NONDESTRUCTIVE EXAMINATION PROCEDURE TVA Nuclear Power	Procedure No. N-UT-9 Revision 8 Page 1 of 20

ULTRASONIC EXAMINATION OF REACTOR VESSEL WELDS

"QUALITY RELATED"

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1	N/A	Inclusion of title page and revision history log, general revisions and clarifications.
2	8/17/82	General revisions and clarifications.
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4	2/6/91	Revised to incorporate TC 90-43; updated references.
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6	1/4/93	Revised to incorporate TC 92-46.
7	9/6/94	General revision.
8	2/20/96	Revised to update to the 1989 edition of ASME Section XI; incorporated TC 95-29 and TC 95-30.

1.0 SCOPE

1.1 This procedure defines the requirements for manual ultrasonic examination of full penetration reactor pressure vessel welds and base material. The requirements described herein are to be used on ferritic materials greater than 2.0 inches in thickness to detect, locate, and evaluate indications within the weld or adjacent base material. Examinations shall be conducted by the contact method from the outside surface and other surfaces if accessible to achieve coverage (e.g., nozzle bore).

1.2 This procedure complies with the requirements for examination, evaluation, and recording of results in accordance with Code category B-A and B-D contained in reference 2.1. This procedure shall be used in conjunction with NDE procedure N-GP- 18.

2.0 REFERENCES

2.1 Sections XI of the ASME Code, 1989 Edition.

2.2 Article 4 of Section V of the ASME Code, 1989 Edition.

2.3 NRC Regulatory Guide 1.150-1, "Ultrasonic Testing of Reactor Vessel Welds During Preservice and Inservice Examinations."

2.4 TVA NDE Procedure N-GP-18, "Ultrasonic Testing Supplements".

2.5 ASME Code Case N-460.

3.0 PERSONNEL

Personnel requirements are contained in N-GP-18.

4.0 EQUIPMENT

4.1 A pulse echo ultrasonic instrument shall be used. The instrument shall be equipped with a stepped gain control calibrated in units of 2dB or less. Analog or digitized units may be utilized. Krautkramer-Branson models USL-38, USL-48, USK-7D, USN-50, USN-52, Sonic MK-1, and Epoch meet these requirements.

4.2 Connecting cables shall be coaxial and their length limited to less than that at which significant signal degradation occurs but shall not exceed 600 feet. The same cable utilized for system calibration shall be used during examination.

4.3 Search unit bandwidths, damping, and center frequency shall be certified. For angle beam and straight beam search units the

active element size shall be as determined in paragraph 4.5.1 or 4.5.2. Appropriate wedges or shoes may be fitted to search units to provide for signal delays, wear surfaces, and required beam angles and modes of propagation.

4.3.1 Angle beam examinations shall be conducted utilizing 45- and 60-degree shear wave search units (± 3 degrees). The beam angle and exit point shall be verified utilizing a standard reference block (Rompas, IIW, DSC, etc.) of similar metallurgical structure as the component under examination. The basic calibration block may also be used for angle determination. Other angles may be used for examination of the following:

A) Flange welds, when the examination is conducted from the flange face.

B) Nozzle and nozzle welds, when the examination is conducted from the nozzle bore.

C) Attachment and support welds.

D) Examination of double taper welds.

4.3.2 Search units utilized for examination shall have a nominal frequency of 2.25 Mhz.

4.3.3 Other angles, sizes, and frequencies may be utilized with the approval of a TVA Level III.

4.4 Couplant shall be limited to the materials and applications listed in N-GP-18.

4.5 Calibration blocks utilized shall be as specified on the inspection scan plan. Typical basic calibration block is shown in N-GP-18.

4.5.1 An adjustment of receiver gain may be required when flat calibration blocks are used. The gain corrections apply to the far field portion of the sound beam. The minimum radius to be examined shall be determined and the search unit contact area and frequency shall be selected so that the minimum radius is greater than the critical radius as determined by Appendix A of Article 5 of Section V. For determining the maximum allowable search unit contact area for the frequency and couplant selected, Article 5 shall be applied for both straight beam and angle beam examinations and for convex, concave, or compound curvatures. If rectangular search units are used, the width of the search unit face tangent

to the minimum radius shall be used instead of the transducer diameter in Article 5. For example:

4.5.1.1 Using a 1" diameter 2.25 MHz transducer with a quartz wear face and synthetic couplant, no dB gain is required for vessels with radii 60" and greater.

4.5.1.2 Using a 1" diameter 2.25 MHz transducer with a plastic wear face and synthetic couplant, no dB gain is required for vessels with radii 18" and greater.

4.5.1.3 Using a 3/4" diameter 2.25 MHz transducer with a quartz wear face and synthetic couplant, no dB gain is required for vessels with radii 40" and greater.

4.5.1.4 Using a 1/4-inch diameter, 2.25 MHz transducer with a plastic wear face and synthetic couplant, no dB gain is required for radii 2 inches and greater.

4.5.1.5 Using a 3/8-inch diameter, 2.25 MHz transducer with a plastic wear face and synthetic couplant, no dB gain is required for radii 3 inches and greater.

4.5.2 For transducer/vessel combinations other than those listed in 4.5.1.1, 4.5.1.2, and 4.5.1.3, gain correction factors must be calculated using Appendix A of Article 5 of ASME Section V, 1989 Edition.

4.6 Ultrasonic instrument and search unit RF wave form photos shall be taken of the 1/2 t SDH reflector in the basic calibration block. This shall be performed before (within six months) and after the completion of reactor pressure vessel examinations conducted in one outage and upon change of ultrasonic instrument, search unit, type or length of coaxial cable, and use of a different calibration block as follows:

4.6.1 Preset the controls on an oscilloscope capable of delayed sweep to measure an RF waveform of approximately 0.5 volts, peak to peak.

4.6.2 Connect a coaxial cable to the oscilloscope channel 1 and to the RF output jack on the ultrasonic instrument.

4.6.3 The ultrasonic instrument noise suppression, frequency, and pulse shape controls shall be the same as used during calibration as determined in paragraph 5.0.

4.6.4 Adjust the oscilloscope controls to obtain a stable RF waveform and expand the presentation, by using the delayed sweep function, to a desired form for photographing.

4.6.5 Using a CRT camera obtain a picture of the RF waveform and identify the picture with the ultrasonic instrument and search unit's serial numbers.

4.7 Alternative methods for obtaining RF waveform photos may be used if approved by the UT Level III.

5.0 CALIBRATION

5.1 General Requirements

5.1.1 Calibration shall include the complete ultrasonic system. Any change in search unit, couplant, cables, ultrasonic instrument, or any other component of the system shall be cause for recalibration.

5.1.2 The surface temperature of the calibration block(s) shall be within ± 25°F of the component temperature. The component and/or the calibration block(s) shall not exceed 125°F.

5.1.3 Resolution

The ability of each search unit to detect reflectors shall be demonstrated. The verification of resolution shall be conducted once per search unit/basic calibration block combination at the primary reference gain level determined in paragraph 5.3.2. The necessary information shall be documented.

A. Near surface resolution estimate shall be accomplished by positioning the search unit on a calibration standard (basic calibration block, IIW, Rompas, etc.) and obtaining a signal which has the shortest metal path achievable that is clearly discernible from the inherent noise level.

B. Far surface resolution shall be accomplished by positioning the search unit to obtain a reflector

from the 4/8 vee path notch contained in the basic calibration block.

C. The ability of the ultrasonic system to detect the calibration reflectors at scanning sensitivity (i.e., + 6 dB) shall be verified. This shall be accomplished by scanning the calibration block at scanning sensitivity and normal speed. Verify that the calibration reflectors produce amplitudes of at least 50 percent DAC on the CRT.

5.1.4 Initial Calibration - shall be performed prior to the start of examination, and calibration checks shall be performed per N-GP-18. The calibration checks may be performed on a calibration block simulator (i.e., Rompas, IIW) if referenced during the original calibration. Calibration checks shall be performed utilizing at least two reflectors of differing depths.

5.1.5 Instrument Calibration for screen height and amplitude control linearity shall be verified and recorded at the beginning of each period of extended use (or every three months, whichever is less). The technique for evaluating screen height and amplitude control linearity is in N-GP-18.

5.2 Straight Beam Calibration

5.2.1 Sweep Range

Position the search unit on the unclad side of the applicable calibration block and obtain reflectors from the side-drilled holes. Using the range and delay controls position the responses from the 1/4 t, 1/2 t, and 3/4 t side-drilled holes in the basic calibration block at two, four, and six horizontal screen divisions, respectively. Alternately, position the search unit on the appropriate reference block, observe the back reflections, and set up a linear sound path distance along the screen baseline. Select a screen size that will include at least 1/4t beyond the nominal production material thickness.

5.2.2 Distance Amplitude Correction Calibration

Position the search unit to obtain a maximum response from the side-drilled hole which gives the highest amplitude. The centerline of the transducer shall be a

minimum of 3/4-inch from the block edge. Adjust the gain control to provide an 80 percent FSH response from the applicable hole and mark the peak of the response on the CRT; this is the primary reference sensitivity. Without changing the gain control, obtain the peak responses from the remaining holes and mark their positions on the CRT. Connect the marks with a smooth curve extrapolated to cover the examination range creating a DAC curve.

5.3 Angle Beam Calibration

5.3.1 Sweep Range

Position the search unit on the unclad side of the applicable calibration block and obtain reflectors from the side-drilled holes. Using the range and delay controls, position the responses from the 1/4 t, 1/2 t, and 3/4 t holes at two, four, and six horizontal screen divisions, respectively. Alternately, position the search unit on an appropriate reference block, observe radius echos, and set up a linear sound path distance along the screen baseline. Select a screen distance that will include at least 1/8 vee-path beyond the anticipated examination range.

5.3.2 Distance Amplitude Correction Calibration

A. Position the search unit on the unclad side of the calibration block for maximum response from the side-drilled hole (1/4 t, 1/2 t, 3/4 t) which gives the highest amplitude. The transducer shall be directed perpendicular to the hole and the transducer centerline a minimum of 3/4-inch from the block edge. Adjust the gain control to provide an 80 percent FSH response from that hole and mark the peak position on the CRT; this is the primary reference sensitivity.

B. Without changing the gain control, position the search unit for maximum response from the remaining holes and mark their peak positions on the CRT. If the calibration block is unclad, position the search unit to obtain a maximum response from the 5/4 t SDH and mark the location on the CRT.

C. For clad calibration blocks position the search unit on the clad side and determine the dB difference between the 3/4 t and 5/4 t side-drilled holes. Mark the horizontal location of the 5/4 t SDH on the baseline of the CRT.

D. Position the search unit on the unclad side of the calibration block and adjust the gain control to the primary reference level sensitivity determined in paragraph 5.3.2.A. Obtain a maximum response signal from the 3/4 t SDH then decrease the signal amplitude by the dB difference determined in paragraph 5.3.2.C. Mark the peak amplitude of this signal at the horizontal position determined for the 5/4 t SDH in paragraph 5.3.2.C.

E. Connect the marks on the CRT with a smooth line creating a DAC curve.

F. With the instrument gain set at the primary reference sensitivity, position the search unit for maximum response from the opposite surface notch; mark the peak position on the CRT.

5.3.3 Beam spread measurements shall be performed once for each search unit/calibration block combination per N-GP-18.

6.0 EXAMINATION

6.1 General Requirements

6.1.1 Coverage plots shall be made to document the area effectively examined for each weldment. The necessary information needed to establish the coverage plots may be derived from taking actual contours and thickness or with the use of fabrication drawings.

6.1.2 Examination volume shall include the weld material and 1/2 t of adjacent base material on each side of the weld as illustrated in figures 1 through 6.

6.1.3 The scan path of the search unit shall overlap adjacent scans by a minimum of 50 percent of the active element dimension perpendicular to the direction of scan. The scanning speed shall not exceed three inches per second.

6.1.4 Examination limitation requirements are contained in N-GP-18.

6.1.5 Examination surfaces shall be free of irregularities, loose material, or coatings which interfere with sound transmission.

6.2 Straight Beam Examination

6.2.1 Weld metal and adjacent base material shall be scanned to cover the examination volume at a gain setting of at least 6 dB above the primary reference level sensitivity. Additionally, the scanning gain shall be sufficient to maintain a back wall reflection of at least 80 percent FSH. When examinations are conducted on nonparallel surfaces, a back surface reflection may not be obtained. In these situations the area shall be examined with the minimum gain setting (i.e., +6 dB).

6.2.2 Base metal through which the angle beams will travel (weld and 2-1/2 t of base metal beyond weld) shall be scanned to detect laminar reflectors which might affect the interpretation of angle beam results. The scanning shall be conducted with a gain setting sufficient to maintain a back wall reflection of at least 80 percent FSH. When examinations are conducted on nonparallel surfaces, the examination shall be conducted per the requirements of paragraph 6.2.1.

6.3 Angle Beam Examination

6.3.1 Scanning shall be conducted at a gain setting of + 6 dB above primary reference level sensitivity as a minimum. Additionally, to ensure sound beam penetration the gain control shall be adjusted to display an opposite surface noise level of approximately 5 percent FSH.

6.3.2 For reflectors oriented parallel to the weld area, aim the search unit about 90 degrees to the weld. Manipulate the search unit laterally and longitudinally so that the ultrasonic beams pass through the required volume as specified in paragraph 6.1.2. When possible, scanning shall be performed in two directions 180 degrees to each other. Start scanning with the 45-degree search unit at least 2 t and the 60-degree search unit at least 2-1/2 t

from the weld edge. Continue the scan until the search unit has passed over the entire weld plus 1/2 t.

6.3.3 For reflectors oriented transverse to the weld, aim the search unit parallel to the weld centerline. Move the search unit along the weld so that the required volume is scanned on both sides of the weld in two directions.

6.3.4 For reflectors oriented transverse to nozzle welds, aim the search unit tangent to the weld. Move the search unit on a line parallel to the tangent so that the beam passes through the required volume; repeat the process in the opposite direction.

7.0 RECORDING

7.1 General Requirements

7.1.1 All observed or calculated values of dimensions for both component thickness and indications, whether they are obtained as decimals or converted from fractions, shall be rounded off to the nearest 0.1 inch for values one inch and greater, and to the nearest 0.05 inch for values less than one inch.

7.1.2 A reference system shall be established to locate the search unit in relation to the weld seam. This shall be accomplished in accordance with N-GP-18.

7.2 Straight Beam

7.2.1 Laminar indications whose length and depth from the surface are oriented within 10 degrees of a plane parallel to the surface shall be recorded as follows:

A. Preservice Examination - Record all areas giving indications equal to or greater than the remaining back reflection. Examinations on nonparallel surfaces shall be recorded per the requirements of paragraph 7.2.1.B.

B. Inservice Examination - Record all areas where one or more reflectors produce a total loss of back reflection accompanied by continuous indications in the same plane. When examinations are performed on nonparallel surfaces with no back

reflection present, record any indication which exceeds 50 percent DAC.

C. The scan pattern shall follow an orderly progression along the indication, beginning and ending with the positions where the indication amplitude equals the remaining back reflection. Recording for total loss of back reflection with an accompanying indication(s) shall continue to the point where either the indications are no longer detectable or the back reflection again becomes detectable.

D. As a minimum, the following information shall be recorded on the examination report form (exhibit A): maximum amplitude of indication and the remaining back reflection, depth of indication (Mpmax), total width of indication (W1 and W2), and total length of indication (L1 and L2).

E. When laminar indications are detected, the angle beam examination techniques shall then be modified to the extent necessary to examine the area affected. The area not effectively examined by the angle beam technique because of laminar discontinuities shall be identified and documented on the examination report.

7.2.2 Planar Indications

Straight beam indications which are not considered laminar in nature shall be recorded and investigated at the 50 percent DAC level. As a minimum, the following information shall be recorded: reflector maximum amplitude, search unit location at maximum amplitude (Lmax and Wmax), metal path at maximum amplitude (Mpmax), and the total length of indication at 50 percent DAC endpoints (L1 and L2). Clad interface and backwall reflections should not be recorded.

7.3 Angle Beam

7.3.1 Geometric Indications

Indications determined to be geometric in nature shall be recorded at the 20 percent DAC level. The basis for geometric determination of indications shall be documented (i.e., indication plotting). As a minimum,

the following information shall be recorded: reflector maximum amplitude, search unit location at maximum amplitude (Lmax and Wmax), metal path at maximum amplitude (Mpmax), and the total length of indication at 20 percent DAC endpoints (L1 and L2). Indications which are intermittent need only be recorded at the maximum amplitude position and the extent noted on the examination data sheet.

7.3.2 Nongeometric Indications

A. Reflectors shall be recorded at the 20 percent DAC level.

B. The following information shall be recorded as a minimum: reflector maximum amplitude, search unit locations at maximum amplitude (Lmax and Wmax); search unit locations at the 20, 50, and 100 percent DAC levels (W1, W2, L1, and L2); metal path readings at maximum amplitude (Mpmax); and at the 20, 50, and 100 percent DAC levels (Mp1 and Mp2).

7.4 Flaw Characterization

7.4.1 Traveling indications which exhibit greater metal path changes than obtained on the calibration reflector applicable to the depth range of the indication shall be characterized as follows:

A. Reflectors within the outer 75 percent of the through-wall depth shall be characterized at the 20 percent DAC level.

B. Reflectors within the inner 25 percent of the through-wall thickness shall be characterized at the 20 and 50 percent DAC levels. When sizing by the 20 percent DAC level, the size may be corrected by subtracting the beam width in the through thickness direction obtained from the calibration hole (between 20 percent DAC points) which is at a depth similar to the flaw depth. If the indication exceeds 50 percent DAC, the size shall also be recorded by measuring the distance between 50 percent DAC points. The determined flaw size shall be the larger of the two.

7.4.2 Nontraveling indications which exhibit lesser metal path changes than obtained on the calibration reflector applicable to the depth range of the indication shall be characterized as follows.

NOTE: Multiple scans shall be performed on nontraveling indications to ensure that these reflectors are not traveling indications.

A. Indications within the outer 75 percent of the total thickness with any dimension exceeding one inch shall be recorded at the 20 percent DAC level.

B. Indications within the inner 25 percent shall also be characterized at the 20 percent DAC level.

7.5 When the reflector is determined to be a flaw, the acceptance standards of IWA-3000 apply.

7.6 Evaluations shall be performed in accordance with ASME Section XI Code Category B-A IWB-3510 and IWB-3512 for Code Category B-D.

8.0 RECORDS AND REPORTS

8.1 An examination report shall be prepared for each item examined, and each examination report shall be related to an ultrasonic calibration record. Typical forms are shown in N-GP-18.

8.2 When only a portion of the weld is to be examined or the examination is limited, the examination report shall contain detail information regarding the area examined.

FIGURE 1

VESSEL SHELL WELDS

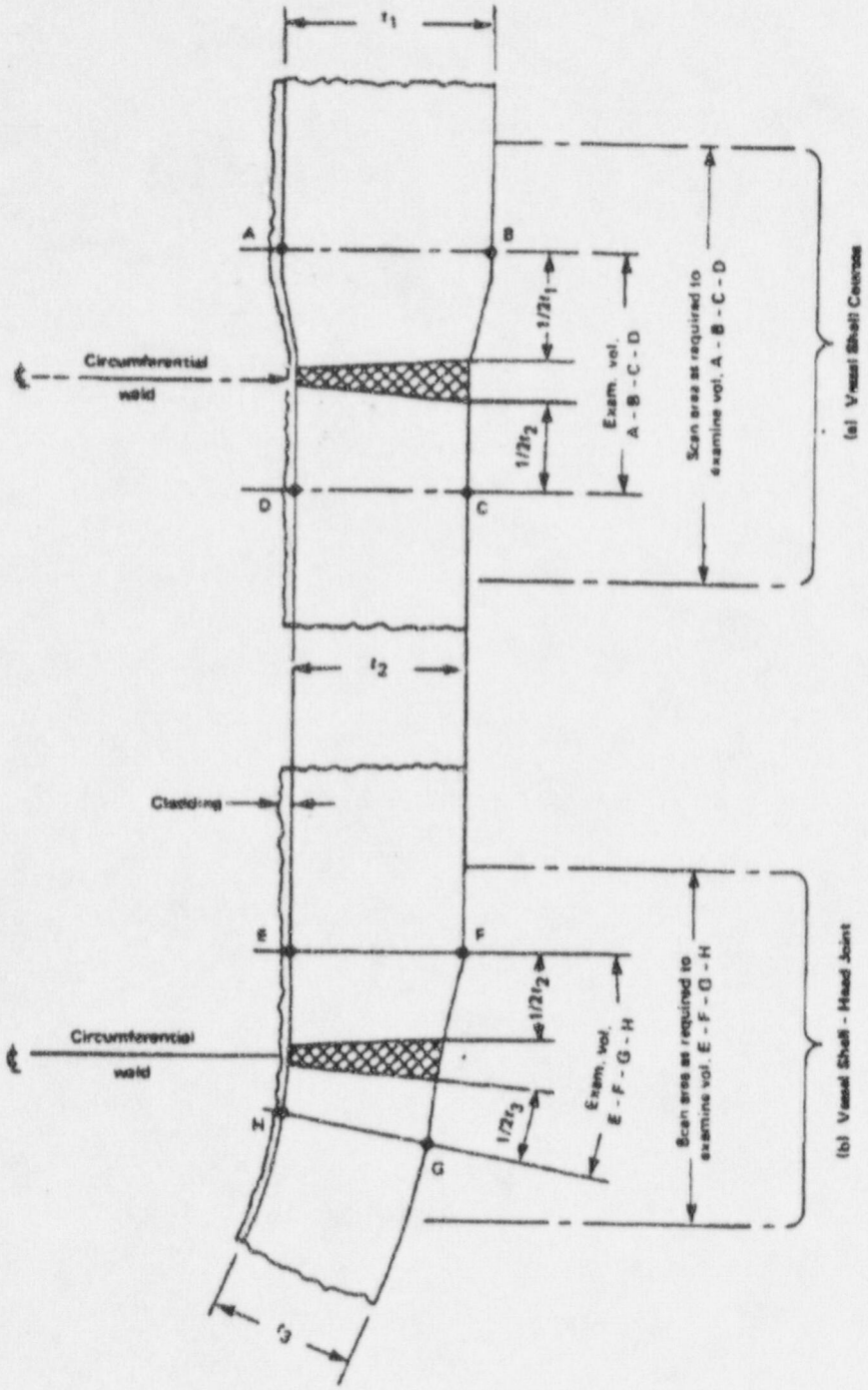


FIGURE 2

VESSEL SHELL LONGITUDINAL WELDS

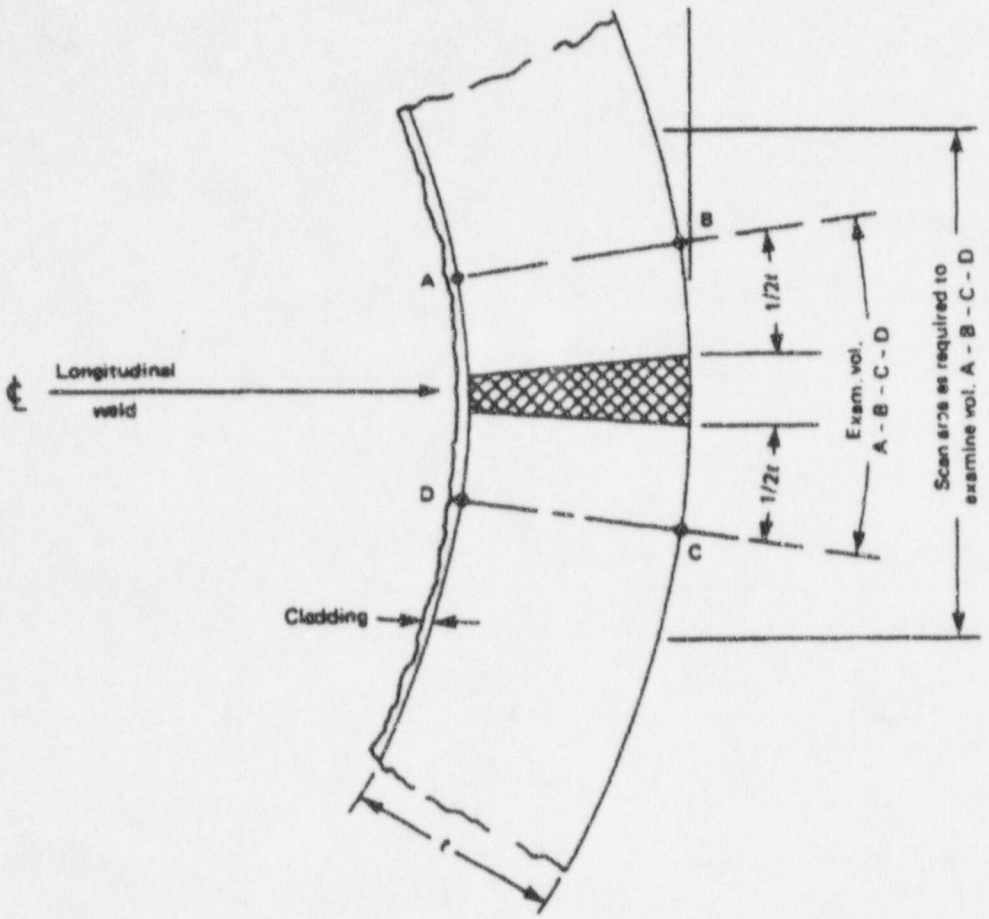


FIGURE 3

VESSEL HEAD CIRCULAR
AND MERIDIANAL WELDS

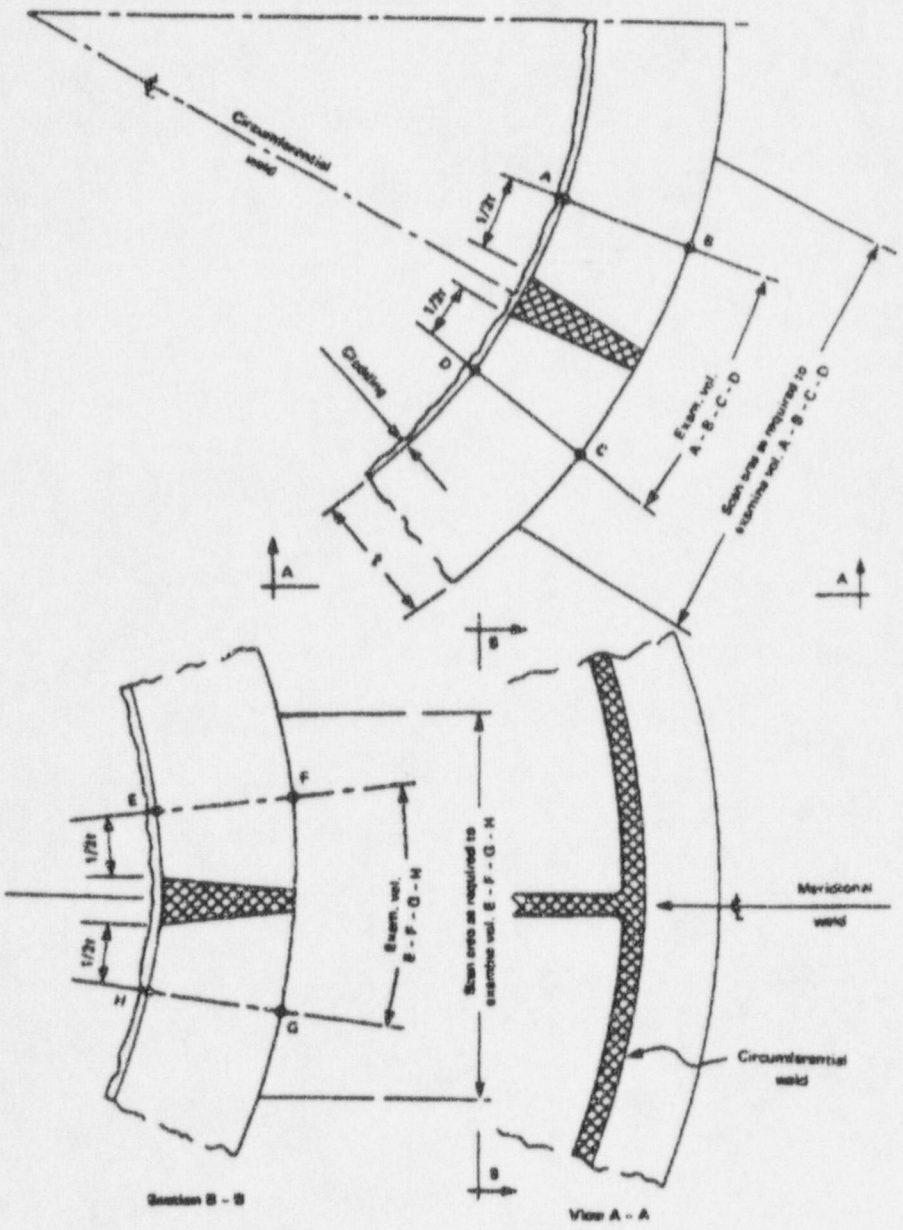


FIGURE 4

SHELL-TO-FLANGE WELD

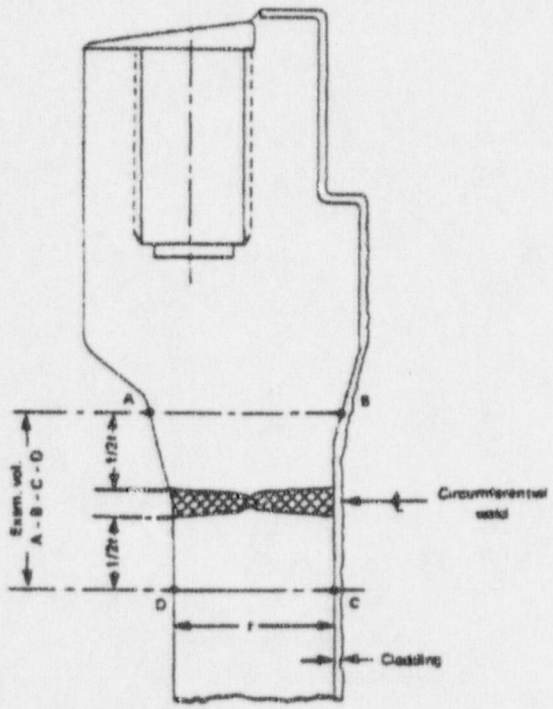


FIGURE 5

HEAD-TO-FLANGE WELD

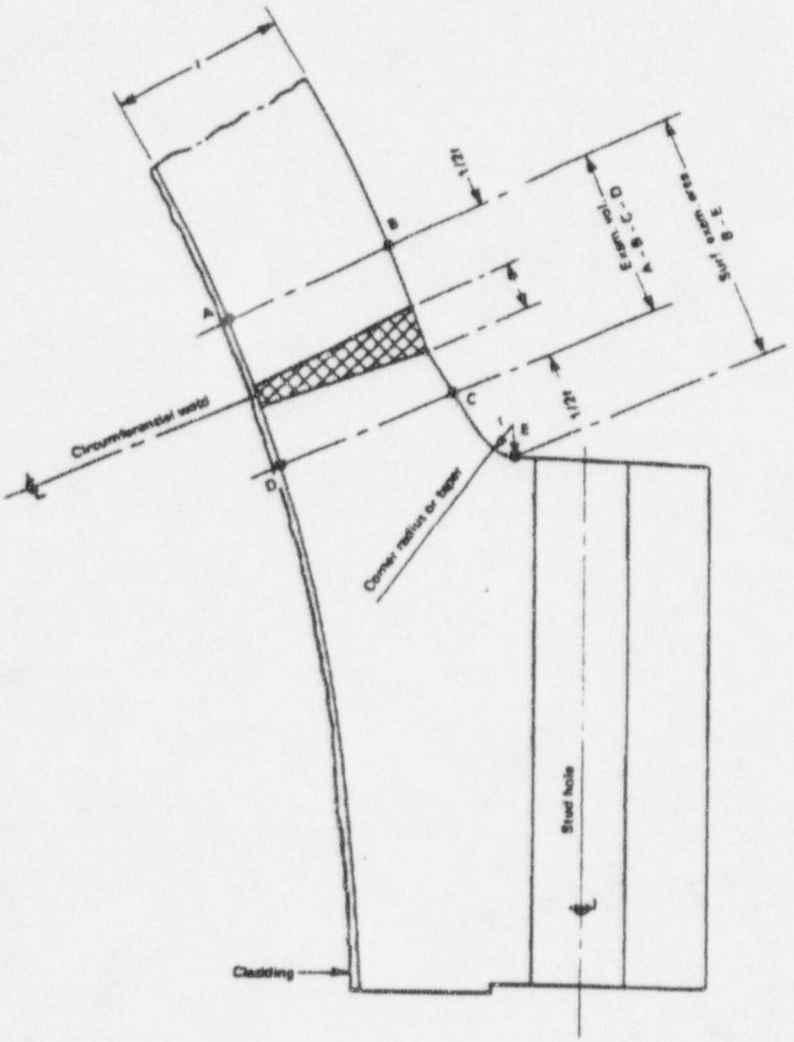
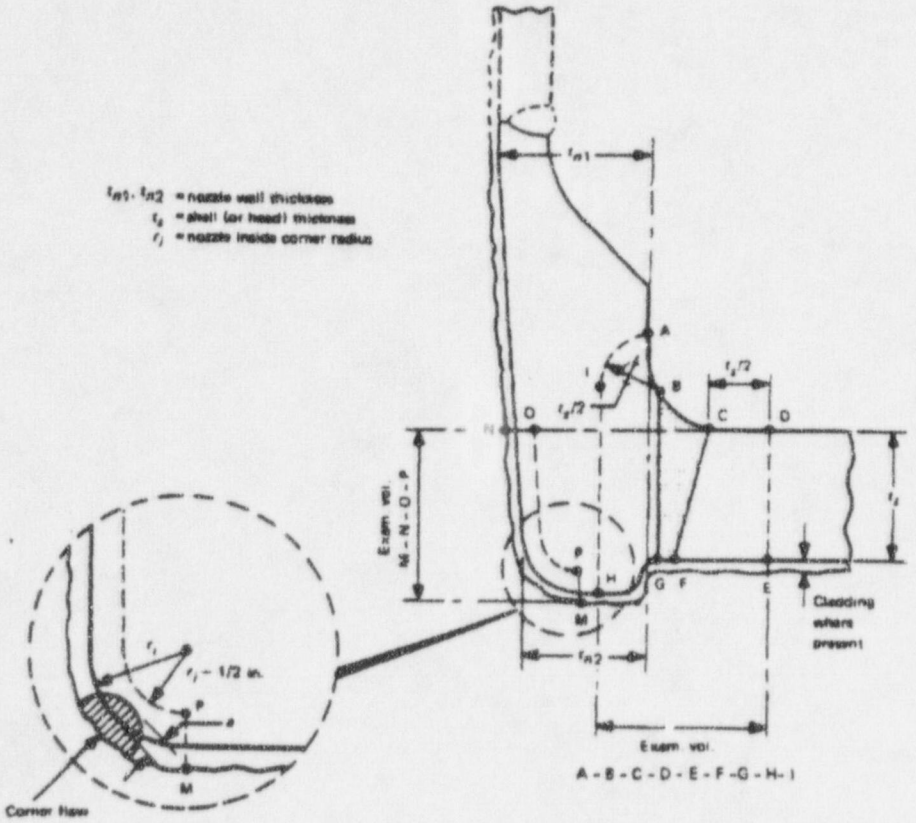


FIGURE 6

NOZZLE-TO-SHELL OR HEAD WELDS



EXAMINATION REGION (Note (1))	EXAMINATION VOLUME (Note (2))
Shell (or head) adjoining region	C-D-E-F
Attachment weld region	B-C-F-G
Nozzle cylinder region	A-B-G-H-I
Nozzle inside corner region	M-N-O-P

NOTES:

(1) Examination regions are identified for the purpose of differentiating the acceptance standards in IWB-3512.

(2) Examination volumes may be determined either by direct measurements on the components or by measurements based on design drawings.