Northeast Utilities System

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Northeast Utilities Service Company
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August 4, 1995

Docket No. 50-336
B15307

Re: 10CFR50.55a(g)

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Millstone Nuclear Power Station, Unit No. 2
Request for Relief From Section XI of ASME
Code Examination Requirements

Title 10CFR50.55a(g) requires ASME Code Class 1, 2, and 3 components (including supports) of a nuclear power facility to meet the requirements set forth in Section XI, "Rules for Inservice Inspection (ISI) of Nuclear Power Plant Components." Millstone Unit No.2, however, was designed and partially constructed prior to the adoption of the examinations required by Section XI of the ASME Code. As a result, certain examinations, which are stipulated by the Code, cannot be performed completely since plant design does not permit direct access to the portions of some examination areas. The purpose of this letter is to request relief from an ASME Code Section XI examination requirement at Millstone Unit No. 2.

The attached Relief Request (RR-16) involves the volumetric examinations on 11 of 19 category B-F dissimilar metal welds. The weld geometry and/or configuration of these 11 welds prevents complete volumetric examinations from being performed. Attachment 1 provides detailed information regarding the applicable Code requirements, the justification for RR-16, and the inspection methods proposed as an alternative.

Northeast Nuclear Energy Company (NNECO) requests that this relief request be granted prior to the start of the next refueling outage currently planned for May 1997.

100048

Should you have any questions or require additional information, please contact Mr. Mario Robles at (203) 440-2073.

Very truly yours,

NORTHEAST NUCLEAR ENERGY COMPANY

FOR: J. F. Opeka
Executive Vice President

BY: [signature]
E. A. DeBarba
Vice President

Attachments 1 through 5

cc: T. T. Martin, Region I Administrator
G. S. Vissing, NRC Project Manager, Millstone Unit No. 2
P. D. Swetland, Senior Resident Inspector, Millstone Unit Nos. 1, 2, and 3

Docket No. 50-336
B15307

Attachment 1

Millstone Nuclear Power Station, Unit No. 2

Request for Relief From Section XI of ASME Code Examination Requirements

August 1995

Millstone Nuclear Power Station, Unit No. 2
Request for Relief From Section XI of ASME Code
Examination Requirements

Relief Request

RR-16, Pressure Retaining Dissimilar Metal Welds

Component Identification

ASME Code Class 1
Code Category B-F
Code Item Nos. B5.40 and B5.130

Code Requirement:

Section XI of the ASME Boiler and Pressure Vessel Code, 1980 Edition, with the Winter 1981 Addenda requires that a volumetric and surface examination be performed on each nozzle to safe end butt weld with a nominal pipe size greater than or equal to four inches. The examination shall be in accordance with Figure IWB-2500-8.

Code Relief Requested:

Pursuant to 10CFR50.55a(g)5(iii), relief is requested from performing a complete volumetric examination on the following 11 (of the total population of 19) Category B-F dissimilar metal welds that require volumetric examination:

1- Item B5.40, 12" Pressurizer Vessel Surge Nozzle to Safe End Butt Weld.

1- Item B5.40, 12" Safety Injection RCS Nozzle to Safe End Butt Weld.

1- Item B5.40, 12" Shutdown Cooling RCS Nozzle to Safe End Butt Weld.

8- Item B5.130, 30" Reactor Coolant System (RCS) Piping to Reactor Coolant Pump Nozzle Safe End Butt Welds.

Per Figure IWB-2500-8, the volume and areas include dissimilar metal welds (e.g., Safe End Butt Welds) between combinations of (a)carbon or low alloy steels to high alloy steels, (b) carbon or

low alloy steels to high nickel alloys and (c) high alloy steels to high nickel alloys as detailed below.

The subject welds can be separated into two categories. The first category(Code Item B5.40) are Safe Ends to Nozzle welds where the outside diameters are approximately 13 inches and the thickness is less than 1.5 inches. These welds are Carbon Steel (C/S) Nozzles with Stainless Steel (S/S) inside diameter cladding welded to Cast Stainless Steel (CSS) Safe Ends. As shown in Matrix #2, 3 of the total population of 11 welds have geometric limitations which preclude obtaining the 90% Weld Required Volume (WRV) coverage as required per Code Case N-460.

These welds were inspected with refracted longitudinal (RL) waves to the maximum extent possible, using a procedure specifically developed for Millstone Unit No. 2 B-F welds and qualified under the provisions of IWA-2240. This procedure (NU-UT-17) is included for information as Attachment 2. Matrix #2 lists the welds and the percentages of coverage for each scan performed including the total coverage per N-460. Scanning from the CSS side is considered "effective" for these welds. Thus, effective coverage is the same as the "theoretical" coverage.

The second category of welds (Code Item B5.130) is the Safe End to Reactor Coolant System (RCS) pipe welds at the reactor coolant pumps. These welds are over 30 inches in diameter and over 3 inches thick. The base materials are C/S pipe with S/S inside diameter cladding and CSS Safe Ends.

These welds were also ultrasonically scanned with RL waves to the maximum extent possible, using NU-UT-17). Scanning was performed from both the C/S and S/S sides and on the weld crown. The welds were scanned both perpendicular and parallel to the weld crown. In addition to the RL examination, the C/S side of the welds were also examined both perpendicular and parallel to the weld crown to the maximum extent possible with Shear Waves per NU-UT-26, UT procedure. This procedure was developed and used on B-J Category welds in accordance with Relief Request RR-4. This procedure is provided as Attachment 3 and Relief Request RR-4 is provided as Attachment 4.

Five of the eight welds in this category have geometric limitations to UT scanning which preclude obtaining 90% WRV coverage per Code Case N-460. NNECO does not have confidence that UT is reliable when the sound must travel more than 1 or 2 inches through CSS. Therefore, the coverage listed in the attached matrix #1, when scanning from the CSS side can only be considered as "theoretical".

Matrix #1, lists the scans performed as well as the theoretical percentage of coverage achieved for each scan. The theoretical WRV coverage is also shown as calculated in accordance with Code Case N-460. The percentage of what we believe is "Effective Coverage" is also provided.

Basis for Relief:

The weld geometry and/or configuration of the welds listed in the matrices, prevents a complete volumetric examination from being performed. Detailed sketches, Number 1 through 5, are also included identifying the examination coverage and typical configurations of these nozzle safe end welds. Attachment 5 is a report, "Ultrasonic Examination Capabilities for Welds In Cast Stainless Steel Components," and other industry information is the basis for this relief.

Proposed Alternative Examination

In lieu of performing the volumetric examination, the Code required surface examinations have been performed in accordance with Code requirements. In addition, the Code required volumetric examinations have been performed to the extent possible as described and depicted in Attachment 2. Finally, a system leak test was performed during system heat-up from the current refueling outage with satisfactory results.

B-F Weld Relief Request - Matrix #1

B-F WRV UT Coverage (Heavy Wall - Thickness>3")											
Weld # & Code Item Number	Description	Materials	Diameter and Thickness	UT Procedures	Theoretical % Perpendicular Scan		Theoretical % Parallel Scans		Total Theoretical Coverage per N-460	Effective Coverage per N-460	Exam Date
					A. S/S side	B. C/S side	C. S/S side	D. C/S side	(A+B+C+D)/4	(B+D)/4	
P-8-C-1 B5.130	Safe end to elbow weld at Reactor Coolant Pumps	Safe End-SA351 GR CF8M	30 inch plus ID Safe end-3.25"T Elbow-3.5"T	Refracted Longitudinal NU-UT-17	approx 50%	100%	approx 4%	approx 4%	50+100+4+ 100=254	100+100= 200	Dec-94
		Pipe-SA516 GR70 with S/S Clad		Shear NU-UT-26	N/A	100%	N/A	100%	254/4=63.5% approx	200/4=50%	
P-4-C-1 B5.130	Safe end to elbow weld at Reactor Coolant Pumps	Safe End-SA351 GR CF8M	30 inch plus ID Safe end-3.25"T Elbow-3.5"T	Refracted Longitudinal NU-UT-17	approx 50%	100%	approx 4%	approx 4%	50+100+4+ 100=254	100+100= 200	Dec-94
		Pipe-SA516 GR70 with S/S Clad		Shear NU-UT-26	N/A	100%	N/A	100%	254/4=63.5% approx	200/4=50%	
P-9-C-3 B5.130	Safe end to pipe weld at Reactor Coolant Pumps	Safe End-SA351 GR CF8M	30 inch plus ID Safe end-3.4"T Pipe-2.85"T	Refracted Longitudinal NU-UT-17	approx 50%	100%	approx 40%	approx 4%	50+100+40 +100=290	100+100= 200	Dec-94
		Pipe-SA516 GR70 with S/S Clad		Shear NU-UT-26	N/A	100%	N/A	100%	290/4=72.5% approx	200/4=50%	

B-F Weld Relief Request - Matrix #1

B-F WRV UT Coverage (Heavy Wall - Thickness>3")											
Weld # & Code Item Number	Description	Materials	Diameter and Thickness	UT Procedures	Theoretical % Perpendicular Scan		Theoretical % Parallel Scans		Total Theoretical Coverage per N-460	Effective Coverage per N-460	Exam Date
					A. S/S side	B. C/S side	C. S/S side	D. C/S side	(A+B+C+D)/4	(B+D)/4	
P-5-C-3 B5.130	Safe end to pipe weld at Reactor Coolant Pumps	Safe End-SA351 GR CF8M	30 inch plus ID Safe end-3.4"T Pipe-2.9"T	Refracted Longitudinal NU-UT-17	100%	100%	0%	0%	100+100+0 +100=300	100+100= 200	Oct-90
		Pipe-SA516 GR70 with S/S Clad		Shear NU-UT-26	N/A	100%	N/A	100%	300/4=75% approx	200/4=50%	
P-13-C-1 B5.130	Safe end to elbow weld at Reactor Coolant Pumps	Safe End-SA351 GR CF8M	30 inch plus ID Safe end-3.1"T Elbow-3.5"T	Refracted Longitudinal NU-UT-17	approx 20%	N/A	0%	N/A	20+100+0+ 100=220	100+100= 200	Feb-89
		Pipe-SA516 GR70 with S/S Clad		Shear NU-UT-26	N/A	100%	N/A	100%	220/4=55% approx	200/4=50%	
P-17-C-1 B5.130	Safe end to elbow weld at Reactor Coolant Pumps	Safe End-SA351 GR CF8M	30 inch plus ID Safe end-3.1"T Elbow-3.5"T	Refracted Longitudinal NU-UT-17	100%	N/A	100%	N/A	100+100+100 +100=400	100+100= 200	Feb-89
		Pipe-SA516 GR70 with S/S Clad		Shear NU-UT-26	N/A	100%	N/A	100%	400/4=100%	200/4=50%	

B-F Weld Relief Request - Matrix #1

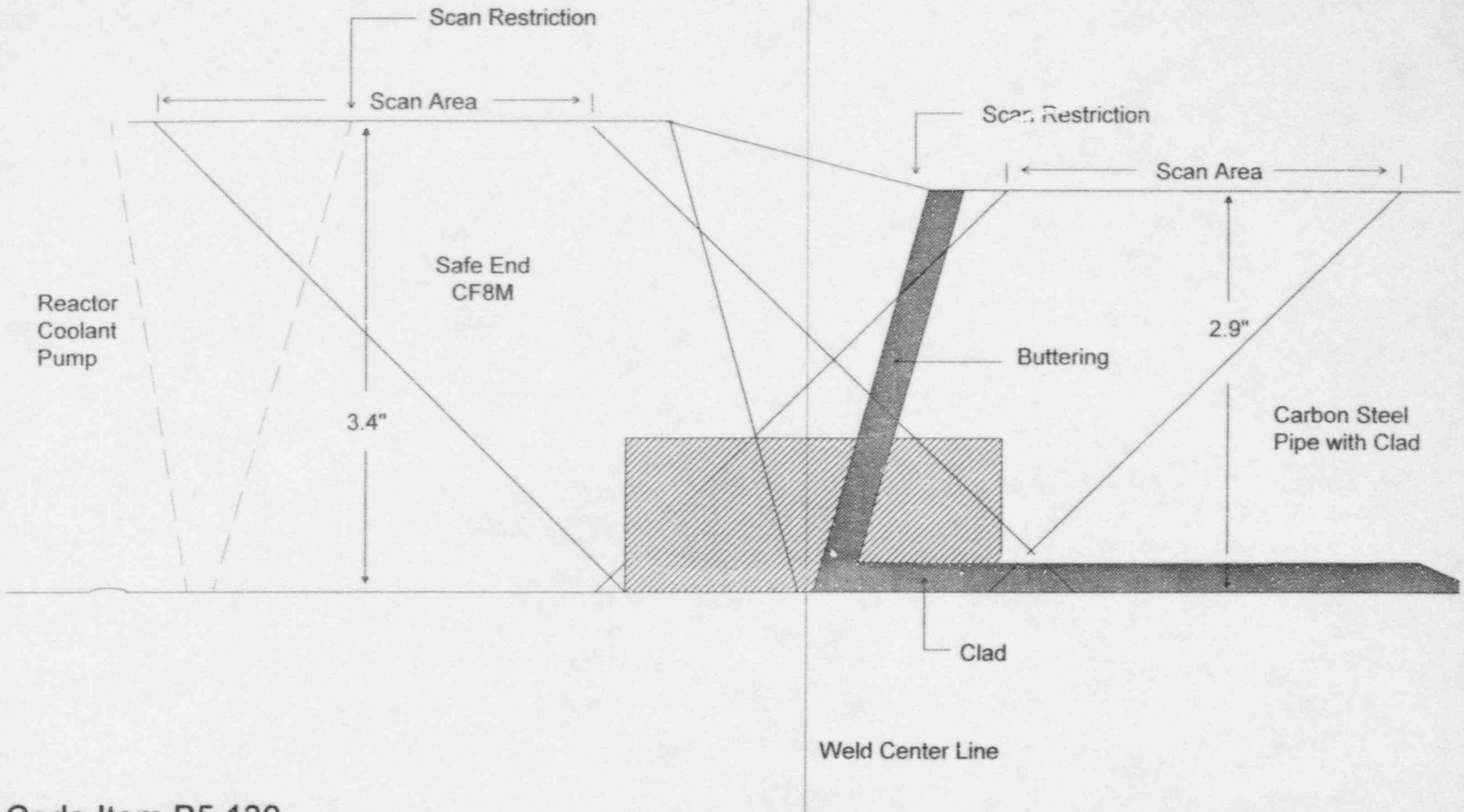
B-F WRV UT Coverage (Heavy Wall - Thickness>3")											
Weld # & Code Item Number	Description	Materials	Diameter and Thickness	UT Procedures	Theoretical % Perpendicular Scan		Theoretical % Parallel Scans		Total Theoretical Coverage per N-460	Effective Coverage per N-460	Exam Date
					A. S/S side	B. C/S side	C. S/S side	D. C/S side	(A+B+C+D)/4	(B+D)/4	
P-18-C-3 B5.130	Safe end to pipe weld at Reactor Coolant Pumps	Safe End-SA351 GR CF8M	30 inch plus ID Safe end-3.1"T Pipe-3.5"T	Refracted Longitudinal NU-UT-17	100%	N/A	100%	N/A	100+100+100 +100=400	100+100= 200	Feb-89
		Pipe-SA516 GR70 with S/S Clad		Shear NU-UT-26	N/A	100%	N/A	100%	400/4=100%	200/4=50%	
P-14-C-3 B5.130	Safe end to pipe weld at Reactor Coolant Pumps	Safe End-SA351 GR CF8M	30 inch plus ID Safe end-3.1"T Pipe-3.5"T	Refracted Longitudinal NU-UT-17	100%	N/A	100%	N/A	100+100+100 +100=400	100+100= 200	Feb-89
		Pipe-SA516 GR70 with S/S Clad		Shear NU-UT-26	N/A	100%	N/A	100%	400/4=100%	200/4=50%	

B-F Weld Relief Request - Matrix #2

B-F WRV UT Coverage (Medium Wall - Thickness<1.5")

Weld # & Code Item Number	Description	Materials	Diameter and Thickness	UT Procedure	Effective & Theoretical % Perpendicular Scan		Effective & Theoretical % Parallel Scans		Total Effective & Theoretical Coverage per N-460	Exam Date
					A. S/S side	B. C/S side	C. S/S side	D. C/S side	(A+B+C+D)/4	
BPS-C-1025A B5.40	Pressurizer Vessel Surge Nozzle to Safe End	Nozzle-A508 Cl2 with S/S ID Cladding Safe End-SA351 Gr CF8M	10.125" ID 13" OD 1.437"T	Refracted Longitudinal NU-UT-17	approx 75%	approx 75%	approx 75%	approx 75%	75+75+75+75 =300 300/4=75% approx	Nov-89
BSI-C-3000 B5.40	Safety Injection Nozzle to Safe End at Pipe	Nozzle-A182 F1 with S/S ID Cladding Safe End-SA351 Gr CF8M	10.188" ID 12.75" OD 1.281"T	Refracted Longitudinal NU-UT-17	approx 80%	approx 100%	approx 75%	approx 90%	80+100+75+ 90=345 345/4=86.25% approx	Oct-86
BSD-C-2001 B5.40	Shutdown Cooling Nozzle to Safe End	Nozzle-A105 Gr2 with S/S ID Cladding Safe End-SA351 Gr CF8M	10.125" ID Nozzle-13.093" OD 1.489"T Safe End-12.750" OD 1.312"T	Refracted Longitudinal NU-UT-17	approx 80%	approx 20%	approx 75%	approx 90%	80+20+75+90 =300 265/4=66% approx	Oct-86

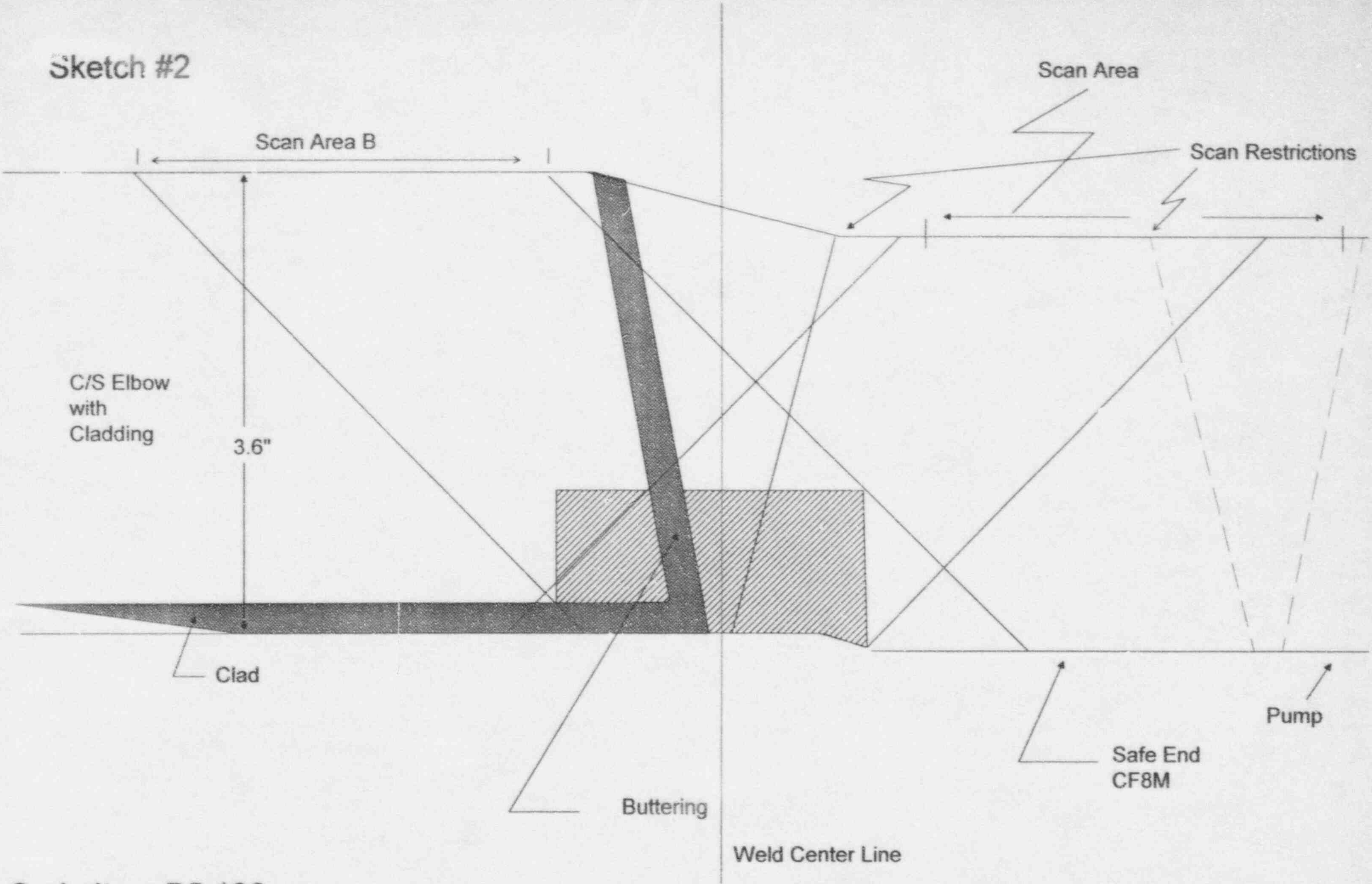
Sketch #1



Code Item B5.130
Typical of Theoretical Coverage
for Perpendicular Scan
Pipe to Safe End

Note:
- Circumferential scanning on weld crown is not possible
- Circumferential scanning from base material only
- Scan restriction from pump to safe end weld is not present in all casess

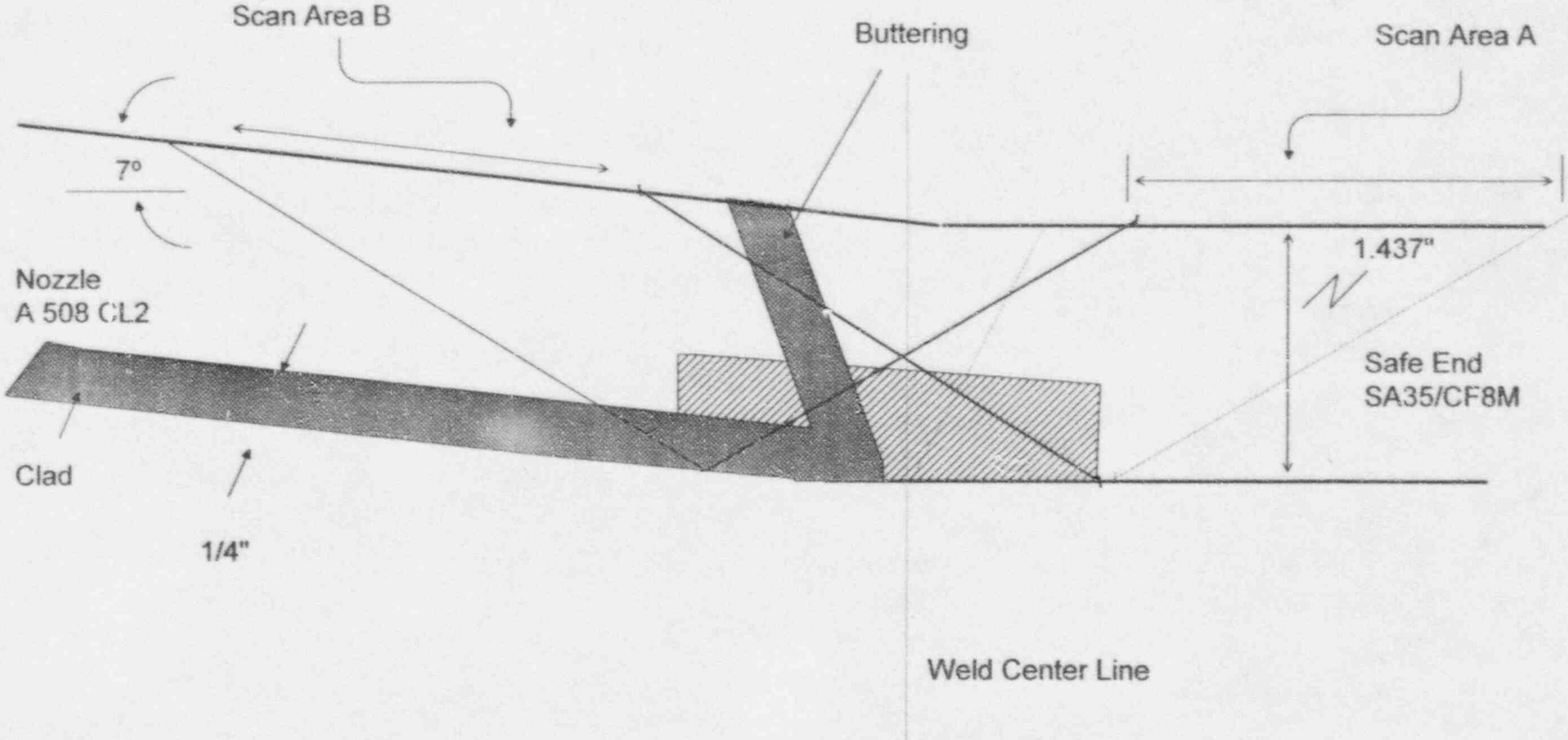
Sketch #2



Code Item B5.130
Typical of Theoretical Coverage for
Perpendicular Scan
Elbow to Safe-End

Note:
- Circumferential scanning on weld crown is nct possible
- Circumferential scanning from base material only
- Scan restriction from safe-end to pump weld is not present in all casess

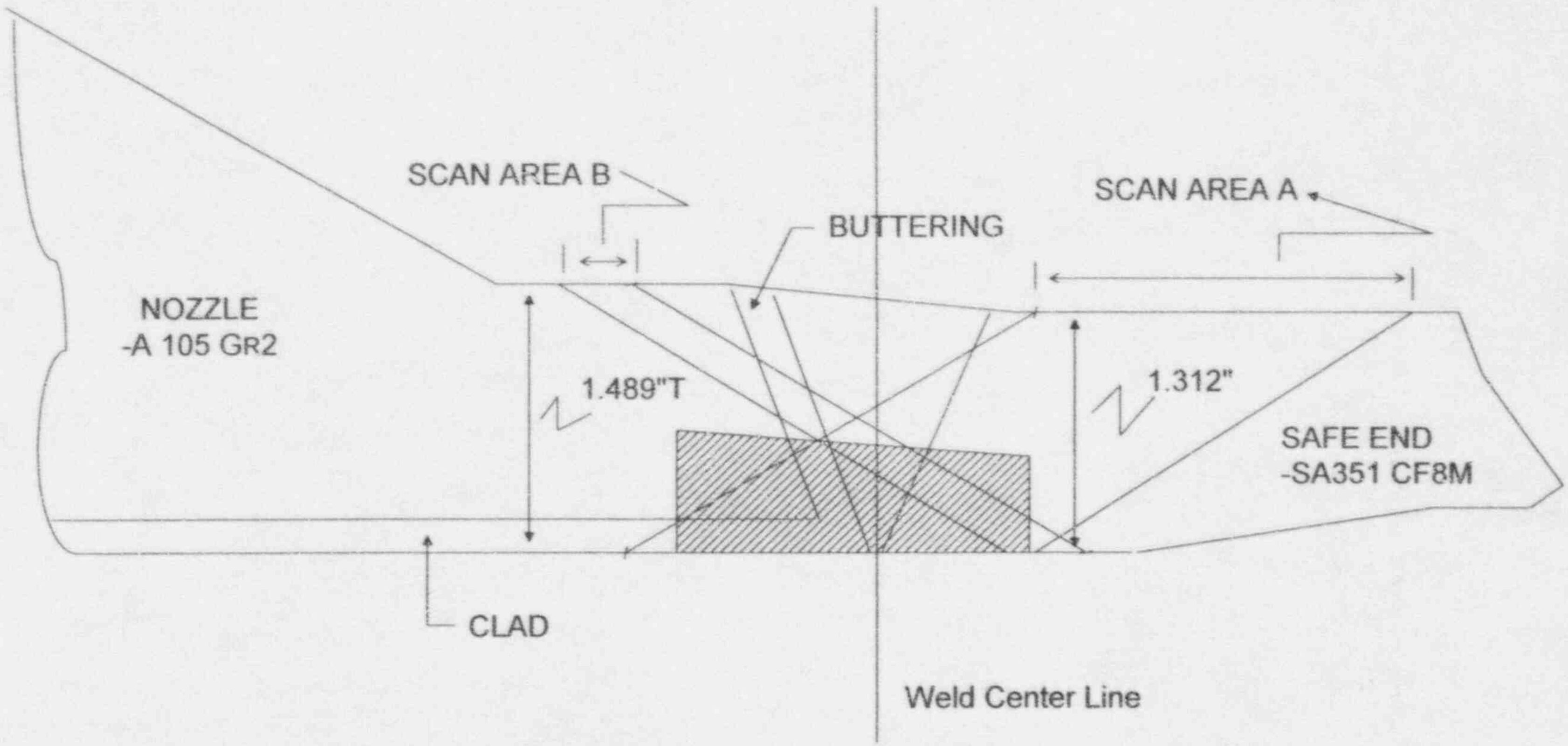
Sketch #3



BPS-C-1025A
Pressuriizer Vessel Surge Nozzle
REF 233-746

Note: Circumferential Scans Limited by Weld Crown Geometry

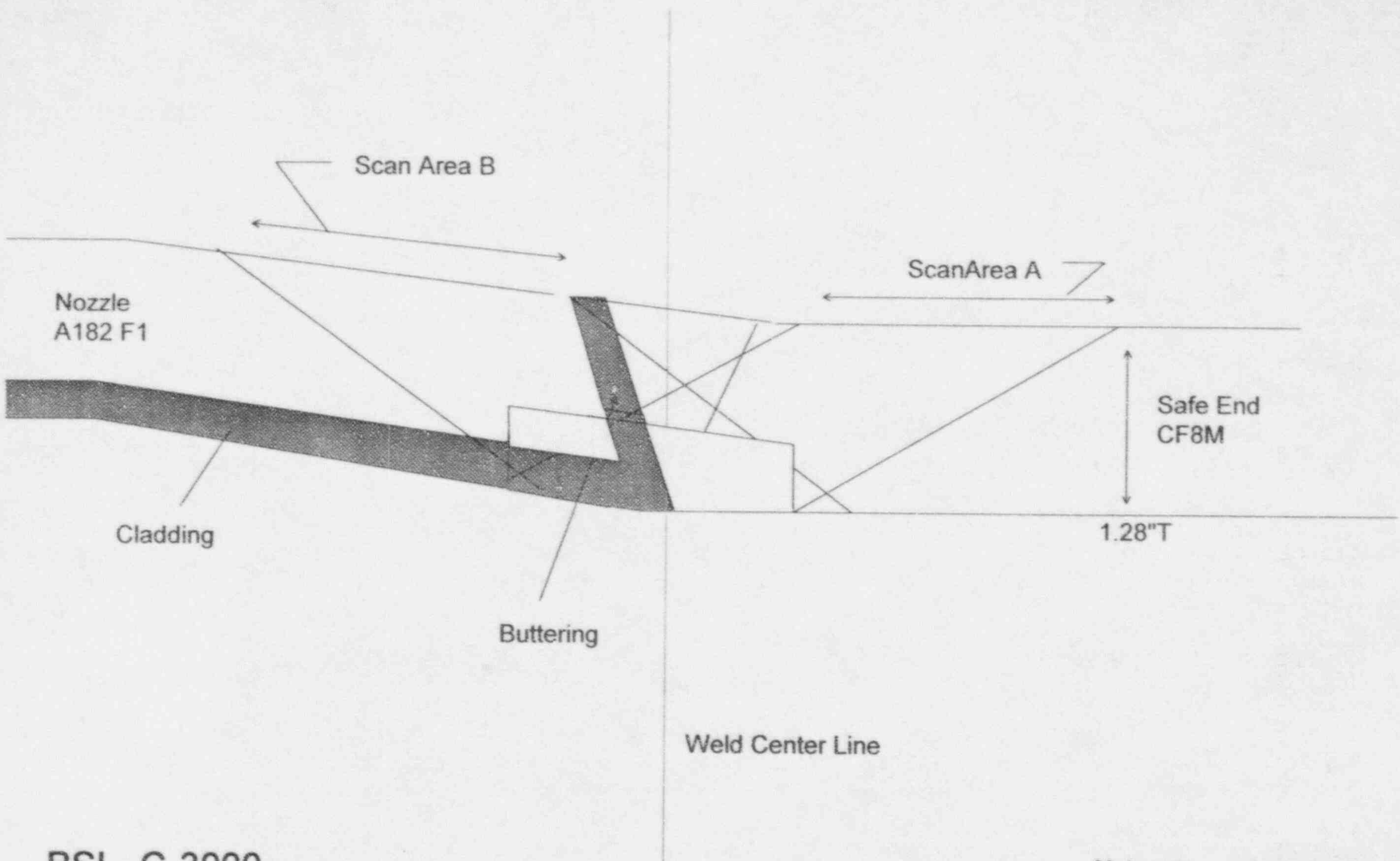
Sketch #4



BSD-C-2001
Shutdown Cooling
REF 234-005

Note: Circumferential Scans Limited by Weld Crown Geometry

Sketch #5



BSI - C-3000
Safety Injection
Ref 234-007

Note: Circumferential Scans Limited By Weld Crown Geometry

Attachment 2

Millstone Nuclear Power Station, Unit No. 2

Request for Relief From Section XI of ASME Code Examination Requirements

August 1995

NORTHEAST UTILITIES

NUCLEAR QUALITY-RELATED
NONDESTRUCTIVE EXAMINATION PROCEDURES

NU-UT-17

Ultrasonic Examination
Nozzle to Safeend Welds
Millstone Unit 2

Rev	Issue Date	6 NNECO Level III Approval/Date	Director QSD Approval/Date	Auth. Insp. Agency Approval/Date
6	4/18/94	[signature] III 3.29.94	B. Kaufman 3/31/94	[signature] 4/15/94

Always verify with the procedure Status Log before using this procedure.

LS0325XK.079

ULTRASONIC EXAMINATION
NOZZLE TO SAFEEND WELDS
MILLSTONE UNIT 2

1. SCOPE

1.1 INTENT

This procedure shall be used in conjunction with Procedure NU-UT-1 unless otherwise specified. NU-UT-1 contains all of the general requirements applicable to this examination procedure. This procedure contains all of the specific application requirements for the examination of areas specified in paragraph 1.3. 6

1.2 PURPOSE

The purpose of this procedure is to establish the requirements for manual or automated ultrasonic examination of full penetration dissimilar metal butt welds for detection and discrimination of cracks in the Inconel or stainless steel weld buttering and adjacent base materials.

1.3 APPLICABILITY

This procedure is applicable to bi-metallic and tri-metallic welds, specifically and nozzle-to-safe-end welds. Components with a nominal wall thickness of 0.500 to 5.0 inches shall be examined using a pulse-echo, ultrasonic instrument. Advanced techniques utilizing imaging systems are outside the scope of this procedure.

2. REFERENCES

1. NU-UT-1 Ultrasonic Examination General Requirements.

2. Appendix A (NDE Procedures Manual), Calibration Blocks for each specific weld to be examined.

3. Applicable Drawings (Not All Inclusive)

   A. CE Assembly Drawing E-234-005

   B. CE Assembly Drawing E-234-006

   C. CE Assembly Drawing E-234-007

   D. CE Assembly Drawing E-233-746

   E. CE Assembly Drawing E-233-750

4. ASME Section XI, IWA-2240

3. PROCEDURE CERTIFICATION

The examination procedure described in this document is in conjunction with Procedure NU-UT-1 and complies with Section XI of the ASME Boiler and Pressure Vessel Code, 1980 Edition, Winter of 1981 Addenda, except where examination coverage is limited by geometry or access.

4. PERSONNEL CERTIFICATION

1. Each person performing ultrasonic examinations governed by this procedure shall be certified in accordance with the documents referenced in Procedure NU-UT-1.

2. In addition, all examination personnel shall have received documented training for the performance of their specific functions in the detection and discrimination of cracking in buttered weld joints. Personnel proficiency shall be demonstrated on mockups representative of the weld to be examined to the satisfaction of the NNECO Level III.

3. Level I and trainee personnel are permitted to calibrate the instrument, manipulate the search unit, and record data under direct supervision of a Level II or III individual provided that the Level I or trainee individual has already demonstrated proficiency in performing the above functions to the satisfaction of the NNECO Level III. At no time is the Level I or trainee individual allowed to perform these tasks independently.

4. Only Level II or III individuals are permitted to investigate indications and make final determinations on reporting of indications.

5. EXAMINATION REQUIREMENTS

5.1 The ultrasonic instrument shall be of the pulse-echo type, capable of generating and receiving frequencies in the range of at least 2 to 4 MHz. The instrument shall provide screen height linearity within ±5 percent of full range for at least 80 percent of full screen height (FSH), and use a calibrated attenuator or amplitude control accurate over its useful range to ±20 percent of the nominal amplitude ratio to enable measurement of indications beyond the linear range of the vertical display on the screen.

5.2 Search units shall have transducers with a nominal frequency range of 2 to 4 MHz. Various roof angles and focal distances should be evaluated to choose the search unit with the maximum signal-to-noise ratio from the inside surface notch for the particular configuration to be examined. Maximum piezoelectric element size (each individual element) shall be 1/2 x 1 inch. The element size will be governed by the outside diameter of the contact surface. When necessary, various transducer frequencies and element sizes may be employed to determine the best signal-noise ratio based upon NNECO Level III concurrence and demonstration to ANII satisfaction. When curved shoes are used, compensation has to be made due to calibration block design. A circumferential notch does not exist; therefore, an amplitude comparison must be made between the 1/2 T hole and the ID notch at 80 percent FSH. The db difference shall be recorded and added or subtracted from the 1/2 T hole at 80 percent FSH during the axial calibration. All reflectors above shall be in

the dissimilar metal weld or in the inconel interface. Under no circumstances shall calibrations be performed on the base material for this technique.

5.3 Wedges shall be used to produce refracted longitudinal waves with nominal angles in the range of 30 to 70 degrees. Angles of 45 degrees have been shown to be successful for notch detection. Shallow angles (around 70 degrees) have been successful for those notches which are quite deep, and have provided the capability of through wall dimension sizing. Steeper angles have also been demonstrated as effective for detection. A combination of refracted angles is recommended. In any case, the effectiveness of the angles chosen shall be demonstrated on mockups as described in paragraph 7.0. Actual angles shall be measured to ±2 degrees and used for beam tracing. Search unit wedge size shall be selected based upon the diameter and configuration of the examination material, such that adequate ultrasonic coupling is achieved. Search units may be contoured to achieve better signal-to-noise ratio and provide better coupling. Examination shall be performed with the contact wedges used during calibration.

5.4 BASIC CALIBRATION BLOCK

The basic calibration block shall be made from material of the same nominal diameter and nominal wall thickness as the component to be examined. The calibration block shall be fabricated from the same materials as contained in the weld to be examined and shall be of the same design and welding process.

The basic calibration block shall contain, as a minimum, an inside surface axial notch, contained within the weld and butter material.

This notch shall be machined to a depth not to exceed 20 percent of the wall thickness. The notch length shall not exceed 0.5 inch.

5.5 PROCEDURE DEMONSTRATION REQUIREMENTS

The ability of the personnel, equipment, and procedure to adequately examine the weld shall be demonstrated on a representative mockup before the actual examination is carried out. The mockup may be the basic calibration block. This demonstration shall consist of an examination of the mockup using the same search unit(s), scanning pattern, scanning speeds, couplant, calibration method, instrumentation, and recording method as that to be used in the actual examination of the nozzle-to-safe-end weld. The demonstration will be considered successful if the 20 percent notch is detected with an amplitude at least twice the surrounding noise level on two successive scans.

Documentation of the demonstration including photographs or other representations of the CRT trace shall be included with the examination report, and documented on the form shown in figure 1.

6. SYSTEM CALIBRATION

6.1 SEARCH UNIT ANGLE VERIFICATION

The exit point and angle of refraction of each search unit shall be verified with an appropriate reference block prior to calibration of the ultrasonic system each day.

6.2 SWEEP CALIBRATION

A stainless steel reference block may be used to establish horizontal sweep calibration. Screen sizes shall be 2.0-, 2.5-, 5.0-, or 10.0-inch full screen width. The size chosen shall be the smallest applicable size which encompasses the examination area.

6.3 DISTANCE AMPLITUDE CORRECTION

Distance amplitude correction (DAC) for circumferential and axial scans shall be constructed by utilizing the response(s) from the reflector(s) oriented in the circumferential and axial direction of the basic calibration block.

System calibration shall include the complete ultrasonic examination system.

The response from the inside surface notch shall be the primary reference and shall be set at 80 percent ± 5 percent FSH. This gain setting is referred to as the primary reference level. End drilled holes may be used to establish a DAC curve, however, the inside surface notch shall be used to establish the primary reference level sensitivity.

System calibration data and instrument settings shall be recorded on the ultrasonic system calibration sheet.

6.4 SYSTEM CALIBRATION CHECKS

Calibration checks shall be performed in accordance with Procedure NU-UT-1.

6.5 SYSTEM CALIBRATION CHANGES

If for any reason the sensitivity level must be increased due to improper response during calibration verification, all welds examined since the previous calibration verification must be reexamined at the corrected sensitivity level.

If for any reason the sensitivity level must be decreased due to improper response during calibration verification, all indications recorded since the previous calibration verification must be reevaluated at the corrected sensitivity level.

If the primary reference point has moved on the sweep line more than 5 percent of full screen width, all indications recorded since the previous calibration verifications must be reexamined with the correct screen calibration.

6.6 REFERENCE SYSTEM

A reference system which will permit accurate relocation of reflectors shall be established per NU-XT-4. The following system is one example of an acceptable reference system. 6

A low stress metal V stamp is used to mark the weld, establishing a starting reference point. The tip of the V should be placed on the weld center line and pointed clockwise along the center line when looking in the direction of flow. Locate the V mark on the weld at TDC for horizontal nozzles.

The weld edges shall be determined and marked on the surface on each side of the weld.

7. EXAMINATION

7.1 EXAMINATION

The complete weld, weld butter, and adjacent base material shall be examined with the refracted longitudinal beam directed perpendicular and parallel to the weld axis in two directions (i.e., clockwise and counterclockwise). Experiments with mockups containing notches have shown that probes with refracted L-wave beam angles from 35 to 70 degrees are effective for detection. The number and type of probes to be used depends on the geometry of the joint as well as the time and radiation exposure conditions at each site. In any event, the particular method chosen for examination must be demonstrated as described in paragraph 5.5. Extreme care must be taken to ensure that the entire weld and buttering volume is examined.

The finished contact surfaces shall be free from weld splatter and any roughness that would interfere with free movement of the search unit or impair the transmission of ultrasonic vibrations. It is the responsibility of the examiner to determine if the surface condition is adequate.

Scanning shall be conducted at a minimum increase in sensitivity of 6dB above primary reference level. If the material noise level in the component being examined is not at least 5 percent FSH, the instrument gain shall be increased accordingly, and documented on the data sheet.

Examination scanning speed shall not exceed 1 inch per second, with a minimum overlap of 50 percent of the smallest individual search unit active element dimension.

Caution: The search unit should not be scanned over the base metal on either side of the weld at the sensitivity settings established for weld examination. High amplitude indications are to be expected from the cladding and austenitic base material at these gain levels. Separate DACs shall be established for base materials.

Attachment 5

Millstone Nuclear Power Station, Unit No. 2

Request for Relief From Section XI of ASME Code Examination Requirements

August 1995

ULTRASONIC EXAMINATION CAPABILITIES FOR WELDS IN CAST STAINLESS STEEL COMPONENTS

December 1, 1994

Rick Pfannenstiel
Northeast Utilities

Sam Volk
Yankee Atomic Electric Company

Greg Selby
EPRI NDE Center

ULTRASONIC EXAMINATION CAPABILITIES FOR WELDS IN CAST STAINLESS STEEL COMPONENTS

ABSTRACT

Yankee Atomic Electric Company (YAEC) and Northeast Utilities (NU) sponsored a workshop to determine the present capabilities for ultrasonic examination of cast stainless steel (CSS) materials. Vendors experienced with examination of stainless steels were invited to demonstrate their latest technology and equipment for detection of cracking in CSS material. Heavy wall CSS welds with known cracks were examined using manual and automated ultrasonic examination techniques.

The results show that the better teams, on average, correctly classified 50% of the cracked areas and 80% of the uncracked areas. The results show that there has been little change in CSS examination capabilities since the 1988 workshop. Advanced imaging and signal processing capabilities did not appear to be of great benefit; in fact, manual examination performance levels were roughly equivalent to those of automated examination, and manual examination was superior in terms of axial position accuracy.

Based upon these results, the sponsoring utility representatives have concluded that ultrasonic examination is unreliable for welds in CSS components.

ULTRASONIC EXAMINATION CAPABILITIES FOR WELDS IN CAST STAINLESS STEEL COMPONENTS

INTRODUCTION

Ultrasonic examination of cast stainless steel (CSS) components has been long recognized as a particularly difficult application because of the high levels of attenuation and noise from scattering at grain boundaries. Nondestructive evaluation (NDE) personnel have generally found conventional shear wave examination techniques to be ineffective in this material since it is frequently impossible to detect even the nearest calibration reflector.

Most ultrasonic examination procedures that are intended to detect inner surface defects in CSS materials specify that large, low-frequency, 45° longitudinal-wave (L-wave) search units be used. The transducer crystal size is usually about one inch, with a frequency of 1 MHz. Most are mounted on plastic wedges in a side-by-side, dual, pitch-catch configuration to avoid the internal wedge reflections typical of contact angled L-wave probes. Other configurations have included front-to-back, dual, contact probes; single-channel contact probes with more than one transmitting and/or receiving crystal; and water column search units or other self-contained immersion systems.

Several round robin tests of examination effectiveness for CSS materials have been conducted and no reliable techniques have been identified.

SCOPE

Yankee Atomic Electric Company (YAEC) and Northeast Utilities (NU) with the assistance of the Electric Power Research Institute (EPRI) NDE Center sponsored a workshop to determine present capabilities for ultrasonic examination of CSS materials. Interested and qualified vendors were invited to demonstrate their equipment and capabilities. This document contains the results of the YAEC and NU workshop and makes comparisons to the results of previous workshops on CSS materials.

PURPOSE

A major objective of this exercise was to determine the reliability of the data obtained from examinations performed on CSS material. The workshop intent was to determine realistic expectations for ultrasonic flaw detection in CSS materials by experienced vendors using their most current technology. It is recognized that some CSS materials are more easily inspected with ultrasonic techniques than are others, but the effect of the particular grain structure encountered cannot be predicted without the removal of a through-thickness section.

BACKGROUND

The participants were selected in late 1992 and given opportunities to practice on CSS specimens similar to the ones to be used in the workshop. The workshop was held at the EPRI NDE Center in January and February 1993; an additional participant examined the specimens in late April 1993, and another in the summer of 1993.

This report describes the conduct of the workshop and the results. The results are compared to those of earlier CSS studies and to a hypothetical application of Section XI, Appendix VIII of the American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel (B&PV) Code (1).

Previous Workshops

Pipe Inspection Round Robin - PNL, 1980. Battelle, Pacific Northwest Laboratory (PNL) conducted a pipe inspection round robin (PIRR) test under the sponsorship of the Office of Nuclear Regulatory Research of the United States Nuclear Regulatory Commission (NRC) (2). Pipe-to-pipe welds in centrifugally cast stainless steel (CCSS) pressurized water reactor (PWR) main coolant piping were a part of this investigation.

Four commercial NDE vendor companies examined the CCSS specimens. Three of the vendors correctly classified cracked material in less than 25% of their opportunities. The fourth team classified about 70% of the cracked specimens but also incorrectly classified about half of the blank (uncracked) specimens as being cracked.

CCSS Round Robin Test - PNL/JRC, 1984-5. The first component of the Programme for Inspection of Steel Components (PISC) III was a preliminary round robin examination of some of the same CCSS pipe specimens used in the 1980 PIRR (2). PNL managed the PISC III CCSS Round Robin Test (CCSSRRT) program under NRC sponsorship and organized the participation of the six domestic participants. The Commission of European Communities' Joint Research Centre at Ispra, Italy coordinated the participation of the European participants. The total number of teams was 18. This was a screening test in preparation for the actual PISC III CCSS examinations, the results of which have not yet been published.

Each team was allotted one week to examine a set of 14 specimens. Teams were allowed to use more than one procedure and report their results separately for each, as the intent of the exercise was to identify promising examination procedures. The procedures' performance was expressed in terms of correct identification of the cracked or uncracked status of each increment of weld length. The axial positions of the indications and of the cracks are disregarded. The results are shown in Figure 1. The vertical axis represents the ratio:

$$\frac{\text{(total length of cracked weld that was called cracked)} \times 100}{\text{(total length of cracked weld)}}$$

and the horizontal axis represents the ratio:

$$\frac{\text{(total length of uncracked weld that was called cracked)} \times 100}{\text{(total length of uncracked weld)}}$$

Each symbol on the plot represents the performance of one procedure. Perfect performance would be represented by a symbol at the upper left corner.

The performance was generally poor; few procedures exhibited potential for correct classification of cracked CCSS piping. The high false call rates made it difficult to draw rigorous statistical conclusions. Points in the upper right corner of the figure represent procedures that called essentially everything a crack, while points in the lower left corner represent procedures that called nothing a crack. Most of the remaining data points lie too close to the 45° line representing random performance.

The researchers concluded that the expertise of the operators was largely responsible for performance, because the procedures used for the better performances were very similar to procedures which were used for the poorest performances.

Wolf Creek CSS Workshop - WCNOC/NDEC, 1988. In 1988 EPRI sponsored a workshop at the NDE Center on request from Wolf Creek Nuclear Operating Company (WCNOC) to determine the present state of NDE vendor capability for examining CSS components. The Wolf Creek plant is a Westinghouse PWR with CSS reactor coolant piping. Five NDE vendor companies performed manual ultrasonic examinations and four went on to provide automated ultrasonic results as well.

The teams examined specimens selected from a set designed and fabricated by Westinghouse for the Westinghouse Owners Group (WOG) (3). Seven specimens were used for practice, seven others for the manual examinations, and a third group of seven were used for automated examinations. Teams were allowed two hours per specimen for performing and reporting on manual examinations. Two hours were allowed for automated data acquisition on each specimen; one day was allotted for automated data analysis and reporting for all seven specimens. Report forms divided each specimen into cells, each representing one half inch of the weld length, which the NDE vendor would indicate as being cracked or not cracked.

The results are shown in Figure 2. The meaning of the vertical and horizontal axes is essentially the same as in Figure 1 except for a certain coarseness imposed by the 0.5-inch resolution of the 1988 data. The level of performance is improved over the PISC results. Manual and automated examination results are essentially equivalent.

One team's automated results were exceptional, indicating that their length measurements were quite accurate. Using this weld length-based performance statistic, a crack detection performance of 50%, for example, does not mean that only half of the cracks were detected; rather, more than half of the cracks may indeed have been detected, but the reported locations did not completely overlap the true locations.

EXPERIMENTAL DESIGN OF 1993 WORKSHOP

Invitation

The initial invitations for vendor participation were issued in October 1992. The target number of participants was 12. A few invitees declined immediately, explaining that they felt unable to examine CSS components effectively. Substitute vendors were invited to participate.

Practice

A group of cracked practice specimens were distributed among the vendors. The vendors used them as they saw fit and then exchanged them for other vendors' practice specimens. This continued through mid-January 1993. Most vendors saw four to six practice specimens in all.

Teams

Several vendors withdrew themselves from workshop participation during this practice phase, citing schedule conflicts or difficulty examining the practice specimens. New vendors were invited to replace them; the newer participants had correspondingly fewer practice opportunities.

Ultimately, nine teams participated. They are listed in Table 1. PNL is not an NDE vendor organization, but was invited to participate because of the sophisticated three-dimensional synthetic aperture imaging system they have developed with NRC funding. Pacific Gas & Electric (PG&E), also not an NDE vendor, participated to help themselves evaluate their own capabilities.

TABLE 1

Participating NDE Vendors

Vendor	Manual	Automated (System)	
ABB Amdata	X	X	(IntraSpect)
AEA O'Donnell		X	(Zipscan)
Babcock & Wilcox	X	X	(Acusonex)
Ebasco	X	X	(P-scan)
Nuclear Energy Services	X		
Pacific Gas & Electric		X	(Workstation/Viper)
Pacific Northwest Laboratory		X	(SAFT-UT)
Thielsch Engineering	X	X	(Test-Pro)
Virginia Corp. of Richmond	X	X	(ALARA II)

Procedures

Manual examination techniques were evaluated separately from automated techniques. Five teams performed both manual and automated ultrasonic examinations; three teams performed automated only; one team performed manual examinations only.

Search Units. Most teams used 1 MHz, 40°-45°, dual, L-wave probes.

Automated Systems. The following automated systems were used by the participants. In most cases, the systems have more data acquisition and analysis features than are listed here; this list includes the features that were used most for this workshop.

- The IntraSpect System was used for standard A-, B-, B'-, and C-scan imaging.
- The Zipscan System specializes in forward-scattered, time-of-flight diffraction imaging, an advanced technique that has been shown to produce highly accurate flaw characterizations in steel components.
- Acusonex is an imaging system with interactive spatial filtering capabilities.

- The P-scan imaging system uses a logarithmic amplifier to achieve a dynamic range of 120 dB, much higher than is available with the more common linear amplifiers.

- The synthetic aperture focusing technique for ultrasonic testing (SAFT-UT) uses time-corrected signal averaging over a large scan surface aperture to sum coherently all the responses obtained from each point in the examination volume.

- The TestPro System is capable of analyzing various time- and frequency-domain features of an ultrasonic waveform and comparing them to databases previously acquired from known reflector types. If the behavior of the reflector types are sufficiently distinct, the reflector type may be discerned for the new waveform.

- ALARA-II was used to produce images coded for amplitude and for time-of-flight.

- The PC-based NDE Workstation was used for acquisition only, followed by off-line analysis using PG&E's Viper data analysis software. Viper is configured for high-speed viewing of B-scan images, with spatial processing capabilities.

Specimens

One set of eight specimens was examined by each manual team, and a separate set of eight specimens was examined by each automated team. The specimens were selected from the two largest sets of CSS pipe specimens in the U.S. Each of the intended defects in the selected specimens was oriented primarily in the circumferential direction. The true crack depth range was 15% - 45% through-wall for the specimens selected for this exercise.

Westinghouse Owners Group Specimens. Each set of eight specimens contained five WOG specimens. The WOG set was fabricated by Westinghouse in 1986-7. The specimen design was based on a Westinghouse survey of actual weld joint configurations. Of 51 Westinghouse PWRs in commercial operation, the piping systems in 25 of the plants are made of CCSS (4, 5).

The set consists of 75 mock-ups of primary loop piping joints. Each specimen contains about a foot of circumferential weld length and is about two feet long axially. The thickness at the weld centerline ranges from about 2.0 to 2.7 inches depending on the type of mock-up.

The mock-ups were cut from a total of nine full-circumference weld joints, representing seven pipe-to-component configurations. The configurations selected for this demonstration included pump outlet-to-pipe, safe end-to-pipe, and pipe-to-elbow.

The pump outlet-to-pipe joint has a sharp thickness transition across the width of the weld crown. Westinghouse has smoothed this transition by applying a band of weld buildup on the pipe side, tapering down to zero thickness over about six inches of pipe length. The pump and pipe materials are both SA351/CF8A 304SS; the joint was made by the submerged arc welding (SAW) process.

The safe end welds are in mock-ups that contain a reactor pressure vessel (RPV) main coolant outlet nozzle, safe end, and pipe. Only about an inch of the SA182 316SS safe end forging is exposed to the outside surface between the two welds. The nozzle-to-safe end weld was made by the shielded metal arc welding (SMAW) process. This weld was not examined by the participants, but was a factor in examination of the safe end-to-pipe weld because the safe end is so short. The safe end was joined to the SA351/CF8A 304SS pipe by an SAW joint.

There are three types of pipe-to-elbow mock-ups. One has SA351/CF8A 304SS pipe joined to an SA351/CF8A 304SS elbow by SAW; the second has SA351/CF8A 304SS pipe joined to an SA351/CF8A 304SS elbow by SMAW; and the third has SA351/CF8A 304SS pipe joined to an SA351/CF8M 316SS elbow by SAW.

Intentional defects were induced in the WOG specimens by either thermal or mechanical fatigue. The flaws were not implanted; the specimens were fatigued full-size. The true length and position of each flaw was documented by fluorescent dye penetrant examination. The true depth is known roughly based on a calibration of the fatigue process in which a few cracks were induced and then examined destructively.

Pacific Northwest Laboratory Specimens. Each set of eight specimens contained three PNL specimens. A set of CCSS pipe specimens was fabricated in the late 1970's and early 1980's by PNL under sponsorship of the NRC. These specimens were used in PNL's PIRR and CCSSRRT programs in the 1980's.

The specimens are pipe-to-pipe joints of centrifugally cast 304 stainless steel. The intentional defects in these specimens were induced in place by thermal fatigue. The true positions and lengths were determined by visible dye penetrant examination; the depths were estimated using a rough calibration of the fatiguing process.

Test Protocol

Most examinations were conducted at the EPRI NDE Center. PNL's examinations were conducted at Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Examination Volume. The candidates were asked to examine the ASME Section XI required examination volume for each specimen. (For the WOG nozzle-to-safe end-to-pipe mock-ups, only the safe end-to-pipe weld was examined.) Examination was required in only the axial direction. Participants were permitted to perform circumferential examinations if they wished. Volumetric flaws were not of interest; the participants were asked to report only inside surface-connected reflectors.

Access. Both-sides access was provided on all specimens. The inside surface and all four cut faces of each specimen were masked. The shape of the inside surface in the weld area was hidden. For automated examination, each specimen was mounted in a full-circumference shell for mounting scanner tracks.

Time Limits. There was no strict per-specimen time limit, though there was an unenforced administrative guideline of two hours per specimen for data acquisition. Manual examinations were generally performed, analyzed, and reported in two or three days. Automated examinations generally took a full three days.

Reporting. Participants recorded their findings on a map of each specimen, providing a sketch of each indication's actual dimensions. The weld length was not divided into cells or grading units. In addition to flaw indications, participants were encouraged to report indications they had determined to be from counterbores or the weld root, or other irrelevant indications.

RESULTS

All reported indications were entered into a computer database along with the truth state of each specimen. Software was written to view the 1993 data in various ways and to compare it with the results of the 1988 and 1985 studies.

Appendix VIII

Ultrasonic examination of reactor piping systems soon will have to be performed using procedures and personnel qualified to the requirements of Section XI, Appendix VIII of the ASME B&PV Code. Appendix VIII requires that the flaw detection capability of procedures and personnel be demonstrated on realistic specimens containing realistic flaws. The appendix contains rules concerning the make-up of the specimen set and the sizes, locations, types, and number of flaws; and also defines the minimum flaw detection and maximum false call criteria of an acceptable demonstration. Application-specific supplements to the appendix provide the detailed requirements for various components. Eventually there will be a supplement (Supplement 9) for demonstrating examination of CSS piping.

In addition to providing another observation in the history of CSS examination capability, the 1993 CSS workshop provides timely information on the likelihood of success for performance demonstrations to be required by the upcoming Supplement 9.

Incremental Detection Statistic

This method characterizes detection performance by combining flaw detection, circumferential position measurement, and length measurement into two parameters that can be plotted easily. The procedures' performance was expressed in terms of correct identification of the cracked or uncracked status of each increment of weld length. The axial positions of the indications and of the cracks are disregarded. The vertical axis in such plots represents the ratio:

$$\frac{\text{(total length of cracked weld that was called cracked) x100}}{\text{(total length of cracked weld)}}$$

and the horizontal axis represents the ratio:

$$\frac{\text{(total length of uncracked weld that was called cracked)x100}}{\text{(total length of uncracked weld)}}$$

This is the same statistic that was used in the PNL CCSSRRT Report and is a higher-resolution implementation of the approach used in the 1988 WCNOC workshop analysis. Perfect performance would be represented by a symbol at the upper left corner. Random performance would fall on the 45° line. Note that a vertical coordinate of, for example, 50% does not indicate that only half of the cracks were detected; more than half may have been detected but somewhat mislocated. Also, most of the total weld length was uncracked; therefore, the horizontal axis represents more weld length than does the vertical axis.

The results of the 1993 workshop are shown in Figure 3. Figures 4 and 5 compare the 1993 performance to the PISC and 1988 results, respectively.

Applying an Axial Accuracy Requirement. The results were assessed without regard to the relative axial positions of the cracks and the reported crack indications; this permitted direct comparison to the earlier studies which had followed the same procedure. Inspection of the raw data revealed, however, that this procedure caused detection credit to be given for many reported crack indications that were quite distant from the true defect location and did not give the appearance of being detections at all (see Figures 6, 7, and 8). The thick line on these figures represents the true location of the cracks and the thin lines represent the crack locations as reported by the various examination teams. The specimen represented in Figure 7 has no cracking.

The data was reanalyzed with an additional requirement for crack detection: cracked weld-inches were considered to have been detected only if the reported crack axial position was within 0.59 inch (15mm) of the true position. The 15mm tolerance was developed during the PISC study (2) in a separate analysis using a different statistical technique. Since the 15 mm axial tolerance had been applied in the PISC analysis, it was selected as a reasonable figure to represent position errors caused by the influence of CSS on beam direction.

Figure 9 shows the 1993 performance with the axial accuracy requirement. Figure 10 shows the 1993 performance both with and without the axial position accuracy requirement. Each team has a symbol on the graph representing its performance before and after application of the requirement, and the two are connected by a line. An axial tolerance of 15 mm was applied in Figure 10a and an axial tolerance of 20 mm was applied in Figure 10b.

Two effects are apparent. First, the impact of the requirement varied widely. Some teams were brought down to the line of random performance, several teams were significantly affected, and some were affected hardly at all. (A couple of teams actually benefited from the requirement; new area became available for false calling -- area in cracked weld length, but more than 15mm from the defect axial location -- and was correctly called blank.) The general effect was negative. Figure 9 shows that with the requirement for axial as well as circumferential accuracy, only half the teams correctly characterized half or more of the total cracked weld length. Second, the axial accuracy requirement affected the automated teams more than the manual teams. This may be due to errors inherent to mechanical systems (scanner setup, for example), or perhaps to injudicious selection of measurement points off the screen image of the defect indication. If the axial tolerance is increased to 20mm most of the large effects disappear.

1993 Results. Figure 9 shows that two teams correctly characterized 65% of the cracked area with a miscall of 10% to 15% of the uncracked area. Eight teams on average correctly characterized 45% of the cracked area with a miscall average of 15% of the uncracked area. Four teams showed random performances.

Direct comparison was made between the 1993 results and previous workshop results. The comparison used the raw data, in which the axial tolerance had not been applied.

1993 vs. PISC III Screening Results. Figure 4 shows that much better performance was achieved in 1993 than in the 1985 PISC screening exercise. Only one 1985 procedure performed as well as an average 1993 team. The basic techniques - beam mode, angles, frequency, scan patterns - have not changed much through the years; the improvement is apparently centered in operator expertise and the amount of practice time available.

1993 vs. 1988 Results. Figure 5 shows that the level of performance in 1993 is numerically about the same as it was in 1988. The specimen sets are very similar. The specimen set in 1993 may have been a little more difficult since it contained more specimens, more diversity, and only cast pipe, the 1988 set included a small amount of forged stainless steel piping, which is far simpler to examine ultrasonically. The 1988 data includes a data point near the upper left corner marking a particularly good performance by an automated examination team; this vendor also participated in 1993 with some of the same personnel and a newer version of the same examination system. Their 1993 performance, while among the best of the exercise, was not as accurate as their 1988 performance. The change may be due in part to normal variation and, in part, to the changes in the specimen set. The practice time available in 1993 did not seem to improve this performance.

DISCUSSION

The results of the 1993 workshop show that there has been little change in CSS examination capabilities since the 1988 workshop, which was conducted on a similar specimen set. Advanced imaging and signal processing capabilities did not appear to be of great benefit; in fact, manual examination performance levels were roughly equivalent to those of automated examination, and manual examination was superior in terms of axial position accuracy.

Appendix VIII Analysis

Earlier studies could measure CSS examination capability but could not judge its efficiency because there was no objective definition of what was "good enough." Now, however, there is (or soon will be) a specific target capability level. Adequate CSS examination capability will be considered to be that which allows performance of an acceptable demonstration according to the criteria of Appendix VIII to Section XI of the ASME B&PV Code.

The examination results were subjected to a hypothetical application of the rules of Appendix VIII, which defines the criteria that will be used for performing practical demonstrations of personnel, procedure, and equipment capabilities in examination of RPVs, nozzles, piping, and bolting. Piping demonstrations began in 1994. Application of the rules of Appendix VIII provides an opportunity to gauge the capability of present examination techniques to perform successful demonstrations.

Grading Units. According to Appendix VIII, the piping specimen set is considered in terms of "grading units." Each specimen is to contain one or more grading units, defined as a minimum of 3 inches of weld length. Each grading unit is flawed (contains a crack) or unflawed. The person examining the specimen set does not know where the boundaries of the grading units are; he simply reports the locations of crack indications, which are later compared to the grading unit locations.

An acceptable demonstration for wrought austentitic piping is defined in Table VIII-S2 of Supplement 2 to Appendix VIII. For the number of flawed grading units (7) in this specimen set, at least six must be detected. A flawed grading unit is considered to have been identified correctly if one or more reported flaw indications overlap it in the circumferential dimension. Axial position is not considered. For the number of unflawed grading units in this set, only one false call is allowed. An unflawed grading unit is considered to have been falsely called if one or more reported crack indications overlaps it in the circumferential dimension.

Supplement 2 does not specify exactly how the grading units must be distributed on the demonstration specimens. Since specific placement of the grading unit boundaries is largely an arbitrary matter that is determined by the organization administering the demonstration and since the details of this placement can affect the outcome of a demonstration, the grading unit boundaries for this specimen set were determined separately by two individuals using the same Code requirements. The two different grading unit schemes were used to analyze the workshop data.

Exceptions. The appendix does not yet contain specific criteria for demonstrations of CSS pipe examination, so the rules for wrought stainless steel piping (Supplement 2) were applied. The make-up of the specimen set did not meet the criteria of Supplement 2, so it was necessary to violate the following requirements of Supplement 2:

1) Supplement 2 requires that each grading unit include at least three inches of weld length, and that there be at least twice as many unflawed as flawed grading units.

This specimen set was not rich enough in unflawed weld length to meet these criteria. Therefore, unflawed grading units were allowed to be as small as 2 inches instead of 3 inches minimum. With this modification, the ratio of unflawed to flawed grading units became almost, but still not quite, allowable. The modification also introduces a bias toward minimized false call performance.

2) Supplement 2 requires that the specimen set include axial defects.

While this specimen set did indeed contain axial components of nominally circumferential cracking, the participants were not required to scan for them. Only the circumferential cracking was included in the analysis.

3) Supplement 2 requires that specimens shall include examples of the following fabrication conditions:

(a) unground weld reinforcement (crowns);

(b) wide crowns, such that the total crown width is 1-1/2 to 2 times the nominal pipe wall thickness;

(c) geometric conditions that normally require discrimination from flaws (e.g., counterbore or weld root conditions such as excessive internal reinforcement);

(d) typical limited scanning surface conditions, such as diametrical shrink or single-side access due to safe ends or fittings.

Supplement 2 also requires that at least 50% of the cracks be coincident with areas described above.

Specimen sets did not typically contain fabrication conditions a, b, or d set forth above, though all contained counterbores. This allowed for two-sided examinations and scanning over the weld which provide the best possible scanning conditions.

Results. The results are presented in Figures 11 and 12. The difference between the two figures is in the specific placement of the grading units by two different individuals as discussed above. The two different arrangements are identified as Scheme 1 and Scheme 2.

In each figure, performance on flawed grading units is shown on the vertical axis and performance on unflawed grading units is shown on the horizontal axis. The gray box in the upper left corner of each plot represents the performance target: no more than one flawed grading unit may be missed, and no more than one unflawed grading unit may be falsely called.

Only one or zero of the examination performances would be acceptable Appendix VIII demonstrations, depending on who drew the grading unit boundaries.

Had the specimens been larger and the grading units not so crowded together, the results may have been affected, though it's difficult to predict in which direction; some false calls may have been eliminated due to a reduced

impact of circumferential mislocation, or there may have been additional false calls due to an increase in the available uncracked weld length, or both. More unflawed material must be examined in order to achieve a more suitable margin around the true flaw locations and comply with the rules on grading unit size.

CONCLUSIONS

A workshop on ultrasonic examination of CSS pipe welds was conducted. Fourteen teams, mostly from NDE vendor companies, performed blind manual and automated ultrasonic examinations of several mock-ups. Their reported results were compared to the truth as established by dye penetrant examination. The results of this workshop were compared to earlier studies (1985, 1988) to estimate the degree of improvement in examination capability. The present results were also compared to the requirements of Appendix VIII to Section XI of the ASME Code, which will govern performance demonstrations of ultrasonic examination capability in the near future. The following conclusions are drawn as a result of the conduct of this workshop:

1) Ultrasonic examination is unreliable for welds in CSS components.

2) The general capability of present ultrasonic examination techniques and operators has not improved since 1988. The 1993 and 1988 capabilities showed considerable improvement over the capabilities observed in 1980 and 1985.

3) The ability to discriminate irrelevant reflectors from cracks must be improved.

4) Automated examination techniques did not perform significantly better than manual techniques. Automated techniques exhibited generally worse defect axial location accuracy than manual techniques.

5) The crack detection performance of the best team may be adequate, based on a hypothetical application of Appendix VIII, where significant exceptions to the protocol of Appendix VIII were required. The performance of the other 13 teams was inadequate according to this application of Appendix VIII criteria.

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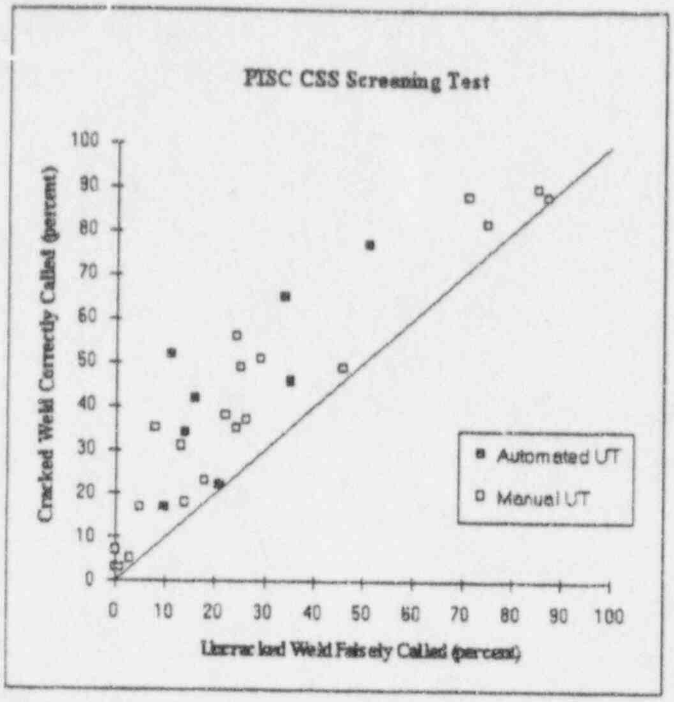


Figure 1. Results of PISC III CSS examination screening test.

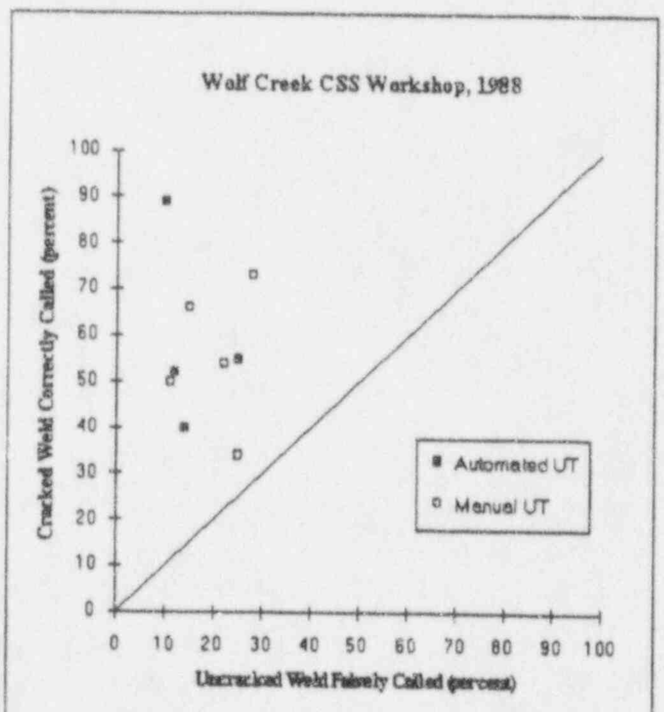


Figure 2. Results of Wolf Creek Nuclear Operating Company CSS examination workshop, 1988.

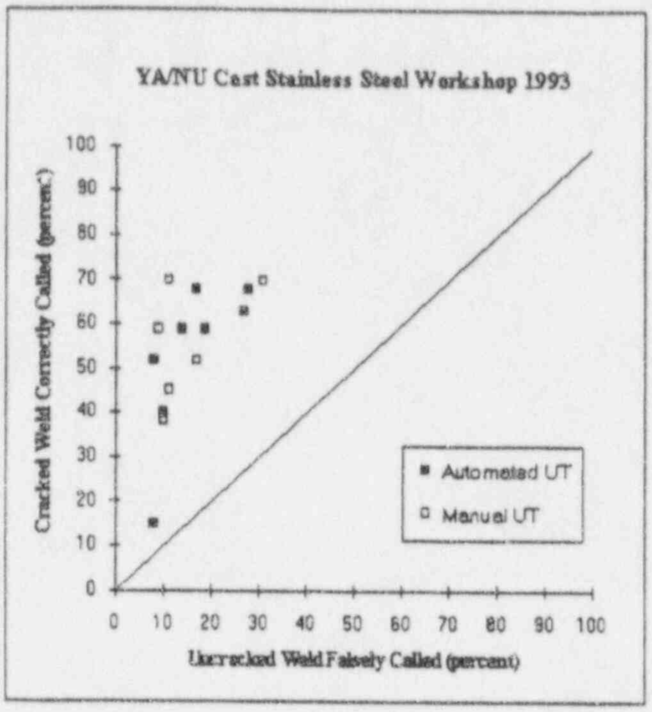


Figure 3. Results of YA/NU CSS examination workshop, 1993.

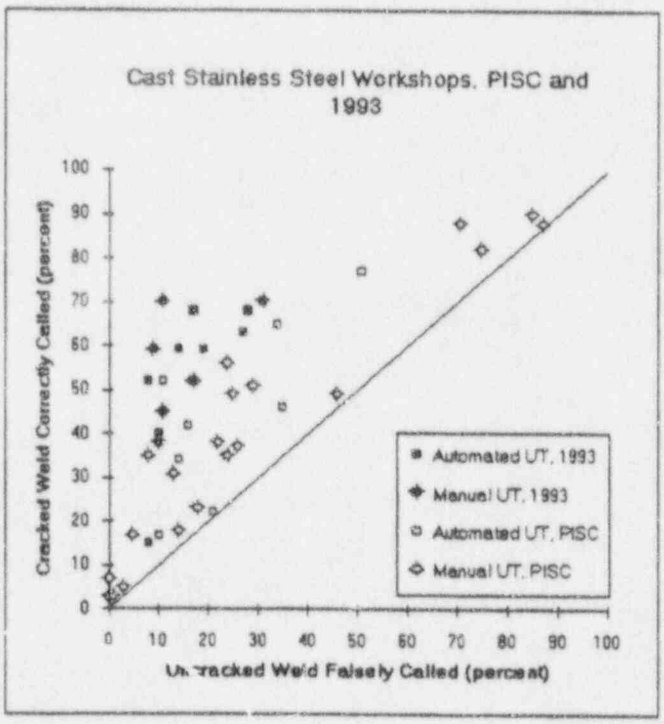


Figure 4. 1993 workshop results compared to PISC III screening test results.

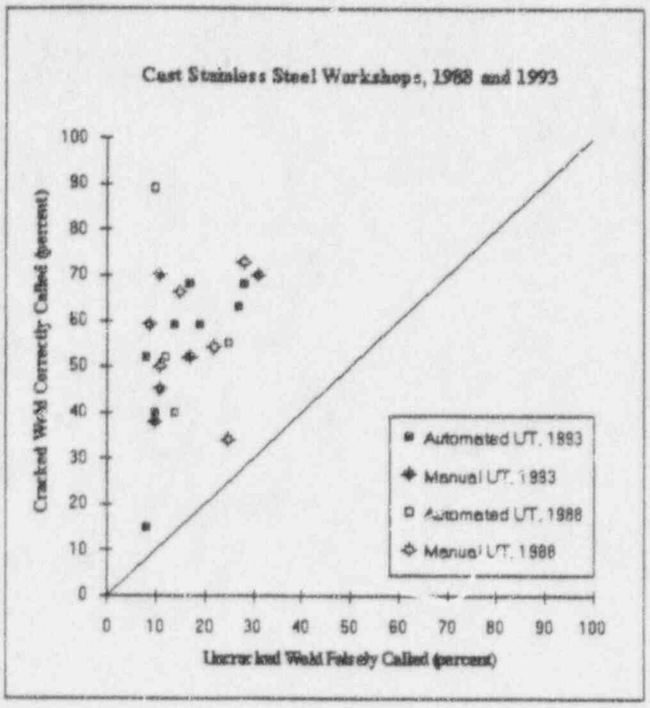


Figure 5. 1993 workshop results compared to 1988 workshop results.

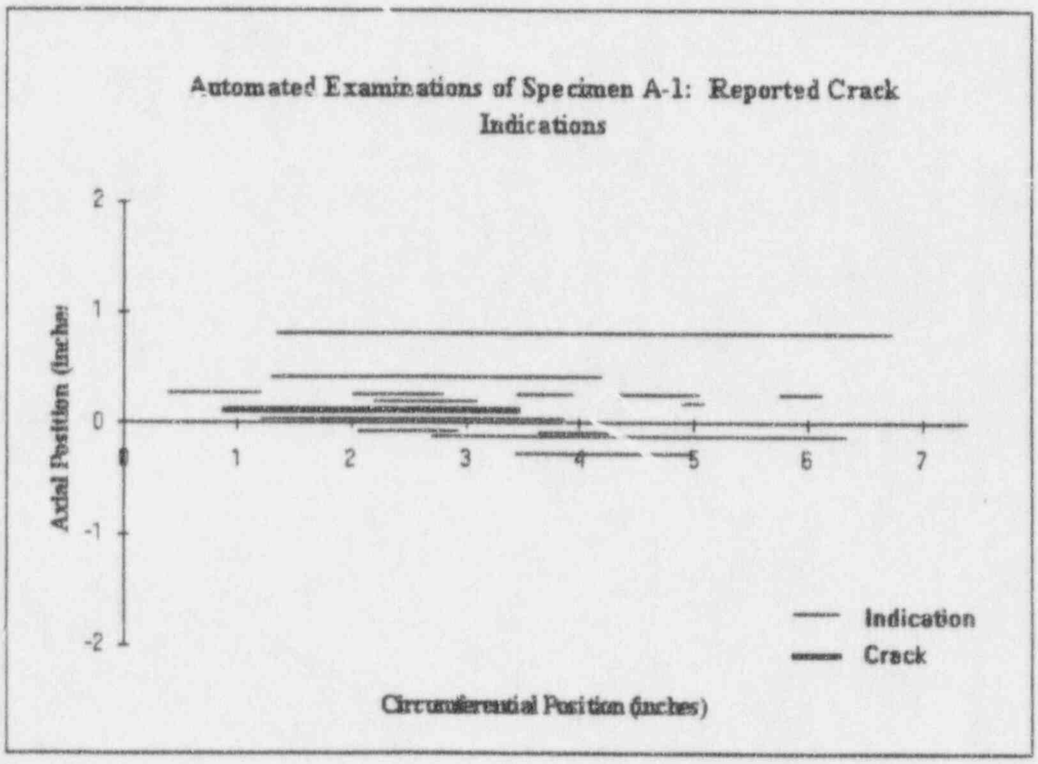


Figure 6. Crack locations reported by automated examination teams for specimen A-1 during 1993 CSS Workshop.

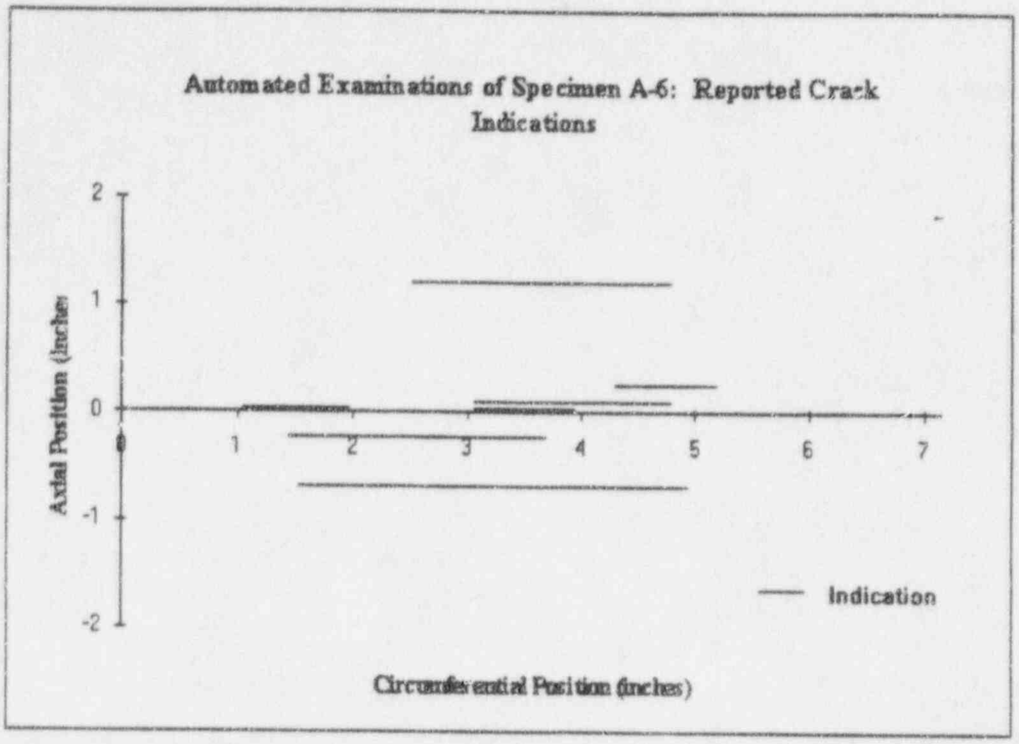


Figure 7. Crack locations reported by automated examination teams for specimen A-6 during 1993 CSS Workshop.

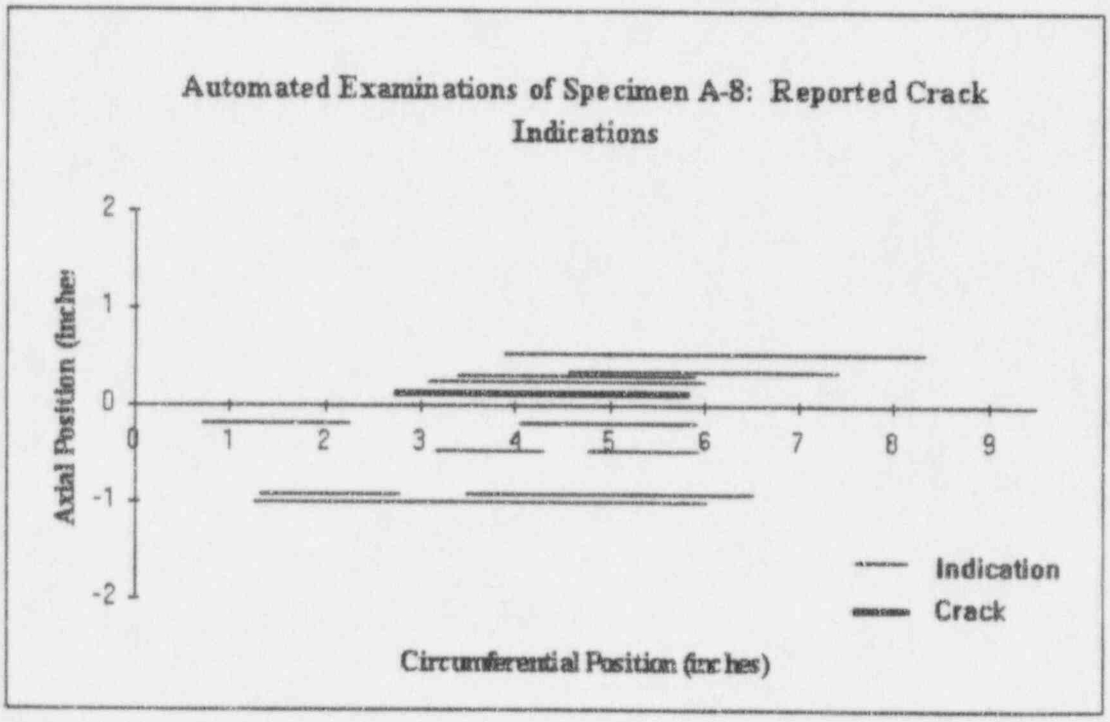


Figure 8. Crack locations reported by automated examination teams for specimen A-8 during 1993 CSS Workshop.

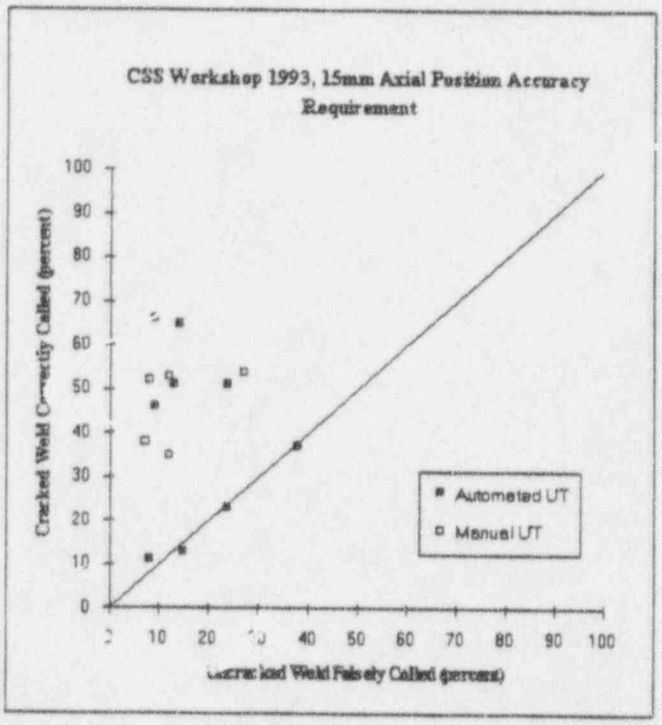


Figure 9. 1993 Workshop performance with 15mm axial location accuracy requirement.

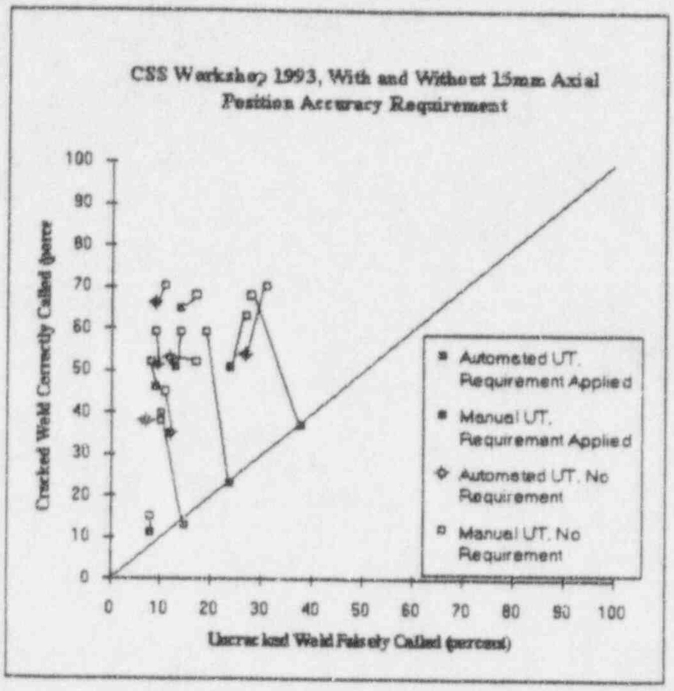


Figure 10a. 1993 Workshop performance with and without 15mm axial location accuracy requirement.

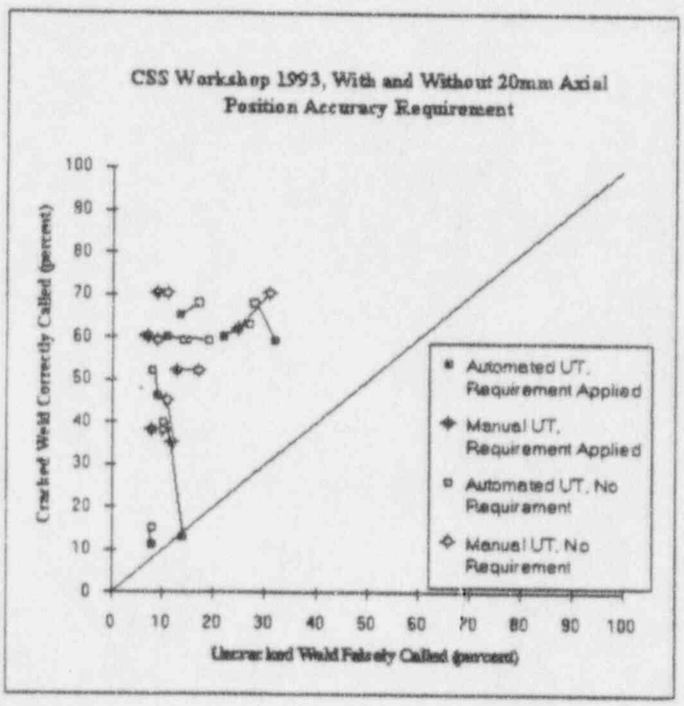


Figure 10b. 1993 Workshop performance with and without 20mm axial location accuracy requirement.

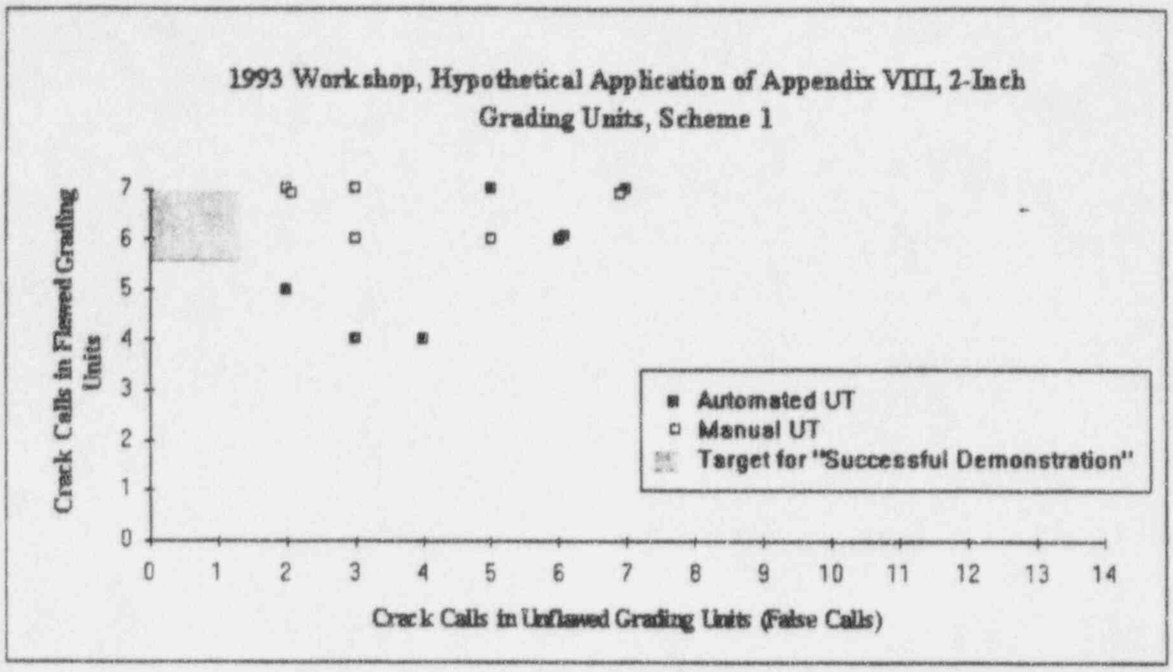


Figure 11. 1993 Workshop results analyzed by hypothetical application of Appendix VIII criteria; grading unit scheme 1.

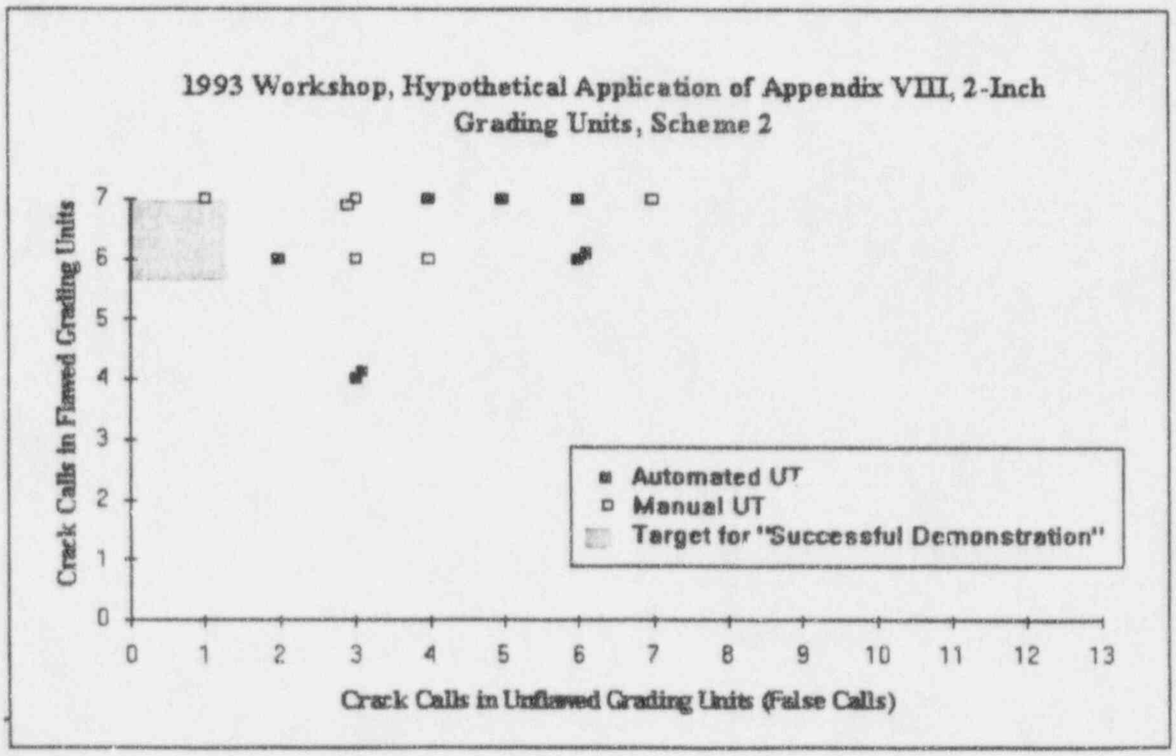


Figure 12. 1993 Workshop results analyzed by hypothetical application of Appendix VIII criteria; grading unit scheme 2.

8. RECORDING CRITERIA

8.1 RECORDING OF DATA

Ultrasonic indications that "walk" through the weld noise indications shall be recorded, regardless of signal amplitude. Signals which have a broad echo-dynamic pattern are typical when scanning over a planar reflector with refracted longitudinal waves. Watch closely for this pattern and record when noted.

When present, tip signals should also be identified on the examination record. Tip signals provide information as to the through wall extent of the reflector.

8.2 INVESTIGATION OF INDICATIONS

All recorded indications shall be investigated by a Level II or III examiner to the extent necessary to determine the shape, identity, and location of the reflector. The criteria for flaw identification should include the signal characteristics. A large echo-dynamic pattern is characteristic of planar flaws when scanned with refracted longitudinal waves. The flaw tip is generally visible and should be considered when evaluating the extent of the flaw.

Any indications which may be considered counterbore or other ID geometry must be verified by straight beam exam, radiographs, drawings of the weld joint design or further evaluation techniques.

8.3 METHOD OF RECORDING EXAMINATION DATA

When indications other than geometric have been identified within the fusion zone, the heat affected zone, or the base material, the transducer's position shall be recorded as follows: 1) The transducer's position for each data point perpendicular to the indication orientation. 2) The data shall be obtained at 1/4-inch intervals along the length of the reflector for indications that are continuous for less than two inches in length. In addition, the maximum amplitude data points shall be taken at one-inch intervals for indications greater than two inches. 3) The continuity of indications between intervals shall be confirmed.

As a minimum, the following shall be recorded for each data point: 1) Metal path to indication, 2) Surface distance from the exit point of the transducer to a surface point directly above the indication, 3) Depth indicating the point at which the indication is detected within the material, and 4) The distance from the exit point of the transducer to the toe of the weld. This data shall be taken with the signal peaked and recorded on the data sheets in the spaces provided.

8.4 PLOTTING OF INDICATIONS

Use form shown in Figure 9 of NU-UT-1 for plotting indications.

In order to accurately plot indications, the ID and OD weld contour must be established. The OD contour shall be recorded with the use of a contour gauge. The ID contour is established by performing a thickness check of the weld and adjacent base material to establish the location, depth and slope of any existing counterbore.

The thickness and contour data is then plotted on a full scale weld profile. Angle beam recordings are transferred to this plot to determine the position of these indications.

Plots of all recordable indications shall be made to show location with respect to the weld root and the weld heat affected zone. These plots shall be submitted with the examination data sheets. Examination data sheets that have indications will be considered incomplete without a plot attached. The calibration sheet number and weld number shall be referenced on the plot.

To assist in the preparation of plots, the plant owner shall assure that thickness measurements and weld joint design drawings, where required, are available.

8.5 EVALUATION OF INDICATIONS

Any indications determined not be from geometric reflectors shall be evaluated for flaw penetration and characterized whenever possible.

<u>FIGURE 1</u>

Name: ______________________

S.S.N.: ______________________

SNT-TC-1A Level: ____________

Company: ____________________

Date: ______________________

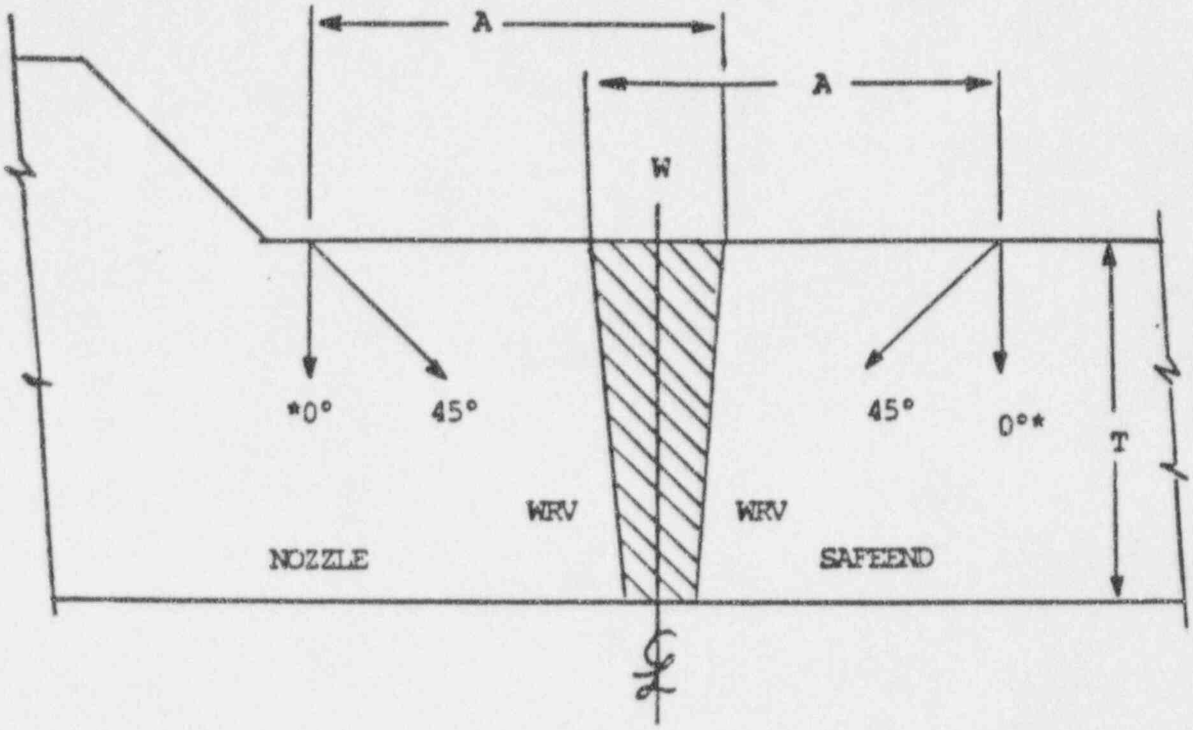
Cal. Block No.: ____________

The following above listed individual has demonstrated his/her proficiency in performing ultrasonic examinations to this procedure. This was accomplished per the criteria of paragraph 5.5 of NU-UT-17. He/she is considered capable of performing ultrasonic examinations required by this procedure when signed below by the NNECO Level III. 6

NNECO Level III ____________________ 6

Date ______________________________

Figure 2



SCAN PATHS

A = W + 1/2 + T
W = Weld Width
T = Thickness

SCAN LEGEND

⊥ Perpendicular to Weld
= Parallel to Weld
* 0° Base Material
WRV Weld and Required Volume

TYPICAL NOZZLE TO SAFEEND WELDS

FIGURE 3

SCAN PATH TABLE

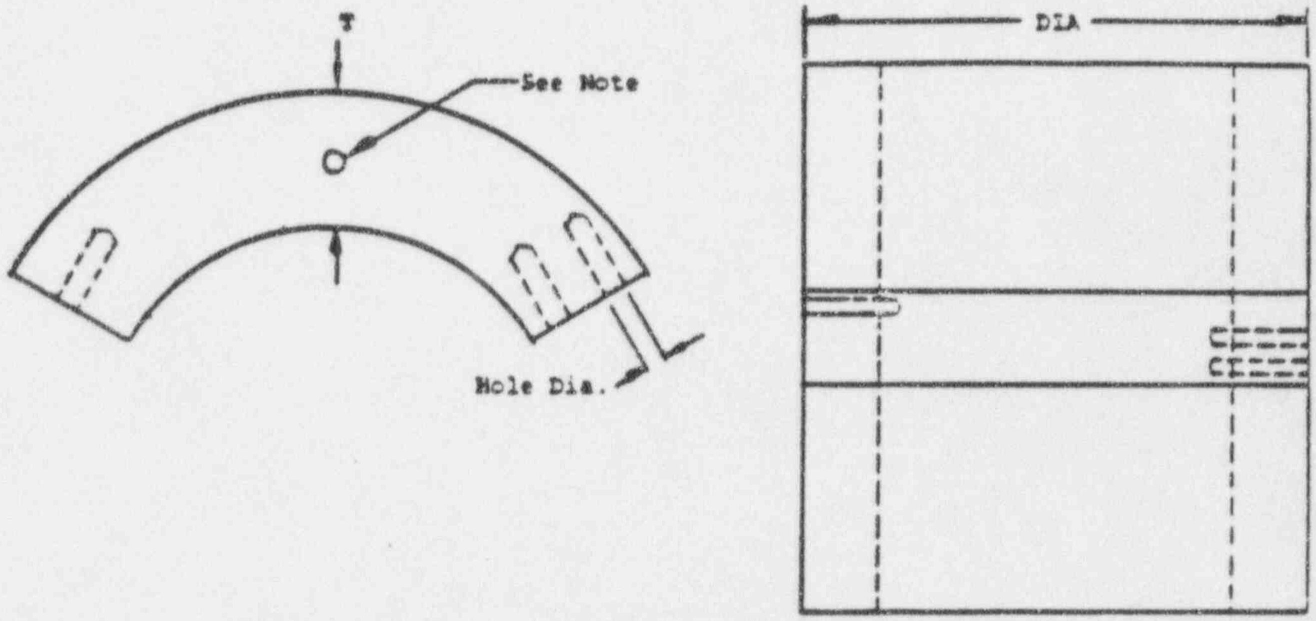
THICKNESS	SURFACE DISTANCE 45°	SURFACE DISTANCE 60°
.50" to .75"	W + 1.25"	W + 1.75"
.76" to 1.00"	W + 1.50"	W + 2.25"
1.01" to 1.25"	W + 2.00"	W + 3.00"
1.26" to 1.50"	W + 2.25"	W + 3.50"
1.51" to 1.75"	W + 2.75"	W + 4.00"
1.76" to 2.00"	W + 3.00"	W + 4.50"
2.01" to 2.25"	W + 3.50"	W + 5.25"
2.26" to 2.50"	W + 3.75"	W + 5.75"
2.51" to 2.75"	W + 4.25"	W + 6.25"
2.76" to 3.00"	W + 4.50"	W + 6.75"
3.01" to 3.25"	W + 5.00"	W + 7.50"
3.26" to 3.50"	W + 5.25"	W + 8.00"

FORMULA: $45° = W + 1/2T + T$
$60° = W + 1/2T + (1.73 \times T)$
W = Weld Width
T = Thickness

ALL SCAN PATHS ROUNDED-UP TO THE NEAREST .25"

FIGURE 4

Note: Calibration standards UT-18 and UT-19 have two sets of holes. One set is 1/8" diameter and the other set is 3/32" diameter. The examiner shall verify that the 3/32" diameter holes are used for calibration.



Calibration Std. No.	Diameter	T	Hole Dia.	Hole Depth 1/4T	1/2T	3/4T
UT-16	12-3/4"	1-1/4"	1/8"	5/16"	9/16"	13/16"
UT-17	6"	1-1/4"	1/8"	5/16"	9/16"	13/16"
UT-18	5-3/8"	7/8"	1/8"	3/16"	7/16"	11/16"
UT-19	3"	5/8"	1/8"	5/32"	5/16"	15/32"

Ultrasonic Reference Standards for Nozzle to Safeend Welds Millstone Unit 2

Revision/Change Attachment

Revision	Section	Change
3	All	Major Rewrite
4	All	Major Rewrite
5	Para 8.1	Revised Sentences 2 & 3
	Para 8.3	Reworded
6	Cover sheet	Changed NUSCO to NNECO
	Para 1.1	Changed para 1.4 to read para 1.3
	Para 5.1	Deleted the word "analog"
	Para 5.2	Deleted the words "dual element"
	Para 6.6	Added "per NU-XT-4 to the end of the first sentence
	Figure 1	Changed NUSCO to read NNECO

Docket No. 50-336
B15307

Attachment 3

Millstone Nuclear Power Station, Unit No. 2

Request for Relief From Section XI of ASME Code Examination Requirements

August 1995

Figure 7.2

NDE Procedure Change Notice # NU-UT-26-2

X NDE Procedure Intent Change or N/A Nonintent Change

N/A Temporary NDE PCN (expires in 90 days from date originated)

Plant ALL Unit ALL

Procedure No. NU-UT-26 Revision No. 4

Item Identification PARAGRAPH 5.1 Page 2 of 5

Originator SCOTT DUPLANTIS Date 12-28-94

Attached Calibration Data Sheet? Yes N/A No X

Description of Change (For temporary NDE PCNs, identify applicable components):

Paragraph 5.1.3: Add 2nd sentence to read as follows:

If weld crown geometry precludes this scan, then scanning shall be done from each side of the weld and in both directions by skewing the search unit 0 through 30 degrees while scanning.

Attach Sketch if Necessary

Approvals:

NU NDE Level III (or designee) (independent of originator) [signature] 18

Director-Nuclear Quality and Assessment Services (independent of originator) E.S. Peckham

Authorized Inspection Agency* [signature] G1137-NFS Jan 5, 1995
*Required for Section XI NDE Procedure Intent Changes Only

311-5.NEO

Figure 7.2

NDE Procedure Change Notice #PCN NU-UT-26-1

X NDE Procedure Intent Change or N/A Nonintent Change
N/A Temporary NDE PCN (expires in 90 days from date originated)

Plant Millstone Unit 2

Procedure No. NU-UT-26 Revision No. 4

Item Identification See attachment 1 Page 3,4 of 5

Originator Jeff Hecht Date 10-15-94

Attached Calibration Data Sheet? Yes N/A No X

Description of Change (For temporary NDE PCNs, identify applicable components):

Changes are idendified on Attachment 1 to this PCN.

Attach Sketch if Necessary

N/A

Approvals:

NU NDE Level III (or designee) (independent of originator) [signature] 18

Director-Nuclear Quality and Assessment Services (independent of originator) [signature] 10/15/94

Authorized Inspection Agency* [signature] 10/18/94
*Required for Section XI NDE Procedure Intent Changes Only

ATTACHMENT 1 TO PCN NU-UT-26-1

Replace section 6.3 with the following instructions:

6.3 ANGLE BEAM CALIBRATION: 1/2 Vee Technique

1. One-half vee calibration shall be used, and shall be accomplished as follows:

   A. Refer to Procedure NU-UT-1 for the appropriate metal path calibration.

   B. Select a search unit of such angle and size that the root of the weld will be within the ½ vee path.

   C. The shape and slope of the DAC curve is established by obtaining maximized responses from the side drilled holes within the ½ vee path.

   D. Set the highest amplitude signal at 80 percent FSH and mark its amplitude and position on the CRT screen. Without changing sensitivity, maximize the signal(s) from the remaining hole(s) and mark the amplitude(s) at the appropriate position(s) on the CRT.

   E. Plot a DAC curve by connecting the locations (marked on the CRT) with a continuous line extrapolated to cover the full examination volume.

   F. Obtain a maximized signal from the ID notch.

   G. If the response from the notch is greater than the 40 percent FSH, mark it's amplitude on the CRT. Reference sensitivity shall be the gain setting established in paragraph 6.3.1 D.

   H. If the response from the notch is less than 40 percent FSH , adjust the gain to set the notch at 40 percent FSH. Extrapolate the DAC line back towards the one-quarter "T" hole position. This DAC line, set to notch sensitivity, shall be the reference sensitivity level.

   I. Maximize the response from the notch to 80 percent FSH and note the gain setting on the Calibration Data Sheet. This information may be useful for comparisons with previous data.

   J. Upon completion of calibration, ensure that all data and instrument settings are recorded on the Calibration Data Sheet. The examiner(s) shall sign the completed data sheet, noting applicable NDE Certification Levels.

Add paragraph 7.2.3 as follows:

3. Scanning shall be performed at a gain setting at least two times (+6 dB) the reference sensitivity level.

NORTHEAST UTILITIES

NUCLEAR QUALITY-RELATED
NONDESTRUCTIVE EXAMINATION PROCEDURES

NU-UT-26

Ultrasonic Examination
Primary Coolant Pipe Welds

Millstone Unit 2

Rev	Issue Date	4 NNECO Level III Approval/Date	Director QSD Approval/Date	Auth. Insp. Agency Approval/Date
4	3/28/94	[signature] 3/11/94	B. Kaufman 3/14/94	[signature] 3-21-94

Always verify with the procedure Status Log before using this procedure.

JG0312XK.079

ULTRASONIC EXAMINATION
PRIMARY COOLANT PIPE WELDS
MILLSTONE UNIT 2

1. SCOPE

1.1 INTENT

This procedure shall be used in conjunction with Procedure NU-UT-1, unless otherwise specified. NU-UT-1 contains all of the general requirements applicable to this examination procedure. This procedure contains all of the specific application requirements for the examination of areas specified in paragraph 1.2.

1.2 AREA OF EXAMINATION

This document covers the ultrasonic examination procedures for the primary coolant piping welds, such as pipe-to-elbow, pipe-to-pipe, pipe-to-fitting, etc.

1.3 TYPE OF EXAMINATION

1. Volumetric examinations shall be performed using ultrasonic pulse echo nominal 45° angle beam shear wave and 0° straight beam techniques applied to the outside (OD) surface of the piping or fitting. 0° required for preservice examinations or when recordable preservice indications were found. 4

2. The examination shall be performed manually using contact search unit (transducers) and/or scan fixtures.

3. For areas where interference with examination coverage occurs, refer to ASME Section XI, Appendix III, Article III-3000, Paragraph 3230, for alternative approaches.

2. REFERENCES

1. NU-UT-1 Ultrasonic Examination General Requirements.

2. Appendix A (NDE Procedures Manual) - Calibration Blocks for each specific weld to be examined. 4

3. PROCEDURE CERTIFICATION

The examination procedure described in this document is in conjunction with Procedure NU-UT-1 and complies with Section XI of the ASME Boiler and Pressure Vessel Code, 1980 Edition, Winter of 1981 Addenda, except where examination coverage is limited by component geometry or access.

4. PERSONNEL CERTIFICATION

1. Each person performing ultrasonic examination governed by this procedure shall be certified in accordance with Procedure NU-UT-1.

5. EXAMINATION REQUIREMENTS

5.1 EXAMINATION ANGLES AND COVERAGE

1. Each weld and required volume (WRV) of metal of 1/2T on each side of the weld shall be ultrasonically examined using 45° shear wave angle beam techniques. If the distance from the exit point of the wedge is too great so as to preclude ½ vee examination of the weld root a lessor angle shall be used. The following formula provides a guide for determining if the weld root will be examined at ½ vee. 4

   .93T for 43-45 degrees
   1.6T for 58-60 degrees
   2.5T for 68-70 degrees

   Note: This formula is for exit point of wedge to center line of weld.

2. Reflectors Parallel to Weld: The examination shall be performed using a sufficiently long examination beam path to provide coverage of the required examination volume in two beam path directions. The examination shall be performed from two sides of the weld, where practical, or from one side of the weld, as a minimum.

3. Reflectors Transverse to Weld Seam: The angle beam examination for reflectors transverse to the weld shall be performed on the weld crown on a single scan path to examine the weld root by one-half V path in two directions along the weld.

   NOTE: Inaccessible Welds: Welds that cannot be examined from at least one side (edge) using the angle beam technique shall be examined by another volumetric method.

4. When required, straight beam techniques (as described paragraph 6.1) shall be applied, where part geometry permits, to all parent material through which the angle beams will pass during angle beam examinations. Indications detected are to be recorded in accordance with Procedure NU-UT-1, Section 10.1.1.

5. When required, calibrated straight beam techniques (as described in paragraph 6.2) shall be applied to the WRV where part geometry permits. 4

6. Other angles may be used if required for evaluating indications.

7. Zero degree straight beam techniques may be utilized to accurately measure wall thickness, precisely locate counter bore and to detect conditions which may interfere with the angle beam examination. These examinations shall be recorded on NU-UT-1, Figure 16.

6. EXAMINATION SYSTEM CALIBRATION

6.1 STRAIGHT BEAM CALIBRATION FOR BASE MATERIAL

NOTE: Required for preservice examinations or when recordable preservice indications were found.

1. Straight beam calibration for all base material through which the angle beams will pass shall be performed at a sensitivity level which gives an initial back reflection signal amplitude from the component of at least 80 percent Full Screen Height (FSH).

6.2 STRAIGHT BEAM CALIBRATION FOR WRV

NOTE: Required for preservice examinations or when recordable preservice indications were found.

1. Straight beam calibration for T>1" shall be performed as follows: △4

   A. Adjust the instrument sweep controls so that the examination area is displayed on the CRT screen. Mark the horizontal screen positions selected for the hole or holes directly on the CRT screen and on the chart of the Calibration Data Sheet.

   B. Position the search unit to obtain maximum response from the ¼T side drilled hole. Adjust sensitivity control to provide a signal amplitude of 80 percent of FSH and mark location and amplitude on the CRT.

   C. Without changing the sensitivity obtained in (B) above, position the search unit for maximum response from the ¾T hole and mark amplitude on the CRT screen.

   D. Plot a DAC curve by connecting the two signal response positions with a continuous line extending over the full examination range.

   E. Upon completion of calibration, ensure that all data and instrument settings are recorded on the Calibration Data Sheet. The examiner(s) shall sign the completed data sheet, noting applicable NDE Certification Levels.

   F. Indications ≥50% of the reference level shall be recorded in accordance with Section 8. △4

6.3 ANGLE BEAM CALIBRATION: ½ Vee Technique

1. One-half vee calibration shall be used, and shall be accomplished as follows:

   A. Refer to Procedure NU-UT-1 for the appropriate metal path calibration.

   B. Select a search unit of such angle and size that the root of the weld will be within the ½ vee path.

C. The shape and slope of the DAC curve is established by obtaining maximized responses from the side drilled holes within the ½ vee path.

D. Set the highest amplitude signal at 80 percent FSH and mark its amplitude and position on the CRT screen. Without changing sensitivity, maximize the signal(s) from the remaining hole(s) and mark the amplitude(s) at the appropriate position(s) on the CRT.

E. Plot a DAC curve by connecting the locations (marked on the CRT) with a continuous line extended to cover the full examination range.

F. Obtain a maximized signal from the ID notch and adjust the instrument sensitivity to bring its peak to 80 percent FSH.

G. This is the reference sensitivity level. Record all sensitivity control settings on the appropriate Calibration Data Sheet.

H. Upon completion of calibration, ensure that all data and instrument settings are recorded on the Calibration Data Sheet. The examiner(s) shall sign the completed data sheet, noting applicable NDE Certification Levels.

6.4 Calibration Checks

Calibration checks shall be performed in accordance with Procedure NU-UT-1, Section 7.3.

7. EXAMINATION PROCEDURES

7.1 STRAIGHT BEAM EXAMINATION OF BASE MATERIAL

When required, straight beam examination of all base material shall be performed at the sensitivity level established in paragraph 6.1. ⚠4

7.2 STRAIGHT AND ANGLE BEAM EXAMINATION OF WRV

1. For all straight and angle beam examinations, a rectilinear scan pattern shall be used. For angle beam examinations, the search unit shall be swivelled to ensure maximum coverage.

2. For the locations and the numbers of the welds, refer to the examination plan. Examinations shall not be considered completed until all recordable indications have been evaluated.

8. RECORDING CRITERIA

8.1 During piping examinations, all angle beam indications showing a signal amplitude of ≥20 percent of DAC in the lower 1/3T shall be recorded showing length, extent, and position. The remaining 2/3T shall require recording of indications ≥50 percent of DAC showing length, extent, and position. ⚠4

8.2 For indications ≥100 percent DAC, record the forward and backward 50 percent DAC points and the 50 percent L1 and L2 points.

9. EVALUATION OF INDICATIONS

9.1 Use form shown in Figure 9 of NU-UT-1 for plotting indications.

1. In order to accurately plot indications, the ID and OD weld contour must be established. The OD contour shall be recorded with the use of a contour gauge. The ID contour is established by performing a thickness check of the weld and adjacent base material to establish the location, depth, and slope of any existing counterbore.

2. The thickness and contour data is then plotted on a full-scale weld profile. Angle beam recordings are transferred to this plot to determine the position of these indications.

3. Plots of all recordable indications shall be made to show location with respect to the weld root and the weld heat affected zone. These plots shall be submitted with the examination data sheets. Examination data sheets that have indications will be considered incomplete without a plot attached. The calibration sheet number and weld number shall be referenced on the plot.

4. To assist in the preparation of plots, the plant owner shall assure that thickness measurements and weld joint design drawings, where required, are available.

5. Any indications determined not to be from geometric reflectors shall be evaluated for flaw penetration and characterized whenever possible.

Attachment 4

Millstone Nuclear Power Station, Unit No. 2

Request for Relief From Section XI of ASME Code Examination Requirements

August 1995

Date: November 29, 1985
Revision: 1
Change No: 2

Relief Request: RR #4 (Granted)

Use of UT Calibration Block UT−15 for Reactor Cooling System Loop Piping

Component Identification:

ASME Code Class: 1

Examination Category: B−J
Item Numbers: B9.11 and B9.12

Code Requirement:

Appendix III, Subparagraph III−3400, in the applicable edition of the 1980 ASME Code, including the 1981 Winter Addenda requires that basic calibration blocks be used. The calibration blocks shall be made from material of the same nominal diameter and nominal wall thickness or pipe schedule as the pipe to be examined.

Code Relief Requested:

Relief is requested, to use calibration block UT−15, (36″ diameter pipe to safe end weld) when ultrasonically examining 30″ and 42″ Reactor coolant piping carbon steel to carbon steel welds.

Basis for Relief:

1. The use of this block will be enhanced by adding a side drilled hole in the carbon steel side of this calibration block. The attached drawing #25203−29449 sh. 30 shows the location of the side drilled hole that has been added.

2. The side drilled holes are the proper size and diameter for the thickness of the 30″ and 42″ diameter pipe.

3. A new calibration block (material SA516 gr. 70) complete with roll bond cladding would be difficult to obtain especially in pipe diameters of 30″ and 40″ to match our reactor coolant system piping. This type of material is manufactured only in large quantities.

4. There is no assurance a new calibration block would possess the desired acoustic properties and minimize attenuation differences between the block and component. Testing has shown UT−15 is almost a perfect match (±2 db).

5. UT−15 is a smaller diameter (36″) than hot leg piping and would provide a greater sensitivity when examining hot leg (42″) piping. Per Section XI, Paragraph IWA−2240, this substitution is permissible with the concurrence of the ANII Inspector. The ANII has reviewed and concurred with the use of UT−15.

6. Examinations would be performed at side drilled hole sensitivity using axial side drilled holes, which are more sensitive than the notches required by ASME Section XI Code Appendix III. They are also more sensitive than circumferential side drilled holes.

Date: November 29, 1985
Revision: 1
Change No: 2

Proposed Alternative Examination:

All future ultrasonic examinations of the reactor coolant system welds, in the 30" and 42" piping, shall be examined utilizing UT procedures specific to Millstone Unit 2. The ultrasonic examination procedures mentioned above and the specified use of UT–15 calibration block have received concurrence of the ANII Inspector.