the full-volume scan. An example of this is shown in Section 9.6, Figure 9.4.

There is an optional trip-switch feature available to use as an absolute home.

6.5.3 Rescan Integration

If a rescan is performed, can the new data be seamlessly integrated into the previous data?

Yes [ ] No [ ] Sometimes [X]

Sometimes. If the new data is taken in the usual P-scan imaging mode, at the same resolution as before, and in the original data set, then the data becomes part of the original set. A subvolume scan is an entirely separate file and is not integrated in any way with the original data.

6.5.4 Rescan Scope

[X] Any subset of previously inspected volume
[ ] Only previously defined subsections
[ ] Must rescan entire section

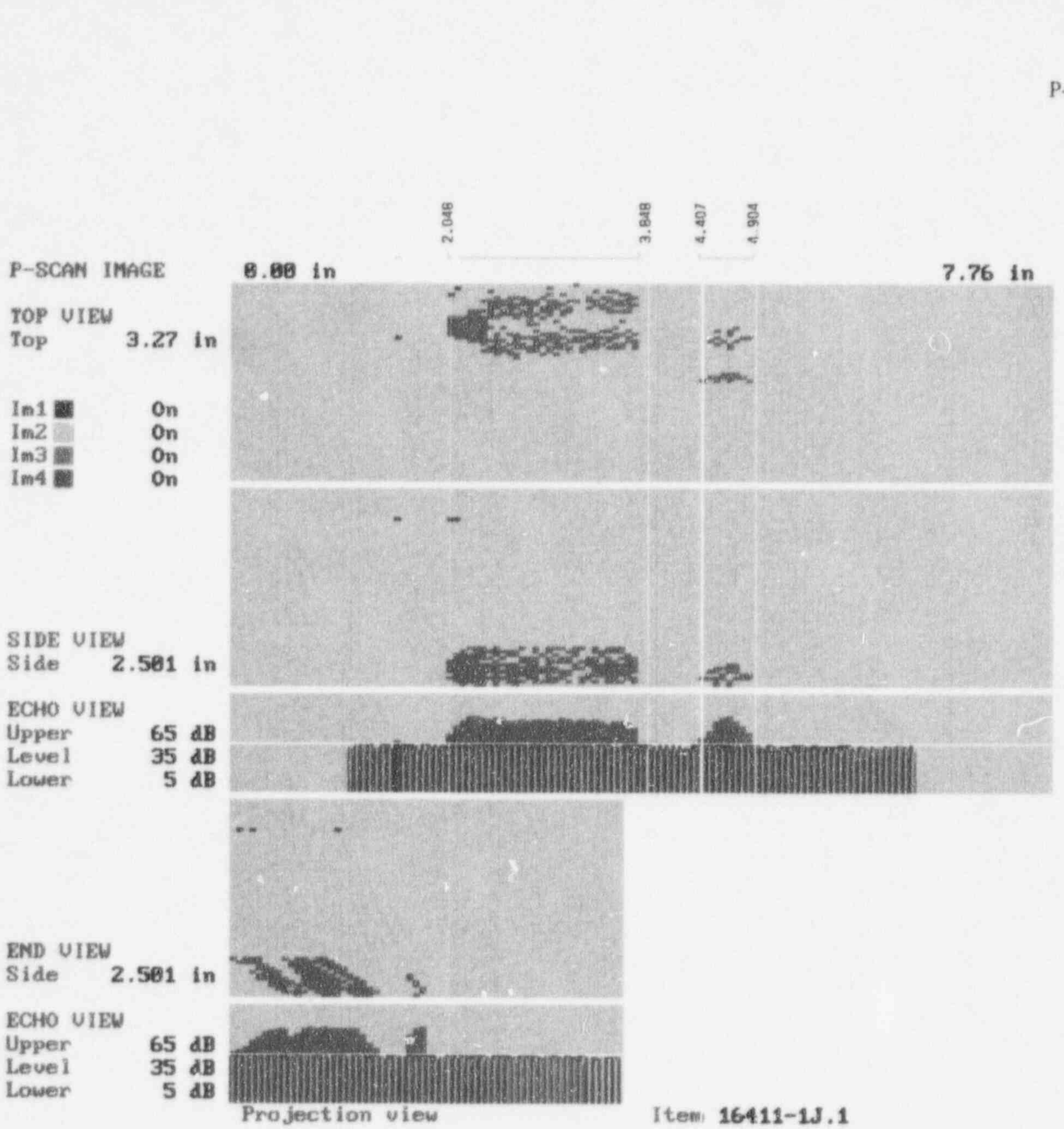


Figure 6.6 P-scan image showing effect of too low a repetition rate

7.0 Ultrasonic Measurements

7.1 Dynamic Range (dB)

120 dB nominal.

The measured dynamic range was 104 dB. This was done using asynchronous square waves at 0.6 and 0.8 MHz, an external oscilloscope, and an attenuator. An engineer at FORCE Institutes stated that the amplifier is not designed for continuous wave signals, and that using a tone-burst the measured dynamic range will be measured as 115 to 120 dB. There appears to be between 2 and 6 dB of noise on the baseline. A logarithmic amplifier is used and it appears to have an auto-ranging capability: when a large signal was input and was increased to nearly full scale, the displayed amplitude suddenly dropped by about 20 dB. No tests were performed to see whether this could ever lead to a sudden drop in sensitivity during inspection. An engineer at FORCE Institutes stated that large continuous-wave signals result in saturation effects; thus, the observed effect would not arise in pulse-echo testing.

7.2 Resolution Blocks

Scanning of the resolution blocks is performed to show imaging of standard targets. It also measures resolution obtained under less-than-ideal conditions. The standard probes used are not focused probes, so the lateral resolution is not the best that the system is capable of, unless the system has image processing options such as SAFT or holography, in which case the images provide a test of the processing options.

The geometry and purpose of the resolution blocks are described in detail in Section 7 (Ultrasonic Measurements) of Appendix A of the Introduction to NUREG/CR-

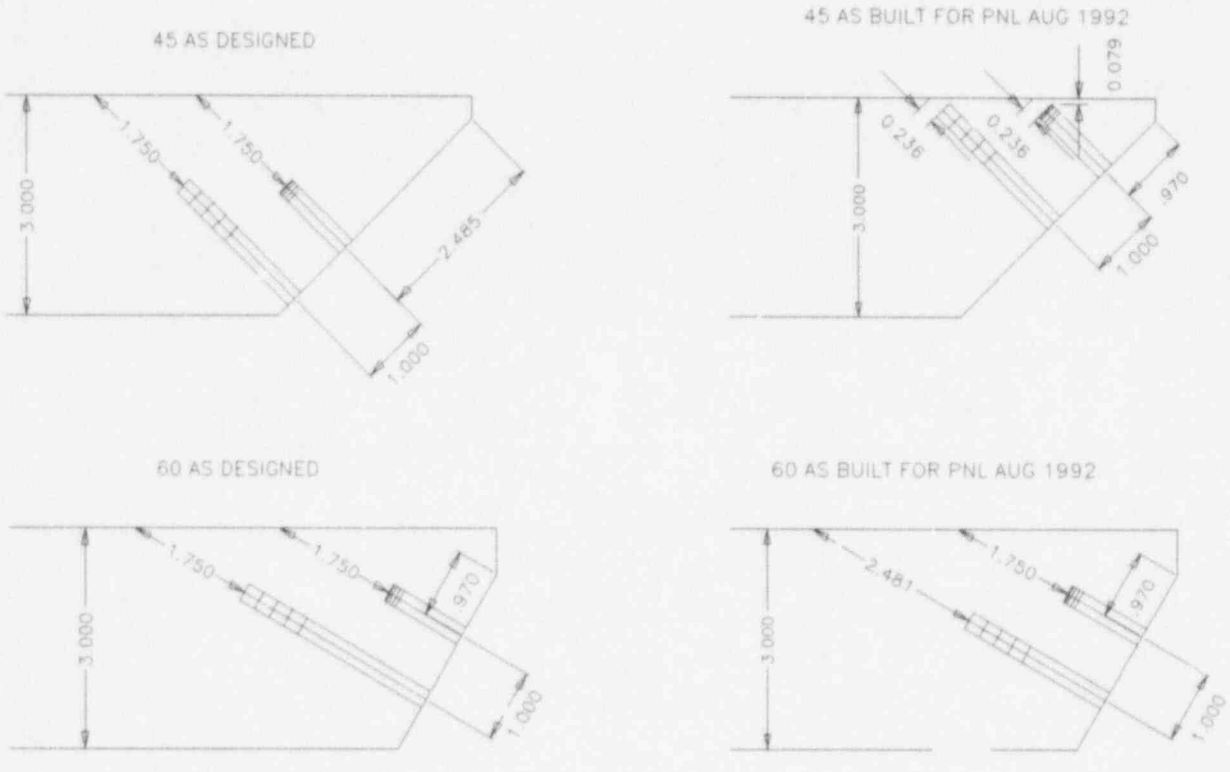


Figure 7.1 45° and 60° depth resolution faces of UT-RES-4560-2

5985. However, due to an error in the instructions provided to the machinist at PNL, the depth-resolution faces of the angle-beam block (UT-RES-4560-2) differ slightly from the specifications, as shown in Figure 7.1. In brief, the 45° holes were drilled too close to the edge of the block, and one row of 60° holes was not drilled deep enough. Since these anomalies do not affect the purpose of the block, and time for the study project was very short, the block was used as is.

7.2.1 Lateral Resolution

Measure the lateral resolution by using the standard test blocks. The lateral resolution is defined as the minimum separation between targets that results in a signal drop of at least 6 dB below the peak amplitude of the weaker target.

7.2.1.1 0 Degree Longitudinal

0.125-in. (3.17-mm) separation at 6 dB between edges of 0.250-in. (6.35-mm) holes, using a 5 MHz, 0.5-in. (13-mm) probe with 6 dB bandwidth of 56% (KBA S/N G05167).

Figure 7.2 shows an image of UT-RES-0000 (see Appendix A, Figure A.1 and Table A.1 or A.2). Hole Y is at lower left, hole J at upper right. The closely-spaced column of five pairs of indications at right are (top to bottom) holes J, I, H, G, F. The probe was not well coupled during the scan over the center of the holes, resulting in a very low amplitude. The two pairs to the left of J and I are E and D, likewise with a poorly-coupled scan along the center. The cluster of indications comprises holes Q through U. It is seen that holes N and O are separated by white space. The distances between centers of these holes is 0.375 in., and subtracting the radius of each (0.125 in. + 0.125 in. = 0.250 in.), the separation of edges is found to be 0.125 in. (in millimeters, the center separation is 9.52 mm, the two radii total 6.35 mm, and the edge separation is therefore 3.17

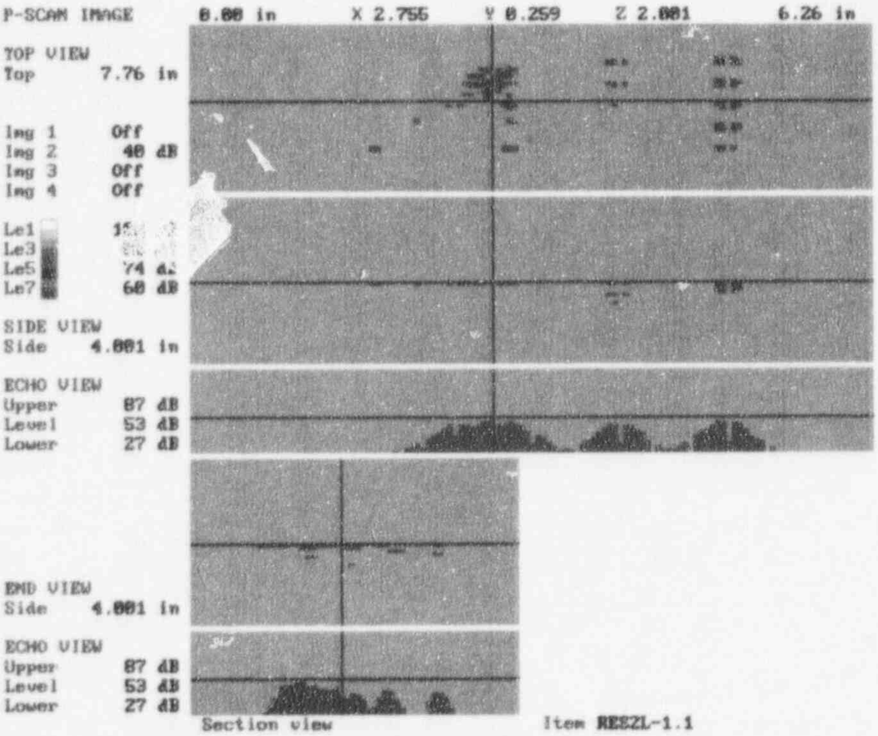


Figure 7.2 P-scan image of Resolution Block UT-RES-0000-2: 6 dB separation (blue areas are within 6 dB of peak; gray areas are more than 6 dB below peak)

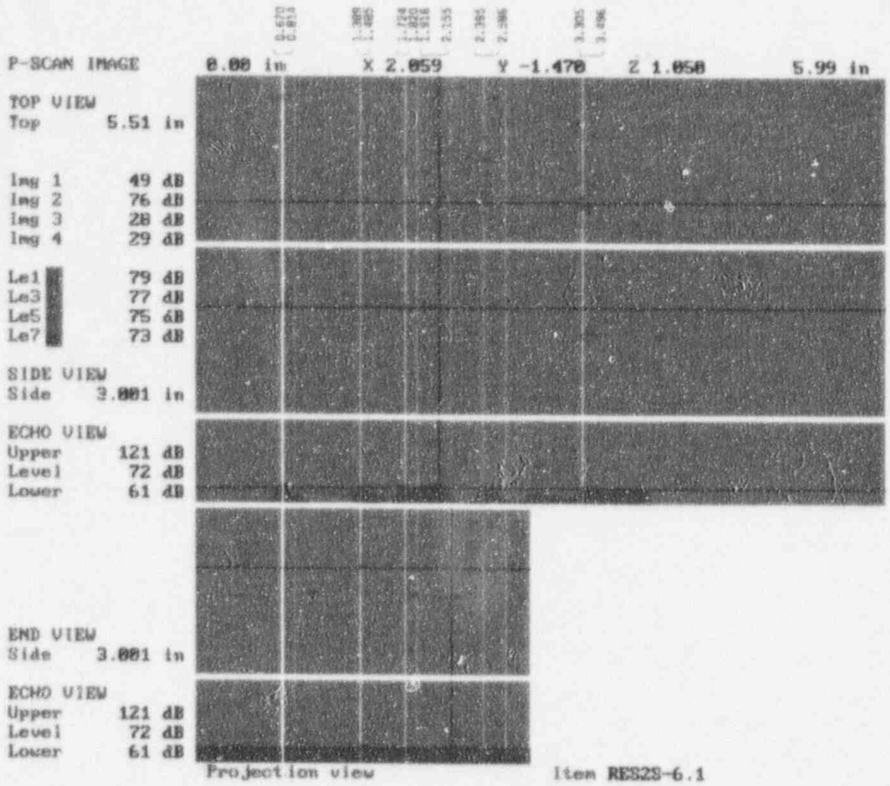


Figure 7.3 P-scan image of 45° lateral-resolution face of Resolution Block UT-RES-4560-2: 6 dB separation (blue areas are within 6 dB of peak; gray areas more than 6 dB below peak)

mm). The image was examined on-line using the PC-PROG post-inspection software to ascertain these results.

7.2.1.2 45 Degree Shear

0.063-in. (1.6-mm) separation at 6 dB between edges of 0.250-in. (6.35-mm) holes, using a 5-MHz, 0.25-in. (6-mm) probe with 6 dB bandwidth of 48% (KBA S/N D23411), mounted on a 45° refracted angle wedge.

Figure 7.3 shows an image of the 45° lateral-resolution face of UT-RES-4560-2. Holes Y through S curve in from top left to center, and holes K through R are in a column just to the right of hole S. The column farther to the right is a secondary reflection.The apparent separation between holes Q and R is an anomaly; holes O and P are the last resolved pair.

7.2.1.3 60 Degree Shear

0.063-in. (1.6-mm) separation at 6 dB between edges of 0.250-in. (6.35-mm) holes, using a 5-MHz, 0.25-in. (6-mm) probe with 6 dB bandwidth of 48% (KBA S/N D23411), mounted on a 60° refracted angle wedge.

Figure 7.4 shows an image of the 60° lateral-resolution face of UT-RES-4560-2. The orientation is the same as Figure 7.3. Note that again, the separations between P, Q and R are illusory, and the closest resolved pair is O and P.

7.2.2 Depth Measurement

Measure the depth resolution (0°) and verify depth and metal travel measurements (45° and 60°) by using the standard test blocks.

The depth resolution of the system is at least as high as the depth resolution of the test blocks. The minimum separation of target depths in the blocks is 0.023 in. (0.6 mm); this difference was easily resolved and correctly measured by the system. T-scan images are theoretically capable of resolution to the limit of the sampling rate of 32 MHz, which is equivalent to 0.004-in. depth (0.09-

P-scan

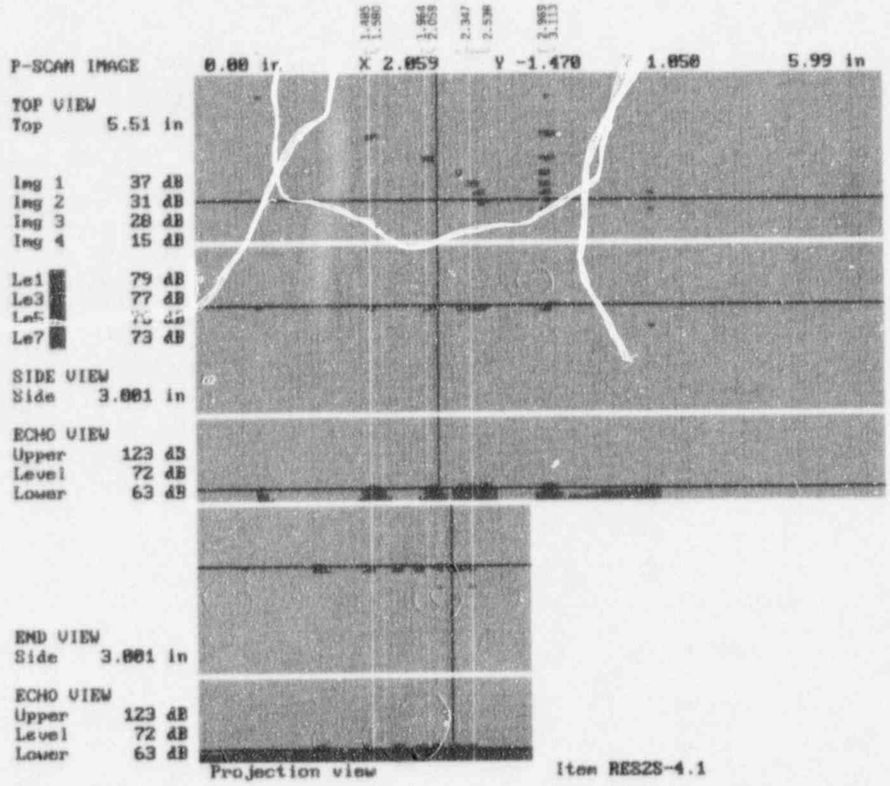


Figure 7.4 P-scan image of 60° lateral-resolution face of Resolution Block UT-RES-4560-2, showing 6dB separation (blue areas are within 6dB of peak; gray areas are more than 6dB below peak).

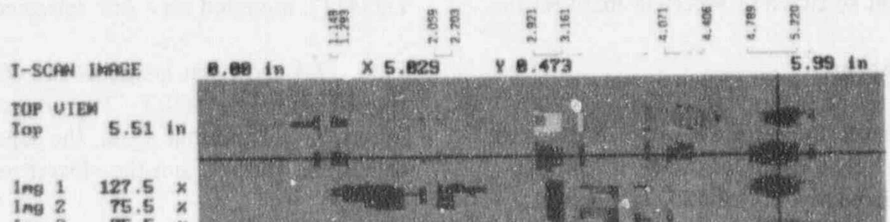


Figure 7.5 T-scan image of Resolution Block UT-RES-0000-2, depth resolution holes

mm) for longitudinal waves and 0.002 in. (0.05 mm) along the sound beam direction for shear waves; this was not verified experimentally. For very thick samples, the useful resolution is limited by the three-digit precision of the post-processing program display, to 0.001 times the thickness range of interest; e.g., if the part thickness is 10 in. (25 cm), the resolution is 0.010 in. (0.025 cm), simply because the thickness discrimination ranges are specified in percentages of part thickness, to tenths of a percent.

7.2.2.1 0 Degrees

Figure 7.5 shows test block UT-RES-0000. Hole J is at upper left and hole F at upper right. The depth scale is non-linear; the colors are selected to differentiate among the five fine-resolution holes and most of the coarse-resolution holes. With eight colors it is not possibie to show all ten holes in different colors on the same image. Figure 7.6 shows the color scale used for Figure 7.5.

LEVEL, Scale and Range   Setup.1

Item: RES2L-1T.1   Images: 1 2 3 4

Color	Scale		Thickness %	Range	Area %
LEV 1		<	53.0	.....	10.5
LEV 2		<	54.0	1.0	3.0
LEV 3		<	55.0	1.0	1.0
LEV 4		<	56.0	1.0	1.5
LEV 5		<	57.0	1.0	1.1
LEV 6		<	60.0	3.0	0.0
LEV 7		<	75.0	15.0	1.3
LEV 8		<	80.0	5.0	2.0
BGIMG		≥	98.5	.....	78.7
BASIS			80.0	.....	78.7
Basis area			7038 of 35000		20.1

Min value	52.0 %
Mean value	92.6 %
Max value	103.0 %
Deviation	19.2 %

Figure 7.6 Color scale for Figure 7.5

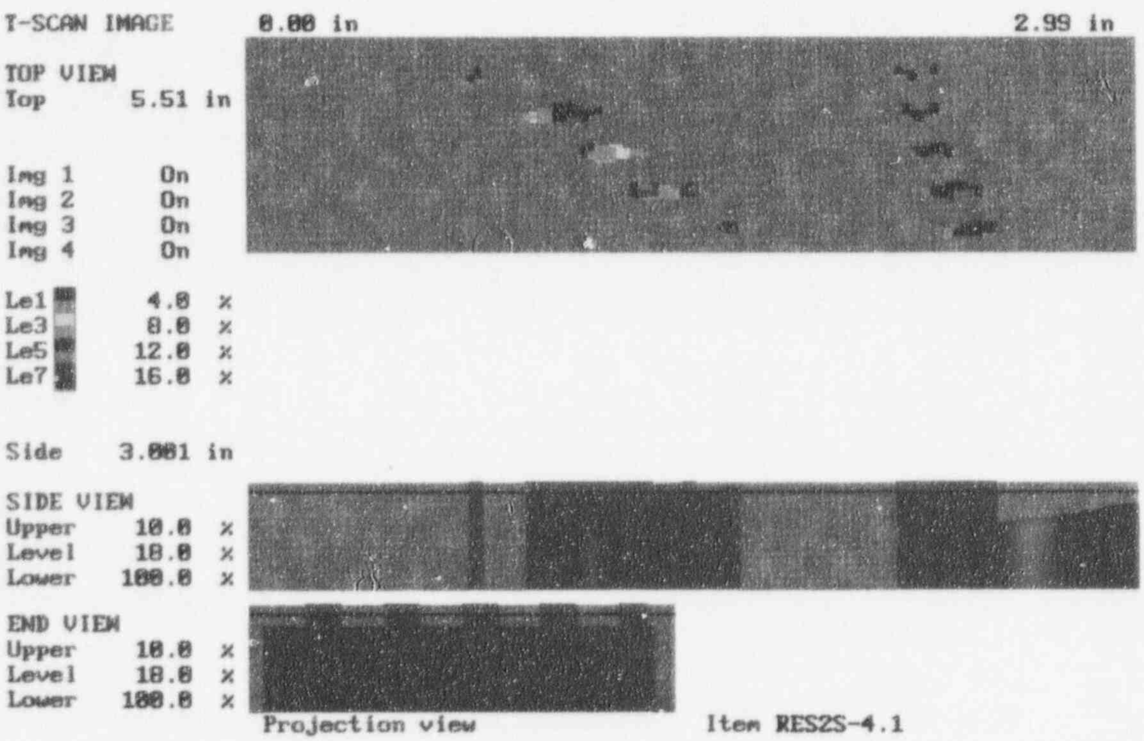


Figure 7.7 T-scan image of 45° depth-resolution face of Resolution Block UT-RES-4560-2

P-scan

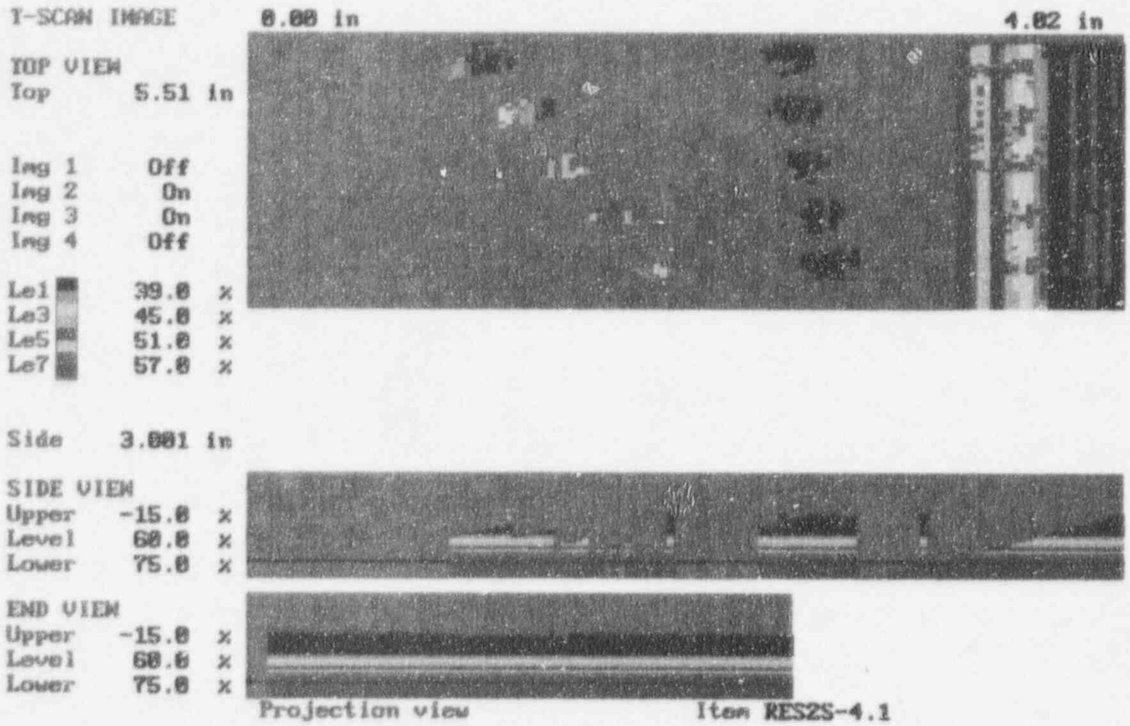


Figure 7.8 T-scan image of 60° depth-resolution face of Resolution Block UT-RES-4560-2

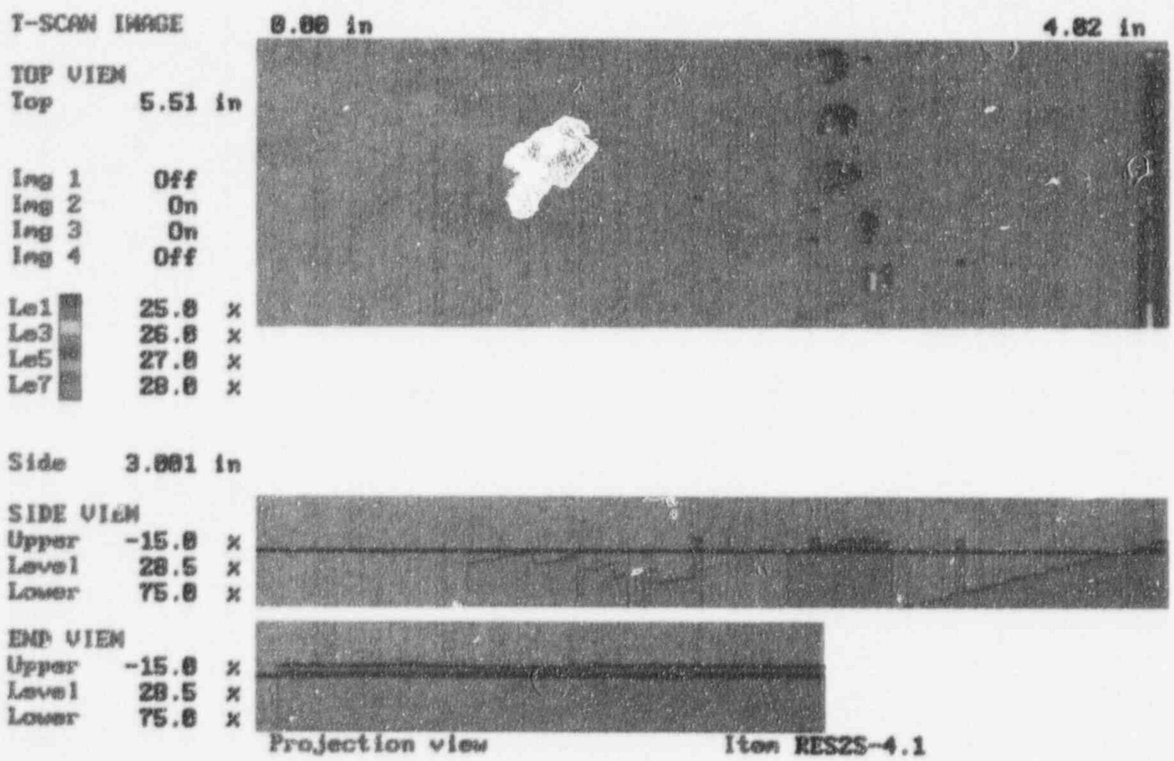


Figure 7.9 T-scan image of 60° depth-resolution face of Resolution Block UT-RES-4560-2, fine holes only

7.2.2.2 45 Degrees

Figure 7.7 shows the 45-degree depth resolution face of UT-RES-4560. Hole F is at upper left, hole A at upper right. The colors are assigned to discriminate among the coarse-resolution holes.

7.2.2.3 60 Degrees

Figure 7.8 shows the 60-degree depth resolution face of UT-RES-4560. Hole F is at upper left, hole A at upper right. The colors are assigned to discriminate among the coarse-resolution holes. Figure 7.9 shows the same data, with the colors chosen to discriminate among the fine-resolution holes. Note that in both cases, the deepest portion of one hole is in the same depth range as the shallowest portion of the next hole, so that there is color overlap between discriminated holes, and holes do not have a unique color. In Figure 7.9, since the scale used is linear and very fine, all of the coarse-resolution holes are out of range of the color scale, and appear in background color. Their presence can still be noted on the Side View.

7.3 Repeatability Block

Report the results from scanning repeatability test block UT-RPT-CIRC-1.

The repeatability block UT-RPT-CIRC-1 used for the P-scan evaluation was not identical to the generic description of UT-RPT-CIRC given in NUREG/CR-5985 Appendix A. Figures 7.10 through 7.13 show the actual configuration.

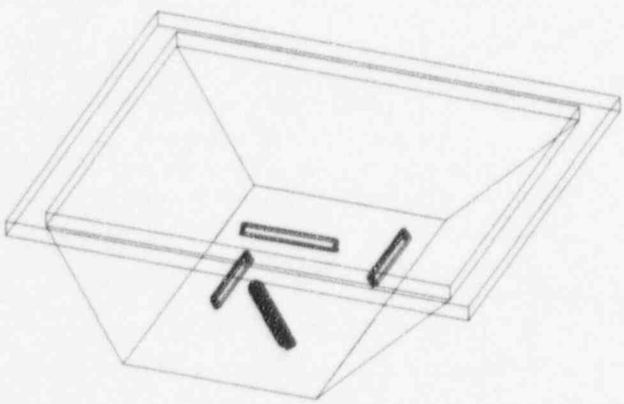


Figure 7.10 UT-RPT-CIRC-1, 3-D view

Figure 7.11 UT-RPT-CIRC-1 B-scan view

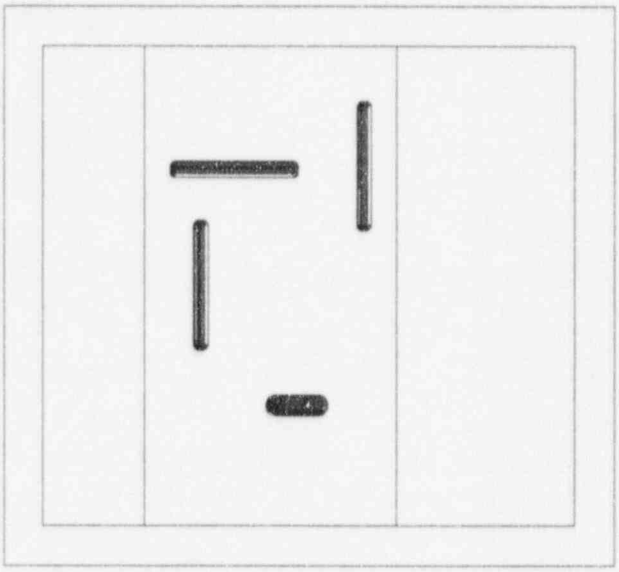


Figure 7.12 UT-RPT-CIRC, C-scan view

The results concerning repeatability are presented in Section 6.1.9. The emphasis here is on the imaging of the block. Figures 7.14, 7.15, and 7.16 are taken at

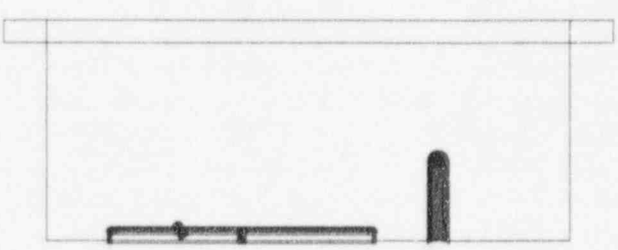


Figure 7.13 UT-RPT-CIRC-1, B-scan end view

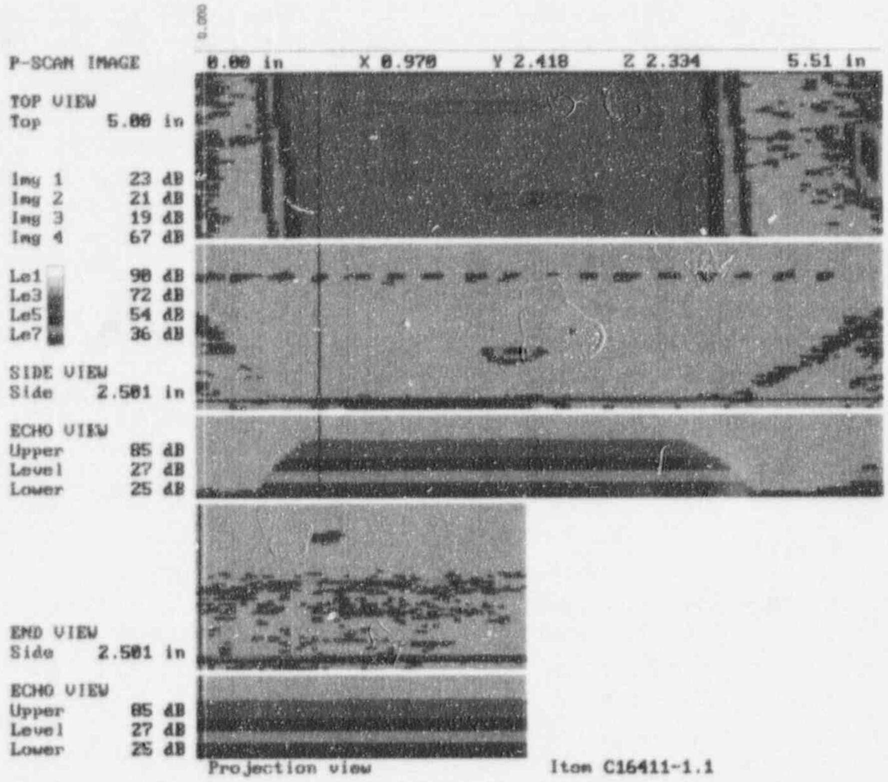


Figure 7.14 P-scan loss-of-backface image of repeatability block UT-RPT-CIRC-1, at normal incidence

normal incidence. The TOP VIEWs are in the same orientation as Figure 7.12, the SIDE VIEWs as Figure 7.11, and the END VIEWs as Figure 7.13. Figure 7.14 clearly shows the layout of the block (note that Figure 7.14 is almost the same as Figure 5.5, except for the cursor position and being a Projection view rather than a Section view). In the TOP VIEW, the four targets show up in outline, due to contrast between the high amplitude of the backwall echo and the lower amplitude reflections from the machined targets. In the SIDE VIEW, the outline of the block is clearly discernible due to noise from the front and edges, and the spherical-tipped hole shows up clearly; the upside-down appearance of the tip is an artifact due to the amplitude pattern of the echo. The ECHO VIEW of the SIDE VIEW shows the bottom of the block as high amplitude, and the angled ends as low amplitude. The END VIEW is too cluttered with noise to give useful information. Figure 7.15 shows the reflections from the targets in the block at a scan index of 0.4 mm (0.016 in.). In the TOP VIEW, note that the object in the lower right appears only as a circle now; this is the spherical tip of a hole drilled at a 45° angle. The other three objects are cylindrical grooves in the bottom of the block; for some reason the one in the upper right is poorly imaged. In the SIDE VIEW the spherical tip shows up clearly, as do the grooves, although the two on the left cannot be distinguished from each other. The END VIEW now clearly shows the grooves (lower left), the hole (center right) and a machining gouge across the center of one face (center; also visible at far right in the TOP and SIDE views).

A comparison of Figure 7.15 and Figure 7.16 shows how use of a small index hides the backlash in the probe motion. In Figure 7.15, no backlash is apparent because each scan line in the image contains data from at least two adjacent scan lines of motion, which are by definition taken in opposite directions. Since the largest data is kept, the backlash is hidden, and the objects appear slightly larger than true size, by the amount of backlash. Figure 7.16 shows the same scan as Figure 7.15 but with a scan index of 1.0 mm (0.040 in.). In this image, because of the larger index, the backlash shows up clearly as jagged edges in the TOP and SIDE views.

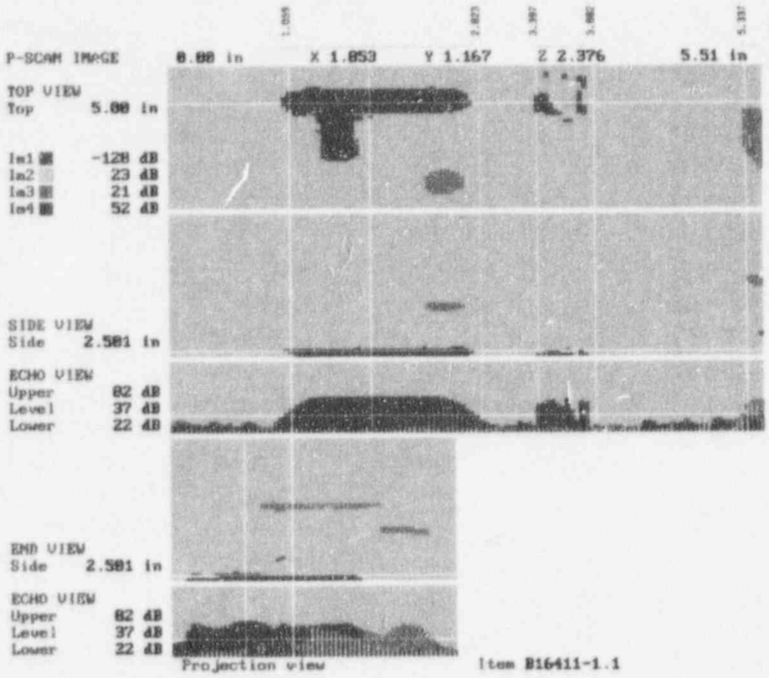


Figure 7.15 P-scan image of repeatability block UT-RPT-CIRC-1, at normal incidence, with scan increments finer than image resolution, so backlash is hidden

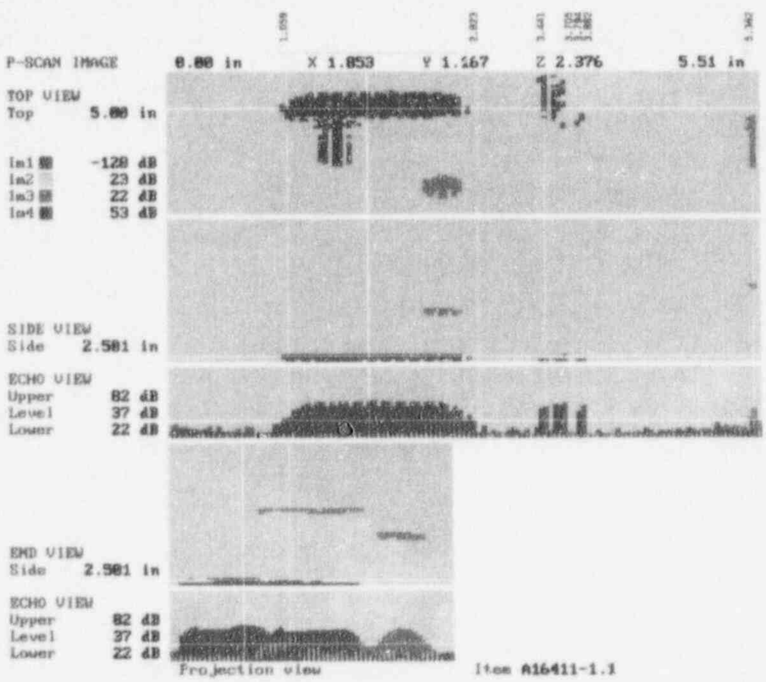


Figure 7.16 P-scan image of repeatability block UT-RPT-CIRC-1, normal incidence: backlash (ragged edges at top and bottom of object at upper left)

7.4 Field Procedure for Measurements

How accurate is the field procedure for measuring depth or length?

N/A (There are no specific written procedures, except that the operator be EPRI qualified to operate the equipment).

7.5 Procedure Review

Describe any procedural elements (calibration, examination, evaluation, etc.) that should be specifically addressed in field procedures for this equipment.

Special attention should be paid to ensuring that the settings recorded in the computer for physical scanning parameters, correspond to the actual settings made on the scanner control unit. This should preferably be documented with a photograph of the scanner control unit front face.

7.6 Test Specimens

Follow the calibration procedure to scan piping, flat plate, or other appropriate test specimens so that the data output for known specimens may be reported.

The resolution block scans have been presented and described in other sections. Three other specimens scanned were a pipe with saw cuts, a pipe with artificially induced cracks, and a Y-pattern test block.

7.6.1 The first pipe specimen, B216, has 7 saw-cut notches adjacent to a weld. A drawing of the pipe specimen is shown in Figure 7.17, and a P-scan image of it in Figure 7.18. Figure 7.17 shows construction details of the pipe, and includes a drawing of the true curvature of the pipe and a scale. In Figure 7.18, note that the top view shows each saw cut as an elongated disk. This is because most of the signal is from a double reflection ("corner reflection") from the saw cut and the pipe surface. Apparently the wedge delay and beam angle were not specified accurately, as the highest-amplitude part of the reflection should be at the inside of the pipe: in the SIDE and END views, the images of the saw cuts are all seen to be shifted toward the outside of the pipe.

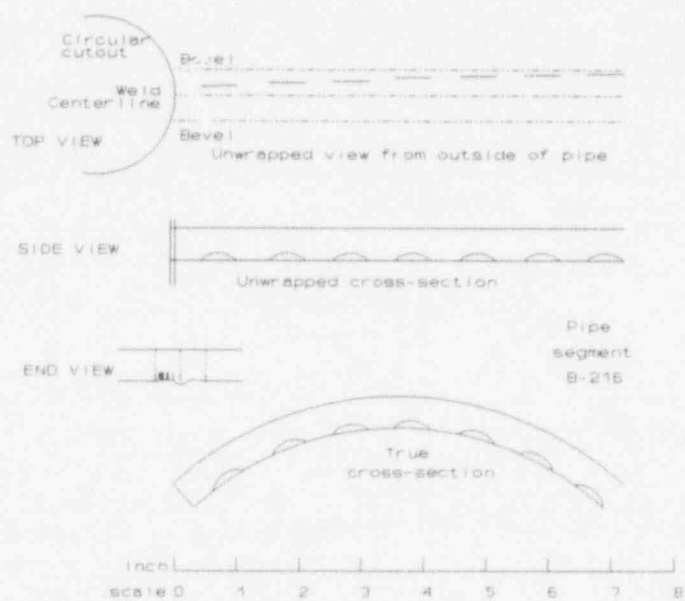


Figure 7.17 Drawing of pipe section B-216, with TOP, SIDE, and END views arranged like P-scan views. Note that the SIDE VIEW is from the side of the weld but the end of the pipe, and vice versa.

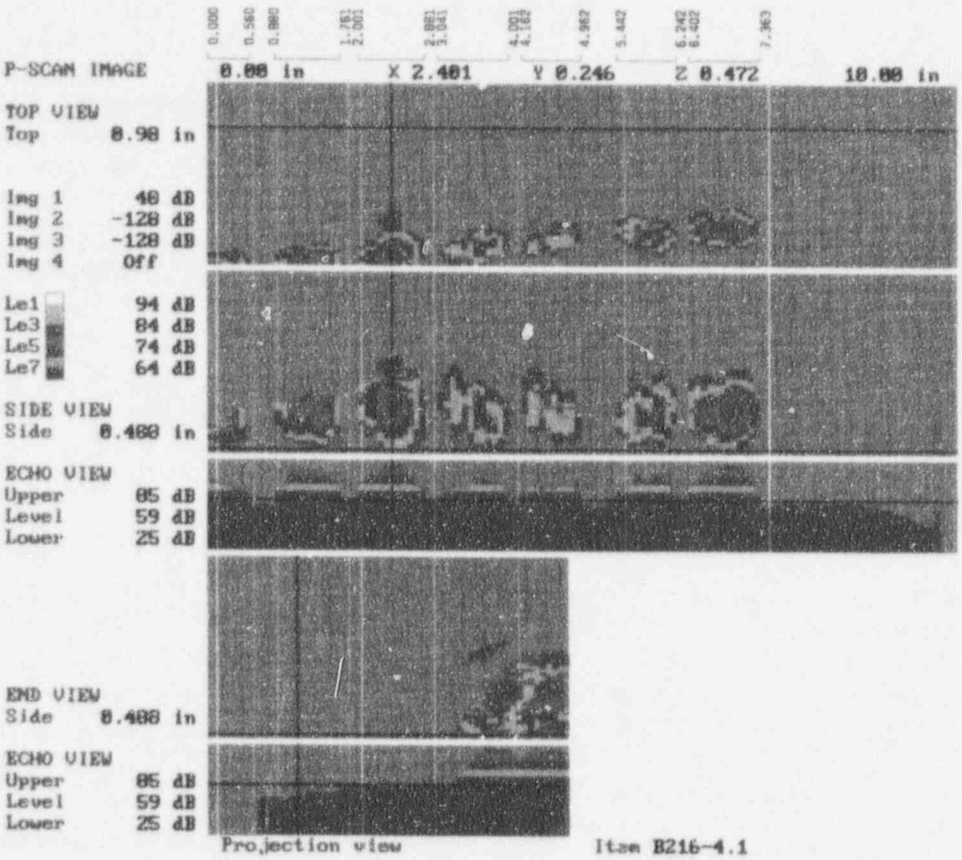


Figure 7.18 P-scan image of pipe specimen B-216 (7 saw cuts)

The left-most saw cut is only partly imaged because of difficulty scanning so close to the circular cutout. The third saw cut from the left shows an extra image above it, clearly visible in the END VIEW as a separate reflection. This is probably a signal from the tip of the saw cut, which is earlier in time than the corner reflection, and therefore appears closer to the probe. Note also that the end view shows the composite projection of the saw cuts at an angle, even though the saw cuts are actually perpendicular to the surface of the pipe. This is because the image is created by assuming the beam to be a narrow "pencil" beam, whereas it is really a wide beam whose shape depends on the characteristics of the probe and depth of the target; this effect is common to many ultrasonic imaging systems when using angle-beam inspection. Note the differences in scale of the TOP VIEW, SIDE VIEW, and END VIEW. In the TOP VIEW, the ratio of the Y-axis scale to the X-axis scale is 2.5:1; in the SIDE VIEW, the ratio of the Z-axis scale to the X-axis scale is 5:1; and in the END VIEW, the ratio of the Z-axis scale to the Y-axis scale is 1:1. Also, the Y-axis scale in the END VIEW is twice the Y-axis scale in the TOP VIEW. The effect of the 5:1 distortion of the SIDE VIEW is shown schematically in Figure 7.19.

Figure 7.20 shows a reproduction of a set of nine subsection scans of the same specimen B-216, all printed together. The image has been reduced by 50% to fit on a fold-out page; the original covers five pages. This image shows how large pipes (or small ones, as in this instance) can be scanned in subsections ("parts") with P-scan. The method of doing this is to specify that the surface to be scanned consists of a number of "parts" of a specified length. The system then automatically pauses at the end of each "part" and saves it in a separate file. After the inspection, each "part" may be viewed and plotted separately. The "parts" may also be plotted contiguously as in Figure 7.20.

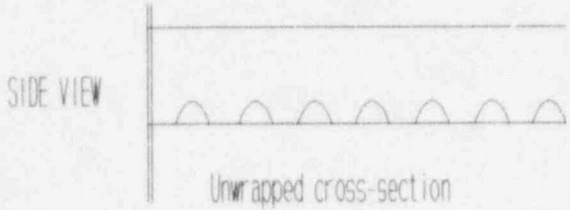


Figure 7.19 Five to one distortion of saw cuts in pipe B-216

Figure 7.20 also shows tip diffraction signals for several saw-cuts. These are visible as separate areas of red in the end views, because the data for each subsection is projected only over the subsection ("part") rather than over the entire inspected zone as in Figure 7.18.

7.6.2 The second pipe specimen is a 10-in. (254-mm) diameter pipe with 0.360-in. (9-mm) wall. It contains two saw cuts and a large crack, all emanating from the inner surface. The crack is the smallish yellow-orange indication just left of center in Figure 7.21. The large red indication is one of the saw cuts; the other saw cut shows up as three small blue and green indications at the left side of the image, slightly lower than the other saw cut; evidently it is in the weld metal and little sound reaches it.

7.6.3 The Y-pattern test block image is shown in Figure 7.22, along with a drawing of the hole positions. The apparent separation of the hole on the right is an anomaly, since the right-hand holes are actually more closely spaced than the others. The Y-shape appears as a shadow in the back-echo signal to the right of the reflected signal.

7.7 In-Place Calibration

Is there a mechanism for in-place calibration reference checks?

[X] Yes
[ ] No

Full calibration is done with all cables in place.
The system is capable of performing reference checks while in-place by using reference blocks. It is also able to perform system software checks (PSP-3) anytime under inspection conditions. Encoder scale factors can be adjusted in place, as noted under encoder descriptions.

7.8 Probe Characteristics, per ASTM E-1065

List and characterize, according to ASTM E-1065, the center frequency and bandwidth of all ultrasonic probes used in the review, whether provided with the system or supplied by PNL.

KB-Aerotech Gamma 1.0 MHz, 0.5-in. (12.7-mm) diameter, S/N A24335, mounted on 45° shear angle acrylic shoe: center frequency = 1.13 MHz, bandwidth = 44.2% at -6 dB

KB-Aerotech Alpha 5.0 MHz, 0.25-in. (6.35-mm) diameter, 18040, S/N G05167: center frequency = 4.69 MHz, bandwidth = 56.1% at -6 dB

KBI (owned by Siemens), 4 MHz, 8 mm x 9 mm (0.32 in. x 0.35 in.), 45°, S/N 56927-07975: center frequency = 4.06 MHz, bandwidth = 40.1% at -6 dB

KB-Aerotech Gamma, 5 MHz, 0.25-in. (6.35-mm) diameter, S/N D23411, mounted on acrylic shoe: center frequency = 4.63 MHz, bandwidth = 47.6% at -6 dB

7.9 Number of Channels

7.9.1 Number of Channels

What is the number of channels used by the system?

1 to 4 channels for 4 single-element probes or 2 pitch/catch probes or any combination of these

7.9.2 Non-functional Channel Response

How does the system respond to non-functional channels?

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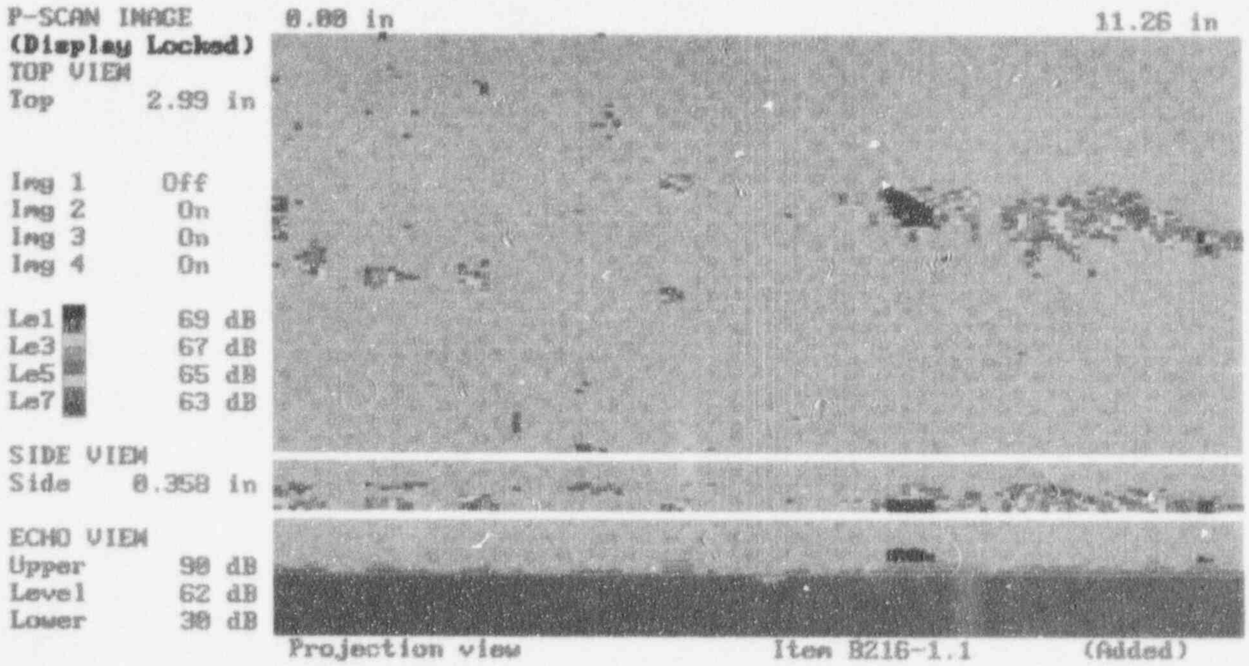


Figure 7.21 P-scan image of cracked pipe specimen

The system responds to non-functional channels by displaying a code on the PSP-3. Some of the codes are:

- Low power for the PSP-3 module (the PSP-3 can run on battery for 6-8 hours)
- X and Y positional data lost by causes such as hitting obstructions, slippage due to gravity forcing the scanner to move quicker than it should, etc.
- Storage media full

If the operator sets up the PSP-3 to function with more than one channel and only one probe is connected, there is no way for the PSP-3 to tell that the second probe is not connected. The operator would need to recognize that no A-scan is present and that no data is being collected on the missing channel. Moving cursors are displayed for X and Y axes while scanning (top, side, end, and echo views).

Figure 7.23 shows a screen dump of the PSP-3 screen, made by the PSP-3 printer, while a scan is in progress. Note that the right-most half of the ECHO box is empty; this shows that only part of the scan has been completed (it always fills from left to right). Also note the small dots just outside the frames of the ECHO, END, TOP, and SIDE views. These dots move with the scanner as the scan progresses, which helps the operator visualize the inspection process. Figure 7.24 shows printouts that occur automatically in case of system problems. The screen displays the error message in a reserved area, but each message is replaced by the succeeding one. The printed record enables the operator to see multiple or repeated errors.

7.9.3 Software Checks

Are there software checks to ensure that all necessary data is taken?

The system stops scanning and displays an error message when an error occurs (including when a channel is lost). The image background is zero in areas where no data was taken. The previous section discusses this, and an example of missing data, resulting from specifying excessive scan speed at insufficient repetition rate, is

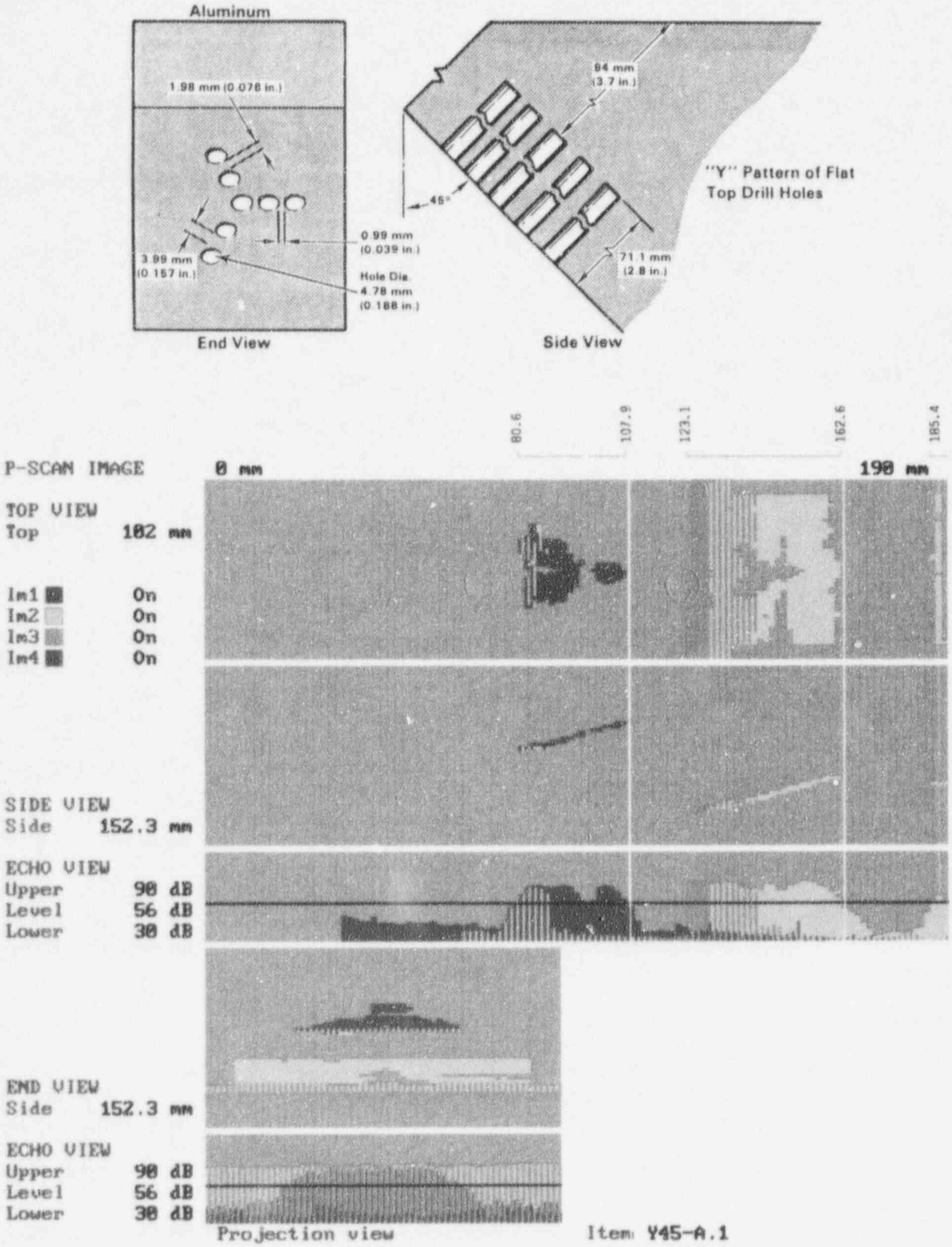


Figure 7.22 P-scan image of Y-pattern test block

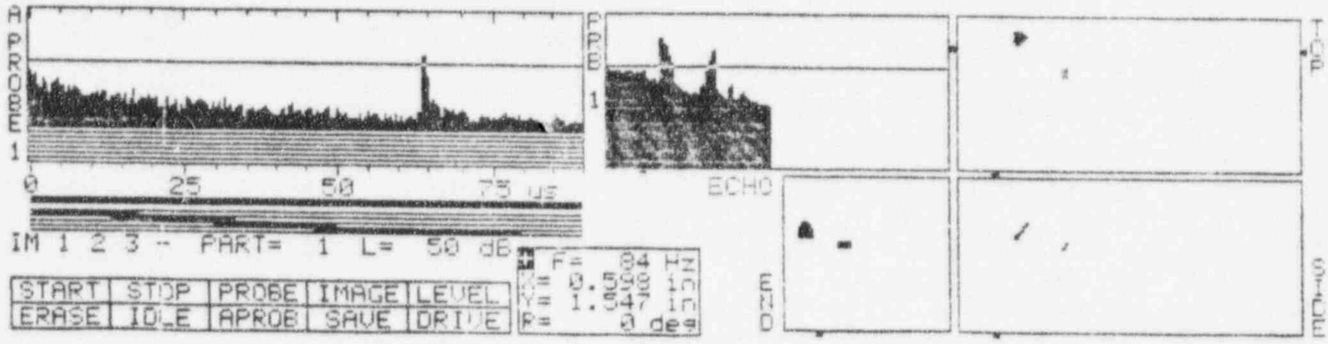


Figure 7.23 Screen dump from PSP-3 printer, showing scan in progress

shown in Figure 6.6. There are other types of necessary data (probe identification, fixture positioning information, etc.) which are not demanded by the system, and their lack will not give rise to any system message.

7.9.4 Non-functional Channel Consequences

What are the consequences of having non-functional channels?

The image for the non-functional channels will be zero (no background noise). The operator determines this condition by inspection of the image.

7.10 Error Recovery

Is there a mechanism to allow recalibration and continuation after an error?

[X] Yes (describe)
[ ] No

In case of error, the inspection can be restarted from the current or any previous scan.

7.11 Frequency Ranges

7.11.1 Pulser Frequency Ranges

What are the pulser frequency ranges used by the system? (e.g. 1 MHz, 5 MHz, 20 MHz, etc.)

0.5 to 15 MHz continuous, but the data-taking rate (32 MHz maximum) implies it is not prudent to use a probe and pulser combination yielding higher than 5 MHz, to guarantee that amplitude errors induced by the sampling process will be no more than 10% of actual signal height. A 10 MHz single-cycle signal could have up to 44% amplitude error, and a 15 MHz signal, up to 90%.

7.11.2 Receiver Frequency Ranges

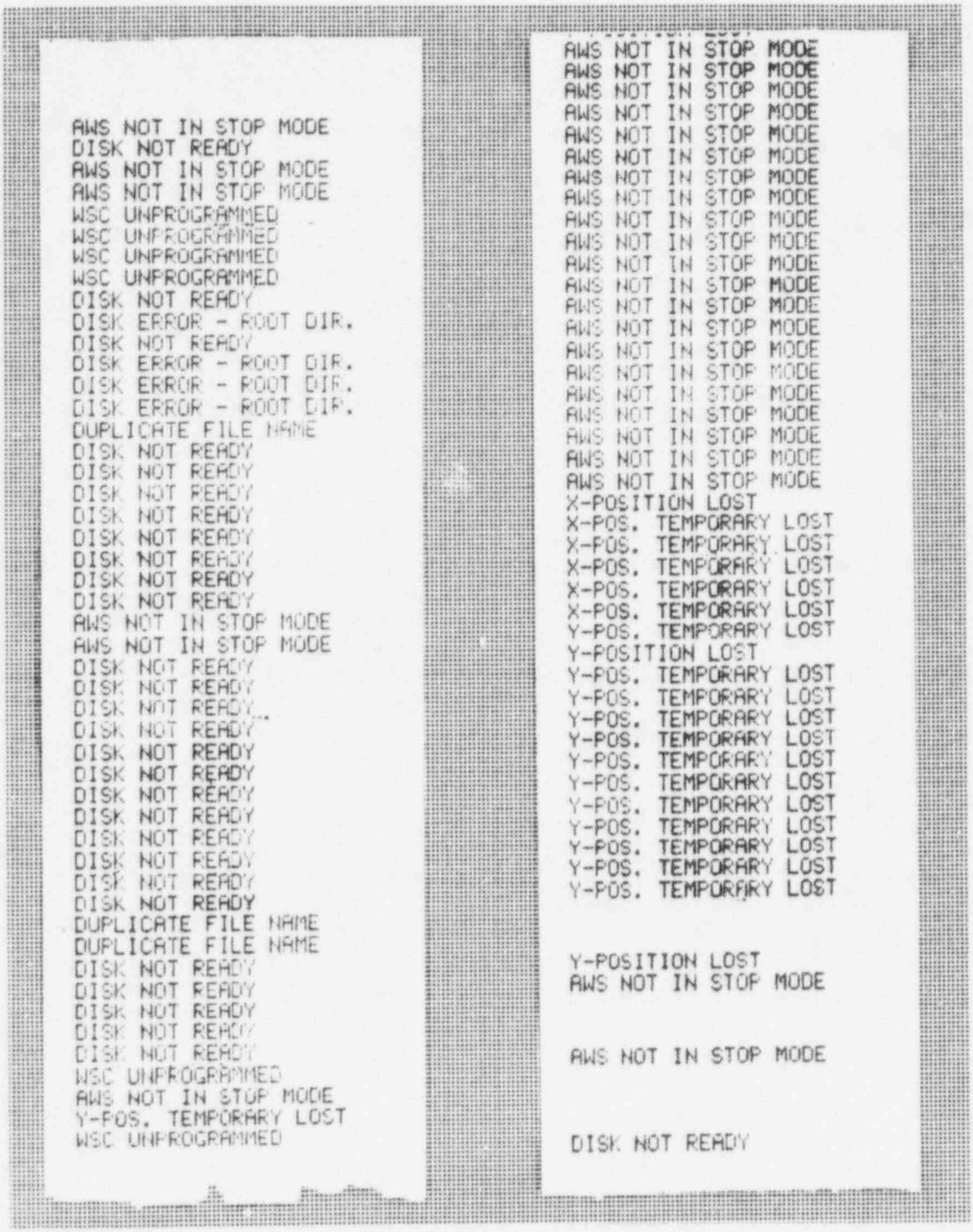
What are the receiver frequency ranges used by the system? (e.g. 1 MHz, 5 MHz, 20 MHz, etc., as determined by the preamp and receiver)

The RF amplifier has selectable low cutoffs of 0.5, 1.0, 2.0, and 3.0 MHz, and high cutoffs of 4.5, 6.5, 10.0, and 15.0 MHz (roll-offs not specified). The rectifier filter has selectable droop rates of 0.5, 0.6, 0.8, 1.0, 1.5, 2.2, and 3.5 mV/μs.

7.11.3 Pulser and Receiver Frequencies

What method is used to assure the pulser frequencies and the receiver frequencies coincide?

The software provides no assurance of this; the operator must follow the recommended procedures.



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AWS NOT IN STOP MODE
DISK NOT READY
AWS NOT IN STOP MODE
AWS NOT IN STOP MODE
WSC UNPROGRAMMED
WSC UNPROGRAMMED
WSC UNPROGRAMMED
WSC UNPROGRAMMED
DISK NOT READY
DISK ERROR - ROOT DIR.
DISK NOT READY
DISK ERROR - ROOT DIR.
DISK ERROR - ROOT DIR.
DISK ERROR - ROOT DIR.
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AWS NOT IN STOP MODE
Y-POS. TEMPORARY LOST
WSC UNPROGRAMMED
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X-POS. TEMPORARY LOST
X-POS. TEMPORARY LOST
X-POS. TEMPORARY LOST
X-POS. TEMPORARY LOST
Y-POS. TEMPORARY LOST
Y-POSITION LOST
Y-POS. TEMPORARY LOST
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Y-POS. TEMPORARY LOST
Y-POS. TEMPORARY LOST


Y-POSITION LOST
AWS NOT IN STOP MODE


AWS NOT IN STOP MODE


DISK NOT READY
```

Figure 7.24 Error printouts from PSP-3 printer

The poor readability is typical because the ribbon of the built-in printer wears out quickly and is not frequently replaced.

7.12 Repetition Rate for the System

7.12.1 Maximum Repetition Rate (Hz)

1000 Hz

7.12.2 Spatial Sampling

Describe the control of spatial sampling. What is the minimum number of pulses per beamwidth, and how is it controlled (e.g. inspection rate versus pulse repetition rate, scanning speed, increment)?

The system generates a uniform pulse repetition at a maximum possible rate. When the repetition rate required to satisfy the scanning speed becomes too high the system automatically stops scanning (this feature is in operation by default, but can be disabled for special purposes).

7.13 Pitch/Catch Ability

Yes [X] No [ ]

Two pitch/catch probes is the maximum.

7.14 Methods of Operation

[ ] Tone Bursts
[X] Multiple Probes
[X] Lamb Waves
[X] Creeping Waves
[ ] Square Wave Excitation
[ ] Tandem SAFT Mode
[ ] Phased Array
[X] Spike Excitation
[X] Other:
Bi-modal probes
Longitudinal probes
Shear wave probes

8.0 Data Acquisition/Processing

8.1 Acquisition Scheme

What type of data acquisition scheme is used by the system (raster scan, spiral, heuristic, etc.)? If not raster scan (which is detailed in separate questions), give details here.

The usual scheme is raster scan (called "meander" pattern in the P-scan literature), in normal operation, with the X-axis stepping and the Y-axis scanning across once for each step of the X-axis. It is possible to vary this by manually resetting the position and rescanning, adding the new data to the image without erasing the old data; this allows scanning of triangular areas or areas containing obstacles to the passage of the probe. The areas missing from the scan will show up as background color in the images.

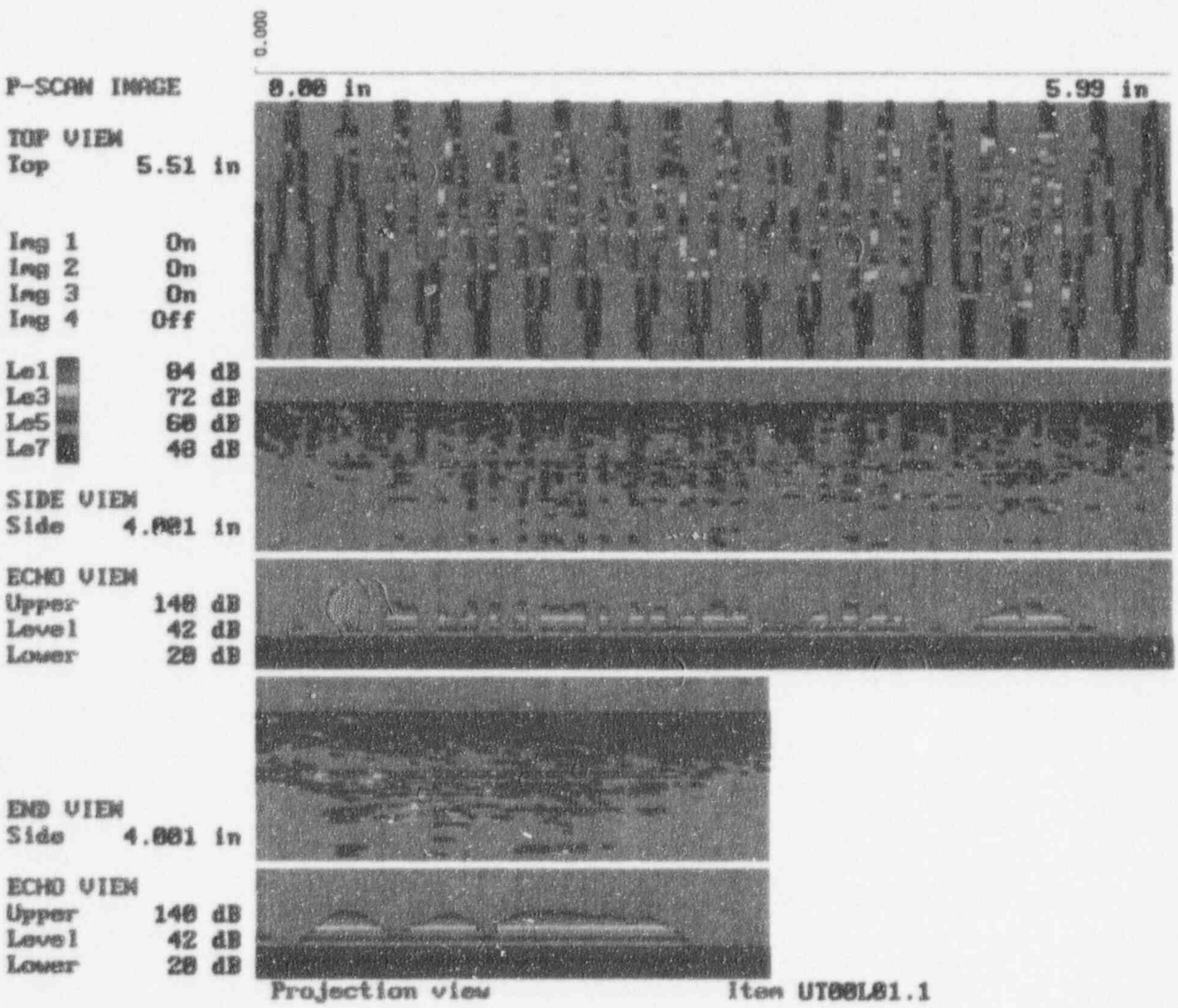


Figure 8.1 P-scan image in Continuous mode

There is also a variant of the raster scan, called "continuous," and described as a "zigzag" pattern, which is a sort of reversing spiral or helix: the X-axis moves at a constant rate while the Y-axis scans back and forth. Figure 8.1 shows an example of a continuous-mode scan. The object scanned is the normal-beam test block UT-RES-0000. The zig-zag scan pattern is visible against the background color in the TOP VIEW; the SIDE view is difficult to interpret; the END ECHO VIEW shows the two rows of depth-resolution holes as humps on the left, and the lateral-resolution holes as a larger hump on the right. Note (TOP VIEW) that the density of coverage in this mode is not uniform. At the ends of the stroke the distance between adjacent data points along the X-axis is W x XS / YS, where W is the part width (stroke length), XS is the X-axis speed, and YS is the Y-axis speed (all in units of mm or mm/s). At the middle of the stroke it is half as much, and between them it varies linearly. Since the minimum X-axis speed is 1 mm/s and the maximum Y-axis speed is 250 mm/s, the smallest ratio is 1/250, and the most dense coverage possible in this mode is a spacing of W/250 at the center of the stroke, W/125 at the ends; for a more typical Y-axis speed of 1 in. per second (25 mm/s), the spacing at the center is W/25; for a 5-in. (127-mm) part width, this gives a spacing at the center of 0.2 in. and 0.4 in. (10 mm) at the ends, which is approximately what is shown in Figure 8.1.

8.2 Detection of Indications

Does the system automatically produce a list of indications?

Yes [X] (in a limited sense)   No [ ]

X-direction information for all indications is provided when a printout is made in the "Expanded and Flaw" mode. Information is not provided on the screen, only on the printout. The operator sets a cut-off level and the post-processing software provides the X-position information for any signals (indications) that are present above the cut-off level. The numbers are printed above the TOP VIEW, at right angles to the rest of the text information on the printout. Figures 7.5 and 7.18, among many others, show examples of indication lists.

8.2.1 Information Given

What information is given about the indications?

[X] Location
[ ] Amplitude
[ ] Other:

The only information given explicitly is the beginning and end X-axis coordinates.

8.2.2 Probe Display

Does the system display which probe was used to find the indications?

Yes [X]   No [ ]   N/A [ ]

Only if the color coding is in image mode.

8.2.3 Detection Methods

[X] Threshold
[ ] Target Motion
[ ] Other:

8.2.4 Technical Basis

What is the technical basis for the procedure? (the physics)? Test this if possible.

Amplitude thresholding, within a time-defined gate.

8.2.5 Documentation of Algorithms

Does documentation exist to describe how the system determines the detection of indications (the algorithms)?

Yes [ ]   No [X]

8.2.6 Test Data Set

Is the system provided with a test data set that verifies the automatic detection methods?

Yes [X]   No [ ]

8.2.7 Operator Procedures

What procedures exist for the operator to determine indications?

Amplitude color coding is available. X, Y, and Z cross-hairs (called markers) are provided to determine the location and amplitude of the indication.

8.3 Characterization of Indications

Does the system have a facility to automatically characterize indications?

Yes [X] No [ ]

Only in the ways listed in the following subsections.

8.3.1 Geometric Indications

Can the system recognize and exclude geometric indications?

Yes [ ] No [X]

It can display a weld profile. The types of weld profiles are I, V, X, Y, YY, U, and UU. Figure 8.2 shows the various weld profile types, and Figure 8.3 shows a sample image with a weld overlay (in this sample image, the overlay is not over a weld).

8.3.2 Parameters Characterized

[X] Location
[X] Orientation
[X] Size
[ ] Type: Volumetric/Planar (inclusion, void, crack, etc.)
[ ] Shape
[ ] Other:

Location is measured with cross-hairs. Orientation is not given explicitly, but can be found by looking at the end and side views. Size (in the X-axis direction only) can be found by subtracting the beginning and ending coordinates listed above the image.

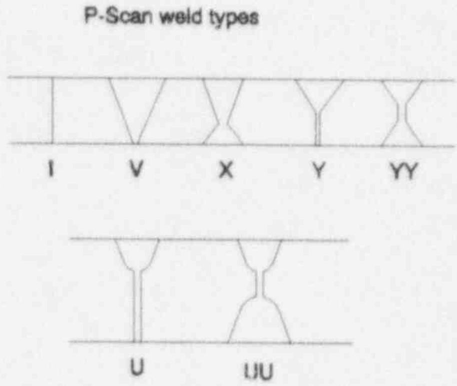


Figure 8.2 P-scan weld profile types I, V, X, Y, YY, U, and UU

8.3.3 Characterization Methods

[X] Multiple Probes
[ ] Spectrum Analysis
[ ] Signal Smoothing
[ ] Spatial Signal Averaging
[ ] Automatic Image Analysis
[ ] Analyst-assisted Image Analysis
[X] Other: SuperSAFT

8.3.4 Technical Basis

What is the technical basis for the procedure (the physics)? Test this if possible.

For multiple probes, the system places the images of the reflections from the various probes in the proper relative positions. The operator analyzes the resulting image to determine what types of reflectors can have caused such a combination.

For SuperSAFT, the SAFT analysis is performed.

8.3.5 Documentation of Algorithms

Does documentation exist to describe how the system determines the characterization of indications (the algorithms)?

Yes [ ] No [X]

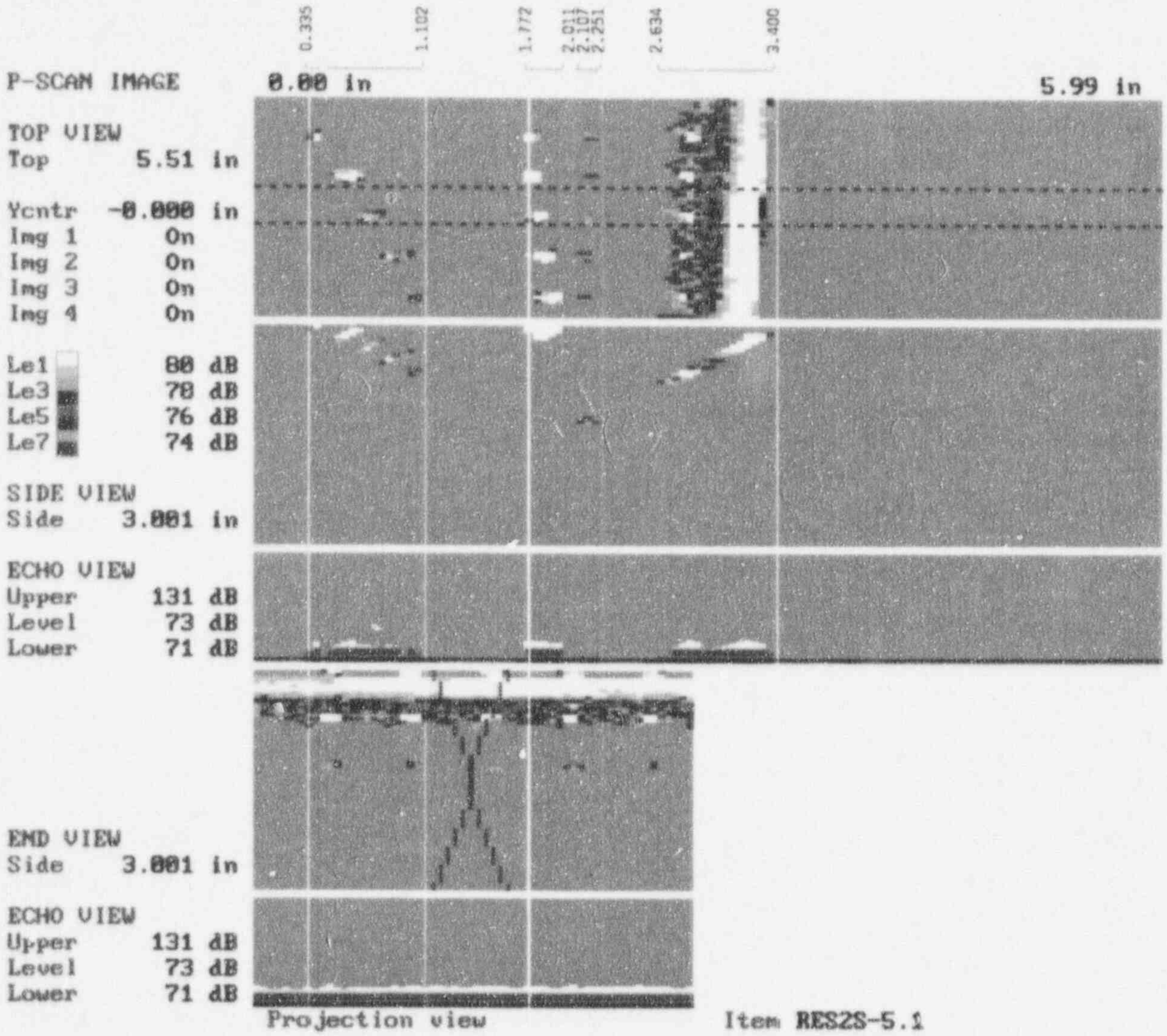


Figure 8.3 P-scan image with weld overlay, type YY, shown on END VIEW

8.3.6 Test Data Set

Is the system provided with a test data set that verifies the automatic characterization methods?

Yes [ ] No [X]

8.3.7 Operator Procedures

What procedures exist for the operator to characterize indications?

The operator visually inspects the image data.
All characterizations can be viewed from the image data.
The operator must rescan if A-scans are desired.

8.4 Material Characterization

What types of material characterization are done, other than localized indications, e.g. noisiness, multiple cracking, attenuation?

None.

9.0 Image Presentation

9.1 Cursor Readout

Is there a cursor readout? (used for aiding detection and characterization)

Yes [X] No [ ]

There are cross-hairs (called markers) that can be moved about on the TOP VIEW and either the SIDE or the END view, whichever is selected.

9.2 Graphics Tool

Record the performance of the graphics tool for the following tests by using photographs of the display. Also, generate hard copies with a printer when appropriate.

Since the PSP-3 provides color printouts, identical to the display, photographs were not made. Also, most of the features are visible in various figures throughout, so few additional figures are given in this section.

9.3 Non-Flat Geometries

How is data analyzed and presented for non-flat geometries?

[ ] Generic 3-D
[X] Cylinder: unwrap
[X] Slices (1-dimensional, amplitude versus position)
[ ] Other (describe)

All data is presented and analyzed in a flat plane for all geometries that it is able to handle.

The system projects (P-scan) images in unwrapped positions.

Distances between points at the same radius are shown correctly.

Distances between points along the same radius are shown correctly.

Distances between points must always be calculated using the coordinates displayed by the markers.

The PSP-3 performs all of the beam correction before the images are displayed on the screen.

The PSP-3 retrieves a formula table for each geometry before the scans are run.

9.4 Image Fidelity

What is the fidelity of the imaged geometry (i.e., correct scaling)?

There is no attempt made to scale the distances and shapes to the actual distances and shapes. However, reflectors in angle-beam inspections appear in all views at their proper locations as projected along the sound-beam.

Figure 9.1 shows the geometry of the 60-degree depth resolution face in test block UT-RES-4560-2. The solid lines show the top of the block; the dashed lines just delineate the views. Figure 9.2 shows a P-scan image of the same block. The upper and lower images in Figure 9.2 show the same scan; in the upper image, the data from the greatest depths has been suppressed so that the top view shows all the holes clearly; in the lower image, the data from the greatest depths is shown, so that the side view shows all portions of all holes. It is not possible with this data to obtain an image that shows all holes clearly in the end view, because of the overlap in depth between the holes and the backface. In comparing Figure 9.1 to Figure 9.2, note that in the P-scan image, the shapes and angles of the holes are distorted due to the different scales used for the different axes. Note also that the scale of the Y-axis is different in the end view than in the top view.

Measurement of an image of the test block UT-RES-0000 indicated an error of 3.4% in the Y-axis scale, i.e. 1.000 in. on a test piece would measure 1.034 in. on the image. Correcting this requires simply changing the Y-axis correction factor in the data file. No correction was attempted, since the discrepancy was not detected until the unit had been returned to the vendor. No skewing of the image was found, and no X-axis error was detected.

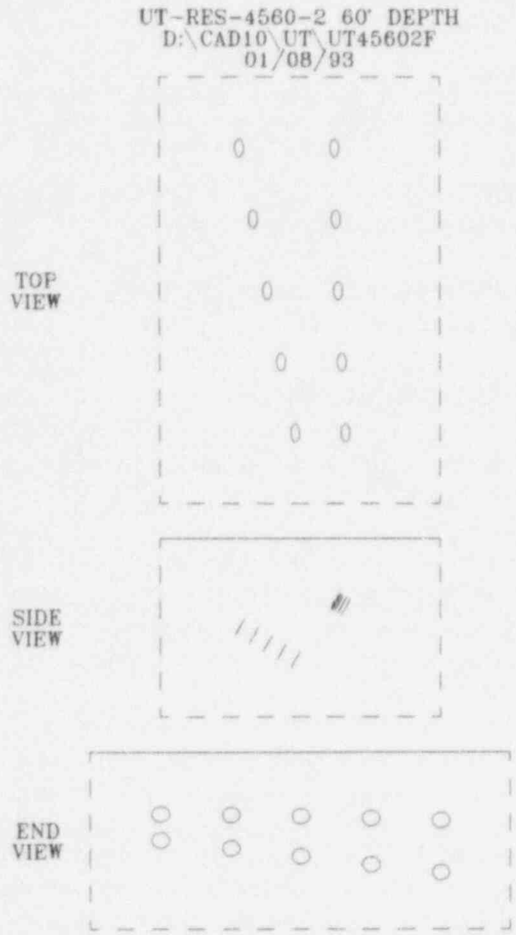


Figure 9.1 Drawings of UT-RES-4560-2, showing the same views as the P-scan image

A distorted and/or mirrored image can be produced by entering an incorrect probe rotation angle. Figure 9.3 shows the same holes as Figure 7.8, and almost the same color scale, but a different horizontal scale. Because the probe rotation angle was specified as 180 degrees instead of 0 degrees, the objects are all projected toward the left instead of toward the right. This projection is superimposed on the probe motion, which is calculated correctly. This leads to the backwall's being shown directly under the holes instead of to the right of the holes as in Figure 7.8, and to the holes' being stretched out horizontally. An error in probe rotation angle is not likely to occur in a routine situation, since the data does not show up in the expected location during scanning; however, it is possible when scanning objects of an unfamiliar geometry. During one of our lab trials an experienced operator specified a rotation of 90 degrees instead of 0 degrees, which resulted in an incomprehensible image. Photos of the setup (the probes, in this case) would be valuable in post-inspection analysis.

9.5 Geometrical Corrections

Can the system perform geometrical corrections for scans done on complex geometries and curved surfaces?

Yes [X] No [ ]

Plane, circumferential, helix, longitudinal, sphere. The positions are calculated according to the geometry, but the inspection surface is always displayed as flat. Figure 7.18 shows an example of a scan of a pipe.

9.6 Views Provided

[X] Top
[X] End
[X] Side
[X] 3-D (SuperSAFT only)
[X] Echo (true echoes in A-scan mode only)
[X] Projection
[X] Section (ultrasonic, not geometrical)
[X] Other: Subvolume (requires re-scan)

3-D: There is a 3-D view provided in SuperSAFT post-processing.

Echo: For a P-scan or T-scan image, the ECHO VIEW shows the highest amplitude at each point or along each line. Only in the A-scan mode is a true ultrasonic echo recorded.

Section: The "Section view" option of the ECHO VIEW provides the only approach to section views that is available. It is a plot of amplitude versus position along a given slice, parallel to the X-axis in the Side View and parallel to the Y-axis in the End View.

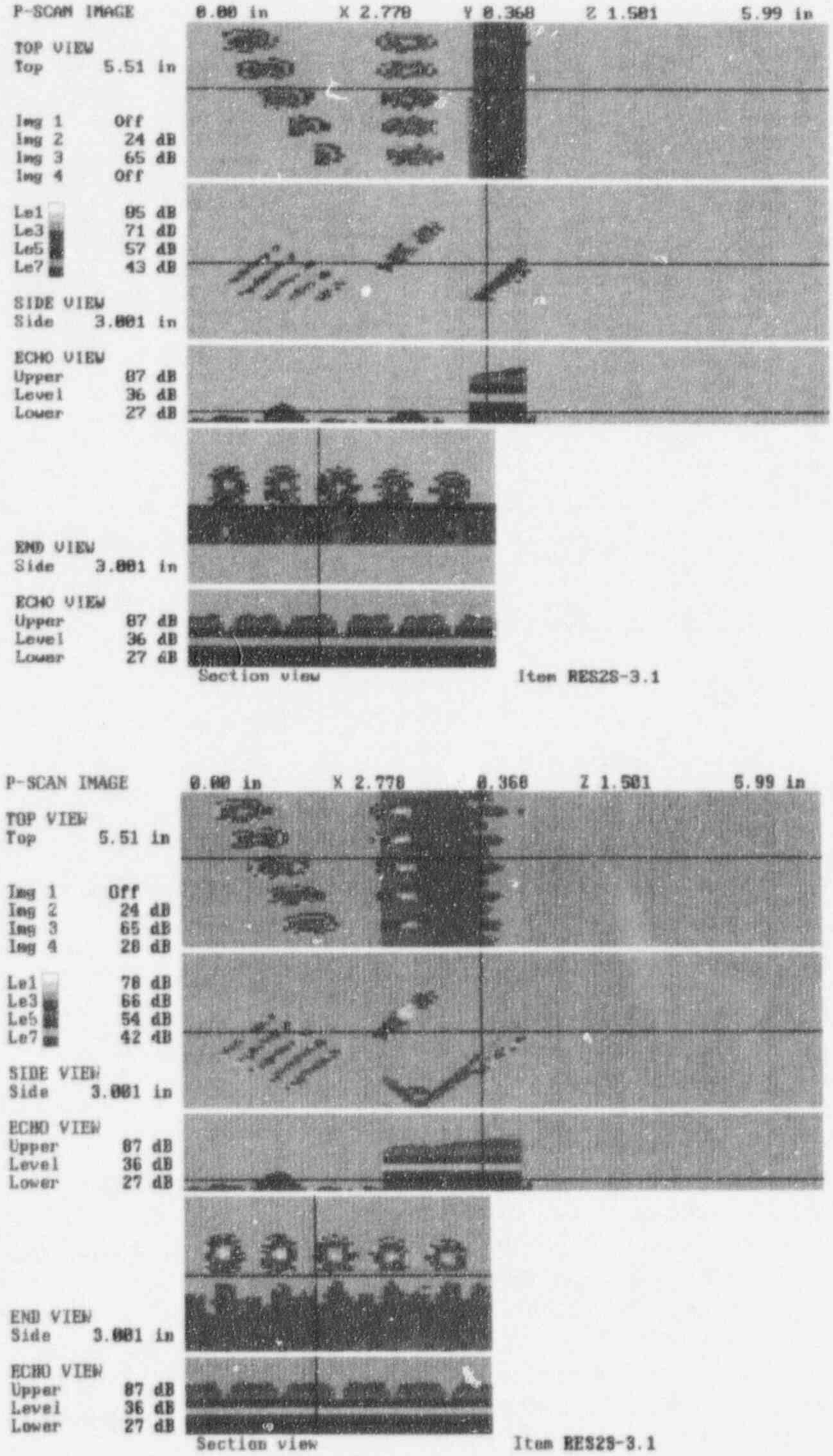


Figure 9.2 P-scan image of the 60-degree depth resolution face in the test block UT-RES-4560-2, without and with the signals at greatest depth

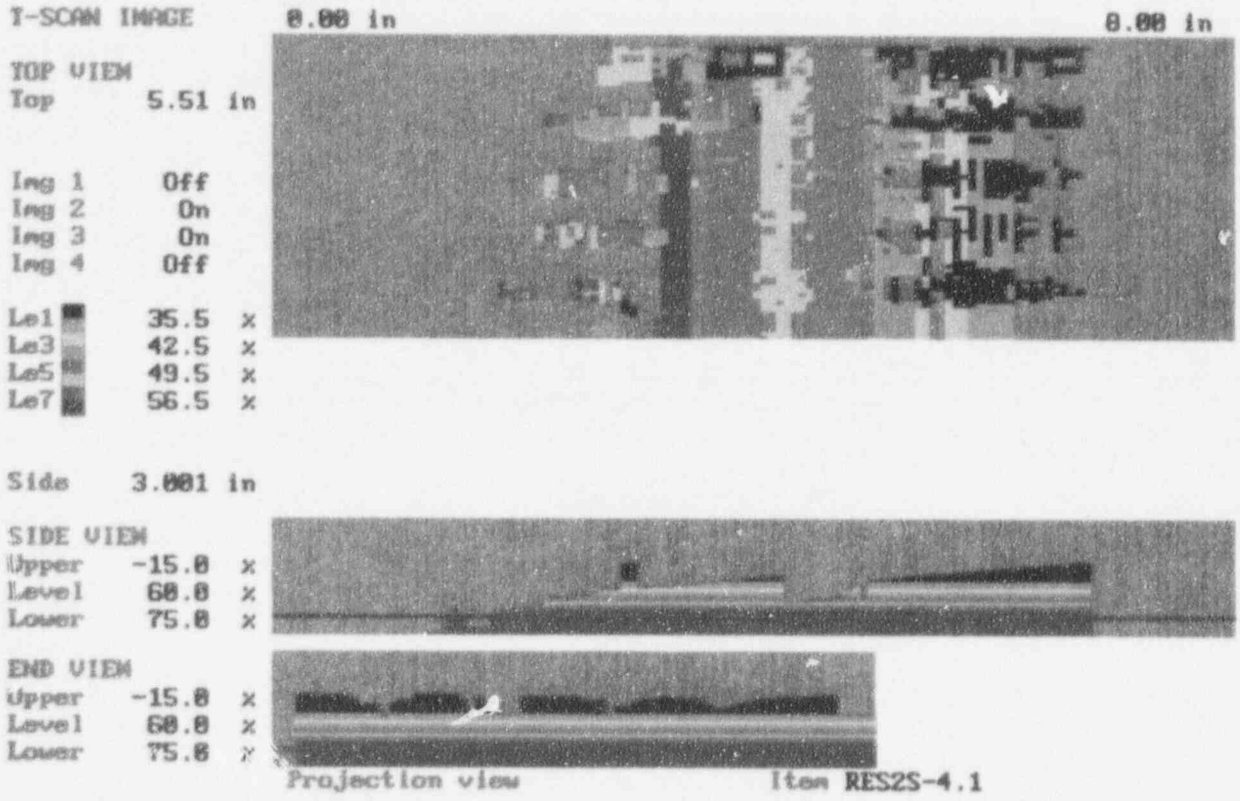


Figure 9.3 P-scan image showing distorted mirror image of Figure 7.8

Subvolume: Figure 9.4 shows a test block scan and below it a subvolume scan of the region boxed between the cross-hairs and a drawn line. Note that in the subvolume scan, the top, side, and end views are labeled with both starting and ending Y- and Z-coordinates (2.03 and -0.45 for the Y, 2.249 and 3.249 for the Z, indicated by arrows pointing up and down), whereas in the original scan, only the extent of the Y and Z axes (7.76 for the Y, 4.001 for the Z) are given. In both scans, the starting and ending X-coordinates are given (0.00 and 6.26 in the original, 2.23 and 3.21 in the subvolume). The X, Y, and Z numbers at the top of each scan indicate the position of the cross-hairs. The subvolume scan shows considerably better resolution than the original, which shows that the resolution in the original is limited by the data-taking and imaging processes, not by the ultrasonics.

9.6.1 Labeling

Are the views labelled?

Yes [X] No [ ]

9.6.2 Number of Views

What is the number of views that can be displayed at the same time?

Two ordinary views plus one signal-amplitude view can be displayed on the screen at one time. Three ordinary views plus two signal-amplitude views can be printed on one sheet.

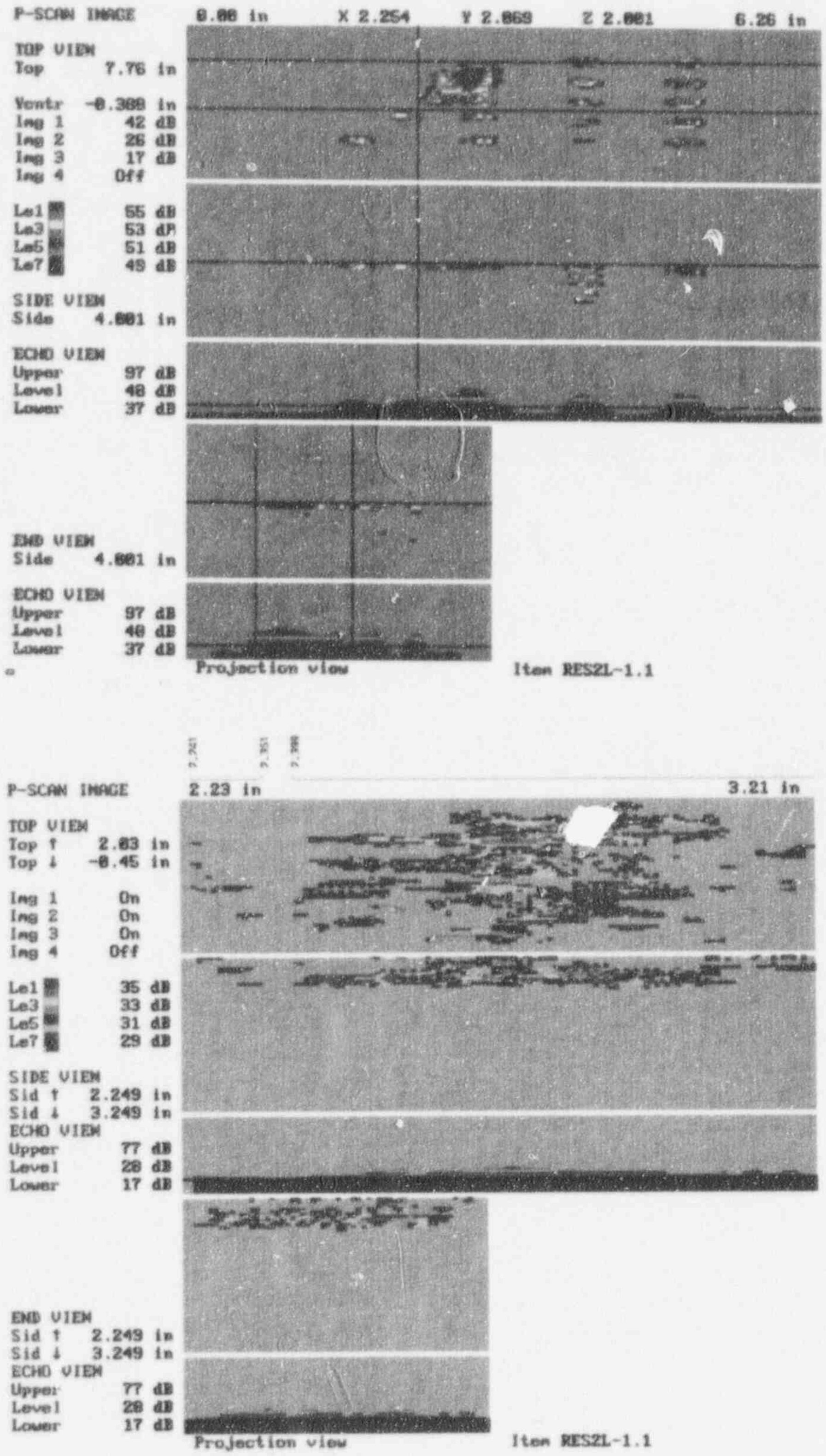


Figure 9.4 Example of subvolume scan

9.6.3 Maximum Amplitude Composites

Are the views maximum amplitude composites that are calculated from the individual planes of data? (if not, or if other calculations are also provided, describe).

Yes [X] No [ ]

Sectional signal-amplitude views are also provided.

9.6.4 Composite View Calculation

Does the graphics tool calculate the composite views each time the user requests a display?

Yes [ ] No [X]

The data is stored in such a way that the composite views are displayed almost instantaneously.

9.7 Color Scale

Do the views use a color scale to represent the data?

Yes [X] No [ ]

Colors can be used to represent quantitative data (Level coded) or qualitative (Image coded).

In Level Coded mode a color scale is used to represent dB or percent thickness, thus the name Level Coded. The operator can assign colors to ranges (i.e. the colors used in a presentation can be selected by the operator). The operator has the ability to enter up to eight different colors to represent the different dB ranges. There are also predefined color scales that can be used. The operator can also save the color scales that were customized.

In Image Coded mode a color scale is used to represent images (images can be assigned to gates, probes, or files), thus the name image coded. In this mode as well, the operator is able to select different colors for different images. The maximum number is four different colors. PALS and PALET, mentioned below, are also available.

The operator selects "F2 PALS" or "F3 PALET" from the Device Control mode to be able to select the predefined color scales/pallets or customize a scale/pallet, respectively.

9.7.1 Adjustment

Is the color scale adjustable?

Yes [X] No [ ]

In Level Coded mode the scale is adjustable. The operator selects "F6 STEP" from the Image Control mode to have the ability to adjust the color scale. The scale is adjusted by selecting different dB values for "Common Range." Figure 9.5 shows two images of the same data using different color scale levels. The difference in the respective TOP, SIDE, and END VIEWs is due only to the difference in color scales (changing the value of the lowest-amplitude color changes the threshold, so the indications appear smaller, having lost their low-amplitude portions). The respective ECHO VIEWs are different because they are in Section mode and the crosshairs were unintentionally placed in different locations.

9.7.2 Alternatives

Is a scale other than color available?

Yes [X] No [ ]

Type (gray, pattern, etc.):
A gray scale printout can be made by using an Epson printer. The PSP-3 built-in mini-printer can accept color-scaled images, but all the colors except the background will print as black. Normally, a color printer is used to print out the color images. By proper selection of colors, the images can be photocopied or faxed and still have distinguishable shades.

9.7.3 Purpose

If color or any other differentiating scales are possible, what are they used for?

The adjustable color scales can be either level coded (amplitude for P-scan, depth for T-scan) or image coded (gates assigned to images). For the level coding, the individual colors in the color scales can be separated by a user specified dB amount that need not be uniform throughout the scale. Most of the images shown here are level-coded; Figures 5.3 and 7.22, among others, are image-coded.

9.8 Angle Projection

Does the graphics tool project the ultrasonic data along the insonification angle?

Yes [X]   No [ ]

9.9 Sequencing Data Planes

Does the graphics tool permit the user to sequence through the individual planes of data for a given view?

Yes [ ] No [X]

The Section view provides something similar to this function, but not automatically. On the PSP-3, in A-scan mode, the user can sequence automatically through the points of the scan, displaying all the A-scans sequentially.

9.10 Tiling Data Planes

Can all or several of the individual planes of data be displayed (as separate tiles or windows) at the same time on the display?

Yes [ ]   No [X]

Except with SuperSAFT. Figure 9.6 shows an image produced during a training session. The images in the small tiles represent the data that is to be selected for SAFT processing. (The color original of this display was not available.)

9.11 Axis Scales

Are the scales for the axes of the views equal? (i.e. does the display use the same number of screen inches per inch of material for both horizontal and vertical axes)

Yes [ ]   No [X]

Unless specially requested during the scanning, or by using SuperSAFT.

9.12 Multiple View Scales

Is an option available to force all scales to be equal when more than one view is presented?

Yes [X]   No [ ]

This option must be chosen during the scanning process; the post-processing program cannot change the scales. SuperSAFT images are always in equal scales.

9.13 Tick Marks

Are tick (fiducial) marks provided on all axes?

Yes [ ]   No [X]

If not, explain. Start and end of part length are provided without tick marks. Width and height are each shown as a single figure. Cross-hairs are used to find positional information.

9.14 Axis Units

Are all the axes of the views labeled in English and/or metric units?

Yes [X]   No [ ]

The operator can specify inches or mm.

9.15 Axis Labels

Are the labels in scanner or material coordinates?

Scanner [X]   Material [ ]

In a general sense, material coordinates are used: an X and a Y offset can be used so that linear dimensions over the surface are referenced to a known point on the part. Also, the depth of indications is given as true perpendicular depth, not path length along the (angled) beam. However, there is no option to convert dimensions into a cylindrical or spherical coordinate system appropriate to the part under examination.

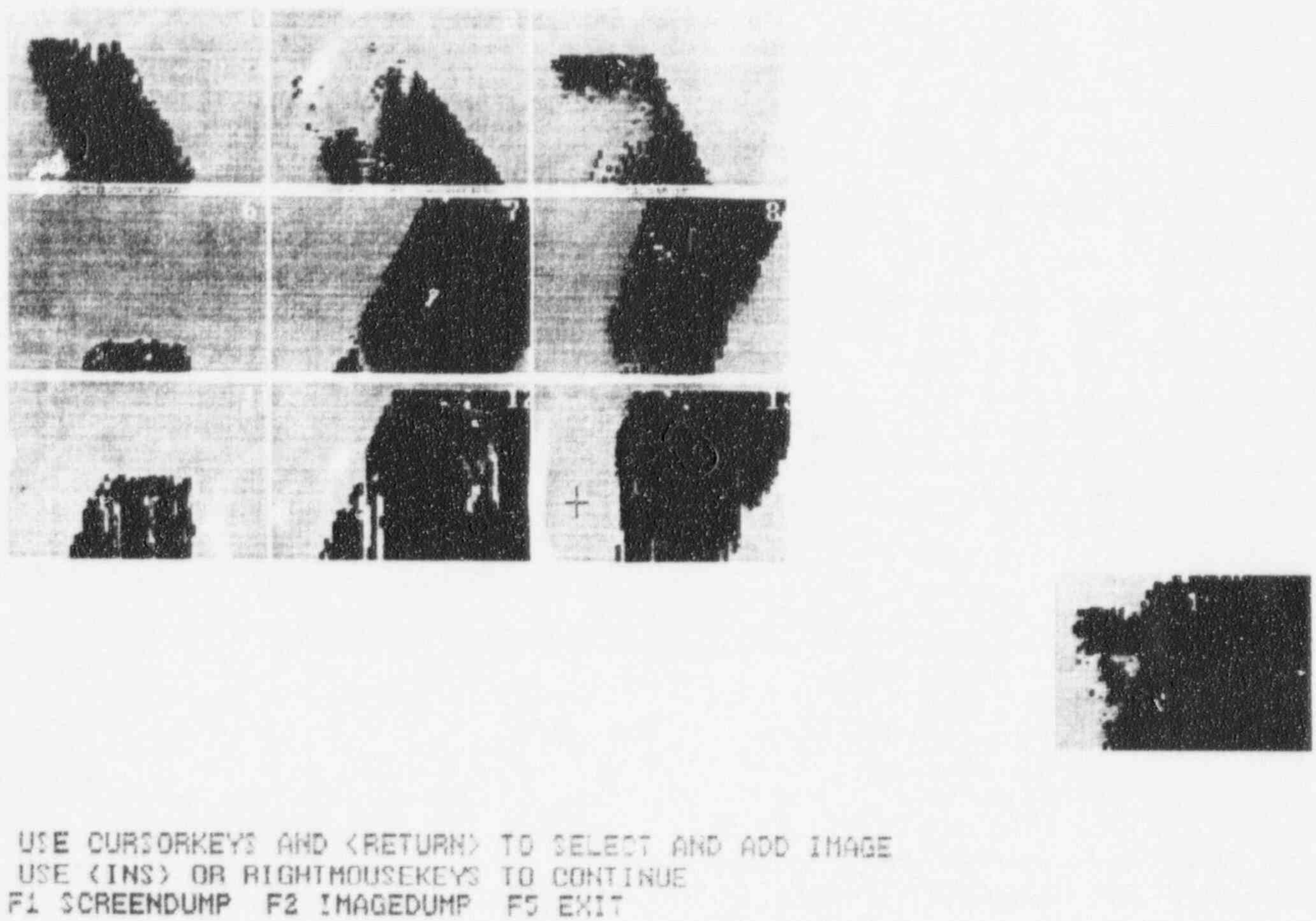


Figure 9.6 SuperSAFT screen with individual planes of data in separate tiles

9.16 Positional Data

What is the format of positional data? List the data elements (X, Y, Z, tilt, rotation, etc.).

Scanner positional data is in rectangular coordinates: X for the crawler wheels and Y for the scanner arm.

Ultrasonic data includes depth (or Z) as a third rectangular coordinate.

Tilt and rotation are referred to as refracted angle and skew angle respectively. Values for these for each probe must be entered by the operator, and are valid for the entire scan. There is also an operation mode with variable skew angle, but it is not treated as a coordinate, and this mode was not available on the scanner tested.

All of the elements (X and Y) are in either inches or mm as selected by the operator. The operator selects a scanner correction factor so that the readout is correct in the selected units.

There are two axes: X (circumferential) and Y (axial). Ultrasonic image positions are calculated and presented based on material velocity and refracted and skewed beam angles, and diameter and thickness of part if applicable.

9.17 Positional Tags

Does the system record positional data that is tagged to each data point?

The X,Y positions are implicit from the data structure, which is an array.

The format is proprietary, but the answer appears to be yes, at least functionally.

The operator is able to use a cursor and line it up over a data point to obtain the positional data; however, the resolution is only as high as the monitor and image resolution permit, even though the data may have been scanned at a higher resolution.

9.18 Position Conversion

How are axis positions converted to probe positions?

In the case of X-Y scanning systems, is the encoder step the same as (or an exact submultiple of) the position read-out step? For a multi-axis system, does positional accuracy depend on the collective positions of the axes; i.e., are there portions of inspection space that have better resolution than other portions?

There are two perpendicular axes, so the only conversion from axis to probe position is addition of the probe offset in each axis.

To obtain correct axis position measurements, the operator physically measures the length of the scan and then runs the scanner from the starting to the end point. A correction factor is then determined from the two values. A correction factor can be used for both the X- and Y-directions.

Y-correction factors might be used in special cases, such as a curved Y-module (scan track) to be scaled according to curvature. The image dimensions represent the actual (corrected) distances.

If the scan is performed in counter-clockwise mode (CCW), then the sign (direction of positive motion) of both X and Y axes is reversed.

9.19 Multi-Axis Positioning

In the case of a complex multi-axis vessel scanner, perform tests to verify the positioning of all relevant axes, including angular position, within a volume.

N/A

9.20 Sub-image Display

Does the graphics tool permit the user to display a subset of the current image? (this is sometimes called zooming or boxing)

Yes [ ] No [X] (with exceptions)

In SuperSAFT, using A-scan mode data, there is a zoom function.

In imaging mode, an image subset requires a physical rescan, called a subvolume scan (see Figure 9.4).

9.21 Consistency of View

Does a reduction in the data of interest in one view carry over to any other views?

Yes [ ] No [ ]

N/A

Image mode has no zoom.

SuperSAFT only allows the end view to be zoomed.

9.22 Image Display Size

Can you select the displayed size of a given image?

Yes [ ] No [X]

9.23 Pixel Information

Does the graphics tool permit the user to move a cursor to individual pixels and obtain additional information on an individual datum?

[X] Yes [ ] No
[X] Amplitude
[X] Position
[X] Other:

The cursor can move on command to a highest-amplitude point.

X, Y, and Z positional information are provided.

9.24 A-Scan Selection

Does the graphics tool permit the user to display individual A-scans from the data volume?

Yes [ ] No [ ] Sometimes [X]

If the scan was done in A-scan mode, individual A-scans can be displayed.

If the scan was done in Imaging mode, the individual A-scan data is not available.

With data taken in A-scan mode, it is possible to display Individual A-scans, a Composite A-scan and a Composite B-scan. When a Composite scan is displayed, the operator can select a data point and display an individual A-scan (called the "appointed" A-scan).

9.25 A-Scan Display

Does the graphics tool permit the user to easily identify and display A-scans of interest from the various views?

Yes [X] No [ ]

A cursor is used in the Composite views (A-scan mode only).

9.26 Multi-File Displays

Does the graphics tool permit the user to display data from more than one file at a time on the display?

Yes [X] No [ ]

A push/add menu is used to display a comparison of two data files at a time within the same image, using different colors for the two files. When amplitudes are displayed by using a color scale, the two files can still be overlapped. The scan origin on both files must be the same. There is also a MERGE function that allows consecutive parts (i.e. portions of a single physical part) to be combined into one file, provided the files all have the same part name with different file extensions. This effectively gives two scales of view for the part.

9.26.1 Multi-File Images

Does this option include a single view that contains (color coded) data from more than one channel or file?

Yes [X] No [ ]

It can't do anything else - it only superimposes.

9.27 Multi-File Data Selection

Does the graphics tool permit the user to box across files?

Yes [ ] No [X]

9.28 Material Location

How is the information (axis labels, etc.) used to determine where an indication is located in the material?

There are three steps involved in locating an indication within the material. The first is to locate the scan origin relative to a feature of the part, the second is to determine the scan coordinates of the indication, and the third is to combine the two to determine material coordinates of the indication. To illustrate, we show how to locate an indication in a pipe scan.

To locate the scan origin relative to the part, a part reference point (a mark on the part or a feature of the part) must be recorded. A measurement in X (circumferential) and Y (axial) directions is then made from the mark or feature to the beam entry point of the probe; call these amounts XP and YP. The X-axis and Y-axis values showing on the screen at this point are also recorded; call them X0 and Y0. The physical arrangement should be recorded photographically if possible.

The correct material velocity, the time delay within the probe shoe or wedge, and the beam angle are input into the computer, so that the top surface of the part corresponds to a Z-axis value of 0, and depths within the part correspond to their Z-axis values. The part thickness is also input, so that the true depth will be shown for signals reflected secondarily from the far surface.

The scan is then performed. The scan coordinates of the indication are found by placing the cross-hairs on the indication in the top view, and reading the X-axis and Y-axis values; call them XS, YS; and then placing the Z-axis cross-hair on the indication in the side view. The circumferential and axial locations of the indication are then found by calculating X=XP+XS-X0 and Y=YP+YS-Y0, and measuring a distance X circumferentially from the part reference point, and Y axially from the point just found. The depth of the indication is shown directly as the Z-axis value.

To simplify finding circumferential and axial locations, the P-scan processor has parameters XSTRT (X start position), XVAL (X-positioning value), and YVAL (Y-positioning value), along with relative offsets for multiple probes, to allow direct reading of positions relative to the part reference point (i.e. X0=XP, Y0=YP).

9.29 Image and Ultrasonic Resolution

Is the image resolution at least as high as the ultrasonic data resolution?

Yes [ ]   No [X]

Except in SuperSAFT mode, using A-scan data.

In imaging mode, there is no facility for zooming the image, so if you make more scans than there are pixels on the screen, the image resolution degrades (this may have been improved with the newer MS Windows-compatible software). The maximum number of pixels in any axis is 125. There are 125 pixels on the X-axis, and typically 50 on the Y-axis and 50 on the Z-axis for P-scan images; for T-scan images, the Y-axis value is 125 rather than 50. The philosophy seems to be that if you want a detailed image, you will do a subvolume scan or take A-scan data, so there is no need for extensive imaging options in imaging mode. The relatively low importance assigned to image manipulation is shown by the small size of the chapter on "Image Display" in the P-scan Post-Processing Software Operation Manual.

9.30 Multiple Data, Single Pixel

Can the graphics tool map more than one datum to a given pixel?

Yes [X]   No [ ]

What is the method used to do this (e.g. maximum value, last value, etc.)?

For P-scan the highest value is shown; for T-scan, the smallest thickness is shown.

9.31 Single Datum, Multiple Pixels

Can the graphics tool map a given datum to more than one pixel?

Yes [ ]   No [X]

The question only arises along the X-axis. If the number of scans is less than 125, the space between scan lines is filled with background color. Figure 9.7 shows two scans of Repeatability Block UT-RPT-CIRC-1, shown also in Figures 5.3 and 5.5. The image in the upper portion was made with only 33 scans; in the lower portion is the same object imaged with 125 or more scans. Note that the TOP and SIDE views show a difference, but the END views look almost identical, since the sampling rate along the scan axis has not changed.

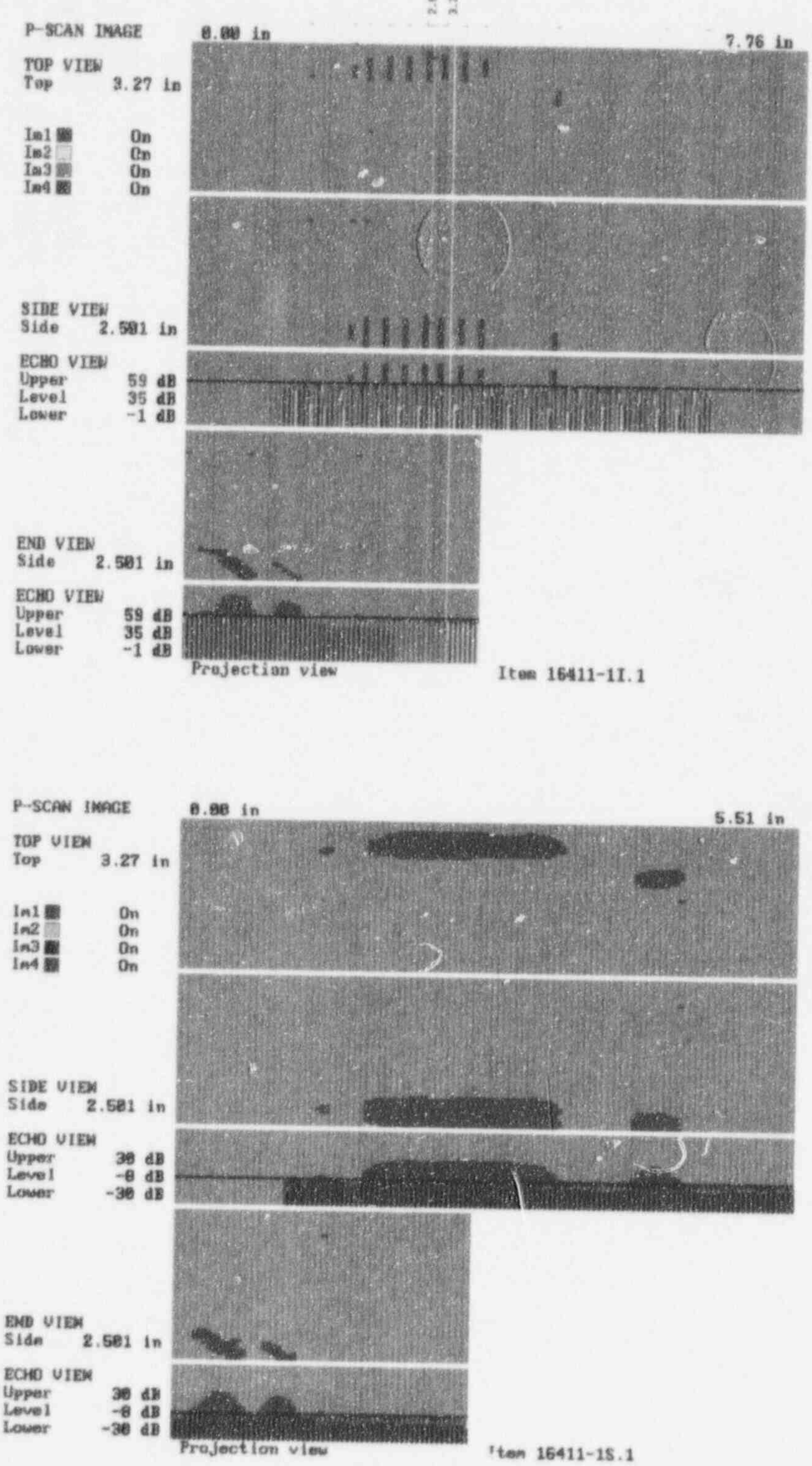


Figure 9.7 Test Block UT-RPT-CIRC-1. Upper portion: number of scans is 33. Lower portion: number of scans is at least 125.

9.31.1 Method

What is the method used to do this? (e.g., data expanded to rectangle of pixels, smoothing, etc.)

N/A

10.0 Digitization

10.1 Waveform Digitization

Does the system digitize the waveform?

Yes [X] No [ ]

The PSP-3 acquires the A-scan and digitizes it. In the Imaging mode, the TOP, SIDE, and END views are saved so that they can subsequently be displayed and possibly processed, but the A-scan is not saved. In the A-scan mode no images are produced, but the A-scan is saved.

The data processing methods and format are proprietary, but the effect of Imaging mode data acquisition is approximately as follows: as each A-scan is acquired, each datum in the A-scan is compared with the TOP, SIDE, and END views already acquired. The datum is projected onto each view, along the axis perpendicular to that view. If the new datum is greater than the old value in that view, the new replaces the old. Thus at the end of the scan, the views are maximum-amplitude projections (as indicated in the name P-scan, "projection image scanning"). Even the lowest-amplitude data is represented in the images, except where higher-amplitude data masks it.

Data-taking in A-scan mode saves all the data.

10.2 RF Digitization

Is the RF signal digitized?

Yes [X] No [ ]

If in RF mode; but only saved if in A-scan mode.

10.3 Video Digitization

Is the video (detected) signal digitized?

Yes [X] No [ ]

If in Rectified mode; but only saved if in A-scan mode.

10.4 Digitizer Frequency

What is the minimum digitizer sampling interval or maximum digitizer frequency?

8, 16, or 32 MHz are the selectable sampling rates in A-scan mode.

The rate is always 32 MHz in P-scan or T-scan mode.

The maximum record length is 1024 μs.

10.5 Digitizer Resolution

How many bits resolution does the digitizer have?

The ultrasonic amplitude is digitized to 8 bits (0 to 120 dB in 0.5 dB increments, for P-scan images).

T-scan images are in thickness, with a resolution of 31 nanoseconds. This implies that the smallest distance theoretically resolvable in steel is 0.004 in. (0.09 mm) in longitudinal mode and 0.002 in. (0.05 mm) in shear mode. The calculation is as follows: at sampling frequency f, the time between samples is 1/f. At velocity v, the sound path traveled between samples is then v/f, and the change in distance for a round-trip measurement is $v/(2\cdot f)$. The frequency f is 32 MHz, and in steel, the longitudinal velocity is about 0.23 in./μs (0.59 cm/μs), so $v/(2\cdot f) = 0.23/64 = 0.004$ in. ($0.59/64 = 0.009$ cm). The calculation for the shear case is similar, but using a velocity of 0.13 in./μs (0.32 cm/μs).

The position digitizer has 14 bits resolution, 12 bits accuracy (1 part in 4096).

The A-scan has 8 bit resolution (1 part in 256). This corresponds to 0.4% of peak value for a linear, rectified display; 0.4% of peak-to-peak value for a linear, RF display; 0.5 dB resolution in logarithmic, rectified mode; and 1 dB resolution in logarithmic, RF mode.

The receiver has a logarithmic amplifier with a measured dynamic range of 104 dB at 1 MHz.

11.0 Data Acquisition Limitations

11.1 Maximum A-scan Length

1024 microseconds, which gives an equivalent steel thickness of 3.58 in. (9.09 cm) as the maximum that can be included within one A-scan.

11.2 Maximum Scan Length (Points)

What is the maximum number of A-scans in a scan line?

This question is being interpreted in the context as "maximum number of image pixels on the scanning axis," which is equivalent to "number of A-scans per scan line."

In P-scan and T-scan modes, normal practice is to limit the scan line length to around 50 A-scans to assure that image resolution is similar to scan resolution. To calculate the theoretical maximum, we consider the 84-kbyte file that results from a scan of 70 mm × 83 mm at 0.5-mm step (2.8 in. × 3.3 in. at 0.02-in. step). Since each millimeter is two steps or scans, this data represents 140 scans of 166 steps each, making 140 × 166 = 23,240 points. Dividing the file size of 86,016 (84 × 1,024) by the number of points represented, we see that it requires roughly 4 bytes for each point scanned. We then note that the data for one scan line must all fit in internal storage. Since there are 288 kbytes of internal storage, the maximum number of points that can be stored internally is 288 × 1024/4 = 73,728. Thus it is theoretically possible to have some 70,000 A-scans in a scan line; but this number is not useful, as the machine would have to write all the data to diskette after each scan line, then it would be necessary to insert a new diskette every 5th scan line. Finally there is no way to view the image in any reasonable detail with present software. A reasonable upper limit, assuming development of post-processing software to view the image at full resolution, would probably be 1000 A-scans per scan line.

In A-scan mode, the limit depends on the length of A-scan stored. For an A-scan length of 250 samples, the maximum is about 1000 A-scans per scan line; the practical limitation is around 100, for reasonable data-taking and image interpretation.

11.3 Maximum Scan Length (Bytes)

What is the maximum amount of data in a scan line?

Maximum internal storage = 288 kbytes. Can store more by using multiple floppy disks. It is not feasible to go beyond 288 kbytes per scan line, as data-taking would be very slow due to waiting to write to diskettes and change diskettes. Incorporation of a hard disk would increase this limit, if it were desired to do so.

11.4 Maximum Number of Scan Lines

In P-scan and T-scan modes, normal practice is to limit the scan line length to around 125 A-scan samples to assure that image resolution is similar to scan resolution. The theoretical limit is indefinite, except that data-taking would be very slow due to waiting to write to diskettes and change diskettes.

11.5 Scan Limitations

Is the amount of material that can be inspected during a scan limited by the computer system?

Yes [X] No [ ]

For the normal use of the system, to inspect welds, there is no limit on the length of weld that can be inspected in one scan, provided that by "scan" we understand a set of scans performed in automatic sequence, with manual intervention to change diskettes as needed. However, the width of material is limited by the length of the Y-axis scanning arm.

11.5.1 Cause of Limitation

If the amount of material that can be inspected during a scan is limited by the computer system, what causes the limitation? Is the inspection limit determined by limitation on the number of samples in each A-scan, on the number of A-scans in each scan line, or the number of scan lines in a scan?

[ ] Number of Samples
[X] Number of A-scans
[ ] Number of Scan lines
[ ] A combination of the above (describe):

11.5.2 Nature of Limitation

Are the limits set by the data storage medium or by the data processing software?

Storage Medium [X] Processing Software [X]

The limitations are as described in Section 11.2.

12.0 Data Types

12.1 Header Format

Proprietary.

12.2 Data Storage Options

What processed data storage options are available? (ASCII, binary, etc.)?

None.

12.3 Equipment Setting Location

Are the equipment settings attached to the data file itself or saved in a separate file?

Attached [X]   Separate [ ]

12.4 Equipment Setting Limitations

Does the system record all or only some of the equipment settings that are needed to repeat a measurement? If only some are recorded, list all those that are necessary but not recorded.

All [ ]   Some [X]

Not specifically recorded: Scanner serial number, cable descriptions, scanner control settings (including speed and index), type of couplant, calibration block identification.

Note: Up to 20 notes of 11 characters each can be used to record supplementary information, which is only correct if the operator has taken pains to enter and verify it.

12.5 Format (Portable or Machine-Specific)

Does the system save the equipment settings in a portable format such as ASCII encoded strings or in machine specific (binary) format?

Portable [ ]   Specific [X]

Format:
Proprietary. Character data is ASCII, but embedded in other data, and numeric data is binary.

12.6 Format Documentation (Parameters)

Is the format of the archived equipment settings given in the system documentation?

Yes [ ]   No [X]

Documentation states that the format is proprietary.

12.7 Format Documentation (Data)

Is the format used to archive the data given in the documentation?

Yes [ ]   No [X]

Documentation states that the format is proprietary.

12.8 Data Format (Proprietary or Public)

Is the data format strictly proprietary, or fully public, or something in between? If it is proprietary, what means are provided for translating or exporting it into a non-proprietary format?

Strictly proprietary; there are no means of exporting or translating the data for third party use unless the third party wants to invest in the software packages (PC-PROG and SuperSAFT).

12.9 RF Data Storage

Does the system store RF data? If so, indicate the format.

Yes [ ] No [ ] Sometimes [X]

Only if in RF A-scan mode.

Format:
8 bit, proprietary format

12.10 Video Storage

Does the system store video detected data? If so, indicate the format.

Yes [ ] No [ ] Sometimes [X]

Only if in rectified A-scan mode.

Format:
8 bit, proprietary format

12.11 RF or Video Data Portability

Is the RF or video data portable to other machines?

Yes [ ] No [X]

Can only be used on PC's with programs supplied by the manufacturer of P-scan: the Danish Welding Institute, a division of FORCE Institutes.

13.0 Processing Options

13.1 Data Processing Options

Do data processing options exist for the system (e.g. SAFT)?

Yes [X] No [ ]

13.2 Data Processing Examples

Review and describe all data processing options by way of example from the data taken during the system review process or other available data.

The PSP-3 allows replay of A-scans, and has an option called Image Processing. The post-processing computer provides color presentations, analysis of amplitude or thickness by area, and a post-processing tool called SuperSAFT.

13.2.1 Replay of A-scans

When data has been taken in A-scan mode, the PSP-3 can sequence automatically through the acquired A-scans.

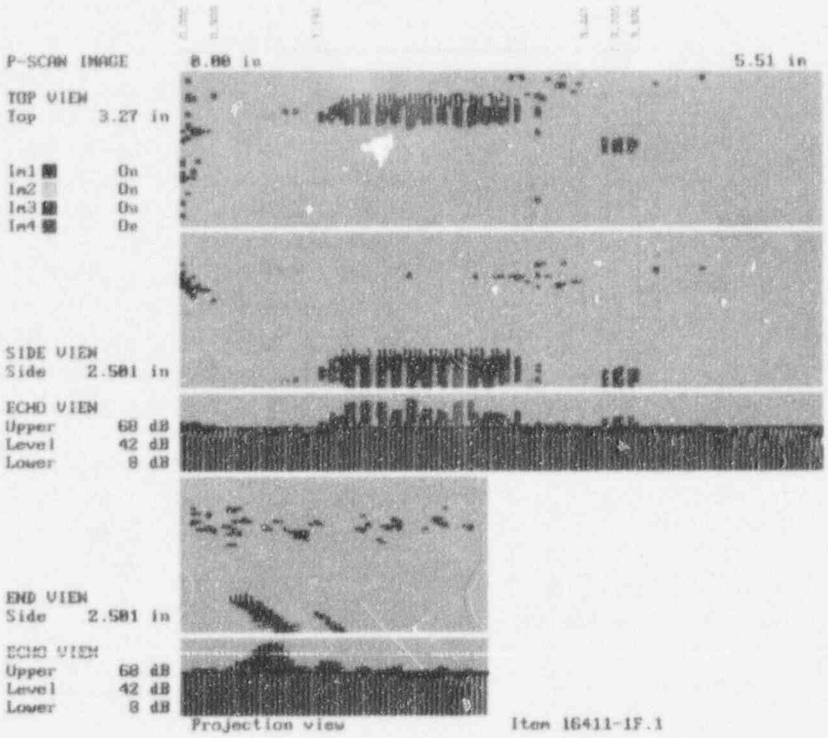
13.2.2 PSP-3: Image Processing

Image Processing is an averaging or filling process used to smooth images. The original image is destroyed by the process, so a copy should always be used. When a file has been image processed, it cannot be image processed a second time. The file is marked so that the program knows it has been image processed. There are two slightly different image processing methods, one optimized for P-scan mode and the other for T-scan mode. Figure 13.1 shows a P-scan image processing example, with the unprocessed image at top and the processed image at bottom. Note that in the lower image, the black and blue areas of the two large indications have been filled in solidly along the bottom. Note also that there is no printed indication on the lower image that it has been image processed, even though the file is recognized as such by the program.

There are two possible problems with the use of image processing. One is that closely spaced, but physically separate, indications may be blended into one. The other is that coverage may appear to be much denser than it really is. The P-scan manual recommends that data be saved before image processing, and then saved under a new name after processing. This procedure should be followed, and both files retained.

13.2.3 SuperSAFT Images

SuperSAFT is a line SAFT (planar 2-D, not volumetric 3-D) analysis available for sets of A-scans meeting certain criteria. We are not aware of field use of this tool at present, and were not able to successfully use the tool ourselves. The examples shown were prepared during a training session attended by the P-scan demonstrator. An example of a SuperSAFT data selection screen with data in multiple tiles is shown in Figure 9.6. Other SuperSAFT images are shown in Figures 13.2 and 13.3. The object from which these were made is not known; they have been included only to show the format of SuperSAFT presentations. The color originals of these images were not available.



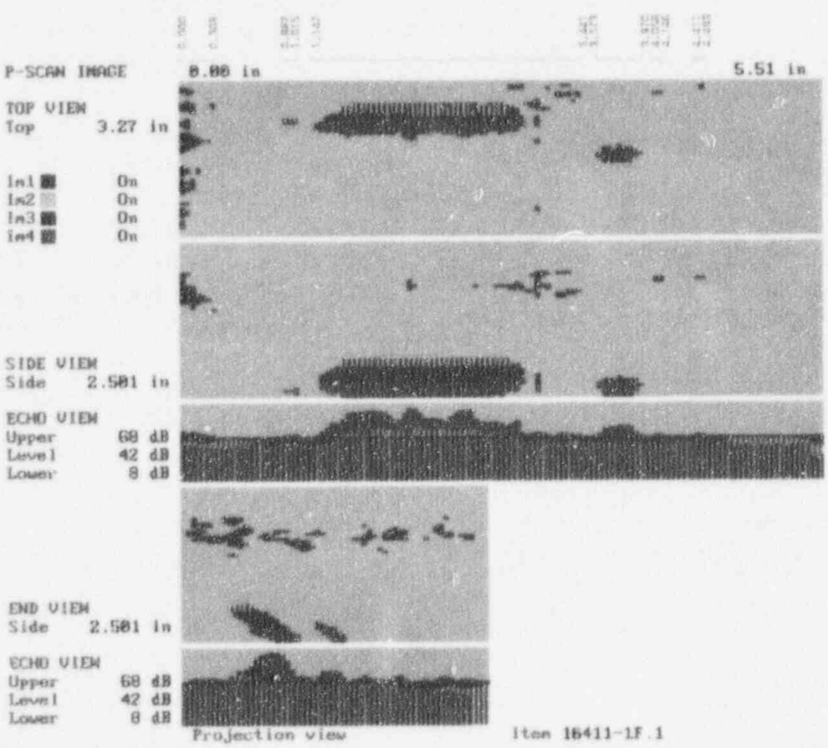


Figure 13.1 Image Processing example. Top image is unprocessed, bottom image is after processing.

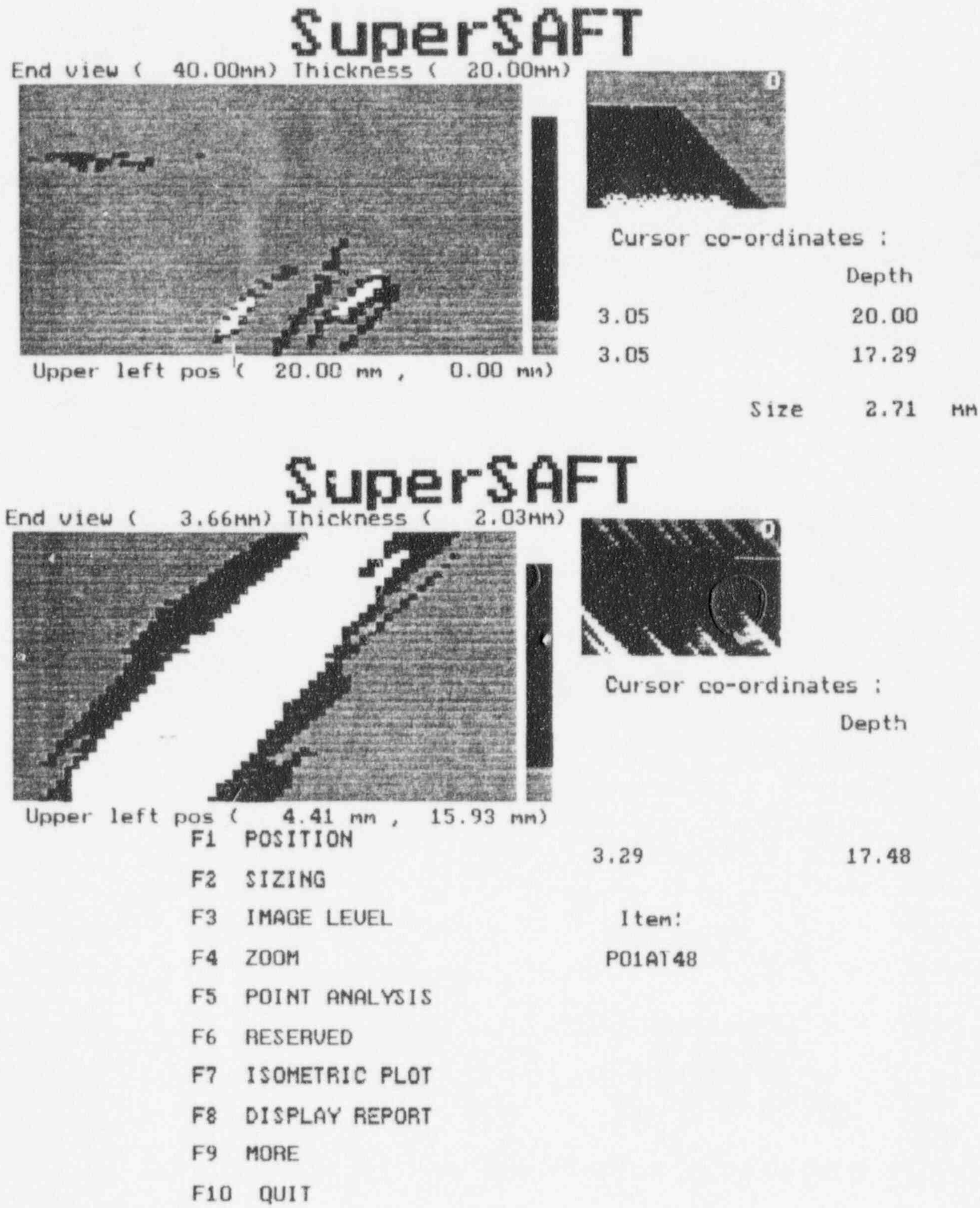


Figure 13.2 SuperSAFT images: normal size (upper) and zoomed (lower)

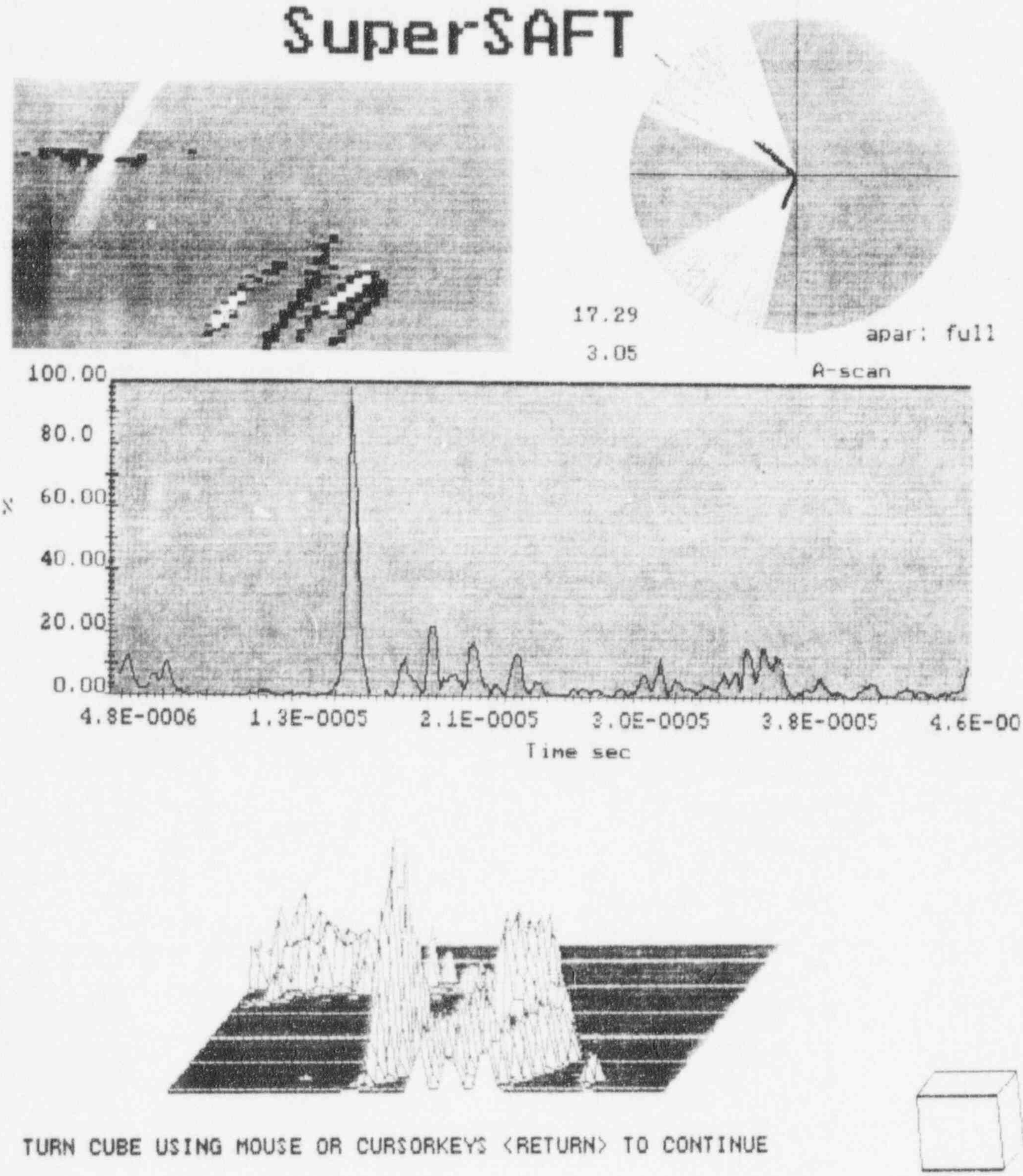


Figure 13.3 SuperSAFT images: Point analysis (upper right), A-scan (center) and 3-D

14.0 Data Storage And Portability/Third Party Review

14.1 Storage Media/Durability

14.1.1 Removable Data Archiving

Does the system archive data files onto a removable data storage medium? Record the type of media used; if none, explain.

Yes [X] No [ ]

Type: 3½-in. high-density floppy, DOS format (multiple disks supported).

14.1.2 Size and Life Limitations

What are the size and media life limitations for the medium?

Size: 1.44 Mbytes
Life: Estimated at 10 yrs.

14.2 Data Availability for Third Party Review

14.2.1 Physical Rescanning

Is there any type of data which requires physical re-scanning?

Yes [X] No [ ]

14.2.1.1 Describe:

Normally scanning is done in imaging mode. To then view A-scans or do SAFT, area of interest must be rescanned in A-scan mode. Also to view detailed sub-images, rescanning is required.

14.2.2 Second System

Does the system produce data files that may be used by a second system?

Yes [X] No [ ]

14.2.3 System Configuration for Data Analysis

Describe the configuration of hardware and software needed to analyze data from the system.

Another PSP-3 or on a PC with software from FORCE Institutes.

14.3 Recommendations for Portability

Make a list of recommended changes for the sake of increased portability of data files. Recommendations:

Make the format non-proprietary, or provide data export options. Include other data as mentioned in Section 12.4.

15.0 Review Checklist

15.1 Before and During Inspection

Have reference standards been scanned to assure proper system operation and required sensitivity?

Have scanner parameters been correctly recorded, either on the computer, or by color photograph, or in writing? Assure the correct recording of the following parameters:

- X-MOTION
  - STEP (ON/OFF)
  - STEP SIZE (mm)
  - CORRECTION FACTOR (+/-percent)
  - CONT (ON/OFF)
  - SPEED (+/-mm/s)
- DIRECTION (CW/CCW)
- Y-MOTION
  - NEAR END (+/-mm)
  - SPEED (mm/s)
  - FAR END (+/-mm)

Have positioning conventions been observed and clearly noted, and photographed if appropriate? Assure that the following have been noted:

- Zero angle reference marks
- Weld centerline
- Positioning of the scanner unit relative to the part
- Clockwise/counterclockwise
- Scanner arm relative to flow direction
- Orientation of probe(s)
- Channel number for each probe

Is scanner arm zero position correctly calibrated or noted?

If a curved Y-arm was used, has it been fully described? Has the correction factor been set and recorded?

If scanner is mounted on a pipe of different diameter than the one being inspected, have both diameters been recorded and the appropriate correction factors entered (both on the scanner control unit and in the software)?

Was the scanner mounted on a track? If not, the final position should be very carefully checked to ensure that the scanner has not become unduly skewed during the scan.

Have the following ultrasonic parameters been properly set and noted?

- Probe frequency
- Refracted angle
- Skew angle
- X and Y offsets
- Delay of shoe
- Material velocity (shear or longitudinal as appropriate)
- Part thickness, width, and length
- A-scan start and range
- Gate starts and lengths
- Attenuation, if used
- Probe reference levels, if used

For any parameters recorded in writing, have the corresponding sections of the computer record been left blank or made identical to the written record, so that there can be no confusion? Particularly, step size and speed?

Has full coverage been assured? If any C-scan view is examined at full gain, there should be no areas of missing or intermittent data. Areas of missing data indicate lack of coverage. Areas of intermittent data indicate either poor couplant or excessive speed relative to the repetition rate.

In areas of multiple overlapping indications, has A-scan data (which allows image manipulation) been taken or real-time evaluation been performed?

In the unusual case of multiple indications lined up along both X and Y axes, have A-scans or subvolume scans been made?

If RF or Rectified data were used to evaluate indications, has an appropriate A-scan data set been recorded and printed?

Have all scanner arm screws been checked for tightness at intervals during the inspection? If found loose, has area been rescanned?

Has final scanner position been verified to correspond to expected travel?

Is each image clearly marked to indicate its position relative to the entire part scanned?

If Image Processing has been used, have the original as well as the processed files been saved?

If welds longer than about 1 foot (30 cm) were scanned, were they scanned as separate sections (called "parts")? This is important because the files can then be merged to view the entire weld, or viewed separately to achieve maximum resolution.

If blank lines appear between the scans, verify that the combination of beam width and scan increment indicates full coverage.

15.2 After Inspection

Have printed images been made of all areas containing indications (at least for reportable indications; preferably for all indications evaluated)?

Have printed copies been made of all inspection parameters set in the software?

Have backup copies been made of all data diskettes?

Have printed images been carefully annotated? In particular, have beginning or ending coordinate values been noted for Y and Z axes (the vertical axes in the printed image)?

Are image interpretations consistent with the length, width, and height scales?

16.0 P-scan Parameter Table

The left-hand portion of this table shows a composite of the parameter print-outs as produced by the P-scan Post-Processing program, for several of the trial inspections performed for this Supplement. The designations F1, F2, etc. indicate the Function Key used to access the given parameter for that data set. Since there are some parameters that may or may not be present, depending on the type of data set, the function key will not always be the same. For example, under JOB IDENTIFICATION 2, if the image has been Image Processed, a parameter will be inserted between DATE and REVISION NUMBER, and REVISION NUMBER will therefore be accessed by F5 instead of F4. Such parameters are denoted as "optional" in the P-scan manuals. The short word, immediately after the F-key, is the abbreviation used for the parameter, and the longer word is the name of the parameter in full. After the ">" symbol is the value of the parameter for the present inspection.

The right-hand portion of the table describes the parameter, if a description is needed. The first line of each parameter description indicates the type of parameter; succeeding lines (if any) give the meanings of various values. Parameters for which the type is indicated as "[Data]" have an effect on data taking and/or processing. Parameters for which [Notebk] is indicated are "Notebook" parameters, which may be of interest in interpretation of results, but do not affect how the system records or processes the data.

Since this table is a composite of several data print-outs, some F-keys are repeated (e.g. F4 appears three times in JOB IDENTIFICATION 2). In any single printout, not all of the parameters would appear, and the F-key is never repeated. All F-keys (F1, F2, ..., F9, F0) are always listed; here, the blank ones at the end of each menu have been omitted, to conserve space.

Metric-inch equivalents are not given in this section, as the purpose is to show the format and not to communicate measurements. Wherever "inch" is indicated, "mm" would be indicated, along with a properly converted value, if the display mode were changed from "inch" to "metric."

Parameter	Type, values	Description
Dataset JOB IDENTIFICATION 1: ==================================		
F1 PROG PROGRAM> P-SCAN	[Data]	Type of inspection to be performed
	P-SCAN	Amplitude testing for cracks or other flaws
	T-SCAN	Thickness testing for corrosion or other depth/thickness measurements
F2 MODE MODE> IMAGING	[Data]	Type of data to record
	IMAGING	A single amplitude or time-of-flight measurement for each point inspected
	A-SCAN	RF or rectified waveform recorded for each point inspected. The dataset file name will have an "A" extension.

F3 SCAN	SCANNER>	AWS-TYPE 1	[Data]	Type of scanner used
			AWS	Automatic Weld Scanner
			MWS	Manual Weld Scanner
F4 OPER	OPERATOR:		[Notebk]	Operator name
F5 JOB	JOB:	DETECTION	[Notebk]	
F6 LOC	LOCATION:	EPRI	[Notebk]	
F7 ITEM	ITEM:	C16411-1	[Notebk]	Generally the same as the file name
F8 HEAD1	HEAD1:	0-DEG	[Notebk]	
F9 HEAD2	HEAD2:	4-MHZ	[Notebk]	
F0 LUNIT	LENGTH UNIT>	inch	[Data]	Units: metric or English
			mm, inch	

Dataset JOB IDENTIFICATION 2:
===================================

F1 AUNIT	A-SCAN UNIT>	usec	[Data]	Unit used for horizontal axis in A-scan displays
			usec	Time in microseconds
			mm	Distance in millimeters or inches
			%	Percent of through-wall (used for T-scan images)
F2 TIME	TIME:	06:05:36	[Notebk]	Time at which the inspection was performed, 24-hour clock
F3 DATE	DATE:	92-08-04	[Notebk]	Date on which the inspection was performed, Year-Month-Day
F4	SEQ. NUMBER	1	[Data]	Sequence number of this data set; used for A-scans and certain Subvolume scans (otherwise this parameter does not appear)
			1, 2, 3, 4,...	
F4	IMAGE PROC.:	METHOD 2	[Data]	Image processing method, if any (if the data set has not been image processed, this parameter does not appear)
			METHOD 1	For unscanned pixels only, average the 2 or 4 adjacent pixels (best for T-scan)
			METHOD 2	Use the largest of: this pixel; average of horizontally adjacent pixels; average of vertically adjacent pixels (best for P-scan)
F4	REV. NO.:	5.05	[Data]	Software revision number used to record data

```
F5         SERIAL NO.:        325        [Data]   Serial number of P-scan system con-
                                                  troller used to record data

F6 NOTES NO. OF NOTES          20        [Data]   Number of optional extra notes, which
                                                  will appear in 1 or 2 optional menus
                                                  below this menu


Dataset  NOTE BOOK PARAMETERS 1:         [Notebk] (Appears only if NOTES is 1 or great-
                                                  er)
=====================================
F1 A       A:              AVG 2MM                (These are arbitrary notes recorded to
                                                  verify the use of this feature)
F2 B       B:              REF 03
F3 C       C:              VINKEL I ST
F4 D       D:              1. ANG 44.2
F5 E       E:              2. ANG 44.0
F6 F       F:
F7 G       G:              0
F8 H       H:              0
F9 I       I:              0
F0 J       J:              1111111111


Dataset  NOTE BOOK PARAMETERS 2:         [Notebk] (Appears only if NOTES is 11 or great-
                                                  er)
=====================================
F1 K      *K:                                     (Asterisks indicate that nothing was
                                                  recorded)
F2 L      *L:
F3 M      *M:
F4 N      *N:
F5 O      *O:
F6 P      *P:
F7 Q      *Q:
F8 R      *R:
F9 S      *S:
F0 T      *T:


Dataset  MAIN GEOMETRY:
=====================================
F1 THICK THICKNESS       2.501 inch  [Data]   Part thickness, in current units.
                                              Here, the units are inches.  At any
                                              time during data acquisition or analy-
                                              sis, the units can be converted to
                                              millimeters; the number displayed
                                              would then change to 63.52 mm.
```

F2 WIDTH WIDTH	5.00 inch	[Data]		Scan width. This indicates how wide a band around the weld is being inspected. Here, data will be recorded for 2.5 inches either side of the weld centerline.
F3 SUBV SUBVOLUME>	NO	[Data]		Subvolume indicator
		NO		This is a primary scan
		YES		This is a subvolume scan, used to acquire more data about a portion of the part. The dataset file name will have an "S" extension.
F4 GEOCL GEOM. CLASS>	PLANE	[Data]		Geometry class: determines how the scanner and ultrasonic positional data is interpreted in generating images. Not used for manual scanner. PLANE is normally used, even for pipe scans.
		PLANE		
		CIRCUMFERENTIAL		
		HELIX		
		LONGITUDINAL		
		SPHERE		
F5 DIAMETER		[Data]		Used for all except PLANE
F6 PITCH		[Data]		Used for HELIX

Dataset SUBVOLUME DEFINITION: — This section is present only for SUBVOLUME scans.

====================================

F1 XCHNG X CHANGE>	YES	[Data]	Is the starting or ending X-coordinate of this scan different from those of the primary scan?
F2 X-CTR X-CENTRE	2.72 inch	[Data]	If X CHANGE is YES, what is the midpoint of the X values for this scan?
F3 X-RNG X-RANGE	0.98 inch	[Data]	If X CHANGE is YES, what is the difference between the starting and ending X values for this scan?
F4 YCHNG Y CHANGE>	YES	[Data]	Similar to X CHANGE
F5 Y-CTR Y-CENTRE	0.79 inch		
F6 Y-RNG Y-RANGE	2.48 inch		
F7 ZCHNG Z CHANGE>	YES	[Data]	Similar to X CHANGE
F8 Z-CTR Z-CENTRE	2.749 inch		
F9 Z-RNG Z-RANGE	1.000 inch		

Dataset SCANNER OPERATION:

F1	XCORR	X-CORRECTION	1.000	[Data]	Correction factor for use if the diameter of the scanner track is different from the diameter of the pipe
F2	YCORR	Y-CORRECTION	1.000	[Data]	Correction factor for use if the Y-arm has a non-standard encoding (e.g. curved Y-arm for spherical scanning)
F3	XMODE	X-MODE>	STEP	[Notebk]	Is scanner control unit set to STEP or CONTinuous?
F4	X-STP	X-STEP	0.39 inch	[Notebk]	What is X motion STEP set to?
F4		X-SPEED		[Notebk]	What is X SPEED set to?
F5	DIR	DIRECTION>	[illegible]	[Notebk]	What is DIRECTION set to?
F6	Y-SPD	Y-SPEED	1.97 in/s	[Notebk]	What is Y SPEED set to?
F7	NEND	NEAR END	0.00 inch	[Notebk]	What is Y-MOTION NEAR set to?
F8	FEND	FAR END	0.00 inch	[Notebk]	What is Y-MOTION FAR set to?

Dataset INSPECTION SYSTEM:

F1	MXPRF	MAXIMUM PRF	0 Hz	[Data]	Maximum pulse repetition frequency (repetition rate)
				0	Automatically regulate repetition rate as fast as data-taking will allow
				1,2,....	Maximum repetition rate per second
F2	XSTRT	X START POS.	0.00 inch	[Data]	Offset from a fixed zero point on the pipe
F3	PARTL	PART LENGTH	5.51 inch	[Data]	Length of region over which data is to be taken
F4		PART NUMBER	1	[Data]	When an automatic sequence of scans is made along the weld, the part number increases by 1 for each scan. For example, for a 10-in. (25-cm) diameter pipe, the 32 in. (81 cm) of circumference might be covered in 4 scans of 8 in. (20 cm) each; the part numbers would be 1, 2, 3, and 4.
F5	T/S	T/S RATIO>	SAME SIZE	[Data]	Top to Side ratio for image: determines the relative sizes of the Y dimension of the TOP image and the Z dimension of the SIDE image. This does not affect the X pixels.

```
                                  SAME SIZE  -Use the same number of pixels for
                                             both.
                                  SAME SCALE  - Use a number of pixels proportion-
                                             al to the actual Y and Z dimensions.
                                  OPTIONAL   - Choose your own proportion.

F6       TOP                      [Data]     Defines the number of pixels in the
                                             TOP Y dimension if OPTIONAL is chosen
                                             for T/S RATIO.
                                  1-119      60 is the same as SAME SIZE.

F6 IMAGS IMAGES            4      [Data]     Number of images in use for this scan
                                  1-4

F7 PROBS PROBES            1      [Data]     Number of probes in use for this scan
                                  1-4


Dataset  PROBE 1 SPECIFICATIONS:
====================================
F1 IDENT PROBE IDENT:  L17595     [Notebk]
F2 FREQ  PROBE FREQ.    4.00 MHz  [Notebk]
F3 IDLY  INDEX DELAY    8.30 usec [Data]     Internal delay: delay from the element
                                             to the exit point of the delay line

F4 IPNT  INDEX POINT:  8.6        [Notebk]   Arbitrary description of the beam exit
                                             point on the probe face

F5 ANGLE PROBE ANGLE     0.0 deg  [Data]     Beam angle in the material, normal
                                             being 0

F6 NGATE NO. OF GATES      4      [Data]     Number of gates used for this probe


Dataset  PROBE 1 TIME GATES:
====================================
F1 GT1ST GATE 1 START     50 %    [Data]     Starting point of the first gate,
                                             relative to the top surface, as a
                                             percentage of the part thickness (al-
                                             lowing for the beam angle and the
                                             internal probe delay).  For instance,
                                             in a part of 2-in. (5-cm) thickness
                                             with a 60-degree beam angle, a 50%
                                             setting would begin at a 1-in. (2.5-
                                             cm) depth, using a time delay corre-
                                             sponding to 2 in. (5 cm) of metal
                                             travel plus delay in the delay line.

F2 GT1RG GATE 1 RANGE     25 %    [Data]     The extent of the first gate, relative
                                             to the start of the gate (not relative
```

				to the top surface) as a percentage of part thickness. To continue the above example, a 25% setting would cover from a depth of 1 in. (2.5 cm) to a depth of 1.5 in. (3.75 cm).
F3 GT2ST	GATE 2 START	70 %	[Data]	Starting point of the second gate, still relative to the top surface (not relative to the end of the first gate). Continuing the above example, a 70% setting would begin at a depth of 1.4 in. (3.5 cm), slightly overlapping the first gate.
F4 GT2RG	GATE 2 RANGE	30 %	[Data]	Extent of the second gate. Continuing the example, a 30% setting would cause this gate to end at the first backwall reflection.
F5 GT3ST	GATE 3 START	80 %	similarly...	
F6 GT3RG	GATE 3 RANGE	25 %		
F7 GT4ST	GATE 4 START	90 %		
F8 GT4RG	GATE 4 RANGE	25 %		

Probe 1 ROTATIONAL GATES:
==================================

This is used for manual probes. This option was not reviewed.

Dataset PROBE 1 GATE EVALUATION:
==================================

F1 GT1IC	GT. 1 I-CODE	20	[Data]	Amplitude difference to use in discriminating separate echoes from fluctuations within an echo, in half-decibel units. 20 represents 10 dB, and is the recommended setting. The peak-detection algorithm uses this figure; a dip of 10 dB defines the end of one peak and the beginning of another.
F2 GT2IC	GT. 2 I-CODE	20		
F3 GT3IC	GT. 3 I-CODE	20		
F4 GT4IC	GT. 4 I-CODE	20		

Dataset PROBE 1 GATES/IMAGES:
==================================

F1 GATE1	GATE 1 IMAGE	1	[Data]	Defines the correspondence between images and gates. Shown are the nor-

mal values for one probe. For two probes, F3 and F4 would normally be omitted here, and Image 3 would be used for Gate 1 of Probe 2, Image 4 for Gate 2 of Probe 2. Assignment is at the user's discretion; it is even possible to assign the same image to more than one probe, but the data then becomes impossible to separate.

```
F2 GATE2 GATE 2 IMAGE        2
F3 GATE3 GATE 3 IMAGE        3
F4 GATE4 GATE 4 IMAGE        4
```

```
Dataset  PROBE 1 TRANSM./RECEIV.:
====================================
F1 TRANS TRANSM. NO.         1        [Data]    Transmitter: the channel (connector)
                                                used to pulse PROBE 1

F2 RECIV RECEIV. NO.         2        [Data]    Receiver: the channel (connector) used
                                                to receive from PROBE 1.  Shown is the
                                                setup for a dual-element probe.  For a
                                                single-element probe, the Transmit and
                                                Receive channels must be the same.

F3 EXMAT EXT. MATCH.>  NO             [Notebk]  If YES, two more Notebook parameters
                                                follow, doucmenting the cable and
                                                external matching network used.

F4 OPSET OPT SETTING>  YES            [Data]    Always equal to YES
F5 RECTF RECTIFIER>    FULL WAVE      [Data]    Setting of rectification
                                      FULL WAVE, POS. HALF WAVE, NEG. HALF WAVE

F6 LOCUT LOW CUT-OFF>      1.0 MHz    [Data]    Low-frequency cutoff of RF filter
                                      0.5, 1, 2, 3 MHz

F7 HICUT HI. CUT-OFF>     10.0 MHz    [Data]    High-frequency cutoff of RF filter
                                      4.5, 6.5, 10, 15 MHz

F8 DROOP DROOP RATE>       1.0 V/ms   [Data]    Rectifier filter setting (recommended
                                                setting is 1/4 of the probe frequency,
                                                e.g. 1.0 for a 4.0 MHZ probe).
```

```
Dataset  PROBE 1 VELOCITY/TVG:
====================================
F1 VELOC VELOCITY       233.47 i/ms   [Data]    Sound velocity in the material
F2 ATTEN ATTENUATION      0.00 dB/i   [Data]    Attenuation in the material
```

```
F3 NEARF NEAR FIELD      0.04 inch  [Data]    Near field distance, including the
                                              delay line

F4 COMP  COMPENSAT.>   OFF          [Data]    Time-variable gain compensation (this
                                              option was not reviewed)


Dataset  PROBE 1 OPTIONAL TVG(1):
=================================== [Data]    Defines the time-variable gain (TVG)
                                              curve, using up to 10 points.  This
                                              option was not reviewed.
F1 1.Distance
F2 1.Amplitude
F3... (repeated pairs of Distance and Amplitude, up to 5 pairs)


Dataset  PROBE 1 OPTIONAL TVG(2):
=================================== [Data]    TVG, second 5 pairs


Dataset  PROBE 1 REFERENCES:
===================================           This section provides for transfer of
                                              amplitudes from a reference block to
                                              the part under inspection.  The dB
                                              levels reported in image analysis are
                                              based on the instrument reading plus
                                              the reference level (F4) which is
                                              defined as F1-F2-F3.  The use of these
                                              values was not reviewed.
F1 RECHO REF. ECHO          0 dB    [Data]    Reference echo amplitude
F2 TRANS TRANS. CORR        0 dB    [Data]    Transfer correction
F3 BLOCK BLOCK CORR.        0 dB    [Data]    Block correction
F4       REF. LEVEL         0 dB    [Data]    Reference level

Dataset  PROBE 1 SETUP:
===================================
F1 ROT   ROTATION           0 deg   [Data]    For angle-beam probes, the counter-
                                              clockwise angle of the front of the
                                              probe relative to the X-axis.  If the
                                              probe is pointed along the Y-axis
                                              (perpendicular to the weld centerline,
                                              for circumferential welds), the rota-
                                              tion is 90; opposite to the Y-axis is
                                              270.  Values are always positive.
```

```
F2 POSM  POS. METHOD>  ABSOLUTE     [Data]    Positioning method
                                    ABSOLUTE - Position measurements for this probe
                                              are relative to the scanner origin
                                              point.
                                    RELATIVE - Position measurements for this probe
                                              are relative to another probe.

F3 X VAL X-POS VALUE      5.51 inch [Data]    Probe X position relative to origin
                                              (absolute only)

F4 Y VAL Y-POS VALUE    -2.607 inch [Data]    Probe Y position relative to origin
                                              (absolute only)


Dataset  PROBE 1: A-SCAN REC PAR.             A-scan recording parameters (for A-
                                              scan data sets only)
====================================
F1 ATYPE ASCAN TYPE>   RECTIFIED    [Data]    Type of A-scan data
                                    RF, RECTIFIED

F2 ASTRT A-SCAN START     40.0 us   [Data]    Start of data recording for the A-
                                              scan, from Main Bang

F3 ASRNG A-SCAN RANGE     25.0 us   [Data]    Duration of data recording for the A-
                                              scan, from A-SCAN START

F4 RECRT REC. RATE>    32 MHz       [Data]    Sampling and digitization rate
                                    8, 16, 32

F5 TRIGM TRIG. MODE>   TIME         [Data]    Triggering mode for Main Bang
                                    TIME      Take data at intervals defined by R-
                                              INT (below)
                                    X-POS     Take data at axis positions beginning
                                              at X-STA (below) and separated by P-
                                              INC (below)
                                    Y-POS

F6 R-INT REC INTERVAL       20 msec [Data]    Time interval between Main Bangs, for
                                              TIME mode

F6 X-STA X START POS.    1.575 inch [Data]    Beginning X-position for A-scan data
                                              taking, for X-POS mode

F7 P-INC POSIS. INC.    -0.020 inch [Data]    Interval between X positions for A-
                                              scan data taking, for X-POS mode

F6 Y-STA Y START POS.    1.575 inch [Data]    Beginning Y-position for A-scan data
                                              taking, for Y-POS mode
```

F7	P-INC	POSIS. INC.	-0.020 inch	[Data]	Interval between Y positions for A-scan data taking, for Y-POS mode
F8	A-NUM	NUM. A-SCANS	100	[Data]	Number of A-scans to take
F9		FIRST A-SCAN	1	[Data]	Number of the first A-scan in this sequence (supplied by the computer)
F0		LAST A-SCAN	100	[Data]	Number of the last A-scan in this sequence (supplied by the computer)

Dataset PROBE 2 SPECIFICATIONS...
==================================

For multiple probes, all the PPOBE datasets will be repeated, once for each additional probe. Since only one probe can be used for A-scan data, the A-SCAN dataset will appear only once.

Bibliography

PSP-3 P-scan Processor Operation Manual. 1991. FORCE Institutes, Park Allé 345, DK-2605 Brondby, Denmark.

P-scan Scanners Operation Manuals. 1991. FORCE Institutes, Park Allé 345, DK-2605 Brondby, Denmark.

P-scan Post Processing Software Operation Manual. 1991. FORCE Institutes, Park Allé 345, DK-2605 Brondby, Denmark.

Nielsen, Niels. 1981. "P-scan System for Ultrasonic Weld Inspection," in *Nondestructive Evaluation in the Nuclear Industry*, American Society for Metals, pp. 171-195.

Glossary

This Glossary gives special or additional meanings of the indicated words, as used in the context of P-scan operation. For basic or general meanings of many terms, see the Glossary to the Introductory Volume of NUREG/CR-5985.

A-scan mode: Data gathering and analysis in which either the RF or the rectified waveform is stored. A-scan data may be displayed as an Individual A-scan or a Composite A-scan (see Section 5.7).

Add: Take two data files covering the same volume and combine the data (distinguished from Push and Merge).

Attenuation: See Level.

AWS: Automatic Weld Scanner (distinguished from Manual Weld Scanner).

B-scan: In P-scan usage, reserved for a B-scan view of A-scan mode data. In Imaging mode, projected B-scans are referred to simply as SIDE and END views.

C-scan: Not used in P-scan terminology. It is called a TOP view.

Centreline: A horizontal marker line used for sizing or to control the center of the Weld Overlay.

Circumferential (Geometry Class): Butt weld in pipe.

Composite A-scan: A display showing one scan line of color-coded A-scans (see Section 5.7).

Continuous: A zigzag scan pattern in which the X axis moves continuously while the probe moves back and forth across the Y axis (distinguished from Meander).

Crosshair: The X and Y marker lines, as a pair.

Diameter: Outside diameter of pipe or sphere.

Echo View: A data presentation format in which the vertical axis represents peak echo amplitude and the horizontal axis represents reflector position. See Section 5.

End View: A projected view from the end of the weld, i.e. the weld centerline appears as a single vertical line (for a circumferential weld, this is from the side of the pipe). See Section 5.

Far: A rotary switch setting on the AWS scanner, indicating the most positive or least negative Y-axis position of each stroke (opposed to Near).

Gain: See Level.

Gate: P-scan records data within the time periods specified by one to four gates. If multiple probes are used, each probe has one or more gates assigned to it, but the total number of gates used cannot exceed four. Use of the Manual Weld Scanner permits the definition of four Rotational Gates in addition to the four time gates.

Gate Start, Range: Gate times are specified in percentage of part thickness. the beginning and duration of each gate is specified.

Geometry: The items that define the overall shape of a part: Thickness, Width, Geometry Class, Diameter, and Pitch.

Geometry Class: Type of weld: Plane, Circumferential, Helix, Longitudinal, and Sphere. "Plane" may legitimately be used in many types of pipe weld inspections.

Helix (Geometry Class): Spiral weld in pipe.

Im1, Im2,...: Abbreviation for Image 1, Image 2,....

Image: Data taken by the P-scan is defined in terms of four images, referred to as Image 1, Image 2,.... Normally each image corresponds to a gate, although Image 1 might correspond to Gate 3, Image 2 to Gate 1, etc. It is also possible to use the operations of Add, Merge, and Push to obtain images that correspond to combinations of gates.

Image Processing: An averaging or filling process used to smooth images. The original image is destroyed by the process, so a copy should always be used.

Imaging Mode: Data gathering and analysis using only the projected values of the A-scans (see Sections 5 and 10.1).

Img 1, 2,...: Abbreviation for Image 1, Image 2,....

Inch: A derivative display unit, equal to 2.54 cm. Data is taken and recorded in millimeters, but may be specified and presented in inches whenever desired. Conversion is automatic.

Index Point: The point on the surface of the probe through which the geometrical center of the ultrasonic beam passes; exit point.

Individual A-scan: A display showing a single A-scan (see Section 5.7).

Level (1): Presentation amplitude is specified as a "Level." Since data is taken over the full amplitude range of the instrument, the concept of "gain" or "attenuation" is not meaningful. Instead levels are specified for "Minimum," "Maximum," "Level," and each color.

Level (2): The minimum level displayed in the Top, Side, and End views of a P-scan imaging mode presentation.

Longitudinal (Geometry Class): Longitudinal seam weld in pipe.

Lower: The minimum level displayed in the Echo Views

Main Geometry: Geometry.

Marker Line: Movable lines on the P-scan post-processing display. There are two horizontal lines on the Top View (Y marker line and Centreline) one vertical line passing through the Top and Side Views (X marker line), and one horizontal line on the Side view (Z marker line).

Maximum: The maximum level displayed in the Echo Views of a P-scan imaging mode presentation.

Meander: Step mode, i.e. a scan pattern in which the probe travels across the Y axis, then the X axis moves one step, then the probe travels back across the Y axis.

Menu: Any screen presentation on the PSP-3; also, parameter definition screens in the P-scan post-processing program.

Merge: Take two data files covering adjacent volumes and combine the into a single file (distinguished from Add and Push).

Minimum: The minimum level displayed in the Echo Views of a P-scan Imaging mode presentation.

mm: Used generically to mean "length unit" as distinct from "time unit" (regardless whether mode is inch or metric).

Mode: Imaging mode or A-scan mode.

Module (X-module, Y-module):

MWS: Manual Weld Scanner, with automatic data taking by the P-scan system controller (distinguished from Automatic Weld Scanner).

Near: A rotary switch setting on the AWS scanner, indicating the least positive or most negative Y axis position of each stroke (opposed to Far).

Notebook: Notebook parameters are various data that are input into the PSP-3 system controller (or the Post-Processing program) that are displayed but have no effect on inspection or processing. In particular, the scanner controls (Speed, Near, Far, Step Size) are notebook parameters: the operator sets them on the scanner control unit front panel, and may also input them into the PSP-3; but it is only the settings on the scanner control unit that control the probe motion.

P-scan: Stands for Projection Image Scanning. It is the name used by FORCE Institutes for its proprietary computer-based ultrasonic inspection system (see Sections 5 and 10.1).

Part: A section of an item under inspection, delimited by X and Y values. A large pipe is generally scanned in several parts, in order to provide reasonable detail and avoid excessively large data sets. The parts for a circumferential weld, for example, might be four quadrants, with all four having the same Y boundaries, but the first X value of the second part would be one step beyond the last X value of the first part, and so on.

Part Number (1, 2, 3,...): In a multi-part inspection, the adjacent (non-overlapping) sections scanned are automatically consecutively numbered from 1, so that their images can later be combined.

PC-PROG: A FORCE Institutes proprietary post-processing program for P-scan data. PC-PROG runs on a PC-compatible computer, and produces color images.

Pitch: Pitch angle of a spiral weld (clockwise, relative to the circumferential direction)

Plane (Geometry Class): A weld in a planar surface. Also, a weld in a non-planar surface that can be adequately inspected and presented as though it were in a planar surface (to reduce program calculation times).

Positioning (absolute, relative): If only one probe is used, absolute positioning is used. If more than one probe is used, the second (third, fourth) probe(s) may use either absolute positioning, relative to the axis definitions, or relative positioning, which locates them relative to the first probe.

Probe: Ultrasonic transducer plus housing, beam angle, rotation angle, offsets, frequency, etc. Up to four probes may be defined at one time. Note that the word "transducer" is not used for this in P-scan terminology.

Processing: Image Processing

Projection: One of two types of Echo View. See Section 5.

Projection Image Scanning: see P-scan.

PSC: Charger unit for the PSP.

PSP: P-scan Processor, system control unit for P-scan inspections. As of this writing, the PSP-3 is used.

Push: Take two images in the same file and combine them into a single image (distinguished from Merge).

RCU: Remote Control Unit.

Remote Control Unit: A box with pushbuttons and a cable attached to the Weld Scanner Control Unit, allowing manual intervention in the control of the Automatic Weld Scanner.

Rotation: For an angle-beam probe with the Automatic Weld Scanner, the counter-clockwise angle in degrees between the positive X-axis and the "front" of the probe. For example, using a 60 degree shear wave probe with the beam aimed perpendicular to the weld root of a circumferential weld, in the positive X direction, the Rotation is zero. If the direction is negative X, the Rotation is 180. Using the same probe to inspect a longitudinal seam weld, if the weld is to the left of the probe (positive Y), the Rotation is 90, and if the weld is to the right, the Rotation is 270.

Rotational Gate: For an angle-beam probe with the Manual Weld Scanner, a gate that defines the amount of skewing that the operator can perform while inspecting.

Scan: A part or a set of adjacent parts (see "Part").

Scanner Control Unit: Weld Scanner Control Unit.

Scanner: The electro-mechanical apparatus, connected by cable to the Scanner Control Unit and the PSP-3 System Controller, allowing the probe to move over the part to perform P-scan inspections.

Screen Dump: A printed sheet containing the screen image (in black-and-white for the PSP-3 system controller; in color for the Post-Processor).

Section: One of two types of Echo View. See Section 5.

Sequence Number: Part Number.

Side View: A projected view from the side of the weld (for a circumferential weld, this is from the end of the pipe). See Section 5.

Skewing: For the Manual Weld Scanner, the operator can twist the probe left and right while scanning. This motion is not encoded, so the exact direction of the beam is not known; but the limits of skew are indicated by the Rotational Gate.

Sphere (Geometry Class): A weld in a spherical surface.

Standby: A P-scan operating mode in which the ultrasonics are active, but the mechanical system is under operator control.

Step: An increment in the X axis.

Step Mode: A scan pattern in which the probe travels across the Y axis, then the X axis moves one step, then the probe travels back across the Y axis.

Stroke: A single sweep of the Y axis from Near to Far or from Far to Near. Note that in many systems, it would be the X-axis that is stroked.

Subvolume: A scanning mode in which a portion of a part is re-scanned in order to bring out more detail.

SuperSAFT: A line SAFT (planar 2-D, not volumetric 3-D) processing mode applicable to certain sets of A-scans.

T-scan: Thickness scan, a mode of P-scan inspection optimized for measuring thickness variations, and used for corrosion detection and measurement.

Thickness: Thickness of the weld or component being inspected.

Time Gate: A gate defining data that is to be acquired. Up to four gates may be defined at one time. Distinguished from Rotational Gate.

Top View: C-scan view. See Section 5.

Transducer: In P-scan literature, the word "probe" is used for ultrasonic transducers, and "transducer" is used only for position transducer: an encoder, or device that translates position information into electrical signals for use in P-scan data acquisition.

Unit: Parameter defining whether English (inch) or Metric (mm) units are in use.

Upper: The amplitude of signals in the Echo Views that reach the top of the Echo View window.

View: Any of the P-scan image presentations, as Top, Side, End, Echo, A-scan, B-scan. See Section 5.

Weld Overlay: A set of dotted lines overlaid on a view, indicating the nominal positions of the weld faces.

Weld Scanner Control Unit: The electronic control box, attached by cable to the scanner and to the PSP-3 system controller, and controlling the motion of the scanner.

Width: Width of the examination zone; the difference between the smallest and largest Y-axis value on the Top View.

WSC: Weld Scanner Control Unit.

X-Axis: The crawler axis, which is stepped between scans. Note that this is called the Y-axis on many other systems. For a circumferential pipe weld, this is parallel to the weld centerline. For a longitudinal seam weld, this is perpendicular to the weld centerline.

X marker line: A vertical marker line through the Top and Side Views indicating the X coordinate of a point of interest. The value is displayed at the top of the screen.

X-module: The motor and encoder allowing travel along the X-axis, consisting of magnetic crawler wheels and an encoder wheel that rides on the part.

Y-Axis: The scanning axis, which scans from side to side as the crawler moves along. Note that this is called the X-axis on many other systems. For a circumferential weld, this is perpendicular to the weld centerline. For a longitudinal weld, this is parallel to the weld centerline.

Y marker line: A horizontal marker line on the Top View indicating the Y coordinate of a point of interest. The value is displayed at the top of the screen.

Y-module: A straight or curved arm allowing the probe to move in the direction perpendicular to the X-axis. The curved arm is used for scanning spherical surfaces.

Z-Axis: The display axis perpendicular to the plane of inspection, positive being taken as increasing depth; or for a cylindrical or spherical surface, the radial direction (inward).

Zigzag: Continuous mode.

Z marker line: A horizontal marker line on the Side View indicating the Z coordinate of a point of interest. The value is displayed at the top of the screen.

Zoom: A magnification of part of an image taken in A-scan Mode (not available for Imaging Mode images, except by doing a Subvolume scan).

Index to Supplement 1