FORM 48779

Nuclear Service Division	INSPECTION SERVICES NONDESTRUCTIVE EXAMINATION PROCEDURE	PROCEDURE NUMBER ISI-206 Rev. 0

TITLE

MANUAL ULTRASONIC EXAMINATION OF WELDS

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MANUAL ULTRASONIC EXAMINATION OF WELDS

1.0 SCOPE

1.1 This procedure defines requirements for manual ultrasonic examination of full penetration circumferential and longitudinal butt welds, and adjacent base materials of these and fillet or corner welds. It is applicable to such welds in piping systems (.25" to 6 " thick) and vessel materials (.25 to 2" thick), in ferritic or austenitic steels of either wrought or cast product forms. Technical contents are based on the ASME Code, including Section XI, IWA-2240, when dictated due to Code omissions and to implement upgraded technology or good practice.

1.2 Procedure OPS-NSD-101, Preservice and Inservice Documentation, and the Examination Program Plan noted therein are considered part of this procedure and are to be used as applicable.

1.3 Examinations in accordance with this procedure are intended to satisfy volumetric examination requirements based on the applicable edition and addenda of ASME B and PV Code specified in the Examination Program Plan.

2.0 GENERAL REQUIREMENTS

2.1 Personnel performing examinations to this procedure shall be certified to at least LEVEL II for ultrasonic examinations, based on a written procedure prepared in accordance with SNT-TC-1A, as may be modified by the applicable ASME Section XI. Personnel certified to any LEVEL for ultrasonic examinations may be employed as assistants.

2.2 Ultrasonic flaw detection instruments shall be of the pulse echo type with an A-Scan presentation and shall be qualified to the requirements of NSD-ISI-10 at the beginning of each period of extended use. Qualifications may be valid for a period not to exceed three months.

2.3 Piezoelectric transducers shall be in accordance with TABLE 1 and shall be capable of providing the applicable calibration as required herein.

2.4 Couplant shall be a suitable liquid, semi-liquid or paste, such as Echogel, Exosen, Sonotrace, Trim, Ultragel or glycerin, that is certified as containing not more than 1% by weight, of residual sulphur and halogens.

2.5 The item to be examined, including the required extent of adjacent volume to be examined, shall be as defined in the Examination Program Plan. This information shall be provided to the examiner assigned to conduct the examination. Examination of the required volume shall be to the maximum extent practical. For preservice examinations only, the extent that cannot be examined shall be noted. See 9.0.

2.6 Transducer scan surfaces including the weld crown, shall be essentially free of dirt, spatter, paint, coatings and irregularities that impair smooth uninterrupted contact of the search unit and coupling of the sound beam into the material.

2.6.1 Surface condition, and access support (e.g., scaffolds, lighting, etc.) if required, shall be the responsibility of the utility.

2.7 Generally the examinations conducted in accordance with this procedure will be done from the O.D. surface. When examinations are to be conducted from an I.D. surface, calibration must be accomplished on the I.D. of the appropriate calibration block and noted on the report.

2.8 CALIBRATION BLOCKS

2.8.1 Calibration blocks shall be fabricated from the same product form and the same material specification as one of the materials in the weld assembly to be examined. Alternatively, for welds in austenitic materials, material of an equivalent P-number or P-number grouping may be used. Calibration blocks and the general items for which they are applicable shall be as listed in the Examination Program Plan.

2.8.2 Calibration blocks shall be of the same nominal diameter and nominal wall thickness as the item to be examined, and shall contain notch reflectors. Notch depth shall be in accordance with the applicable code.

Alternatively, for austenitic material and for vessels; (1) reflectors may be side drilled holes, (2) for materials with diameters greater than 20", the block may be flat, (3) for materials with diameters of 20" and less, the examination surface may be within the range of .9 to 1.5 times the block diameter.

When drilled holes are provided, nominal depth (length) shall be 1 1/2" minimum if end or side drilled; and thru-wall or 1 1/4" minimum if drilled on a chord line. Diameter and location shall be based on nominal thickness, as follows:

THICKNESS (T)	DIAMETER	LOCATION (T)
Up to 1" Incl.	3/32"	1/2 (or 1/4 & 3/4)
Over 1" thru 2"	1/8"	1/4 & 3/4
Over 2" thru 4"	3/16"	1/4 & 3/4
Over 4" thru 6"	1/4"	1/4 & 3/4
Primary RC Loop	3/16"	1/4, 1/2 & 3/4

2.8.3 Temperature difference between the surface of the block on which calibration is accomplished and the surface of the item to be examined shall not exceed 25°F. Devices for determining this difference are not considered as MT&E equipment.

2.8.4 Where the component is clad, the block shall be clad by the same welding procedure. If impractical, welding may be by manual procedure.

2.8.5 Surface finish of blocks shall be representative of surface finish of examination scan surfaces.

3.0 SYSTEM CALIBRATION

3.1 Prior to conducting examinations, the complete system to be utilized shall be calibrated on the applicable calibration block (See 2.8.1) for the examinations to be conducted. The system is defined as; the ultrasonic instrument (and battery pack if applicable), cable(s), transducer, couplant, and any other apparatus, instrument or circuit employed between the instrument and the calibration block surface. Once calibration has been established, any change to any part of the system will require at least a verification of the calibration.

3.2 Sweep range calibration shall be sufficiently long so as to allow examination of the entire required volume by a: full "vee path" from one side of the weld; half "vee path" from each side of the weld; or a combination of such coverage so that the entire volume required to be examined is covered by at least 2 sound beam directions. See Figures 1 thru 4.

3.2.1 A "Vee path" is composed of a downward and an upward path or leg of the calibrated sound beam in the material through which it is traveling.

A 1/2 Vee path is either a downward or an upward leg. Example: for 1 1/2 V (or 3T) calibration where the volume required to be completely covered by the first 1/2 V from one side and by the last (3rd 1/2V) from the opposite side, 1/2 Vee path coverage from both sides has been satisfied. A 1 1/2 V is composed of 3 half vees and 2 full vees, one of which is inverted.

3.2.2 Sweep shall be calibrated to provide equally spaced increments of the appropriate reference reflectors. Table 2 specifies specific sweep limitations.

3.3 Reference sensitivity shall be established from notch reflectors except, for vessels, castings, 1/2 node techniques, and for austenitic materials greater than 1.7 inches thick, drilled holes may be used. Primary reference sensitivity shall be established from not nearer (in sweep time) the applicable reflector that provides the highest amplitude response. For primary loop reactor coolant piping, sensitivity shall be established from the 3/4 T hole. For pressure boundary base metal adjacent to and underneath integrally welded supports, sensitivity shall be established on an O.D. notch or on holes representing an up-leg.

3.4 Reference sensitivity shall be established by adjusting the peaked signal from the applicable calibration reflector to 80% of FSH (Full Screen Height).

3.4.1 Without moving the search unit from this peaked signal location point, check vertical linearity of the system by decreasing signal amplitude 6dB, and then by an additional 6dB. The resulting signal decrease must be within 32% to 48% FSH and 16% to 24% FSH respectively.

3.4.2 If either signal falls outside of its' range, such controls as reject, clipping, damping, filtering, etc., shall be adjusted such that this check can be accomplished satisfactorily. If adjustment of controls fails to provide a satisfactory check, the transducer and/or cable shall be changed and calibration repeated.

If the system continues to fall outside of the acceptable range, the instrument shall be changed. Once adjustment of controls that affect linearity is established, if necessary, they shall remain fixed for the period of the examinations.

3.5 Return primary reference signal to 80% FSH and without changing gain control, determine peak indication amplitude from the remaining applicable reflector positions in the examination region. Construct a distance amplitude curve (DAC) on the screen by a curved line connecting each of the peaked points. The DAC may be extrapolated at either end for a distance of 1/2 T.

3.5.1 Where the primary reference sensitivity is established from a notch reflector, signals from the 1/4 T and 3/4 T holes may be used to establish slope of the DAC when 1/2 node examination is used. Alternatively, the next two notch reflector positions may be used to extrapolate the DAC slope to cover the examination range. Holes shall not be used to establish a DAC for examinations requiring a calibration block of less than .8" thick.

3.5.2 For primary loop RC piping, slope of the DAC shall be established with the peaked signal from the 1/4 T hole set to 80% FSH and connecting the resulting peaks from the 1/2 T and 3/4 T holes with a curved line. With the peaked signal from the 3/4 T hole adjusted to 80% FSH reference sensitivity, the DAC curve shall be drawn as a line parallel to the line established above. The line shall extend through the 80% reference point and through a vertical line of the screen that represents a minimum of 1 1/4 T or 100% of sweep.

3.5.3 Reference points at 50% and 20% of DAC shall also be established on the screen by decreasing each DAC curve reference point by 6dB and then by an additional 8dB. The resulting 50% and 20% points shall be connected by curved lines drawn on the screen.

3.5.3 (cont'd)

To minimize screen clutter, lines connecting 50% points may be deleted, provided the points are clearly defined and are separated by not more than approximately one major screen division. When investigating indications which may or are required to be recorded at the 50% DAC level, a line connecting the applicable adjacent points must be considered or, alternatively, 2X reference sensitivity may be used, with the 100% DAC curve then representing the 50% DAC line.

3.6 When calibrating for angle beam examination of primary loop reactor coolant piping system and for cast austenitic materials, a primary reference DAC shall be established by adjusting the 1/4 T hole reflector to 80% FSH and another DAC established by adjusting the 3/4 T hole reflector to 80% FSH. DAC curve for the 3/4 T shall parallel the 1/4 T curve. Examinations shall be conducted once for each DAC.

3.7 Calibration for reflectors transverse to the weld shall be based on 1/2 V.

3.8 Straight beam calibration for welds in vessels shall be as follows:

a. Welds less than .8" thick

The signal amplitude from the 1/2 T hole shall be set at 80 percent of full screen. A DAC curve is not required.

b. Welds .8" thick and greater

The signal amplitude from 1/4 T hole shall be set at 80 percent of full screen. Mark the amplitude of both the 1/4 T and 3/4 T holes to establish a DAC.

4.0 SYSTEM CALIBRATION VERIFICATION

Calibration shall be verified at the beginning of each day of examination, and at the end of examinations for which calibration is applicable or every four hours, whichever is less, and with any change in examination personnel.

4.1 A DECREASE in sensitivity of more than 2 DB shall require recalibration and re-examination of all items examined since the previous acceptable calibration or check. An INCREASE in sensitivity of more than 2 DB shall require recalibration and re-examination and data correction of all indications recorded since the previous acceptable calibration or check.

4.2 If any point on the DAC curve has moved on the sweep line more than 10% of the sweep division reading, correct the sweep range calibration and note the correction in the examination record. If recordable reflectors are on the data sheets, those data shall be voided, a new calibration established, and areas relative to the voided data shall be re-examined.

5.0 EXAMINATION

5.1 Extent of examination

5.1.1 Examination for reflectors parallel to the weld shall be conducted to achieve coverage of the required volume to the extent described in 3.2, from one side of the weld. As necessary, examination shall be conducted from both sides and the "second" side examination may be limited solely to coverage of that volume in which the required coverage was not achieved from the "first" side.

5.1.2 Calibrated straight beam (see 3.8) examination when required in the Examination Program Plan, shall be accomplished to examine all of the volume required to be examined, to the extent practicable.

5.2 Examinations utilizing more than one DAC curve shall be accomplished once for each curve.

5.3 Rate of search unit movement shall not exceed 6" per second.

5.4 When practical, scanning sensitivity shall be at least twice the primary reference sensitivity.

5.5 Base Metal Straight Beam Examination

5.5.1 Prior to performing angle beam examination the base material through which the angle beam will pass shall be completely scanned with a straight beam search unit to detect reflectors which might interfere with the angle beam examination. This examination is to be done for preservice only.

5.5.2 Sensitivity of the instrument shall be adjusted at a location free of indications so that the first reflection from the back surface will be 50 to 80 percent of full screen height. Sensitivity as adjusted above shall be continuously monitored during the examination, and adjusted as necessary to maintain at least this minimum amplitude. Alternatively, calibration in accordance with 3.8 may be used.

5.5.3 Areas containing indications (principally laminar) that affect angle beam examinations shall be noted, considered during that examination, and recorded on the data sheet if they are confirmed as interfering. See 9.0.

5.6 Angle Beam - Reflectors Parallel to the Weld

5.6.1 The scan pattern shall start with the search unit transmitting an angle beam perpendicular to and towards the weld. The search unit shall be moved towards and away from the weld such that a necessary amount of the beam path passes through the maximum accessible volume of weld and base metal to be examined. Concurrent with this scan, the search unit shall be angled right and left and progressively indexed along the length of the weld such that the whole scan pattern follows a "saw-tooth" pattern. The "pitch" of the "saw-tooth" shall be such that the beam covers at least 10 percent of the area covered by the previous adjacent pass. The weld and required amount of adjacent base metal is to be fully scanned by this method. When necessary and practicable examination shall be accomplished from both sides of the weld. This relates to examination directions 2 and 5 in OPS-NSD-101.

5.7 Angle Beam - Reflectors Transverse to the Weld

5.7.1 This examination is to be accomplished only where satisfactory sound beam coupling into the weld can be achieved and maintained. Crowns should be flat for at least 90% of width.

5.7.2 The search unit shall be placed on one edge of the weld directing the angle beam into the material parallel to the weld axis. From this position, the search unit shall be moved parallel to the weld and indexed toward the opposite side such that the next scan will cover at least 10 percent of the area covered by the previous adjacent scan. Parallel scans shall be repeated in this manner until the length and width of the required volume under this surface has been scanned; and then repeated in the opposite direction. This relates to examination directions 7 and 8 as described in OPS-NSD-101.

6.0 INTERPRETATION AND INVESTIGATION

6.1 The examiner shall interpret all indications that exceed 20% of the primary reference DAC such that he can assess their source and cause in terms of their being either valid or non-valid. Indications from or near the root of welds may require other aids. See 6.3.

6.1.1 Valid indications are reflectors caused by flaws, such as cracks, lack of penetration or fusion, inclusions and porosity. All other indications are considered non-valid, including those due to: scanning noise, grain structure, beam redirection, internal liquid levels, clad interface, straight beam back surface and geometric reflectors.

6.2 Valid indications that exceed 20% of primary reference DAC shall be investigated by the examiner, in terms of the recording requirements of 7.0.

6.3 Other transducers, search units, frequencies, techniques, etc., may be used to aid interpretation and investigation.

6.3.1 If such aids necessitate use of any control that cannot be positively returned to its calibrated position, (such as a potentiometer control on sweep, damping, uncalibrated gain, etc.) primary reference calibration shall be verified before use and re-established prior to continuing examinations.

7.0 RECORDING INDICATIONS

7.1 Prior to recording indications that require dimensioning, complete primary reference calibration, including linearity check shall be verified. Scribe/Ref. line data shall be recorded or verified.

7.2 Valid flaw indications which provide a response equal to or greater than 50% of primary reference DAC shall be considered as--recordable indication--and noted as RI.

7.2.1 For each such indication, peak amplitude, sweep position, and search unit location and direction shall be recorded. The indication shall also be dimensioned to record, as a minimum, sweep positions and search unit locations representing minimum and maximum 50% DAC points, parallel and perpendicular to the length axis of the indication.

7.3 Valid flaw indications which provide a response between 20% and 50% of primary reference DAC shall be considered as--non-recordable indication--and noted as NRI.

7.3.1 For preservice examination of pipe welds where primary reference sensitivity was established from a notch, each such indication shall be noted on an RI data sheet. As a minimum, peak amplitude, sweep position, search unit location and direct, and scanning side thickness shall be noted.

7.4 Non-valid indications, and the absence of valid indications shall be considered as--no indication--and noted as NI.

8.0 POST CLEANING

8.1 Examined areas shall be dry-wiped to remove excess wet couplant, if necessary.

9.0 EXAMINATION RESULTS AND DOCUMENTATION

9.1 All data relative to examinations shall be recorded in accordance with OPS-NSD-101.

TABLE 1

ANGLE BEAM EXAMINATION

NOMINAL MATERIAL THICKNESS	TRANSDUCER (1) MAX. SIZE	MINIMUM FREQ. MHz	NOMINAL ANGLE
.250" to .750"	1/4"	2.25	45°S
.751" to 1.000"	1/2"	2.25	45°S
1.001" to 1.200"	3/4"	2.25	45°S
1.201" and Greater	1"	2.25	45°S
Main Coolant Piping			
Forged	1"	1.0	41°L/45°S
Centrifugally Cast or cast	1"	1.0	41°L

STRAIGHT BEAM EXAMINATION

	SIZE MIN.	MAX.	MAX. FREQ. MHz
Main Coolant Piping	1"	1.25"	2.25
All other to 12" Dia.	1/4"	1/2"	5.0
12" Dia. and greater	1/4"	1"	5.0

NOTES:

(1) Other transducers may be used where metallurgical characteristic or geometry impede effective use of the above listed angle beams or frequencies. Size is the element viewed from the side and shall not be increased.

TABLE 2

1/4 T	= 1/8 Node	= 1/8 V	1 1/4 T	= 5/8 Node	= 5/8 V
1/2 T	= 2/8 Node	= 1/4 V	1 1/2 T	= 6/8 Node	= 3/4 V
3/4 T	= 3/8 Node	= 3/8 V	1 3/4 T	= 7/8 Node	= 7/8 V
1 T	= 4/8 Node	= 1/2 V	2 T	= 8/8 Node	= 1 V

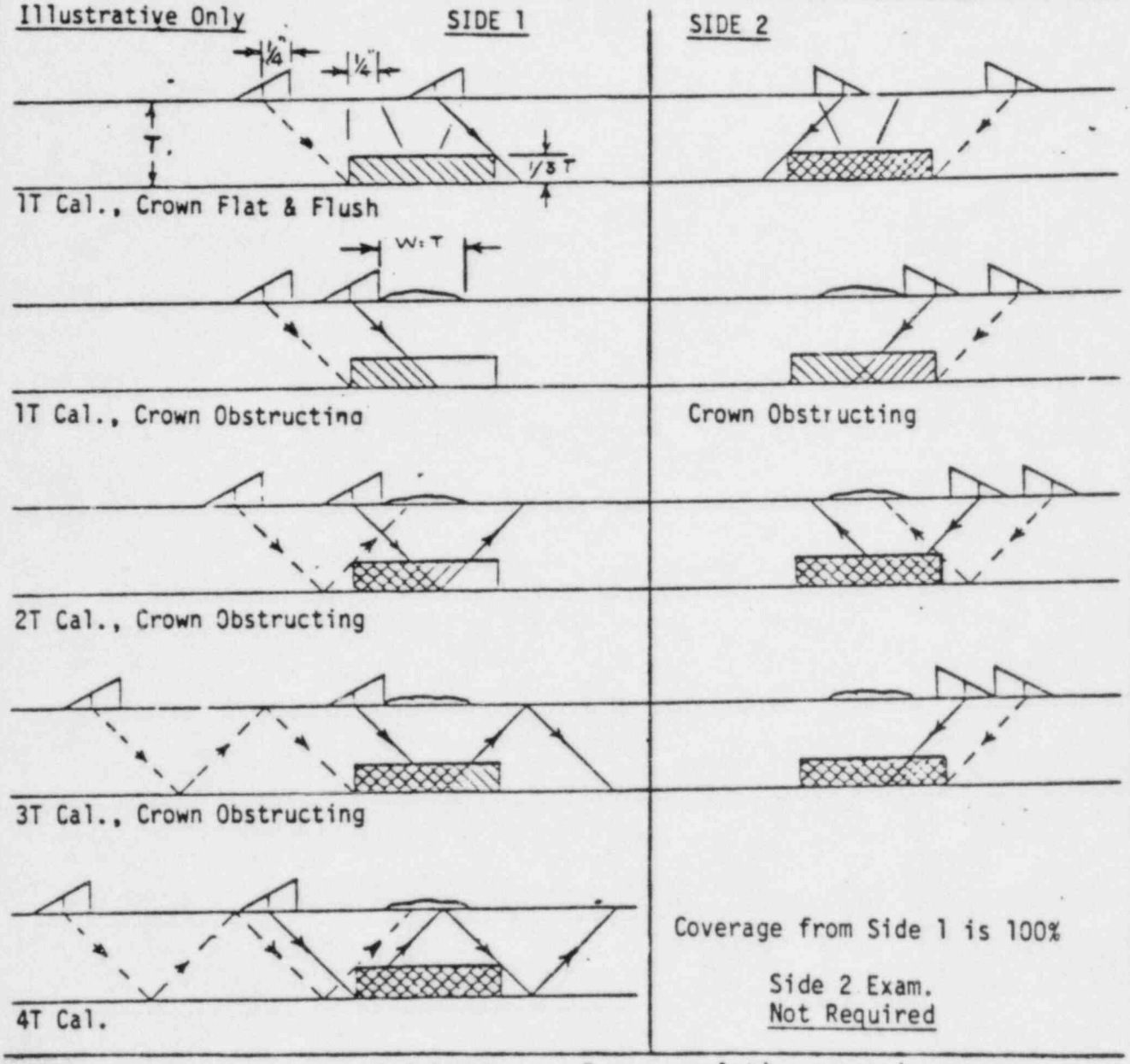
ETC.

SWEEP RANGE CALIBRATION

FOR SWP. RANGE CAL. OF:	MAX. LAST LEG % SWP. LOCATION (1)
1 T	70
2 T	75
3 T	75
4 T	75

(1) Applicable for "T" calibration point from notch reflector, or last "T" point as extrapolated or extended from calibration hole reflectors. Maximum last leg location indicated, is based on piping calibration block at minimum "T" and of volume to be examined at maximum "T". Last leg positions indicated above may be changed if thickness of calibration block and the examination area are determined to be other than this basis. Calculate for maximum last leg position as follows:

$$100 \div \frac{\text{EXAM. VOL. "T"}}{\text{CAL. BLOCK "T"}} = \text{MAX. \%SWP. LOCATION FOR LAST LEG.}$$

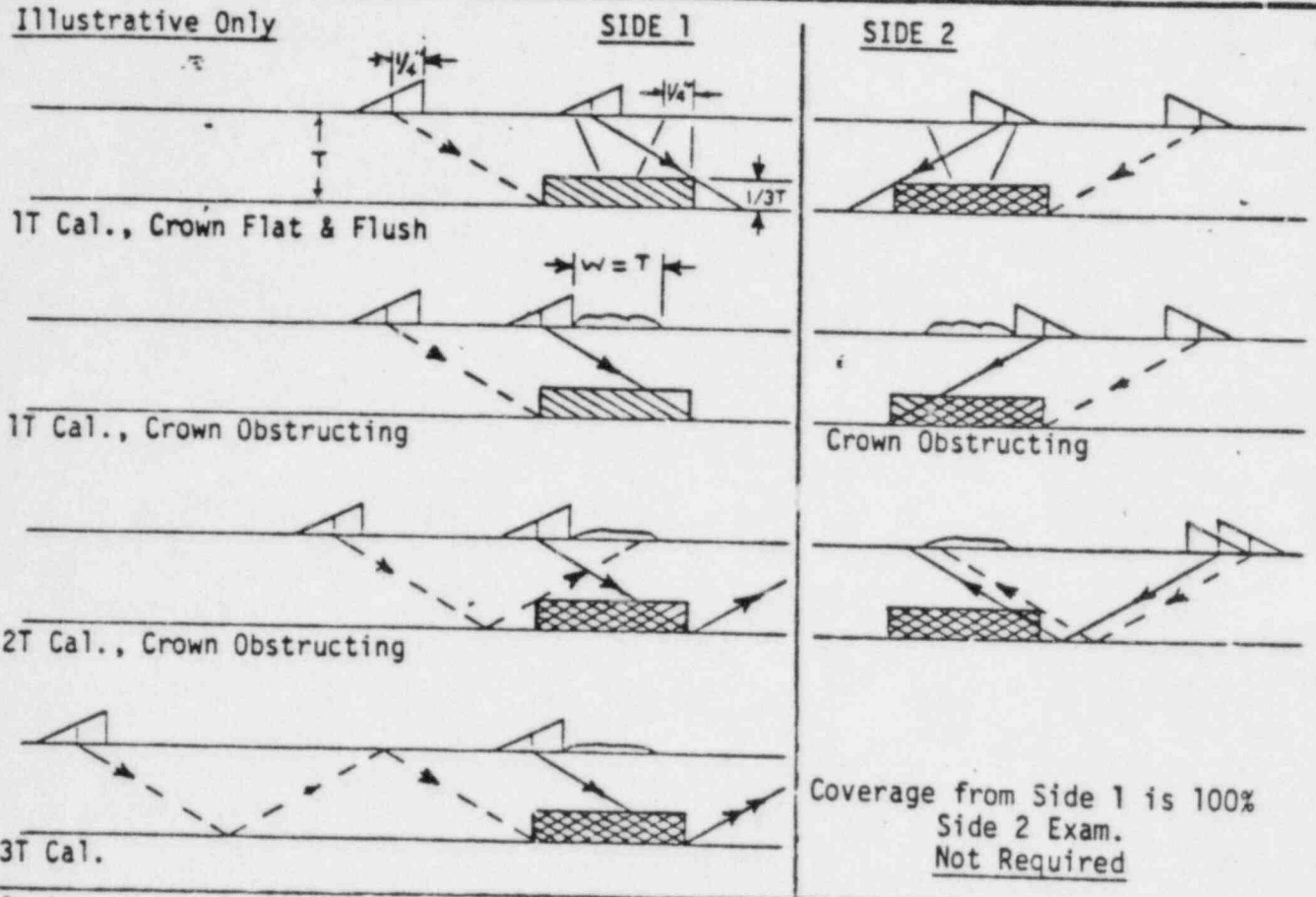


Broken beam = Exam. start. Solid beam = Exam. completion or maximum access.

All Beam Angles - 45°

See Figure 2 for Commentary

FIGURE 1



Broken beam = Exam. start. Solid beam = Exam. completion or maximum access.

ALL BEAM ANGLES-60°

Figures and views illustrate extent of examination volume coverage that is obtained based on parameters depicted. Actual parameters exisiting for or during each examination alter significantly the depicted coverage.
Key parameters depicted are:

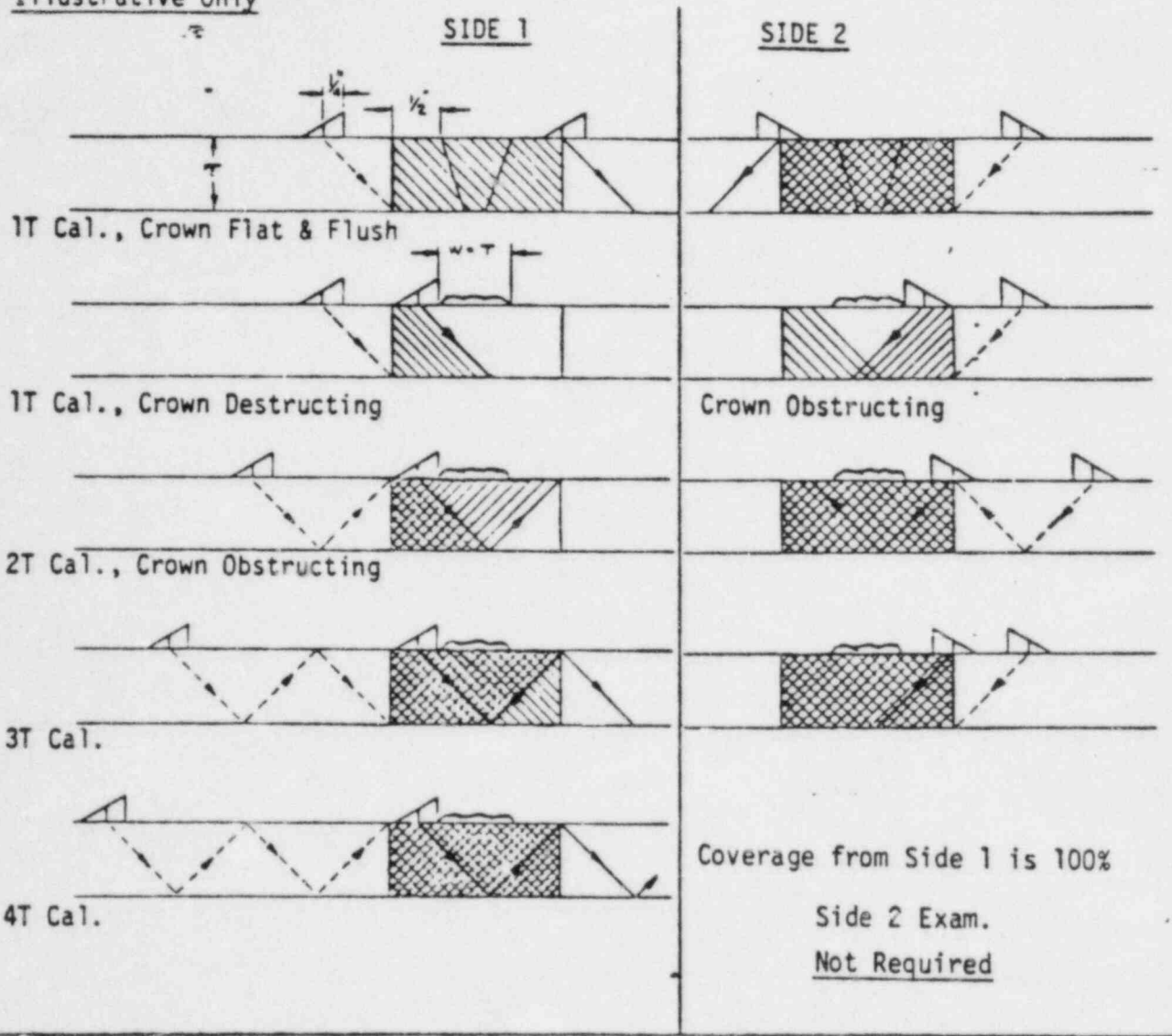
1. Search unit is essentially minimum size
2. Nominal beam angle (in the part) is achieved and maintained
3. Beam has zero spread
4. Beams reflect from parallel planes equal to T at I.D. and crown areas
5. Width of obstructing crown is equal to T
6. Scan access is available on both sides.

Where weld crown is not obstructing, 2T cal. range or greater can satisfy required coverage from one side.

Cal. range and transducer or angle shall be such that examination and data required (see 2.5) can be satisfied. Maximum extent of required coverage achieved during examination is, that volume that has been "cross-hatched" by calibrated beams, as perceived solely by the examiner.

FIGURE 2

Illustrative Only



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All Beam Angles - 45°

See Figure 2 for Commentary

FIGURE 3

Illustrative Only

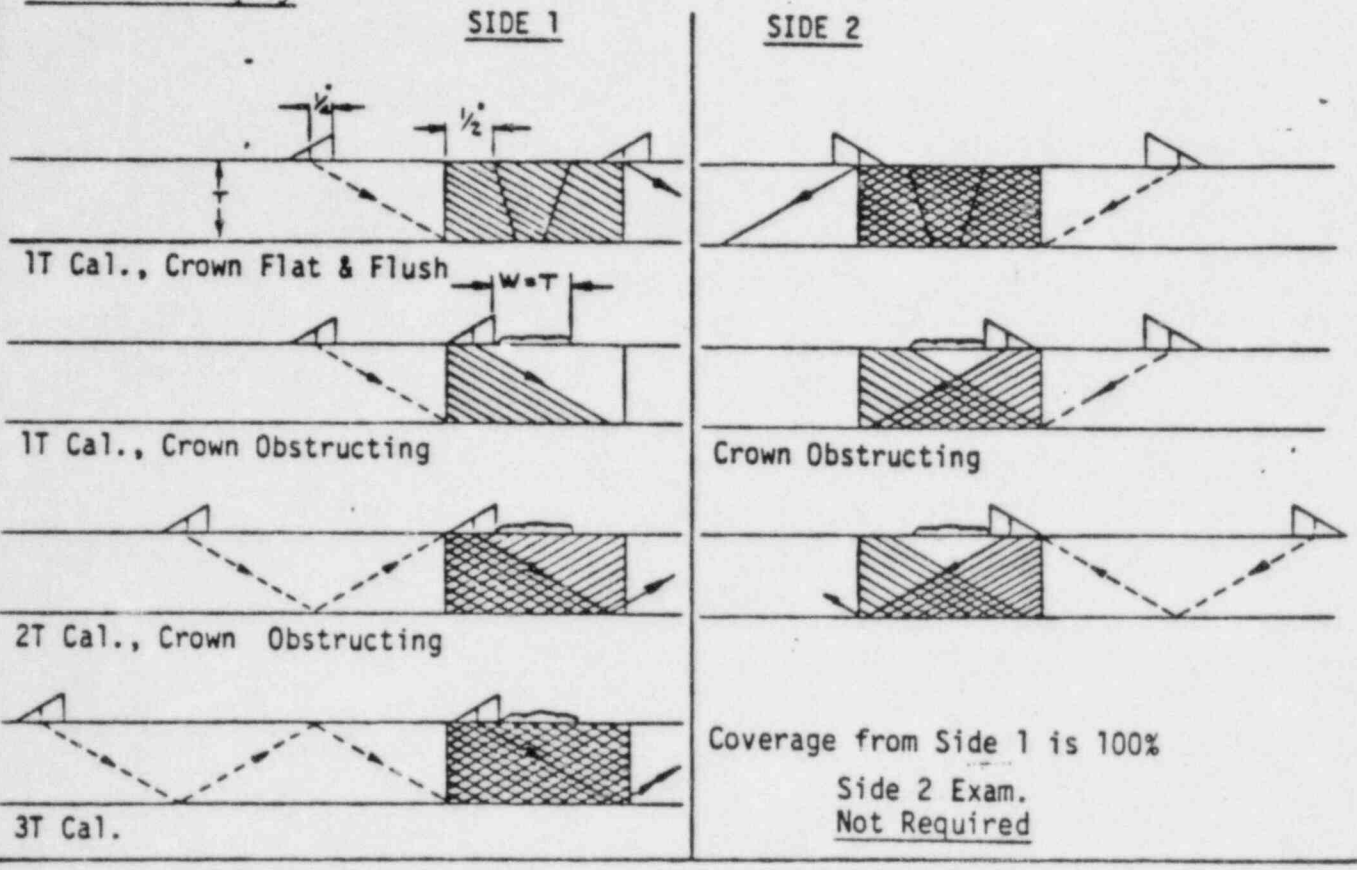

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FIGURE 4