application before removing the magnetic field, to prevent high-velocity particle flow that may wash away or remove fine or weakly held indications.

14.0 LIGHTING

14.1. Visible Light Intensity

14.1.1 A minimum light intensity of 100-foot candle (*1076 lux*) is required to ensure adequate sensitivity during the examination and *evaluation* of indications. “A Hand lamp with 240 Volts, 09 Watt LED Electric bulb white light is held at 300 mm distance normal to the test surface within a circle of 280 mm diameter” is considered adequate to provide above level of illumination. The supplemental white light source, technique used, and light level verification shall be demonstrated one time, documented, and maintained on file.

14.1.2 Lux meter shall be calibrated at least once a year or whenever the meter has been repaired. If meter has not been used for one year it shall be calibrated before use.

14.2. Black Light

14.2.1 Black light intensity at the examination surface shall be not less than 1000 micro watt/cm square at a height of 250 mm. The black light intensity shall be measured at least once every 8 hr. and whenever the work station is changed.

14.2.2 With fluorescent particles the examination is performed in a darkened area.

14.2.3 The examiner shall be in the darkened area for at least 5 minutes prior to performing the examination for eye adaptation. Glasses or lenses worn by the examiners shall not be photochromic or exhibit any fluorescence.

14.2.4 The black light shall be warmed up for a minimum period of 5 minutes prior to use or measurement of intensity.

14.2.5 Light meters shall be calibrated at least once a year or whenever a meter has been repaired

15.0 SYSTEM PERFORMANCE CHECK (Fig.4 & 4a)

15.1. For prod magnetization with HWDC, performance sensitivity shall be checked at least once in a shift before start of the examination on a test plate that contains machined grooves to different depths. The indication of a groove at 3 mm depth from the surface of the test plate will indicate adequate sensitivity.

15.2. For electromagnetic yokes, the adequacy or direction of the magnetizing force shall be verified by positioning the 'Magnetic Field Indicator' (Fig 5) on the surface to be examined. The pattern in the indicator should be clearly developed on the surface of the block.

16.0 DEMAGNETISATION

16.1. When residual magnetism in the part could interfere with subsequent processing or usage, the part shall be demagnetized any time after completion of the examination.

17.0 EVALUATION OF INDICATION

17.1. Mechanical discontinuity at the surface would be indicated by the retention of the powder or medium.

17.1.1 All the indications are not necessarily defects, however, since certain metallurgical discontinuities and magnetic permeability variations may produce similar indications which are not relevant.

17.1.2 Any indication that is believed to be non-relevant shall be reexamined to verify whether or not actual defects are present. Surface conditioning may precede the reexamination. Non relevant indications that would mask indications of defects are unacceptable.

Relevant indications are those which result from unacceptable mechanical discontinuities.

17.2. Relevant indications are indications which result from imperfections. Relevant indications are caused by a condition or type of discontinuities that requires evaluation.

17.2.1 Linear indications are those indications in which the length is greater than three times the width.

17.2.2 Rounded indications are circular or elliptical with the length equal to or less than three times the width.

18.0 ACCEPTANCE STANDARDS AS PER ASME (Sec. I, VIII Div. 1 & 2)

18.1. Welds and Materials

18.2. An indication of an imperfection may be larger than the imperfection that causes it. However, the size of the indication is the basis for acceptance for evaluation.

18.3. Only indications which have dimensions greater than 1.5 mm shall be considered relevant.

18.4. All surfaces to be examined shall be free of

18.4.1 Relevant linear indications.

18.4.2 Relevant rounded indications greater than 5.0 mm

18.4.3 Four or more relevant rounded indications in a line separated by 1.5 mm or less edge to edge.

18.4.4 In welds joining nipples to drums, spheres or headers, all slag or porosity indications shall be investigated to assure that no leak-path exists.

18.4.5 In attachment welds of non-load carrying class, indications from cracks or due to material separation are unacceptable.

19.0 For Power Piping (as per ASME B 31.1 Power Piping)

19.1. Indications whose major dimensions are greater than 2.0 mm shall be considered relevant.

19.2. The following relevant indications are unacceptable:

a) Any cracks or linear indications.
b) Rounded indications with dimensions greater than 5.0 mm.
c) Four or more rounded indications in a line separated by 2.0 mm or less edge to edge.

d) Ten or more rounded indications in any 3870 mm² of surface with the major dimension of this area not to exceed 150 mm with the area taken in the most unfavourable location relative to the indications being evaluated.

20.0 ACCEPTANCE STANDARD FOR STRUCTURAL COMPONENTS AS PER AWS

20.1. The magnetic Particle acceptance criteria is based on the size of the actual discontinuity and not the size of the discontinuity as indicated by the magnetic particle inspection medium. Where discontinuity cannot be visually seen (with magnification if required), after removal of the indicating medium, evaluation shall be based on size and nature of the magnetic particle indication.

21.0 Statically loaded Non-tubular connections

21.1. Cracks, Lack of Fusion, and Incomplete Penetration are not acceptable.

21.2. Undercut - for material with thickness less than 25 mm, undercut shall not exceed 1.0 mm, except that a maximum 2.0 mm is permitted for an accumulated length of 50 mm in any 300 mm. For material equal to or greater than 25.0 mm thick, undercut shall not exceed 2.0 mm for any length of weld.

21.3. Porosity - a complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible piping porosity. For all other groove welds and for fillet welds, the sum of the visible piping porosity 1.0 mm or greater in diameter shall not exceed 10.0 mm in any linear 25.0 mm of weld and shall not exceed 20mm in any 300 mm length of weld.

22.0 Cyclically Loaded Non-Tubular Connections

22.1. Undercut - In primary members, undercut shall be no more than 0.25 mm deep when the weld is transverse to tensile stress under any design loading condition. Undercut shall not be more than 1.0 mm deep for all other cases.

22.2. Porosity - The frequency of piping porosity in fillet welds shall not exceed one in each 100 mm of weld length and the maximum diameter shall not exceed 2.5 mm. Exception: for fillet connecting stiffeners to web, the sum of the diameters of piping porosity shall not exceed 10mm in any linear 25mm of weld and shall not exceed 20 mm in 300 mm length of weld.

22.3. Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have NO Piping Porosity.

22.4. PIPING POROSITY - (General) is elongated porosity whose major dimension lies in a direction approximately normal to the weld surface. Frequently referred to as pin holes when the porosity extends to the weld surface.

23.0 EDGE DISCONTINUITIES IN CUT MATERIALS

23.1. No crack is acceptable.

23.2. Mill induced discontinuity

23.3. Length 25 mm and less - acceptable.

23.4. Length over 25 mm and depth up to 3 mm – acceptable. Here the depth shall be explored for 10 % of the discontinuities on the cut surface by grinding.

23.5. Length over 25 mm and depth between 3 mm and 6 mm - indications shall be removed, but filling up of this region by welding is not required.

23.6. Length over 25 mm and depth greater than 6 mm and less than 25 mm- indications shall be removed and re-welded. The method explained in 23.6(1) through (4) shall be followed for disposition.

23.6.1 Where discontinuities such as W, X or Y in figure 6 are observed prior to completing the joint, the size and shape of the discontinuity shall be determined by UT. The area of the discontinuity shall be determined by the area of total loss of back wall reflection. When tested in conformance with ASTM A 435.

23.6.2 For acceptance of W,X or Y discontinuities, the area of discontinuity(or aggregate area of multiple discontinuities) shall not exceed 4% of the cut material area(length times width) with the following exception: if the length of the discontinuity of aggregate width of discontinuities on any transvers section , as measured perpendicular to the cut material length, exceeds 20% of the cut material width, the 4% cut material area shall be reduced by the % amount of the width exceeding 20&.(For example, if a discontinuity is 30% of the cut material width, the area of discontinuity cannot exceed 3.6% of the cut material area). The discontinuity of the cut surface of the cut material shall be removed to a depth of 25 mm beyond its intersection with the surface by chipping, gouging or grinding, and blocked off by welding with a low hydrogen process in layers not exceeding 3 mm in thickness for atleast the first four layers.

23.6.3 Repair shall not be required if a discontinuity Z, not exceeding the allowable area in 23.6(2), is discovered after the joint has been completed and is determined to be 25 mm or more away from the face of the weld, as measured on the cut base-metal surface. If the discontinuity is less than 25 mm away from the face of the weld, it shall be removed to a distance of 25 mm from the fusion zone of the weld by chipping, gouging or grinding. It shall then be blocked off by welding with a low hydrogen process in layers not exceeding 3 mm in thickness for atleast the first four layers.

23.6.4 If the area of discontinuity W, X, Y or Z exceeds the allowable in 23.6(2), the cut material and the subcomponent shall be rejected and replaced.

24.0 REPAIR AND RE-EXAMINATION

24.1. Whenever an imperfection is repaired by chipping or grinding or and subsequent repair by welding is not required, the excavated area shall be blended into the surrounding surface so as to avoid sharp notches, crevices or corners. The extent of the crack shall be ascertained by use of acid etching, MT, PT, or other equally positive means; the crack and sound metal 2 in [50 mm] beyond each end of the crack shall be removed, and rewelded.

24.2. After a defect is thought to have been removed and prior to making weld repairs, the area will be examined by suitable methods to ensure that the defect has been removed or reduced to an acceptable size of an imperfection.

24.3. Where welding is required after repair of an imperfection the area shall be cleaned and repair carried out. After repairs have been made the repaired area shall be blended into the surrounding surface so as to avoid sharp notches, crevices or corners.

24.4. After repairs have been made, the repaired area shall be re-examined by methods of examination that were originally required for the affected area.

25.0 PERSONNEL QUALIFICATIONS

25.1. All personnel carrying out the examination and evaluation shall be qualified to as per BHE: NDT: G: CRT. The testing shall be done by minimum Level-I working under Level II and Evaluation by Level II / III Personnel.

26.0 POST EXAMINATION CLEANING

26.1. When the inspection is concluded, the magnetic particles shall be removed from the surface by using dry white cloth/cotton waste or any suitable means without adversely affect the part, leaving the product in a dry and clean condition.

27.0 REPORTING AND RETENTION PERIOD

27.1. The report shall include as a minimum, the data as specified in T-190(a) of Article-1, T 792 & T-793 of ASME Section V Article 7. Then report shall be reviewed and signed by NDT Level II / III and issued. All the reports will be retained for a period of 1 year or Final Inspection clearance whichever is later and reports for ASME Coded works for a period of 5 years.

****

Table 1
MAGNETIC PARTICLES USED *

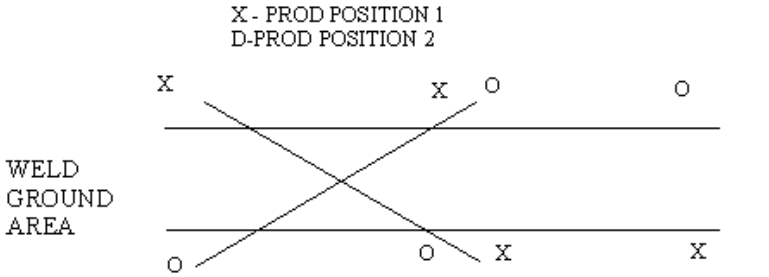
Manufacturer	Brand	Method	Color
Pradeep NDT Products	Automag RD-7	Dry	Brick Red
Arora Technologies Pvt Ltd	DR 100	Dry	Brick Red
Magnaflux	8A Red	Dry	Brick Red
Pradeep NDT Products	Flawguide	Wet Fluorescent	--
MR Chemie	114HB	Wet Fluorescent	--
Ferrochem NDT	1332C/P-5	Wet Fluorescent	--
Arora technologies	Flawglo WF 10	Wet Fluorescent	--

*The above Brand of MPI particles will be used or other brands may also be used with the approval of Level III / NDT.

Table 2
DEMONSTRATION RECORD FOR ESSENTIAL AND NON-ESSENTIAL VARIABLES

Sl. No	Requirement	Type of variable	Covered in the procedure as
01	Magnetizing technique	Essential	Clause 7.1-Prod- Dry particle method
02	Magnetizing current type or as previously qualified	Essential	Clause 8.1-Single phase HWDC
03	Surface preparation	Essential	Clause 5.1-As welded, as ground surface -Free from oil, grease etc.
04	Magnetic particle(Fluorescent/ visible, Color, size, wet / dry)	Essential	Clause 4.2 -Visible Dry-Brick Red
05	Method of particle application	Essential	*Clause 13.1*: Hand Powder applicators-Squeeze bulb
06	Method of excess particle removal	Essential	*Clause 13.1.2* -Gentle air stream while the current is on.

07	Minimum light intensity	Essential	Clause 14.1.1 - 1076 lux Source: A hand lamp with 240 V/ 09 W LED bulb white light kept at a maximum distance of 300 mm.
08	Coating thickness greater than qualified	Essential	Not used
09	Non-magnetic surface contrast enhancement when utilized	Essential	Not used
10	Performance demonstration, if required	Essential	A change of requirement in Table-3 identified as essential variable from the specified value, or range of values, Procedure shall be re-qualified by satisfactory demonstration to the AI.
11	Part Surface temp. outside of the temp range recommended by the supplier of the powder or as previously qualified	Essential	Clause 4.2-Maximum 345^{0}C for Dry method (within recommended range by M/s Pradeep NDT Products, Pune)
12	Shape / size of object	Non-Essential	Clause 1.1:Butt and fillet welds in Steam Generator, piping, pumps, valves, Pressure Vessel and Heat Exchanger components used for Nuclear applications
13	Equipment of same type	Non-Essential	Clause 3.0- Prod type
14	Temperature (within those specified by manufacturer or as previously qualified)	Non-Essential	Clause 4.2: 17^0 C to 345^0 C for Dry method (within recommended range by M/s. Pradeep NDT Products, Pune)
15	Demagnetizing technique	Non-Essential	Clause 16.1- No demagnetization unless otherwise specified
16	Post examination cleaning technique	Non-Essential	Clause 20.0
17	Personnel qualification requirement	Non-Essential	Clause 25.0



FIG(1): TECHNIQUE FOR EXAMINATION OF LONG SEAMS AND CIRCUMFERENTIAL SEAMS

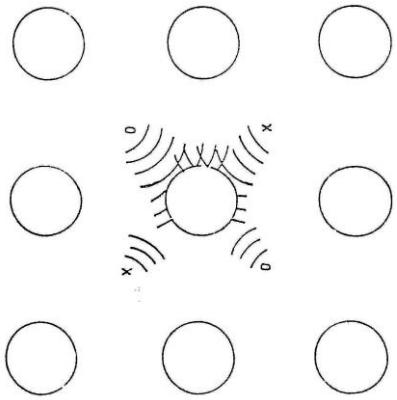


FIG (2): TECHNIQUES FOR EXAMINATION OF FILLET WELDS

0 – POSITION 1 X – POSITION 2 ARC BREAK LOCATION

NOTE:

1) Prods must be placed on Drum / Header perpendicular to plate Surface.

2) Inspection will be 100% of weld for each shot.

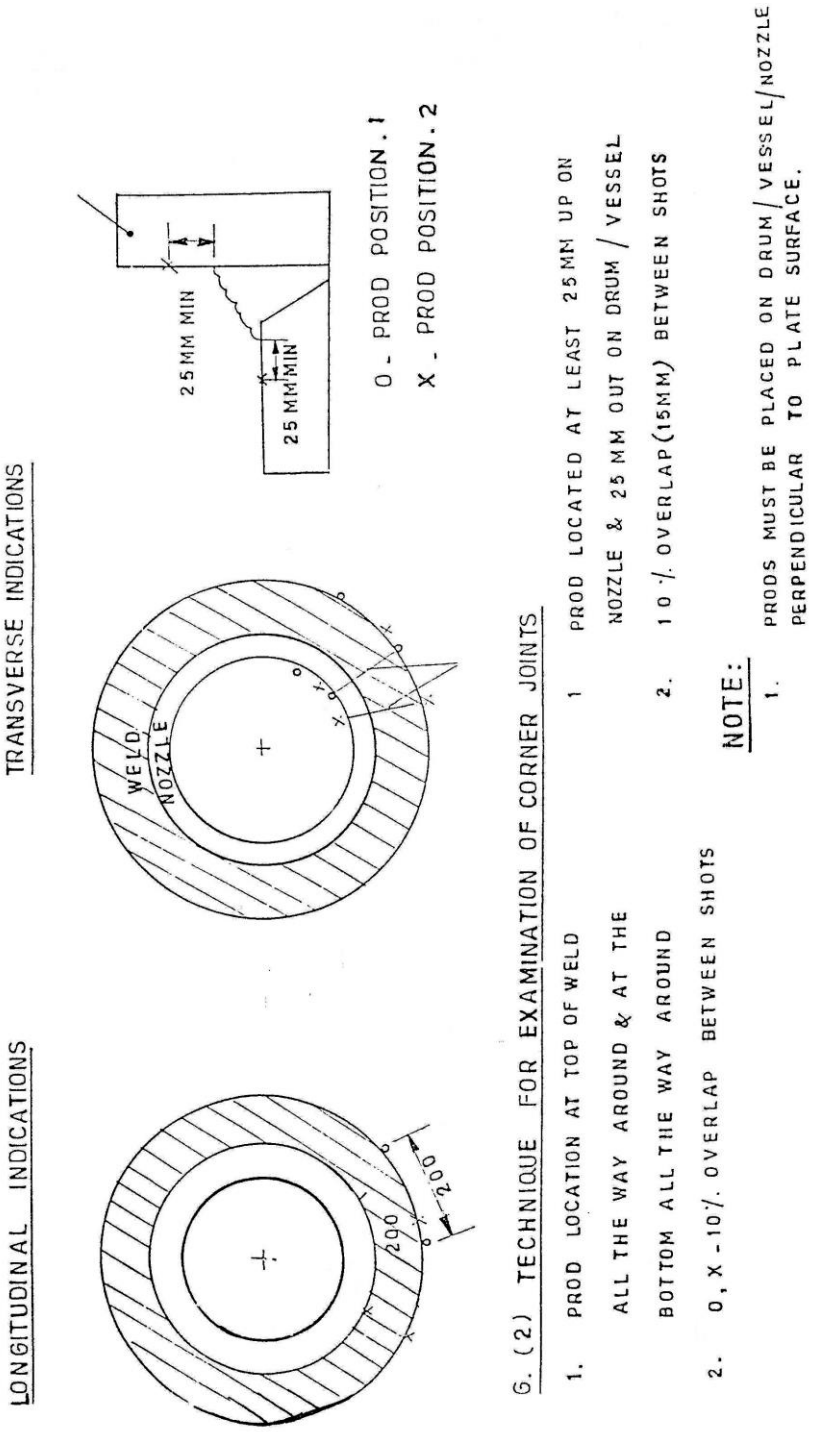


Fig (3) Technique for examination of Corner Joint

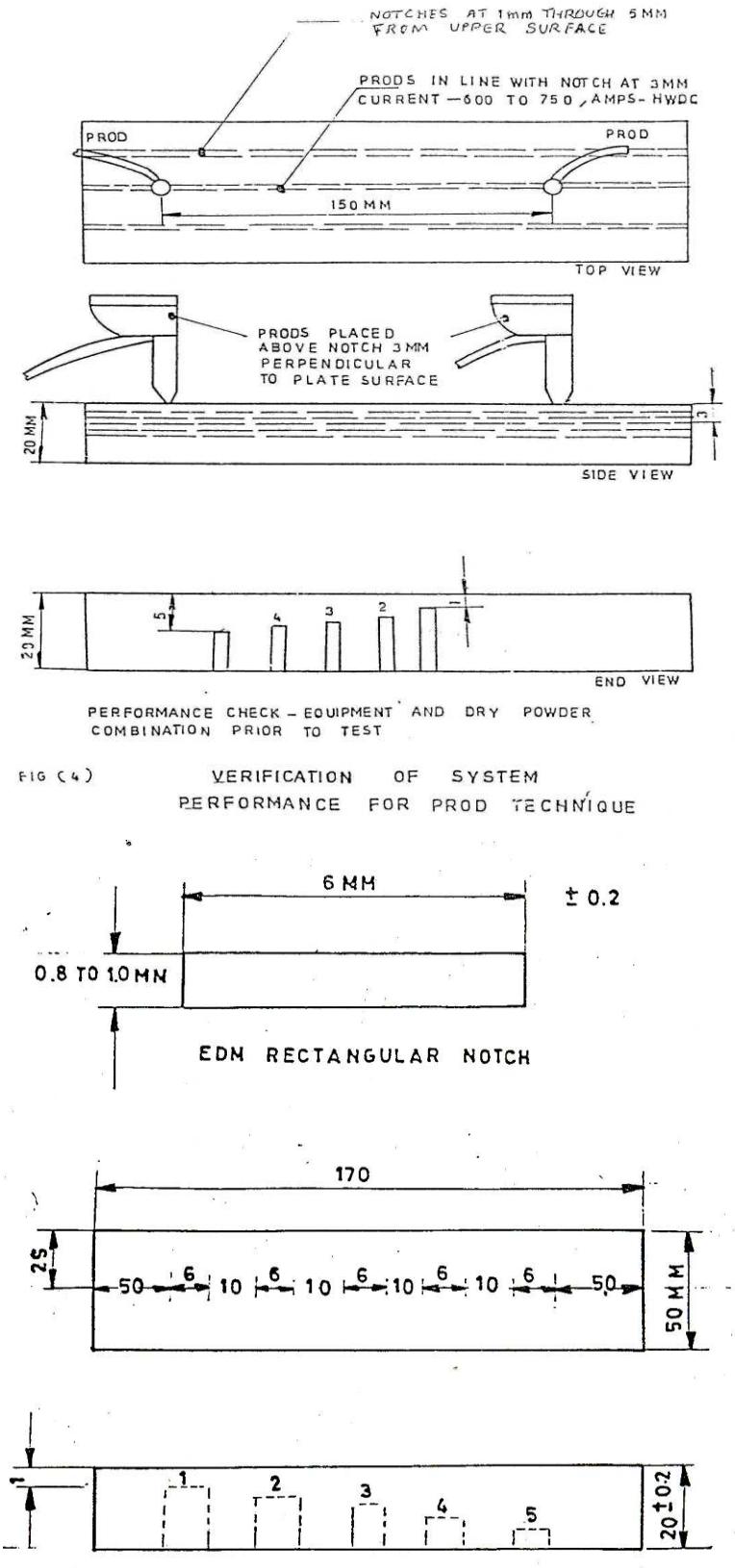


Fig 4a. SENSITIVTY BLOCK WITH EDM NOTCH

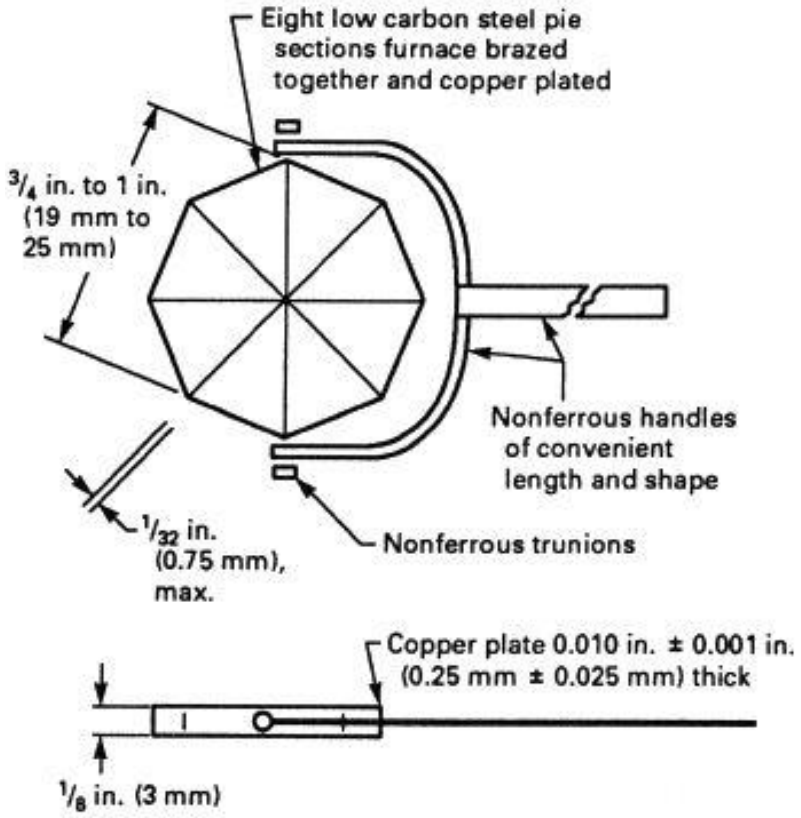


Fig (5): Pie shaped Magnetic Field Indicator

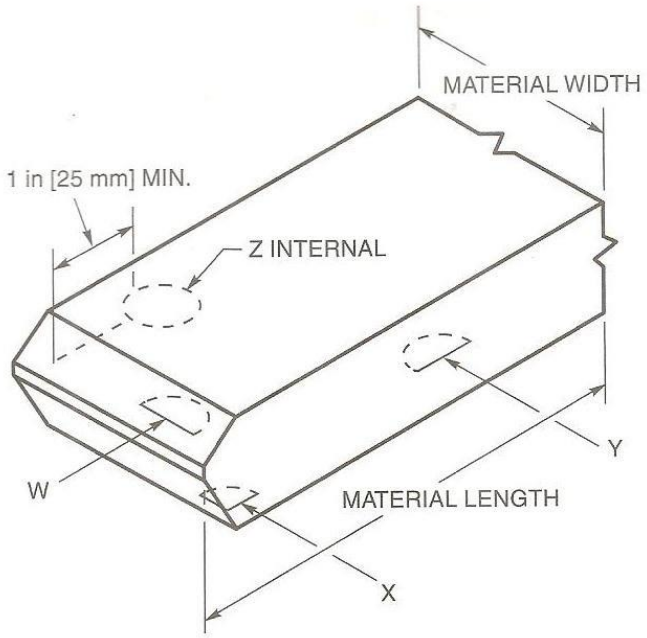


Fig (6) Edge discontinuities in cut material (See sec. 23.6)

BHARAT HEAVY ELECTRICALS LIMITED, Trichirappalli-620014
Dept. 235-Non-destructive testing / Quality
MAGNETIC PARTICLE TESTING REPORT

Report No: Date: Call / Notification Ref:

Work Order: Material: Stage of test: Before / After HT

Part: Drawing No:

Thickness: mm Surface Condition:

Equipment: Calibration validity:

Magnetization: Circular/Longitudinal Technique: Prod/Head shot/Coil/Yoke
Method: Visible/Fluorescent/Non Fluorescent/Wet/Dry Surface Pre cleaning:

Color contrast enhancement: Lifting Power:

Prod / Pole spacing: mm current: Amps

Powder / Fluid Color : Brand:

Particle / Fluid application: Excess particle removal:

Sensitivity / Field direction check: Demagnetization: Done/Not done

Lighting Equipment: Light intensity:

Temperature of part: Deg. C Date of Testing:

Procedure & Acceptance: BHE: NDT: PB: MT- Rev

Sl. No	Joint No	Details of Part	Reference from	Indication Location			Findings	Disposition
				From	To	Length		

SAMPLE

Performed by	Evaluated by	Reviewed / Witnessed by
Level I / II	Level II / III	AI / Customer

CHAPTER 1.3

MAGNETIC PARTICLE EXAMINATION OF MATERIAL SURFACE, WELDING GROOVES AND WELD JOINTS OF X-20, P91 AND P92 MATERIALS

PROCEDURE FOR MAGNETIC PARTICLE EXAMINATION OF MATERIAL SURFACE, WELDING GROOVES AND WELD JOINTS OF X-20, 91 AND 92 MATERIALS

Prepared by	Reviewed by	Approved by	Issued by
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31.12.2020	01/01/2020	B.K. Sethupathy 01-01-2020	01/01/2020

EFFECTIVE FROM 01.01.2020

RECORD OF REVISION

Rev No	Revision Date	Details of Revision
01	27-07-1998	(a) Revised to include Fluorescent Particle Testing
02	15-03-2000	(a) Requirements of P91 added (b) Reference Modified (c) Editorial corrections made
03	08-08-2016	(a) Clause 1.2.1 revised (b) Clause 1.2.2 added (c) Clause 1.1 revised (d) Clause 2.2 revised (e) Clause 2.3 added (f) Form 235-011 added (g) Clause 8.1 revised
04	26-10-2018	(a) Clause 1.2.2 added (b) Clause 6.2 revised (c) Clause 7.2.2 modified (d) Clause 8.1 revised (e) Clause 5.1 modified (f) Clause 7.2.1 modified (g) Clause 7.2.3 modified (h) Clause 8.1 modified (i) Clause 8.2 modified (j) Clause 9.1 modified
05	03-01-2019	Procedure title modified, Clause 1.1, 1.2.2 modified, Clause 1.2.3 added, Clause 6.3 added, Clause 10.1, 10.2 and 10.3 revised
06	21-11-2019	(a) Clause 2.3 a. modified. (b) Clause 10.4 deleted.
07	01-01-2020	(a) Clause 1.2.2 modified. (b) Clause 2.3b, 2.3c modified. (c) Clause 7.1.1 modified. (d) Clause 7.2 modified. (e) Clause 9.1 modified

1.0 **SCOPE**

1.1 This procedure deals with the testing methods and acceptance standard for the magnetic particle examination of material surface, welding groove bevels, Butt and Fillet weld joints of X-20, 91 and 92 materials.

1.2 **REFERENCES**

1.2.1 AD- Merkblatt HP 5/3 / 2011

1.2.2 *ASME Sec I & Sec V / 2019*

1.2.3 ASME B31.1 2015

2.0 **EQUIPMENT**

2.1 AC or HWDC Yoke magnet shall be used for examination.

2.2 Non fluorescent dry or wet magnetic particles of black, grey or red colour or wet fluorescent magnetic particles, suspended either in kerosene or water conditioned with suitable wetting agent shall be used. The particle used shall be of high permeability, low retentivity and of suitable sizes and shapes to produce readily magnetic particle indications. The colour of the non- fluorescent particle chosen shall be in sharp contrast to the material surface being examined.

2.3 (a) The magnetizing power of yokes shall be verified prior to use on every day the yoke is used. The magnetizing power of yokes shall be verified whenever the yoke has been damaged or repaired.

2.3 (b) Each alternating current electromagnetic yoke shall have a lifting power of at least 4.5 kg at the maximum pole spacing that will be used *with contact similar to what will be used during the examination.*

2.3 (c) Each direct current or permanent magnetic yoke shall have a lifting power of at least 18 kg at the maximum pole spacing that will be used *with contact similar to what will be used during the examination.*

2.3 (d) Each weight shall be weighed with a scale from a reputable manufacturer and stencilled with the applicable nominal weight prior to first use. weight need only be verified again if damaged in a manner that could have caused potential loss of material.

3.0 **SURFACE PREPARATION**

3.1 The surface to be examined shall be even and free of impurities. Drag lines, notches or weld beads (also arc strikes or tacks) shall be removed. A surface roughness equal to or smaller than 20 microns is desired. Undercuts, overlaps or abrupt edges and valleys in the weld metal shall be smoothly merged with the parent metal.

4.0 **TYPE OF MAGNETISATION**

Longitudinal magnetization with yoke and alternate current or half wave DC (HWDC) shall be used for examination.

4.1 Examination shall be made by continuous method, i.e. magnetizing current remains on while inspection medium is being applied.

5.1 **MAGNETIC FIELD ADEQUACY AND DIRECTION**

The Direction and Field Adequacy of the magnetic field should be checked over the area to be tested, to ensure clear visibility of indication on a Berthold type field indicator/ ASTM Pie shaped Magnetic Particle Field Indicator

5. 2 Care shall be taken to ensure that field strength is not excess at the area to be tested, as excessive field strength may cause non relevant indications of edge, draglines etc.

6.0 **CONTROL OF THE INSPECTION MEDIUM**

6.1 The characteristics of the magnetic particle dispersion is checked by using the Berthold type/ASTM Pie shaped field indicator . The reference piece shall be held at the test section (with the cross at an angle of about 45 degree for Berthold type) to the magnetization direction and during the course of magnetization the medium is sprayed. The concentration of the dispersion is considered good if the notch is clearly visible .

6.2 The wet testing method uses the liquids like kerosene or water with corrosion protective means and antifoam additives .

The concentration of the magnetic particle shall be between 1.2 to 2.4 ml per 100 ml for non-fluorescent particle method and 0.1 ml to 0 .4 ml per 100 ml for fluorescent particle method. A Pear shaped centrifuge settling tube will be used to check the concentration. Before sampling the suspension should be run through the circulating system for at least 30 min to ensure thorough mixing of all particles. The settling Time is 60 min with Petroleum distillate suspensions or 30 min with water-based suspensions before reading.

6.3 Application of wet MT on high alloyed materials shall not be carried out before PWHT.

7.0 LIGHTING

7.1 Visible Light Intensity

7.1.1 The examination area and the accumulation of magnetic particles shall be observed under adequate lighting. An intensity of *1076* lux is adequate. The minimum light intensity shall be 100 fc (*1076 lux*). The light intensity, natural or supplemental white light source, shall be measured with a white light meter prior to the evaluation of indications or a verified light source shall be used. Verification of light sources is required to be demonstrated only one time, documented, and maintained on file.

7. 2 Black Light (UV-A Light)

7 .2 .1 Black light intensity at the examination surface shall be not less than 1000 micro watt/ cm $^{2.}$ The black light intensity shall be measured at least once in every 8 hrs. and whenever the work station is changed. The UV-A and White Light Meter should be calibrated once in Six months.

7. 2. 2 With fluorescent particles the examination is performed in a darkened area. The Intensity of Ambient visible light in the darkened area shall not exceed 2 fc or 21.5 lux.

7. 2. 3 The examiner shall be in the darkened area for at least 5 minutes prior to performing the examination for eye adaptation. The examiner shall not wear glasses with permanent Tint or Photo Chromic (light sensitive) lenses which change colour in Sunlight.

7. 2. 4 The black light shall be warmed up for a minimum period of 5 minutes prior to use or measurement of the intensity.

8. 0 TEST PERFORMANCE

8. 1 The periodic checking of Magnetic Field Adequacy and Direction shall be done twice in a shift on a pie gauge. The magnetizing power of yokes shall be verified prior to use each day the yoke is used. The magnetic Yoke shall be calibrated once in six months or after any major electrical repair within a year.

8. 2 All examinations shall be conducted with sufficient field overlap to ensure 100% coverage. The following minimum periods shall be observed for a test

(i) Magnetising & rinsing (minimum 3 seconds)
(ii) post magnetising (minimum 5 seconds)
Interpretation and evaluation shall be performed during the post magnetisation period.

9.0 PERSONNEL QUALIFICATION

9.1 All personnel carrying out the examination and evaluation shall be qualified to as per BHE: NDT: G: CRT in line with SNT-TC-1A 2016. The testing shall be done by minimum Level-I working under Level II and Evaluation by Level II / III Personnel.

10.0 INTERPRETATION OF MAGNETIC PARTICLE INDICATION

10. 1 Any indication that is believed to be non-relevant shall be re-examined to verify whether or not actual defects are present. Surface conditioning may precede the re-examination. Non relevant indications that would mask indications of defects are unacceptable.

10. 2 Acceptance standard based on ASME B 31.1: -

i. Cracks ,lack of fusion and lack of penetration are not acceptable.

ii. Indications whose major dimensions are greater than 1⁄16 in. (2.0 mm) shall be considered relevant. The following relevant indications are unacceptable: -

(a) any cracks or linear indications

(b) rounded indications with dimensions greater than 3⁄16 in. (5.0 mm)

(c) four or more rounded indications in a line separated by 1⁄16 in. (2.0 mm) or less, edge to edge

(d) ten or more rounded indications in any 6 in^2 (3870 mm^2) of surface with the major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavourable location relative to the indications being evaluated.

10 .3 Acceptance standard based on ASME BPVC Section I: -

All surfaces to be examined shall be free of

(a) relevant linear indications.

(b) relevant rounded indications greater than 3/16 in. (5 mm)

(c) four or more relevant rounded indications in a line separated by 1/16 in. (1.5 mm) or less, edge to edge.

11. 0 POST CLEANING

11. 1 When inspection is concluded, the magnetic particle residue remaining on the surface shall be removed by any suitable means leaving the product in dry and clean condition.

12. 0 REPORTS

12. 1 Report in the approved form No .235-011 or equivalent signed by a Level - II or Level - III shall be issued.

235-011 MAGNETIC PARTICLE TESTING REPORT

Report No Date: Test No. Ref:

Material Stage of Test: Before SR / After SR

part Surface Condition:

part Magnetisation. Circular / Long

Work Order: Method Dry / Wet / HWDC / AC

Drawing No Prod/Yoke Spacing:

Procedure: Demagnetisation Done / Not done

Acceptance: As per Procedure

No	Details of Part	Quantity	Findings	Remarks

ACCEPTED | | DEFECTS NOTICED

Operator's Name & Level I / I1	Approved Level II / III	Inspection Agency

CHAPTER 1.4

PROCEDURE FOR RADIOGRAPHIC EXAMINATION OF WELDS

PROCEDURE FOR RADIOGRAPHIC EXAMINATION OF WELDS

Prepared by	Reviewed and approved by	Issued by
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01/01/2020	01-01-2020	01/01/2020

Effective from 01-01-2020

RECORD OF REVISION

Rev No	Revision Date	Revision of Details
03to 06	01-06-1983 01-03-1990	Revision details are maintained separately
07	28-03-1994	Changed for its entirety to include ASME Section VIII Div I and 2
08	01-08-1996	Revised in entirety
09	25-02-1997	ProceduresBHE:NDT:PB:RT01/01,01/02and01/03 merged with this procedure and revised in its entirety
10	10-06-1997	Revised to incorporate the revision in ASME Section V/1995-1996 Addenda. Clause 16 modified
11	11-05-1998	Clauses 2.1,6.1,10.1,22.1 and 23.1 revised
12	20-03-2000	Clauses 2.0,6.1 and Annexure I modified
13	28-12-2002	Clause 4.2.1 deleted. 8.1, 10.2, 11.1.1, 13.1, 17.4, revised. Annexure I and II modified.
14	15-03-2005	2.0, 10.2, 12.3 Modified. Annexure-I Revised. Annexure III modified.
15	28-12-2006	Clause 2.1 Revised Annexure III- Figure 6 Revised.
16	30-12-2007	Clause 2.1 Revised
17	31-12-2009	Clause 2.1 Revised. Clause 19.2 Modified. Porosity Acceptance level charts added
18	15-12-2011	Clause 2.1, 2.2 Revised Clause 6.1.1 Clause 10.3, 16.5.1, 17.2.1,17.3.1 Revised Clause 18.1.7 Added
19	30-01-2015	Clauses 2.1, 2.2., 5.2.2, 6.5.2, 11.1.1, 14.2.1, 17.4.1, Annexure-I and Annexure-II revised
20	01-01-2016	Clause 2.1 revised Clause 1.1,5.2.1,6.2.1,11.1.1,22.1 modified
21	07-10-2017	Clause 5.2.1,5.2.2,6.5.2,12.3 revised. Clause 11.1.1 (a),(b) deleted. Clause 13.1.1,20.5 added
22	28-06-2018	Clause 1.1,2.1,2.2,4.1,6.4.1,6.5,6.5.1,6.5.2,8.1,13.1,21.1 revised. Annexure III column 1 revised
23	01-01-2020	Clause 2.1,4.1,5.2,8.1, 14.2.1 revised. Clause 17.2.1 modified.

1.0 SCOPE

1.1 This procedure describes the techniques and acceptance standard for Radiographic Examination of butt welds in steel (Carbon Steel, Alloy Steel, Stainless Steel etc.) and nonferrous materials up to 200 mm thickness, of boilers (drums, headers, pipelines etc.), Pressure Vessel and Heat Exchanger components.

2.0 REFERENCE

2.1 ASME Section I, V, VIII (Divn.1 & 2) 2019 Edition.

2.2 ASME B 31.1 / 2016

3.0 SURFACE PREPARATION

3.1 The weld ripples or weld surface irregularities on both outside and inside (where accessible) shall be removed by grinding or any other suitable process to such a degree that the resulting radiographic image due to irregularities cannot mask or be confused with the image of any discontinuity.

3.2 The finished surface of all welded joints may be flush with the base material or may have reasonably uniform crowns, with reinforcement not to exceed that specified in Annexure I in each face. If there is a question regarding the surface condition of the weld when interpreting radiographs, then radiographs shall be compared to the actual weld surface for determination of acceptability.

4.0 BACK SCATTER RADIATION

4.1 A lead letter 'B' of minimum 1.5 mm thick and 11 mm height shall be attached to the back of each film holder within the area of radiograph which meets the density requirements mentioned in para 17.1 to 17.3 during each exposure to determine if back scatter is exposing the film.

4.2 Excessive back-scatter: If the image of the letter 'B' appears as lighter density than the back ground, it is an indication that protection against back scattering is insufficient and that additional Lead backing shall be used.

5.0 SYSTEM IDENTIFICATION

5.1 Each radiograph shall have a permanent identification traceable to the contract, component, and weld seam or part numbers as appropriate.

5.2 In addition, BHEL symbol or name and the date of the radiography shall be plainly and permanently included on the radiograph. *NDE subcontractor's name or symbol may also be used together with that of the Manufacturer.*

5.2.1 This identification system does not necessarily require that the information appear as radiographic images. It can be done either by placing lead numbers during radiographic exposure or vibro etching on the radiograph. This information shall not obscure the area of interest.

5.2.2 These images will appear on all the radiographs exposed individually or by panoramic exposure.

5.3 For longitudinal welds in shells or in plate formed pipes the reference for the start of the segment shall be from one end of the weld. Sufficient overlap in the film shall be given to ensure 100% coverage in radiograph.

5.4 The entire longitudinal seam shall be divided, stamped and marked into number of segments.

5.5 Any geometric imperfection that requires rework by surface conditioning (and not by welding) after initial radiography, the affected area shall be blended smooth with adjoining surfaces by grinding to avoid sharp notches, crevices or corners.

5.6.1 The blended area shall be re-radiographed with letters suffixed G1, G2, G3 etc. to the original identification number to denote the number of times the weld has undergone surface conditioning.

5.7 Letters R1, R2 etc will be suffixed to the original identification number, when radiographs are taken after repair by welding, to denote the number of times the weld has undergone repair.

5.8 Wherever retake has been performed, letters RT/(RT1), RT2 etc. will be suffixed to the original identification number.

6.0 EQUIPMENT AND MATERIALS

6.1 Film:

6.1.1 The film used for radiography shall be as per SE 1815 and type ASTM System Class I or II. Generally the following brands of film shall be used. Other brands of films may be used subject to the approval of Head / NDT.

(a) Kodak-Industrex AA 400/T 200/M
(b) Agfa Gevaert - Agfa D7/D5/D4

6.1.2 The exposed films shall be processed as per procedure BHE: NDT: PB: RT: 14

6.2 Intensifying Screens:

6.2.1 Lead Screens of minimum thickness as listed below will be used on the front and back side of the film to improve the quality of the radiograph depending upon radiation energy selected.

X-rays	upto 420 kV	0.02 to 0.25 mm
Ir.192		0.10 mm
Co.60		0.20 mm
4 MeV/6Mev Linac		0.25 mm

6.2.2 All intensifying screens shall be handled carefully to avoid dents, scratches, dirt or grease on the active surface, which might cause false indications.

6.3 Image Quality Indicator (IQI)

6.3.1 IQI shall be hole type and shall conform to SE 1025 and Table T.233.1 of ASME Section V.

6.4 Density Monitoring

6.4.1 Step wedge comparison filmstrip or a densitometer shall be used to judge the radiograph density. (Refer BHE:NDT:RT:Calib:01 for filmstrip requirements)

6.5 Facility for Viewing of Radiographs

6.5.1 The radiographs shall be viewed in a room with subdued background lighting of an intensity that will not cause troublesome reflections, shadows or glare on the radiograph.

6.5.2 Illuminators / radiograph viewers shall be used to view radiographs for interpretation. The illuminator shall provide a variable light source sufficient for the essential IQI hole to be visible for the density range specified and obtained in the radiograph. The viewing conditions shall be such that light from around the outer edge of the radiograph or coming through low-density portions of the radiograph does not interfere with interpretation. This can be taken care by masking the region around the edges of the radiograph.

7.0 CALIBRATION

7.1 Source Size

7.1.1 The technical manual or written statements of the equipment manufacturer or supplier's publication documenting the actual or maximum source size or focal spot shall be acceptable as source size verification.

7.2 Step Wedge Film and Densitometer

7.2.1 The density of step wedge comparison films and densitometer calibration shall be verified by comparison with a standard step wedge film as per procedure BHE:NDT:RT:Calib:01.

8.0 RADIATION ENERGY

8.1 The radiation energy (X-rays energy up to 6 Mev, Iridium 192, *Selenium -75 (for Close Proximity Radiography)* and Cobalt 60) employed for any Radiographic technique shall achieve the Density and IQI image requirements.

9.0 DIRECTION OF RADIATION

9.1 The direction of the central beam shall be centered on the area of interest whenever practical

10.0 GEOMETRIC UNSHARPNESS (Source to Film Distance)

10.1 Film shall be kept in close contact with the object.

10.2 Table 1 may be used as a guideline for Geometric un-sharpness.

TABLE - 1

MATERIAL THICKNESS	μ_g Max.
Under 50.0 mm	0.51 mm
Over 50.0 to 75.0 mm	0.76 mm
Over 75.0 to 100.0mm	1.02 mm
Greater than 100.0 mm	1.78 mm

Material thickness is the thickness on which the IQI is based.

10.3 Minimum source to film distance shall be kept such that the geometric unsharpness of the radiograph shall be kept as low as practical within the above range, but in any case shall not exceed 1.78 mm for Power Boiler components complying with ASME Section I or 2.0 for power piping components complying with ASME B 31.1.

10.4 Final acceptance of Radiographs shall be based on the achievement of required IQI sensitivity.

11.0 EXAMINATION - FULL RADIOGRAPHY

11.1 Radiographic technique

11.1.1 A single-wall exposure technique shall be used for radiography whenever practical. When it is not practical to use a single-wall technique, a double wall technique shall be used. An adequate number of exposures shall be made to demonstrate that the required coverage has been obtained. Two methods for Double wall technique are double wall single image technique and double wall double image technique.

11.1.2 The Real Time Radioscopy examination in lieu of Radiography for Straight Tube Butt welds shall be carried out as per the procedure BHE:NDT:PB:FT 01

12.0 EXAMINATION - SPOT RADIOGRAPHY

12.0 The total length of the weld shall be divided into equal segments of length, approximately equal to 15 cms or 30 cms. The segment where the spot is marked for examination shall be radiographed with the corresponding segment numbers.

12.2 Single wall single image technique shall be used wherever possible:

12.3 One spot shall be examined on each vessel for each 15 meters increment of weld or fraction thereof per welder or welding operator. However, for identical vessels each with less than 15 meters of weld, 15 metres increments weld may be represented by one spot examination. A sufficient number of spot radiographs shall be taken to examine the welding of each welder or welding operator.

12.4 Under condition where two or more welders or welding operators make weld layers in a joint, one spot may represent the work of all welders or welding operators.

12.5 Each spot examination shall be made as soon as practicable after completion of the increment of weld length to be examined. The minimum length of spot radiography shall be 150 mm.

13.0 LOCATION OF MARKERS

13.1 Location markers made of lead that are to appear as radiographic images on the radiograph shall be placed on the part adjacent to the weld. Their locations shall be marked and stamped on the surface of the part being radiographed in such a manner that an area of interest appearing on the radiograph will be accurately located. The location markers shall provide evidence on the radiograph that complete coverage of the weld has been obtained. Location markers shall not interfere with the interpretation of the radiograph. Location markers shall be placed as given in figures (a) to (f) given in Annexure IV.

13.1.1 Single wall Viewing : Location markers shall be placed on Source side when radiographing flat components or longitudinal joints in cylindrical or conical components/curved or spherical components whose convex side is toward the source. Location markers shall be placed film side when radiographing either curved or spherical components whose concave side is toward the source and when the "source to material" distance is greater than the inside radius. For flat components or longitudinal joints in cylindrical or conical components as an alternative location markers shall be placed on the film side when the radiograph shows coverage beyond the location markers to the extent demonstrated in Annexure IV. Location markers may be placed on either the source side or film side when

radiographing either curved or spherical components whose concave side is toward the source and the " source to material" distance equals the radius of the component.

13.2 Double wall Viewing

13.2.1 For double-wall viewing at least one location marker shall be placed on the source side surface adjacent to the weld for each radiograph - (Double Wall elliptical images with source off set for butt welds in Boiler Tubes).

14.0 SELECTION OF IQI

14.1 IQI shall be selected from either the same material group or grade as identified in SE - 1025 or from a material group or grade with less radiation absorption than the material being radiographed.

14.1.1 The designated hole IQI with essential hole shall be as specified in Annexure II / Table-5. A smaller hole in a thicker IQI or a larger hole in a thinner IQI may be substituted for any section thickness, provided equivalent Hole type IQI sensitivity as in Annexure II / Table-6 is maintained and all other requirements for radiography are met.

14.2 Weld with Reinforcement

14.2.1 The thickness on which the IQI is based is the nominal single wall thickness plus the actual weld reinforcement thickness estimated to be present on both sides of the weld (ID and OD). *The values used for the estimated weld reinforcement thicknesses shall be representative of the weld conditions* and shall not exceed the maximum specified as in Annexure I / Table 2, 3 and 4.

14.2.2 Backing rings or strip are not to be considered as part of the thickness in IQI selection. The actual measurement of the weld reinforcement is not required.

14.3 Weld without reinforcement

14.3.1 The thickness on which the IQI is based is the nominal single wall thickness. Backing rings or strips are not to be considered as part of the weld thickness in IQI selection.

14.4 Welds joining dissimilar materials or welds with dissimilar filler metal

14.4.1 When the weld material has a radiation attenuation that differs from the base material, the IQI material selection shall be based on the weld metal and be in accordance with 14.1. When the density limits of +30 % to -15% cannot be met with one IQI and the exceptional density area(s) is at the interface of the weld metal and the base metal, the material selection for the additional IQI shall be based on the base material and be in accordance with 14.1.

15.0 PLACEMENT OF IQI

15.1 Source Side IQI

15.1.1 Wherever possible, the IQI shall be placed on the source side of the part being examined.

15.2 Film Side IQI

15.2.1 Where inaccessibility prevents hand placing the IQI(s) on the source side, the IQI shall be placed on the film side in contact with the part being examined. A lead letter 'F' shall be placed adjacent to the IQI(s) but shall not mask the essential hole.

15.3 IQI Location for welds

15.3.1 The IQI will be generally placed adjacent to the weld. When placed on the weld, the identification numbers, the lead letter 'F' etc. shall not fall in the area of interest, except when geometric configuration makes it impractical.

15.4 IQI Location for materials other than welds

15.4.1 The IQI with the IQI identification, letter 'F' etc. may be placed in the area of interest.

16.0 NUMBER OF IQI

16.1 For components when one or more film holders are used for an exposure, at least one IQI image shall appear on each radiograph except as outlined below:

16.1.1 For circumferential welds in cylindrical and spherical components, where the source is placed on the axis of the weld for a single exposure (Panoramic Exposure), at least three IQI's shall be spaced approximately 120° apart,

(a) When the complete circumference is radiographed using one or more film holders, or;

.

(b) When a section or sections of the circumference, where the length between the ends of the outermost sections span 240 or more degree is radiographed using one or more film holders. additional film locations may be required to obtain necessary IQI spacing.

16.1.2 For Cylindrical or Spherical components where the source is placed on the axis of the component for a single exposure, at least three IQI(s), with one placed at each end of the span of the circumference radiographed and one in the approximate centre of the span are required under the following conditions:

(a) When the section of the circumference, the length of which is greater than 120 degree and less than 240 degree is radiographed using just one film holder, or;

(b) When a section or sections of circumference, where the length between the ends of the outermost sections span less than 240 deg., is radiographed using more than one film holder.

16.1.3 In 16.1.1 and 16.1.2 above, where sections of longitudinal welds adjoining the circumferential weld are radiographed simultaneously with circumferential weld, an additional IQI shall be placed on each longitudinal weld at the end of the section most remote from the junction with the circumferential weld being radiographed.

16.1.4 In spherical components, where other welds are radiographed simultaneously with the circumferential weld, one additional IQI shall be placed on each other weld.

16.2 When an array of components in a circle is radiographed, at least one IQI shall show on each component image.

16.3 **In order to maintain the continuity of records involving subsequent exposures, all radiographs exhibiting IQI that qualify the techniques permitted in 16.1.1, 16.1.2, 16.1.3 or 16.1.4 shall be retained. Annexure V may be used as guide.**

16.4 **Multiple IQI**

16.4.1 **If the requirements of 17.2 are met by using more than one IQI, one shall be representative of the lightest area of interest and the other the darkest area of interest, the intervening densities on the radiograph shall be considered as having acceptable density.**

16.5 **Shims under IQI**

16.5.1 **A shim of material radiographically similar to the weld metal shall be placed between the part and the IQI, if needed, so that the radiographic density throughout the area of interest is within minus 15% from the radiographic density through the body of IQI adjacent to the essential hole.**

16.5.2 **The shim dimensions shall exceed the IQI dimensions such that the outline of at least three side of the IQI image shall be visible in the radiograph.**

17.0 **EVALUATION**

17.1 **Quality of radiographs**

17.1.1 **All radiographs should be free from mechanical, chemical or other blemishes such as fogging, processing defects to the extent that they do not mask or are not confused with the image of any discontinuity in the area of interest of the object being radiographed.**

17.2 **Radiographic density**

17.2.1 ***The transmitted film density through the radiographic image of the body of the designated hole type IQI adjacent to the essential hole and the area of interest shall be 1.8 minimum for radiographs made with an X-ray source and 2.0 minimum for radiographic made with a gamma ray source.***

17.2.2 **In both cases the maximum density shall be 4.0. A tolerance of ±0.05 in density is allowed for variation between the densitometer readings.**

17.3 **Density variation**

17.3.1 **If the density of radiograph anywhere through the area of interest varies by more than minus 15% or plus 30% rounded to the nearest 0.1 from the density through the body of designated hole type IQI adjacent to the essential hole within the minimum/maximum allowable density ranges specified in para 16.2.1, then an additional IQI shall be used for each exceptional area, one shall represent the lightest area and the other the darkest area of interest.**

17.3.2 **With shims: When shims are used, the +30% density restriction of 17.3.1 above may be exceeded, provided the required IQI sensitivity is displayed and the density limitation of 17.2 are not exceeded.**

17.4 **IQI Sensitivity**

17.4.1 **Radiography shall be performed with a technique of sufficient sensitivity to display the IQI image and 2T-hole, which are the essential indications of the image quality of the radiographs. The radiographs shall also display the identifying numbers and letters. A**

thinner or thicker IQI than listed in Annexure II (Table 5) may be used if an equivalent IQI sensitivity as specified in Annexure II (Table 6)is obtained.

18.0 ACCEPTANCE - FULL RADIOGRAPHY

18.1 The following type of discontinuities shall be unacceptable:

18.1.1 Any type of crack, zone of incomplete fusion or incomplete penetration.

18.1.2 Any other elongated indication on the radiograph whose length exceeds the following:
a) 6 mm for thickness up to 19 mm.
b) 1/3 t for 't' from 19 mm to 57 mm.
c) 19 mm for 't' over 57 mm.
Where 't' is the thickness of weld excluding any allowable reinforcement. For a butt weld joining two members having different thickness at the weld, 't' is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in 't'.

18.1.3 Any group of aligned indications that have an aggregate length greater than 't' in a length of 12t except when the distance between successive indication exceeds 6L where 'L' is the longest indication in the group.

18.1.4 Rounded indications (whose length is less than three times the width) in excess of that shown as acceptable as in Appendix A 250 of ASME Section I or Appendix 4 of ASME Section VIII Division 1 or appendix 8 of ASME Section VIII Division 2 (all are identical), Table 7.

18.1.5 For circumferential joint in pipe, tube and headers, the thickness of the weld measured between the inside surface of the weld preparation and the outside surface of the pipe or tube shall not be less than the minimum thickness permitted by the applicable material specification for the particular size and thickness of the pipe or tube used.

18.1.6 The contour of the concavity shall be smooth and the resulting thickness of the weld, including reinforcement, shall be at least equal to the required thickness of the thinner section. Root concavity shown without abrupt change in density is acceptable provided it is not greater than 2.5 mm in depth or 20% of thinner of the two sections, whichever is minimum for components fabricated as per Section I and 0.8 mm or 10% for components fabricated as per Section VIII. Comparable outside reinforcement shall be provided whenever acceptable root concavity is present.

18.1.7 Root concavity when there is an abrupt change in density, as indicated in the radiography, is not acceptable for power piping welds.

18.2 Repaired area in a weld shall be re-radiographed using the same technique used for original radiography.

19.0 ACCEPTANCE - SPOT RADIOGRAPHY

19.1 Any zone of crack, lack of fusion or in-complete penetration are unacceptable.

19.2 Slag inclusion or cavities whose length is greater than 2/3T or 19 mm, whichever is less, where T is the thickness of the weld excluding any allowable reinforcement is unacceptable.. For all thicknesses, indications less than 6 mm are acceptable and indications greater than 19 mm are unacceptable. For a butt weld joining two members having different thickness at the weld, 'T' is the thickness of the thinner of the two sections.

19.3 If several indications within the limitation given 19.2 above exists in a line, the welds shall be judged acceptable if the sum of the larger dimensions of all such indications is not more the 'T' in a length of 6T (or proportionately, for radiographs shorter than 6T) and if the longest indications considered are separated by at least '3L' of acceptable weld metal where L is the length of the longest indication. Any such indications shorter than 6 mm shall be acceptable for any plate thickness.

19.4 Rounded indications (length less than three times the width) are not a factor in the acceptability of welds not required to be fully radiographed.

20.0 EVALUATION AND RETEST: (Spot Radiography)

20.1 When radiograph of one spot is found acceptable, the entire weld increment represented by this radiograph is acceptable.

20.2 If any spot is found defective, then two additional spots shall be radiographed from the same weld increment at location away from the original spot. If additional spots are found acceptable, then the entire weld increment represented by the three radiographs is acceptable. The defective area in the first radiograph will be removed, re-welded and re-radiographed as given above.

20.3 If either of the two additional spots examined are found defective, then the entire increment of weld represented shall be radiographed and repaired or the entire weld shall be rejected.

20.4 If the entire weld is removed and re-welded based on the spot radiography result, the welded joint or weld repaired area shall be spot radiographically examined at one location in accordance with the procedure given above.

20.5 For original and additional spot selection AI Permission shall be obtained.

21.0 PERSONNEL QUALIFICATION

21.1 Personnel performing examination shall be qualified in accordance with BHE:NDT:G:CRT to at least one of the following levels.

1) Operator - Minimum Level- I 2) Radiograph Evaluation- Minimum Level-II

22.0 RECORDING AND REPORTING

22.1 BHEL's evaluation report shall be given in the format (Annexure VI) and shall be presented along with radiographs to External Inspector for review.

23.0 STORAGE:

23.1 Radiographs of Products to ASME Code Sec. I, Sec. VIII Div.1 and Div.2 and Boiler drums:

23.1.1 A complete set of radiographs with proper identification shall be preserved for a period of 5 years as in Quality Control Manual.

23.2 Radiographs of Other components:

23.2.1 Radiographs of header, pipe and tubular butt welds shall be retained and kept on file for a period of three years or till the final inspection, whichever is earlier.

23.2.2 Records such as registers and reports shall be maintained till the final inspection is completed.

24.0 SAFETY

24.1 Radiography shall be performed in accordance with all applicable safety requirements as specified in BHEL's Safety Procedure BHE:NDT: G:SFT.

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ANNEXURE I

Table 2- MAXIMUM WELD REINFORCEMENT AS PER ASME SECTION I

Weld Thickness in mm (nominal thickness of the thinner section at the weld joint)	Circumferential welds in Pipes & Tubes (mm)	Other welds (mm)
Up to 3.0	2.5	2.5
Over 3.0 to 5.0	3.0	2.5
Over 5.0 to 13.0	4.0	2.5
Over13.0 to 25.0	5.0	2.5
Over 25.0 to 50.0	6.0	3.0
Over 50.0 to 75.0	The greater of 6 mm or 1/8 times the width of the weld (in mm).	4.0
Over 75.0 to 100.0		5.5
Over 100.0 to 125		6.0
Over 125		8.0

TABLE 3- MAXIMUM WELD REINFORCEMENT AS PER ASME SECTION VIII-Division 1

Weld Thickness in mm (nominal thickness of the thinner section at the weld joint)	Category B & C Butt welds (mm)	Other welds (mm)
Up to 2.4	2.4	0.8
Over 2.4 to 4.8	3.0	1.5
Over 4.8 to 13.0	4.0	2.5
Over13.0 to 25.0	5.0	2.5
Over 25.0 to 51.0	5.0	3.0
Over 51.0 to 76.0	6.0	4.0
Over 76.0 to 102.0	6.0	5.5
Over 102.0 to 127	6.0	6.0
Over 127	8.0	8.0

TABLE 4- MAXIMUM WELD REINFORCEMENT AS PER ASME SECTION VIII-Division 2

Weld Thickness in mm (nominal thickness of the thinner section at the weld joint)	Circumferential welds in Pipes & Tubes (mm)	Other welds (mm)
< 2.5	2.5	0.8
≥ 2.5 to < 5.0	2.5	1.5
≥ 5.0 to <13.0	3.0	2.5
≥ 13.0 to <25.0	4.0	2.5

≥ 25.0 to <50.0	4.0	3.0
≥ 50.0 to <76.0	4.0	4.0
≥ 76.0 to <100.0	5.5	5.5
≥ 100.0 to <125.0	6.0	6.0
≥ 125.0	8.0	8.0

ANNEXURE II
TABLE 5 - IQI SELECTION

IQI		
Nominal Single Wall thickness Range(mm)	Source side Desgn.	Film Side Desgn.
Up to 6.4 mm	12	10
Over 6.4 thro' 9.5	15	12
Over 9.5 thro' 12.7	17	15
Over 12.7 thro' 19.0	20	17
Over 19.0 thro' 25.4	25	20
Over 25.4 thro'38.1	30	25
Over 38.1 thro' 50.8	35	30
Over 50.8 thro'63.5	40	35
Over 63.5 thro' 101.6	50	40
Over 101.6 thro'152.4	60	50
Over 152.4 thro'203.2	80	60
Over 203.2 thro'254.0	100	80
Over 254.0 thro'304.8	120	100

Note: The radiograph should display the designated IQI and 2T-hole image

TABLE – 6 EQUIVALENT HOLE TYPE IQI SENSITIVITY (T-283 of ASME Sec.V, Article 2)

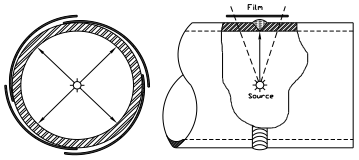
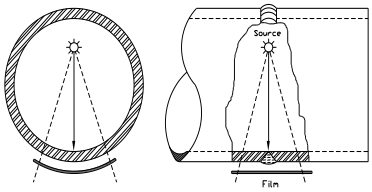
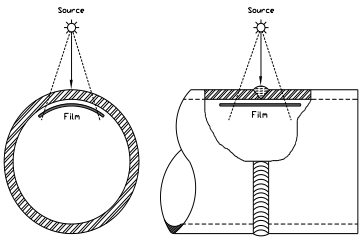
Hole Type Designation 2T - Hole	Equivalent Hole Type Designation	
	1T Hole	4T Hole
10	15	5
12	17	7
15	20	10
17	25	12
20	30	15
25	35	17
30	40	20
35	50	25
40	60	30
50	70	35
60	80	40
80	120	60
100	140	70
120	160	80
160	240	120
200	280	140

Table-7

Thickness t mm	Max size acceptable mm		Max size of non relevant indication
	Random	Isolated	
< 3	1/4t	1/3t	1/10t
3	0.79	1.07	0.38
5	1.19	1.60	0.38
6	1.60	2.11	0.38
8	1.98	2.64	0.79
10	2.31	3.18	0.79
11	2.77	3.71	0.79
13	3.18	4.27	0.79
14	3.61	4.78	0.79
16	3.96	5.84	0.79
19 to 50 incl	3.96	6.35	0.79
Over 50	3.96	9.53	1.60

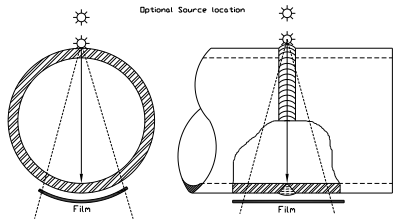
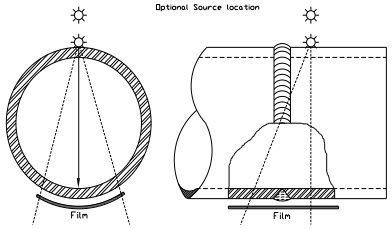
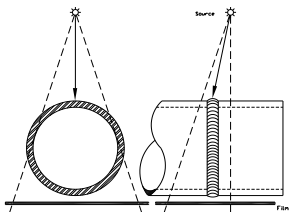
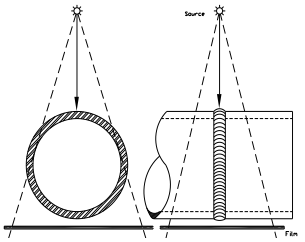
.ANNEXURE III

SINGLE WALL RADIOGRAPHIC TECHNIQUES

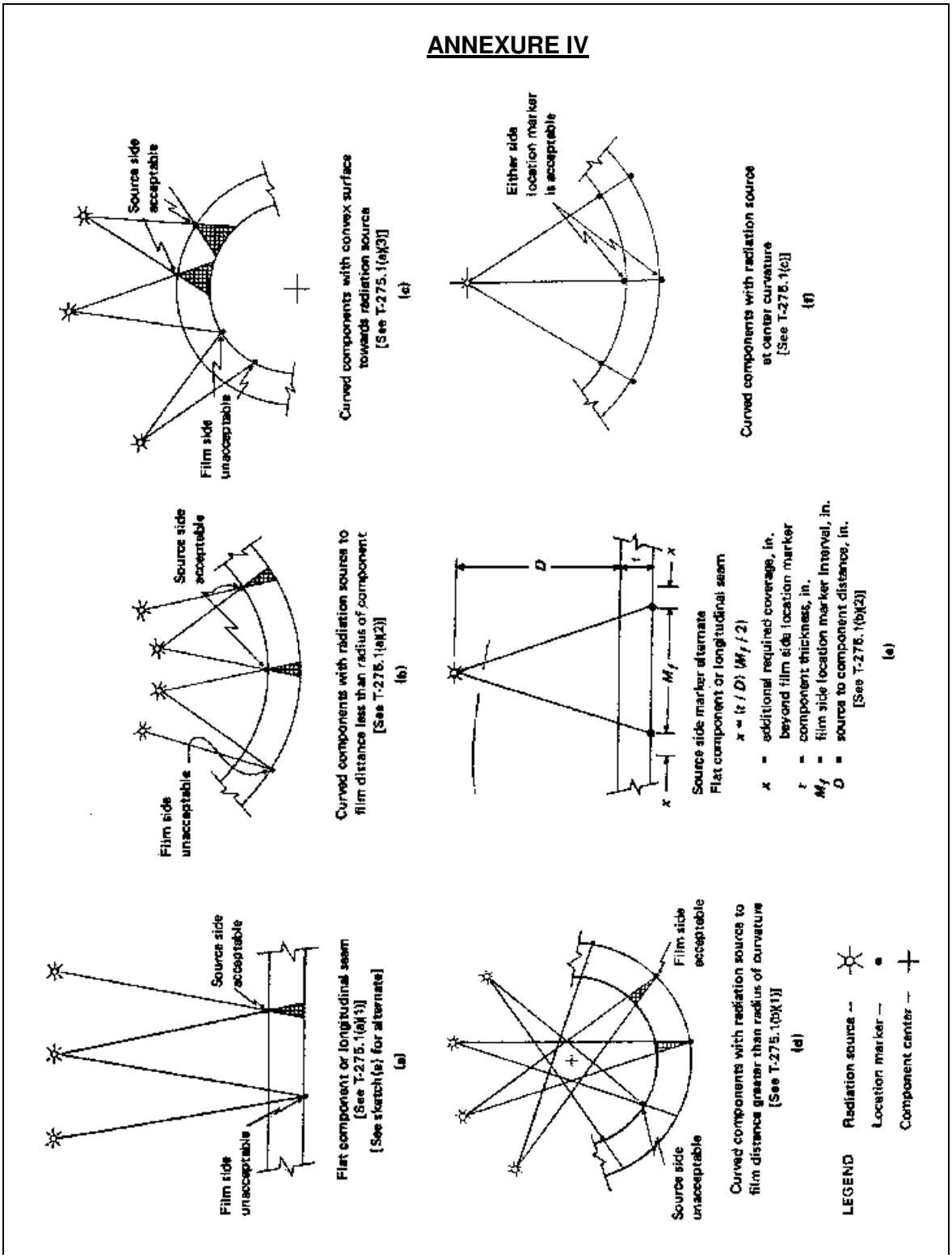
O.D	Exposure Technique	Radiograph Viewing	Source-weld-film Arrangement		IQI		Location Marker Placement
			End View	Side View	Selection	Placement	
Any	Single wall	Single wall	 1)Panoramic		Table 2	Source side (15.1)	Either side (13.0)
						Film side (15.2)	
Any	Single wall	Single wall	 2)Source inside – Film outside		Table 2	Source side (15.1)	Film side (13.0)
						Film side (15.2)	
Any	Single wall	Single wall	 3)Source outside – Film inside		Table 2	Source side (15.1)	Source side (13.0)
						Film side (15.2)	

ANNEXURE III

DOUBLE WALL RADIOGRAPHIC TECHNIQUES

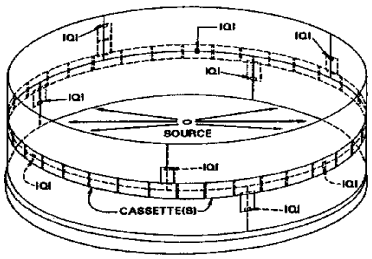
O.D	Exposure Technique	Radiograph Viewing	Source –weld-film Arrangement		IQI		Location Marker Placement
			End View	Side View	Selection	Placement	
Any	Double wall: at least 3 exposures 120° to each other for complete coverage	Single wall	 4)Double wall single image		Table 2	Source side (15.1) Film side (15.2)	Film side (13.0)
Any	Double wall: at least 3 exposures 120° to each other for complete coverage	Single wall	 5)Double wall single image- source offset		Table 2	Source side (15.1) Film side (15.2)	Film side (13.0)
89 mm or less	Double wall: at least 2 exposures 90° to each other for complete coverage	Double wall (Ellipse): Read offset source side and film side images	 6)Double wall double image		Table 2	Source side (15.1)	Either side (13.0)
89 mm or less	Double wall: at least 3 exposures at 60° or 120° to each other for complete coverage	Double wall: Read Super imposed source side and film side images	 7)Double wall double image- superimpose		Table 2	Source side (15.1)	Either side (13.0)

ANNEXURE IV

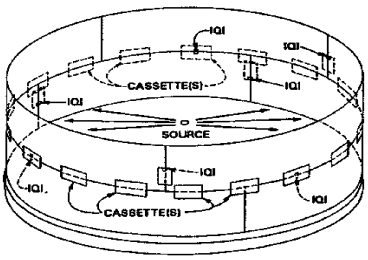


LOCATION MARKER SKETCHES

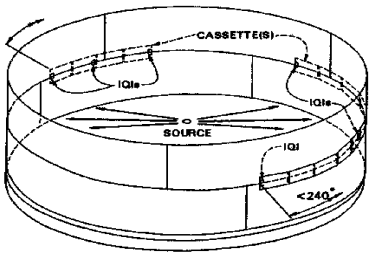
ANNEXURE V



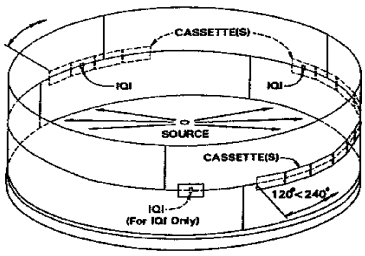
COMPLETE CIRCUMFERENCE
CYLINDRICAL COMPONENT



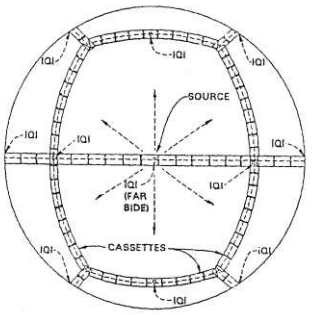
SECTION OF CIRCUMFERENCE
240 deg. OR MORE CYLINDRICAL COMPONENT
(EXAMPLE IS ALTERNATE INTERVALS)



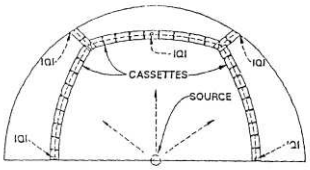
SECTION(S) OF CIRCUMFERENCE
LESS THAN 240 deg. CYLINDRICAL COMPONENT



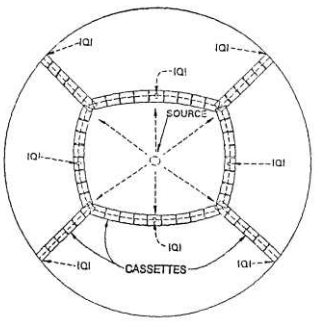
SECTION(S) OF CIRCUMFERENCE
EQUAL TO OR MORE THAN 120 deg. AND LESS THAN
240 deg. CYLINDRICAL COMPONENT



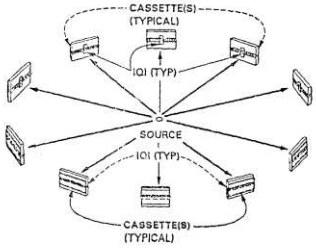
COMPLETE CIRCUMFERENTIAL WELDS SPHERICAL COMPONENT



WELDS IN SEGMENTS OF SPHERICAL COMPONENT



PLAN VIEW A-A

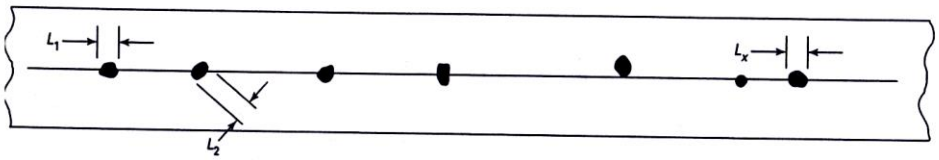


Note: Special Cases IQI Locations are Typical in All Figures.

ARRAY OF OBJECTS IN A CIRCLE

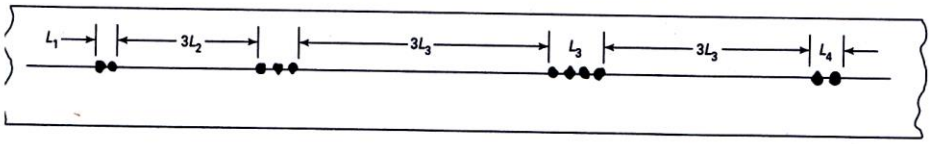
POROSITY-ACCEPTANCE LEVEL

FIG. A-250.3.4.-1 ALIGNED ROUNDED INDICATIONS



GENERAL NOTE: Sum of L_1 to L_x shall be less than t in a length of 12 t.

FIG. A-250.3.4-2 GROUPS OF ALIGNED ROUNDED INDICATIONS



Maximum Group Length
L = 1/4 in. (6 mm) for t less than 3/4 in. (19 mm)
L = 1/3 t for t 3/4 in. (19 mm) to 2 1/4 in. (57 mm)
L = 3/4 in. (19 mm) for t greater than 2 1/4 in. (57 mm)

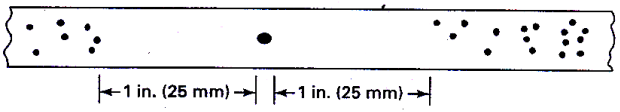
Minimum Group Spacing
3L where L is the length of the longest adjacent group being evaluated.

GENERAL NOTE: Sum of the group lengths shall be less than t in a length of 12 t.

FIG. A-250.3.6-1 CHARTS FOR t 1/8 in. (3 mm) TO 1/4 in. (6 mm), INCLUSIVE

GENERAL NOTE: Typical concentration and size permitted in any 6 in. (150 mm) length of weld

(a) Random Rounded Indications

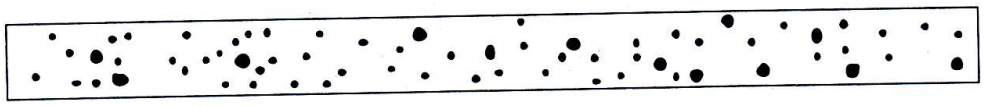


(b) Isolated Indication (Maximum size per Table A-250.3.2)

(c) Cluster

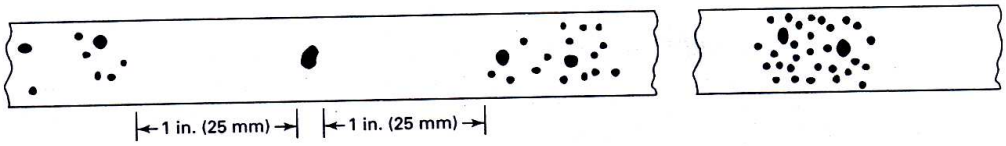
POROSITY-ACCEPTANCE LEVEL

FIG. A-250.3.6-2 CHARTS FOR *t* OVER 1/4 in. (6 mm) TO 3/8 in. (10 mm), INCLUSIVE



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (150 mm) length of weld

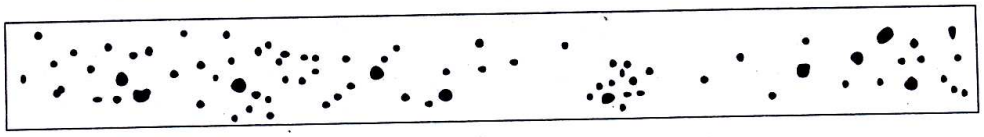
(a) Random Rounded Indications



(b) Isolated Indication
(Maximum size per Table A-250.3.2)

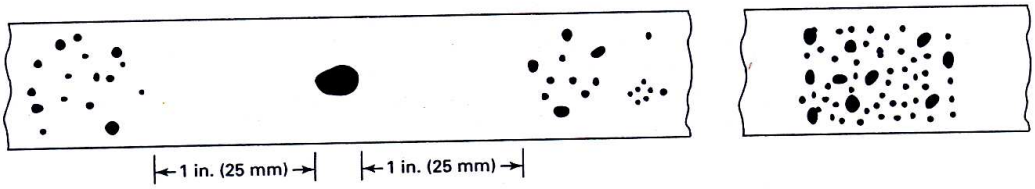
(c) Cluster

FIG. A-250.3.6-3 CHARTS FOR *t* OVER 3/8 in. (10 mm) TO 3/4 in. (19 mm), INCLUSIVE



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (150 mm) length of weld

(a) Random Rounded Indications

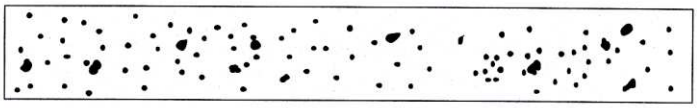


(b) Isolated Indication
(Maximum size per Table A-250.3.2)

(c) Cluster

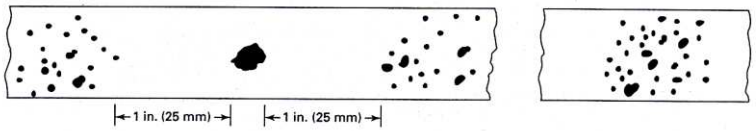
POROSITY-ACCEPTANCE LEVEL

FIG. A-250.3.6-4 CHARTS FOR t OVER $^3/_4$ in. (19 mm) TO 2 in. (50 mm), INCLUSIVE



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

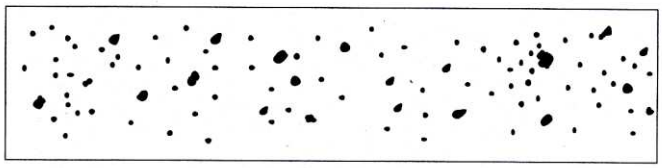
(a) Random Rounded Indications



(b) Isolated Indication (Maximum size per Table A-250.3.2)

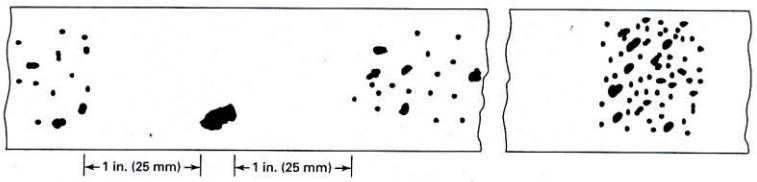
(c) Cluster

FIG. A-250.3.6-5 CHARTS FOR t OVER 2 in. (50 mm) TO 4 in. (100 mm), INCLUSIVE



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

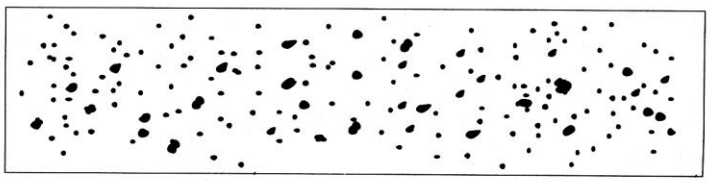
(a) Random Rounded Indications



(b) Isolated Indication (Maximum size per Table A-250.3.2)

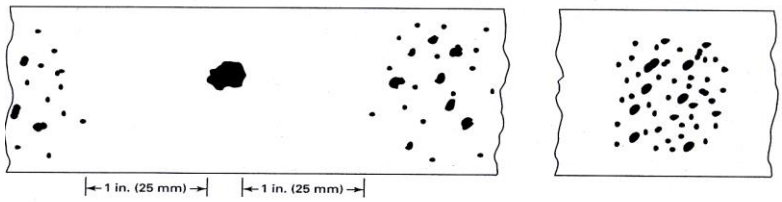
(c) Cluster

FIG. A-250.3.6-6 CHARTS FOR t OVER 4 in. (100 mm)



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(a) Random Rounded Indications



(b) Isolated Indication (Maximum size per Table A-250.3.2)

(c) Cluster

ANNEXURE VI
RADIOGRAPHIC REPORT CUM REVIEW FORM

Report No.:	**Date:**	**Ref.:**	**Stage of Test:**
Description:	**Material:**	**Dia.:** mm	**Thickness:** mm
W.O. No.:	**Drg. No.:**	**DU No.:**	
Pb. Screen Front/Back	**Welding Process:**	**Weld reinforcement:** mm	
Source: X- Rays/ Ir. 192/ Co.60	**Source Size:**	**Exposure: KV:** mA / Ci.mts:	
Source to Object distance: mm	**Source side of object to Film Distance:** mm		
IQI: ASTM Hole / Wire type:	**Source side /Film side**	**Sensitivity:**	**Density:**
Single/Double wall/Panoramic technique	**Single/ Double wall viewing**	**Markers: Source / Film side**	
Film Manufacturer: Agfa. / Kodak.	**Film Type / Designation :**		
No. of Radiographs (Exposures):	**No. of films in each cassette:**	**Date of Evaluation:**	
Procedure & Acceptance : BHE:NDT:PB / SS / VV / NU / RT			

Sl. No.	Welder No.	Radiograph No./ Joint No.	Seg. No.	Findings	Disposition (Repair/Accept)

SAMPLE

Operator **Level I / II**	**Approved by :** **Level II / III**	**External Inspection Agency**

CHAPTER 1.5

PROCEDURE FOR RADIOGRAPHIC EXAMINATION OF BUTT WELDS IN STRUCTURES

PROCEDURE FOR RADIOGRAPHIC EXAMINATION OF BUTT WELDS IN STRUCTURES

Prepared By	Reviewed By	Approved By	Issued By
01-01-2020	01/01/2020	01-01-2020	01/01/2020
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Effective from 01-01-2020

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
01	01-08-1981	Revised in its entirety
02	13-07-1993	Clauses 1.1, 2.0, 4.2, 10.1, 13.3.1 and 15.2(b) modified. Clause 11.8 added.
03	03-03-1997	Clauses 2.0, 5.0, 9.1 are modified. Clauses 11.4, 15.3 and 17 added. Editorial corrections made
04	23-10-2006	Revised in its entirety
05	20-07-2016	Clause 2.1,2.2 updated Clause 18.1 modified Clause 16.3 and Table 5 added
06	01-01-2020	Clause 2.0 modified Clause 18.1 modified Figure 5 modified to depict cases 1 to 4

1.0 SCOPE

1.1 This procedure describes the technique and acceptance for the radiographic examination of Butt Welds of carbon steel, alloy steel and stainless steel structures used in Boilers .

2.0 REFERENCE

2.1 AWS D1.1/ D1.1M 2015 Structural Welding Code – Steel
2.2 ASME Article 2 / Section V 2019 Edition

3.0 SURFACE PREPARATION

3.1 Radiography can be taken in as welded condition unless Contract requirements calls for or its surface irregularities or junction between weld and base metal may cause objectionable weld discontinuities to be observed in the radiograph.

4.0 FILM AND SCREEN

4.1 Radiographs shall be made from films of good commercial quality and the following brands of films or equivalent shall be normally used:

a) Kodak AA 400 / T 200 b) Agfa D7/D5/D4
c) Any other brand of film with the approval of Head / NDT

4.2 Lead Screens- Front 0.1 mm for X-rays and Iridium 192
Front 0.25 mm for Cobalt 60 and Linear Accelerator
Back screen will be of same thickness or slightly larger

5.0 QUALITY OF RADIOGRAPH

5.1 All radiographs shall be free from mechanical, chemical or Processing Markings

6.0 RADIOGRAPHIC DENSITY

6.1 The optical density of the radiographs shall meet the requirements as given in the Table

Table 1

Source	Minimum Density	Maximum Density
X-rays	1.8	4.0
Gamma Rays	2.0	4.0

7.0 BACK SCATTER

7.1 A lead symbol 'B' of 2 mm thick and 12mm height, shall be kept at the back of each film cassette to check the back scattering effect and the radiograph is unacceptable if light image of the letter 'B' appears on a darker background of the radiograph. A dark image of "B" on a lighter background is not a cause for rejection.

8.0 SYSTEM OF IDENTIFICATION

8.1 The following identifications shall be available in the radiograph.
a) Job Identification number/ Work order
b) Segment identification number
c) Date of RT,
d) Firm code No
e) Weld repair ./ rework status details(R1, R2, R3 etc, RT, GRT or MRT) if applicable,
f) Location identification markers
Location marker identification shall be marked / stamped on the surface.
These identification numbers shall be placed 20mm away from the weld edge.

10.0 RADIATION SOURCES

10.1 The radiation energy employed for any radiographic technique shall achieve the density and IQI requirement requirements.

11.0 RADIOGRAPHIC TECHNIQUE

11.1 A single-wall exposure technique shall be used for radiography whenever practical. When it is not practical to use a single-wall technique, a double wall technique shall be used .

11.2 The film shall be kept close and parallel to the back surface of the weld, to avoid enlargement and distortion of image.

11.3 The width of the film shall be sufficient to depict all portions of the weld joint including the heat affected zones and shall provide sufficient additional space for required IQI and film identification without infringing upon the area of interest in the radiograph.

11.4 Films shall have sufficient length and shall be placed to produce at least 12.5 mm of film exposed to direct radiation from the source beyond each free edge where the weld is terminated.

11.5 Welds longer than 350mm may be radiographed by overlapping film cassettes by making a single exposure or by using a single film cassettes and making separate exposures.

11.6 Edge blocks shall be used when radiographing butt welds >12 mm thickness. Fig (6)
The edge blocks shall have the following dimensions:
Length: Minimum 50 mm on each side with respect to weld center line
Thickness: Equal to or greater than the weld thickness
Width: Equal to half of thickness or 20 mm whichever is higher
Gap: 2 mm Maximum
Surface finish: 3 micrometer

12.0 GEOMETRIC UN SHARPNESS (μ_g)

12.1 Geometric un sharpness (μ_g) shall not exceed the following limitations

TABLE - 2

MATERIAL THICKNESS	μ_g Max.
Under 50.0 mm	0.51 mm
Over 50.0 to 75.0 mm	0.76 mm
Over 75.0 to 100.0mm	1.02 mm
Greater than 100.0 mm	1.78 mm

Material thickness is the thickness on which the IQI is based.

12.2 The minimum source to object distance shall be seven times the maximum thickness of the weld plus reinforcement and backing if any, under examination or the total length of the film being exposed in a single plane whichever is greater

13.0 REINFORCEMENT

13.1 When weld reinforcement is not removed, the allowable reinforcement shall not exceed 3.0 mm.

14.0 IMAGE QUALITY INDICATORS (IQI)

14.1 Hole type or wire type image Quality Indicators(IQI) made of carbon steel or type 304 stainless steel shall be used for radiography. the thickness on which the IQI based is on nominal single wall thickness plus the reinforcement permitted in 13.4.

15.0 NUMBER OF IQI

15.1 For welds joining nominally equal thickness

15.1.1To radiograph 250 mm or greater of weld length, IQI shall be placed at the ends of the segment, one on either side of the weld.

For length less than 250 mm of weld, one IQI shall be placed at the center away from the weld. IQI shall be placed 10mm away from weld edge. Fig (1 & 2).

15.2 For welds at a transition in thickness

15.2.1To radiograph 250 mm or greater of weld length, two IQI s on either end of the weld in thinner side and one at the centre of the thicker side weld and shall be placed 10 mm away from the weld. The IQI on the transition thickness shall be based on the maximum thickness under the IQI . Similarly for weld length less than 250 mm one IQI shall be placed on thinner side and one on thicker side. Fig(3 & 4)

16.0 SELECTION OF IQI

16.1 The essential hole size and thickness of the IQI shall be as specified below:-

Table - 3

Nominal Material Thickness range	Source side Designation of IQI	IQI Essential Hole
Up to 6.0 mm	10	4T
Over6.0 mm thro 10 mm	12	4T
Over10.0 mm thro 16 mm	15	4T
Over16.0 mm thro 20 mm	17	4T
Over20.0 mm thro 25 mm	20	4T
Over25.0 mm thro 32 mm	25	4T
Over32.0 mm thro 38 mm	30	2T
Over38 mm thro 50 mm	35	2T
Over50 mm thro 65 mm	40	2T
Over65 mm thro 75 mm	45	2T
Over75 mm thro 100mm	50	2T
Over100 mm thro 150 mm	60	2T
Over150 mm thro 200 mm	80	2T

Number of IQIs to be placed

Table- 4

	Segment length < 250 mm	Segment length ≥ 250 mm
Equal weld Thickness	1	2
Unequal weld thickness	2	3

16.2 The thickness shall be measured at the place where the IQI is placed and Shims may be used to compensate with the thickness of allowable reinforcement, provided the dimension of the shim extends 3.0 mm beyond three sides of the IQI. Backing plate shall not be considered part of the weld or reinforcement.

16.3 The essential wire type IQI shall be as specified below:-

Table - 5

Nominal Material Thickness range	Source side Maximum wire dia mm	Film side Minimum wire dia mm
Up to 6 mm	0.25	0.20
Over6 mm thro 10 mm	0.33	0.25
Over10 mm thro 16 mm	0.41	0.33
Over16mm thro 20 mm	0.51	0.41
Over20 mm thro 38 mm	0.63	0.51
Over38mm thro 50 mm	0.81	0.63
Over50 mm thro 65 mm	1.02	0.81
Over65 mm thro 100 mm	1.27	1.02
Over100 mm thro 150 mm	1.60	1.27
Over 150 mm thro 200 mm	2.54	1.60

17.0 PERSONNEL

17.1 Personnel performing examination shall be qualified in accordance with BHE:NDT:G:CRT to at least one of the following levels.
1) Operator - Minimum Level-1 2) Film Evaluation and Reporting- Minimum Level II

18.0 ACCEPTANCE- STATICALLY LOADED NONTUBULAR WELDS

18.1 The following type of discontinuities shall not be acceptable:

a. Any type of crack

b. Elongated discontinuities exceeding the maximum size of Figure 5

c. Discontinuities closer than the minimum clearance allowance of Figure 5

d. Rounded discontinuities greater than a maximum of size t / 3 (where t is the weld thickness) , not to exceed 6 mm .
However when the weld thickness is > than 50 mm, the maximum rounded indication may be 10 mm.
The minimum clearance of rounded discontinuities greater than or equal to 2.5 mm to an acceptable elongated or rounded discontinuity or to an edge or end of an intersecting weld shall be 3 times the greatest dimension of the larger of the discontinuity being considered.

e. At the intersection of a weld with another weld or a free edge (i.e., an edge beyond which no material extension exists), acceptable discontinuities shall conform to the limitations of Figure 5, Cases 1–4.

f. Isolated discontinuities such as cluster of rounded indications, having a sum of their greatest dimensions exceeding the maximum size single discontinuity allowed in Fig (5) The minimum clearance to another cluster or an elongated or rounded discontinuity or to an edge or end of an intersecting weld shall be 3 times the greatest dimension of the larger of the discontinuities being considered.

g. The sum of the individual discontinuities each having a greater dimension of less than 2.5 mm shall not exceed 2t / 3 mm or 10 mm whichever is less, in any linear 25mm of weld . This requirement is independent of (b), (c), (d) above.

h. In-line discontinuities, where the sum of the greatest dimensions exceeds 't' in any length of 6t When the length of the weld being examined is less than '6t', the allowable sum of the greatest dimensions shall be proportionally less.

Figure 7 and 8 illustrate the application of the requirements given above.

18.2 All these radiographs shall be retained for one full year after completion of work or will be handed over to the customer as the case may be.

19.0 REPAIRS

19.1 The welds that are subjected to repairs shall be re-examined by the same procedure and technique that was employed prior to repairs.

20.0 SAFETY REQUIREMENTS

20.1 Radiography shall be performed in accordance with all applicable safety requirements In accordance with BHEL:NDT:SFT.

21.0 REPORT

21.1 All radiographs of the welds subjected to radiographic testing including any that show unacceptable quality prior to repairs and a report interpreting them shall be submitted to the inspector concerned, in the standard RT Report Form or its equivalent/latest revision.

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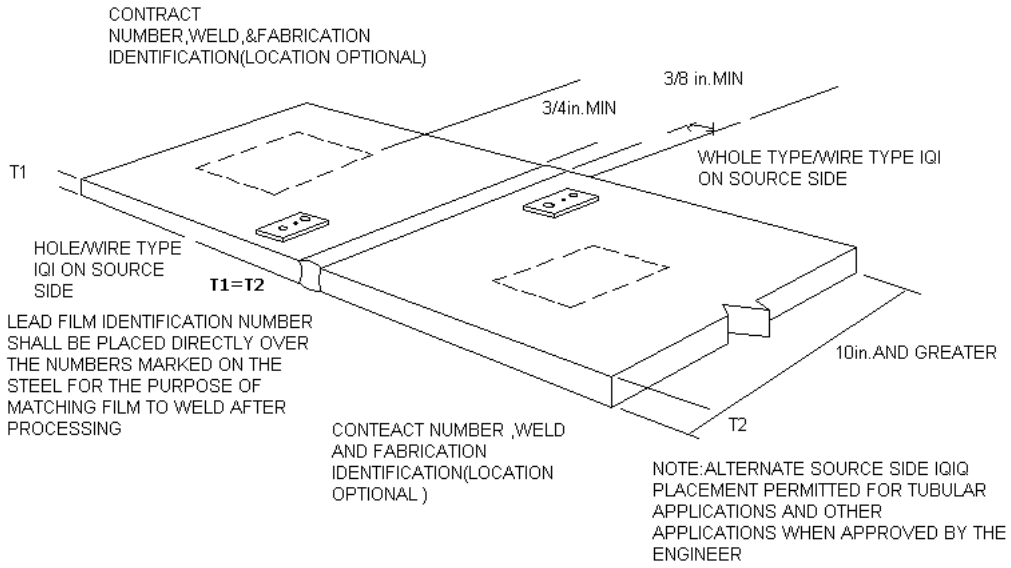


Figure (1)
RT Identification and IQI Locations on equal thickness joints of length ≥ 250 mm

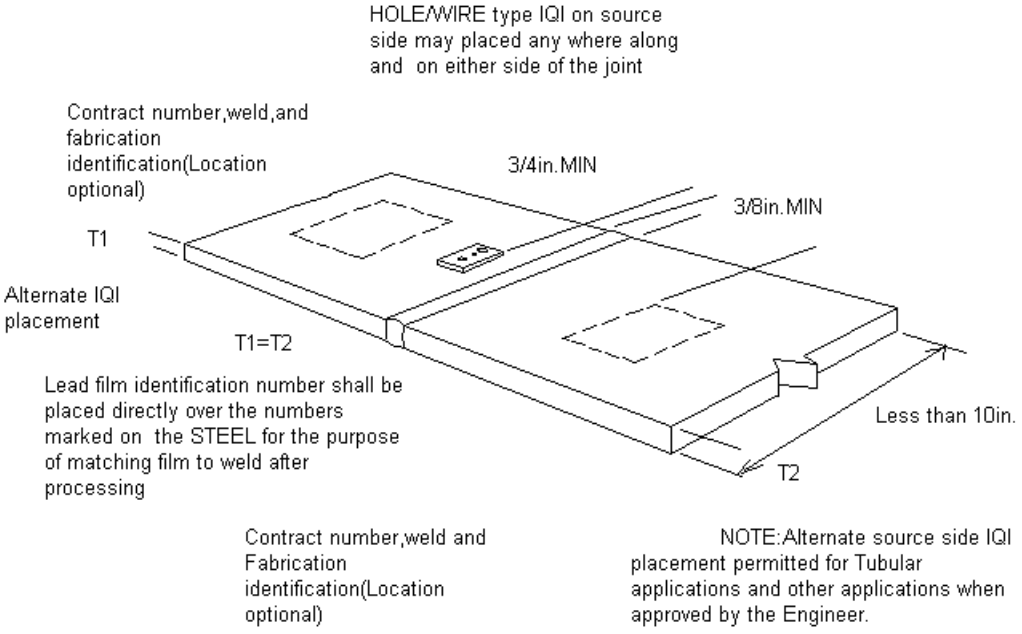


Figure (2)
RT Identification and IQI Locations on equal thickness joints of length < 250 mm

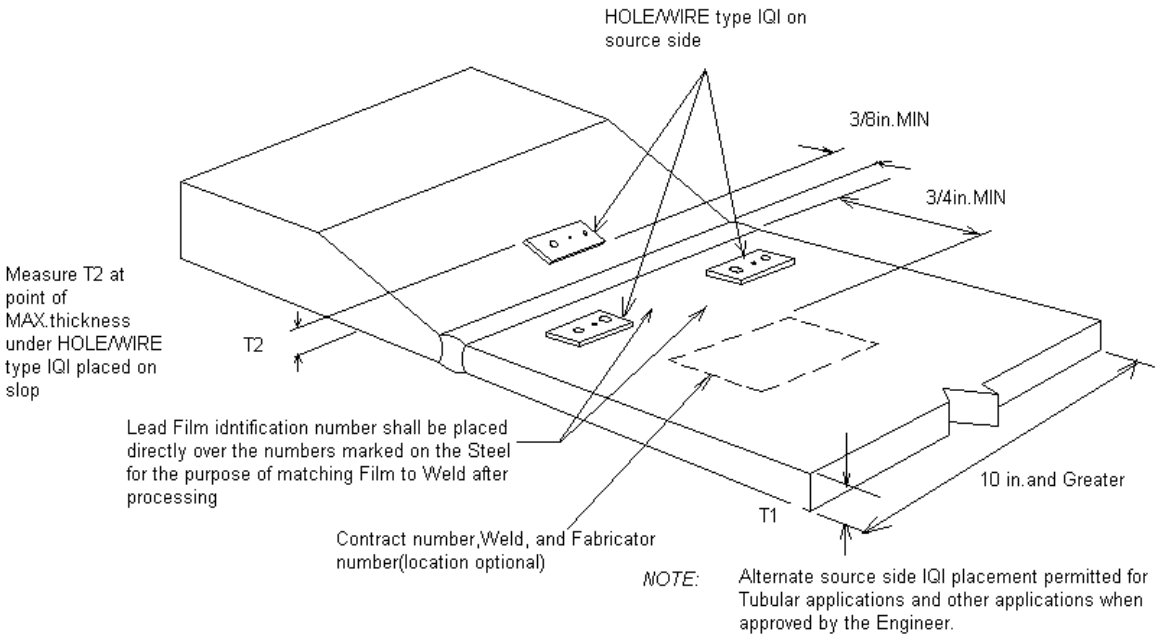


Figure (3)
RT Identification and IQI Locations on transition joints of length ≥ 250 mm

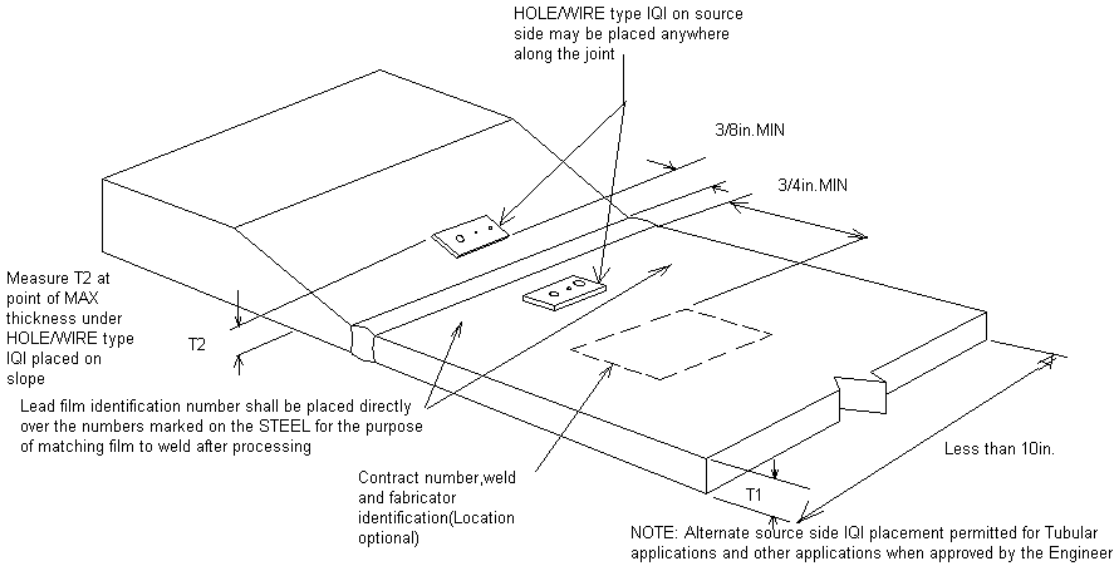
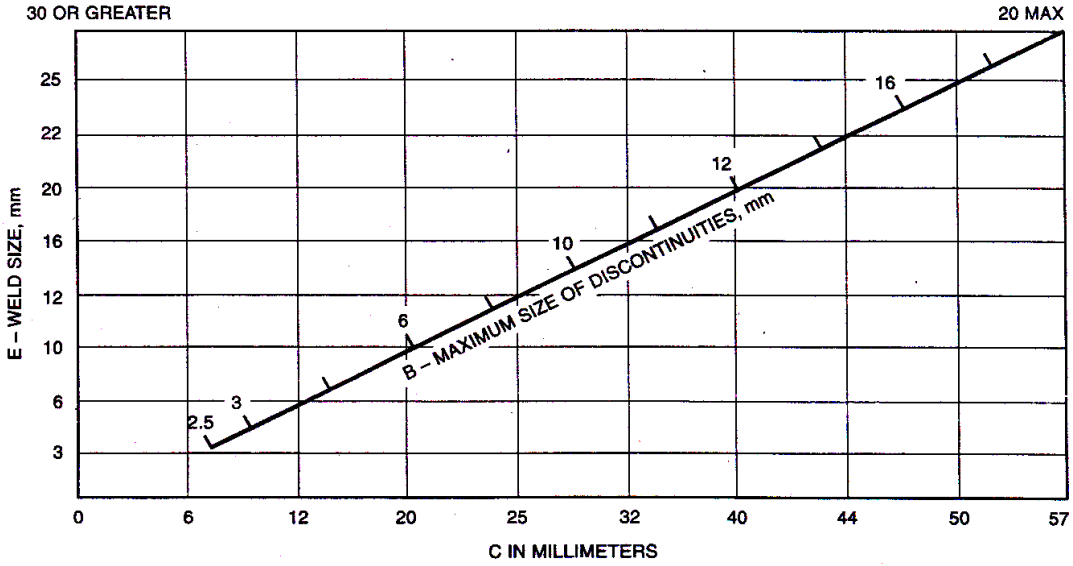


Figure (4)
RT Identification and IQI Locations on transition joints of length < 250 mm



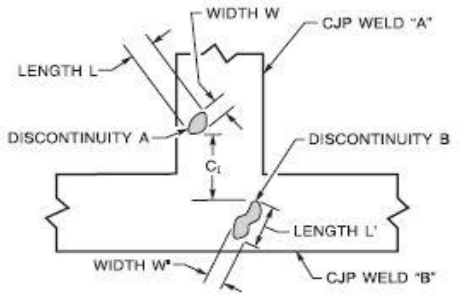
To determine he maximum size of discontinuity allowed in any weld size, project E horizontally to B
To determine the minimum clearance allowed between edges of discontinuities of any size greater than or equal to 2.5 mm, project B vertically to C
B – Maximum allowable dimension of discontinuity E- Weld thickness
C- Minimum clearance measured between edges of porosity or fusion type discontinuities

Figure (5) Weld Quality requirements for elongated discontinuities by RT for Statically Loaded Non tubular Structures

DISCONTINUITY A = ROUNDED OR ELONGATED DISCONTINUITY LOCATED IN WELD A
DISCONTINUITY B = ROUNDED OR ELONGATED DISCONTINUITY LOCATED IN WELD B

L AND W = LARGEST AND SMALLEST DIMENSIONS, RESPECTIVELY, OF DISCONTINUITY A
L' AND W' = LARGEST AND SMALLEST DIMENSIONS, RESPECTIVELY, OF DISCONTINUITY B

E = WELD SIZE
C_1 = SHORTEST DISTANCE PARALLEL TO THE WELD A AXIS, BETWEEN THE NEAREST DISCONTINUITY EDGES

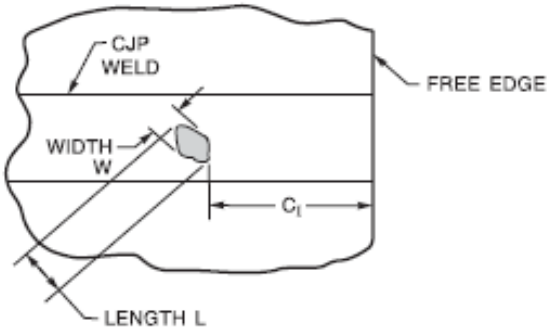


CASE I DISCONTINUITY LIMITATIONS[a]

DISCONTINUITY DIMENSION	LIMITATIONS	CONDITIONS
L	< E/3, ≤ 1/4 in [6 mm]	E ≤ 2 in [50 mm]
	≤ 3/8 in [10 mm]	E > 2 in [50 mm]
C_1	≥ 3L	(A) ONE DISCONTINUITY ROUNDED, THE OTHER ROUNDED OR ELONGATED[a] (B) L ≥ 3/32 in [2.5 mm]

[a] The elongated discontinuity may be located in either weld "A" or "B." For the purposes of this illustration the elongated discontinuity "B" was located in weld "B."

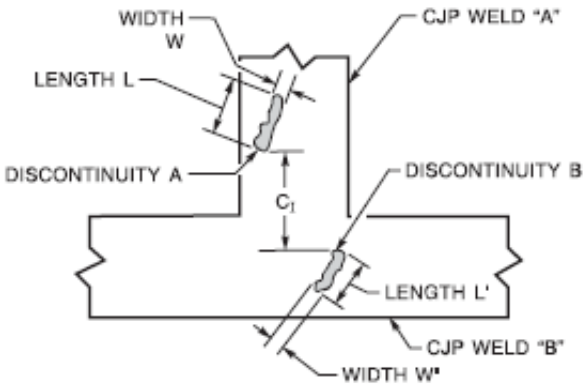
Figure 5 Case I- Discontinuity at weld intersection



CASE II DISCONTINUITY LIMITATIONS

DISCONTINUITY DIMENSION	LIMITATIONS	CONDITIONS
L	<E/3, ≤1/4 in [6 mm]	E ≤ 2 in [50 mm]
	≤3/8 in [10 mm]	E > 2 in [50 mm]
C_1	≥3L	L ≥ 3/32 in [2.5 mm]

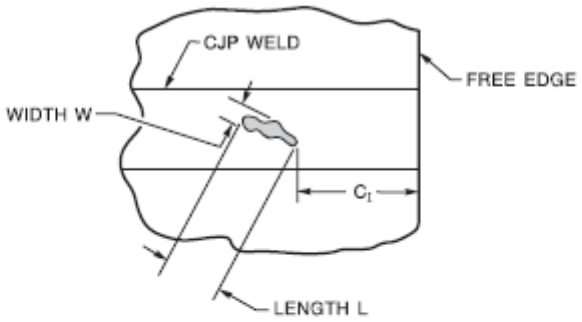
Figure 5 Case 2- Discontinuity at Free Edge of CJP Groove Weld



CASE III DISCONTINUITY LIMITATIONS

DISCONTINUITY DIMENSION	LIMITATIONS	CONDITIONS
L	≤2E/3	L/W > 3W
C_1	≥3L OR 2E, WHICHEVER IS GREATER	L ≥ 3/32 in [2.5 mm]

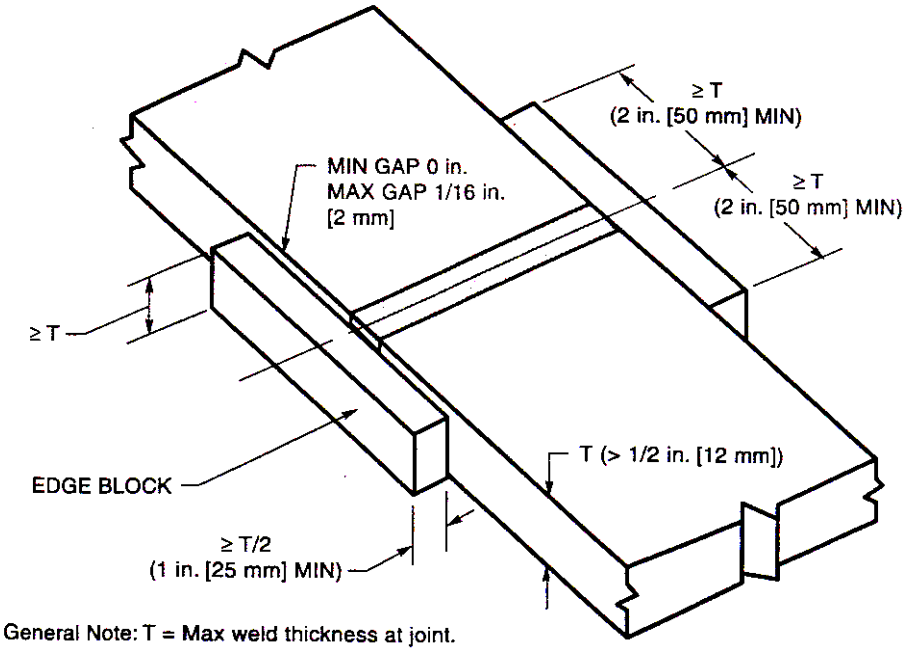
Figure 5 Case 3- Discontinuity at Weld Intersection



CASE IV DISCONTINUITY LIMITATIONS

DISCONTINUITY DIMENSION	LIMITATIONS	CONDITIONS
L	≤2E/3	L/W > 3
C_I	≥3L OR 2E, WHICHEVER IS GREATER	L ≥ 3/32 in [2.5 mm]

Figure 5 Case 4- Discontinuity at Free Edge of CJP Groove Weld



General Note: T = Max weld thickness at joint.

Figure (6) RT Edge Block

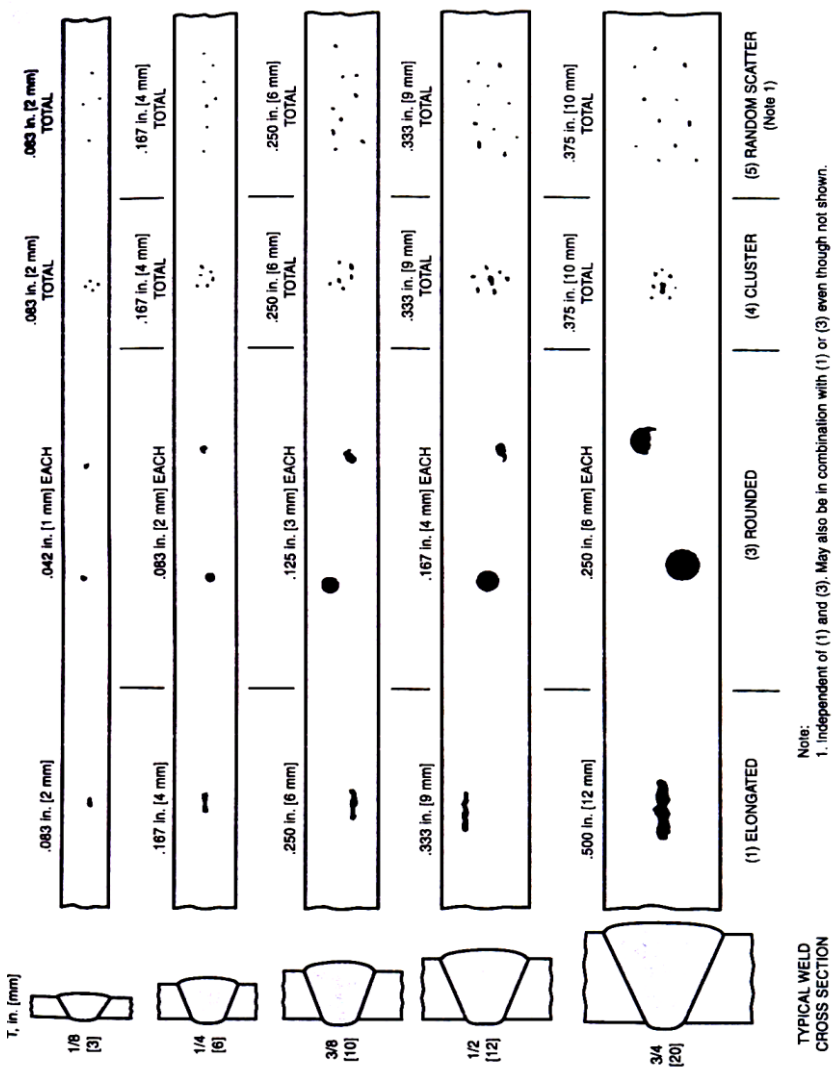
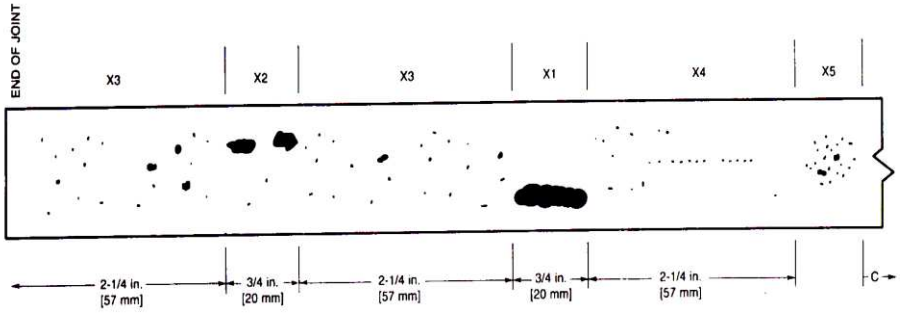


Fig (7) Maximum Acceptable RT Images



C- Minimum clearance allowed between edges of discontinuities 2.5 mm or larger
X1-Largerst permissible elongated discontinuity for 30 mm joint thickness
X2-Multiple discontinuities within a length may be handled as a single discontinuity
X3- X4 – Rounded type discontinuity less than 2.5 mm
X5-Rounded type discontinuities in a cluster. Such a cluster having a maximum of 20 mm for all pores In the cluster shall be treated as requiring the same clearance as a 20 mm long discontinuity

Interpretation: Rounded and elongated discontinuities shall be acceptable as shown. All are within the size limits and the minimum clearance allowed between discontinuities or the end of a weld joint

Fig (8) Random Acceptable Discontinuities

CHAPTER 1.6

PROCEDURE FOR ULTRASONIC EXAMINATION OF WELDS

PROCEDURE FOR ULTRASONIC EXAMINATION OF WELDS

Prepared by	Reviewed by	Approved by	Issued by
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	01/01/2020	01-01-2020	01/01/2020

EFFECTIVE FROM 01-01-2020

RECORD OF REVISION

Sl No.	Date	Details of Revision
06	28-03-94	Revised in entirety.
07	01-08-96	Revised in entirety.
08	01-04-97	Revised to merge and replace BHE:NDT:PB:UT:01/01,01/02,01/03, 11,13,14,16,17 & 25 to represent as a single procedure.
09	16-03-16	Revised to incorporate ASME BPV Code edition 2015, Clause 2.1, 4.1, 8.1.1, 8.1.4, 8.1.5, 8.1.6, 8.2.2, 8.5.4, 25.3 added, 21.2.1 revised, 25.3 added, Fig 1, 2, 6 revised.
10	07-10-17	Clause 4.1, 6.1 modified.
11	21-10-17	Revised in entirety.
12	01-09-2018	2.1, 2.2, 23.6.2 & Fig (16) revised.
13	01.01.2020	2.1, 2.2, 4.1, 22.5, 23.2 revised. Clause 25.0 Added.

1.0 SCOPE

1.1 This procedure defines the requirements of equipment, calibration, examination procedure and acceptance standards for ultrasonic examination of ferritic welds (carbon or alloy steel) by manual, contact method, that is required to be performed by ASME code for the following products:

a)Butt, Corner and Tee joints in components of boilers, Pressure vessels , heat- exchangers and HP / LP bypass Valves, with a dia greater than 120 mm and thickness equal to or greater than 10 mm.

b) Butt joints in pipes with Outer dia >120 mm and thickness ≥10mm.

c) Butt joints in boiler pipes / tubes dia 31.8 to 120 mm and thickness 3.6 mm to 13 mm.

2.0 REFERENCE

2.1 ASME Section I, V, and VIII Division 1 & 2 – 2019.

2.2 ASME B 31.1 / 2018

3.0 EQUIPMENT

3.1 Equipment features

3.1.1 A Digital Ultrasonic Flaw Detector of pulse - echo, Manual contact method type that responds to frequencies 1 MHz to 6 MHz and equipped with a stepped gain control of 2 dB or less shall be used as the UT instrument. The equipment setting values shall be detailed in the report.

3.2 Equipment Calibration

3.2.1 The Screen height linearity and amplitude control linearity shall be performed in accordance with BHE: NDT: UT: Calib: 1 (latest revision)at the beginning of each period of extended use or every 3 months (for Analog) and 1 year for Digital equipment, whichever is less.

3.3 Probes

3.3.1 Probes can be either single or dual transducer elements. Probes with curved contact wedges may be used to improve ultrasonic coupling in which case calibration shall be done with contact wedges used during the examination.

3.3.2 Search unit of 2 MHz to 4 MHz frequency shall be selected to produce a desirable signal- to- noise ratio (S / N) from the material to be examined at the specified sensitivity. Probes / search unit can be either single or dual transducer elements. An S / N value of at least 3 to 1 shall be usually considered to be minimum. Frequency < 2 MHz will be used to assure adequate penetration, when coarse grain structures are encountered. Crystal size 8 x 9 mm / 20 x 22 mm / dia 10 mm / dia 25 mm shall be used as per the application. Usage of any other crystal size shall be demonstrated to fulfill the requirements. To achieve proper contact, ultrasonic coupling and sensitivity on the smaller diameter surface, probes with contour contact wedges / shoes may be used in which case calibration shall be done with contact wedges / shoes used during the examination.

3.4 Couplant

3.4.1 Grease and Servo 35 oil mix will be used as couplant. The couplant used for the examination shall be the same that is used for calibration.

4.0 PERSONNEL QUALIFICATION

4.1 Personnel performing examinations shall be qualified in accordance with employer's written down document which is prepared in line with ASNT SNT – TC -1A (2016). The testing shall be conducted by minimum Level-I Personnel (Under the supervision of Level II OR Level III) or Level II and the interpretation and evaluation shall be done by minimum Level-II personnel.

5.0 SURFACE PREPARATION

5.1 As welded or ground surface shall be acceptable for the examination of the weld. The surface shall be free of dirt, scale, weld spatter, rust, paint, or any other extraneous matter that could prevent the scanning.

6.0 EXAMINATION

6.1 GENERAL EXAMINATION REQUIREMENT:

6.1.1 The entire volume of the full weld length inclusive of adjacent base metal shall be examined by moving the probe over the examination surface. During scanning the probes shall be moved to and from, with swiveling action of 10º to 15º on either side with overlap between successive scanning. Each pass of the probe shall overlap a minimum of 10 % of the crystal element dimension perpendicular to the direction of the scan. The rate of probe movement for examination shall not exceed 150 mm / sec.

6.2 STRAIGHT BEAM EXAMINATION:

6.2.1 For straight beam examination, longitudinal wave probes (0 degree) with crystal dimensions in the range of 10 to 25 mm shall be used.

6.2.2 The weld and fusion-zone of adjacent base material shall be scanned to the extent possible from one surface of the production part.

6.3 ANGLE BEAM EXAMINATION:

6.3.1 Scanning angle:

6.3.1.1 The search unit and beam angle selected shall be 45^0 or an angle appropriate for the configuration, groove angles and thickness of the weld being examined and shall be capable of detecting the calibration reflectors, over the required angle beam path.

6.3.2 Scanning Position and Directions:

6.3.2.1 Scanning shall be performed from both surfaces and from each side of the weld between 1/8 to 5/8 skip distances from the weld-centre line. (Fig 1.)

6.3.2.2 When examination is practical from one surface only, the 1/4-T volume lying below the examination surface, shall be examined from each side of the weld, by additionally positioning and moving the probe from 3/4-T to 1-T (full) skip distance. (Fig 2.)

6.3.2.3 When examination is practical from one surface and one side only two angle-beam probes shall be used. One of the angle-beam employed shall be 45 degree. The extent of limit coverage shall be noted in the examination report.

6.3.2.4 For Corner joints the scanning directions shall be such that the entire volume of the weld is scanned by angle and straight probes. (Fig 3, 4)

6.4 Angle beam / Longitudinal flaw scanning:

6.4.1 The angle beam shall be directed at 90º to the weld axis. The probe shall be manipulated so that ultrasonic energy passes through the required volumes of weld and adjacent base material.

6.5 Angle-beam/ transverse flaw scanning:

6.5.1 Scanning with weld reinforcement: If the weld cap is not machined or ground flat, the examination shall be performed from the base material on both sides of the weld cap. While scanning parallel to the weld axis, the angle beam shall be directed from 0 deg. to 60 deg. with respect to the weld axis in both axial directions, with the angle beam passing through the required examination volume.

6.5.2 Scanning without weld reinforcement: If the weld cap is machined or ground flat, the examination shall be performed on the weld. While scanning, the angle beam shall be directed essentially parallel to the weld axis in both axial directions. The search unit shall be manipulated so that the angle beam passes through the required examination volume.

6.6 Scanning sensitivity:

6.6.1 The scanning shall be performed at a gain setting + 6 dB of the primary reference level. If detection and evaluation of all indications exceeding 20 % of FSH required, scanning shall be performed at +14 dB. Evaluation shall be performed with respect to primary reference level.

7.0 REPAIR

7.1 Repaired welds in all the above materials shall be re-examined by the same procedure used for original testing.

8.0 REPORT

8.1 A detailed report duly signed by a minimum Level II NDE personnel shall be issued in the approved format.

6.8.2 The reports shall be retained for a minimum period of Five years for products made as per ASME Section I and Section VIII Div 1 and 2.

9.0 POST EXAMINATION CLEANING

9.1 After the examination is over the couplant applied on the surface shall be removed, if the residue couplant could interfere the further use of the test piece.

10.0 BUTT WELDS IN BOILER DRUMS, PRESSURE VESSELS AND VALVES

10.1 BASIC CALIBRATION BLOCK:

10.1.1 The material from which the block is fabricated shall be of the same product form and material specification or equivalent P-Number grouping of the materials being examined with similar Heat treatment conditions. P-No.s. 1, 3, 4, 5A through 5C, and 15A through 15F materials are considered equivalent. The material selection shall be based on the material on the side of the weld from which the examination will be conducted. If the examination will be conducted from both sides, calibration reflectors shall be provided in both materials.

10.1.2 The finish on the surfaces of the block shall be representative of the surface finishes on the production material.

10.1.3 The temperature difference between the examination and basic calibration block surfaces shall be within 14 degree C.

10.1.4 For examination in materials where the examination surface dia is greater than 500 mm, either a block of essentially the same curvature or a flat basic calibration block shall be used.(Fig. 5)

10.1.5 For materials with examination surface diameter 500 mm or less, the basic calibration block shall be curved. A single curved basic calibration block may be used to calibrate, examination of surfaces, in the range of 0.9 to 1.5 times the basic calibration block diameter. (Fig. 6)

10.1.6 The block thickness shall be as per Fig. (5). When the block thickness ± 25 mm spans two of weld thickness ranges in the table in Fig.5, the block's use shall be acceptable in those portions of each thickness range covered by 25 mm of the calibration bloc thickness. (E.g. A calibration block with thickness 38 mm could be used for weld thickness of 13 mm to 64 mm).

10.1.7 In cases such as single sided access welds (corner), if the calibration block detailed in Figure 5 does not provide the necessary sound path distances to the reference reflectors to provide distance-amplitude correction (DAC) that will fully cover the area of interest for the straight beam technique, a second calibration block is required whose thickness (T) and reference reflector locations are based on the sound path distance that provides for coverage of the area of interest.

10.1.8 No point on the DAC curve shall be less than 20% of full screen height (FSH). When any portion of the DAC curve will fall below 20% FSH, a split DAC shall be used. The first calibration reflector on the second DAC shall start at 80% ± 5% FSH. When reflector signal-to-noise ratio precludes effective indication evaluation and characterization, a split DAC should not be used.

10.2 Calibration Confirmation

10.2.1 When any part of the examination system is changed, a calibration check shall be made on the calibration block to verify that distance range points and sensitivity settings satisfy the requirements of 8.3. A calibration check on at least one of the basic reflectors in the basic calibration block shall be made at the finish of each examination, every 4 hrs. During the examination and when examination personnel are changed.

10.3 Confirmation Acceptance values

10.3.1 Distance range points: If any distance range point has moved on the sweep line more than 10% of the distance reading or 5% of full sweep, whichever is greater, then the sweep range calibration shall be corrected and recorded. All recorded indications since the last valid calibration shall be re-examined with corrected calibration and their values changed on the data sheets.

10.3.2 Sensitivity settings: If any sensitivity setting has changed by more than 20% or 2 dB of its amplitude, correct the sensitivity calibration and record. If the sensitivity setting has decreased, all the data sheets since the last calibration or calibration check shall be considered invalid. A new calibration shall be made and recorded. The invalid areas covered shall be re-examined. If the sensitivity setting has increased, all recorded indications since the last valid calibration or calibration check shall be re-examined and their values shall be changed on the data sheets or re-recorded.

11.0 SCANNING ADJACENT BASE MATERIAL

11.1 The scanning of adjacent base material shall be performed with straight-beam probe to detect reflectors that might affect interpretation of angle beam results. Locations and areas of such reflectors shall be recorded. This adjacent base material examination is not to be used as acceptance - rejection examination.

12.0 TECHNIQUES FOR ANGLE BEAM CALIBRATION

12.1 SWEEP RANGE:

12.1.1 The Sweep range is calibrated using IIW Block. The multiple reflection signals from 100 mm quadrant in IIW block are adjusted such that first reflection coincides with 5th division and 2nd signal at 10th division for 200 mm range. Similar settings shall be done for the different sweep ranges according to the thickness and skip distances used for scanning (Fig 7)

12.2 DISTANCE AMPLITUDE CORRECTION (DAC): Fig (8)

12.2.1 The probe is to be positioned for maximum response from the SDH, which gives the highest amplitude

12.2.2 The sensitivity control is to be adjusted to get an indication of 80% of full screen height (FSH) and the peak is to be marked on the screen.

12.2.3 The probe is to be positioned from another SDH for maximum response without altering the gain settings.

12.2.4 The peak point is to be marked on the screen.

12.2.5 The third SDH is positioned and the peak point is marked on the screen.

12.2.6 The 3/4T SDH is positioned for maximum amplitude after the beam bounces back from the opposite surface. The peak point is to be marked on the screen.

12.2.7 All the screen marks are to be connected for the required DAC

12.3 CALIBRATION CORRECTION FOR RECTANGULAR NOTCHES:

12.3.1 The probe shall be positioned for maximum amplitude from the notch on the opposite surface and the peak of the indication marked with an 'X' on the screen. The opposition surface notch may give an indication 2 to 1 above DAC for 45 degree shear wave, but only ½ DAC for a 60º shear wave. Therefore, the indication from the notch shall be considered when evaluating reflectors at the opposite surface. (Fig 9)

12.3.2 When a vessel or other component with a thickness of 13 mm or less and a diameter equal or less than 500 mm, the angle beam calibration for DAC may be performed as given in 17.1.

13.0 STRAIGHT BEAM CALIBRATION

13.1 The Sweep range is calibrated using IIW Block. The multiple reflection signals from 25 mm thickness in IIW block are adjusted such that first reflection coincides with 2.5 division, 2nd signal at 5th division, 3rd signal at 7.5 division and 4th signal at 10th division for a range of 100 mm. Similar settings shall be done for the different sweep ranges according to the thickness and skip distances used for scanning. (Fig. 10.)

13.2 Distance Amplitude Calibration (DAC) for Straight beam shall be done as in 10.2.1 to 10.2.5 and 10.2.7. (Fig. 11.)

14.0 NOZZLE SIDE WELD FUSION ZONE AND ADJACENT NOZZLE PARENT METAL EXAMINATION

14.1 CALIBRATION BLOCK

14.1.1 The calibration block configuration shall be as in figure (15).The block size and the reflector location shall be adequate to perform calibrations to cover the nozzle side weld fusion zone and the adjacent nozzle parent metal

14.1.2 Thickness: The calibration block shall be the maximum thickness of the nozzle wall adjacent to the nozzle weld plus 19 mm.

14.1.3 Curvature: For examination of nozzles with an inside diameter equal to or less than 500 mm, the contact surface of the calibration block shall have the same curvature or be within the range of 0.9 to 1.5 times the diameter (Fig 6).

14.1.4 Calibration reflectors: the calibration reflectors shall be side drilled holes that are in accordance with the requirements of figure (5).

14.1.5 Alternative calibration blocks may be used for similar types of examination, provided the sound path distance(s) to the block's reflector(s) is (are) within 6 mm of what is required and the side drilled hole is the same or a smaller diameter than what is required.

14.1.6 Calibration confirmation as per 8.3 shall be ensured.

14.2 EXAMINATION-specific requirements:

14.2.1 The requirements of clause 6, are applicable. The full circumference of the nozzle shall be scanned to cover the entire nozzle side fusion zone of the weld plus 25 mm beyond the weld toes. The search unit may be moved either circumferentially around or axially across the examination zone, as shown in figures 3 and 4. The screen range shall cover as a minimum, 1.1 times the full thickness of the nozzle wall. Nozzles that cannot be fully examined (e.g., restricted access that prevents hand placement of the search unit) shall be noted in the examination report.

15.0 EVALUATION:

15.1 Any imperfection which causes an indication in excess of 20% DAC shall be interpreted to determine the identity, shape and locations of all such imperfections to characterize them for their nature and type.

15.2 Indications that are determined to originate from metallurgical structure such as weld metal to austenitic clad interface shall be classified as spurious indications.

15.3 To classify an indication as geometric, reflected coordinates are to be verified and plotted and a cross sectional sketch of the weld shall be prepared showing the reflector position and surface discontinuities such as root and counter-bore.

16.0 RECORDING:

16.1 All indications having signal amplitudes equal to and above 50% of the reference level shall be recorded.

17.0 FLAW SIZING: Fig. (12)

17.1 Indications from discontinuities that remain from 100% DAC to 30% of DAC, the length of the reflector shall be obtained by recording the position and location along the lengths of the weld as determined by 50% level of maximum amplitude for each end of reflector (6 dB drop).

17.2 Indications that exceed the reference level the length of the reflector shall be determined by recording the position and location along the lengths of the weld until the maximum amplitude echo just falls below the 100% DAC reference response curve (0 dB drop).

18.0 ACCEPTANCE STANDARD:

18.1 Indications characterized as cracks, lack of fusion of incomplete penetration are not acceptable regardless of length.

18.3 Indications from other imperfections are not acceptable if the indications exceed the reference level and have lengths which exceed

a) 6 mm for `t' up to 19 mm,
b) 1/3t for t from 19 mm to 57 mm
c) 19 mm for t over 57 mm
Where `t' is thickness of weld excluding any allowable reinforcement.

18.3 For a butt weld joining two members having different thickness at the weld 't' is the thinner of the thickness. If a full penetration weld includes a fillet weld, the thickness of `throat' of the fillet shall be included in `t'.

19.0 WELDS IN PIPES WITH OUTER DIAMETER > 120 MM AND THICKNESS ≥ 10 MM

19.1 The basic calibration block configuration and reflectors (notches) shall be as shown in Fig 13. Thickness, T, shall be ± 25% of the nominal thickness of the component to be examined. The block size and reflector locations shall be adequate to perform calibrations for the beam angle(s) and distance range(s) to be used.

19.2 For examination in materials where the examination surface dia is greater than 500 mm, either a block of essentially the same curvature or a flat basic calibration block shall be used.(Fig. 13). For materials with examination surface diameter 500 mm or less, the basic calibration block shall be curved. A single curved basic calibration block may be used to calibrate, examination of surfaces, in the range of 0.9 to 1.5 times the basic calibration block diameter. (Fig. 6).

19.3 The surface finish of the calibration block shall be representative of the surface finish of the piping.

19.4 Calibration confirmation as per 8.3 shall be ensured.

20.0 ANGLE BEAM CALIBRATION:

20.1 The angle beam shall be directed toward the notch that yields the maximum response. The gain control shall be set so that this response is 80% ± 5% of full screen height. This shall be the primary reference level. The search unit shall then be manipulated, without changing instrument settings, to obtain the maximum responses from the calibration reflectors at the distance increments necessary to generate a three-point distance-amplitude correction (DAC) curve. Separate calibrations shall be established for both the axial and circumferential notches. These calibrations shall establish both the distance range calibration and the distance amplitude correction.

21.0 ANGLE BEAM EXAMINATION:

21.1 Scanning angle:

21.1.1 For angle beam examination one shear wave angle beam probe of 45º shall be generally used. Other beam angles 60º or 70º will be used when it is appropriate to the configuration of piping being examined, its thickness and groove angle employed for welding. (Fig 14)

21.1.3 For angle beam examination the crystal dimensions shall be selected appropriate to the contact examination surface and generally be in the range of 8 mm to 35 mm.

21.2 Scanning Position and Directions:

21.2.1 Scanning shall be performed from outer surface only and from each side of the weld between 1/3 to one full skip distance.

21.2.3 When examination is practical from one surface and one side only two angle beam probes shall be used. One of the angle-beam employed shall be 45 degree.

22.0 EVALUATION:

22.1 Any imperfection which causes an indication in excess of 20% DAC shall be interpreted to determine the identity, shape and locations of all such imperfections to characterize them for their nature and type.

22.2 Indications that are determined to originate from surface conditions such as weld root geometry, counter-bore, and weld reinforcement shall be classified as 'geometry indications'.

22.3 Recording:

22.3.1 All indications having signal amplitudes equal to and above 50% of the reference level shall be recorded.

22.4 Flaw length measurement:

22.4.1 The measurements shall be made as in 15.0

22.5 ACCEPTANCE STANDARD:

a. Indications characterized as cracks, lack of fusion & incomplete penetration are not acceptable regardless of length.

b. Indications from other imperfections are not acceptable if the indications exceed the reference level and have lengths which exceed

   a) 6 mm for `t' up to 19 mm,
   b) 1/3t for t from 19 mm to 57 mm
   c) 19 mm for t over 57 mm

c. Where `t' is thickness of weld excluding any allowable reinforcement.

d. For a butt weld joining two members having different thickness at the weld 't' is the thinner of the thickness. If a full penetration weld includes a fillet weld, the thickness of `throat' of the fillet shall be included in `t'.

23.0. WELDS IN PIPES / TUBES OUTER DIA (OD) ≤ 120 mm

23.1. This procedure is applicable to induction pressure welds (IPW) & fusion welds in boiler tubes for the purpose of detecting radial-type defects having their major dimension circumferentially relative to the tube axis.

23.2. BASIC CALIBRATION BLOCK

23.2.1. The basic calibration block shall be a section of the pipe / tube with an outer diameter (OD) within 0.9 to 1.5 times the OD of the test pipe / tube, and thickness within ± 25 % of that of the test pipe / tube. The material of the block shall meet the requirements specified in clause 10.1.1.

23.2.2. The calibration reflectors shall be circumferential notches on both the inner and outer surface. The calibration reflectors shall be of length ≥ 25 mm, depth 8%T minimum to 11%T maximum (where T is the thickness of the test pipe). Notch width shall be maximum 6 mm.

23.2.3. The notches in the calibration piece shall be kept clean. If contaminated by Couplant or accumulated dirt the notches shall be cleaned by washing with a stream of water directed into and along the notch and rinsed with acetone, or other rapid drying solvent.

23.3. ANGLE BEAM CALIBRATION:

23.3.1. The angle beam probe shall be directed toward ID notch that yields the maximum response, adjusting the instrument settings to 80% of full screen height (FSH), in half node if practicable or in 1.5 skip or more so that this indication appears around 50 % of the time-base. The left end of the gate shall be adjusted to this position on the CRT.

23.3.2. The probe shall be then positioned at distance necessary to resolve the OD notch and the right end of the gate shall be adjusted to this sweep position on the CRT. The gate length just established will be the area for acceptance or rejection of indication when combined with the proper transducer position. The OD notch shall be used as reference to establish the gate length only.

23.4. ANGLE BEAM SCANNING:

23.4.1. Only longitudinal flaw scanning shall be performed from outer surface and from each side of the weld up to 2 skip distances using 70 deg. shear-wave probe.

23.5. EVALUATION:

23.5.1. Indications that are determined, by careful evaluation of the examination area, to originate from surface conditions such as weld root geometry, counter-bore, weld reinforcement, mismatched upset on ID and OD they shall be classified as geometry indications.

23.5.2. Indications contained within the OD upset may be removed and re-examined provided the OD reinforcement has not been reduced below the specified minimum wall thickness.

23.6. ACCEPTANCE STANDARD:

23.6.1. Any flaw-indication exceeding the primary reference shall be unacceptable.

23.6.2. On Induction Pressure welded tube joints, UT need not be carried out in case if visually unacceptable joints found viz. Offcentre > 1.5 mm, Peak, Melt, Overlap and Mismatch on OD (as shown in Fig.16) and are not acceptable.

23.6.3. Any indication arising out of root geometry which gives echo response at any level with respect to primary reference and only one side of weld scanning is acceptable.

24.0 POST CLEANING:

24.1 When post cleaning is required by the procedure, it should be conducted as soon as practical after evaluation and documentation using a process that does not adversely affect the part.

25.0 Record Retention:

25.1 The Records of reports signed by min. Level II/III shall be retained for the period of 5 years for components fabricated as per ASME Sec-I and 3 years for components of ASME SEC-VIII.

****

Table-1
ESSENTIAL AND NON- ESSENTIAL VARIABLES

Sl. No	Requirement	Type of variable	Applicable clauses in the procedure
01	Weld configuration to be examined-Thickness, dimension, base material product form	Essential	Clause 1.1 & 5.1
02	Surface from which examination performed	Essential	Clause 6.2.2,6.3.2
03	Technique	Essential	Straight beam, Angle beam(contact) Clause 6.2,6.3
04	Angle and mode	Essential	Clause 6.2.1 & 6.3.1.1
05	Search unit type, frequency and dimensions	Essential	Clause 3.3.2, 6.2.1
06	Special search unit when used	Essential	Clause 3.3.2
07	Ultrasonic instrument	Essential	Clause 3.1
08	Calibration blocks and techniques	Essential	Clause 8, 12,17,18, Fig. 5,6,13,14 & 15
09	Direction and extent of scanning	Essential	Clause 6.1, 6.2, 6.3
10	Scanning (Manual)	Essential	Clause 6.1
11	Method for discriminating geometry and flaw	Essential	Clause 13.3
12	Method of sizing indications	Essential	Clause 15
13	Computer enhanced data acquisition	Essential	Not Applicable
14	Scan overlap(decreased only)	Essential	Clause 6.1
15	Personnel performance requirement	Essential	Clause 4.1
16	Personnel qualification requirement	Non Essential	Clause 4.1
17	Surface condition	Non Essential	Clause 5
18	Couplant: brand name or type	Non Essential	Clause 3.4
19	Post examination cleaning technique	Non Essential	Clause 24.1
20	Automatic alarm and recording equipment	Non Essential	Not applicable.
21	Records including minimum calibration data to be recorded (e. g-Instrument settings)	Non Essential	Equipment setting values & calibration data covered in the report

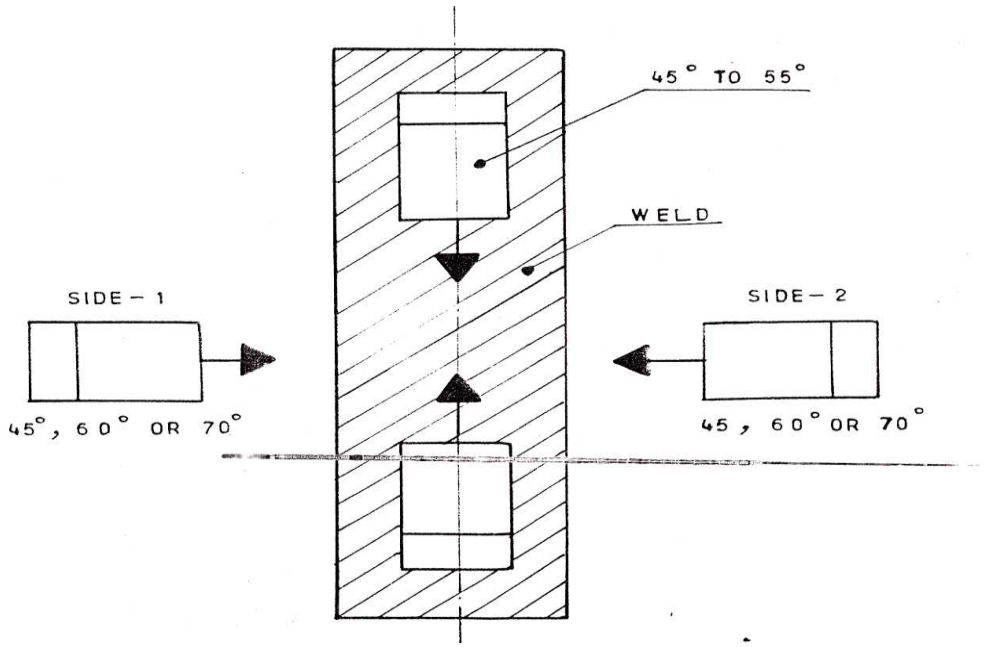
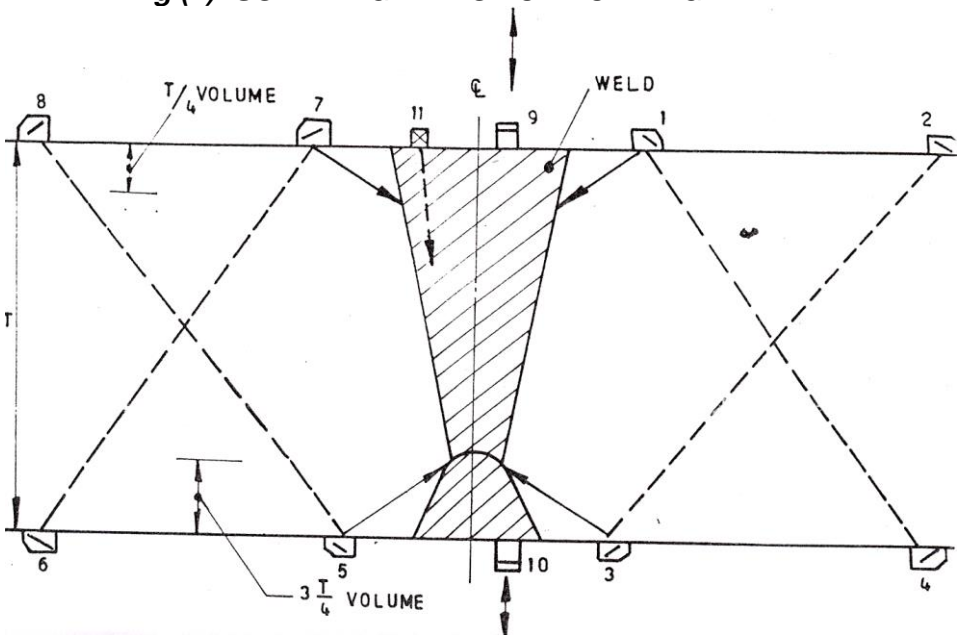


Fig (1): SCANNING DIRECTION FOR ANGLE BEAM



Probe position: 1 to 8: scanning perpendicular to weld axis- angle beam
9 & 10: scanning along weld axis- angle beam
11 : straight beam scanning

Evaluation area: ¼ TO 5/4 T on sweep line

Fig (2): SCANNING DIRECTIONS AND EVALUATION AREAS FOR BUTT WELDS

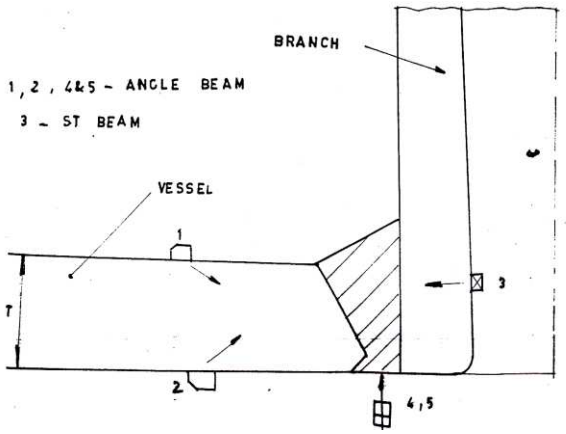


Fig (3): SCANNING DIRECTIONS FOR FULL PENETRATION CORNER WELDS (SET – THROUGH)

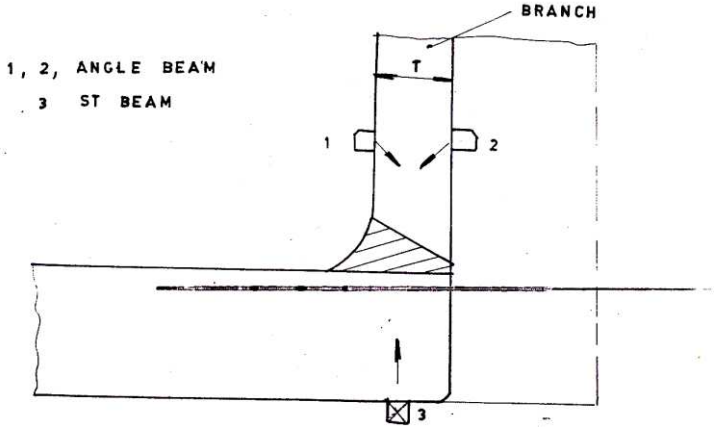
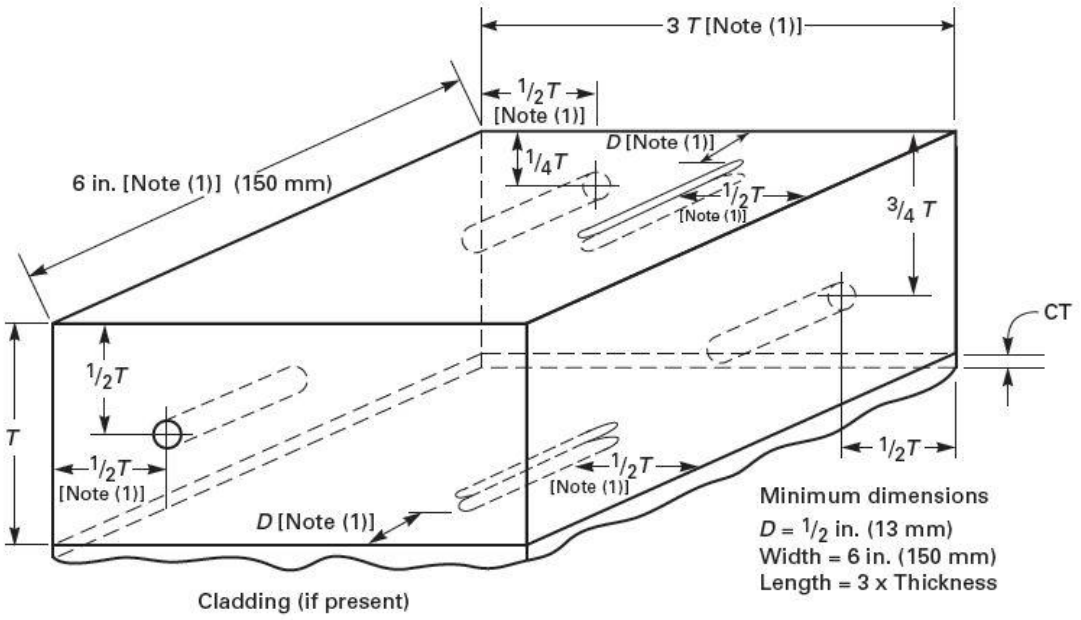


Fig (4): SCANNING DIRECTIONS FOR FULL PENETRATION CORNER WELDS (SET- ON)



Wall Thickness (t) (mm	Calibration Block Thickness (T) mm	Hole Diameter-mm
Up to 25	19 or t	2.5
Over 25 through 50	38 or t	3
Over 50 through 100	75 or t	5
Over 100	T ± 25	For each increase in weld thickness of 50 mm or fraction thereof over 100 mm, the hole diameter shall increase 1.5 mm.

Notch Dimensions	
Notch Depth (mm)	1.6% T to 2.2 %T
Notch Width (mm)	6 mm Maximum
Notch Length	25 mm minimum

GENERAL NOTES:

(a) Holes shall be drilled and reamed to a minimum length of 38 mm, essentially parallel to the examination surface.

(b) For components equal to or less than 500 mm in diameter, calibration block diameter shall meet the requirements of Clause 8.1. Two sets of calibration reflectors (holes, notches) oriented 90 deg. from each other shall be used. Alternatively, two curved calibration blocks may be used.

(c) The tolerance for hole diameter shall be ±0.8 mm. The tolerance for hole location through the calibration block thickness (i.e., distance from the examination surface) shall be ±3 mm.

(d) For blocks less than 19 mm in thickness, only the 1/2T side-drilled hole and surface notches are required.

(e) All holes may be located on the same face (side) of the calibration block, provided care is exercised to locate all the reflectors (holes, notches) to prevent one reflector from affecting the indication from another reflector during calibration.

(f) When cladding is present, notch depth on the cladding side of the block shall be increased by the cladding thickness, CT (i.e., 1.6% T + CT minimum to 2.2% T + CT maximum).

(g) Maximum notch width is not critical. Notches may be made by EDM or with end mills up to 6.4 mm in diameter.

(h) Weld thickness, t, is the nominal material thickness for welds without reinforcement or, for welds with reinforcement, the nominal material thickness plus the estimated weld reinforcement not to exceed the maximum permitted by the referencing Code Section. When two or more base material thicknesses are involved, the calibration block thickness, T, shall be determined by the average thickness of the weld; alternatively, a calibration block based on the greater base material thickness may be used provided the reference reflector size is based upon the average weld thickness.

***NOTES*:**

(1) Minimum dimension.

Fig (5):NON-PIPING CALIBRATION BLOCKS

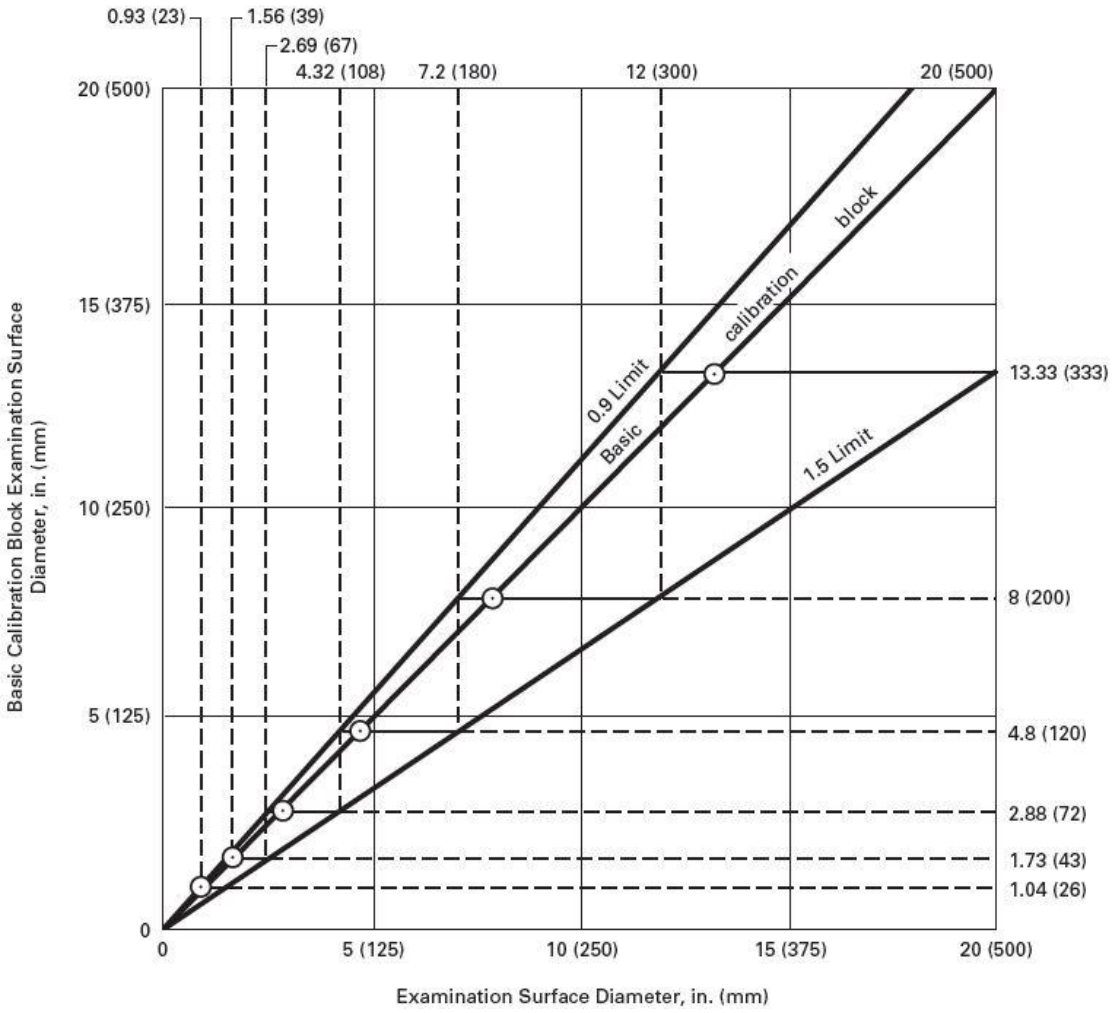


Fig (6): RATIO LIMITS FOR CURVED SURFACES

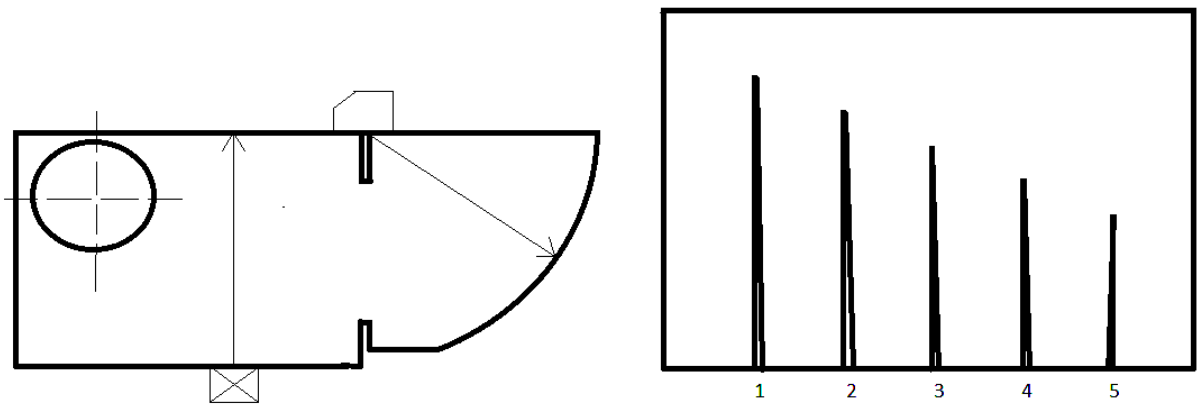


Fig (7): SWEEP RANGE (ANGLE BEAM)

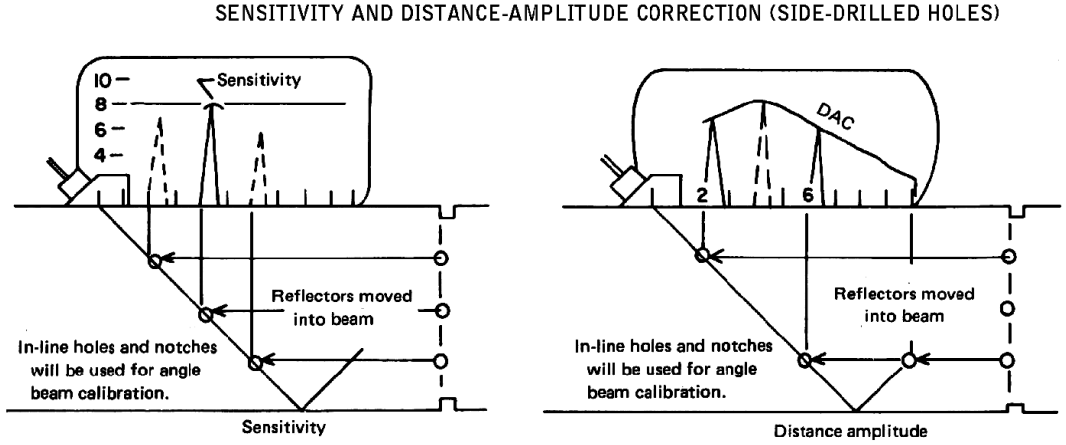


Fig (8): DISTANCE-AMPLITUDE CORRECTION (ANGLE BEAM)

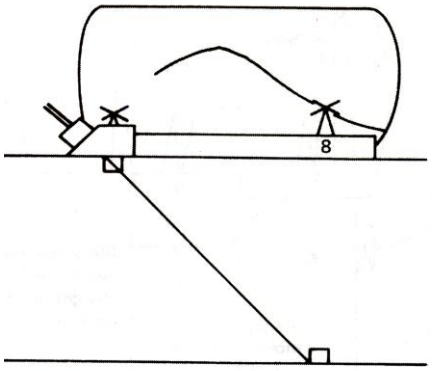


Fig (9) :(ANGLE BEAM) PLANAR REFLECTIONS

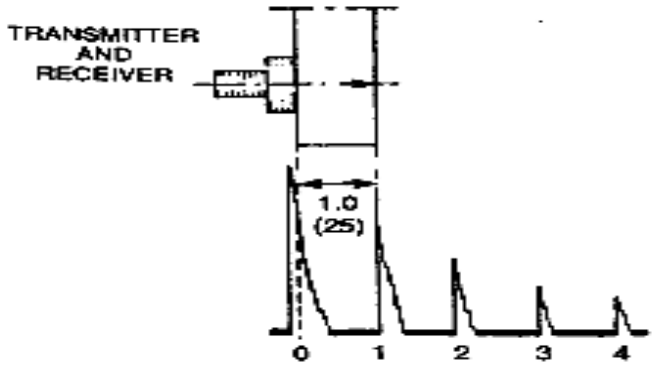


Fig (10): SWEEP RANGE (STRAIGHT BEAM)

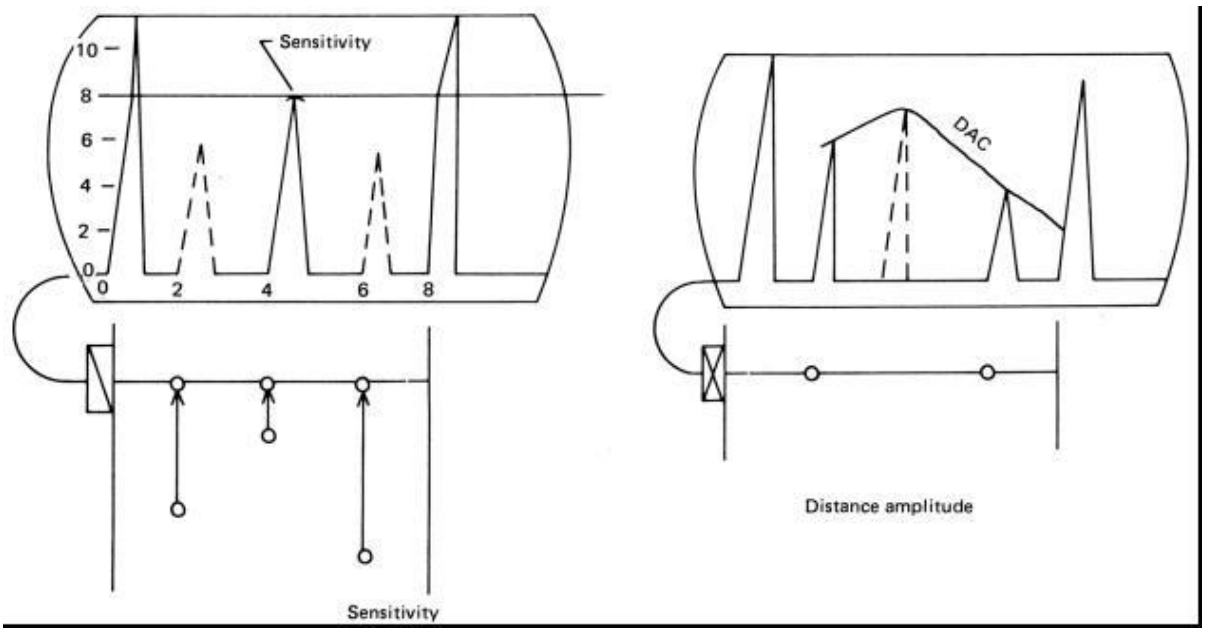


Fig (11): Sensitivity and Distance Amplitude Correction

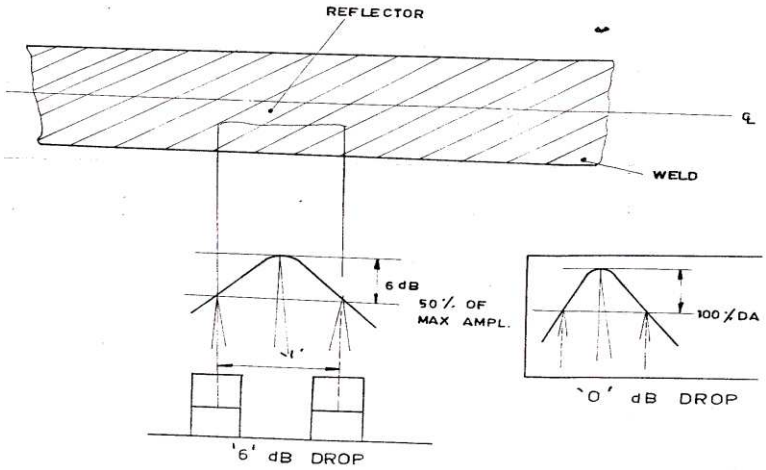
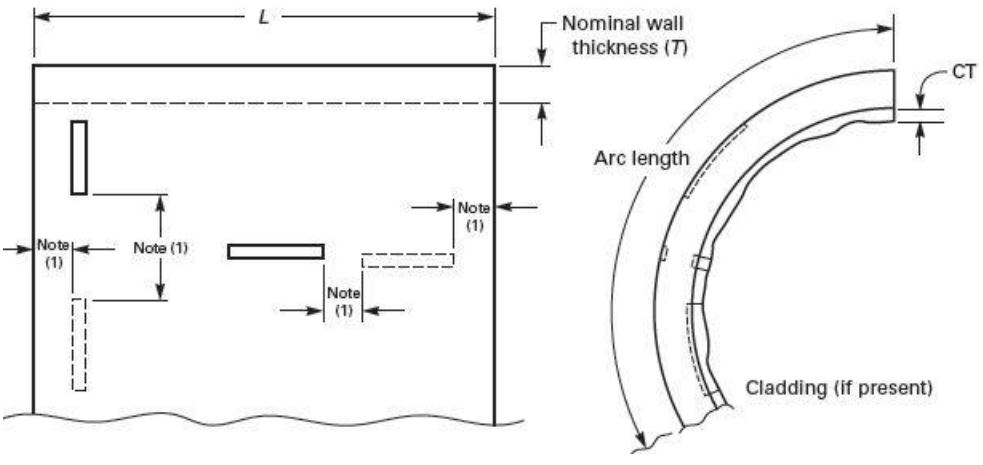


Fig (12): MEASUREMENT OF LENGTH OF REFLECTOR



General Notes:

(a) The minimum calibration block length, L, shall be 200 mm or 8T, whichever is greater.

(b) For OD 100 mm or less, the minimum arc length shall be 270 deg. For OD greater than 100 mm, the minimum arc length shall be 200 mm or 3T, whichever is greater.

(c) Notch depths shall be from 8% T minimum to 11% T maximum. Notch widths shall be 6 mm maximum. Notch lengths shall be 25 mm minimum.

(d) Maximum notch width is not critical. Notches may be made with EDM or with end mills up to 6 mm in diameter.

(e) Notch lengths shall be sufficient to provide for calibration with a minimum 3 to 1 signal-to-noise ratio.

(f) Two blocks shall be used when a weld joining two different thicknesses of material is examined and a single block does not satisfy the requirements of Clause 17.

(g) When a flat block is used as permitted by Clause 17.2, the two axial notches may be omitted and the block width may be reduced to 100 mm provided the I.D. and O.D. notches are placed on opposite examination surfaces of the block. When cladding is not present, only one notch is required provided each examination surface is accessible during calibrations.

NOTE: (1) Notches shall be located not closer than 1/2T or 1/2 in. (13 mm), whichever is greater, to any block edge or to other notches.

Fig (13).CALIBRATION BLOC FOR PIPE

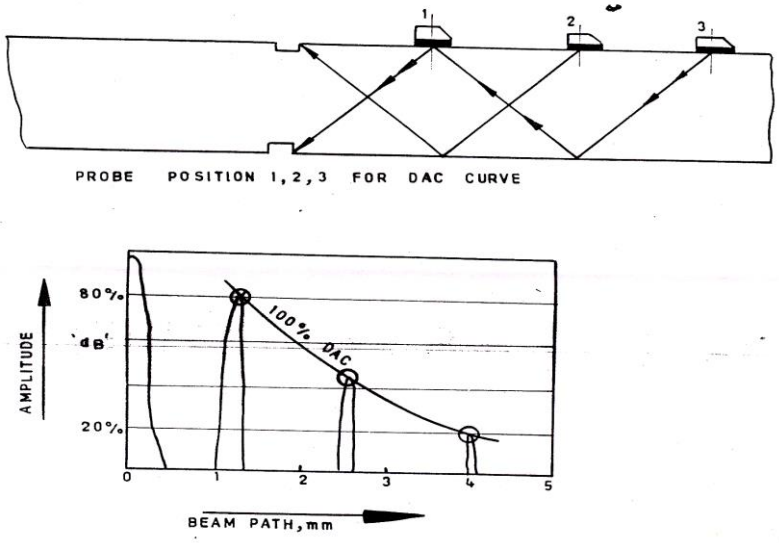
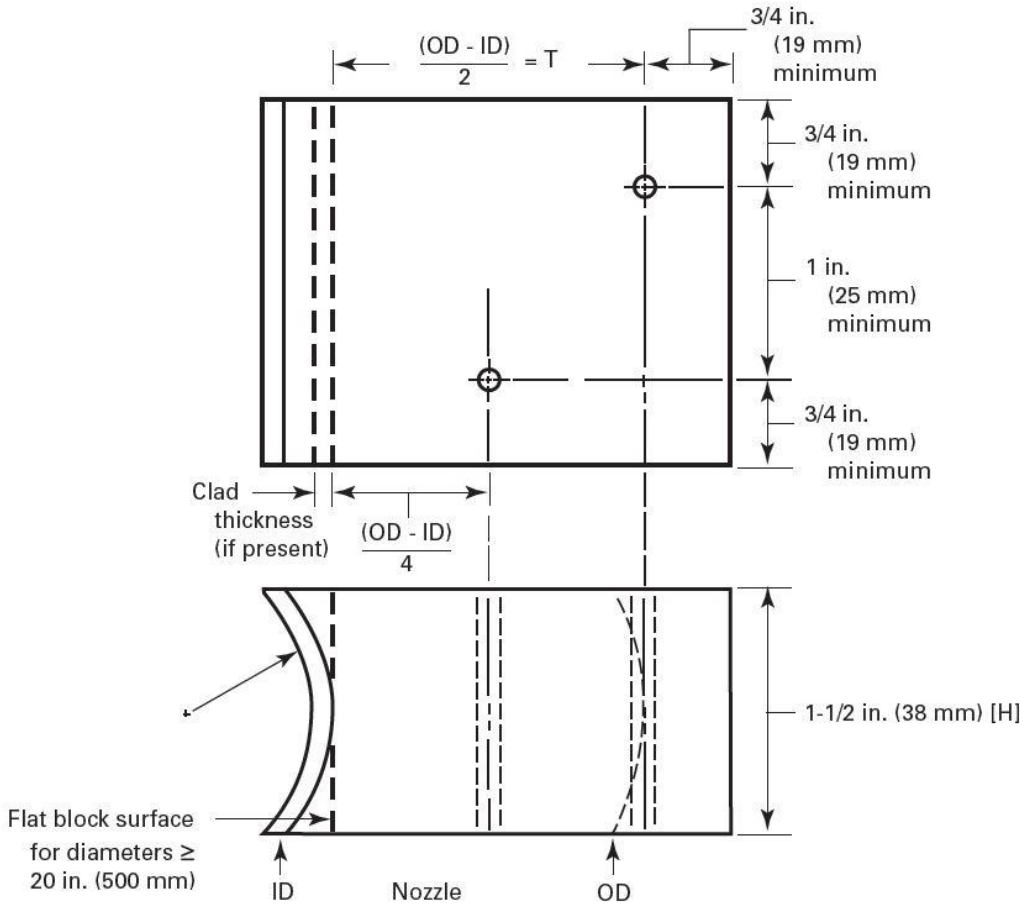


Fig (14): DISTANCE AMPLITUDE CORRECTION (ANGLE BEAM)



Calibration block wall thickness(mm)	Hole location 5/8 T	Hole location 6/8 T	Hole location 7/8 T
>50 through 75		X	
>75	X		X

GENERAL NOTES:

(a) The thickness (T) of the calibration block (OD – ID)/2 shall be selected for the maximum nozzle wall thickness under the nozzle attachment weld.

(b) Side-drilled holes shall be drilled and reamed the full height [H] of the block.

(c) The diameter of the side-drilled holes shall be selected for the maximum nozzle wall thickness per (a) above and Fig (5).

(d) For nozzle side examinations, when the wall thickness of the calibration block exceeds 50 mm, additional side-drilled holes shall be placed in the block as required in the table below.

Fig (15): Calibration block-nozzle side weld fusion zone and adjacent nozzle parent metal examination

Fig (16): Surface Conditions over which UT need not be carried out

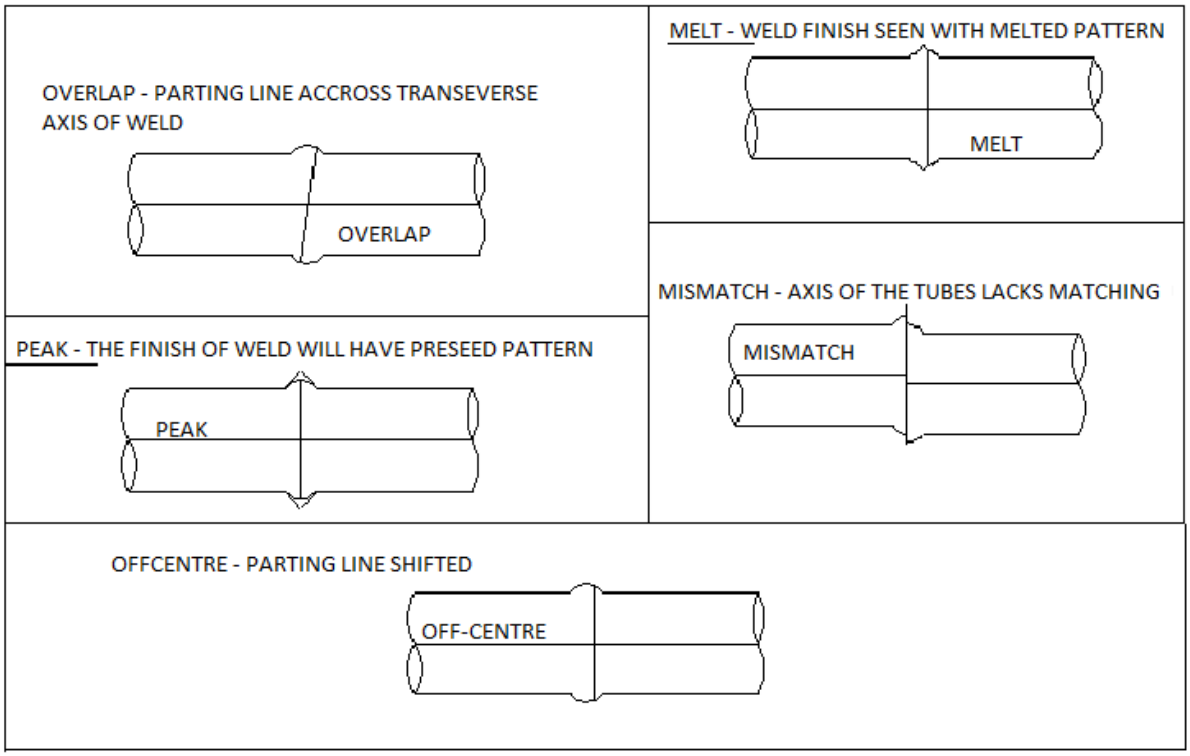


FIG:16

NOTE:

(1).Off-Centre,>1.5 mm, Peak, Melt, Mismatch and overlap are not acceptable

(2).UT need not to be done in case if IPW tube is found to be having such unacceptable defects mentioned in point No 1 above.

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CHAPTER 1.7

ULTRASONIC EXAMINATION OF BUTT WELDS IN X-20, P91 AND P92 PIPES

	BHARAT HEAVY ELECTRICALS LIMITED DEPT.235 – TIRUCHIRAPALLI – 620 014 Non-Destructive Testing	BHE: NDT: PB: UT- 21 Revision 09 Page 1 of 13

ULTRASONIC EXAMINATION OF BUTT WELDS IN X-20, P91 and P92 PIPES

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EFFECTIVE FROM 01.01.2020

RECORD OF REVISION

Rev. No.	Revision Date	Revision of Details
01	01-04-90	**********
02	01-09-97	Revised in entirety
03	15-03-2000	Revised to include P 91 material. Editorial corrections made
04	4-07-2000	8.4.1.1- Straight beam examination of base metal added. 9.2.3-weld geometry records added.
05	18.01.2010	1.1. 2.1, 3.2, 8.3, 8.4.1 modified Fig 9 added
06	05-06-2012	Title changed. 1.1,2.1,5.2,8.3 and 11.2 modified. 8.2.1 added. Figures 10,11,12 added.
07	16-07-2016	Clause 2.1,4.1,15.1,3.3.1 Revised
08	14-08-2018	Clause 2.2 revised
09	01-01-2020	Clause 2.2 & 4.1 revised

1.0 SCOPE

1.1. This procedure defines the requirements of equipment, calibration, examination procedure and acceptance standards for ultrasonic examination of butt welds, corner welds, Tee welds, fillet welds in X-20, P91 and P92 pipes of dia 120mm to 900 mm and thickness between 10 mm to 150 mm.

2.0 REFERENCE DOCUMENTS

2.1. AD-Merkblatt 2000 HP 5/3 –2011 edition

2.2. ASME-Section-V 2019 Edition

3.0 EQUIPMENT

3.1. The examination shall be conducted by manual contact testing. The equipment shall be of pulse - echo type with A-scan presentation that generates and receives frequencies in the range of 1 MHz to 5 MHz.

3.2. Analog or Digital equipment of Krautkramer /Germany or equivalent make will be used.

3.3. EQUIPMENT CALIBRATION

3.3.1. The Screen height linearity and amplitude control linearity shall be performed in accordance with ASME Sec V Article 4 Mandatory Appendix I & II at the beginning of each period of extended use or every 3 months for analog instrument and one year for digital instrument whichever is less.

3.4. PROBES

3.4.1. The nominal frequency of the probe shall be 4 MHz for thickness less than or equivalent to 40 mm and 2 MHz for thickness greater than 40 mm.

3.4.2. The crystal dimensions will be 8 x 9 mm or 20 x 22 mm and shall be appropriate to the examination surfaces ensuring adequate contact for transmission of ultrasonic vibrations.

3.4.3. Probes with curved contact wedges may be used to improve ultrasonic coupling in which case calibration shall be done with contact wedges used during the examination.

3.5. COUPLANT

3.5.1. Oil, Grease - oil mix or glycerine will be used as couplant. The couplant used for the examination shall be the same as that used for calibration.

4.0 PERSONNEL QUALIFICATION

4.1. Personnel performing examinations shall be qualified in accordance with employer's written down document which is prepared in line with ASNT SNT – TC -1A (2016). The testing shall be conducted by minimum Level-I Personnel & the interpretation and evaluation shall be done by minimum Level-II personnel.

5.0 SURFACE CONDITION

5.1. The probe-to-specimen contact area shall be free from weld spatter, rust, scale, grooves/depressions and other contaminations, which might interfere with probe-to-specimen contact.

5.2. To facilitate the detection of transverse flaws, the weld reinforcement shall be smoothly ground to ensure that there is proper contact between the probe and weld metal and with adjacent parent metal.

6.0 BASIC CALIBRATION BLOCK: Fig (1) and (2)

6.1. The basic calibration block will be a section of the pipe of same nominal size, schedule, heat treatment and material specification or equivalent P-number grouping. Separate calibration blocks shall be used to examine longitudinal and transverse flaws.

6.2. The surface finish of the calibration block shall be representative of the surface finish of the piping. The block width shall be a minimum of 50 mm.

6.3. The basic calibration reflectors shall be 3 mm dia cylindrical holes drilled through the entire width of the block as shown in the sketch.

6.4. A square notch of size 1 mm x 1 mm shall be used to adjust the sensitivity for detection of flaws in the root area and to furnish proof of form echoes in welds at root.

7.0 DISTANCE AMPLITUDE CORRECTION (DAC) - FIG (3) and (4)

7.1. DAC shall be established with basic calibration reflectors. The peak of the indications is marked on the screen and extended to cover the entire examination range for 3/8 to full skip distance between 80% to 20% of Full Screen Height (FSH). This is the reference response (PRR) level.

8.0 EXAMINATION

8.1. The ultrasonic test shall be performed after the last heat-treatment of the production weld.

8.2. The examination shall be performed with TWO angle beam probes. One of the beam angles (incident angle from entry surface) for testing shall be 45 degrees and the other either 60 or 70 depending on the weld configuration.

8.3. The scanning shall be performed from outer surface and from each side of the weld by moving the probes from 3/8th to one-vee sound path (full skip) distances. If only one side is accessible, testing within the stated scope takes place on one side only. In the case of nozzle welds, wherever scanning distance is insufficient, it can be also be done from inside of the nozzle (Fig 9).

8.4. Area of base-metal coverage - FIG (5)

8.4.1. The entire volume of the weld inclusive of adjacent base metal (heat-affected zone) shall be scanned by moving an angle-beam probe over the examination surface to appropriate distances. The evaluation range includes the entire skip distance in the case of smaller beam angle and includes half skip distance in the case of large beam angle. The adjacent base metal on both sides of the weld, to be included for scanning is: 10 mm for weld thickness (t) less than or equal to 30mm;1/3 't' for 't' greater than 30 mm and less than or equal to 60 mm and 20 mm for 't' greater than 60 mm.

8.4.2. The entire area of base metal inclusive of heat affected zone on both sides of the weld on which the angle-beam probe is employed for examination shall be examined using a straight-beam probe to detect reflectors that might affect interpretation of angle-beam results and is not used for acceptance -rejection examination. Location and areas of such reflectors shall be recorded.

8.5. During scanning the probes shall be moved to and fro, with swiveling action of 10 degrees to 15 degrees on either side with overlap between successive scanning. Each pass of the probe shall overlap a minimum of 10% of the crystal element dimension perpendicular to the direction of the scan. (FIG 5).

8.6. The rate of probe movement for examination shall be less than or equal to 150 mm/sec.

8.7. LONGITUDINAL FLAW SCANNING

8.7.1. The angle beam shall be directed at 90 degrees to the weld axis. The probe shall be manipulated so that ultrasonic energy passes through the required volumes of weld and adjacent base material as in 8.4.

8.8. TRANSVERSE FLAW SCANNING

8.8.1. The incident beam angle shall not be less than 45 degrees.

8.8.2. The angle beam shall be directed essentially parallel to the weld axis and the probe shall be manipulated so that the angle beam passes through required volumes of weld and adjacent base metal as in 8.4. The probe shall be rotated 180 degree and examination repeated.

8.9. ROOT FLAW SCANNING

8.9.1. For the evaluation of "Root Flaws" the amplitude response level from 1mm deep notch located at ID surface shall be compared with "PRR level". If the amplitude response is less than DAC, the gain setting shall be further increased to equalise DAC. If the response level is greater than DAC no further correction necessary.

8.10. EXAMINATION SENSITIVITY

8.10.1. For scanning, sensitivity settings shall be further increased by 6 dB and evaluation shall be performed at Primary Reference Response Level.

8.11. RECORDING LIMIT

8.11.1. All indications that equal or exceed 50 % of DAC, for longitudinal flaw scanning & 25% of DAC, for transverse flaw scanning at PRR Level shall be recorded.

9.0 EVALUATION OF ECHOES- FIG (6) and (7)

9.1. Indications that are determined to originate from surface conditions or weld shapes such as weld reinforcement, root protrusion, counter-bore, mismatched upset on ID and OD shall be assessed to identify and classify them as 'geometry indications'.

9.2. CONTROL MEASURES FOR GEOMETRY INDICATIONS

9.2.1. Response from 1 mm x 1mm square notch shall be employed for verification and accurate determination of projection distances involved during examination.

9.2.2. The following conditions related to indications obtained and which are assessed in line with 9.2.1, as a 'geometry indications due to shape' are acceptable. The verification shall be demonstrated over the total length of the reflector.

a) Mismatch / counter-bore: The reflector does not indicate an echo when scanned from the other side of weld

b) Excess penetration or Root-concavity: The echoes are received from both sides of the weld, that may be from the edges of a root-reinforcement or root-concavity with an overlap or a gap greater than 3mm between the locations of projected surface distances.

9.2.3. Weld geometry records will be made available at the time of examination.

10.0 LENGTH DIMENSIONING: FIG (8)

10.1. When the height of the indication from discontinuity exceeds the recording level, the length shall be obtained by 6 dB (50%) drop method for weld thickness less than or equal to 40 mm and by 12 dB (25%) drop method for weld thickness greater than 40 mm.

10.2. The lengths equal to and less than 10 mm shall be recorded as 10 mm. Other lengths measured shall be recorded in steps of 5 mm.

10.3. The measured length of Longitudinal flaw, as above, may be corrected for

a. Beam spread;
b. Projection of measured length of the defect to the outer surface.

10.4. Higher frequency/special probes may be used for assessment of flaws and flaw length measurement.

11.0 ACCEPTANCE STANDARD FOR LONGITUDINAL FLAW

11.1. All indications that exceed the primary reference level are not acceptable.

11.2. Indications from imperfections are not acceptable if the indications exceed 50% of the primary reference response level and have lengths which exceed

a. 20 mm for 't' greater than 10 mm and less than or equal to 20 mm

b. 25 mm for 't' greater than 20 mm and less than or equal to 40 mm

c. 30 mm for 't' greater than 40 mm and less than or equal to 60 mm

d. 40 mm for 't' greater 60 mm and less than or equal to 120 mm

e. 50 mm for 't' greater than 120 mm

where 't' is thickness of weld excluding any allowable reinforcement.

11.3. In any '6t' length of weld the aggregate length of indications shall not exceed '1.5 t' for thickness upto 60 mm and '2t' for thickness greater than 60 mm.

11.4. f the distance between successive indications is less than twice the length of the longer indication, the two indications in question shall be considered as continuous and evaluated as in 11.2.

11.5. For a butt weld joining two members having different thickness at the weld, 't' is the thinner of the thickness. If a full penetration weld includes a fillet weld, the thickness of 'throat' of the fillet shall be included in 't'.

12.0 ACCEPTANCE STANDARD FOR TRANSVERSE FLAW

12.1. All indications that exceed 50% DAC are unacceptable. Between 25% and 50% of DAC, only 3 indications of length upto 10 mm are permissible per meter of weld as transverse flaws.

13.0 POST CLEANING:

13.1. After the examination is over the couplant applied on the surface shall be removed, if the residue couplant on the surface applied could interfere the further use of the test piece.

14.0 REPAIR:

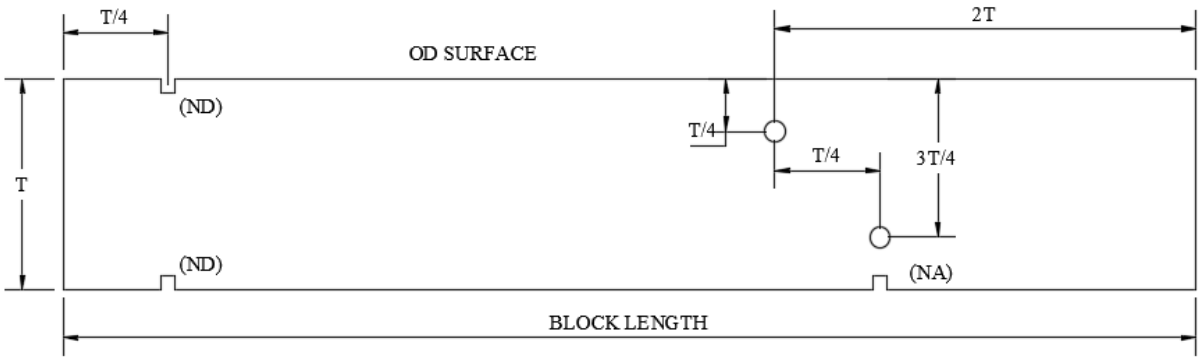
14.1. Repaired welds in shall be re-examined by the same procedure used for original testing.

15.0 REPORT:

15.1. A detailed report duly signed by a minimum Level II NDE personnel shall be issued in accordance with T-491 & T-492 of Article 4 ASME Sec V.

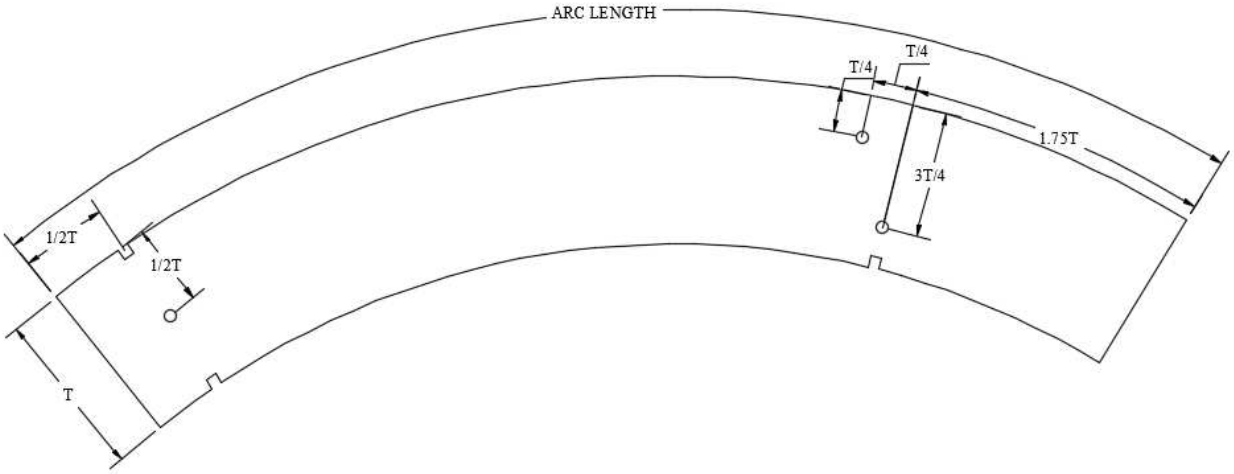
15.2. The records made in the inspection register shall be retained till manufacturing is completed, unless otherwise required.

****



CALIBRATION BLOCK 1 (L)
(SECTION OF PIPE PARALLEL TO PIPE AXIS)
3 mm CYLINDERICAL HOLE
ND 1mm x 1 mm NOTCHES(DIN)
NA 10% T DEEP NOTH

Fig (1)



CALIBRATION BLOCK 2 (T)
(SECTION OF PIPE PERPENDICULAR TO PIPE AXIS)
FIG (2)

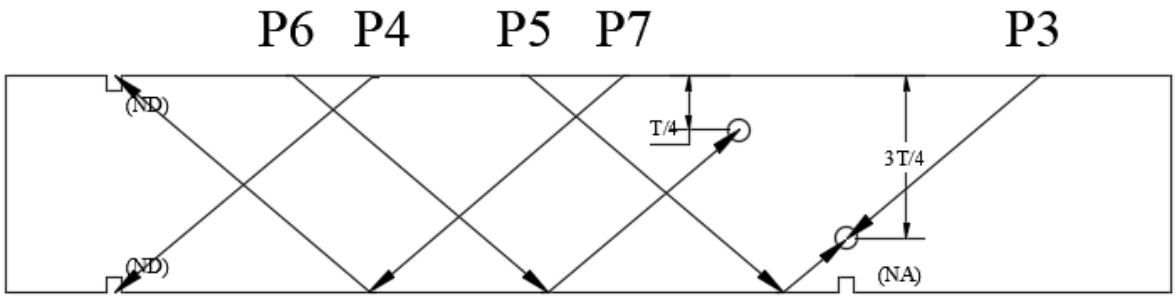


FIG (3) ANGLE BEAM CALIBRATION: AXIAL SCAN

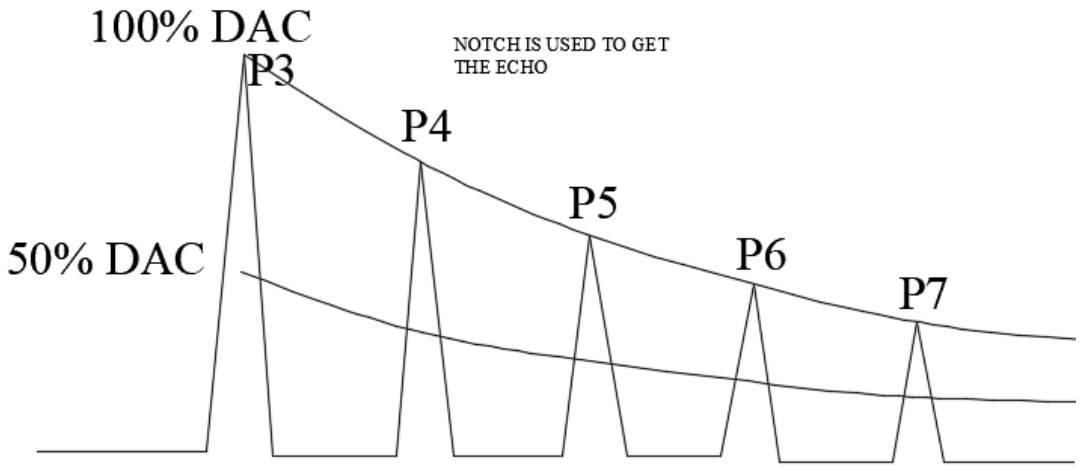


FIG (4) DAC FOR AXIAL SCAN

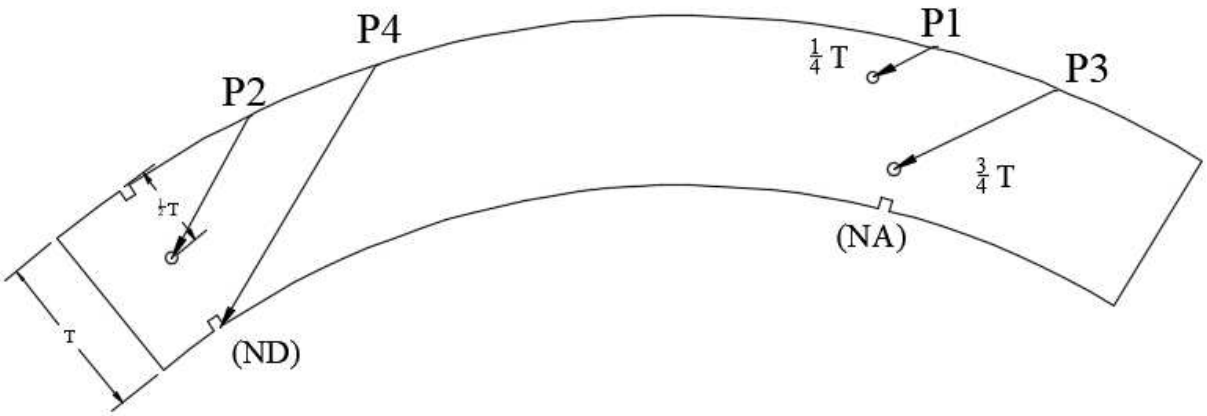


FIG (5) ANGLE BEAM CALIBRATION: CIRCUMFERENTIAL SCAN

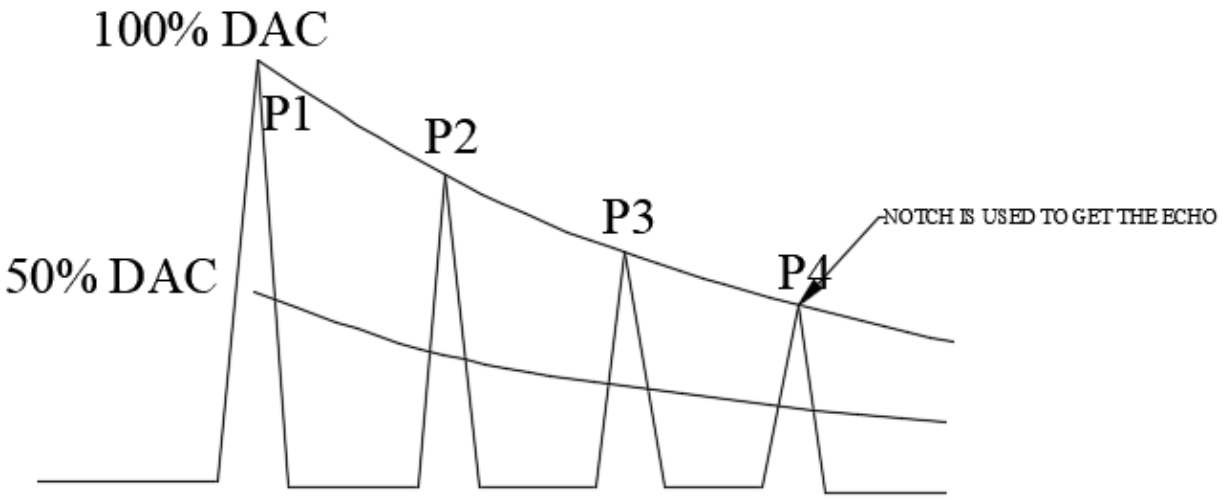
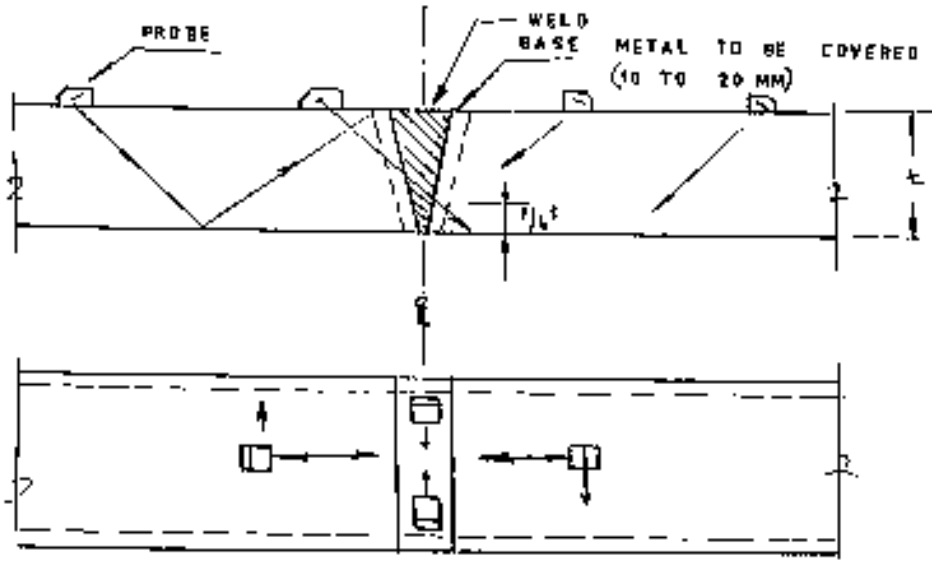
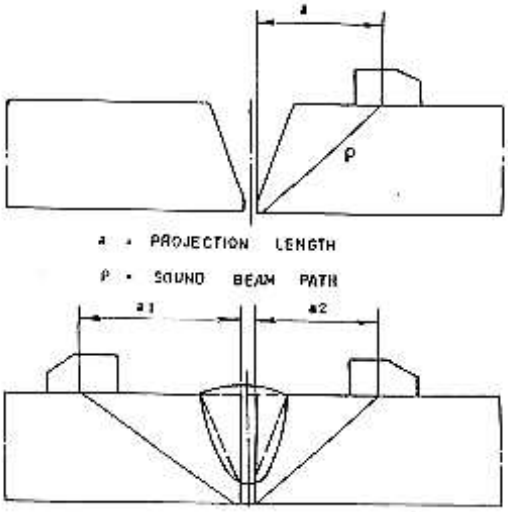


FIG (6) DAC FOR CIRCUMFERENTIAL SCAN

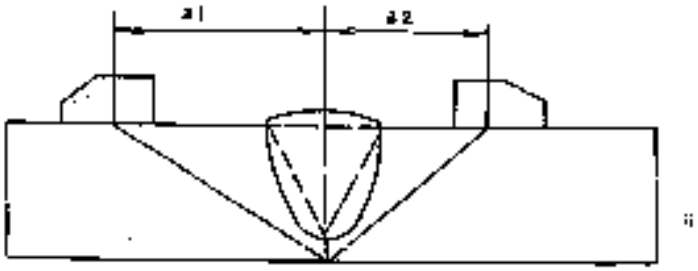


OVERLAP 10% **SWIVELLING** 10 to 15 Degrees

FIG (5) SCANNING DIRECTIONS

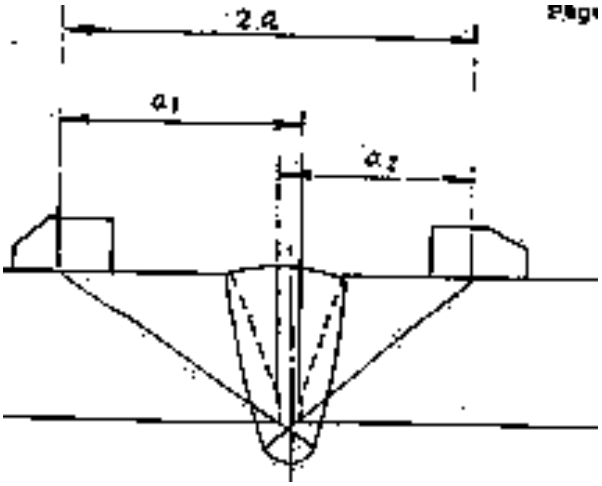


a1 and a2 INCOMPLETE ROOT PENETRATION

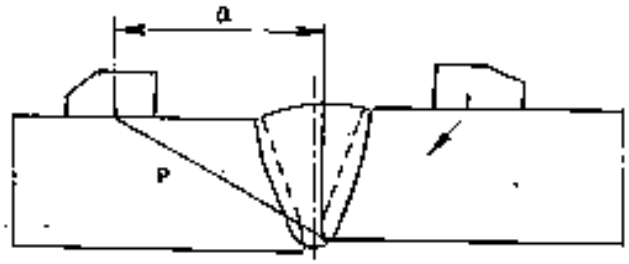


a1 and a2 TIGHT INCOMPLETE ROOT PENETRATION

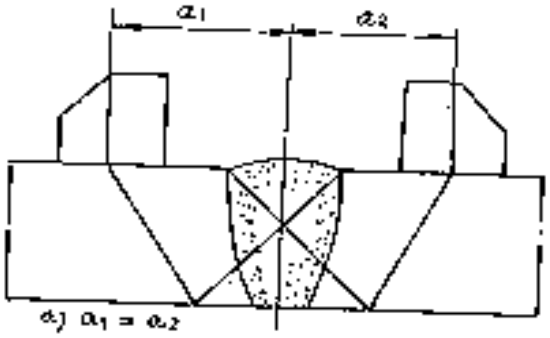
Fig (6)



EXCESSIVE ROOT PENETRATION (a1+a2)=2a = >2MIN



LINEAR MIS ALIGNMENT



EXCESSIVE REINFORECEMENT (Fig 7)

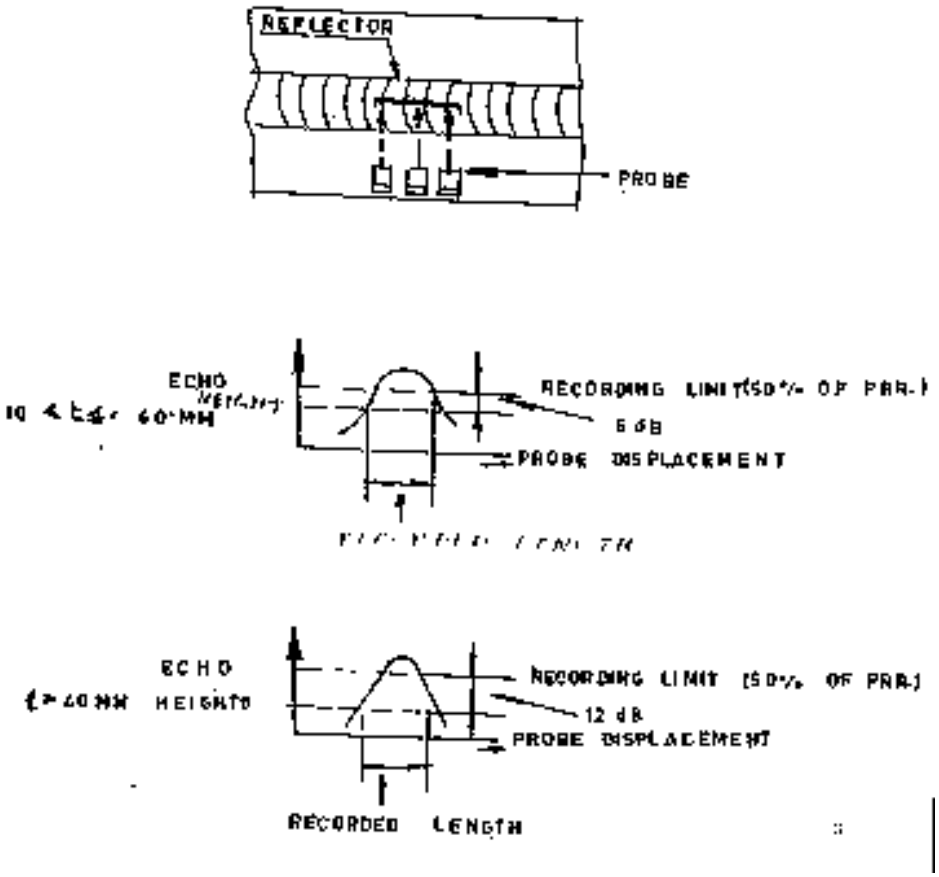
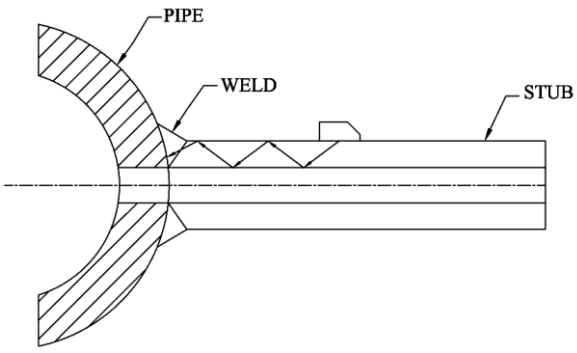


FIG (8) DETERMINATION OF LENGTH OF REFLECTOR



Fig(9) FILLET WELD EXAMINATION

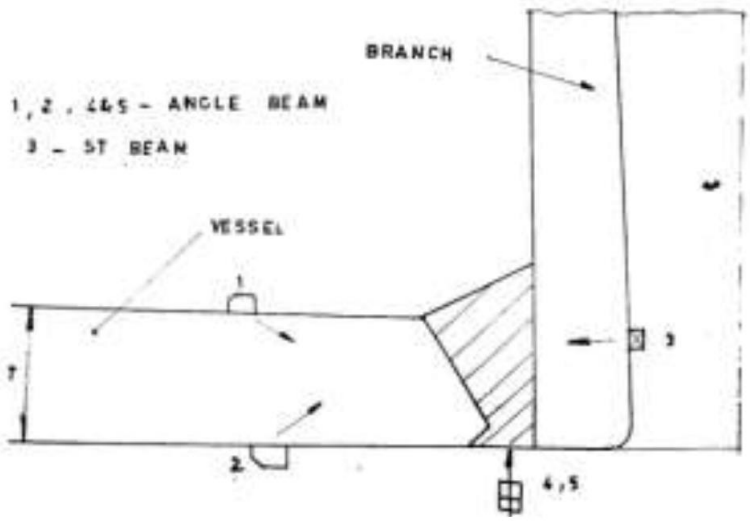


Fig. 10. SCANNING DIRECTION- FULL PENETRATION CORNER WELD (SET-THROUGH)

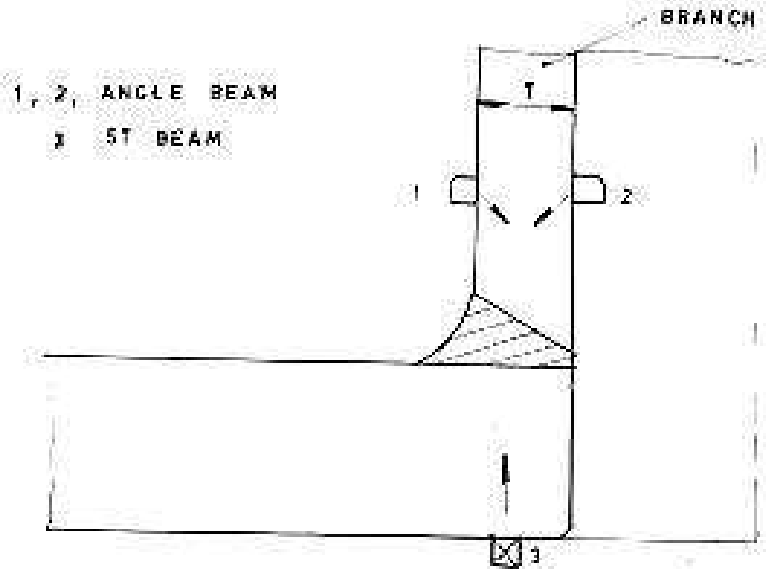


Fig.11. SCANNING DIRECTIONS FULL PENETRATION CORNER WELDS (SET-ON)

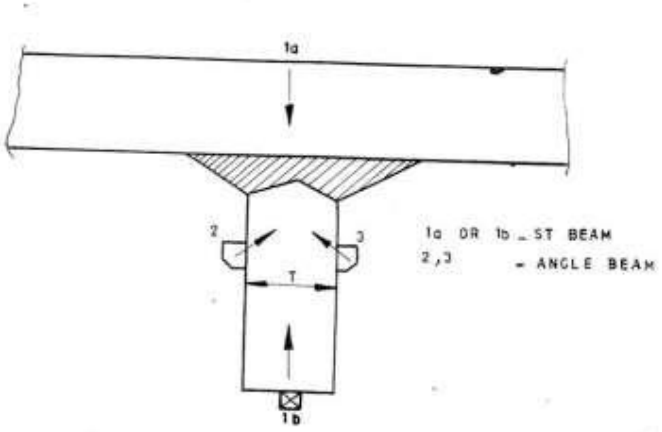


Fig.12. SCANNING DIRECTION FOR 'T' WELDS (ATTACHMENT)

CHAPTER 1.8
PROCEDURE FOR CALIBRATION OF PULSE-ECHO ULTRASONIC TESTING SYSTEMS

PROCEDURE FOR CALIBRATION OF PULSE-ECHO ULTRASONIC TESTING SYSTEMS

Prepared By	Reviewed By	Approved By	Issued By
01-01-2020	01/01/2020	01-01-2020	01/01/2020
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Effective from 01-01-2020

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
01 & 02	****	Kept separately
03	21-07-1997	Editorial corrections reflecting Addenda 1996
04	26-12-2006	2.1 Revised 5.2 Modified 10.1 Modified Figure numbers 1 to 4 rearranged
05	30-12-2011	2.1 Revised 9.2 Revised 9.3 Added
06	29-07-2013	Clause 1.0, 2.1, 3.2, 9.2 Revised Clause 9.4 Added Report Format Revised
07	01-01-2016	Clause 2.1 and Table 1 revised
08	01-01-2020	Clause 2.1, 2.2, 6.2, 7.1 revised

1.0 Scope

1.1. This procedure describes the method of Calibration of Pulse-echo, manual contact method Ultrasonic testing equipment with A-scan display.

2.0 REFERENCE DOCUMENTS

2.1. ASME - Section V - *2019*

2.2. SE317-16

3.0 Equipment

3.1. Ultrasonic Testing Equipment.

3.2. 4MHz Miniature Normal and Angle Beam Probe, and basic calibration block, shall be used for calibration. The calibration block shall be of similar metallurgical structure and possess the same attenuation characteristics as that of the material under test. For contact examination the temperature difference of the examination surface and the calibration block surface shall be within 14 degree C.

4.0 Linearity of Time Base

4.1. Linearity of the time base shall be checked using Normal probe on IIW block or any other basic calibration block.

4.2. The linearity shall be verified for 100mm, 250mm and 500mm range.

4.3. 100mm range shall be verified with N-23 or 4 MHz miniature normal probe with the IIW block or any of the basic calibration blocks. 4 echoes will be obtained from 25mm side. 1st echo and 3rd echo will be made to coincide with 25mm and 75 mm of the time base. Then 2nd and 4th echo will automatically align with 50mm and 100 mm mark.

4.4. For 250mm range, using delay control, the leading edge of first echo will be adjusted to the '0' division of the time base. If the 6th echo remains on 10th division, the range is linear.

4.5. The procedure as in 4.4 will be repeated for 500 mm range, with first echo on '0' division and 11th echo on 10th division.

4.6. The non-linearity of the time-base shall not be greater than 2% of the full scale range or ± one minor sub-division of the chosen range of the time base (fig-1&fig.-2).

5.0 Verification of Screen Height Linearity

5.1. A straight-beam search unit having the nominal frequency 2MHz or 4 MHz, shall be used. The search unit shall be positioned over the depth resolution notch in the IIW Block so that the signal from the notch is 40% of the screen height, and the signal from the 100mm back surface is 80% of screen height, to give 2:1 ratio.(Fig.3).

5.2. Without moving the search unit, the gain setting is decreased in 2 dB step and the height of notch signal and back reflection are to be recorded. The reading of notch echo shall be 50%

of back reflection echo within 5% of full screen height. The setting and readings shall be established to the nearest 1% of full screen height.

6.0 Verification Of Amplitude-Control Linearity

6.1. Drilled holes shall serve as basic calibration reflectors. The depth, location and diameter of the holes shall be as given in Fig.4. Alternatively, any other conventional reflector from any calibration block may be used with straight or angle beam.

6.2. To verify the amplitude control linearity, an angle beam search unit is positioned as shown in Fig.4, and beamed towards the 1/2t hole in the basic calibration block. The indication is peaked on the screen to 80 %. With the decrease and increase of dB as shown in the table-1 below. The amplitude of the corresponding echo is noted. The indications must be within the specified limits.

TABLE - 1

Indications set at % of full screen	dB control change	Indication limit % of full screen
80%	-6 dB	35 to 45%
80%	-12dB	*15 to 25%*
40%	+6 dB	*65 to 95%*
20%	+12dB	*65 to 95%*

The setting and readings must be estimated to the nearest 1% full screen.

7.0 Sensitivity

7.1. The sensitivity of the equipment shall be checked with an angle beam probe by detecting the 1.5 mm side drilled hole in the IIW block. Sensitivity shall also be checked with a straight beam probe by placing on the surface of the plastic insert of IIW Calibration block and verifying the number of full- screen bottom echoes visible on the screen. At the full-gain setting, if necessary, the number of echoes shall be not less than the numbers shown below for the appropriate frequency range.

Frequency Range MHz	Minimum number of full screen bottom echoes
1.0 to 2.0	3
2.0 to 5.0	2

8.0 CHECKING OF RESOLUTION

8.1. The search unit and apparatus combined shall be capable of clearly resolving two or more echoes reflected from defects situated close to one another. When the search unit (normal probe) is position over the depth resolution notch in IIW block, the reflection is from 85, 91 and 100mm.

8.2. The echoes from 91 and 100mm shall be kept equal to 80% of screen height. If the falling edge of the first echo is within 20% of the full screen (the first major division of the vertical scale) the resolution is satisfactory. Patterns of good and poor resolution are shown in Figure-5.

9.0 Frequency Of Calibration

9.1. During calibration if the linearity is not within the limits mentioned above, the equipment will be sent for rectification.

9.2. Verification of vertical scale linearity, amplitude control linearity and linearity of time-base shall be performed every 3 months for analog and every one year for digital equipment, or whenever the unit has under gone major repairs or maintenance, or the accuracy of the equipment is suspected.

9.3. When the equipment is lost, damaged, or found to be out of calibration, the validity of previous measurement, inspection or test results and the acceptability of items previous inspected or tested shall be evaluated.

9.4. The normal and angle beam probes along with the cables used shall be checked before the use.

10.0 Report and Retention Period

10.1. A report in the prescribed format shall be generated after calibration and issued to the custodian of the equipment. All the reports are to be retained for a period of three years from the date of calibration.

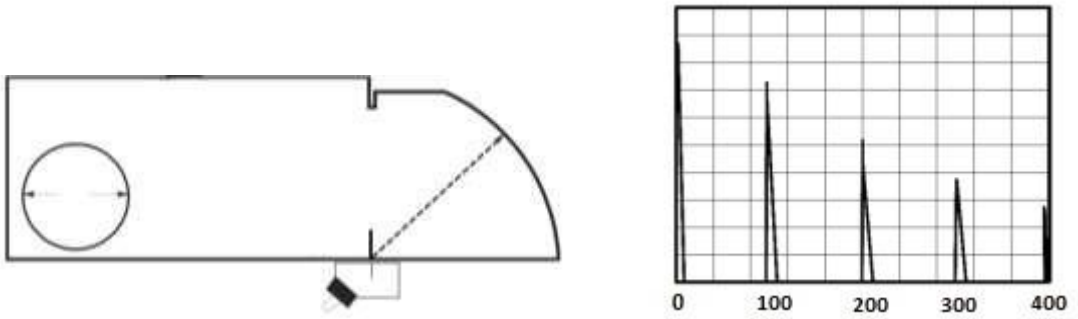

Fig 1 CALIBRATION FOR HORIZONTAL LINEARITY-ANGLE BEAM

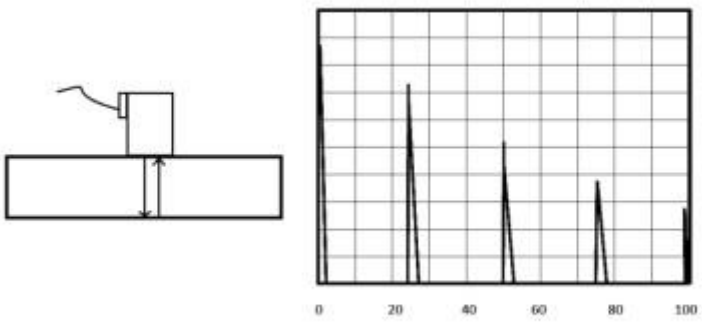

Fig 2 CALIBRATION FOR HORIZONTAL LINEARITY-NORMAL BEAM

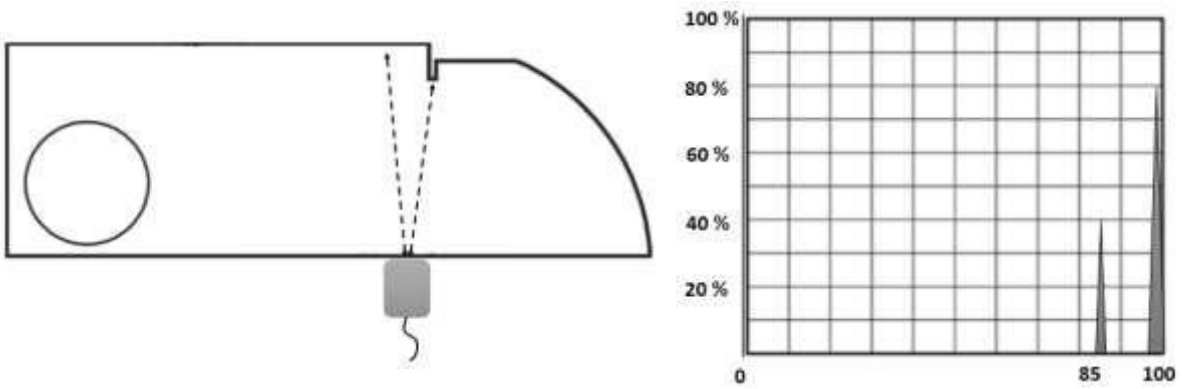

Fig. 3 CALIBRATION FOR SCREEN HEIGHT LINEARITY

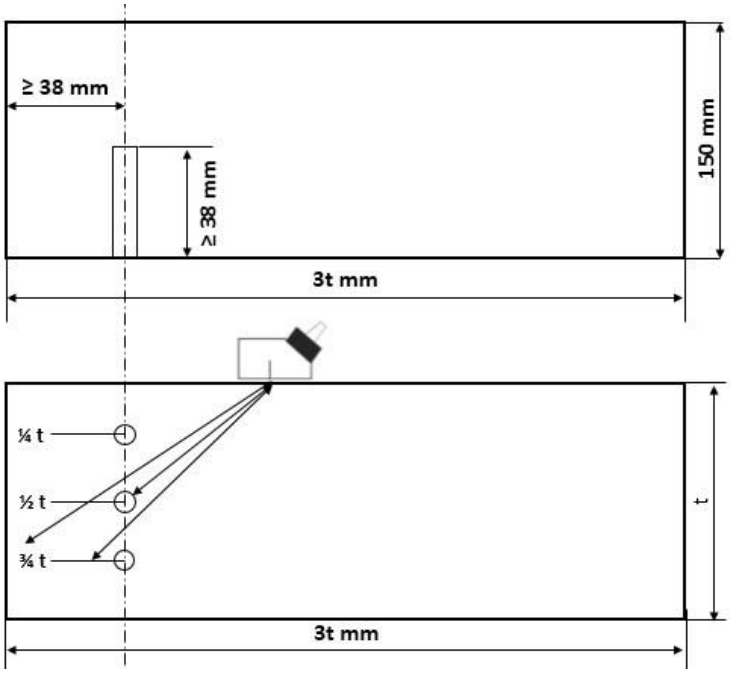

Fig 4 CALIBRATION BLOCK FOR AMPLITUDE CONTROL LINEARITY

Thickness 't' in mm	Calibration Block thickness 'T' in mm	Hole depth(mm)	Hole Dia(mm)
Over 50 thru 100 Over 100 thru 150 Over 150 thru 200	75 mm ot 't' 125 mm or 't' 175 mm or 't'	≥ 38 ≥ 38 ≥ 38	4.75 6.25 7.50

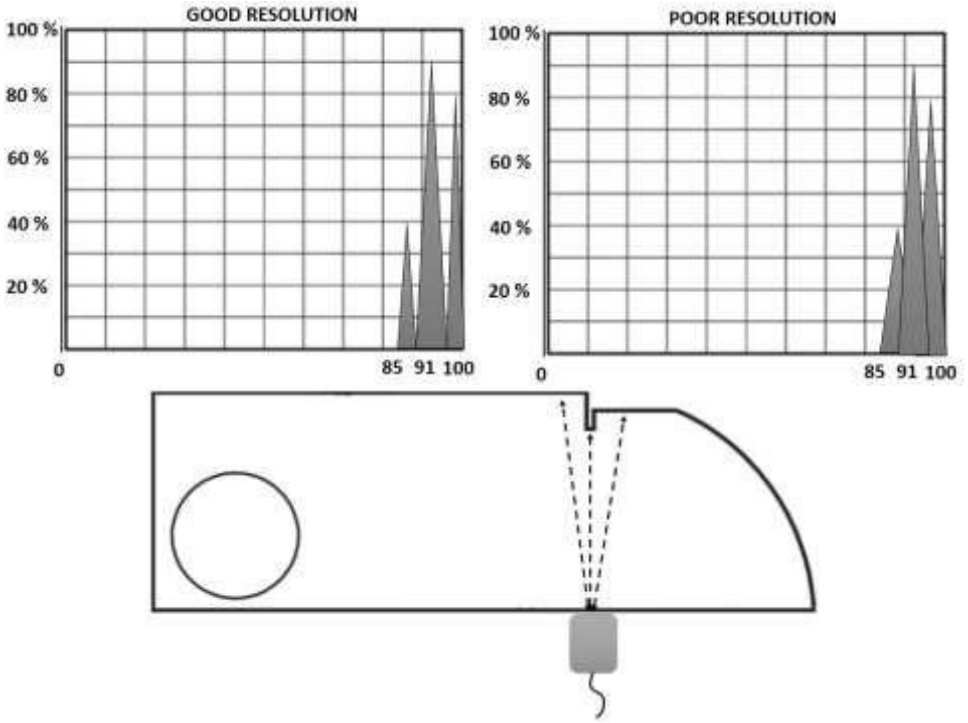

Fig 5 RESOLUTION PATTERN

Ultrasonic Test
Calibration Report

Area :
Type : Digital/Analog
For :

A: Equipment Details

01. Unit Model :
02. Serial No :
03. Make :

B: Calibration Details

04. Procedure Ref : BHE:NDT:UT:CALIB:01 Rev 08.
05. Date of Calibration :
06. *Validity of Calibration* :
(If the equipment has undergone any repair during the intervening period then the validity is not applicable.)

C: Calibration Data:

07. *Probe*:	Frequency	Size
Straight:	4MHz	mm
Angle:	2MHz	mm

08. Verification of screen height linearity:

dB value of larger height indication	1st Larger indication (a%)	2nd Smaller indication - Actual (b%)	2nd smaller indication- Expected (c%)	Deviation (Difference of b& c)
X=__dB X-2dB X-4dB X-6dB X-8dB X-10dB X-12dB				

Note: Deviations within ±5% of FSH are acceptable.

09. Verification of amplitude control linearity:

Indication set at % of full screen	dB control change	Indication Limits	Actual readings % of Full screen
80% 80% 40% 20%	-6dB -12dB +6dB +12dB	35% to 45% *15% to 25%* *65% to 95%* *65% to 95%*	

10. Linearity of Time Base:

Range	Reading	Echo Positions				
		1	2	3	4	5
100	Actual					
	Expected					
	Deviation					
250	Actual					
	Expected					
	Deviation					
500	Actual					
	Expected					
	Deviation					

Note: Deviation ±2% of range or ± one minor sub division is acceptable.

11. *Resolution* :

12. Sensitivity :

13. Remarks :

14. *Recommendation for Rectification* : Not Required /Required

Calibrated By
(Level-II)

Accepted By
(Level-II/III)

CHAPTER 1.9

ULTRASONIC EXAMINATION OF WELD JOINTS IN STRUCTURALS

ULTRASONIC TESTING OF WELD JOINTS IN STRUCTURALS

Prepared By	Reviewed &Approved By
Deepesh. V Level II Manager/ NDTL 01-11-2017	L. Marimuthu Level III Addl. General Manager, Head / NDTL 01/11/17

EFFECTIVE FROM 01-11-2017

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ISSUED TO	ISSUED ON	CONTROL NO.	ISSUED BY

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
01	23-10-2006	Clause 12.0 modified
02	01-07-2016	Clauses 1.0, 2.1, 3.1, 4.2.1, 9.2, 9.3, 9.5.1, 18, Annexures A, B (B.1.6, B.3.1, B.3.2, B.3.11, B.4.0, B.4.1, B. 4. 2), C, Revised. Captions for Figures (1), (2), (3), 4(a), 4(b), 5, 6 added. Notes Added in Figure (6). Clauses B.4.3, B.4.3 (Annexure B) removed.
03	01-11-2017	Clause 13.3 removed. Clauses 17.1.1 modified.

1.0 SCOPE

This procedure describes the Ultrasonic testing method for butt welds in Steel structures (thickness > 8 mm *and < 200 mm both inclusive*) where radiography with Ir-192 is not feasible at site. *This procedure shall not be applicable to tube-to –tube T, Y, K connections.*

2.0 REFERENCE

2.1 AWS D1.1 / D1.1.M 20*15- Structural welding code -Steel*

3.0 PERSONNEL QUALIFICATION

3.1 Personnel shall be trained and certified as Level II as per SNT-TC-1A of ASNT. *The qualification of the personnel shall include a specific and practical examination as per the requirements of this procedure or referencing code.*

4.0 EQUIPMENT

4.1 Ultrasonic equipment shall be of pulse echo A-scan type and operate in 1-6 MHz Frequency range.

4.2 CALIBRATION

4.2.1 The equipment shall be qualified as per annexure B at the following interval

- Gain control check –2 months.
- Horizontal Linearity – *2 months.*
- Internal Reflection - every 40 hours of equipment use.
- *Angle beam search units (Index point, Angle)-8 hours of use.*
- *Instrument / search unit combinations(Resolution for normal/angle beam)-prior to initial use*
- *Range, Sensitivity calibration for testing-Just prior to at the location of the first weld tested*

4.2.2 Equipment shall have a calibrated gain control adjustable to 1 or 2 dB step over a range of 60 dB. The accuracy of the gain setting shall be within +or- 1 dB.

4.2.3 Display Range

4.2.3.1 The dynamic of the display shall be such that a difference of 1 dB of amplitude can be easily detected on the display.

5.0 PROBES / TRANSDUCERS

5.1 STRAIGHT BEAM PROBES

5.1.1 Probes shall be Rounded or Square.

5.1.2 Crystal area shall be between 323 Sq mm and 645 Sq mm.

5.1.3 Resolution shall be good.

5.2 ANGLE PROBES

5.2.1 The transducer and angle wedge may be of an integral unit or two separate elements.

5.2.2 Probe shall be square or Rectangular.

5.2.3 Crystal width may be between 15 to 25 and height between 15-20 mm

5.2.4 Transducer frequency shall be between 2 to 2.5 MHz.

5.2.5 Angle of the probe shall be 70°, 60° or 45° with +/- 2° tolerance.
5.2.6 The distance between edge of probes and index point shall not exceed 25 mm.

6.0 REFERENCE STANDARDS.

6.1 IIW block shall be the standard block used for distance calibration and Sensitivity calibration.

6.2 Use of corner reflection for calibration shall be prohibited.

7.0 SURFACE PREPARATION.

7.1 All surfaces shall be free from weld spatters, dirt, grease, oil, paint, loose-scales etc.

8.0 COUPLANT.

8.1 Couplant to be used shall be glycerin, grease, oil, or grease and oil mixture.

8.2 Couplant used for calibration and testing shall be the same.

9.0 RANGE SETTING.

9.1 Calibration and testing shall be made with Nil reflection level. (Reject/clipping/suppression control shall be turned off)

9.2 Calibration for Sensitivity and range setting shall be done *by the UT operator just prior to and at the location of the first weld tested.*

9.3 Recalibration shall be done after
- Change of operator.
- *2 hours of interval.*
- Probe change.
- Battery change.
- Cable change.
- Power failure.

9.4.1 STRAIGHT BEAM TESTING OF BASE METAL.

9.4.2 Range setting shall be made by keeping the probe on face A (Fig 1.) of base metal and sweep adjusted for a distance of at least 2 Plate thickness.

9.4.3 From defect free location the back wall echo shall be adjusted using gain control for a height of 50% to 75 % Full Screen Height (FSH).

9.5 ANGLE BEAM RANGE SETTING.

9.5.1 The angle probe shall be placed in position D on IIW block (*Refer Fig. 2*) and sweep adjusted to have indications at 100 mm, 200 mm, 300 mm, etc. according to the probe angle and thickness of weld to be tested.

10.0 ZERO REFERENCE LEVEL ('b' on ultrasonic test report).

10.1 The probe shall be placed on position 'A' (fig 2) on IIW block and focused towards 1.59mm hole to attain a height of 50% of Full screen height by adjusting gain control. This gain shall be used as Zero Reference gain "b" in the report.

11.0 TESTING PROCEDURE

11.1 X-line -weld centerline on the Butt Weld shall be marked as X line to mark the defect location.

11.2 Y- line -to identify face A to measure the location, a 'y' line shall be drawn at the start of the weld.

11.3 Inaccessibility

11.3.1 If testing is not possible due to lamination in parent metal one of the following shall be used as an alternate.

- Weld shall be ground flush.
- Testing from face A and B shall be performed.
- Other angles may be used.

11.4 All butt joints shall be tested from each side of the face. Corner and T joints shall be from one side of the weld axis.

11.5 The scanning pattern shall be as in (fig3).

11.6 All welds shall be tested for entire volume and HAZ in 2 crossing directions wherever possible.

11.7 Probe swelling of 10° shall be given during scanning as in A in (Fig3).

11.8 The scanning towards the weld as in B (Fig 3) shall be such that the entire volume is covered.

11.9 Progression distance 'C' shall be ½ of probe width.

11.10 Flush ground weld transverse scanning shall be as in D(Fig 3)

11.11 For ungrounded weld, pattern 'e" shall be used for Transverse scanning at angle of 15° maximum.

12.0 TESTING ANGLE, SCANNING FACE & THICKNESS COVERAGE SELECTION.

Table-1

	Material Thickness, in [mm]																	
Weld Type	5/16 [8] to 1-1/2 [38]		>1-1/2 [38] to 1-3/4 [45]		>1-3/4 [45] to 2-1/2 [60]		>2-1/2 [60] to 3-1/2 [90]		>3-1/2 [90] to 4-1/2 [110]		>4-1/2 [110] to 5 [130]		>5 [130] to 6-1/2 [160]		>6-1/2 [160] to 7 [180]		>7 [180] to 8 [200]	
	*		*		*		*		*		*		*		*		*	
Butt	1	O	1	F	1G or 4	F	1G or 5	F	6 or 7	F	8 or 10	F	9 or 11	F	12 or 13	F	12	F

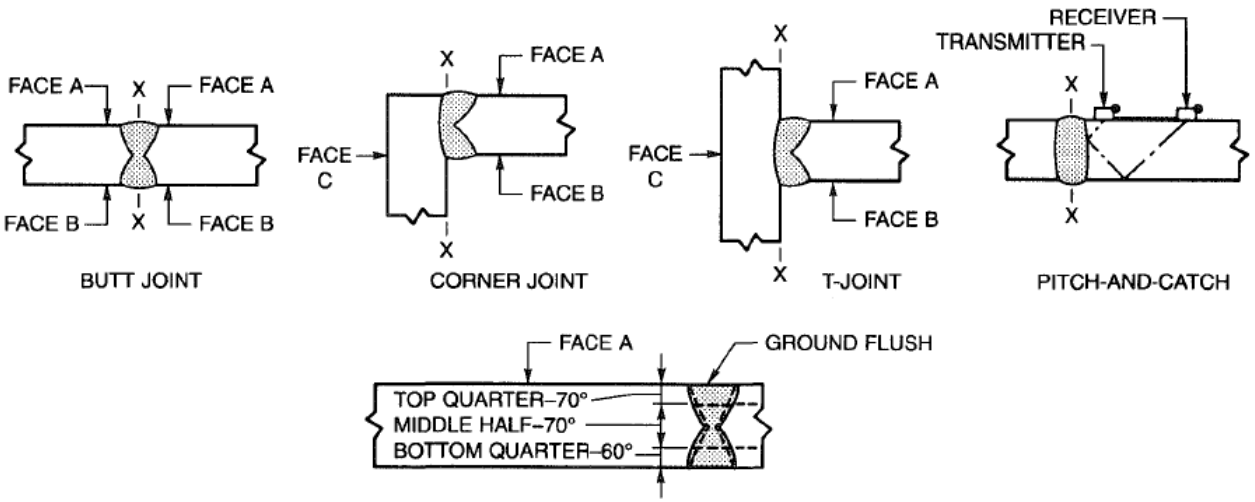


Fig (1)

General Notes

- Wherever possible all examinations shall be from Face A and Leg 1(0-1/2 skip) unless specified.
- Root areas of single groove weld which have backing not requiring removal, shall be tested in leg 1 and Face A opposite to Backing
- If weld is un-ground, Testing in Leg 2 or 3 shall be done.
- Testing in leg 3 shall be done when thickness or geometry prevents full coverage of weld.
- On Tension welds in cyclically loaded structures, top quarter shall be tested from Face A in leg 2 or from Face B in leg 1.
- The weld face shall be flush ground for procedure 1G, 6, 8, 9, 12, 14, 15

PROCEDURE LEGEND

Table-2

	AREA OF WELD THICKNESS		
	Top Quarter	Middle Half	Bottom Quarter
01	70º	70º	70º
02	60º	60º	60º
03	45º	45º	45º
04	60º	70º	70º
05	45º	70º	70º
06	70º G A	70º	60º
07	60º B	70º	60º
08	70º G A	60º	60º
09	70º G A	60º	45º
10	60º B	60º	45º
11	45º B	70º **	45º
12	70º G A	45º	70º G B
13	45º B	45º	45º
14	70º G A	45º	45º
15	70º G A	70º A B	70º G B

LEGEND

X :Check from Face A
G :Grind weld face flush
O :Not required
A Face :The face of material from which the initial scanning done
B Face :Opposite to Face A
C Face :The face opposite the weld on the connecting member of a T or Corner joint.
* :Required only where display reference height indication noted at the weld metal-base metal interface

** : Use 400 or 500 mm range
P : Pitch and Catch shall be conducted
F : weld metal-base metal interface indication shall be further evaluated with either 70, 60 or 45 probe.

13.0 SCANNING LEVEL

13.1 Statically loaded Non-tubular welds

Table-3

Beam Path in mm	Above Zero Reference dB
Up to 65 mm	14
65-125mm	19
125-250mm	29
250-380mm	39

13.2 Cyclically loaded Non-tubular welds

Table-4

Beam Path in mm	Above Zero Reference dB
Up to 65 mm	20
65-125mm	25
125-250mm	35
250-380mm	45

14.0 ATTENUATION FACTOR

14.1 Attenuation factor 'C' value in dB shall be calculated as follows

C= (Beam path in inches –1 inch) x 2
e.g. Beam path 115 mm = 4½"
C= (4½"-1") x 2= 3½" x 2=7
C=7dB

dB less than ½ rounded to the lower level and greater than ½ to the higher level

15.0 INDICATION RATING

15.1 When an indication noticed during scanning, the maximum indication from the discontinuity shall be set to 50% of FSH (Zero reference level) and the gain value is registered as indication level "a" dB.

15.2 The indication rating "d" = a – b - c dB.

16.0 LENGTH OF DISCONTINUITIES

16.1 Straight beam

16.1.1 The boundary of the laminar discontinuities shall be found by 6 dB drop method.

16.2 Angle beam scanning

16.2.1 After attaining the maximum peak from the discontinuity, the probe shall be moved either sides of the indications to drop to 50% (6dB)of the original height. The length between the probe centers on either side is the discontinuity length.

17.0 EVALUATION AND RECORDING

17.1.1 Each weld discontinuity shall be accepted or rejected based on its indication rating and length in

accordance with table 5 for statically loaded Non Tubular and Table 6 for cyclically loaded Non Tubular structures.

17.2 Indications which are within 6 dB inclusive of the minimum reflectable rating shall be recorded in the report.

18.0 ACCEPTANCE CRITERIA

18.1 Statically Loaded Non-tubular welds

18.1.1 For web to flange welds, acceptance of discontinuities detected by scanning movements other than 'e' may be based on the weld thickness equal to the actual web thickness plus 25 mm.
18.1.2 Discontinuities detected by scanning pattern 'e' shall be evaluated for the actual web thickness.
18.1.3 Weld thickness is the nominal thickness of the thinner of the two parts being welded.
18.1.4 Class A (large discontinuities): Any indication in this category not acceptable regardless of length.
18.1.5 Class B (Medium discontinuities):20 mm and above length not accepted
18.1.6 Class C (Small discontinuities):50 mm and above length not accepted.
18.1.7 Class D (Minor discontinuities): Any indication regardless of length and location accepted.

Table-5

Discontinuity Severity Class	Weld Size[a] in inches [mm] and Search Unit Angle										
	5/16 through 3/4 [8–20]	> 3/4 through 1-1/2 [20–38]	> 1-1/2 through 2-1/2 [38–65]			> 2-1/2 through 4 [65–100]			> 4 through 8 [100–200]		
	70°	70°	70°	60°	45°	70°	60°	45°	70°	60°	45°
Class A	+5 & lower	+2 & lower	–2 & lower	+1 & lower	+3 & lower	–5 & lower	–2 & lower	0 & lower	–7 & lower	–4 & lower	–1 & lower
Class B	+6	+3	–1 0	+2 +3	+4 +5	–4 –3	–1 0	+1 +2	–6 –5	–3 –2	0 +1
Class C	+7	+4	+1 +2	+4 +5	+6 +7	–2 to +2	+1 +2	+3 +4	–4 to +2	–1 to +2	+2 +3
Class D	+8 & up	+5 & up	+3 & up	+6 & up	+8 & up	+3 & up	+3 & up	+5 & up	+3 & up	+3 & up	+4 & up

[a] Weld size in butt joints shall be the nominal thickness of the thinner of the two parts being joined.

General Notes:

- Class B and C discontinuities shall be separated by at least 2L, L being the length of the longest discontinuity, except that when 2 or more such discontinuities are not separated by at least 2L, but the combined length of discontinuities and their separation distance is equal to or less than the maximum allowable length under the provision of class B or C, the discontinuity shall be considered s a single acceptable discontinuity.
- Class B and C discontinuities shall not begin at a distance less than 2L, from weld ends carrying primary tensile stress, L being the discontinuity length.
- Discontinuity detected at scanning level in the root face area of CJP double groove welds shall be evaluated using an indication rating 4 dB more sensitive than described in 15.2 when such welds are designated as " Tension welds"(Subtract 4 dB from the indication rating 'd'). This shall not apply if the weld is back coughed to remove the root face and MT used to verify that the root face has been removed.
- ESW or EGW: Discontinuity detected at scanning level which exceeds 50 mm in length shall be suspected as being piping porosity and shall be further evaluated by Radiography.
- For indications that remain on the display as search unit is moved towards and away from the discontinuity (scanning movement "b") may be indicative of planar discontinuities with significant through- throat dimensions.

18.2 Cyclically Loaded Non-tubular Welds

18.2.1 For web to flange welds, acceptance of discontinuities detected by scanning movements other than 'e' may be based on the weld thickness equal to the actual web thickness plus 25 mm.

18.2.2 Discontinuities detected by scanning pattern 'e' shall be evaluated for the actual web thickness.

18.2.3 Class A (large discontinuities): Any indication in this category not acceptable regardless of length.

18.2.4 Class B (Medium discontinuities):20 mm and above length not accepted

18.2.5 Class C (Small discontinuities):50 mm and above length in middle half or 20 mm in top or botton quarter of weld thickness not accepted

18.2.6 Class D (Minor discontinuities): Any indication regardless of length and location accepted.

Table-6

Discontinuity Severity Class	Weld Size[a] in inches [mm] and Search Unit Angle										
	5/16 through 3/4 [8–20]	> 3/4 through 1-1/2 [20–38]	> 1-1/2 through 2-1/2 [38–65]			> 2-1/2 through 4 [65–100]			> 4 through 8 [100–200]		
	70°	70°	70°	60°	45°	70°	60°	45°	70°	60°	45°
Class A	+10 & lower	+8 & lower	+4 & lower	+7 & lower	+9 & lower	+1 & lower	+4 & lower	+6 & lower	–2 & lower	+1 & lower	+3 & lower
Class B	+11	+9	+5 +6	+8 +9	+10 +11	+2 +3	+5 +6	+7 +8	–1 0	+2 +3	+4 +5
Class C	+12	+10	+7 +8	+10 +11	+12 +13	+4 +5	+7 +8	+9 +10	+1 +2	+4 +5	+6 +7
Class D	+13 & up	+11 & up	+9 & up	+12 & up	+14 & up	+6 & up	+9 & up	+11 & up	+3 & up	+6 & up	+8 & up

[a] Weld size in butt joints shall be the nominal thickness of the thinner of the two parts being joined.

General Notes:

- Class B and C discontinuities shall be separated by at least 2L, L being the length of the longer discontinuity, except that when 2 or more such discontinuities are not separated by at least 2L, but the combined length of discontinuities and their separation distance is equal to or less than the maximum allowable length under the provision of class B or C, the discontinuity shall be considered s a single acceptable discontinuity.
- Class B and C discontinuities shall not begin at a distance less than 2L from weld ends carrying primary tensile stress, L being the discontinuity length.
- Discontinuity detected at scanning level in the root face area of CJP double groove welds shall be evaluated using an indication rating 4 dB more sensitive than described in 15.2 when such welds are designated as " Tension welds"(Subtract 4 dB from the indication rating 'd'). This shall not apply if the weld is back gouged to remove the root face and MT used to verify that the root face has been removed

19.0 IDENTIFICATION OF REJECTED AREA.

19.1 Unacceptable discontinuity on weld shall be marked by paint or punching and the depth shall be noted side by.

20.0 REPORT

20.1 The test report as in annexure "A" shall be issued by Level II / III personnel and submitted to the Customer/ Inspection Agency.

21.0 REPAIR

21.1 The repaired area shall be tested and results shall be recorded as above in the report form clearly mentioning the status i.e., after 1st repair or 2nd repair.

ANNEXURE A
REPORT FORMAT

Work Order / Joint Number

Report No.

Weld Identification

Material Thickness

Weld Joint

Weld Process

Quality requirement

Section No

Remarks

Line No	Ind. No	Angle	Face	Leg	Ind.Level	Ref.Level	Attn. Factor	Ind. Rating	Length	Beam path	Depth from Face A	Display		Evaluation	Remarks
												X	Y		

We, the undersigned, certify that the statements in this record are correct and that the welds were prepared and tested in conformation with the requirements of Section 6, Part F of AWS D1.1/ D1.1M , 20*15*, Structural Welding Code- Steel.

Test Date

Manufacture / Contractor

Inspected by

Authorised by

Date

ANNEXURE B
EQUIPMENT QUALIFICATION PROCEDURE

B.1 HORIZONTAL LINEARITY

B.1.1 Probe: 2 MHz- Accuracy 2%
B.1.2 Bloc: IIW
B.1.3 Range: 500 mm
B.1.4 Normal probe shall be kept in position E (Fig 2) to get 5 reflections. First and Fifth reflections shall be set at 2nd and 10th divisions on CRT by adjusting sweep and delay controls
B.1.5 Each indication shall be adjusted to 50% FSH using gain control for each intermediate indication 2, 3 and 4 to coincide with respective positions within 2% of total range or ± 1 division.
B.1.6 *In the case of qualification with angle beam transducer (shear wave), it is necessary to double the shear wave distance ranges to be used in applying this procedure. (E.g. The use of a 250 mm screen calibration in shear wave would require a 500 mm screen calibration for this procedure.)*

B.2 dB ACCURACY

B.2.1 Probe- Straight Beam- 2MHz
B.2.2 Bloc- Distance and Sensitivity 'DS' Reference Bloc (Fig 2)

B.3 PROCEDURE

B.3.1 To get the required ±1% accuracy in reading the indication height, the vertical screen height shall be graduated at 2% *intervals for Analog units, or 2.5 % intervals for instruments with Digital amplitude read out at horizontal mid screen height*. The graduation will be marked on the screen from 60% to 100% screen height.
B.3.2 The normal beam is coupled to DS bloc at position "T". *(Fig. 2)*
B.3.3 50 mm back reflection set at horizontal mid screen by using sweep and delay controls.
B.3.4 Gain is adjusted to have the height exactly above 40% of FSH.
B.3.5 Probe shall be moved to position "U" until the indication is exactly at 40% screen height.
B.3.6 Gain is increased by 6 dB and the height shall be exactly 80% theoretically.
B.3.7 The dB reading shall be recorded in Row 'a' under column 1and actual screen height in Row 'b' under column 1 in the calibration report. (Annexure C)
B.3.8 Probe is moved further towards "U" till the indication is fixed at 40%.
B.3.9 The gain is increased further 6 dB, i.e. totally 12 dB and recording of the gain in row 'a' and actual height in row 'b' under column 2 shall be done.
B.3.10 Operation shall be repeated till the full range of the gain control is reached (60 dB minimum).
B.3.11 Values in Rows 'a' and 'b' shall be applied to the following equation to calculate the corrected dB reading in Row 'c', *or to the "Nomograph" described in B4.0*.

$$dB_2 - dB_1 = 20\ log\ \frac{\%_2}{\%_1}$$

or

$$dB_2 = dB_1 + 20\ log\ \frac{\%_2}{\%_1}$$

Where, dB1=Row 'a'
dB2=Row 'c'
$\%_1$=Row 'b'
$\%_2$=Average of Row 'b' disregarding first and last 3 values

B3.12 dB error in row 'd' = ± (a-c)
B3.13 Collective dB error 'e' is established by starting with dB error 'd' nearest to 0.0, collectively add the dB error 'd' values horizontally, placing the sub totals in Row 'e'.
B3.14 Moving horizontally, left and right from the average % line, find the space in which largest and smallest collective dB error remain at or below 2 dB. The number of horizontal spaces of movement counted and 1 is subtracted from it and the balance is multiplied by 6. This dB value is the acceptable range of unit.

B4.0 GRAPHICAL REPRESENTATION (*NOMOGRAPH*)

B4.1 The following notes apply to the use of the nomograph.

B4.1.1 Rows a, b, c, d and e are on certification sheet, Annexure C

B4.1.2 The A, B, and C scales are on the nomograph, (Example in Figure (6))

B4.1.3 (3) The zero points on the C scale shall be prefixed by adding the necessary value to correspond with the instrument settings; i.e., 0, 10, 20, 30, etc.

B4.2 Procedure for using the nomograph.

B4.2.1 A straight line between the decibel reading from Row "a" applied to the C scale and the corresponding percentage from Row "b" applied to the A scale shall be extended.

B4.2.2 The point where the straight line from step 1 crosses the pivot line B as a pivot point for a second straight line shall be used.

B4.2.3 A second straight line from the average % point on the A scale through the pivot point developed in step 2 and on to the dB scale C shall be extended.

B4.2.4 This point on the C scale is indicative of the corrected dB for use in Row "c."

B5.0 INTERNAL REFLECTION

B5.1 After calibrating the equipment for straight or angle beam, the probe is removed.

B5.2 The calibrated gain is increased to 20 dB more than the reference gain.

B5.3 The screen area beyond 12 mm beam path and above reference level height shall be free from any indication.

B6.0 INDEX POINT

B6.1 Probe shall be coupled at ‘D’ on IIW block (Fig 2).

B6.2 Reflected indication from the 100 mm quadrant is maximized. The point at which the probe coincides with the slot marking on IIW bloc shall be the Probe index value.

B7.0 PROBE ANGLE.

B7.1 Probe is coupled in position ‘B’ on IIW bloc for 40º to 60º or in ‘C’ position for 60º to 70º.

B7.2 Probe is moved back and forth and focused towards the Perspex and maximized. The probe index shall be compared with the angle marking on the bloc. ± 2º tolerance is allowed.

Model
ANNEXURE C

ULTRASONIC UNIT CALIBRATION REPORT- AWS

Ultrasonic Unit Model : USN52R Serial No : 12358
Probe Size : 25 mm Dia Type : Normal beam Frequency: 2MHz
Calibration Date: *02-07-2016* Interval : 2 Months Method : AWS D1.1
Block Sl.No :01

Horizontal Linearity
Range: 0-100 mm Back-wall echo from 25 mm side

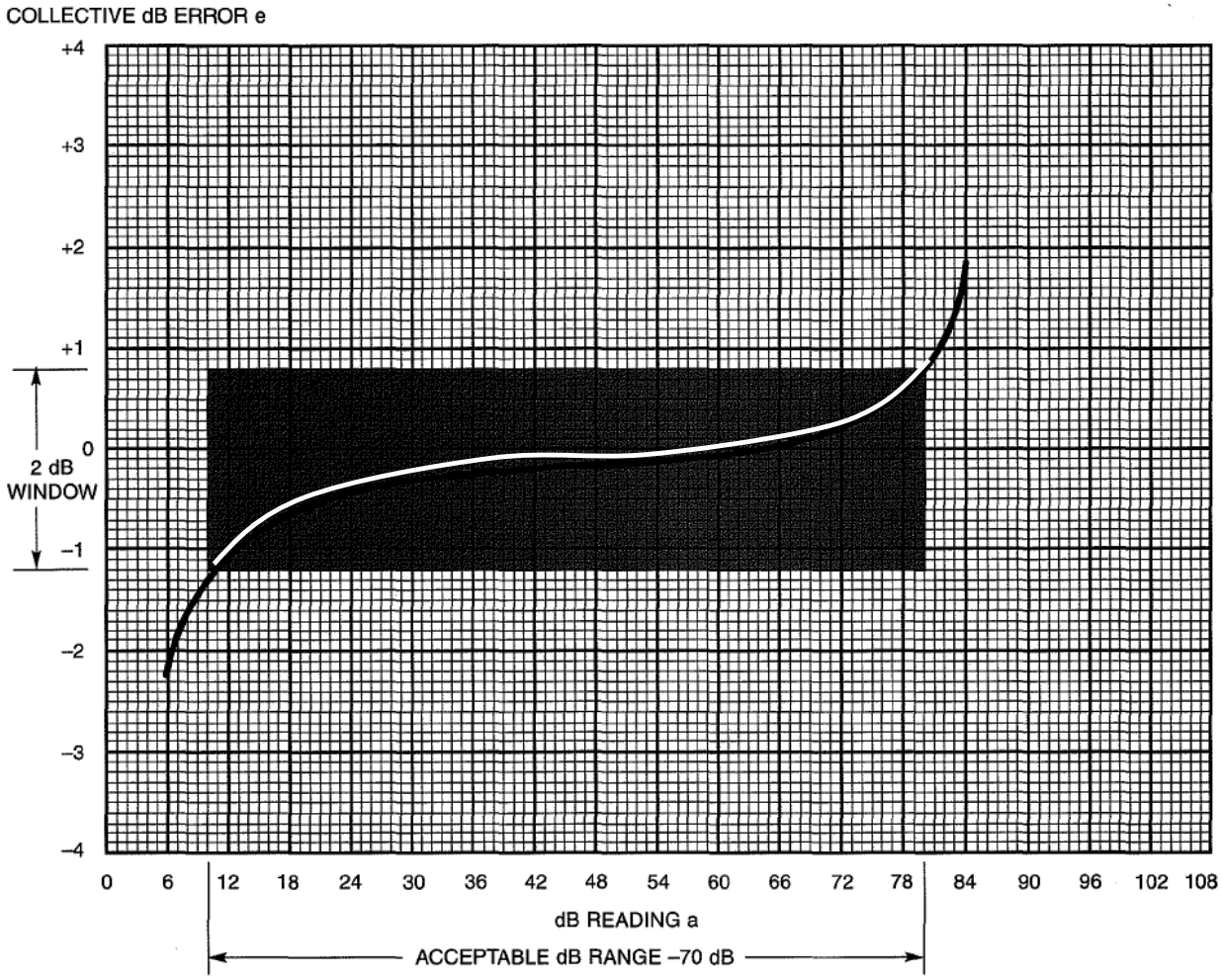
Reflection No.	ECHO		Deviation
	Actual	Expected	
01	25	25	NIL
02	52	50	2 %
03	75	75	NIL
04	100	100	NIL

Row		1	2	3	4	5	6	7	8	9	10	11	12	13
a	dB reading	6	12	18	24	30	36	42	48	54	60	66	72	80
b	Display Height	69	75	75	77	77	77	77	78	77	78	79	80	81
c	Corrected reading	7.1	12.3	18.3	24.1	30.1	36.1	42.1	48	54.1	60	65.9	71.8	77.7
d	dB error	-1.1	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1	0.0	-0.1	0.0	+0.1	+0.3	+0.6
e	Collective dB error	-2.2	-1.1	-0.8	-0.5	-0.4	-0.3	-0.2	-0.1	-0.1	0.0	+0.1	+0.3	+0.6

Accuracy Required: Minimum allowable range :
‰ (Average) :
Equipment : Acceptable / Not Acceptable for use
Total Quality Range: dB to dB = dB Total error dB(from chart)
Total Quality Range: dB to dB = dB Total error dB(from Annexure D)

Calibrated by: Level: Location:

ANNEXURE D – GRAPHICAL REPRESENTATION



THE CURVE ON FORM M-9 EXAMPLE IS DERIVED FROM CALCULATIONS FROM FORM M-8.
THE SHADED AREA ON THE GRAPH ABOVE SHOWS THE AREA OVER WHICH THE EXAMPLE UNIT QUALIFIES TO THIS CODE.

Note: The first line of example of the use of Form M-8 is shown in this example.

Fig (1). dB Accuracy evaluation -AWS

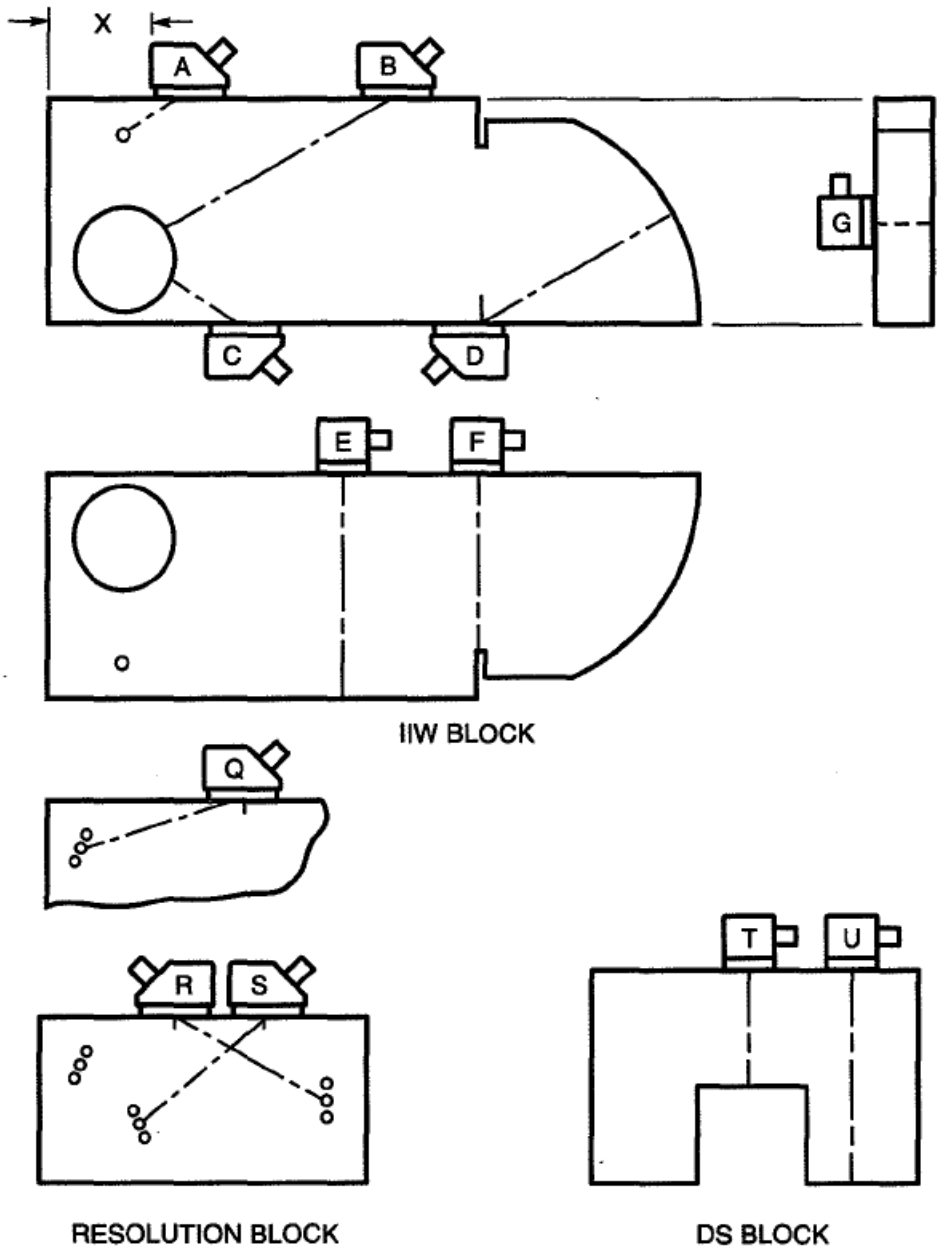


Fig (2). *Typical transducer positions with annotations*

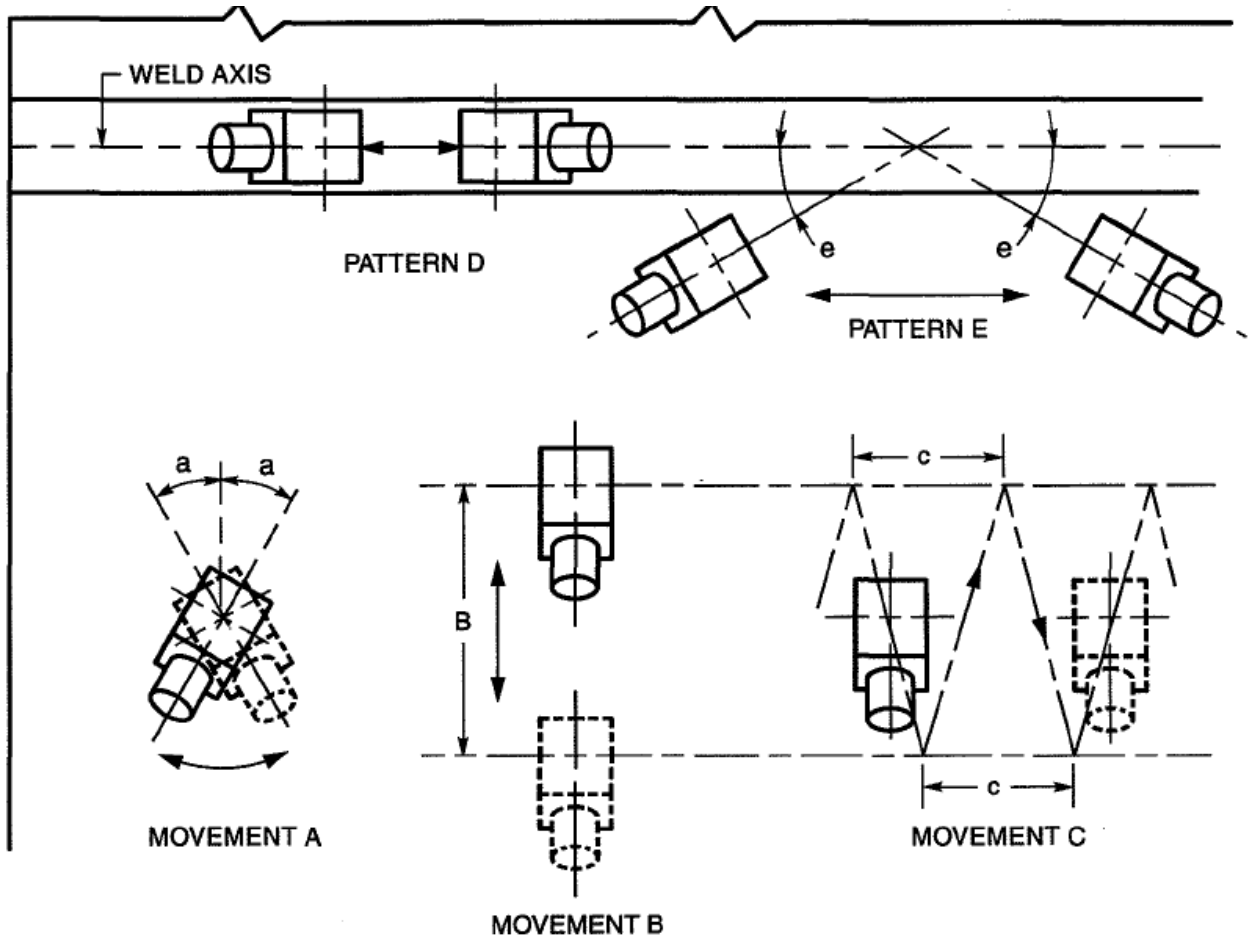


Fig (3) *Plan view of UT scanning patterns*

Notes:

- Testing patterns are all symmetrical around the weld axis with the exception of pattern D, which shall be conducted directly over the weld axis.
- Testing from both sides of the weld axis shall be made wherever mechanically possible.

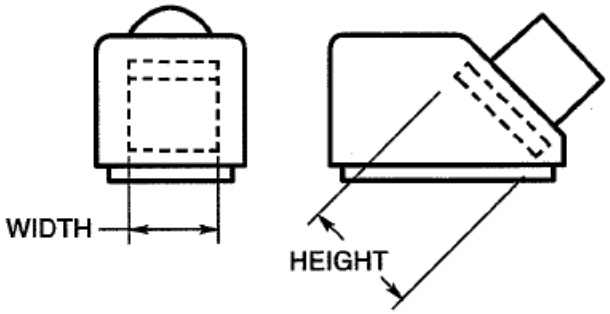


Fig (4) a-Transducer crystal

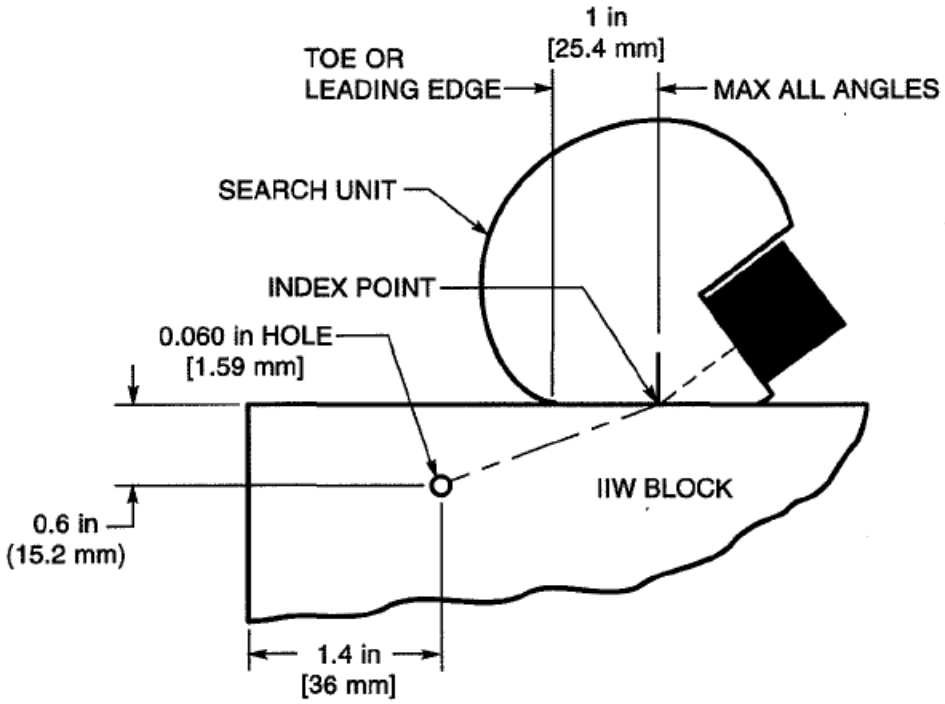
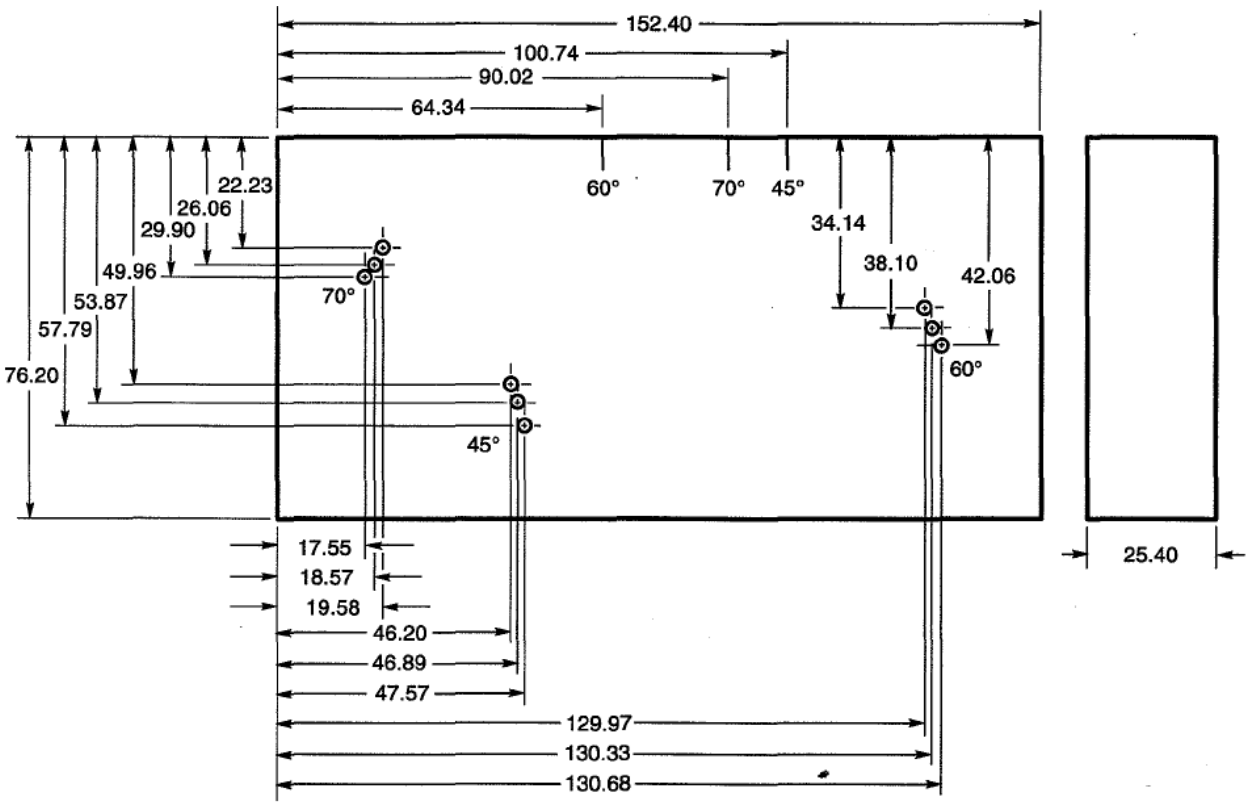


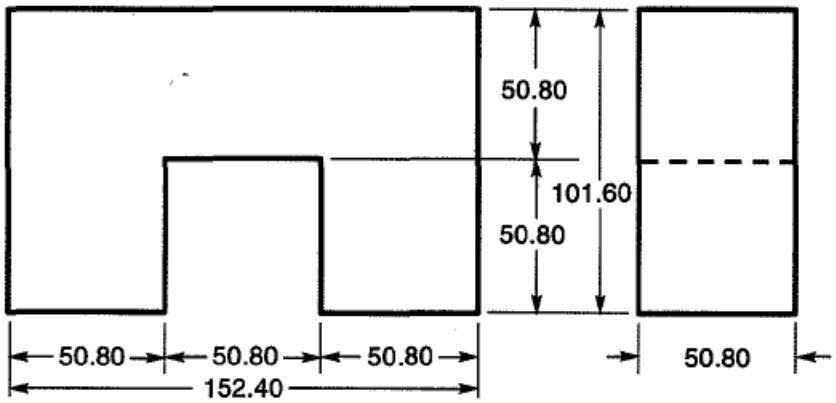
Fig (4) b-Qualification procedure of search unit using IIW reference block



Note: All holes are 1.59 mm in diameter.

DIMENSIONS IN MILLIMETERS

RC – RESOLUTION REFERENCE BLOCK



TYPE – DISTANCE AND SENSITIVITY REFERENCE BLOCK

Fig (5). *Qualification blocks*

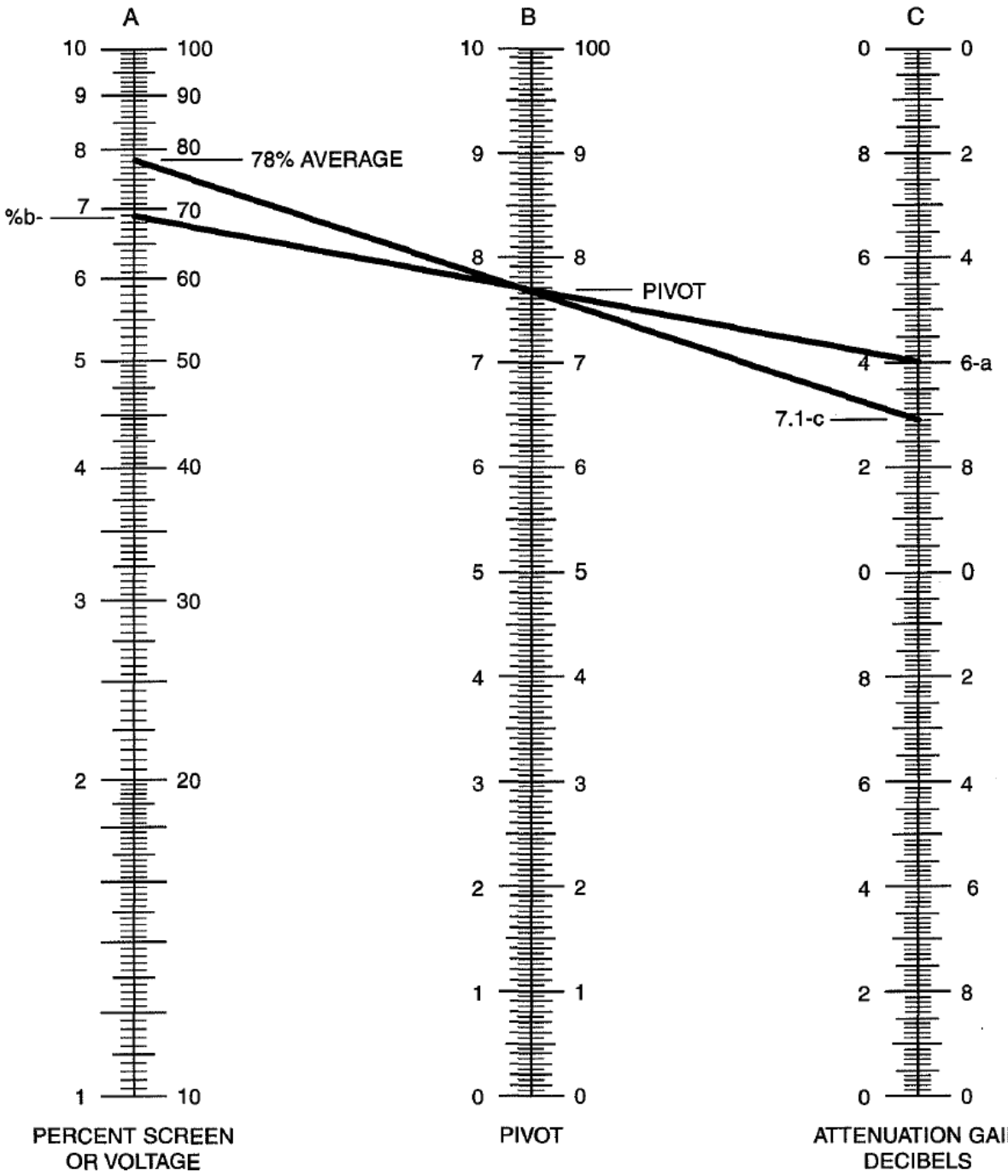


Fig (6). *Example for use of Decibel (Gain or Attenuation) values nomograph-AWS*

NOTES:

1 *The 6 dB reading and 69% scale are derived from the instrument reading and become dB_1"b" and $\%_1$ "c", respectively.*

2 *$\%_2$ is 78 - constant.*

3 *dB_2 (which is corrected dB "d") is equal to 20 times X log $(\frac{78}{69})$ + 6 or 7.1.*

CHAPTER 1.10

PROCEDURE OF DEMAGNETISATION OF FERRITIC STEEL MATERIALS SUBJECTED TO MAGNETIC PARTICLE EXAMINATION

PROCEDURE FOR DEMAGNETISATION OF FERRTIC STEEL MATERIALS SUBJECTED TO MAGNETIC PARTICLE EXAMINATION

Prepared by	Reviewed by	Approved by	Issued by
Vishnu Kumar P Level II Sr. Engineer-NDTL	Deepesh V Level III Sr. Manager-NDTL	B.K. Sethupathy Level III Manager-NDTL	R Arul Prabhu Level III DGM & Head-NDTL
01-01-2020	01/01/2020	01-01-2020	01/01/2020

EFFECTIVE FROM 01-01-2020

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
00	01-01-2016	New issue
01	01-01-2020	Clause No.2.1,3.1,5.1 revised 2.2,4.14 added

1.0 SCOPE

1.1 This procedure describes the techniques for demagnetization of pipe/tube structures in the ferritic steel materials subjected to Magnetic Particle examination.

1.2 This procedure is called for when Demagnetization is required only if specified in the drawings / specification/ purchase order or when any one or a combination of the following undesirable effects of the residual magnetism of the test object are anticipated.

1.2. a. May cause chips, filing, scale, etc. to adhere to the surface affecting subsequent machining operations, painting, or plating.

1.2. b. May affect the sensitive instruments if the part is used in locations near to them.

1.2. c. May affect / interfere the subsequent welding or plating process planned on the test object.

1.2. d. May affect the further magnetic particle examinations on the part.

2.0 REFERENCE

2.1 ASME BPVC Section V , 2019.

2.2 ASTM E-709

2.3 BHE: NDT: PB: MT:01

3.0 TYPE OF MAGNETISATION

3.1 Longitudinal magnetization technique using Alternating current, with value of 5000 to 10000 Ampere-Turns shall be used..

4.0 PROCEDURE

4.1. Use Residual field indicator at one end of pipe and measure the residual field

4.2. Note reading and direction of field +ve or –ve.

4.3. Wrap insulated welding cable 5 turns-clockwise on the OD surface of pipe 50 to 100 mm away from pipe end as shown in figure 1.

4.4. One cable end to be connected to + terminal of Power source / welding generator /MT Equipment. The other end to -ve terminal

4.5. Complete electrical circuit and pass 400 amps current for 2 to 3 seconds

4.6. Reduce the current gradually to zero or minimum

4.7. Measure the residual field at the same end of the pipe

4.8. If demagnetization is effective the reading will come closer to “0”

4.9. Change the polarity of cables attached to the Power source / welding generator / MT Equipment or Wrap the insulated cable (5 turns) in anticlockwise direction

4.10. Pass current slightly excess of 400 Amps

4.11. Reduce the current gradually to 0 Amps in One minute

4.12. Measure the residual field at the same end of the pipe

4.13. Repeat the process till the Gauss meter shows residual field value 3 gauss or less, as shown in figure 2.

4.14. Alternatively the technique of withdrawing the part or coil may be used.

5. PERSONNEL QUALIFICATION

5.1 Demagnetization process shall be performed by at least Level I qualified personnel and acceptance through reporting shall be done by at least a Level II qualified personnel in MT as per SNT-TC-1A 2016 or BHEL's approved written practice for NDT personnel training and certification.

6. REPORTING

6.1 The demagnetization shall consist the following information, as a minimum.

a. Dimensional as well as material details of the test object.
b. Current- type and value
c. Gauss meter reading the beginning and end of the test.
d. Personnel performed and approved the report.

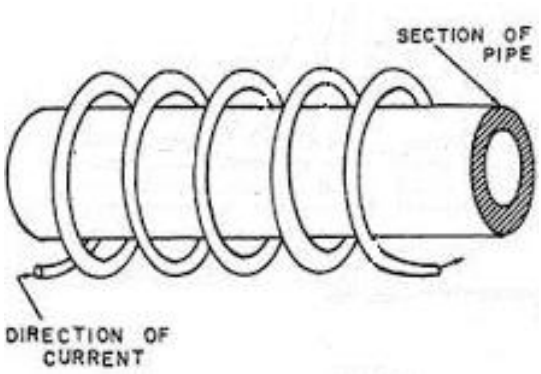


Figure 1. Demagnetization technique

Figure 2. Gauss meter

CHAPTER 1.11

PROCEDURE FOR SAFE WORK PRACTICES IN ENCLOSED RADIOGRAPHY INSTALLATIONS AND IN OPEN FIELD RADIOGRAPHY

PROCEDURE FOR SAFE WORK PRACTICES IN ENCLOSED RADIOGRAPHY INSTALLATIONS AND IN OPEN FIELD RADIOGRAPHY

Prepared By	Reviewed By	Approved By
01-01-2020	01/01/2020	01/01/2020
Jagadeesh.S Deputy Manager Level II Radiation Safety Officer NDTL	R.Raghavendrien Deputy Manager Level III Radiation Safety Officer NDTL	R.Arulprabhu Dy General Manager Head NDTL

Effective from 01.01.2020

RECORD OF REVISION

Rev. No	Revision Date	Record of Revision
01	21.03.2000	2.1 AERB Safety Guide No.SG/IN 3 included 4.6 Revised and modified
02	29.12.2000	Restructured New clauses added &Revised in entirety
03	29.03.2002	2.1 AERB Safety Code No.AERB /SC/IR 1 Included 3.2 Included Restructured Revised in entirety & Annexure included
04	11.06.2012	2.1 Year included 3.2 Restructured 4.7 included 5.1 Restructured 7.8 Restructured 8.1.2 Restructured 8.2.4 Re structured 8.3.1 Name of contact person and Phone no changed 8.3.2 Phone no's changed 9.8 included 10.1 Restructured Annexure Restructured
05	15.12.2014	8.3.2 Name of contact person and Phone no changed
06	16.08.2016	3.1 Modified 4.7 Modified 8.1 & 8.3 Modified 10.1 Modified Annexure modified
07	01.01.2020	2.1,3.1,4.1 &7.5 Modified 8.3.1 & 8.3.2 Name of contact person and Phone no changed Clause 11 added

1.0 SCOPE:

1.1 This procedure describes the safe work practices to be followed in enclosed Radiography installations and in Open Field Radiography

2.0 REFERENCE:

2.1 AERB Safety code for Industrial Radiography AERB / RF- IR /SC–1 (REV 1).

3.0 PERSONNEL:

3.1 All Radiography cameras must be operated only by certified radiographers, Safety site in Charges or Radiation Safety Officers. All radiography personnel (certified radiographers/site incharges /Radiation safety officers) should be registered as a radiation professional in ELORA (e – licensing of radiation applications) portal of AERB.

3.2 All radiation workers must be enrolled in 'Personnel Monitoring Service' of BARC and their instructions shall be followed. Each radiation worker shall wear Personnel monitoring badge during radiography work. In case of suspected over exposure to radiation, the personnel dose shall be evaluated as per clause 8.2.4. The TLD cards are changed every month and used cards sent to Personnel monitoring service of BARC or its Agency for evaluation and dose reporting.

4.0 ISOTOPE RADIOGRPHY OPERATION:

4.1 Radiography must be carried out only with a "type approved radiography camera" duly approved by AERB. A calibrated Radiation survey meter should always be available during entire radiography process.

4.2 A log book must be maintained for each radiography hall / site / source to record the date of radiography, model and Serial number of camera / X-ray equipment, Survey meter used strength of source, name of the radiographer, location of radiography, exposure time in Ci.minutes. or mA mts. and total number of exposures.

4.3 Movement of camera from one location to another must be recorded and signed by Safety site in charge and Radiation Safety Officer shall inspect the logbook and counter sign once in a month.

4.4 The Safety Site in charge shall measure the maximum and minimum readings on the surfaces of the camera and enter in the logbook once in a month. This enables to check the shielding integrity of the camera.

4.5 Before operation, it shall be ensured that the camera is in safe condition. Any malfunction in the camera and its accessories shall be brought to the notice of the concerned Safety site in charge, by the radiographer.

4.6 While using remote controlled cameras, it shall be ensured with survey meter that the source is retrieved safely back into the camera, after the exposure is completed.

4.7 The cameras are always stored in AERB approved storage pits and locked when not in use. The keys are stored in a place accessible only to Safety Site Incharges/RSOs. The certified radiographers will take the key from Incharges and use cameras for radiography. After the work is completed, return back the cameras to storage pit, lock the storage pit and return the key to the Incharges.

5.0 RADIOGRAPHY IN ENCLOSURES

5.1 Unauthorized entry into the radiography hall should be prohibited.

5.2 A warning lamp must be provided at the entrance. A radiation zone monitor must be installed at a suitable location near the entrance to indicate the radiation level in the exposure hall.

5.3 Wherever possible the radiation beam should be directed towards areas of minimum occupancy and must not be pointed towards doors, windows, and control panel.

5.4 While carrying out the radiography in open top enclosures, it shall be ensured that the red warning lamps on the four corners of the hall are switched on.

6.0 OPEN FIELD RADIOGRAPHY:

6.1 The radiography work must be carried out only under the supervision and guidance of the Safety site in charge.

6.2 All operations should be planned in advance and executed in minimum possible time.

6.3 Radiography camera should be moved to the site along with Radiation survey meter.

6.4 As far as possible, field radiography should be carried out when there is minimum occupancy. The area around the field radiography site should be cordoned off so that the radiation at the cordon off does not exceed the permissible level for members of public.

6.5 Radiation warning symbol in English and in local language must be displayed at cordon off distance. Red warning lights must be displayed during night along the cordon off at the point of entry.

6.6 The concerned radiographer must be available at the site very near to the cordoned area throughout the exposure. Entry of unauthorized persons into these cordoned areas during exposures should be strictly prohibited.

6.7 After termination of each exposure, it is to be ensured that the source is safely retrieved back into the camera.

6.8 Proper collimators should be used to limit the radiation beam to the job to be radio graphed.

7.0 CONTROL MEASURES TO REDUCE EXPOSURE TO IONIZING RADIATION

7.1 Radiography shall be performed as far as practicable in approved radiography enclosures by trained and certified radiographers.

7.2 The enclosures where X-rays, Ir-192 and Co-60 sources are employed for examination shall be kept closed when 'not in use 'and 'during exposures'.

7.3 Entry of non-occupational workers to these areas shall be restricted with 'NO ENTRY' posters or boards.

7.4 The enclosures shall not be used as a 'freeway'.

7.5 **Wherever possible, Radiation beam should be directed to area of examination making use of cones, diaphragms and collimators etc and the part placed in such a manner that the' beam' is directed towards area of minimum occupancy.**

7.6 **Only one radiography source should be used at a time in any enclosure.**

7.7 **The key for operating the X-ray machine and locking system of the isotope cameras shall be under the custody of the certified radiographer, performing the operation.**

7.8 **The radiation levels outside the boundary shall not exceed 0.02 m Sv (2 mR) per week, as permitted for general public.**

7.9 **The leakage radiation level of the isotope camera containing the radioactive sources shall be verified before and after each operation to ensure the source is in its safe position inside the camera.**

7.10 **After the exposure is over the source shall be verified for its safe location inside 'S' conduit and the selector ring at the rear of the camera shall be brought to lock position, and then the guide tubes shall be removed and the shipping plug inserted.**

7.11 **The isotope cameras should be returned to source storage enclosures and locked or kept in areas earmarked for this purpose at the end of each shift.**

7.12 **The shielding integrity of isotopes camera shall be verified once in a month by RSO / Safety site in charges.**

7.13 **The guide tubes and associated accessories shall be checked on a day today basis by certified radiographers / Site in charges / radiation safety officer and defects rectified appropriately or discarded.**

7.14 **No repairs are permitted in isotope cameras or its locking mechanism when an 'active source 'is secured inside.**

8.0 **RADIATION EMERGENCY:**

8.1 **The procedure to be followed in case of emergency is detailed in Emergency Preparedness and Response Plan the gist of which is as follows:**

8.1.1 Cordon off the area with the help of survey meter to prevent unauthorized entry.

8.1.1 All efforts to bring back the source into the camera shall be followed

8.1.3 If all efforts to restore the source back to the camera have failed, shield the source with lead sheet, lock the installation and inform the incident / accident to Radiation Safety Division, AERB, Mumbai – 94.

8.2 EMERGENCY PREPARDNESS DURING RADIOGRAPHY:

8.2.1 When a source is stuck in the camera guide tube or when a source pencil has fallen or is misplaced or lost, or damaged or broken resulting in the source remaining in an unshielded condition, a radiation emergency is created. In such circumstances, the following action should be taken by the Safety site in charge / RSO. No person other than RSO / Safety site in charge should be asked to handle the radiation emergencies.

8.2.2 The Safety site in charge should immediately cordon off the area in which the source is known to be present or suspected to be present, and restrict the entry of persons into the area. The Safety site in charge should locate the source within a reasonable time using appropriate radiation monitoring instruments.

8.2.3 When all efforts to locate the source have failed and when the source cannot be brought to its safe shielded position, competent authority should be informed immediately giving essential details of the emergency and action being taken. Necessary assistance should be sought from RSD, AERB, Mumbai – 94.

8.2.4 If any person is suspected to have received high radiation exposure, his personal monitoring badge should be immediately sent to Personnel Monitoring service of BARC or its service provider for urgent evaluation. The suspected individual should be subject to medical examination by a qualified doctor. Such medical examination should include blood examination (RBC, WBC& Platelet count) and general physical examination. The general physical condition of the suspected person should be observed and if any symptoms that can be attributed to radiation should emerge, the person should be brought to BARC Hospital at Mumbai for detailed examination and treatment.

8.3 List of names and phone numbers to be contacted in the event of Emergency should be displayed at work centers.

8.3.1 **RSD, AERB, Mumbai –94**

Ph.: 022-25572989, 90, 91,93,94,95, 2599 0100

8.3.2 **BHEL:**

1. R.Arulprabhu: 0431-2575590, Mobile 9442502921

2. R.Raghavendrien: 0431-2575632 , Mobile 9489202949

3. Jagadeesh.S: 0431-2578393, Mobile 9944615047

The contact numbers are displayed in the work centers.

9.0 SAFE TRANSPORT OF GAMMA RADIOGRAPHY SOURCES:

9.1 All gamma radiography sources are supplied in a sealed capsule and attached securely to a Teleflex cable. The capsule is shielded in a camera and this is loaded in a sturdy wooden box. The wooden box which is in sound condition is provided with spacers for preventing free movement of the shielded container inside, during transport. The outer container must be provided with strong handles to facilitate easy handling and must be closed. This is referred to as the package.

9.2.1 The radiation level on the external surface of the package must be monitored using an appropriate calibrated radiation survey meter and the maximum level recorded. Care must be taken that the camera is securely locked to prevent movement of the source during transport.

9.2.2 The Transport index defined as the number expressing the maximum radiation level in mR / hr at one metre from the external surface of the package and is determined by means of a radiation survey meter.

9.2.3 Based on the maximum permissible surface leakage levels the package shall be labeled with Yellow II or Yellow III.

9.2.4 If the maximum level at the external surface of the package is more than 5 µ Sv per hr (0.5 mrem /hr) but not more than 0.5 mSv/ hr (50 mrem/hr) and if the transport index is not greater than 1, then the package is described as CATEGORY II YELLOW.

9.2.5 If the maximum level in the above case is between 0.5 mSv/hr (50mr/hr.) and 2 mSv / hr. (200mr/hr) and the transport index is between 1and 10 then the package is described as

CATEGORY III YELLOW.

9.3 **The package must be declared as a radioactive consignment in the transport documents.**

9.4 **While booking the cargo a certificate must be issued by the consignor to the effect that the package containing a radioactive material has been properly packed, marked, and labeled and the consignment is in conformity with requirements stipulated by competent authority.**

9.5 **If the package gets involved in an accident during transportation, the consignor and Radiation Safety Division, AERB, Mumbai must be informed within 24 hours and the package must be forwarded for transport only after obtaining the clearance from RSD, AERB, Mumbai.**

9.6 **Additional conditions as may be specified by the competent authority in the interest of radiological safety must be duly adhered to.**

9.7 **The decayed sources are safely disposed by Board of Radiation and Isotope Technology, Mumbai, when the cameras are sent for replenishment.**

10 MEDICAL CHECKUP:

10.1 **Radiography personnel will be medically examined at least once in three years or whenever any direction is received from BARC, based on the Personnel monitoring badge recordings.**

10.2 **Any of the medical reports as in 10.1 reveals that the operator has received more radiation than permitted; BARC's advice will be followed for further course of action.**

10.3 **Medical checkup details shall be retained by the Occupational Health Services.**

11 SUBCONTRACTING OF RT WORKS:

11.1 **Subcontracting agency shall possess a valid license for possession and operation of radiography exposure devices for industrial radiography.**

11.2 **Agency should possess adequate number of radiographers to carry out radiography. Each agency operating in site/Unit should have at least one site charge/ radiation safety officer.**

11.3 Movement of radiography source from one site to another shall be done only with the prior approval of Atomic Energy Regulatory Board through ELORA portal.

11.4 Site/Unit is required to provide storage facility for the radiography sources as per AERB guidelines and assist radiography agency in getting necessary approvals through ELORA.

11.5 Radiography agency shall obtain prior permission from site engineer for carrying out open field radiography. Open field radiography should be carried out only after evacuation of non- radiography personnel from the radiation zone.

11.6 TLD Dose reports of all radiation personnel shall be maintained.

ANNEXURE

PERMISSIBLE LEVELS LISTED AS PER AERB GUIDE LINES

1. **THE CUMULATIVE EFFECTIVE DOSE OVER A BLOCK OF 5YEARS SHALL NOT EXCEED 100 mSV WITH THE MAXIMUM LEVEL FOR A SINGLE YEAR NOT EXCEEDING 30 m SV. THAT IS, THE AVERAGE ANNUAL DOSE LIMIT SHALL NOT EXCEED 20 m SV**

2. **AT 5CMS FROM SURFACE OF EXPOSURE DEVICE, THE MAXIMUM PERMISSIBLE LEAKAGE LEVEL SHALL NOT EXCEED 0.5 mSV /Hr FOR PORTABLE TYPES AND 1.0 mSV/Hr FOR MOBILE TYPES**

CHAPTER 1.12

PROCEDURE FOR APPROVAL OF NDT AGENCIES

	BHARAT HEAVY ELECTRICALS LIMITED DEPT.235 – TIRUCHIRAPALLI – 620 014 Non-Destructive Testing	BHE: NDT: G- 005 Revision 003 Page 1 of 5

PROCEDURE FOR APPROVAL OF NDT AGENCIES

Prepared by	Reviewed by	Approved by	Issued by
R Raghavendrien Level III Dy.Manager-NDTL	Deepesh V Level III Sr.Manager-NDTL	B.K. Sethupathy Level III Manager-NDTL	R Arul Prabhu Level III DGM & Head-NDTL
01/01/2020	01/01/2020	01-01-2020	01/01/2020

With effect from 01-01-2020

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
001	21-03-2000	Clause 7 added.
002	28-03-2015	Clause 2.1 Modified
		Clause 3.3 Modified
		Clause 3.6 Modified
		Clause 3.10 Modified
		Clause 3.14 Modified
		Clause 4.3, 4.4 added
		Clause 5.3, 5.4 added
		Clause 6.2, 6.3 added
		Annexure-I,II & III added
003	01-01-2020	Clause 3.1 Modified
		Clause 3.15 Added.

1.0 SCOPE

1.1 This procedure describes the requirements to be fulfilled by a NDT Agency to get approval from BHEL to carry out NDT - viz Radiography, Ultrasonic Testing, Magnetic Particle Testing and Liquid Penetrant Testing on their products.

2.0 GENERAL REQUIREMENTS

2.1 Registered in Small Scale Industries and IBR (if Applicable) shall be obtained.

2.2 Trained, experienced and certified personnel qualified as Level I / II / III as per SNT-TC-1A of ASNT or BSEN 473 of EN through ISNT or its Accredited Agencies or through approved third Party Inspection Agencies like Lloyds etc should be employed.

2.3 The personnel should have sufficient experience in testing of welds/castings/forgings/plates and should be capable to interpret the given procedure and carry out the test.

2.4 Those equipment's require calibration should have been calibrated and recalibrated in stipulated intervals.

2.5 Calibration and Reference Blocks should be available wherever applicable.

2.6 Film and other consumables used shall be BHEL approved brands.

3.0 REQUIREMENTS FOR RADIOGRAPHY

3.1 Approval from BARC for the Site and to carry out Radiography (in the enclosure as well as open field) should be obtained.

3.2 BARC certified Radiation Safety Officer/Site in charge / RSO should be available.

3.3 Should possess minimum 2 Nos. of Remote Operating Type Iridium 192 Source, preferably one should be Tech/Ops/Amersham.

3.4 Each Radiation source should have an experienced BARC Certified Radiographer Level I to operate the camera.

3.5 In addition, there should be personnel certified to Level II to monitor the activities.

3.6 All the radiation workers should be enrolled with Film Badge Services of BARC.

3.7 Radiation safety equipment's and monitoring equipment's like Survey meter should be available for each source.

3.8 Well maintained and air conditioned dark room should be available, preferably with temperature controlled film processing device.

3.9 High Intensity illuminator with intensity control should be available.

3.10 Calibrated ASTM Image Quality Indicators(IQI), minimum 6 Nos. in each designation and ASTM wire type IQIs should be available.

3.11 Sufficient flexible cassettes with 0.2 mm thick lead screen should be available.

3.12 Lead sheets of thickness 1 mm and 2 mm should be available.

3.13 All safety precautions laid down by AERB should be strictly followed.

3.14 Calibrated Density Strip / Densitometer shall be made available for use.

3.15 If required, agency has to demonstrate and establish various parameters for the quality of radiograph (eg: Image density, sensitivity, source size, source to film distance, geometric unsharpness etc.,) to the satisfaction of NDTL/BHEL Trichy.

4.0 REQUIREMENTS FOR ULTRASONIC EXAMINATION

4.1 Should have Analogue or Digital type Pulse Echo A Scan equipment.

4.2 Probe shall be available in various frequencies (particularly 2 MHz and 4 MHz) and various angles (Normal, 45 degree, 60 degree, 70 degree) of single crystal and double crystal construction. In each type there should be spare probes to meet any eventualities. Probes shall be from reputed manufacturer.

4.3 Calibrated Equipment shall be used for testing.

4.4 Trained, experienced and certified personnel qualified in Ultrasonic testing as given clause 2.2 shall be engaged for testing and interpretation.

5.0 REQUIREMENTS FOR MAGNETIC PARTICLE EXAMINATION

5.1 Should have portable AC/HWAC equipment delivering current of minimum of 1000 amps and portable AC/DC electromagnetic yokes.

5.2 Calibrated Equipment/ Ammeters shall be used for testing.

5.3 Should be capable of testing with visual and fluorescent magnetic particles.

5.4 Trained, experienced and certified personnel qualified in Magnetic testing as given clause 2.2 shall be engaged for testing and interpretation.

6.0 REQUIREMENTS FOR LIQUID PENETRANT EXAMINATION

6.1 Should be capable of testing with Visual and fluorescent penetrants.

6.2 Only Approved brand of chemicals shall be used for testing.

6.3 Trained, experienced and certified personnel qualified in Penetrant testing as given clause2.2 shall be engaged for testing and interpretation.

7.0 VALIDITY AND RENEWAL

7.1 The validity of the NDT Agencies engaged by Outsourced Firms will be renewed at the end of every two years based on the following:

7.1.1 Assessments made in every six months

7.1.2 IBR Approval.

7.1.3 Feedback or complaints, Audit checks and others if any.

7.2 If any NDT Sub contractor was not engaged by any fabrication unit within a period of 2 years, the NDT Sub contractors name will be deleted from the approved list.

7.3 Approved list of NDT sub contractors will be circulated to Outsourcing, Valves subcontracting and Valve purchase, FBC & HRSG and QC/OLI departments.

CHAPTER 1.13

MAGNETIC PARTICLE EXAMINATION OF PIPE BENDS

	BHARAT HEAVY ELECTRICALS LIMITED DEPT.235 – TIRUCHIRAPALLI – 620 014 Non-Destructive Testing	BHE:NDT:PB:MT- 02 Revision 02 Page 1 of 5

MAGNETIC PARTICLE EXAMINATION ON PIPE BENDS

Prepared By	Reviewed By	Approved By	Issued By
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Effective from 01-01-2020

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
00	10-01-2010	New issue
01	16-07-2016	1.2.1,1.2.2,9.1 revised
02	01-01-2020	1.1,1.2.1,1.2.2,8.1,9.1,12.1 revised

1.0 SCOPE

1.1 This procedure describes the method, techniques and acceptance standards for Magnetic Particle Examination on Bends of Carbon steel, Alloy Steel and P91 Pipes. This procedure is used only for detection of Transverse Defects arising during hot bending in the bend area.

1.2 REFERENCES

1.2.1 ASME Section V -2019

1.2.2 ASME B 31.1/ 2018

2.0 EQUIPMENT

2.1 Equipments generating half-wave rectified direct current shall be used for examination.

3.0 SURFACE PREPARATION

3.1 The surface to be examined shall be even and free from scales/undulations, Drag lines, notches etc.

4.0 TYPE OF MAGNETISATION

4.1 Longitudinal magnetization induced by Coil winding over the part using half wave DC (HWDC) shall be used.

4.2 Examination shall be made by dry continuous method, i.e. magnetising current remains on while inspection medium (dry powder) is being applied.

5.0 MAGNETIC FIELD STRENGTH

5.1 The strength of the magnetic field should be checked over the area to be tested to ensure Clear visibility of indication on a berthold type field indicator/ASTM Pie shaped Magnetic Particle Field Indicator.

6.0 LONGITUDINAL MAGNETIZATION TECHNIQUE:

6.1 Magnetization by this method is produced by passing current through a multi-turn cables or coils that is wrapped around the part or section of the part being examined. This produces a longitudinal magnetic field parallel to the axis of the coil.

7.0 CURRENT SELECTION

7.1 If the area to be magnetized exceeds beyond 225 mm on either side of the coil's center, field adequacy shall be demonstrated using a magnetic field indicator or artificial flaw shims

7.2 The magnetizing current shall be 1200 ampere-turns to 4500 ampere-turns. The field adequacy shall be demonstrated using a magnetic field indicator or artificial flaw shims.

8.0 TESTING METHOD

8.1 The bend portion of the pipe shall be marked.

8.2 The insulated magnetic equipment cable shall be wrapped (one or two windings) on the OD surface of the pipe and one end of the cable to be connected to the common terminal of the equipment and the other end to HWDC terminal.(Fig 1)

8.3 The current has to be selected as in 7.2.

8.4 After passing the required current and magnetizing the part , the field adequacy checked using Berthold type field indicator/ASTM Pie shaped Magnetic Particle Field Indicator and the magnetic powder shall be applied on the part while the current is on.(Fig 2)

8.5 Indication, if any, shall be observed and recorded.

8.6 The cable winding shall be moved to the adjacent areas and testing continued.

9.0 LIGHTING

9.1 The examination area and the accumulation of magnetic particles shall be observed under natural or supplemental white light of intensity minimum 100 fc (1076 lx).

10.0 TEST PERFORMANCE

10.1 Ammeter shall be calibrated at least once a year, or after each time it has been subjected to major electrical repair, periodic overhaul or damage.

10.2 Any test area shall overlap by 40 to 50mm.

10.3 Interpretation and Evaluation shall be performed during the post magnetization period.

11.0 DEMAGNETIZATION

11.1 After completion of the testing in the bend portions, the residual field present on the shall be measured with Residual Field Indicator or Gauss Meter.

11.2 If the meter shows + or – field level, demagnetization shall be carried either using the demagnetization facility provided in the Equipment or by changing the polarity and reducing the current and reversing the part or coil.

11.3 The residual field level present after each demagnetization operation shall be measured and the process repeated till the residual field level reaches 3 gauss or below.

12.0 PERSONNEL QUALIFICATION

12.1 Personnel performing examination and evaluation shall be qualified in accordance with BHE:NDT:G:CRT which is in line with SNT-TC-1A 2016.

1) Testing	-	Minimum Level- I
2) Evaluation and Report issue	-	Minimum Level II

13.0 INTERPRETATION OF MAGNETIC PARTICLE INDICATION

13.1 Transverse Indications irrespective of the length are not acceptable.

14.0 POST CLEANING

14.1 When inspection is concluded, the magnetic particle residue remaining on the surface shall be

removed by any suitable mean leaving the product in dry and clea**n condition.**

15.0 REPORT AND STORAGE

15.1 Report in the approved format signed by a Level-II or Level-III shall be issued. All the reports will be retained for a period of 1 year or Final Inspection clearance whichever is later.

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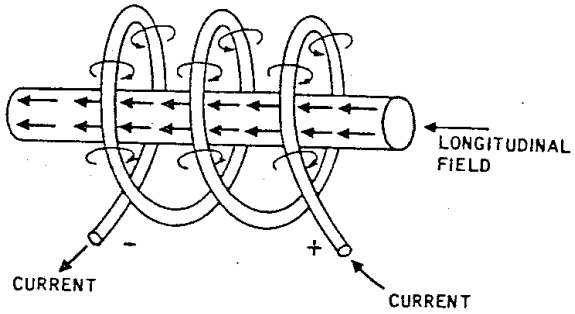
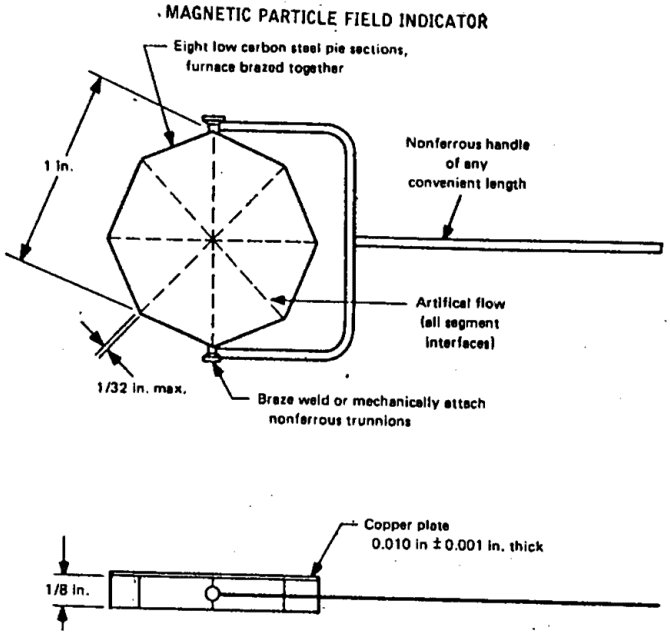


(Fig 1) LONGITUDINAL- COIL(SOLENOID) METHOD



(Fig 2) BERTHOLD PENETRAMETER / FIELD INDICATOR

CHAPTER 1.14

PROCEDURE FOR FILM PROCESSING, FILM STORING AND STORAGE OF RADIOGRAPHS

PROCEDURE FOR FILM PROCESSING, FILM STORING AND STORAGE OF RADIOGRAPHS

Prepared by	Reviewed by	Approved by	Issued by
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	01/01/2020	01-01-2020	01/01/2020

Effective from 01-01-2020

RECORD OF REVISION

Rev.No	Date	Revision of Details
01	28-12-2008	Clause 2.1 Revised, Clause 10.1 revised
04	06-11-2015	Clause 2.1
05	01-01-2020	Clause 2.1 Revised, Clause 2.2,2.3 added

1.0 SCOPE

1.1 This procedure describes the method of storing unexposed films, storage of radiographs, manual deep tank processing and auto-processing of exposed X-ray films.

2.0 REFERENCE

2.1 ASTM E94 – 2010

2.2 ASME SEC V ARTICLE 2 2019

2.3 ASTM E999 – 2015

3.0 STORAGE OF FILMS

3.1 Unexposed films shall be stored in as cool a place as possible and stored in such a manner that they are protected from the effects of light, pressure, excessive heat and humidity.

3.2 Films shall not be stored in the immediate proximity of X-ray processing solutions or storage area of gamma source and shall be protected from damaging fumes or vapors or penetrating radiation.

3.3 Storage of films should be on 'First in' 'first out' basis.

4.0 MANUAL FILM PROCESSING (Deep-Tank)

4.1 Processing shall be carried out under subdued light of a color to which the film is relatively insensitive.

4.2 The processing room as well as the accessories and equipment shall be kept clean. The thermo-meters, film hangers shall be thoroughly washed in clean water immediately after use .

4.3 All tanks shall be cleaned thoroughly before putting solutions into them. Any solutions spilled at any time shall be wiped at once .

4.4 The safe-lights employed for film loading and processing in the dark room shall be periodically checked, once in a month, for its effect on the radiographic films as below:

a) A strip of X-ray film 10x20 cms. long shall be placed in total darkness at the same distance at which the films are normally loaded prior to exposures.

b) The safe light under examination only shall be switched on for 2 minutes after covering the film for a length of 25 mm with a piece of opaque card-board. The above operation shall be repeated for 4 & 8 minutes with 25 mm
additional incremental lengths each time. The exposed film shall be processed and dried. The measured fog density in any area of the affected film shall not exceed 0.3.

5.0 DEVELOPMENT

5.1 Before start of development the developer solution shall be thoroughly stirred and the temperature shall be measured and recorded. The development temperature shall be between 18°C and 26°C.

5.2 The development times as in Table -1 shall be followed based on measured temperature.

TABLE-1 :DEVELOPMENT TEMPERATURE AND TIME

Temperature	Development time- minutes	
	Minimum	Maximum.
18 deg. C / 64 deg. F	6	9
20 deg. C / 68 deg. F	5	8
22 deg. C / 72 deg. F	4	6
24 deg. C / 75 deg. F	3.5	5
26 deg. C / 82 deg. F	2.5	3.5

5.3 The film to film or film to edges of the tank shall be separated to a distance of 13 mm from each other.

5.4 The hanger frames shall be continuously agitated in 2 directions for about 15 secs.

5.4 The films shall be moved vertically and horizontally for 5 seconds each minute during development.

6.0 STOP PATH

6.1 After development is complete the films are allowed to drain above the developer tank for 2 to 3 sec. and shall be immersed immediately in acid stop bath for 30 sec.

6.2 If acid water bath is not used, films shall be rinsed in running water or in clean water in an intermediate tank with vigorous agitation for 30 seconds.

7.0 REPLENISHMENT

7.1 The liquid level in the developing tank shall be maintained to its original level as well as the activity of the solution shall be maintained everyday prior to start of development as follows:

7.2 Based on number of films processed the previous day, for every 8 sheets of 30 x 40 cm films, 300 ml. of developer shall be removed and then approx. 600 ml. of replenisher solution shall be added into the developer tank.

7.3 The quantity of replenisher shall be added to a maximum of 4 times the volume of the developer tank i.e.90 Lit. The developer solution shall be discarded after developing approx.725 sheets of 30 x 40 cm with periodic replenishment or at the end of three months whichever is earlier.

8.0 FIXING

8.1 The films shall not touch one another in the fixer solution. The films shall be agitated vertically for about 10 seconds and again at the end if first minute and every 2 minutes during the course of fixation.

8.2 Films shall be fixed for double the time required to clear the emulsion but not more than 15 minutes. Disappearance of the opalescent milkiness is referred as 'clearing time' which is normally 2 to 3 minutes.

8.3 The fixer solution shall be discarded after approx. 725 sheets of 30 x 40 cm films are fixed or at the end of three months whichever is earlier.

9.0 WASHING

9.1 The films shall be washed in running water for 15 minutes and placed in the wash tank near the outlet end and then moved in the direction of the inlet.

10.0 WETTING AGENT

10.1 The films are immersed for 30 seconds in a solution of wetting agent after the final wash.

11.0 DRYING :

11.1 All films shall be preferably dried in a drying cabinet or in dust free room with ambient temperature with air circulated by a fan. Drying temperature in a cabinet shall be a maximum of 60 °C .

12.0 AUTOMATIC PROCESSING OF FILMS

12.1 The solution deposits shall be wiped from rollers which lie above the solution level with a damp cloth. When the developer temperatures becomes steady the temperature shall be measured and recorded each day before the day's processing operation begins.

13.0 FILM FEEDING

13.1 Three rolls of the rollers-transport system shall be always in contact with the film to maintain proper travel through the processor. Films shall be fed into the processor making it certain they are straight and parallel to the side of the feed-tray. A time lapse of 30 sec. shall be followed between consecutive feedings. Multiple films shall have a space between them to avoid overlapping. Table 2 gives number of films that can be processed at a time.

TABLE-2

FILM SIZE	NO OF FILMS
30X40 Cms.	1
15x40 Cms.	2
10x40 Cms.	3

14.0 TRANSPORT SYSTEM

14.1 The films shall be transported by a system of rollers by a constant speed motor. The rollers shall produce vigorous uniform agitation of the solution at the surface of film.

15.0 RECIRCULATION SYSTEM

15.1 Re-circulation of the developer and fixer solutions shall uniformly mix the processing and replenisher solutions maintaining them at constant temperature. The solutions shall be thoroughly mixed and agitated at the surface of the film moving through the tanks so that the films are constantly bathed in fresh solution. Re-circulation and replenishment for wash-water also shall be accomplished.

16.0 REPLENISHMENT SYSTEM

16.1 The solutions shall be replenished at the rate proper for the type or types of film being processed and the average density of the radiograph.

16.2 Table 3 shows the replenishment rates per minute per 30x40 cms. size for different brands of films for an average film density of 2.0.

TABLE-3 :REPLENISHMENT RATES.

DEVELOPER	FIXER	WATER
50 - 55 mL.	90 - 95 ML.	1.9 - 2.0 LIT.

16.3 Replenishment rates shall be measured accurately and checked periodically once in a month.

17.0 DRYER SYSTEM

17.1 The drying temperature shall be set for the lowest possible temperature consistent with good drying.

TABLE-4: PROCESSING AND DRYING TEMPERATURES.

Developer	25 to 30 deg C
Fixer	25 to 31 deg C
Wash water	27 to 30 deg C
Dryer	40 to 45 deg C

18.0 STORAGE OF RADIOGRAPHS

18.1 Radiographs should be stored in a clean dust free room. Radiographs shall be arranged in definite order of control number year wise for easy identification traceable to applicable products.

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CHAPTER 1.15

GENERAL PHASED ARRAY ULTRASONIC PROCEDURE FOR BUTT WELD JOINTS IN TUBULAR COMPONENTS

General Phased Array Ultrasonic Examination Procedure for butt weld joints in Tubular components

Effective Date 13-02-2020

		13-02-2020	13/02/2020	13-02-2020	13/02/2020
00	13-02-2020	Prepared By (BHEL)	Reviewed By (BHEL)	Approved By (BHEL)	Issued By (BHEL)
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Rev No.	Date	Sr.Engr./NDTL/ PAUT L-II	Sr. Manager/NDTL/ Level-III	Manager/NDTL/ Level-III	DGM/NDTL-HOD/Level-III

1.0 Scope

This procedure describes the requirement and application of Semi-Automated Phased Array Ultrasonic Examination for detection and evaluation of discontinuities within butt weld of tubular products and its effective heat affected zone. This procedure shall be used in combination with specified scan plan and demonstrations approved by UT-Level III with PAUT level II. This procedure is applicable for Carbon and alloy steel tubes with minimum thickness 6 mm (note-1) and outer diameter ranging from 21 mm to 114 mm (note-1).

Note1: For additional range (Greater/Lower for OD/Thickness and different Material grade) examination requirements, this procedure shall be utilized only with proper demonstration qualification on mock up blocks by detecting defects as mentioned by referencing code. ASME sec V art IV Mandatory appendix IX. All qualification shall be approved and accepted by a UT Level III with PAUT level II. Also, it to be noted that for very low thicknesses defect characterization is quite difficult. So, in that case procedure will be used as GO/No GO basis only.

2.0 Purpose

This procedure shall apply to the general aspect of ultrasonic examination of welds using Phased Array technique**. Omni scan MX/MX2/X3** or **equivalent** Phased Array equipment shall be used coupled with Scanner. Any other Phased Array acquisition unit coupled with suitable scanner may be used on successful validation as per mandatory requirement mentioned in ASME Sec-V (2019 edition).

Main objective of this procedure is to;

- Monitor the performance of the equipment
- Configuring the display and data acquisition parameters (Technique Sheet of scan plan)
- Calibration of time base and sensitivity (Wedge Delay, Sensitivity and TCG etc.)
- Description of the recording criteria
- Identification and layout of the components to be tested
- Surface condition required
- Details of the equipment used and volumes covered
- Detection and evaluation of discontinuities in weld metal and HAZ

3.0 Reference

The following documents shall be referred in conjunction with this procedure:

- **BHE: NDT: G: CRT;** BHEL's Written Practice for Training, Examination, Qualification & Certification of NDE Personnel
- **SNT-TC-1A, 2016;** Personnel Qualification and Certification in Nondestructive Testing
- **ASME SEC V (2019 edition);** ASME Boiler and Pressure Vessel Code-Nondestructive Examination

- **ASME SEC I (2019 edition);** Rules for Construction of Power Boilers
- **ASME SEC VIII, Div-1 (2019 edition)**; Rules for Construction of Pressure Vessels
- Equipment Operating Manual

4.0 Table of Essential Variables for Qualification of Procedure

Requirement Requirements of an Ultrasonic Examination Procedure	Essential Variable	Nonessential Variable
Weld configurations to be examined, including thickness Dimensions and base material product form (pipe, plate, etc.)	v	
The surfaces from which the examination shall be performed	v	
Technique(s) (straight beam, angle beam, contact, and/or immersion)	v	
Angle(s) and mode(s) of wave propagation in the material	v	
Search unit type(s), frequency (ies), and element size(s)/shape(s)	v	
Special search units, wedges, shoes, or saddles, when used	v	
Ultrasonic instrument(s)	v	
Calibration [calibration block(s) and technique(s)]	v	
Directions and extent of scanning	v	
Scanning (manual vs. automatic)	v	
Method for discriminating geometric from flaw indications	v	
Method for sizing indications	v	
Computer enhanced data acquisition, when used	v	
Scan overlap (decrease only)	v	
Personnel performance requirements, when required	v	
Personnel qualification requirements		v
Surface condition (examination surface, calibration block)		v
Couplant : brand name or type		v
Post examination cleaning technique		v
Automatic alarm and/or recording equipment, when applicable		v
Records, including minimum calibration data to be recorded (e.g., instrument settings)		v
Requirements of a Phased Manual Raster Scanning Examination Procedure Using Linear Arrays		
Search unit (element size and number, and pitch and gap dimensions)	v	
Focal range (identify plane, depth, or sound path)	v	
Virtual aperture size (i.e., number of elements, effective height, and element width)	v	
Wedge angle	v	
Range of element numbers used (i.e., 1, 126, 10, 50, etc.)	v	
Element incremental change (i.e., 1, 2, etc.)	v	

Angular range used (i.e., 40 deg 50 deg, 50 deg 70 deg, etc.)	v	
Angle incremental change (i.e., deg, 1 deg, etc.)	v	
Requirements of a Phased Array Linear Scanning Examination Procedure Using Linear Arrays (E Scan & S Scan)		
Search unit(s) (element pitch, size, number, and gap dimensions)	v	
Focal range(s) (identify plane, depth, or sound path as applicable)	v	
Virtual aperture size(s) (number of elements, element width, and effective height)[Note (2)]	v	
Wedge natural refracted angle	v	
Scan plan	v	
Weld axis reference point marking.		v
Rastering angle(s)	v	
Aperture start and stop element numbers	v	

Note 2 Effective height is the distance from the outside edge if the first to last element used in the focal law.

Following to be done to qualify the procedure:

a) Complete UT system (Method, Technique, Search units, instrument, all test parameters & conditions etc.) shall be capable of detecting and sizing the reference reflectors & indication throughout the 100% volume.

b) For procedure qualification, the qualification block(s) shall be prepared and shall contain a minimum of three flaws, oriented to simulate flaws parallel to the production weld's fusion line as follows:
   i) One surface flaw on the side of the block representing the component O.D. surface (sensitivity calibration block having OD notch can be used),
   ii) One surface flaw on the side of the block representing the component I.D. surface (sensitivity calibration block having ID notch can be used),
   iii) One subsurface flaw (Side drilled hole at middle thickness, or weld samples having side wall lack of fusion etc. can be used.)

c) Procedure has to be pre-qualified by performing a specific demonstration examination in accordance to the requirements T-150 of Article-1 ASME code Section-V & T-421.2 of ASME code Section-V. Procedure qualification also include the validation of calibration standard/blocks and characterization of recordable signals (if any). All records for the same shall be documented.

d) A change of requirement in Table identified as essential variable from the specified value, or range of values, specific procedure/scan plan shall be re-qualified, established and revised.

e) A change of requirement in above Table identified as non-essential variable from the specified value, or range of values would require revision of the procedure.

5.0 Safety

All personnel are responsible for ensuring that they perform their job in a safe and professional manner, while adhering to the BHEL`s safety regulations, in addition they will also adhere to any statutory requirements along with any project specific safety requirements.

6.0 Personnel Qualification

Personnel performing non-destructive testing to this specification shall be qualified and certified in accordance with NDE written practice for Training, Examination, Qualification & Certification of NDE Personnel as PAUT Level-II minimum.

Personnel who acquires the data, scan the job, does the calibration and analyze Phased Array data shall be trained on same specific technique and certified as NDE PAUT level II. However, data evaluation and analysis shall be performed by a NDE PAUT Level II or NDE Level III.

7.0 Preparation of Examination Area & Surface

Scanning surface should be free from any spatter, foreign materials, paint and any roughness that would interfere with the free movement of the search unit.

Scribe/reference line shall be marked at least on one side of joint configuration before starting the welding.

Maximum Surface roughness of scanning surface area shall be less than 1/3rd of notch depth. Where accessible, prepare the surface of the deposited weld metal so that it merges into the surfaces of the adjacent base materials; however, the weld may be examined in the as-welded condition, provided the surface condition does not interfere with valid interpretation of indications.

Generally, parent material has been tested using normal beam for planar flaw (e.g. lamination) during various stages of fabrication. Raw material records shall be referred. If it is taken care in raw material stage or chance of lamination is not there in the components, then it is not required. If the record is not available then prior to start of the Phased Array Inspection, the base metal distance up to scanning area and its HAZ area shall be scanned using normal beam probe.

The temperature difference between the calibration block and examination surface shall be within 14 degrees Celsius.

The ultrasonic examination area shall include the volume of the weld, plus the lesser of 1 in. (25 mm) or t on each side of the weld. Alternatively, examination volume may be reduced to include the actual heat affected zone (HAZ) plus 1/4 in. (6 mm) of base material beyond the heat affected zone on each side of the weld, provided the following requirements are met:

a) The extent of the weld HAZ is measured and documented during the weld qualification process.

b) The ultrasonic (UT) transducer positioning and scanning device is controlled using a reference mark (paint or low stress stamp adjacent to the weld) to ensure that the actual HAZ plus an additional 1/4 in. (6 mm) of base metal is examined.

8.0 Weld Identification

Weld joints shall be identified with Joint No. This unique joint numbering system shall be recorded as part of the file storage data. On the prepared area for inspection there will be a "ZERO" reference index and/or position numbers on the weld with paint marker, arrow indicating the direction of scanning. Same direction shall be maintained during the scan of similar type of joints.

9.0 Inspection Equipment and Accessories

9.1 Acquisition Unit & Software

Omni scan MX/MX2/X3 **or equivalent Phased Array inspection unit** which can be operated in pulse echo and/or pitch catch mode, shall be used in association to this procedure. It should contain 16/32 independent pulsar/receiver channels and shall handle up to 256 focal laws at a time. In general, the 16:128 modules can be effectively used up to 40 mm thickness which is the maximum thickness under the scope of this procedure. Also, the system shall be capable of generating B-Scan, C-Scan, S-Scan display along with A-scan. Equipment shall be capable of operation at frequencies over the range of 0.5 MHz to 21 MHz equipped with a calibrated stepped gain controls in units of 1dB or less and shall be with digitization of A-scans at a digitizing frequency of 100 MHz Also, equipment shall have option for onboard focal law generation software, various groups (Linear, Sectorial, compound) which can be generated according to the applicable scan plan. The real-time monitoring of the S-scan and C- scan data while doing scanning will ensure that proper data has been collected. The scanned data shall be stored in an external storage device, flash card or USB memory stick and it shall be transferred to a PC/Laptop and analysis of scanned data can be done with the help of OmniPC software or equivalent software. For information, OmniPC is PC-based software used for design, data acquisition, and visualization of ultrasonic signals. For offline analysis of the data a PC with Tom view or Omni PC software can be used. Data can be copied and analyzed remotely using this set up. ES Beam Tool software/ NDT setup Builder software can be used for making scan plan and ensuring 100% coverage of the weld region.

9.2 Scanner, Scanning and Data Acquisition Details:

These tools are adaptable with various wedges and phased array probes to suit any inspection procedures regardless of thickness & material. Examination shall be performed by one of the following techniques:

a) Manual/ semi-automated scanning using semi-automated scanner(s),
b) automated scanning using automated scanner(s)

For the purpose of above, Industrial one axis scanner or XY scanner etc. shall be used for the examination. Refer the table in next page for selection of scanner. Encoded scanners shall be used to improve quality, reliability and performance of data acquisition. Encoded systems shall be equipped with real-time displays to display one or more views of data being collected during the scan. This feature will be used only for assessment of data quality as the scan is progressing and may allow for one or more channels to be monitored. Welds scanned using encoded techniques may be scanned in sections provided that there is an overlap of data collected and the overlap between scans is identified in the encoded position with respect to the weld reference start position (minimum 50 mm overlap is required if more than one subsequent scanning to be done to complete the full weld length scan for example 9000-mm long weld may be scanned in two to complete the full weld length scan a for example, parts; one from 0 to 5000 mm and the second from 450 to 900mm).

Probes shall be mounted on the scanner. The major characteristic of the scanner is its capacity to bend in the center. This allows the scanner to fit on smaller/larger diameter and also to bring the force of the spring-loaded arm in the radial direction of the component for better stability of the wedge, and therefore, optimum data acquisition. Refer below table for recommended Scanner Model:

Inspection Technology	Model (Note*)	Axis		Manual	Motorized	Area Coverage
		One-Axis scanner	X-Y Scanner			
Phased Array	COBRA SCANNER	✓	-	✓	-	21 mm to 114 mm

Note * Any other Phased Array acquisition unit coupled with suitable scanner may be used on successful validation as per mandatory requirement mentioned in ASME Sec-V (2019 edition).

In general Cobra Scanner with the Omni Scan PA flaw detector, shall be used to perform circumferential weld inspections on small-diameter pipes. The COBRA holds up to two PA probes for inspections on tubes/pipes. This spring-loaded scanner is designed to clasp carbon steel and stainless steel tubes/pipes of various diameters using multiple link. The COBRA scanner is characterized by its smooth rolling encoded movement, which enables precise data acquisition. Aperture overlap for linear groups shall not be more than 50% of effective aperture height, and for sectorial groups angular increments shall not be more than 1 degree. In the scan axis, a minimum of 25 mm shall be given as overlap in order to ensure full coverage of the weld. Shear wave ultrasound shall be used for the angle beam inspection. Scanning shall be done at a maximum of 6 dB higher than the primary reference level sensitivity. Scan index distances shall be selected as specified in the scan plan (refer appendix). Generally, if required, for lamination/planar flaw, parent normal beam scan shall be done if required (refer clause 7.0)

9.3 Search Unit and Wedges

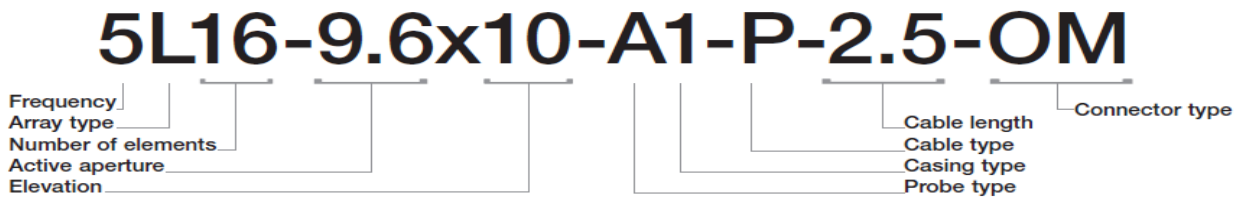
The Phased array probe frequency and size shall be determined by the pertinent parameters for the approved scan plan. Ultrasonic transducers configurations shall be selected in such a way that it shall cover the full volume of the weld. It will depend upon thickness and profile, location etc. of the weld joint. In general, 7.5/5MHz Phased array probes with 16 to 64 elements can be selected. However, the based on the actual joint profile, thickness etc. details a scan plan shall be made and same shall be approved by Level III with PAUT level II. Phased array probes shall be mounted on a wedge of suitable material and refracting angle as to be compatible to provide required beam steering.

Wedges shall have a provision for irrigation hole to provide uniform couplant while scanning.

The complete details of the phased array search units and wedges shall be specified in scan plan. (refer the sample Annexure: 1).

Probes shall be mounted on a wedge of suitable material and refracting angle as to be compatible to provide required beam steering.

Typical probe identification and probe nomenclature which is used by manufacturer are given below:



GLOSSARY USED TO ORDER PHASED ARRAY PROBES (Typical options shown)

Frequency
- 1.5 = 1.5 MHz
- 2.25 = 2.25 MHz
- 3.5 = 3.5 MHz
- 5 = 5 MHz
- 7.5 = 7.5 MHz
- 10 = 10 MHz

Array type
- L = linear
- A = annular
- M = matrix probe (1.5D, 2D)
- CV (ROC) = convex in azimuth
- CC (ROC) = concave in azimuth
- CCEV (ROC) = elevation focused

Number of elements

Example:
- 16 = 16 elements

Active Aperture

Active aperture in mm.
Refer to page vi for details.

Elevation

Elevation in mm
Example:
- 10 = 10 mm

Probe type
- A = angle beam with external wedge
- NW = near-wall
- PWZ = weld inspection angle beam
- W = angle beam with integrated wedge
- I = immersion
- DGS = DGS inspection/Atlas (AVG probe)
- AWS = AWS inspection

Casing type

Casing type for a given probe type

Cable type
- P = PVC outer
- M = metal armor outer

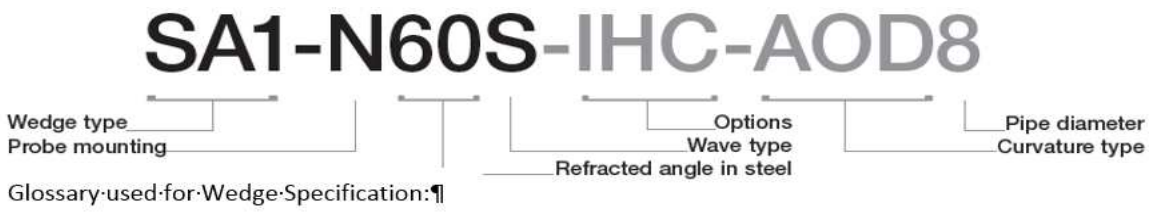
Cable length

Cable length in m
- 2.5 = 2.5 m
- 5 = 5 m
- 10 = 10 m

Connector type
- OM = OmniScan® connector
- HY = Hypertronics™ connector
- OL = OmniScan Connector with conventional UT channel on element 1 (LEMO® 00 connector)

This procedure shall use the following Phased Array Probes & Wedges as mentioned in below table:

Probe Model	Weld	Typical Application Use		Additional Information
		Manual	Automated	
A15	√			Low-profile design. Well suited for boiler tubes, thin-walled/small pipes and applications with minimal height clearance. Compatible with the COBRA* scanner.
A31	√		√	Primary probe for carbon steel weld inspections ranging from 3 mm to 26mm(0.12 in. to 1.02 in.) thickness.
A32	√		√	Primary probe for carbon steel weld inspections ranging from 12 mm to 60 mm(0.47 in. to 2.36 in.) thickness.



Glossary used for Wedge Specification:

Wedge type
SA00 = wedge for angle beam probe type A00
SA0 = wedge for angle beam probe type A0
SA1 = wedge for angle beam probe type A1
SA2 = wedge for angle beam probe type A2
SA3 = wedge for angle beam probe type A3
SA4 = wedge for angle beam probe type A4
SA5 = wedge for angle beam probe type A5
SA10 = wedge for angle beam probe type A10
SA11 = wedge for angle beam probe type A11
SA12 = wedge for angle beam probe type A12
SNW1 = wedge for near-wall probe type NW1
SPWZ1 = wedge for PipeWIZARD probe type PWZ1
SPWZ3 = wedge for PipeWIZARD probe type PWZ3

Probe mounting
N = normal
L = lateral (90° skew)

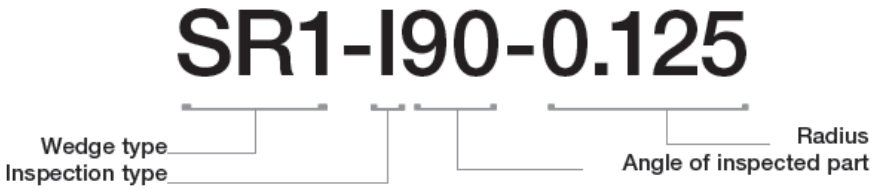
Refracted angle in steel
0 = 0°
45 = 45°
55 = 55°
60 = 60°

Wave type
S = shear wave
L = longitudinal wave

Options
IHC = Irrigation, scanner attachment points, and carbide wear pins
IHC-C = Irrigation, scanner attachment points, and composite wear pins
WP5 = Water pocket 0.005 in.

Curvature type
AOD = Axial outside diameter (circumferential scan)
COD = Circumferential outside diameter (axial scan)

Pipe diameter
Measured external pipe diameter in in.



Glossary used for curved wedge specification:

Wedge type
SR1 = wedge for curved probe type R1
SR4 = wedge for curved probe type R4
SR5 = wedge for curved probe type R5

Inspection type
I = internal
E = external

Angle of inspected part (°)
81 = 81°
90 = 90°
98 = 98°
Custom angles can be ordered.

Radius
Radius in in.
ADJ = adjustable radius

Standard Axial Outside Diameter (AOD) Wedge Curvature values		
External Diameter mm(in.)	**Curvature Range**	
	Minimum mm (in.)	**Maximum mm(in.)**
WEDGE TYPE: SA1,SA2,SA3,SA4,SA5,PWZ1,SPWZ3,S11,S12,S13		
2	45.7 (1.8)	50.8 (2)
2.25	50.8 (2)	57.1 (2.25)
2.5	57.1 (2.25)	63.5 (2.5)
3	63.5 (2.5)	76.2 (3)
3.25	76.2 (3)	82.5 (3.25)
3.5	82.5 (3.25)	88.9 (3.5)
4	88.9 (3.5)	101.6 (4)
4.5	101.6 (4)	114.3 (4.5)
5	114.3 (4.5)	127 (5)
6	127.0 (5)	152.4 (6)
7	152.4 (6)	177.8 (7)
8	177.8 (7)	203.2 (8)
10	203.2 (8)	254.0(10)
12	254.0 (10)	304.8 (12)
16	304.8 (12)	406.4 (16)
22	406.4 (16)	555.8 (22)
30	558.8 (22)	762.0 (30)
FLAT	762.0 (30)	Up to flat
WEDGE TYPE: SA10*,SA11*,SA12*,SA14*SA31,SA32		
2.375	50.8 (2)	60.3 (2.375)
2.875	60.3 (2.375)	73.0 (2.875)
3.5	73.0 (2.875)	88.9 (3.5)
4	88.9 (3.5)	101.6 (4)
4.5	101.6 (4)	114.3 (4.5)
5.563	114.3 (4.5)	141.3 (5.563)
6.625	141.3 (5.563)	168.3 (6.625)
8.625	193.7 (7.625)	219.0 (8.625)
10.75	219.0 (8.625)	273.0 (10.75)
12.75	273.0 (10.75)	323.8 (12.75)
16	323.8 (12.75)	406.4 (16)
24	406.4 (16)	609.6 (24)
FLAT	609.6 (24)	Up to flat

10.0 Computerized Imaging technique

The major attribute of Computerized Imaging Techniques (CITs) is their effectiveness when used to characterize and evaluate indications; however, CITs may also be used to perform the basic scanning functions required for flaw detection. Computer-processed data analysis and display techniques are used in conjunction with automatic or semiautomatic scanning mechanisms to produce two and three-dimensional images of flaws, which provides an enhanced capability for examining critical components and structures. Computer processes may be used to quantitatively evaluate the type, size, shape, location, and orientation of flaws detected by ultrasonic examination.

11.0 Couplant

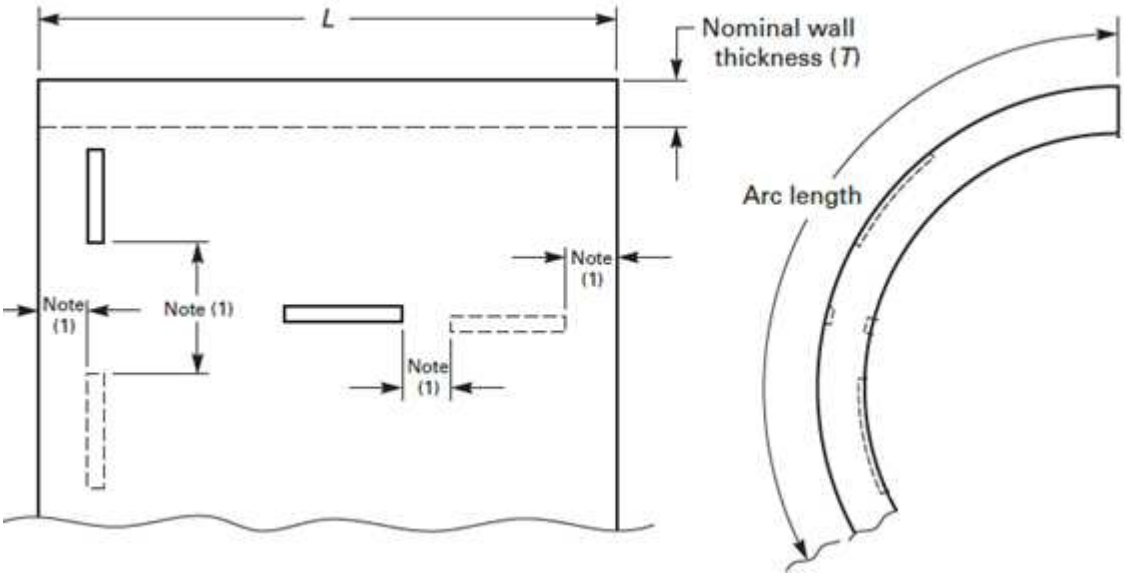
Acoustic coupling shall be obtained by using a medium (oil, grease, cellulose, water) suitable for the purpose. In this procedure water (up to 50°C) shall be used to promote acoustic coupling, however, no residue will remain on the work-piece surface after the water has been evaporated. Couplant to be used during the calibration shall be used for scanning on actual job. The temperature differential between the calibration block and examination surfaces shall be within 25°F (15°C).

12.0 Calibration Blocks

The inspection system shall be calibrated using standard calibration blocks and reference blocks. Following details shall be ensured:

a) **Material, Heat Treatment, Curvature & Surface finish**: The material from which the block is fabricated shall be of the same product form and material specification or equivalent P-Number grouping as one of the materials being examined. For the purposes of this paragraph, P-Nos. 1, 3, 4, 5A through 5C, and 15A through 15F materials are considered equivalent. Generally, the compared specimen (calibration Standard/reference block) shall of the same product form, nominal diameter, thickness, nominal composition, surface conditions, acoustical properties and heat treatment condition as the product being examined. When the block material is not of the same product form or has not received the same heat treatment, it may be used provided it meets all other block requirements and a transfer correction for acoustical property differences is used. All these details shall be reported for the validation of calibration standard/Block. The finish on the scanning surfaces of the block shall be representative of the scanning surface finishes on the component to be examined.

b) **Reflectors:** The standard reflector shall be as per article 4 of ASME Section V. Specific detailed drawing with the tolerance for the calibration standard/Block shall be attached scan plan.



General Notes:

i) The minimum calibration block length(L), shall be adequate enough to take care of scanner as well as probe setup required for calibration. Generally, minimum calibration block length(L) preferred is 500 mm.

ii) Arc length shall be 360 deg/full section to take care of sensitivity calibration as well as scanner block requirement. However, if in some cases machining of reflectors is very difficult then in that case separate block for sensitivity and scanner block for demo can be made. In case of separate block, for OD 100 mm or less, the minimum arc length shall be 270 deg and for OD greater than 100 mm, the minimum arc length shall be 200 mm or 3T, whichever is greater.

iii) Notch depths shall be from 8% T minimum to 11% T maximum.

iv) Notch widths shall be 6 mm maximum. Notch lengths shall be 25 mm minimum. Maximum notch width is not critical. Notches may be made with EDM or with end mills up to 6 mm in diameter.

v) Minimum Notch lengths and maximum notch width shall be sufficient to provide for calibration with a minimum 3 to 1 signal-to-noise ratio.

vi) For dissimilar material/thickness: Two blocks shall be used, if single block does not satisfy the requirements.

vii) Notch(groove) height> 3 times the surface roughness of the block, Block/reflector flatness < 0.5° and Maximum block thickness variation < 0.10 T Component.

viii) Reflectors transverse to the weld seam is required only when cross-defects (such as transverse cracking) is suspected, the requirement of the same can be established during welding process qualification.

ix) Schematic figure of sample calibration block is mentioned in Annexure-II.

Note:1 Notches shall be located not closer than T or 1 in. (25 mm), whichever is greater, to any block edge or to other notches.

C) Quality: Prior to fabrication, the block material shall be completely examined with a straight beam search unit. Areas that contain an indication exceeding the remaining back-wall reflection shall be excluded from the beam paths required to reach the various calibration reflectors. The same shall be recorded. The standard defects shall be machined by very precise machining process in such a way that the indications of each of them are separate and distinct without any mutual acoustic interface or amplification. The calibration block shall be long enough to simulate the handling of the product being examined through the examination equipment. All upset metal, burrs, etc., adjacent to the reference notches shall be removed.

Calibration Standard/Block shall be able to produce minimum SNR value 3:1 with the actual test speed condition. Also, signal from each reflectors have to be clearly distinguishable.

Measurements may be made by optical, replicating, or CMM techniques. Tolerance shall be also specified for the dimensions in the drawing of blocks.

The all actual dimension of the calibration standard/Block including reflectors shape & size details shall be checked and shall be reported. These dimensions shall be also witnessed & certified (once) by the Inspector. However, the detailed documented record shall be made available to the inspector and shall be part of final documentation.

13.0 Calibration

13.1 Equipment Calibration

Phased Array System Linearity verification shall be done as per Article 23, SE- 2491 of ASME Section V. The results of these checks recorded in the ultrasonic instrument linearity forms and are kept as a part of the inspection record. Instrument linearity checks are conducted on a twelve-month cycle.

Prior to the start of shift operator need to carry out an element check and ensure that probe is in working condition and ensure that no more than 10% of elements are inactive and no two adjacent elements are inactive.

13.2 Encoder Calibration

Encoder calibration check shall be performed at intervals not to exceed one month or prior to first use thereafter, by moving the encoder a minimum distance of 20 in. (500 mm). The display distance shall be within 1% of the actual distance moved.

Steps for Encoder Calibration

a) Encoder calibration shall be done to ensure the positional accuracy of the encoder.
b) Mark a distance of minimum 500 mm, and move the encoder through this distance. The value shown by the encoder shall be within +/- 1 % of the moved

distance. If the values are outside the acceptable range, then encoder calibration shall be performed.

c) Move the encoder through a known distance, enter the distance value in the system and calibrate.
d) The system will automatically calculate the resolution of the encoder.
e) Move the encoder to a known distance after the calibration to make sure that the encoder is showing positional accuracy within the acceptable range.

13.3 Velocity & Wedge Delay Calibration

The wedge delay calibration shall be carried out for both linear scan and as well as sectorial scan. The velocity & wedge delay calibration can be carried out in sound path (using 50mm, 100mm radius of IIW V1 block) mode or true depth (using SDH's) mode with known reflector having fixed sound path or depth respectively. Peak up this signal from the calibration reflector and scan the phased array probe backwards and forwards through all the different angles or focal laws. When the signal for all angles and focal laws lies within the threshold, Omni scan system dynamically adjusts delay setting to correctly indicate radius (depth).

Steps for Velocity Calibration:

a) Velocity calibration shall be used for determining the accurate sound velocity in the test Material.
b) Holes or reflectors at different depth shall be used for calibrating velocity.
c) Input the known depth values of the reflectors to the machine and peak up the signals from
d) corresponding reflectors.
e) After recording these points, upon calibrating the machine will calculate the value of sound velocity in the material.

Steps for Wedge Delay:

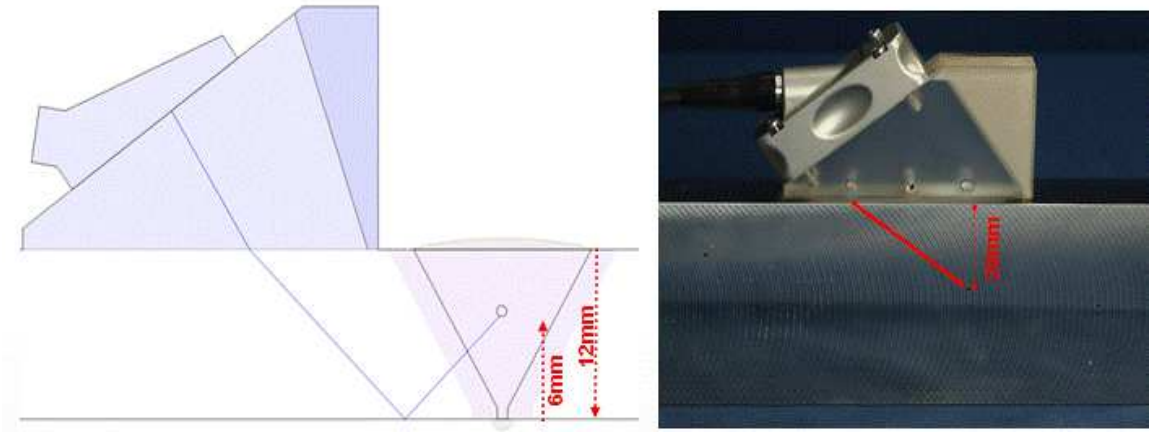
a) Wedge delay calibration shall be used for the true depth with all the angles used in each group.
b) Holes or surfaces (for zero degree) shall be used for calibrating wedge delay.
c) Peak up the signal from the reference reflector and scan the probe back and forth to catch the reflector echo through all the focal laws in the group
d) After calibrating, the system will calculate the respective wedge delays and will make the necessary adjustments so that the system will show the correct depth of reflectors from there on.

13.4 Sensitivity Calibration

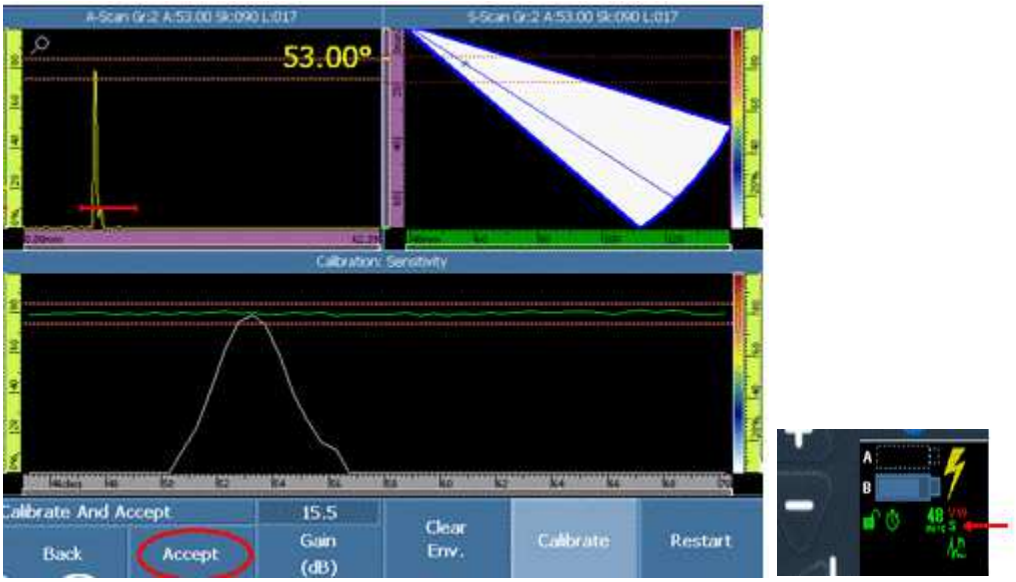
The Sensitivity Calibration will provide the required gain adjustment for each refracted angle or focal law used in a group. All individual beam in the examination shall be calibrated to provide the measurement of distance and amplitude correction over the sound path employed in the examination. This shall include the applicable compensation for the wedge sound path variations and wedge attenuation effects. Focal law to be used during the examination shall be used for calibration. Sensitivity calibration is done to equalize the amplitude of all focal laws in each group. Basic idea is to make sure all focal laws will give same amplitude for same reflector.
Typically, ID/OD notch or SDH of the reference block shall be taken as reference reflector within the zone of material to be examined.

Steps for sensitivity Calibration

a) Select a reflector, within the depth range of examination. In general depth (or beam travel) of reflector has to at least 1.5 times the skip thickness in true depth. For example, refer the figure below:



a) Ensure range is sufficient for all the focal laws (for example 40-70 degrees),
b) Peak up the signal from this reflector, and adjust the amplitude to 80% of FSH.
c) Scan the probe back and forth over the reflector with consistent pressure and coupling such that all the focal laws catch the reflector.
d) After calibrating for sensitivity, system will calculate the compensatory gain and all the focal laws will show the same amplitude range within 80% +/-5% of FSH.
e) Calibrate option may be selected repeatedly until all laws are within tolerance.
f) Finally, select option accept and a green S will appear indicating sensitivity calibration is completed. For example, refer the figure:



g) Already stored calibration files shall be re-verified on the reference block before performing the actual examination to take care of any change in the test components such as probe, cables, instruments, every day before start of the inspection, when examination personnel are changed etc.

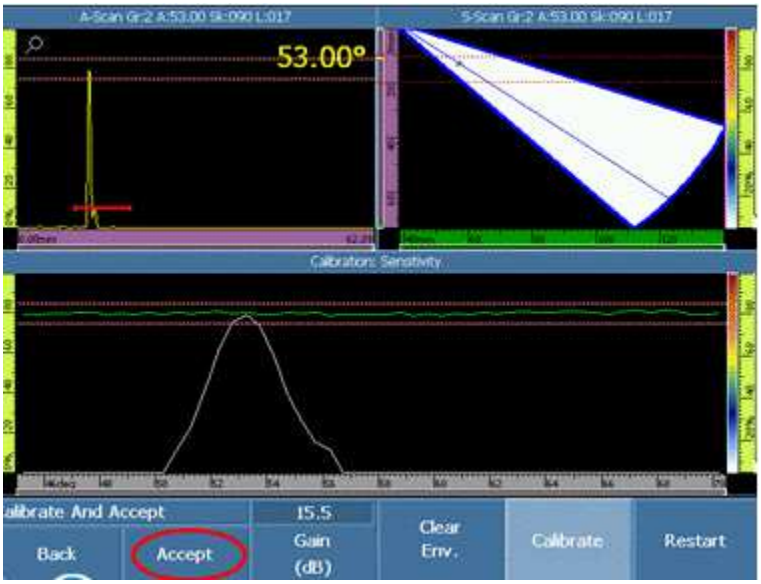
13.5 TCG Calibration

A Time Corrected Gain (TCG) shall be used to compensate the attenuation of sound in the material within the sound paths utilized during examination. TCG to be done to equalize the amplitude of all A-scans or focal laws over the sound path range with a series of calibration targets. Generally, it should be a 3 point TCG. This shall be digitally recorded and documented. TCG calibration wizard uses the same interface as the sensitivity calibration with the exception that it does not allow a negative gain correction and it can be used as successive calibration reflectors/targets. The reflectors/targets used for TCG calibration should cover the entire range of the area of interest for the inspection. TCG calibration has to be carried out for all scan plans in a multi group option while using phased array probe.

Steps for TCG Calibration

a) Depending upon scan plan, two or more reflectors at different depths shall be used for calibrating TCG according to the range requirements.
b) Place the phased array probe perpendicular to the reflector's axis. Move the phased array probe forward and backward to equal the amplitude for all the focal laws and angles and plot the first point.
c) Peak the signal from the respective reflectors and adjust the gain to obtain 80% of amplitude from the reflector.

d) The same process is repeated to set the response from each reflector for each focal law and will be adjusted to 80% of full screen height with 5% tolerance level, by automatically calibrating the compensatory gain.
e) Once all the points (generally three) are picked the TCG can be accepted.
f) Once the TCG is done, the system will show same amplitude for same sized reflectors within the calibrated depth range. Same can be cross checked before acceptance of the TCG. Refer the figure below:



g) Once TCG is accepted, it shall be stored with all parameter such as job Thickness, OD, Job No. etc. for proper identification and retrieval.
h) Already stored calibration files shall be re-verified on the reference block before performing the actual examination to take care of any change in the test components such as probe, cables, instruments, every day before start of the inspection, when examination personnel are changed etc.
i) In case of any practical difficulties faced on notch calibration for very lower thickness/diameter component, the same shall be reported to level III and PAUT II for the obtaining the further decision.

13.6 Calibration Confirmation

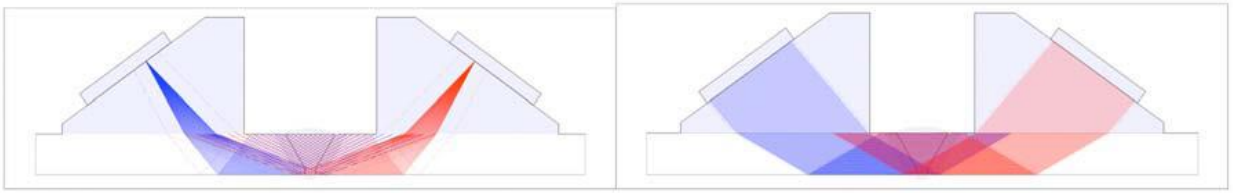
A calibration checks on at least one of the reflectors in the basic calibration block or a check using a simulator shall be performed at the completion of each examination or series of similar examinations, and when examination personnel (except for automated equipment) are changed. If any sensitivity setting has changed by more than 20% or 2 dB of its amplitude, correct the sensitivity calibration and note the correction in the examination record. If the sensitivity setting has decreased, all data sheets since the last valid calibration or calibration check shall be marked void and the area covered by the voided data shall be reexamined. A logbook for the same shall be maintained by the performer and reviewed by the inspector.

14.0 Scan plan

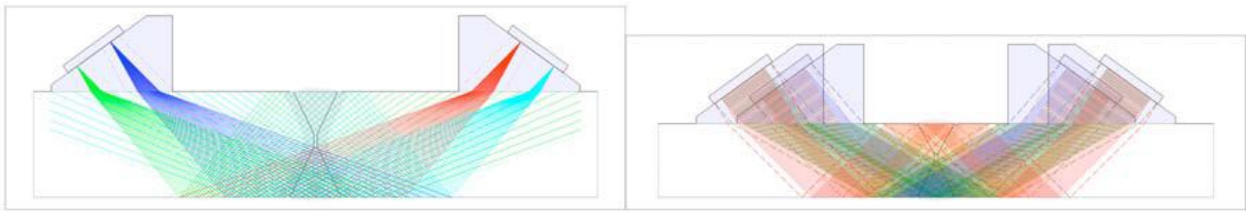
A documented examination strategy or scan plan shall be provided showing transducer placement, movement, and component coverage that provides a standardized and repeatable methodology for weld acceptance. The scan plan shall also include ultrasonic beam angle used, beam directions with respect to weld centerline, weld geometry, number of zones and vessel volume examined for each weld. The specific documentation shall be made.

Scan plan shall provide clear view of scanning, helping to clearly convey weld coverage, HAZ coverage and probe position, in addition to critical dimensions. The beam set parameters dialog displays a visual representation of the transducer elements that are used to form the beam set. These all achieved with the help of ES-Beam software tool and NDT Setup Builder. The scan plan, in combination with the written procedure, shall address all requirements of Table IV-421.

For thin butt welds (S and E Scans) should be examined from both sides of the weld and preferably from the bevel opening side (when access permits). For thin wall sections, a single probe stand-off may be possible for linear scanning if the probe parameters are adequate for full volume coverage.



For thick butt welds (S and E Scans) should be examined from both sides of the weld and preferably from the bevel opening side (when access permits). For thick wall sections, multiple probe stand-offs or multiple focal law stand-offs will be required for linear scanning to ensure full volume coverage.



The sample detailed scan plan for inspection of full volume for given weld geometry and thickness are given in Annexures. Depending upon the actual job configuration, weld bevel profile etc. specific scan plan shall be made and shall be approved by level III for the examination.

Note: It may be required to change the scan plan parameters depends on actual job configuration, weld bevel profile etc. The same shall be verified with demonstration/qualification block to ensure the full coverage.

15.0 Examination Coverage and Scanning

The required volume of the base material and weld to be examined shall be scanned from outer surface using a linear scanning technique with encoder. Each linear scan shall be parallel to the weld axis and at a constant standoff distance with the beam oriented perpendicular to the weld axis. Scanning mechanisms shall be used to maintain a constant distance and alignment between the index points of the probes. Scanning mechanisms can either be motor or manually driven with encoder. They shall be guided by means of a suitable guiding mechanism (steel band, belt, automatic track following systems, guiding wheels etc.). Restricted access welds like single side access and T-Joints shall have to be dressed for its weld cap and examined from single side. During inspection over this dressed weld surface, if data acquisition is not acceptable due to missing data lines, then the weld cap shall be removed for inspection. A maximum sampling of 1mm shall be set for and be used between A-scans collected for thickness up to 50mm. A 2mm resolution can be used for thicknesses more than 50mm. Scanning speed shall not exceed 150 mm/sec. Also, scanning speed will be limited by mechanical ability to maintain acoustic coupling and by the system's electronic ability to ensure full wave forms are captured without missing data points. Missing of data lines shall not exceed 2 data lines per inch or 5% (whichever is less) of the total acquisition with adjacent data shall not be missed. Generally, equipment has the capability of rewriting the data while observed loss of data. The encoder is retrieved back to home position whenever data is missed. Missing data is represented by black lines in the display. Between two consecutive scans there should be and overlap of 50mm. Repaired weld area shall be rescanned with an overlap of minimum 50mm at the start and end of the scan.

For material thickness 8 in. (200 mm) or less, the ultrasonic examination area shall include the volume of the weld, plus the lesser of 1 in. (25 mm) or t on each side of the weld. Alternatively, examination volume may be reduced to include the actual heat affected zone (HAZ) plus 1/4 in. (6 mm) of base material beyond the heat affected zone on each side of the weld, provided the following requirements are met:

a) The extent of the weld HAZ is measured and documented during the weld qualification process.
b) The ultrasonic (UT) transducer positioning and scanning device is controlled using a reference mark (paint or low stress stamp adjacent to the weld) to ensure that the actual HAZ plus an additional 1/4 in. (6 mm) of base metal is examined.

A documented examination strategy or scan plan shall be provided showing transducer placement, movement, and component coverage that provides a standardized and repeatable methodology for weld acceptance. The scan plan shall also include ultrasonic beam angle.

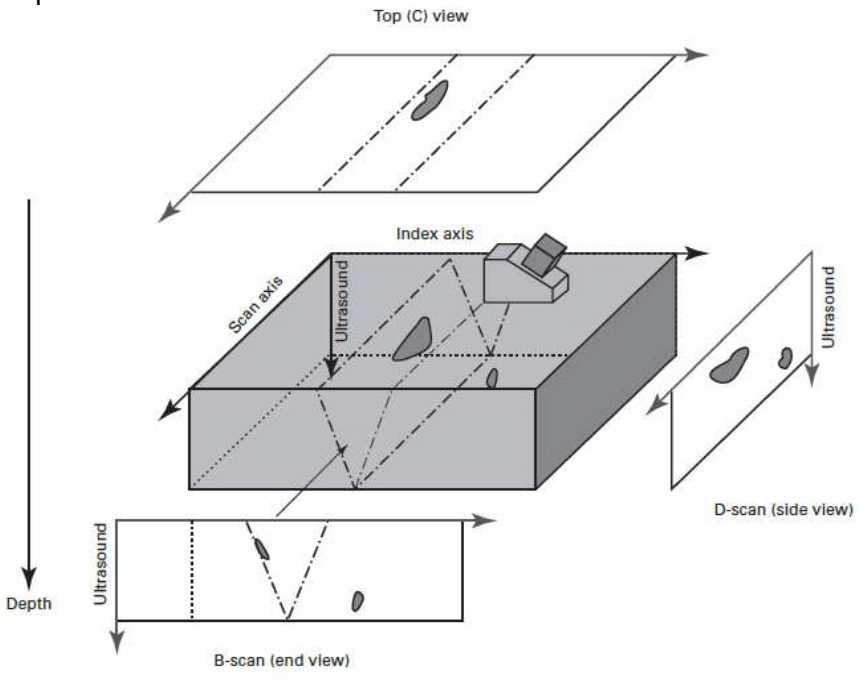
For reflectors transverse to the weld seam, manual shear wave UT should be utilized and the indications originating from actual discontinuities shall be recorded. **This is applicable only when**

cross-defects (such as transverse cracking) is suspected, the requirement of the same can be established during welding process qualification. If required, Manual Pulse-Echo UT examinations are performed along flush ground welds in longitudinal direction; this will be demonstrated by identifying the transverse discontinuity in the validation block. Scanning in both directions along the weld (e.g. Clockwise & counter clock wise for a circumferential seam) is applicable. If the weld cap is not machined or ground flat, the examination shall be performed from the base material on both sides of the weld cap. While scanning parallel to the weld axis, the angle beam shall be directed from 0 deg to 60 deg with respect to the weld axis in both axial directions, with the angle beam passing through the required examination volume.

Prior to scanning, calibration data shall be recorded and stored. The Restricted access welds like T-Joints shall have to be dressed for its weld cap and examined. During inspection over this dressed weld surface, if data acquisition is not acceptable due to missing data lines, then the weld cap shall be removed for inspection.

A maximum sampling of 1mm shall be set for and be used between A-scans collected for thickness up to 50mm. A 2mm resolution can be used for thicknesses more than 50mm. Scanning speed shall not exceed 150 mm/sec. Scanning speed will be limited by mechanical ability to maintain acoustic coupling and by the system's electronic ability to ensure full wave forms are captured without missing data points. Scanning speed shall not exceed that
qualified. Missing of data lines shall not exceed 5% of the total acquisition with adjacent data shall not be missed. Omni Scan equipment has the capability of rewriting the data while observed loss of data. The encoder is retrieved back to home position whenever data is missed.

Each linear scan shall be parallel to the weld axis and at a constant standoff distance with the beam oriented perpendicular to the weld axis.



16.0 Recording and Evaluation

A-scan data shall be recorded for the area of interest in an unprocessed form with no threshold, at a minimum digitization rate of five times the examination frequency.

For amplitude base technique all indications greater than 20% of the reference level shall be investigated to the extent that they can be evaluated in terms of the acceptance criteria of the referencing Code Section.

Missing lines in the display shall not exceed 5% of the scan lines to be collected, and no adjacent lines shall be missed

For welds joining two different thickness of material, material thickness shall be based on the thinner of the two materials.

It is recognized that not all ultrasonic reflectors indicate flaws, since certain metallurgical discontinuities and geometric conditions may produce indications that are not relevant. Included in this category are plate segregates in the heat-affected zone that become reflective after fabrication. Under straight beam examination, these may appear as spot or line indications. Under angle beam examination, indications that are determined to originate from surface conditions (such as weld root geometry) or variations in metallurgical structure in austenitic materials (such as the automatic-to-manual weld clad interface) may be classified as geometric indications. The identity, maximum amplitude, location, and extent of reflector causing a geometric indication shall be recorded. [For example: internal attachment, 200% DAC, 1 in. (25 mm) above weld center line, on the inside surface, from 90 deg to 95 deg] The following steps shall be taken to classify an indication as geometric:

(a) Interpret the area containing the reflector in accordance with the applicable examination procedure.

(b) Plot and verify the reflector coordinates. Prepare a cross-sectional sketch showing the reflector position and surface discontinuities such as root and counterbore.

(c) Review fabrication or weld preparation drawings. Other ultrasonic techniques or nondestructive examination methods may be helpful in determining a reflector’s true position, size, and orientation.

EVALUATION LEVEL

Distance–Amplitude Techniques: All indications greater than 20% of the reference level shall be investigated to the extent that they can be evaluated in terms of the acceptance criteria of the referencing Code Section.

Non-distance–Amplitude Techniques: All indications longer than 40% of the rejectable flaw size shall be investigated to the extent that they can be evaluated in terms of the acceptance criteria of the referencing Code Section.

EVALUATION OF LAMINAR REFLECTORS

Reflectors evaluated as laminar reflectors in base material which interfere with the scanning of examination volumes shall require the angle beam examination technique to be modified such that the maximum feasible volume is examined, and shall be noted in the record of the examination

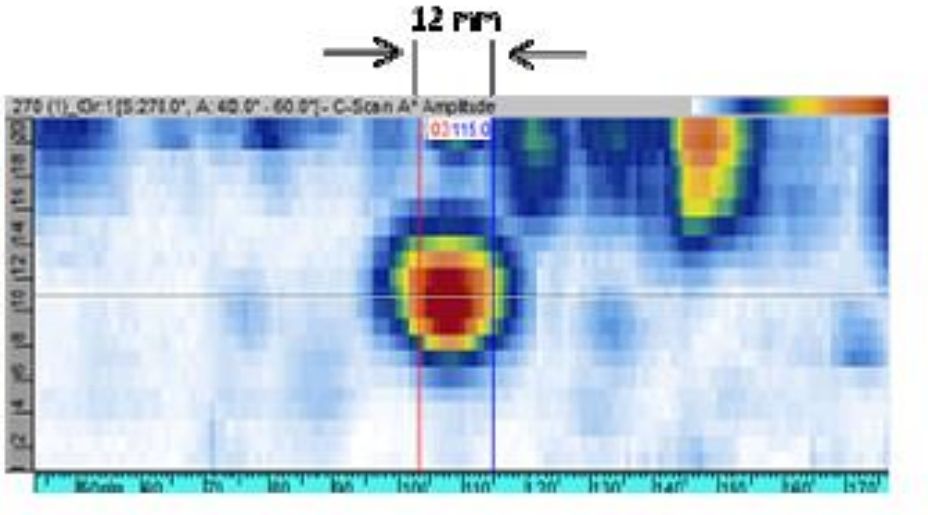
ALTERNATIVE EVALUATIONS

Reflector dimensions exceeding the referencing Code Section requirements may be evaluated to any alternative standards provided by the referencing Code Section

16.1 Relevant Indications

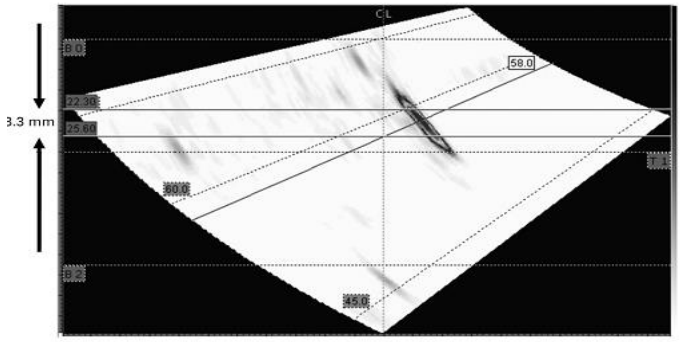
Signals that are determined to result from welding flaws shall be assessed according to the acceptance criteria.

Flaw Length: Flaw lengths parallel to the surface can be measured from the distance encoded C-scan images using amplitude drop (e.g., -6 dB Drop) techniques by placing the vertical cursors on the extents of the flaw displayed on the C-scan display. Below mentioned image shows an example of cursors used for length sizing.

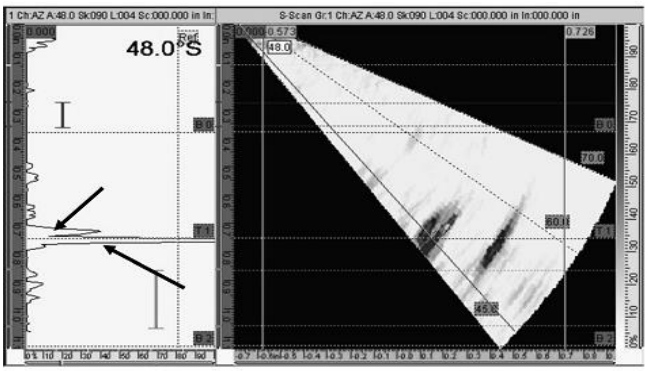


Flaw Height: Flaw height normal to the surface can be measured from the B-, E-, or S-scan images using **(a)** amplitude drop, **(b)** tip diffraction techniques.

(a) Using amplitude drop techniques, the horizontal cursors are placed on the displayed flaws upper and lower extents. Below mentioned image shows an example of cursors used for height sizing with the amplitude drop technique.



(b) Using tip diffraction techniques the horizontal cursors are placed on the upper and lower tip signals of the displayed flaw. Below mentioned image shows an example of cursors used for height sizing with the tip diffraction technique.



17.0 Flaw Evaluation and Acceptance Criteria

For lower thickness where categorization of imperfections by type (surface and sub-surface) and their size (i.e. length and through wall height) is not possible then workmanship acceptance standard shall be followed otherwise fracture mechanics based shall be followed. Same shall be ensured during demonstration and scan plan qualification.

Workmanship:

A standard for acceptance of a weld based on the characterization of imperfections by type (i.e. Crack, Incomplete fusion, Incomplete penetration, or Inclusion) and their size (i.e. length).

a) Indications characterized as cracks, lack of fusion & incomplete penetration are not acceptable regardless of length.

b) Indications from other imperfections are not acceptable if the indications exceed the reference level and have lengths which exceed
   i) 6 mm for `t' up to 19 mm,
   ii) 1/3t for t from 19 mm to 57 mm
   iii) 19 mm for t over 57 mm

   Where `t' is thickness of weld excluding any allowable reinforcement.

c) For a butt weld joining two members having different thickness at the weld 't' is the thinner of the thickness. If a full penetration weld includes a fillet weld, the thickness of `throat' of the fillet shall be included in `t'.

Fracture Mechanics:

A standard for acceptance of a weld based on the categorization of imperfections by type (i.e. surface or subsurface) and their size (i.e. length and through wall height).

Acceptance Criteria:

Flaws shall be evaluated for acceptance using the applicable criteria and with the following additional requirements:

(a) For surface connected flaws, the measured through-wall dimension, a, shall be compared to the value of "a" as determined from the applicable flaw acceptance criteria.

(b) For subsurface flaws, the measured through wall dimension, 2a, shall be compared to twice the value of "a" as determined from the applicable flaw acceptance criteria table.

(c) Surface Connected Flaws:

Flaws identified as surface flaws during the UT examination may or may not be surface connected, as shown in Figures 1 through 5. Therefore, unless the UT data analysis confirms that that flaw is not surface connected, it shall be considered surface connected or a flaw open to the surface. If the flaw is surface connected, the requirements above still apply; however, in no case shall the flaw length, ℓ, exceed the acceptance criteria in the applicable Construction Code for the method employed.

(d) Multiple Flaws:

(1). Discontinuous flaws shall be considered a singular planar flaw if the distance between adjacent flaws is equal to or less than S as shown in Figure 2.

(2). Discontinuous flaws that are oriented primarily in parallel planes shall be considered a singular planar flaw if the distance between the adjacent planes is equal to or less than 1/2 in. (13 mm). (Refer to Figure 3.)

(3). Discontinuous flaws that are coplanar and nonaligned in the through-wall thickness direction of the component shall be considered a singular planar flaw if the distance between adjacent flaws is equal to or less than S as shown in Figure 4.

(4). Discontinuous flaws that are coplanar in the through-wall direction within two parallel planes 1/2 in. (13 mm) apart (i.e., normal to the pressure retaining surface of the component) are unacceptable if the additive flaw depth dimension of the flaws exceeds those shown in Figure 5.

(e) Subsurface Flaws.

Flaw length (*l*) shall not exceed 4*t.*

(j) The nameplate shall be marked under the Certification Mark by applying UT to indicate ultrasonic examination of welded seams required to be inspected in accordance with Section I or Section XII.

(k) This Case number shall be shown on the Manufacturer's Data Report, and the extent of the UT examination shall be noted.

Flaw Acceptance Criteria for 1/2 in. (13 mm) To Less than 1 in. (25 mm) Thick Weld

	a/t	***ℓ***
Surface flaw	≤0.087	≤0.25 in. (6.4 mm)
Subsurface flaw	≤0.143	≤0.25 in. (6.4 mm)

GENERAL NOTES:

(a) *t* = the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thickness at the weld, *t* is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet weld shall be included in *t.*

(b) A subsurface indication shall be considered as a surface flaw if the separation (*S* in Figure 1) of the indication from the nearest

surface of the component is equal to or less than half the through dimension (2*d* in Figure 1, sketch [b]) of the subsurface indication.

Flaw Acceptance Criteria for 1 in. (25 mm) To 12 in. (300 mm) Thick Weld

Aspect Ratio, a/ ℓ	1 in. (25 mm) ≤ *t* ≤ 21/2 in. (64 mm)		4 in. (100 mm) ≤ *t* ≤ 12 in. (300 mm)	
	Surface Flaw, *a/t*	Subsurface Flaw, *a/t*	Surface Flaw, *a/t*	Subsurface Flaw, *a/t*
0.00	0.031	0.034	0.019	0.020
0.05	0.033	0.038	0.020	0.022
0.10	0.036	0.043	0.022	0.025
0.15	0.041	0.054	0.025	0.029
0.20	0.047	0.066	0.028	0.034
0.25	0.055	0.078	0.033	0.040
0.30	0.064	0.090	0.038	0.047
0.35	0.074	0.103	0.044	0.054
0.40	0.083	0.116	0.050	0.061
0.45	0.085	0.129	0.051	0.069
0.50	0.087	0.143	0.052	0.076

Flaw Acceptance Criteria for 1 in. (25 mm) To 12 in. (300 mm) Thick Weld (Cont'd)

GENERAL NOTES:

(a) *t* = thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thickness at the weld, *t* is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet weld shall be included in *t.*

(b) A subsurface indication shall be considered as a surface flaw if separation (*S* in Figure 1) of the indication from the nearest surface of the component is equal to or less than half the through thickness dimension (2*d* in Figure 1, sketch [b]) of the subsurface indication.

(c) If the acceptance criteria in this table results in a flaw length, ℓ, less than 0.25 in. (6.4 mm), a value of 0.25 in. (6.4 mm) may be used.

NOTE:

(1) For intermediate flaw aspect ratio *a/ℓ* and thickness *t* (21/2 in. [64 mm] < *t* < 4 in. [100 mm]) linear interpolation is permissible.

Flaw Acceptance Criteria for Larger than 12 in. (300 mm) Thick Weld

Aspect Ratio, a/ ℓ	Surface Flaw, a		Subsurface Flaw, a	
	in	mm	in	mm

0.00	0.228	5.79	0.240	6.10
0.05	0.240	6.10	0.264	6.71
0.10	0.264	6.71	0.300	7.26
0.15	0.300	7.62	0.348	8.84
0.20	0.336	8.53	0.408	10.4
0.25	0.396	10.1	0.480	12.2
0.30	0.456	11.6	0.564	14.3
0.35	0.528	13.4	0.648	16.5
0.40	0.600	15.2	0.732	18.6
0.45	0.612	15.5	0.828	21.0
0.50	0.624	15.8	0.912	23.2

GENERAL NOTES:

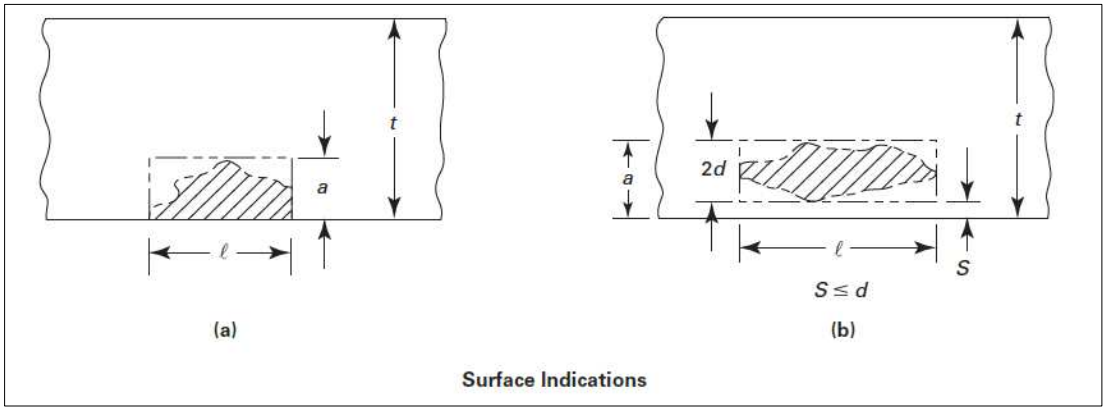
(a) For intermediate flaw aspect ratio, a/ℓ linear interpolation is permissible.

(b) t = the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thickness at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet weld shall be included in t.

(c) A subsurface indication shall be considered as a surface flaw if separation (S in Figure 1) of the indication from the nearest surface of the component is equal to or less than half the through thickness dimension ($2d$ in Figure 1, sketch [b]) of the subsurface indication.

Figure 1

Single Indications



Surface Indications

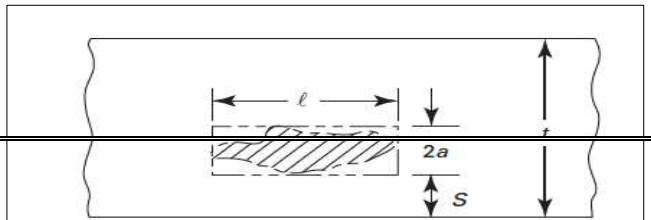


Figure 2

Multiple Planar Flaws Oriented in Plane Normal to Pressure Retaining Surface

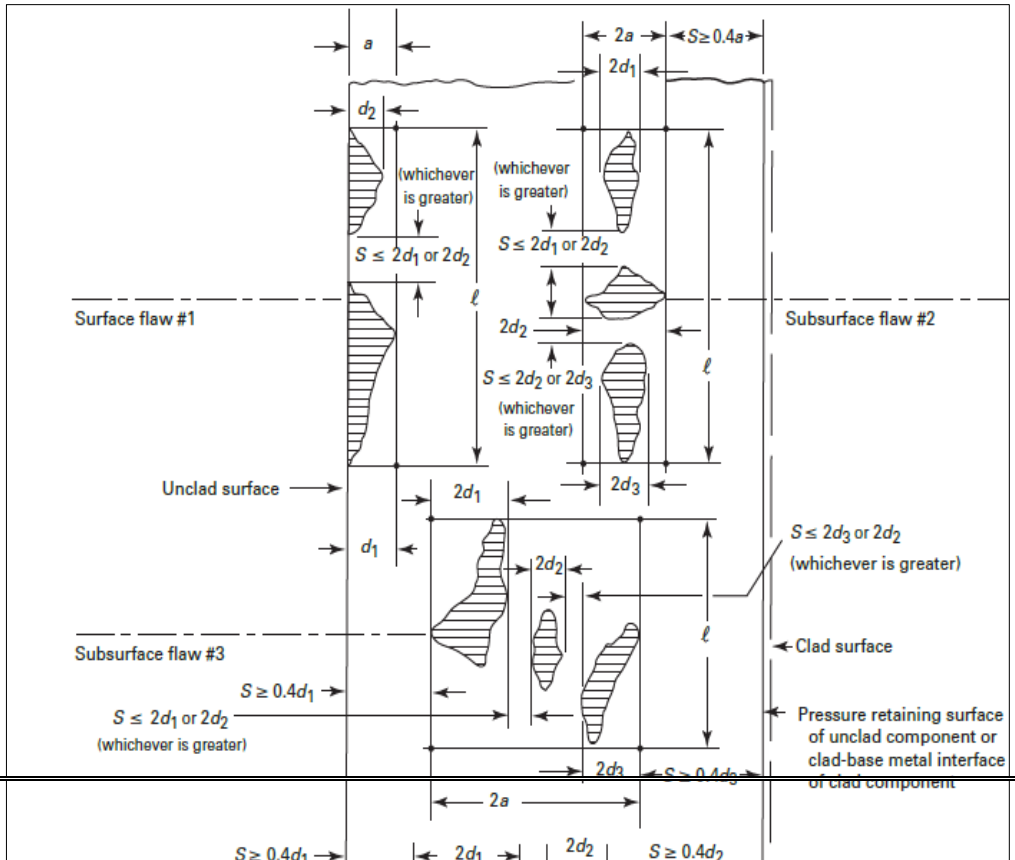


Figure 3

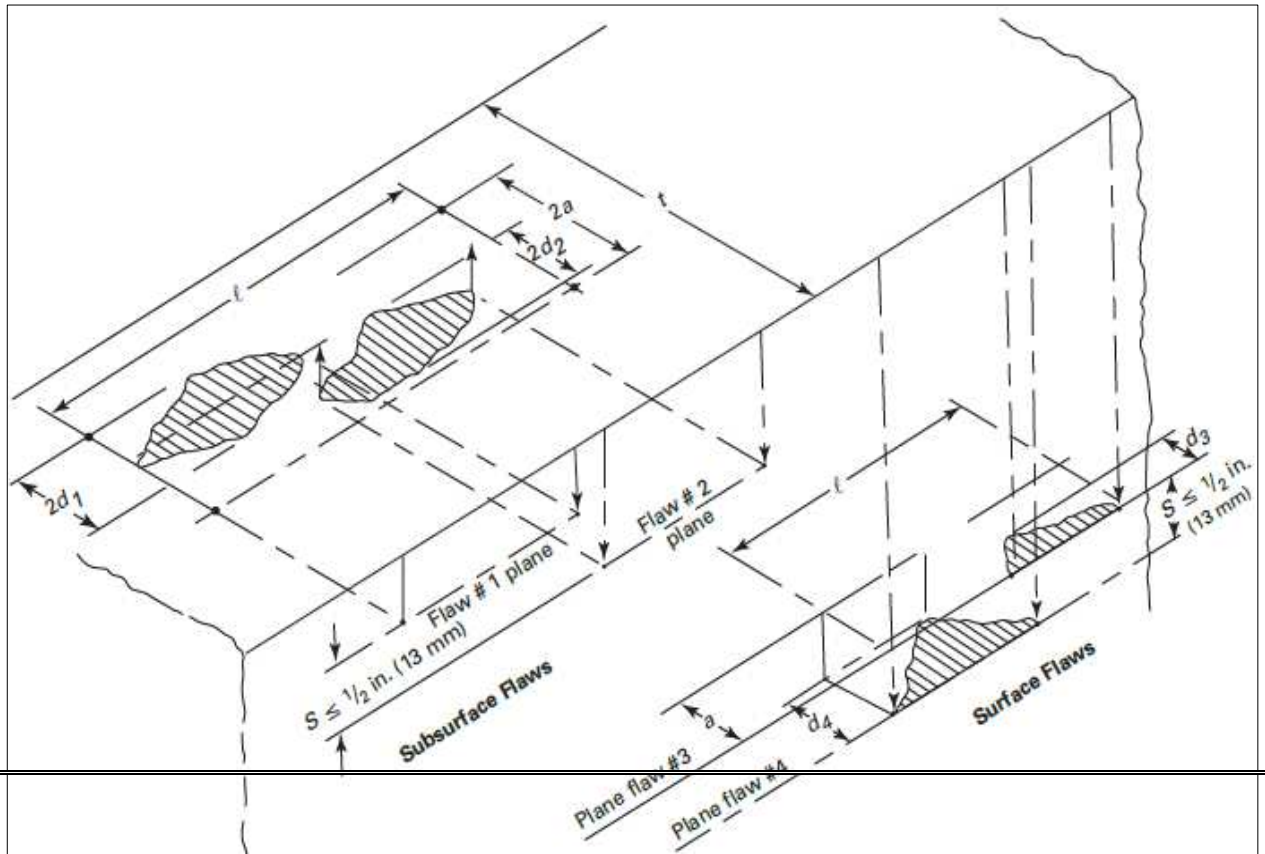


Figure 4

Nonaligned Coplanar Flaws in Plane Normal to Pressure Retaining Surface (Illustrative Flaw Configurations)

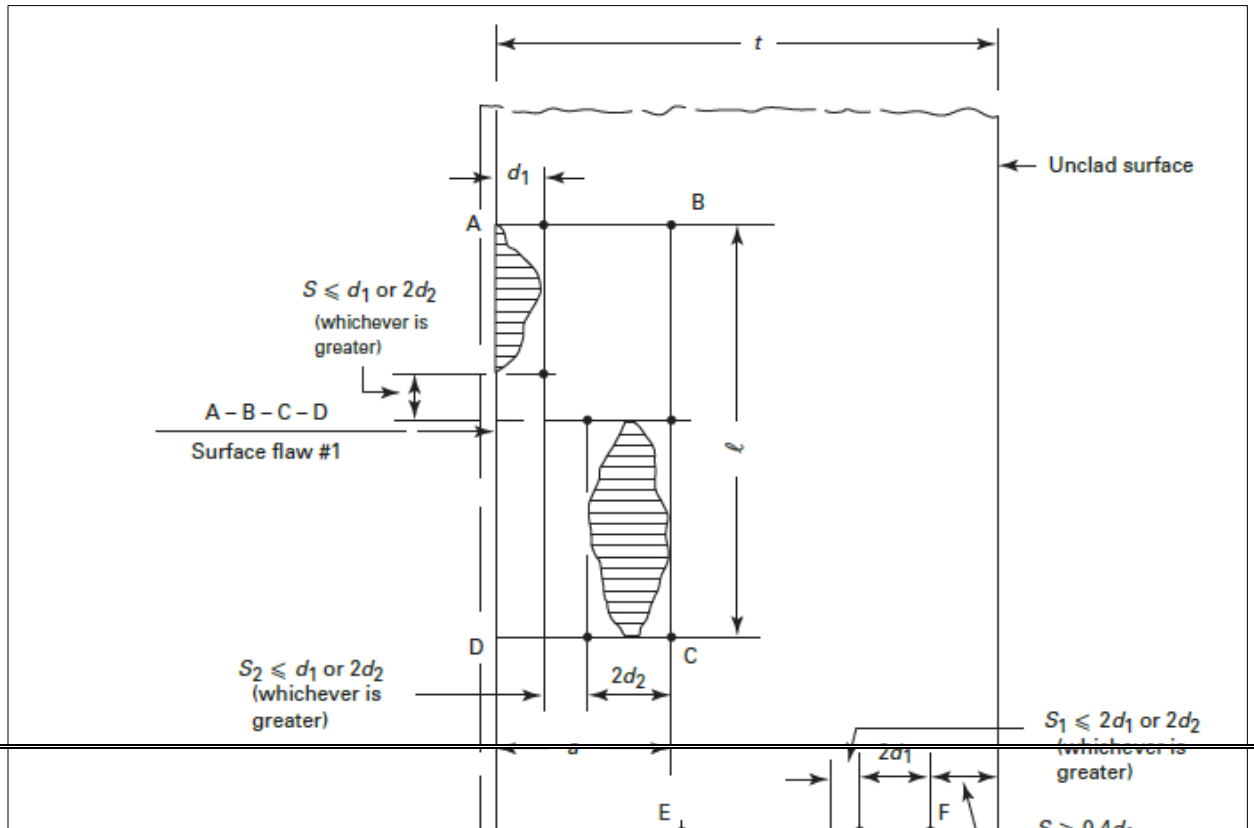
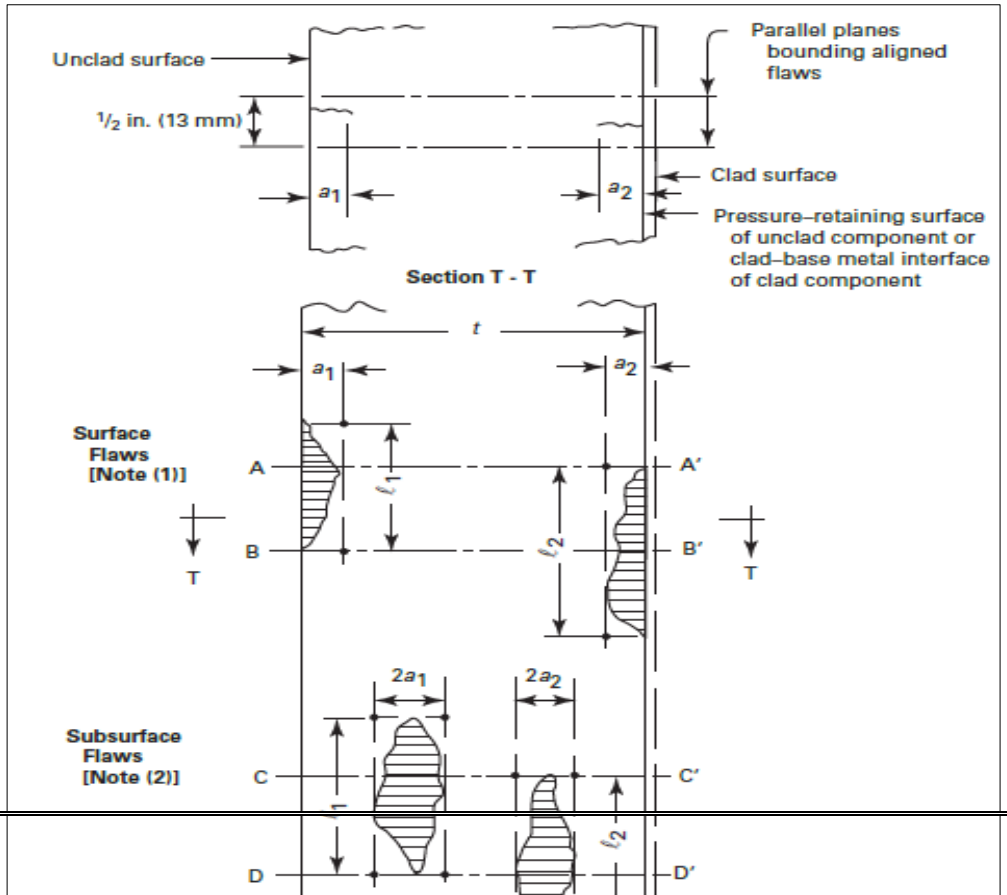


Figure 5

Multiple Aligned Planar Flaws



GENERAL NOTE: In the Notes below, the flaw depth dimensions a_s and a_e are the allowable flaw standards for surface and subsurface flaws, respectively.

NOTES:

(1) This illustration indicates two surface flaws. The first, a_1, is on the outer surface of the component, and the second, a_2, is on the inner surface: $(a_1 + a_2) \leq (a_s + a'_s)/2$ within planes A-A′ and B-B′

(2) This illustration indicates two subsurface flaws: $(a_1 + a_2) \leq (a_e + a'_e)/2$ within planes C-C′ and D-D′

(3) This illustration indicates two surface flaws and one subsurface flaw:
(a) $(a_1 + a_3) \leq (a_s + a'_e)/2$ within planes E-E′ and F-F′
(b) $(a_1 + a_2) \leq (a_s + a_e + a'_s)/3$ within planes F-F′ and G-G′
(c) $(a_2 + a_3) \leq (a'_s + a_e)/2$ within planes G-G′ and H-H′

18.0 Reporting

For each Phased Array examination report, the following information shall be included:

(a) Procedure identification and revision
(b) Ultrasonic instrument identification (including manufacturer's serial number);
(c) Search unit(s) identification (including manufacturer's serial number, frequency, and size)
(d) Beam angle(s) used
(e) Couplant used, brand name or type
(f) Search unit cable(s) used, type and length

(g) Special equipment when used (search units, wedges, shoes, automatic scanning equipment, recording equipment, etc.);
(h) Computerized program identification and revision (when used)
(I) Calibration blocks identification
(j) Simulation block(s) and electronic simulator(s) identification (when used)
(k) Instrument reference level gain and, if used, damping and reject setting(s);
(l) Calibration data [including reference reflector(s), indication amplitude(s), and distance reading(s)]
(m) Data correlating simulation block(s) and electronic simulator(s), when used, with initial calibration
(n) Identification and location of weld or volume scanned
(o) Surface from which examination was conducted, including surface condition;
(p) Map or record of reject able indications detected or areas cleared
(q) Areas of restricted access or inaccessible welds;
(r) Examination personnel identity and, when required by referencing Code Section, qualification level
(s) Date of examination

Report Format

BHARAT HEAVY ELECTRICALS LIMITED TIRUCHIRAPALLI - 620 014 PHASED ARRAY EXAMINATION REPORT								Report No	
								Date	
								Format No.	
Job No						Client			
Procedure & Rev No						cont No & Unit No			
Acceptance Std						Drawing No			
INSTRUMENT DETAILS									
Manufacturer	Equipment Serial No		Calibration Due Date			Model			
Probe	Probe Serial	Frequency(MHz)	Size	Cable Type &Length		Couplant	Brand		Type
Scanner Used	Calibration Block Id		Software			Accessibility			
						□ Accessible □ Not Accessible			
SCAN PLAN DETAILS									
Group No.	Probe	Wedge		Probe Index/PCS(mm)		Start Element		Angle(°)	Skew

PHASED ARRAY PROBE DETAILS							
Probe	Frequency	Number of Elements	Pitch	Element numbers used for focal laws	Mode of transmission	Method of sensitivity standardization	virtual aperture used

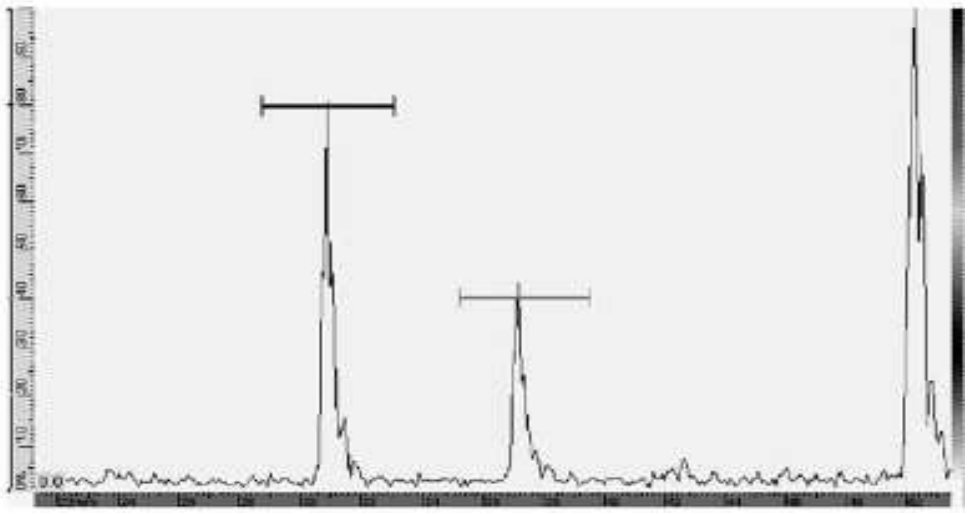
PHASED ARRAY WEDGE DETAILS						
Wedge	Velocity	Incident angle	Dimension	Reference dimension to first element	Encoder used	Recommended wedge angular range from manufacturer

CALIBRATION DETAILS								

Annexure-I

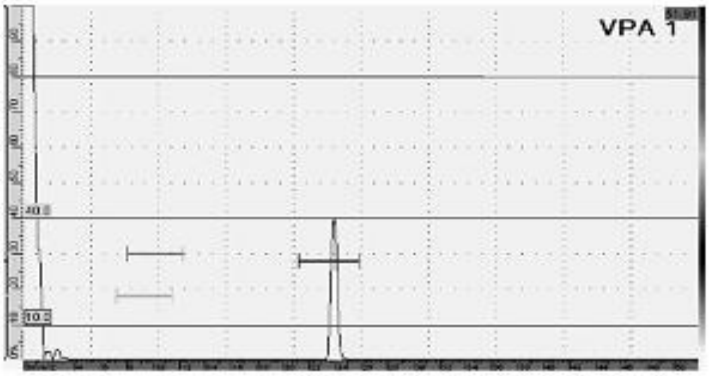
System Calibration

DISPLAY HEIGHT LINEARITY



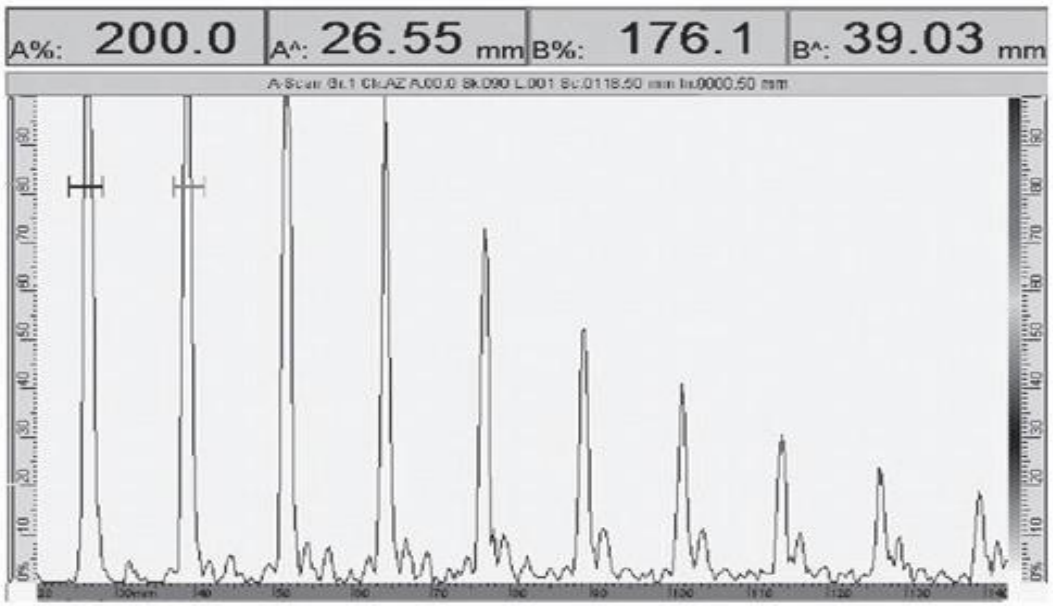
1. With the phased array instrument connected to a probe (shear or longitudinal) and coupled to any block that will produce two signals as shown in fig.6 adjust the probe such that the amplitude of the two signals are at 80% and 40% of the display screen height.
2. Increase the gain using the receiver gain adjustment to obtain 100% of full screen height of the larger response. The height of the lower response is recorded at this gain setting as a percentage of full screen height.
3. The height of the higher response is reduced in 10% steps to 10% of full screen height and the height of the second response is recorded for each step.
4. Return the larger signal to 80% to ensure that the smaller signal has not drifted from its original 40% level due to coupling variation. Repeat the test if variation of the second signal is greater than 41% or less than 39% FSH.
5. For an acceptable tolerance, the response from the two reflectors should bear a 2 to 1 relationship to within •}3% of full screen height throughout the range 10% to 100% (99% if 100% is saturation) of full screen height.
6. The results are recorded on an instrument linearity form.

AMPLITUDE CONTROL LINEARITY



1. A16/64 phased-array instrument has 16 pulsers and receivers that are used to address up to 64 elements. Each of the pulser-receiver components is checked to determine the linearity of the instrument amplification capabilities.
2. Select a flat (normal incidence) linear array phased array probe having at least as many elements as the phased array ultrasonic instrument has pulsers.
3. Using this probe, configure the phased-array ultrasonic instrument to have an electronic raster scan. Each focal law will consist of one element and the scan will start at element number 1 and end at the element number that corresponds to the number of pulsers in the phased-array instrument.
4. Couple the probe to a suitable surface to obtain a pulse-echo response from each focal law. The back wall echo from the 25-mm thickness of the IIW block or the back wall from the 20-mm thickness of the custom linearity block provides a suitable target option. Alternatively, immersion testing can be used.
5. Select Channel 1 of the pulse-receivers of the phased-array instrument. Using the A-scan display, monitor the response from the selected target. Adjust the gain to bring the signal to 40 % screen height.
6. Add gain to the receiver in the increments of 1 dB, then 2 dB, then 4 dB and then 6 db. Remove the gain added after each increment to ensure that the signal has returned to 40 % display height. Record the actual height of the signal as a percentage of the display height.
7. Adjust the signal to 100 % display height, remove 6-dB gain and record the actual height of the signal as a percentage of the display height.
8. Signal amplitudes should fall within a range of 63 % of the display height required in the allowed height range of verification report.
9. Repeat the sequence from 5 to 7 for all other pulse-receiver channels.
10. For instruments having 10- or 12-bit amplitude digitization and configured to read amplitudes in a gated region to amplitudes greater than can be seen on the display, a larger range of check points can be used. For these instruments the gated output instead of the A-scan display would be verified for linearity.

TIME-BASE LINEARITY (HORIZONTAL LINEARITY)



1. Configure the phased array instrument to display an A-scan presentation.
2. Select any compression wave probe and configure the phased-array instrument to display a range suitable to obtain at least ten multiple back reflections from a block of a known thickness. The 25-mm wall thickness of the IIW block is a convenient option for this test.
3. Set the phased-array instrument analog-to-digital conversion rate to at least 80 MHz
4. With the probe coupled to the block and the A-scan displaying 10 clearly defined multiples as illustrated in Figure above, the display software is used to assess the interval between adjacent back wall signals.
5. Acoustic velocity of the test block, determined using the methods described in E494, is entered into the display software and the display configured to read out in distance (thickness).
6. Using the reference and measurement cursors determine the interval between each multiple and record the interval of the first 10 multiples.
7. Acceptable linearity may be established by an error tolerance based on the analog-to-digital conversion rate converted to a distance equivalent. For example, at 100 MHz each sample of the time base is 10 ns. For steel at 5900 m/s each sample along the time base (10 ns) in pulse-echo mode represents 30 m. A tolerance of •}3 timing samples should be achievable by most analog-to digital systems. Some allowance should be made for velocity determination error (~1%). Typically, the errors on the multiples should not exceed •}0.5 mm for a steel plate.

PHASED ARRAY ULTRASONIC INSTRUMENT LINEARITY VERIFICATION REPORT

Location:		Date:	
Operation:		Standard: ASME Sec - V, ARTICLE 23, SE-2491	
Instrument:		Couplant:	
Pulser Voltage (V): Low	Pulse Duration (ns):	Receiver (band) :	Receiver Smoothing: On
Digitization Frequency (MHz): 100 MHz		Averaging: 1	

Display Height Linearity			Amplitude Control Linearity		
Large (%)	Small Allowed Range	Small Actual (%)	Indication Height	dB	Allowed Range
100	47 - 53		40	+ 1	42 - 47
90	42 - 48		40	+ 2	48 - 52
80	40		40	+ 4	60 - 66
70	32 - 38		40	+ 6	77 - 83
60	27 - 33		40	- 6	47 - 53
50	22 - 28				
40	17 -23				
30	12 - 18				
20	7 - 13				
10	2- 8				

Amplitude Control Linearity Channel Results: (Note any channels that do not fall in the allowed range)

Channel (Add more if required for 32 or 64 pulser - receiver units)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Time Base Linearity (for 25 mm IIW block)										
Multiple	1	2	3	4	5	6	7	8	9	10
Thickness	25	50	75	100	125	150	175	200	225	250
Measured interval										
Allowed deviation ± 0.5 mm (Yes / No)										

	Verified by	Reviewd By
Name		
Position		
Signature		
Date		

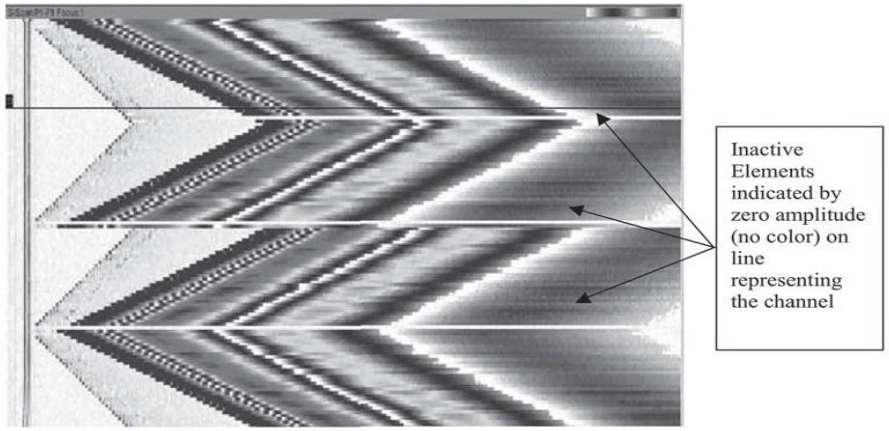
DETERMINATION OF PHASED-ARRAY ELEMENT ACTIVITY

This assessment is used to determine that all elements of the phased-array probe are active and of uniform acoustic energy.

1. Connect the phased-array probe to be tested to the phased-array ultrasonic instrument and remove any delay line or refracting wedge from the probe.
2. Acoustically couple the probe to the 25-mm thickness of an IIW (International Institute of Welding) block with a uniform layer of couplant. This may be accomplished by a contact-gap technique such that the probe-to-block interface is under water (to ensure uniform coupling). Alternatively, an immersion method using a fixed water path may be used and the water-steel interface signal monitored instead of the steel wall thickness.

3. Configure an electronic scan consisting of one element that is stepped along one element at a time for the total number of elements in the array. (This should ensure that the pulser-receiver number 1 is used in each focal law or if the channel is selectable it should be the same channel used for each element). Set the pulser parameters to optimize the response for the nominal frequency of the probe array and establish a pulse-echo response from the block back wall or water path to 80% display height for each element in the probe.
4. Observe the A-scan display for each element in the array and record the receiver gain required to achieve the 80% signal amplitude for each element.
5. Note and record any elements that do not provide a back wall or water path signal (inactive elements).
6. If a prepackaged program is available for checking element activity, this can be used as an alternative.

FIG. A3.1 CONTINUITY DISPLAY FOR PHASED-ARRAY INSTRUMENT OR CABLE



7. Data collected is used to assess probe uniformity and functionality. Comparison to previous assessments is made using the same instrument settings (including gain) that were saved to file. The receiver gains to provide an 80% response should be within a range of •}2 dB of any previous assessments and within •}2 dB of each other.
8. The total number of inactive elements and number of adjacent inactive elements in a probe should be agreed upon and identified in a written procedure. This number may be different for baseline and in-service verifications. Some phased-array probes may have several hundred elements and even new phased-array probes may be found to have inactive elements as a result of manufacturing difficulties ensuring the electrical connections to elements with dimensions on the order of a fraction of a millimeter.
9. The number of inactive elements allowed should be based on performance of other capabilities such as focusing and steering limits of the focal laws being used. No simple

rule for the number of inactive elements can be made for all phased-array probes. Typically, if more than 25% of the elements in a probe are inactive, sensitivity and steering capabilities may be compromised. Similarly, the number of adjacent elements allowed to be inactive should be determined by the steering and electronic raster resolution required by the application.

10. Stability of coupling is essential for the comparison assessment. If using a contact method and the assessment of elements produces signals outside the •}2 dB range the coupling should be checked and the test run again. If still outside the acceptable range the probe should be removed from service and corrected prior to further use. The test using a fixed water path to a water/steel interface will reduce coupling variations.
11. Prior to removing the probe from service the cable used for the test should be exchanged with another cable, when possible, to verify that the inactive elements are not due to a bad cable.
12. Cable continuity adapters can be made that allow the multi-strand connectors to be tested independently. These adaptors can be connected to the phased-array instrument directly to verify that all output channels are active or they can be connected to the probe end of the cable to indicate the continuity of the individual co-axial connectors in the interconnecting cable.

PROBE ELEMENT ACTIVITY CHART: ENTER RECEIVER GAIN FOR 80% FSH

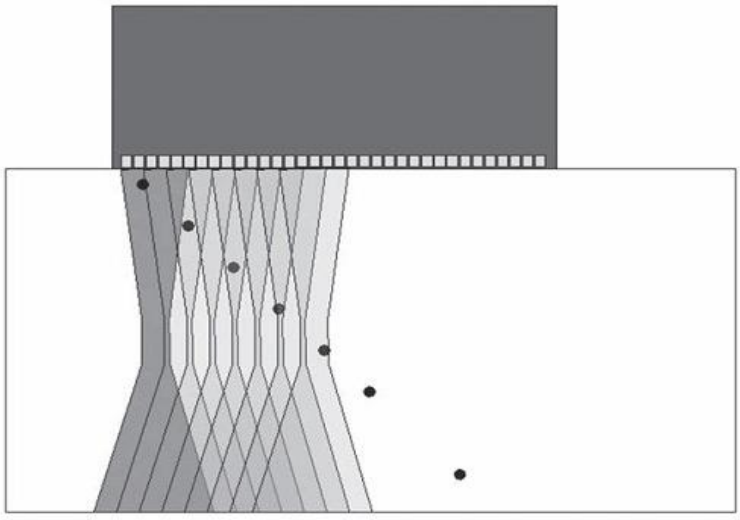
Element	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Gain																
Active([sqcap]) Inactive (x)																

DETERMINATION OF PHASED-ARRAY BEAM PROFILE

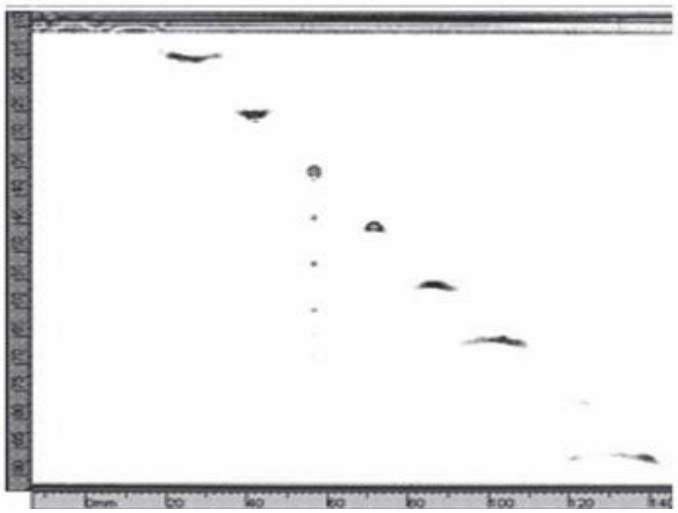
This assessment is used to determine beam profiles of phased-array probes. Either immersion or contact probe applications.

1. Linear-array probes have an active plane and an inactive or passive plane. Assessment of the beam in the active plane should be made by use of an electronic scan sequence for probes with sufficient number of elements to electronically advance the beam past the targets of interest. For phased-array probes using a large portion of the available elements to form the beam the number of remaining elements for the electronic raster may be too small to allow the beam to pass over the target. In this case it will be necessary to have encoded mechanical motion and assess each focal law along the active plane separately.

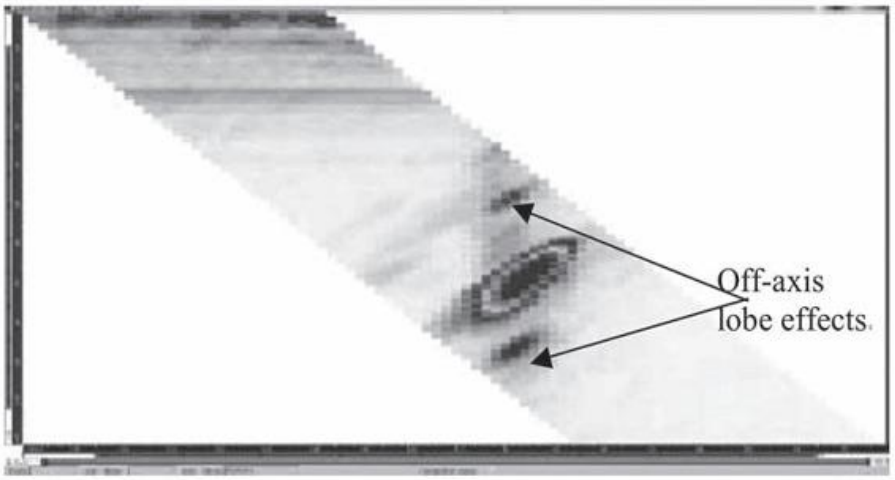
2. Side-drilled holes should be arranged at various depths in a flaw-free sample of the test material in which focal laws have been programmed for. Using the linear scan feature of the phased-array system the beam is passed over the targets at the various depths of interest. The electronic scan is illustrated schematically in below figure.



3. Data collection of the entire waveform over the range of interest shall be made. The display shall represent amplitude as a color or grayscale. Time or equivalent distance in the test material shall be presented along one axis and distance displaced along the other axis. This is a typical B-scan as illustrated in below figure.



4. Data display for an electronic scan using a phased-array probe mounted on a wedge can be similarly made using simple orthogonal representation of time versus displacement or it can be angle corrected as illustrated in below figure.



5. Resolution along the displacement axis will be a function of the step size of the electronic scan or, if the scan uses an encoded mechanical fixture the resolution will be dependent on the encoder step-size used for sampling.
6. Resolution along the beam axis will be a function of the intervals between the target paths. For highly focused beams it may be desirable to have small differences between the sound paths to the target paths (for example, 1 mm or 2 mm).
7. Beam profiling in the passive plane can also be made. The passive plane in a linear-array probe is perpendicular to the active plane and refers to the plane in which no beam steering is possible by phasing effects. Beam profiling in the passive direction will require mechanical scanning.

Waveform collection of signals using a combination of electronic scanning in the active plane and encoded mechanical motion in the passive plane provides data that can be projection-corrected to provide beam dimensions in the passive plane.

Typical Scan Plan

Annexure 1

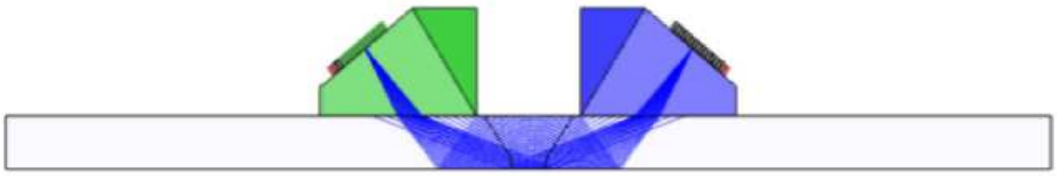
SCAN PLAN DETAILS

Sl.No	Material	Thickness & Dia (mm)	PAUT						
			Probe	Wedge	Index	Aperture element	Start element	Last element	Angle in (degrees)
1	SA213 T 91 & T 23	4.5 & 5.5 Ø63.5	7.5CCEV35-16-A15	SA15-N60S-IH-7.5CCEV35-16-A15 (AOD 2.875)	±6	16	5	12	41-70

Annexure 2

SCAN PLAN IMAGES

Scan plan view 4.5mm & 5.5mm thickness (1st leg)



Note: A documented examination strategy (scan plan) shall be provided showing search unit placement and movement that provides a standardized and repeatable methodology for the examination. Scan plan shall include beam angles and direction with respect to the weld axis reference point, weld geometry and number of zones. Scan plan provides clear view of scanning, helping to clearly convey weld coverage, HAZ coverage and probe position, in addition to critical dimensions. The beam set parameters dialog displays a visual representation of the transducer elements that are used to form the beam set. Varying the focus of the beam is the capability of PA instrument, but generally focusing is not the norm for weld inspection. Beam spread visualization allows more accurately see the beam coverage and near field visualization ensures that any focusing being performed is within the near field. True Depth, Projection and Half Path focus types can be visualized in the workspace and documented as a technique report. These all is achieved with the help of NDT Setup Builder. The scan plan for inspection of full volume of given weld geometry and thickness are given in Annexure: 1

Note: 1. Scan plan given above may require modification based on the actual field conditions to achieve optimum inspection results.

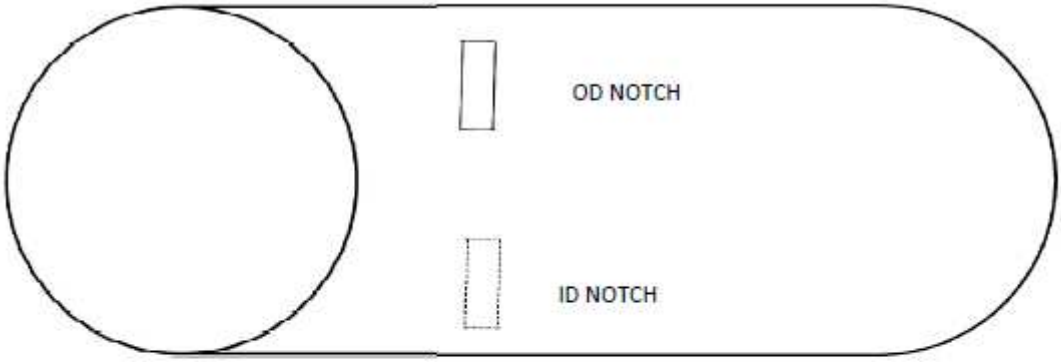
2. For single side access welds (pipe to fitting welds) weld shall be flushed/ground and scan from top of weld or from third leg whichever is possible.

Annexure III

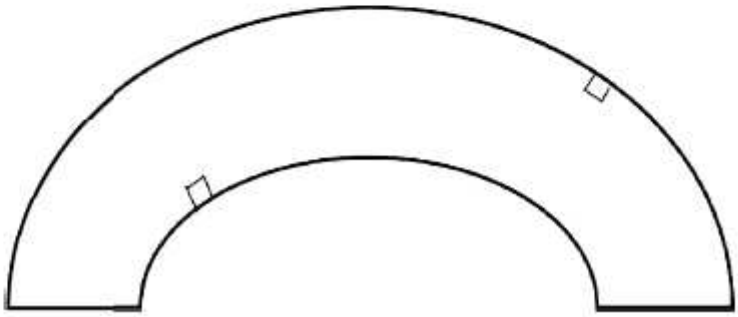
CALIBRATION / DEMONSTRATION BLOCK DETAILS

	Calibration Block Details	
Material	**Pipe details**	**Notch Details:**
SS 213 T91 & T23	Dia -63.5 mm	Length- 30mm
	Thickness- 4.5/5.5 mm	Width-6mm
	Length- 1000 mm	Depth-0.5mm

Side View



Cross sectional View



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CHAPTER 2.0

INSTRUCTIONS FOR ACCESSING NDE PROCEDURES FOR PRESSURE VESSELS, HEAT EXCHANGERS, MILLS, GAS TURBINES AND PIPING

(HPEP HYDERABAD)

Instructions for accessing NDE Procedures for Pressure Vessels, Heat Exchangers, Mills, Gas Turbines and Piping (HPEP Hyderabad)

These documents are restricted as per Corporate Document Repository System and can be accessed from repository only after an access request is approved by the Owner of the document.

Instructions for Accessing Documents Listed Below:

1. Site User may identify the document from the list below.
2. Login to document repository through SSON.
3. Select “Document Administration”. In the next dropdown select “Field Quality- Product Specific Standard Documents”.
4. In case rights to document repository (or for the specific sub-category) has not been allotted to the individual, request may be raised vide e-mail to Head QLY of the region for the document.
5. Head QLY Region or his representatives having access to the document on the document repository may follow Steps 2 and 3.
6. Procedure to be identified in the document repository by using a search string from the table below (Document Title or Document No.). Request may be raised for access on the document repository. Request will go to the document owner.
7. The Document Owner shall verify the current revision of the document and give access rights to the requesting individual.
8. In case if the document is downloaded and issued by Head QLY, Region or his representative, the document shall be issued to site user after including proper control instructions.
9. If the access rights are not received within 24 hrs of making the request or if there is an urgent need for the document, Head QLY, region may request Head QLY, Hyderabad through e-mail with a copy to Head, CQ&BE, New Delhi.

Product	Sl No	Document No.	Document Title
PRESSURE VESSELS, HEAT EXCHANGERS, MILLS	1	HYQC:NDE:01	NDE Procedure for liquid penetrant examination
	2	HYQC:NDE:12	NDE Procedure for magnetic particle examination
	3	HYQC:NDE:19	NDE procedure for radiographic examination of welds
	4	HYQC:NDE:23	NDE procedure for ultrasonic examination of butt welds
GAS TURBINES AND PIPING	1	HYQC:NDT:30	NDE Procedure for liquid penetrant examination of welds
	2	HYQC:NDT:31	NDE Procedure for Magnetic particle examination
	3	HYQC:NDT:27	NDE Procedure for Radiographic examination of welds
	4	HYQC:NDT:28	NDE Procedure for Ultrasonic examination of Plates
	5	HYQC:NDT:29	NDE Procedure for Ultrasonic examination of Welds

CHAPTER – 3.0
NDE PROCEDURES FOR STEAM TURBINE, TURBO-GENERATORS AND AUXILIARIES

(HEEP, HARIDWAR)

NDE for site welds of Steam Turbine, Turbo-Generator and Auxiliaries supplied by BHEL HEEP, Haridwar.
Please refer the following Plant Standards

Sl. No.	Plant Standard	Title
1	HW0620099	Welding-Fusion welded joints in steel, nickel, titanium and their alloys-Quality levels for imperfections
2	HW0850199	Non-Destructive testing of welded joints
	Part 1	General Principles
	Part 2	Requirements on test procedures
	Part 2.4	Hardness Testing
	Part 10	Part specific information on Heat Exchangers
	Part 11	Component specific data for piping

CHAPTER 4.0

BUS DUCT: ACCEPTANCE STANDARD FOR WELDS IN ALUMINIUM (RADIOGRAPHIC QUALITY)

CFP RUDRAPUR

BHEL, RUDRAPUR	PRODUCT STANDARD QUALITY DEPARTMENT	DOC NO:- RU: BD: NDT: RT R-00 PAGE : 1 OF 3

ACCEPTANCE STANDARD WELDS IN ALUMINUM RADIOGRAPHIC QUALITY

1.0 Scope:

This procedure covers the requirements of radiographic testing and acceptance standards for welds in aluminum such as aluminum flexible connection, enclosures and conductors, etc.

2.0 Surface condition:

As welded

3.0 Procedure:

In general, the testing procedure shall be as per ASME, Section V, Article 2.

3.1 Extent of radiographic examination – As indicated in the relevant drawings or as agreed between BHEL and client.

3.2 Radiation source – X rays

3.3 Film – ASTM class 1 or 2, such as Kodak C5, Agfa – Gaevart D7, NDT 65, 70 or equivalent.

3.4 Film density – shall be between 1.8 to 3.0.

3.5 Technique – Single wall, single image or any other suitable technique as per ASME Section V, if necessary.

3.6 Radiographic Quality level – shall be determined by using ASME Penetrameters or wire penetrameters to DIN 54109 or IS 3657.

Penetrameter sensitivity in case of wire penetrameters shall be 2% or better.

Penetrameters shall be placed towards the source side.

4.0 Acceptance standards:

Any of the following imperfections are unacceptable:

4.1 Any type of crack

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4.2 Zone of incomplete fusion or penetration, which exceed 10% of the weld length of the joint. In longitudinal or transverse butt weld, where full penetration is intended by the weld procedure some lack of penetration is acceptable. The total length of weld with lack of penetration shall not exceed 10% of the overall weld length. At no place shall weld penetration be less than 90% of the thickness of the material. Continuous occurrence of lack of penetration is permitted, but shall not exceed 50 mm in any 500 mm length of weld.

4.3 Inadequate weld dimensions, root cavity (shrinkage) and incompletely filled groove, greater than 10% effective throat thickness.

4.4 Excess penetration shall be permitted provided it does not exceed 25% of the wall thickness or 4 mm whichever is smaller.

4.5 Weld reinforcement: Build up in excess of 25% of the effective throat thickness shall be dressed. Any reinforcement shall be substantially symmetrical about the center – line of the weld and shall be of smooth contour blending smoothly at the toes with the parent material.

4.6 Undercutting and over lapping greater than 10% effective throat thickness.

4.7 Elongated cavities and / or worm holes exceeding 3 mm dia or equivalent area in length provided the limitations on porosity are met with.

4.8 Copper, tungsten or oxide inclusions greater than ¼ or 3 mm dia or its equivalent area whichever is smaller.

4.9 Crater pipes exceeding 25% effective throat thickness or 3 mm whichever is smaller.

4.10 Porosity: Scattered porosity not exceeding 0.5 % by volume is acceptable. In general, the size of the pores shall not exceed 0.8 mm dia but occasional 1.6 mm dia pores may be acceptable, provided the following limits are not exceeded:

i) Where pore size is 0.4 mm or less, upto 150 t pores may be permitted in 1000 mm sq area of radiograph.

ii) Where pore size is 0.8 mm dia or less, upto 19 t pores may be permitted in 1000 mm sq area of radiograph.

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iii) Where pore sizes are generally 0.8 dia or less but occasional 1.6 mm dia pores are present, upto 9 t. pores of 0.8 mm dia may be permitted in 1000 sq mm area of radiograph, provided the number of pores up to 1.6 mm in dia does not exceed t.

iv) However, visible surface porosity > 1 mm dia is not acceptable.

Note:

1. In all cases t = thickness in mm of the thinnest section of the weld under examination.

2. Unacceptable weld defects shall be repaired in accordance with the original welding procedure. All repairs shall be 100% respected in accordance with original testing procedure.

3. It is observed, in case of aluminum flexible connections, at the joining zone of aluminum foils to weld metal, a curvilinear type of indication parallel to the longitudinal axis of the welds is observed in general on the film.

It is mentioned in ASME section VIII (1988) para UL W 54
"In case of pressure vessels, parts that are fabricated using layered sections welded to solid sections (similar to aluminum flexible connection), layer wash penetrates slightly into layered sections during welding, resulting in an indication as mentioned above. Such indications are not taken into consideration while interpreting the film".

The above statement needs to be taken into consideration, while interpreting welds in aluminum flexible connection, in the region where foils are welded to weld metal.

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CHAPTER 5.0

PROCEDURE FOR KEROSENE LEAK TESTING

CHAPTER:5.1 KEROSENE LEAK TESTING

1.0 SCOPE :

1.1 This procedure provides details of methods to conduct leak testing using kerosene as penetrant.

1.2 This procedure may be applied for non-pressure parts welds like those in air and flue gas ducts.

2.0 PROCEDURE:

2.1. Weld shall be thoroughly cleaned by hand wire brush or rotary wire brush to remove oil, grease, slag and rust.

2.2. Weld shall be visually inspected and Unacceptable defects if any shall be repaired by grinding and welding.

2.3. Kerosene leak test shall be carried out only at room temperature.

3.0 TESTING

3.1 The weld surface shall be applied with wet/pasty chalk (mixed with water) and dried.

3.1.1 Kerosene shall be sprayed on the other (root) side of weld. The kerosene penetrates through crevices or cracks/ pin holes and is absorbed by dry chalk powder showing up as a dull patch/indication on the bright chalk surface.

3.2 Alternatively weld surface may be wetted with wet (soaked in kerosene) cotton waste or cloth.

3.2.1 In such cases wet/pasty chalk shall be applied on the other (root) side of the weld. This shall be completed before applying kerosene.

3.3 The side on which chalk is applied shall be visually examined for indications of kerosene absorption (sweating/wetting) after 5 minutes of kerosene application. Indications noticed if any shall be repaired as given below.

4.0 REPAIRS

4.1 Leaking spots (indication) shall be marked for repair.

4.2 Repairs shall be carried out by grinding and welding.

4.3 Repaired areas shall be retested as per clause 3.0

5.0 CLEANING

5.1 After testing / retesting is completed the chalk powder and traces of kerosene shall be cleaned off from the welds.

RECORD OF REVISIONS

Sl No	Rev No	Chapter No.	Details of Revision	Date of Revision
1	1	General	All pages revised to include current Rev No., revised Page No. and Date of Issue	10.02.2020
2	1	Table of Contents	Revised as per Contents of Revision No. 1	10.02.2020
3	1	1.1	Current Revision No. 22 updated	10.02.2020
4	1	1.2	Current Revision No. 24 updated	10.02.2020
5	1	1.3	Current Revision No. 07 updated	10.02.2020
6	1	1.4	Procedure No. BHE:NDT:PB:RT-1 Rev 01 included and BHE:NDT:PB:RT-1 Rev 02 removed as it has been obsoleted.	10.02.2020
7	1	1.5	Current Revision No. 06 updated	10.02.2020
8	1	1.6	Current Revision No. 13 updated	10.02.2020
9	1	1.7	Current Revision No. 21 updated	10.02.2020
10	1	1.8	Current Revision No. 08 updated	10.02.2020
11	1	1.9	Current Revision No. 03 updated	10.02.2020
12	1	1.10	Current Revision No. 01 updated	10.02.2020
13	1	1.11	Current Revision No. 07 updated	10.02.2020
14	1	1.12	Chapter Added	10.02.2020
15	1	1.13	Chapter Added	10.02.2020
16	1	1.14	Chapter Added	10.02.2020
17	1	1.15	Chapter Added	10.02.2020
18	1	2.0	Instructions for accessing NDE Procedures For Pressure Vessels, Heat Exchangers , Mills , Gas Turbines And Piping Added	10.02.2020
19	1	2.1 – 2.9	Chapters removed. Documents made available at online document repository system. Instructions for accessing included in Chapter 2.0	10.02.2020
20	1	3.0	Chapter revised to include reference to current procedures.	10.02.2020
21	0		First Issue of the Document, issued after major changes to Document No PSQ-NDEM-COM-2010 (discontinued hereafter)	24.10.2016