PROTOCOL FOR DEMONSTRATING THE PERFORMANCE OF ULTRASONIC TECHNIQUES FOR IDENTIFICATION AND SIZING OF OUTSIDE DIAMETER SURFACE-CONNECTED FLAWS

Duke Power Company / EPRI NDE Center
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1.0 GENERAL

This document will serve as a guideline for the demonstration of candidate examination processes, procedures and equipment for in-service inspections performed by Duke Power Company. The performance demonstration will be conducted in a manner that addresses all pertinent parameters of the actual ISI. The performance demonstration is intended to establish the performance of ultrasonic techniques in detecting, characterizing, locating, and sizing of flaws in large diameter vessels.

Duke Power, with assistance from the EPRI NDE Center will serve as the performance demonstration administrator (PDA). Duties in this administrative capacity will include: performance demonstration protocol development, examination procedure review, demonstration monitoring, demonstration results reporting, specimen security, and maintaining the necessary documentation used during the performance demonstration.

There will be no acceptance criteria. Duke Power will be responsible to determine whether the ISI procedure is adequate. Flaw detection, location and sizing results will be determined upon completion of data collection and analysis.

To insure the credibility of the demonstration process, the examination procedure must contain definitive steps for identifying flaw signals and sizing the flaw dimensions. Compliance with these procedural steps will be monitored during the demonstration. The NDE Center will assist in evaluating the results of the demonstration.

1.1 Mock-up Description

The vessel mockups employed will be a full-scale representations. The mockup will be made from production materials and will be mounted in a representative orientation.

1.2 Flaw Description

Flaws manufactured using the HIP process, and notches will be employed. A description of the flaws is included in Attachment A. Both axial and circumferential orientations will be included.

2.0 EXAMINATION PROCEDURE

2.1 Essential Variables

Clearly identified essential variables. Unless otherwise stated in this document, the examination procedure shall identify parameters for the essential variables defined in Section 3. Essential variables will be specified by a single value or a range of values in the examination procedure and detailed in the demonstration plan.

2.2 Procedure Requirements

The information specified in 2.2.1 shall be made available to the PDA prior to the commencement of the demonstration. Any information considered to be sensitive or confidential will be treated as such, and will be returned upon completion of the demonstration.

2.2.1 Examination system description.

2.2.1.1 System operation manual.

2.2.1.2 System software revision number.

3.0 ESSENTIAL VARIABLES

3.1 The examination procedure shall contain a statement of scope that specifically defines the limits of procedure applicability (e.g.materials, thickness, diameter, product form).

3.2 The examination procedure shall specify a single value or a range of values for all of the identified essential variables.

3.3 The examination procedure shall specify the following essential variables:

3.3.1 instrument or system, including manufacturer and model and series of pulser, receiver, and amplifier.

3.3.2 search units, including:

(a) center frequency and bandwidth or waveform duration;
(b) mode of propagation and nominal inspection angles;
(c) number, size, shape and configuration of active elements and wedges or shoes;

3.3.3 search unit cable, including;

(a) type;
(b) maximum length;
(c) maximum number of connectors;

3.3.4 detection and sizing techniques, including:

(a) scan pattern and beam directions;
(b) maximum scan speed;
(c) minimum and maximum pulse repetition rate;
(d) minimum sampling rate (automatic recording systems);
(e) extent of scanning and action to be taken for access restrictions;

3.3.5 methods of calibration for detection and sizing (e.g. actions required to insure that the sensitivity and accuracy of the signal amplitude and time outputs of the examination system, whether displayed, recorded, or automatically processes, are repeated from one examination to the next examination.

3.3.6 inspection and calibration data to be recorded;

(a) method of data recording;

(b) recording equipment (e.g., strip chart, analog tape, digitizing) when used;

3.3.7 method and criteria for the discrimination of indications (e.g., geometric versus flaw indication and for length and depth sizing of flaws);

3.3.8 surface condition requirements.

4.0 EXAMINATION GROUP COMPOSITION

The Vendor's procedure shall identify the responsibilities and qualification requirements for personnel carrying out the following functions

4.1 Personnel Functions

4.1.1 Examination system setup, calibration and data acquisition.

4.1.2 Reviewing acquired data and initial data screening.

4.1.3 Flaw characterization and sizing.

5.0 DEMONSTRATION PROCESS

The demonstration will consist of two phases; detection and analysis. No time limit will be imposed. All examinations must be successfully completed prior to disclosure of performance results.

5.1 Detection Phase

The detection phase will be performed in strict accordance with the formal procedure as specified in section 2.0. The region to be examined will be identified to the candidate by the PDA.

5.1.1 Calibration, acquisition, and data review steps will be performed by the appropriate candidates in accordance with the vendor's procedure.

5.1.2 The monitor may at any time during the detection phase, request an explanation or demonstration of a procedural step.

5.1.3 Upon completion of the detection phase, the candidate will complete standard detection results reports. At that time, all acquired data will be removed from system storage devices and transferred to the appropriate storage media.

5.1.4 The detection results and all acquired data generated will be transferred to the PDA.

5.2 Analysis and Flaw Characterization Phase

The analysis and flaw characterization phase will be performed in strict accordance with the formal procedure specified in section 2.0.

5.2.1 The analysis phase will be performed by the appropriate personnel as identified in section 6.0.

5.2.2 Detection data to be analyzed will be provided to the candidate by the PDA. Other pertinent information may be requested if it is specifically identified in the Vendor's procedure and the demonstration plan.

5.2.3 The monitor may at any time during the analysis phase, request an explanation or demonstration of a procedural step.

5.2.4 Upon completion of the analysis phase, the candidate will complete formal analysis results report. At that time, all acquired data will be removed from system storage devices and transferred to the appropriate storage media.

5.2.5 The formal analysis report and all acquired data generated will be transferred to the PDA.

5.2.6 Re-looks or re-examinations may be performed as specified in the formal procedure.

6.0 RESULTS REPORTING

The error in flaw location, characterizing, and sizing will be determined. Duke Power Co. will be responsible to determine whether the performance is adequate. RMS error of flaw depth sizing results will be calculated. Linear regression analysis of the demonstration results may also be performed as an aid in evaluating performance.

7.0 DOCUMENTATION

Upon completion of the demonstration, all demonstration documentation will be retained by Duke Power Co.. This documentation include the ultrasonic data acquired on the specimens, NDE procedures, equipment identification, specimen information used during the demonstration, and the results of the performance demonstration.

8.0 SECURITY

Duke Power and the EPRI NDE Center will be responsible for maintaining the test keys during the demonstration and ensuring the test samples contain flaws which can be detected.

ATTACHMENT A

DEMONSTRATION MOCK-UPS

The mock-ups employed in the demonstration contained cracks fabricated using hot isostatic processing (HIP). This fabrication method offers significant cost and scheduling advantages over other fabrication methods. The cracks can be produced with accurate knowledge of the size, shape, and location.

Cracks produced by other techniques such as by adding contaminants to welds are much more difficult to accurately characterize. Another significant consideration is the possible introduction of untentional flaws. These flaws are referred to as "satellite" reflectors which are caused by porosity or small slag inclusions from welding process.

Considerable experimental evidence has been compiled supporting the equivalence of fabricated cracks and mechanical fatigue cracks from an NDE point of view. HIP is the preferred method of implanting intentional cracks when high accuracy is required. This approach as illustrated in Figure 1 consists of:

1) fabricating cracks in laboratory specimens,
2) removing the crack and surrounding material,
3) machining the material into a simple shape such as a cylinder,
4) HIP implanting the cylinder into a matching hole in the mock-up.

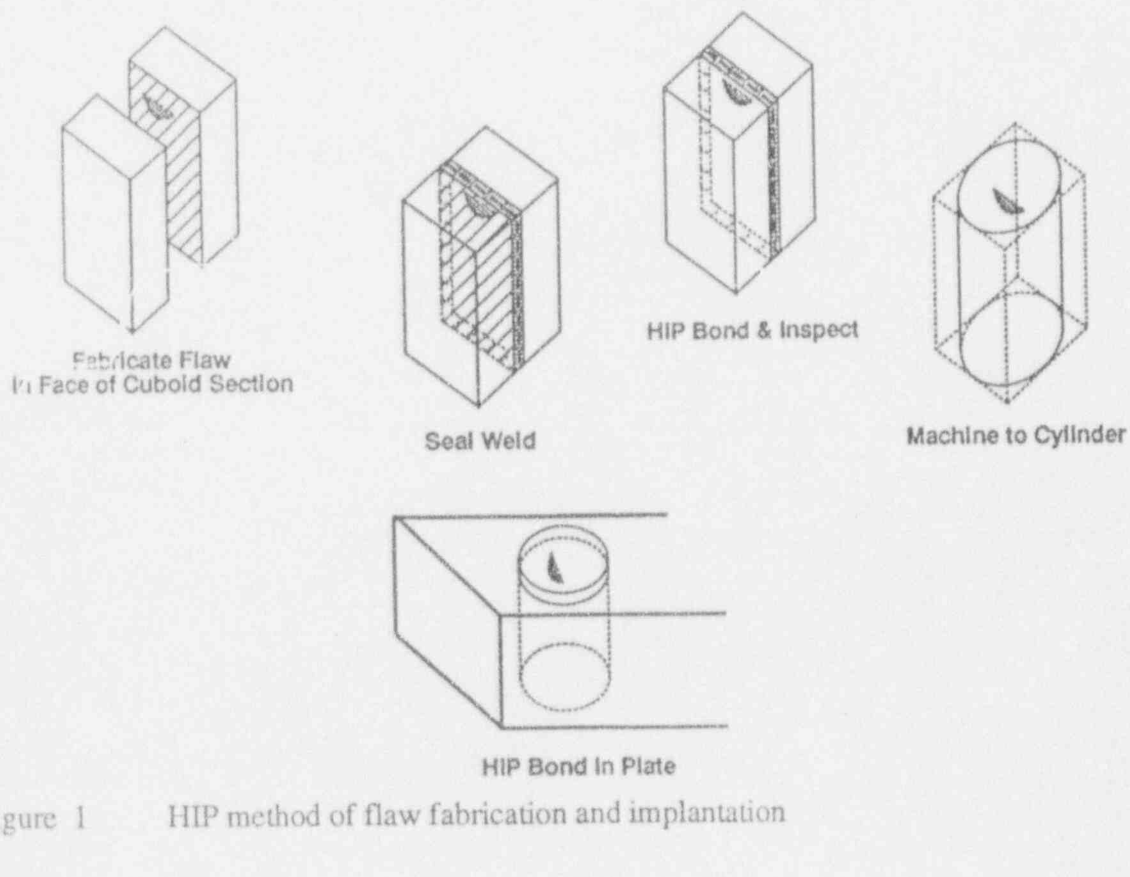
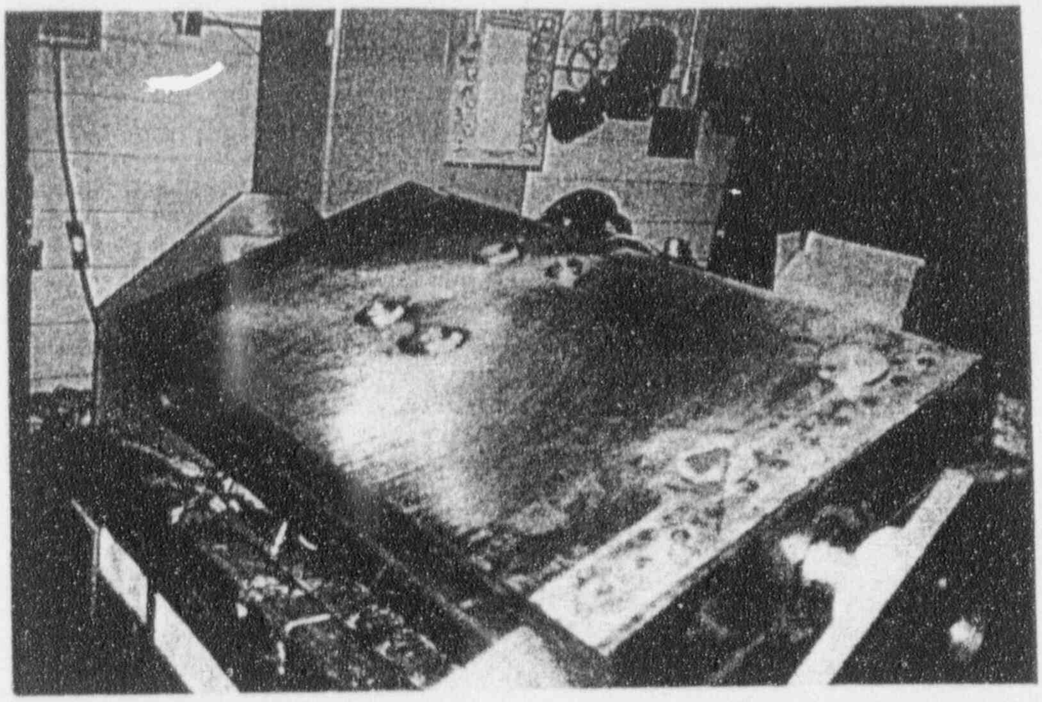


Figure 1 HIP method of flaw fabrication and implantation



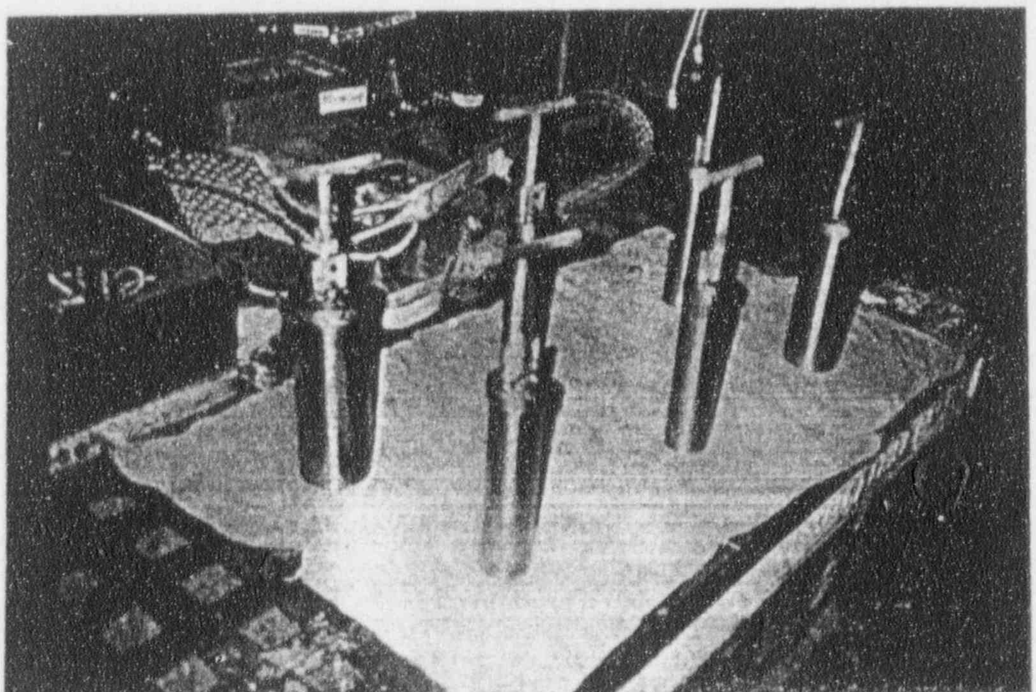


Figure 2 Preparation and installation of flaw cylinder into the demonstration mock-up

This multi-step procedure allows for accurate confirmation of the flaw size during the manufacturing process. Prior to implantation into the mock-up, the flaw specimen can be machined to provide optimum examination conditions for highly accurate NDE methods. Figure 3 shows an example of a focussed-probe ultrasonic examination of a cuboid containing a semi-elliptical shaped crack.

After the specimen is machined into a cylinder, and the cylinder is implanted into the mock-up, the interface between the cylinder and matching hole becomes bonded and is not detectable by conventional ultrasonic methods. Furthermore, with proper implantation procedures, the flaw characteristics are not affected in any detectable way when subject to multiple HIP processes.

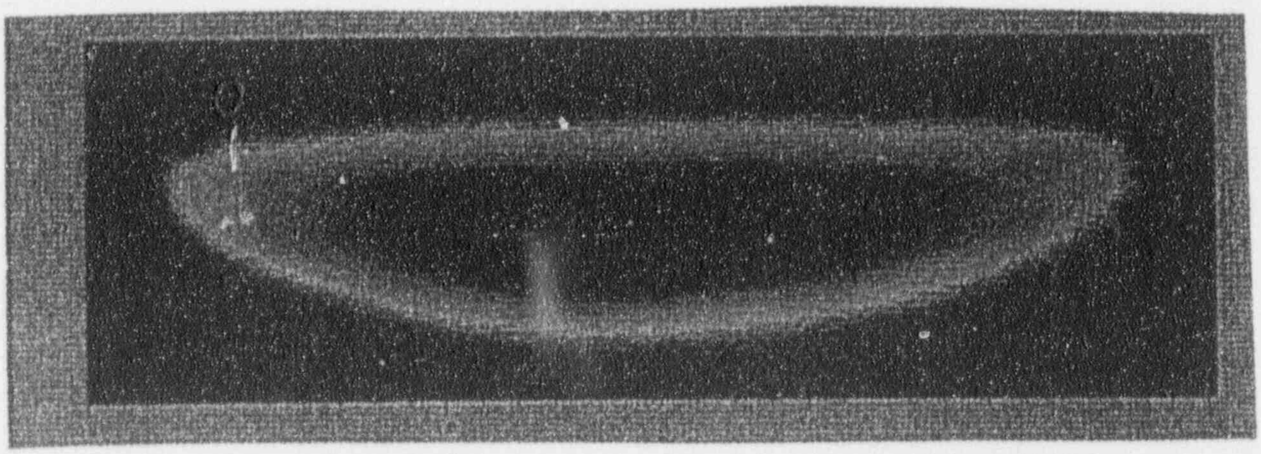


Figure 3 Example of a focussed-probe ultrasonic C-Scan (top-view) image of a semi-ellipticalshaped crack. The examination was performed prior to final machining into a cylinder.

Accurate characterization of the intentional flaws during construction of the practice and performance demonstration mock-ups is of utmost importance to providing a meaningful demonstration. Backward-scatter and forward-scatter (TOF) tip diffraction ultrasonic techniques along with focussed probe techniques were performed to insure the highest degree of accuracy in flaw size estimates.

Figures 4 to 6 show examples of ultrasonic examinations performed at various stages of mock-up construction.

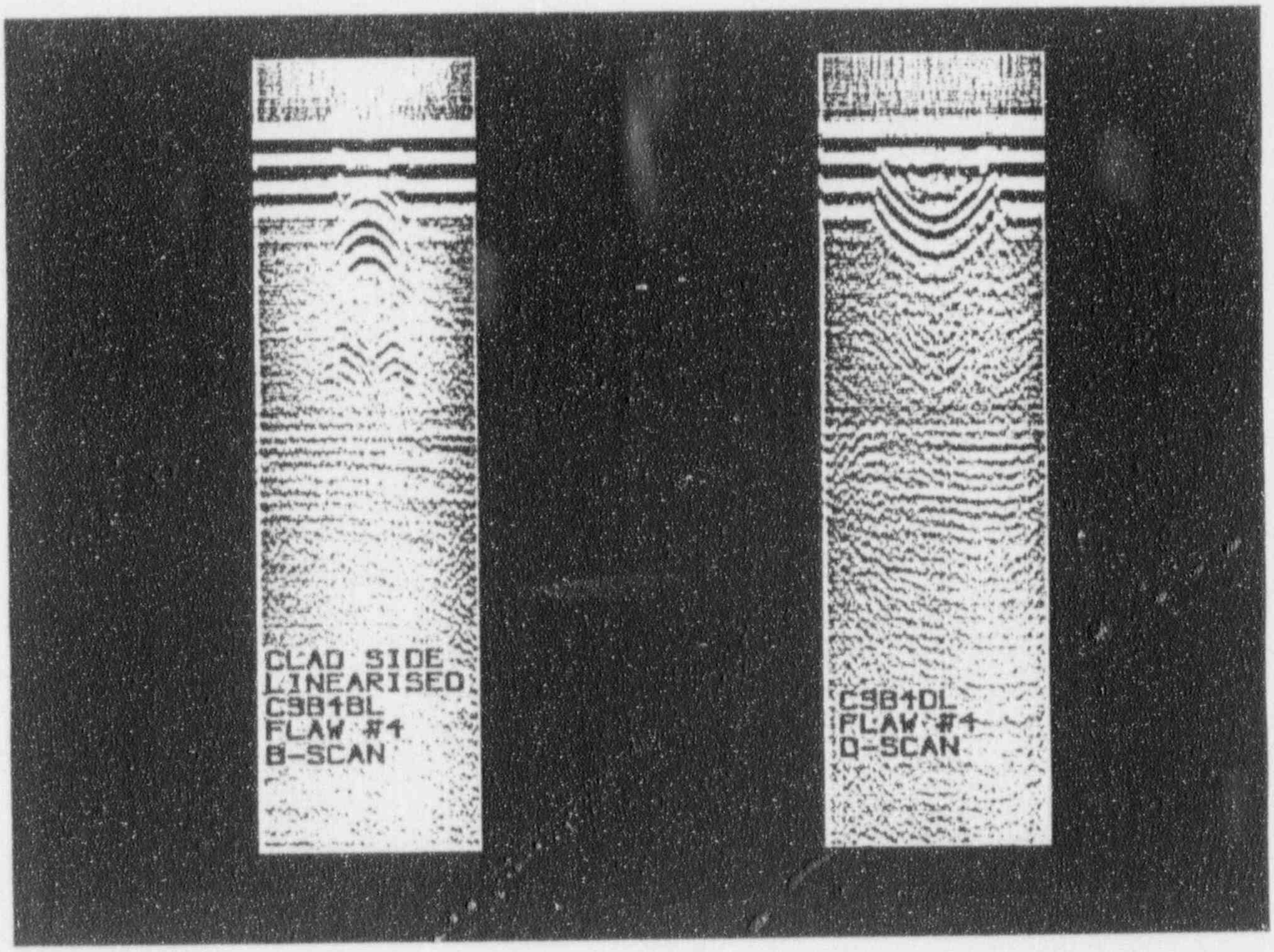


Figure 4 Forward-scatter tip diffraction (TOF) response from intentional flaw prior to application of clad.

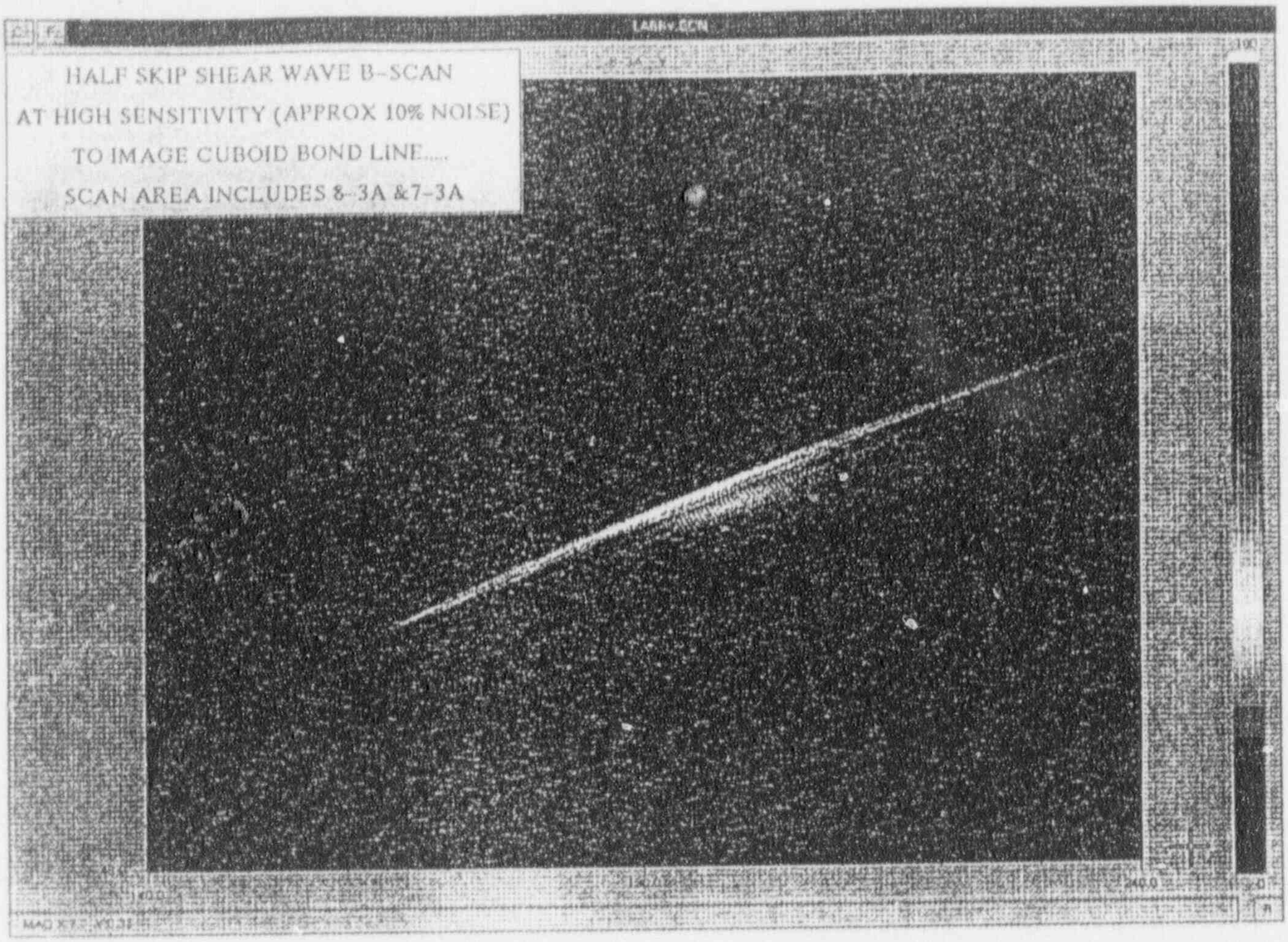


Figure 5 B-scan view of backward-scatter ultrasonic response from intentional flaw.

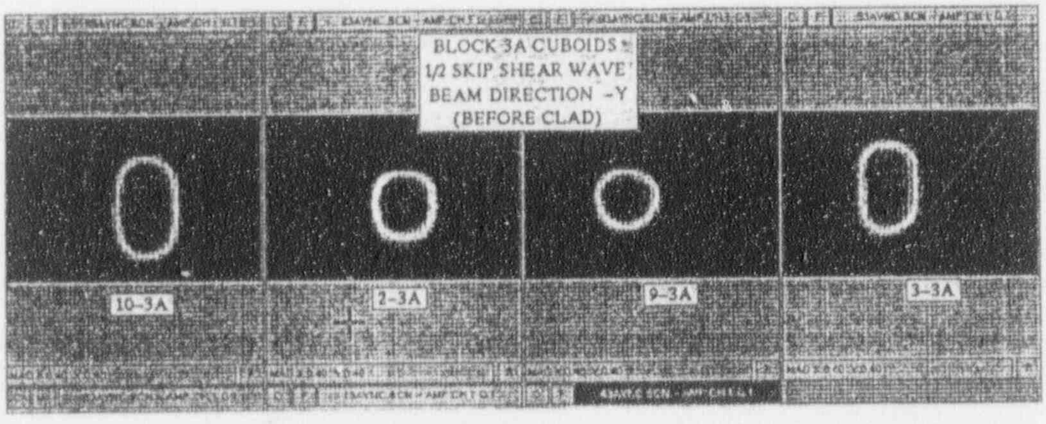


Figure 6 C-scan view of backward-scatter ultrasonic response from intentional flaw.

ATTACHMENT B
DEMONSTRATION RESULTS

Initial procedure development and refinement was performed on a sampling of flaws in the demonstration blocks described in Attachment A, and on additional NDE Center mock-ups. The remaining flaws in the demonstration blocks were reserved for the final demonstrations.

Upon completion of procedure development, areas of the block containing the flaws reserved for demonstration were identified to Duke Power personnel. Detection, characterization, and flaw sizing was then performed according to the formal protocol. The results were then evaluated by NDE Center personnel. The linear regression analysis results for flaw sizing are attached.

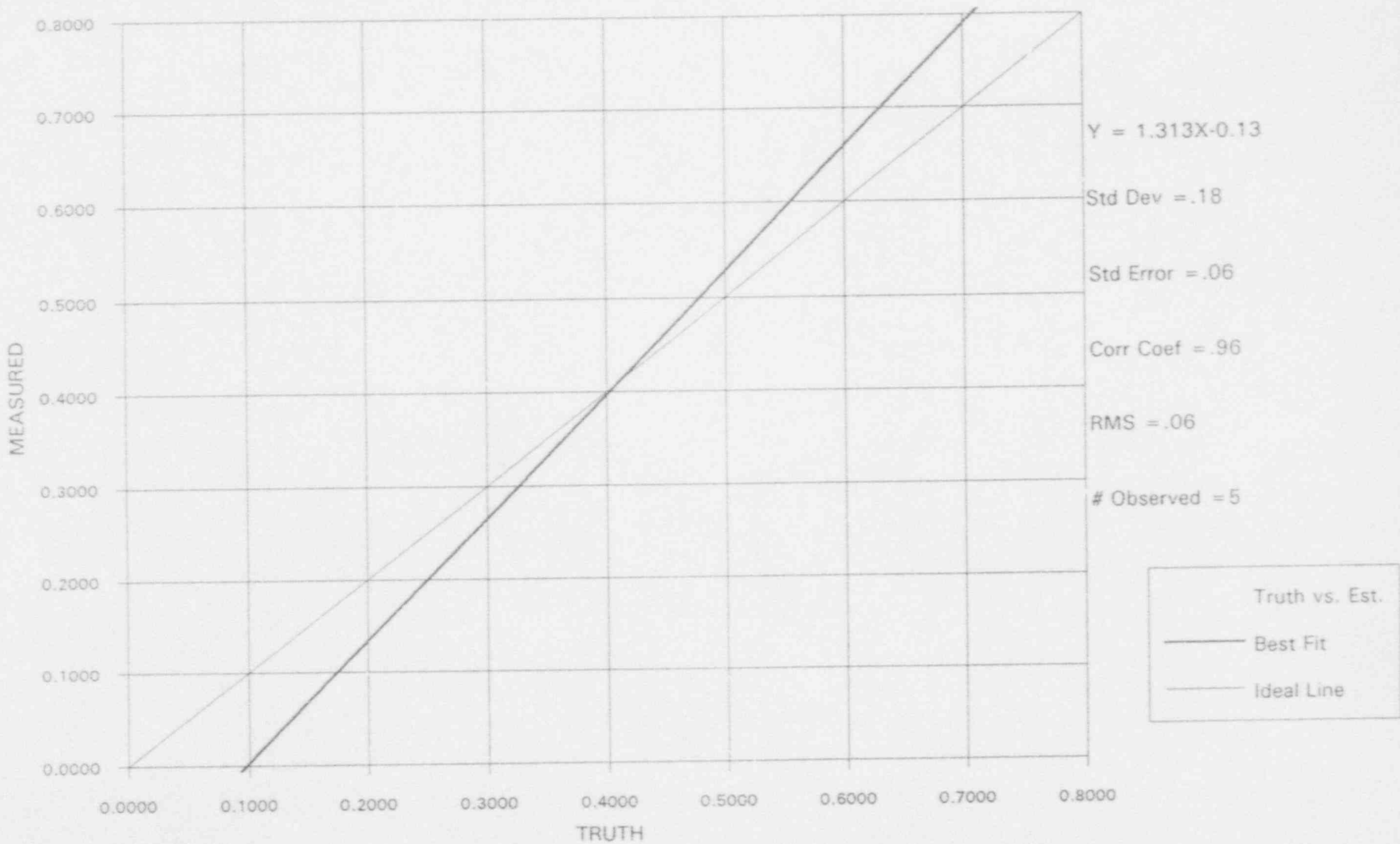
The demonstration results were then reviewed with Duke Power personnel. Results of the discussion were:

- The performance of the forward-scatter time-of-flight flaw sizing procedure was very good
- Flaw characterization and identification of the appropriate flaw tip signals could be improved by incorporating a supplemental backward-scatter ultrasonic technique
- Modifications to the forward-scatter time-of-flight equipment which could enhance flaw characterization were identified:

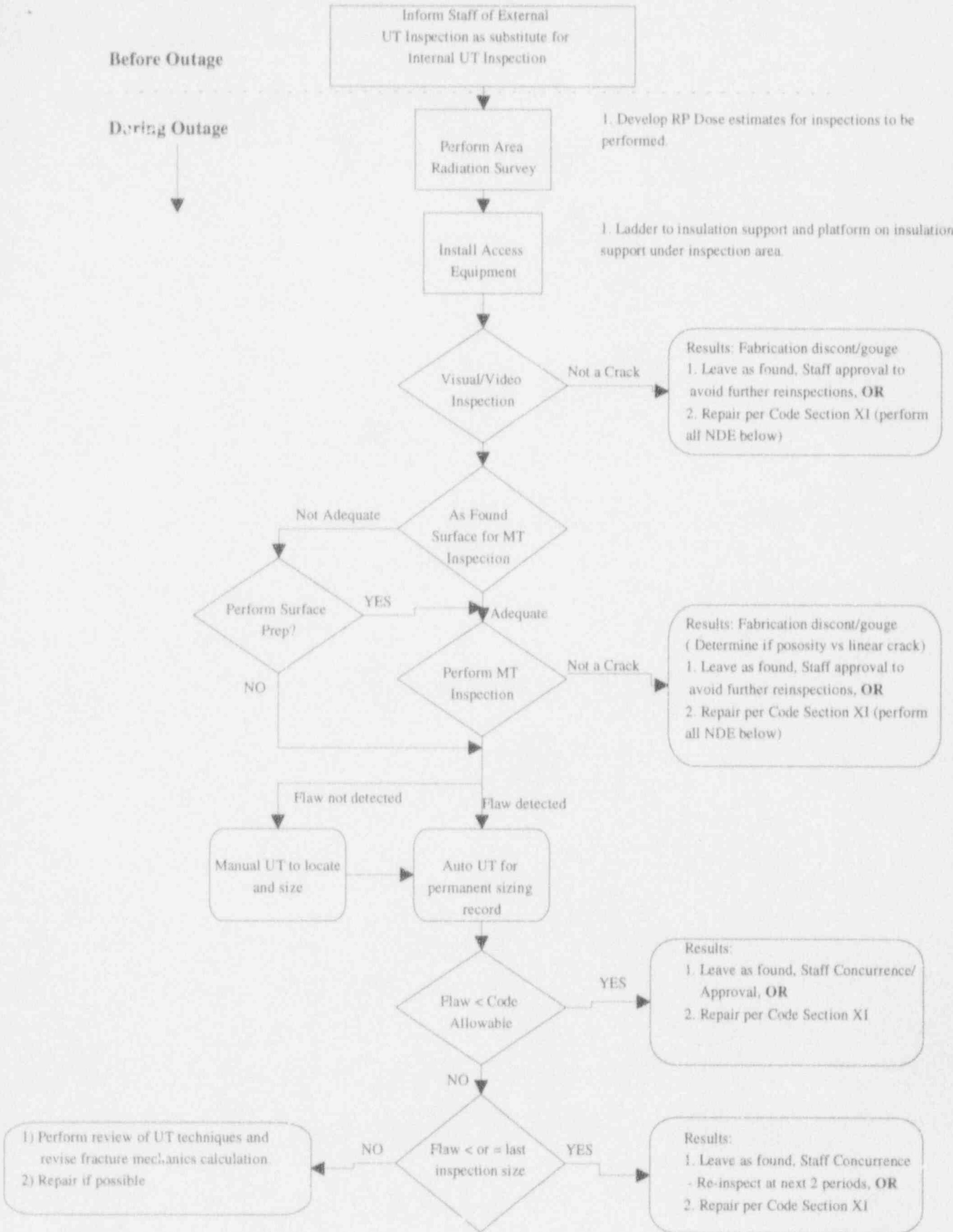
    Operator adjustment of ultrasonic pulse-width to optimize ultrasonic resolution

    Increased resolution in display of signal amplitude (number of gray-scale levels)

FLAW DEPTH SIZING RESULTS
(EXPRESSED IN INCHES)



ENCLOSURE 2



Before Outage
Inform Staff of External UT Inspection as substitute for Internal UT Inspection
During Outage
Perform Area Radiation Survey
1. Develop RP Dose estimates for inspections to be performed.
Install Access Equipment
1. Ladder to insulation support and platform on insulation support under inspection area.
Visual/Video Inspection
Not a Crack
Results: Fabrication discont/gouge
1. Leave as found, Staff approval to avoid further reinspections, **OR**
2. Repair per Code Section XI (perform all NDE below)
As Found Surface for MT Inspection
Not Adequate
Perform Surface Prep?
YES
NO
Adequate
Perform MT Inspection
Not a Crack
Results: Fabrication discont/gouge
(Determine if pososity vs linear crack)
1. Leave as found, Staff approval to avoid further reinspections, **OR**
2. Repair per Code Section XI (perform all NDE below)
Flaw not detected
Flaw detected
Manual UT to locate and size
Auto UT for permanent sizing record
Flaw < Code Allowable
YES
Results:
1. Leave as found, Staff Concurrence/ Approval, **OR**
2. Repair per Code Section XI
NO
Flaw < or = last inspection size
NO
1) Perform review of UT techniques and revise fracture mechanics calculation
2) Repair if possible
YES
Results:
1. Leave as found, Staff Concurrence - Re-inspect at next 2 periods, **OR**
2. Repair per Code Section XI