Ultrasonic testing Handbook

SUBJECT: Guide for Ultrasonic testing

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Scope of document:

The document is a hand book for Non Destructive Testing Engineers to perform Ultrasonic Testing , explains the applicable type of defects, basics of Ultrasonic Testing, Applicable Standards and Acceptance criteria for Ultrasonic Testing

Introduction to NDT

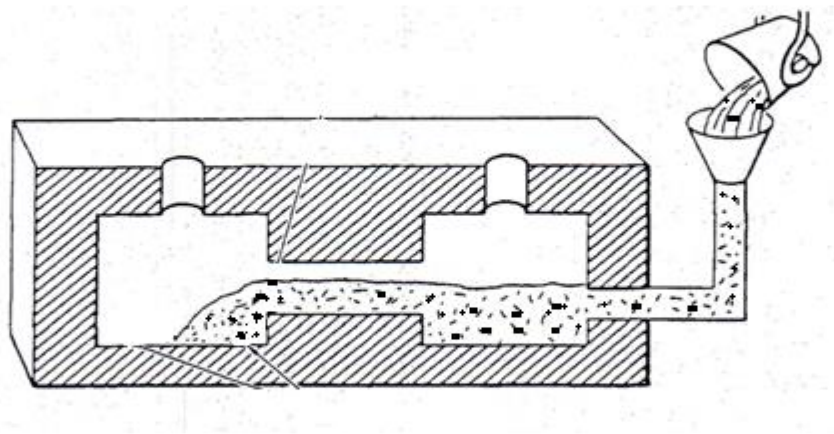
Industries manufacture their components based on the codes mentioned in the international standards, To sell their product in the global market, such products with globally accepted standards will satisfy the clients requirement and will be safe to use, today's competitive market also involves such standards to produce high quality products under reduced cost of control.

The application of Non Destructive Examination will reduce the cost of rejection after processing such as machining, fabrication, heat treatment, coating and transportation.

Types of Defects

The defects can occur in three different periods – during casting (**I. Inherent Defects**), during Processing (**II. processing defects**) & in working condition (**III. service defects**)

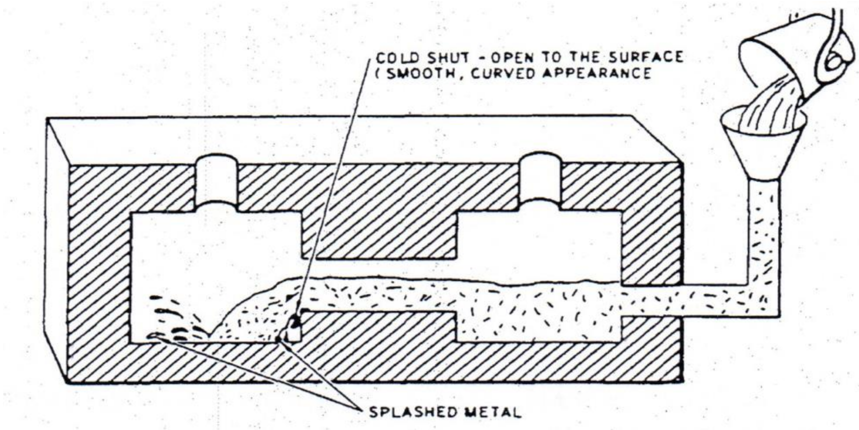
I. Inherent defects



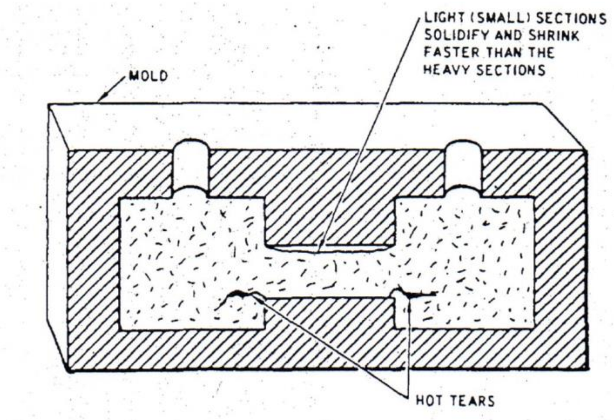
The below mentioned are possible defects that are formed when poured molten metal solidifies to form a component.

Typical inherent discontinuities found in the castings are **Cold Shuts, Hot Tears, Shrinkage Cavities, Micro Shrinkage, Blow Holes and Porosities**.

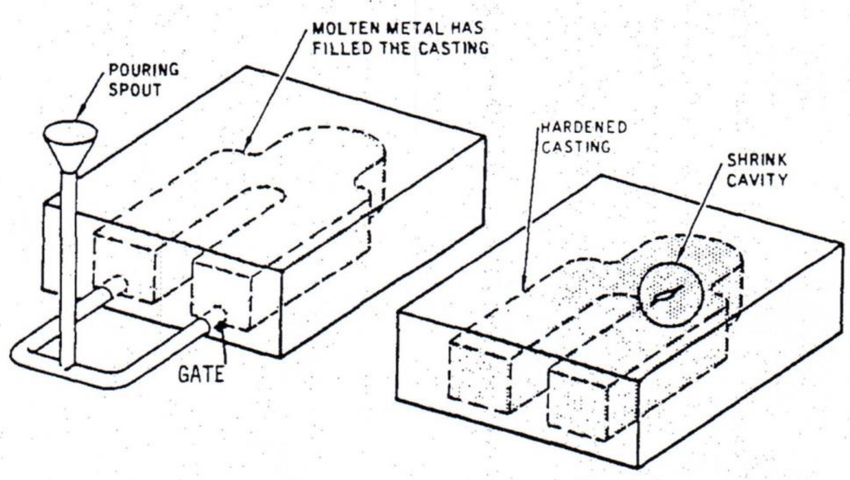
A **Cold Shut** is caused when molten metal is poured over solidified metal as shown below:



Hot Tears (Shrinkage Cracks) occur when there is unequal shrinkage between light and heavy sections as shown below:



Shrinkage Cavities are usually caused by lack of enough molten metal to fill the space created by shrinkage, similar to pipe in the ingot.



Micro Shrinkage is usually many small sub surface holes that appear at the gate of the casting.

Micro Shrinkage can also occur when the molten metal must flow from a thin section into a thicker section of a casting.

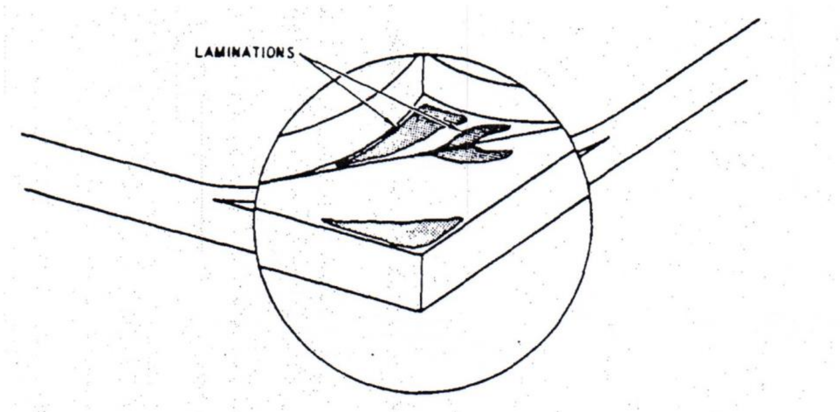
Blow Holes are small holes at the surface of the casting caused by gas which comes from the mould itself, many molds are made of sand, when molten metal comes into contact with the mold, the water in the sand is released as steam,

Porosity is caused by entrapped gas; porosity is usually subsurface but can occur on the surface depending on the design of the mold.

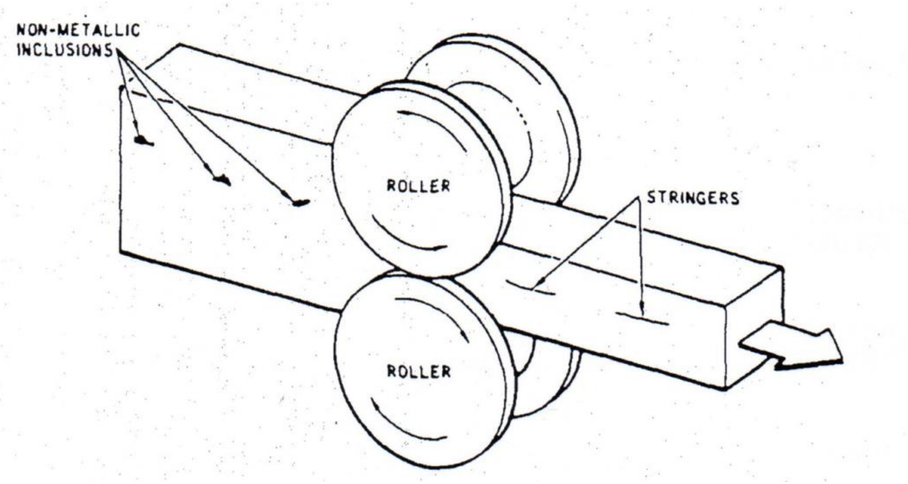
II. Processing Defects

Processing discontinuities are those found or produced by the forming or fabrication operations including rolling, forming, welding, machining, grinding and heat treating,

As a billet is flattened and spread out nonmetallic inclusions may cause a lamination, Pipe and Porosity could also cause laminations in the same manner as shown below:



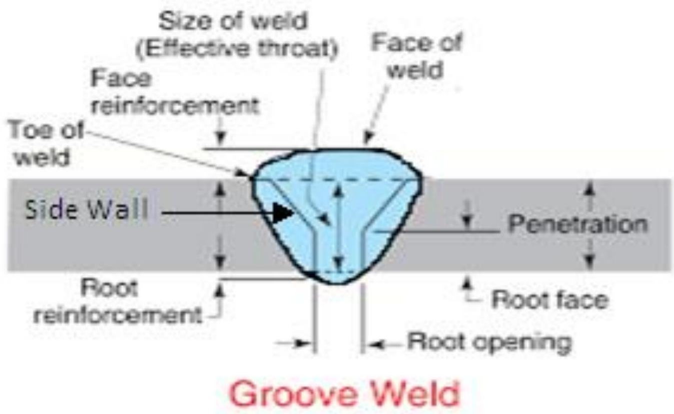
As a billet is rolled into bar stock, nonmetallic inclusions are squeezed out into longer and thinner discontinuities called stringers.

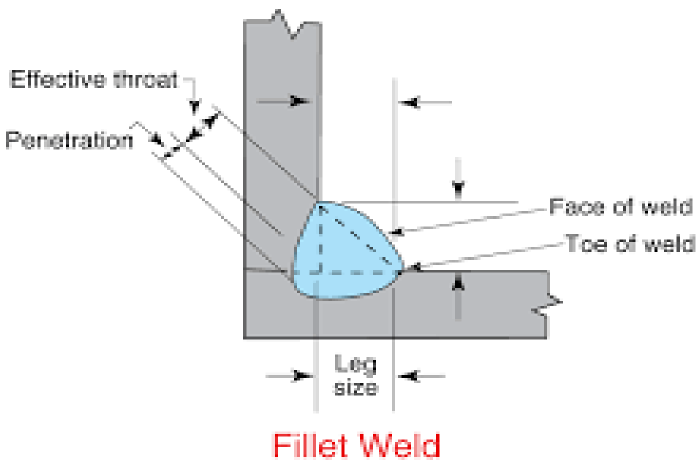


Welding Defects

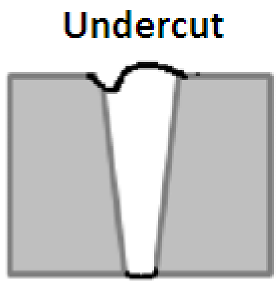
There is possibility of discontinuities in other words called as “Defects” formed during the process of welding or during cooling for solidification. The causes for the defects are various few of them are described below.

Before understanding the defects we will refresh the nomenclature of the weld which is shown in the below figure:



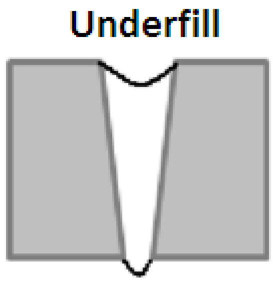


1) **Undercut –** at the weld fusion area/ weld toe on the base metal, may occur on the face side or root side of the weld.



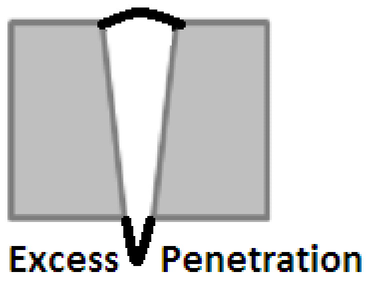
Cause :- Caused due to excessive heat melting the base metal probably caused by two reasons. They are Slowdown of welding speed at that particular location or increase in the current suddenly with constant speed.

2) **Underfill** – Occur at face side of the weld, can be identified as lower surface level than the adjacent base metal.



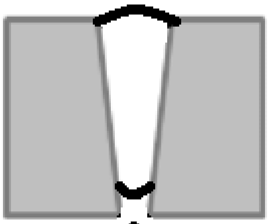
Cause: Pour of less or insufficient weld metal during welding required more filling.

3) **Excess Penetration-** Occurs at root of the weld, can be identified as excess weld drop at root.



Cause:- Occurs due to excessive root Gap , less root face and excess current during these conditions. Avoid too much root gap and provide adequate root face to support the high heat input during weld.

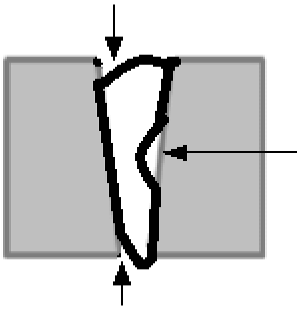
4) **Lack of Penetration** : Occurs at the root side of the weld can be identified as lack of weld metal at the root side and both the root face edges will be visible as shown below.



Incomplete Penetration

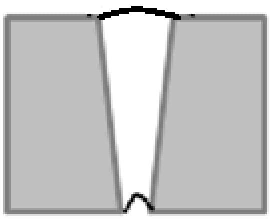
Cause :- May be due to any of the following reasons- Less Root Gap, More root face, too small bevel angle, Less current, Too large electrode diameter, Longer arc length.

5) Incomplete fusion: Occurs as gap between the weld metal and base metal and can be at any location, Root, Face or at Sidewall.



Cause:- Due to improper welding skill, incorrect welding current and voltage, incorrect travel speed, poor inter run cleaning & wrong selection of electrode.

6) **Root Concavity:** Can be observed as suck back or concave like depression in the root, even though both the root faces has fused with weld metal.

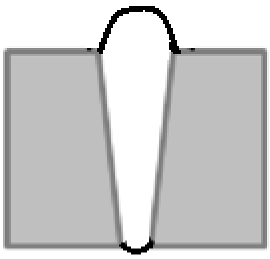


root concavity

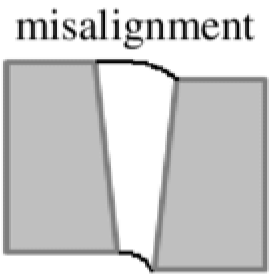
Causes:- Insufficient arc power to produce positive bead, excessive backing pressure (if purging is done), Lack of welder skills, Slag flooding in backing bar groove.

7) **Excess weld Reinforcement**: Occurs in the face side of the weld as improper weld bead as shown below. It is considered as defect because of formation of sharp corners at toes.

reinforcement

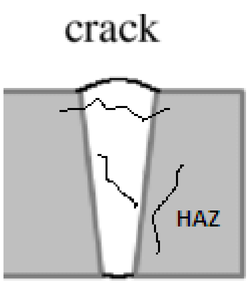


8) **Misalignment:** Found as un even level(up and down) between two joining base metal.



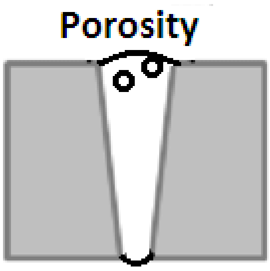
Cause: may be caused during pre-welding fit-up, or after welding due to in adequate tack welds and temporary retainers.

9) **Cracks**: Cracks may be found as longitudinal or transverse, and also may be found in the base metal near to weld (HAZ Heat Affected Zone) as shown in the figure. Hot cracks occur during welding and cooling or during heat treatment process. Cold cracks occurs during the service due to loads



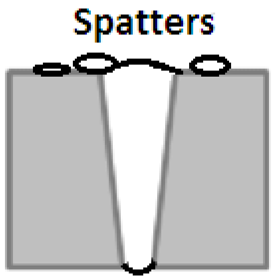
Causes: May be due to any or all of the following reasons. Improper electrode, Improper cooling rate or quenching, High carbon content steel, High Sulphur and phosphor content in steel . Certain alloys, welding on coated steels, Cold cracking mostly starts from HAZ areas due to internal & external stress, and hydrogen induced.

10) **Porosity:** Occurs as round or curved cavities in the weld, may be single, clustered or aligned.



Cause:- Due to absorption of nitrogen, oxygen and hydrogen in the molten weld metal . The gases are involved in the weld metal due to moisture in base metal or welding electrodes, and poor gas shielding.

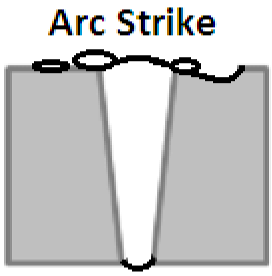
11) **Spatter :** Weld metal splashed and sticks to the surface of the weld or base metal. Few are easily removable and few has to be grinded down.



Causes: Long **welding** arc., Short **welding** arc, Cleanliness of the base material surface. Selection of gas **welding** (CO_2 **welding** yields more), **Welding** at a wrong angle.

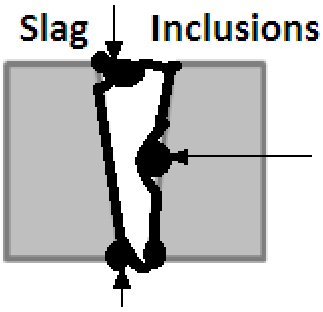
Imbalance between voltage and amperage, incorrect wire feed speed.

12) Arc Strike: Occurs as a base metal damage and splash of melted base metal on the base metal surface.



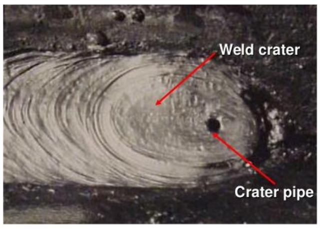
Causes: When Electrode holder touches the other base metal areas causing an arc between the base metal and the holder.

13) Slag Inclusions: Occurs as non-metallic left outs in the weld metal or between the weld metal and base metal as shown below. These slag inclusions causes lack of fusion at few locations



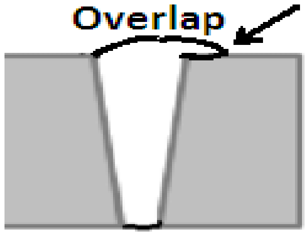
Causes: The flux layer formed over the solidified weld pool if not cleared forms as slag inclusion. The melted holders in MIG welding form **Copper inclusions** on the weld metal. The melted tungsten rod in TIG welding forms **Tungsten inclusions** on the base metal.

14) Crater / Crater Pipe / Crater Cracks: Craters occurs as elliptical shaped depression at end of weld or weld stopping point. Crater pipe occurs as a hole at the center of crater and crater crack occurs as star shaped crack at the middle of the crater.



Causes: Crater is caused due to improper weld stopping technique, crater pipe or crack is formed due to low weld filling at the crater area. Crack is formed during cooling due to insufficient metal.

15) Overlap: Occurs as Weld metal flown more than the edge of the face as shown below.



Causes: Overlap is caused due to wrong electrode angle, slow welding speed, high current and contamination.

III. Service Discontinuity

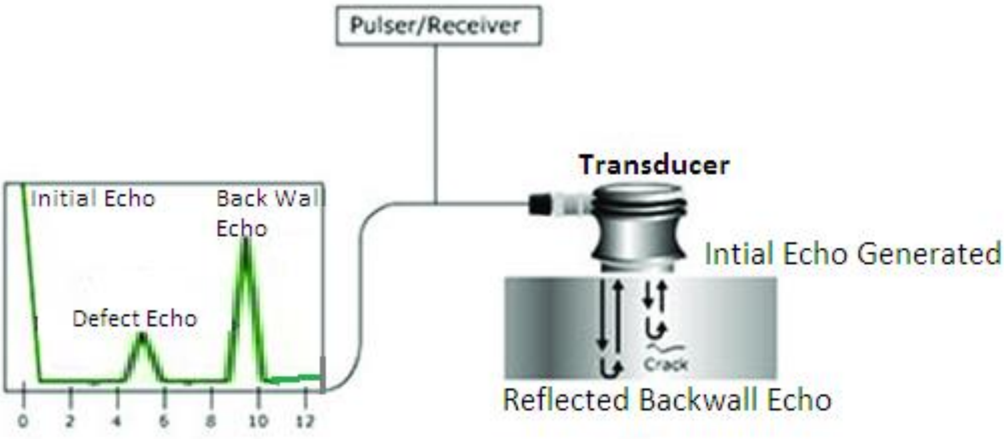
Service discontinuities occur when the finished product is exposed to the working environment which involves exposure of External stress, corrosive environment, chemical attack and much more.

Probable service defects are **Cold Cracks, Pitting, deformation, brittleness and breaking.**

Ultrasonic Testing – UT

Ultrasonic Testing Utilises Sound waves with frequencies more than 20,000Hz to travel into the material to be inspected and finds out Defects or makes measurements,

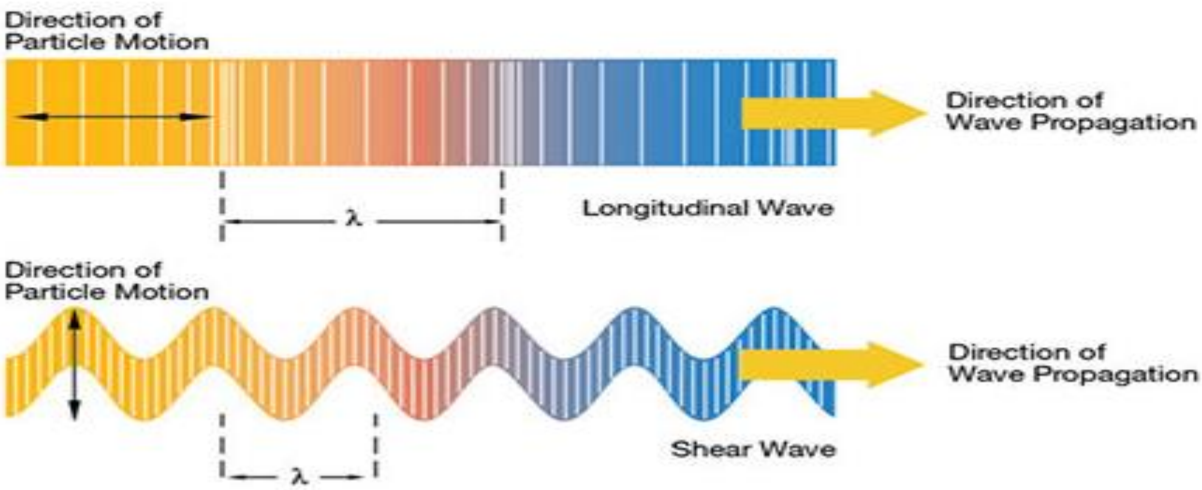
Basic principle:



Any defect or measurement is made by the fact that sound continues to travel in a material until it meets a interference zone of material having different acoustic characteristics (impedance), there is a reflection of few percentage of sound waves (% of reflection depends upon latitude of difference in acoustic impendence)

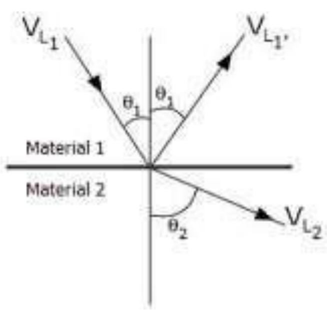
WAVE PROPAGATION:

Ultrasonic testing is based on the vibration in materials which is generally referred to as acoustics. All material substances are comprised of atoms, which may be forced into vibrational motion about their equilibrium positions. Many different patterns of vibrational motion with at the atomic level; however, most are irrelevant to acoustics and ultrasonic testing. Acoustics is focused on particles that contain many atoms that move in harmony to produce a mechanical wave. When a material is not stressed in tension or compression beyond its elastic limit, its individual particles perform their elastic oscillations. When the particles of a medium are displaced from their equilibrium position, internal restoration forces arise. These elastic restoring between particles lead to the oscillatory motions of the medium. In solids, sound waves can propagate in four principal modes that are based on the way the particles oscillate. Sound can propagate as longitudinal waves, shear waves surface waves and in thin materials as plate waves longitudinal and shear waves are the two modes of propagation used in the ultrasonic testing as shown in the figure



Snell's law:

It describes the relationship between the angles and the velocities of the waves. Snell's law equates the ratio of material velocities to the ratio of the sine's of incident and refracted angles, as shown in the following equation



$$\boxed{\frac{\sin\theta_1}{V_{L_1}} = \frac{\sin\theta_2}{V_{L_2}}}$$

Transducers:

There are two types of transducer

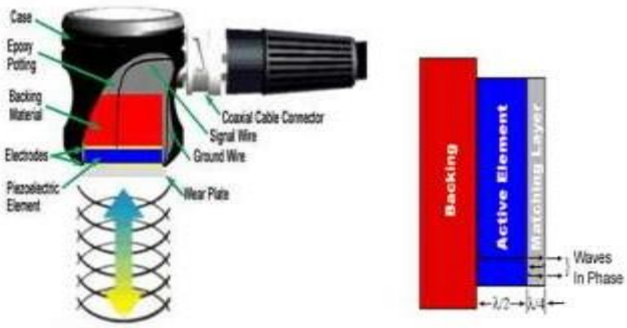
i. Contact type transducer
ii. Immersion transducer

Piezoelectric transducer (contact type)

The conversion of electrical pulses to mechanical vibrations and conversion of returned mechanical vibration into electrical energy is the basis of UT .The conversion is done by the transducer using piezoelectric material with electrodes attached to the two of the opposite faces .When an electric field is applied across the material, the molecules will align themselves with the electrical field causing the material to change dimensions. In addition, a permanently polarized material such as quartz and barium titanate will produce an electric field the material will change dimensions as a result of imposed mechanical force. The phenomenon is known as piezoelectric effect

<u>Characteristics of piezoelectric transducer :</u>

The function of transducer is to convert electrical signal into mechanical vibration and vice versa

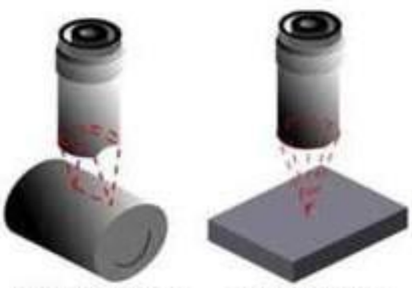


A cut away of typical contact transducer is shown in the fig. To get as much as energy out of the transducer .Optimal impedance matching is achieved by sizing the matching layer so that the thickness is ¼ of the desired wavelength. This keeps the waves that are reflected within the matching layer in the phase when the exit the layer, for this type of transducer is made up of material which has acoustic impedance similar to that of the active element and steel, it also has wear plate to protect the matching layer and active element from scratching

The backing material has greater influence on the damping characteristics of a transducer. As the mismatch in the impedance between the active element and the backing material increases, material penetration increases but transducer sensitivity is reduced. The bandwidth refers to the range of frequencies associated with the transducer. The frequency noted on the transducer s the central frequency and depends primarily on the backing material. The central frequency will also define the capabilities of the transducer

<u>Immersion type:</u>

These transducers are designed to operate in the liquid environment and all the connections are water tight. Immersion transducers usually have an impedance matching layer helps to get more sound energy into water and in into components being inspected. Immersion transducers can be purchased with a planer focused or spherically focused lens. A focused transducer can improve the sensitivity and axial resolution by concentrating the sound energy to a smaller area. It is used inside a water tank or as part of a squitter or bubbler system in scanning application



Cylindrical Focus Spherical Focus

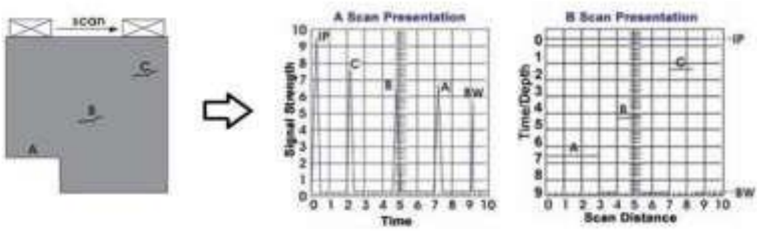
ADVANCED QUALITY CENTRE

Ultrasonic Testing Techniques:

There are three types of techniques which are mainly used during inspection

i. **A-scan technique:**

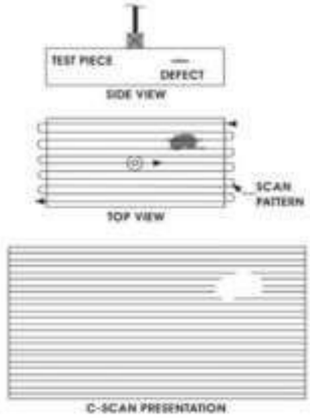
It displays the amount of received ultrasonic energy as a function of time. The relative amount of received energy is plotted along the vertical axis and the elapsed time is displayed along the horizontal axis. Most instruments with a an A-scan display allow the signal to be displayed allow the signal to be displayed in its natural radio frequency form, as a fully rectified RF signal, or as either the positive or negative half of the RF signal, or as the positive or negative half of the RF signal. In the A-scan presentation, relative discontinuity size can be estimated by comparing the signal amplitude obtained from unknown reflector. Reflector depth can be determined by the signal on the horizontal time axis



ii. **B-scan technique:**

The B-scan presentation is a type of presentation that is possible for automated linear scanning systems where it shows a profile of the test specimen. In the B-scan, the time of flight of the sound waves is displayed along the vertical axis and the linear position of the transducer is displayed along the horizontal axis. From the B-scan, the depth of the reflector and its approximate linear dimensions in the scan direction can be determined. The B-scan is typically produced by establishing a trigger gate on the A-scan. Whenever the signal intensity is great enough to trigger the gate, appoint is produced on the B-scan. The gate is triggered by the sound reflected from the back wall of the specimen and by smaller reflector within the material. In the B-scan image shown previously, line A is produced as the transducer moves to the right of this section, the back wall line BW is product. When the transducer is over flaws B and C, lines that are similar to the length of flaws and at similar depth of the material are drawn on the B-scan .It should be noted that limitation to this display technique is that reflectors may be masked by large reflector near surface

iii. **C-scan technique:**



The C-scan presentation is a type of presentation that is possible for automated for two-dimensional scanning systems that provides a plan type view of the location and size of test specimen features. The plane of the image is parallel to the scan pattern of the transducer. C-scan presentations are typically produced with an automated data acquisition system, such as computer controlled scanning system. Typically, a data collection gate is established on the A-scan and the amplitude or the time-of-flight of the signal is recorded at regular intervals as the transducer is scanned over the test piece. The relative signal amplitude or the time-of-flight is displayed as a shade of grey or a color for each of the positions where data was recorded. The C-scan presentation provides an image of the features that reflect and scatter the sound within and on the surfaces of the test piece

High resolution scans can produce very detailed images. The figure shows two ultrasonic C-scan images of a US quarter. Both images were produced using a pulse-echo technique with the transducer scanned over the head side in an immersion scanning system. For the C-scan image on the top/ the gate was set to capture the amplitude of the sound reflecting from the front surface of the quarter. Light areas in the image indicate areas that reflected a greater amount of energy back to the transducer. In the C-scan image on the bottom, the gate was moved to record the intensity of the sound reflecting from back surface of the coin. The details on back surface are clearly visible since the sound energy is affected by these features as it travels through the front surface of the coin

Calibration method:

Calibration refers to the act of evaluating and adjusting the precision and accuracy of measurement equipment. In UT, several forms of calibrations must occur. First, the electronics of the equipment must be calibrated to ensure that they are performing as designed. In UT reference standards are achieved a general level of consistency in measurements and to help interpret and quantify the information contained in the receive signal. The fig shows some of the commonly used to validate that the equipment and the setup provide similar results from one day to the next and that similar results are produced by different systems

Reference standards are mainly used for

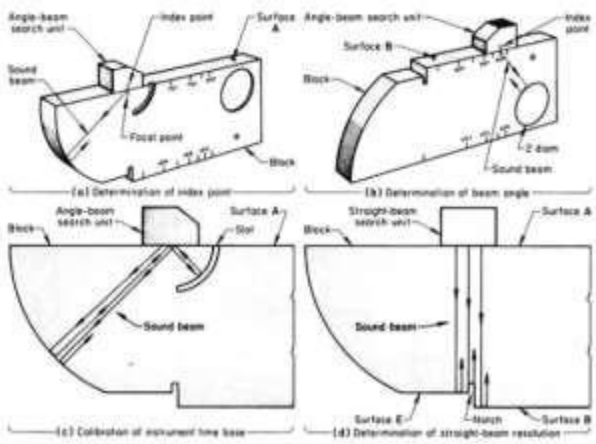
- Checking the performance of both angle beam and normal beam transducers
- Determining the sound beam exit point of angle beam transducers
- Determining the refracted angle produced
- Evaluating instrument performance

Some of the common standards used

IIW Type US-1 **Calibration Block**

This block is a general purpose calibration block that can be used for calibrating angle; beam transducers as well as normal beam transducers. The material from which IIW blocks are prepared is specified as killed, open hearth or electric furnace, low carbon steel in the normalized condition and with a grain size of McQuaid-Ehn No.8. Official IIW blocks are dimensioned in the metric system of units. The block has several features that facilitate checking and calibrating many of the parameters and functions of the transducer as well as the instrument where that includes; angle beam exit, beam angle, beam speed spared, time base, linearity, resolution, dead zone, sensitivity and range setting.T

The figure below shows some of the uses of the block.



ASTM-Miniature Angle-Beam Calibration Block (V2)

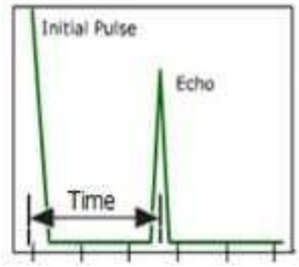
The miniature angle-beam block is used in a somewhat similar manner as the IIW block, but is smaller and lighter. The miniature angle-beam block is primarily used in the field for checking the characteristics of angle-beam transducers.

With the miniature block, beam angle and exit point can be checked for an angle-beam transducer. Both the 25 and 50 mm radius surfaces provide ways for checking the location of the exit point of the transducer for calibrating the time base of the instrument in terms of the metal distance. The small hole provides a reflector for checking beam angle and for setting the instrument gain.

Inspection Technique:

i. **Normal Beam Inspection**

Pulse-echo ultrasonic measurements can determine location of a discontinuity in a part of a structure by accurately measuring the time required for short ultrasonic pulse generated by a transducer to travel through a thickness of a material reflect from the back of a surface of a discontinuity and be returned to the transducer. In most applications, this time interval is a few microseconds or less. The two way transit time measured is divided by two to account down-and-back travel path and multiplied by the velocity of sound in the test material. The result is expressed in the well-known relationship

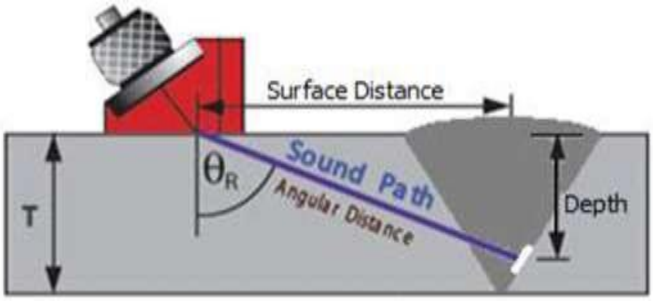


$$\boxed{d = \frac{V\,t}{2}}$$

Where d is the distance from the distance to the discontinuity in the test piece, V is the velocity of sound waves in the material, and t is the measured round-trip transit time.

Precision ultrasonic thickness gages usually operate at frequencies between 500 kHz and 100 MHz, by means of piezoelectric transducers that generate bursts of sound waves when excited by electrical pulses. Typically, lower frequencies are used to optimize penetration when measuring thick, highly attenuating, non-scattering materials. It is possible to measure most engineering materials ultrasonically, including metals, plastic, ceramics, composites, epoxies, and glass as well as liquid level and the thickness of certain biological specimens. On-line or in-process measurement of extruded plastics or rolled metal often is possible, as is measurements of single layers or coatings in multilayer materials.

ii. **Angle Beam Inspection**



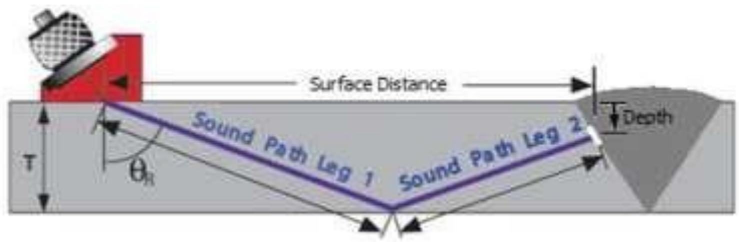
Angle beam transducers and wedges are typically used to introduce a refracted shear wave into the test material. An angled sound path allows the sound beam to come in from the side, thereby improving detectability of flaws in and around welded areas. Angle beam inspection is somehow different than normal beam inspection. In normal beam inspection, the back wall echo is always present on the scope display and when the transducer basses over a discontinuity a new echo will appear between the initial pulse and the back wall echo. However, when scanning a surface using an angle beam transducer there will be no reflected echo on the scope display unless a properly oriented discontinuity or reflector comes into the beam path. If a reflection occurs before the sound waves reach the back wall, the reflection is usually referred to as “first leg reflection”. The angular distance

(Sound Path) to the reflector can be calculated using the same formula used for normal beam transducers (but of course using the shear velocity instead of the longitudinal velocity) as:

$$\boxed{Surface\ Distance = Sound\ Path \times \sin\theta_R}$$

$$\boxed{Depth_{1^{st}\ leg} = Sound\ Path \times \cos\theta_R}$$

where θ_R is the angle of refraction.



If a reflector came across the sound beam after it has reached and reflected off the back all, the reflection is usually referred to as "second leg reflection". In this case, the "Sound Path" (the total sound path for the two legs) and the "Surface Distance" can be calculated using the same equations given above; however the "Depth" of the reflector will be calculated as

$$\boxed{Depth_{2^{nd}\ leg} = 2T - (Sound\ Path \times \cos\theta_R)}$$

Important Formulae for Ultrasonic Testing:

1) **Frequency of Probe: F = V/ λ , Where (λ = 2 x Minimum Size of Defect to be found)**

V- Velocity of sound in material under consideration

λ- Wavelength,

2) **Near Zone of Normal Probe: N = D² / 4 λ, Where (λ = V / F)**

(D – Diameter of probe,

λ- Wavelength,

V- Velocity of sound in material under consideration

F- Frequency of Probe

3) Near Zone of Angle Probe: N = $\dfrac{\sqrt{(L^2 + b^2)}}{4\,\lambda}$

l - Length of the piezo electric element

b – Breath of the piezo electric element

λ – Wavelength of the sound , λ = V / F

4) Beam Spread Angle θ: sin (Ө/2) = 1.22 (ʎ/D)

λ – Wavelength of the sound , λ = V / F

D – Diameter of the probe element

5) Probe Angle Selection : θ = 90° - Thickness of the Weld Plate

6) Skip Distance: ½ Skip = T x Tan θ, 1 Skip = 2 (T x Tan θ), 1 ½ Skip = 3 (T x Tan θ) T – Thickness of the test plate

θ - Probe angle

7) Beam Path : 1st Leg = T / Cos θ, 2nd leg = 2 (T / Cos θ), 3rd Leg = 3 (T / Cos θ)

Few of the important Sound Velocity in the materials are given below:

Material	Longitudinal Velocity	Shear Velocity	Impedance
Air	330 m/s	---	0.003
Water	1400 m/s	---	1.49
Steel	5890 to 5940 m/s	3255 m/s	45.1
Quartz	5740 m/s	2760 m/s	30
Oil	1800 m/s	--	1.5
Aluminium	6300 m/s	3800 m/s	4
Plastic	2700 m/s	2200 m/s	

Near Zone and Beam Spread for different Probes are given below for reference

Probe	N	θ/2
Ø10mm, 2 MHz	8.125	21.16
Ø10mm, 4 MHz	16	10.42
Ø10mm, 6 MHz	25	6.64
Ø24mm, 2 MHz	48.6	7.24
Ø24mm, 4 MHz	97.29	4.37
Ø24mm, 6 MHz	146.60	2.762
8x9 , 2 MHz	1.01	9.47
8x9 , 4 MHz	2.03	4.721
12x12, 2 MHz	1.44	6.708
12x12, 4 MHz	2.8866	3.34

20x20, 2 MHz	4.574	3.823

Inspection Standards:

ASME BPVC Section V, Article 4 – Ultrasonic Examination of Welds

ASME BPVC Section V, Article 5 – Ultrasonic Examination of Materials

ASME BPVC Section V, Article 23 – Ultrasonic Standards

SA-388/SA-388M Standard Practice for Ultrasonic Examination of Steel Forgings

SA-435/SA-435M Standard Specification for Straight-Beam Ultrasonic Examination of Steel Plates

SA-577/SA-577M Standard Specification for Ultrasonic Angle-Beam Examination of Steel Plate

SA-578/SA-578M Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

SA-609/SA-609M Standard Practice for Castings, Carbon, Low-Alloy and Martensitic Stainless Steel, Ultrasonic Examination Thereof

SA-745/SA-745M Standard Practice for Ultrasonic Examination of Austenitic Steel Forgings

SB-548 Standard Test Method for Ultrasonic Inspection of Aluminum-Alloy Plate for Pressure Vessels

SD-7091 Standard for measurement of painting thickness using UT method

SE-213 Standard Practice for Ultrasonic Testing of Metal Pipe and Tubing

SE-273 Standard Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing

SE-317 Standard Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems Without the Use of Electronic Measurement Instruments

SE-797/SE-797M Standard Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method

SE-2491 Standard Guide for Evaluating Performance Characteristics of Phased-Array Ultrasonic Testing Instruments and Systems

SE-2700 Standard Practice for Contact Ultrasonic Testing of Welds Using Phased Arrays

ISO 17640 – Non Destructive Testing of Welds – Ultrasonic Testing – Techniques, Testing Levels an assessment

ISO 16831 Non-destructive testing — Ultrasonic testing — Characterization and verification of ultrasonic thickness measuring equipment

ISO 4992 – Non Destructive Testing of Steel Castings (with ferritic structure for general purpose)

SAE AMS 2630 B – Aerospace Standard for Ultrasonic Testing of Material over 12.7mm Thickness

SAE AMS 2632 – Aerospace Standard for Ultrasonic Testing of Material less than 12.7mm Thickness

AWS D1.1 Part F 6.20 – Ultrasonic Testing Procedure for Structural Steel Welds

ASTM E 164 – Standard Practice for Ultrasonic Contact Examination of Weldments

ASTM E 127 & 428 – Standard for machining of UT Reference blocks

Acceptance Criteria :

ASME Section VIII Division 1 - Pressure Vessel Construction – Ultrasonic Testing

These Standards shall apply unless other standards are specified for specific applications within this Division.

Imperfections which produce a response greater than 20% of the reference level shall be investigated to the extent that the operator can determine the shape, identity, and location of all such imperfections and evaluate them in terms of the acceptance standards given in (a) and (b) below.

(a) Indications characterized as cracks, lack of fusion, or incomplete penetration is unacceptable regardless of length.
(b) Other imperfections are unacceptable if the indications exceed the reference level amplitude and have lengths which exceed:

(1) 1/4 in. (6 mm) for t up to 3/4 in. (19 mm);
(2) 1/3t for t from 3/4 in. to 21/4 in. (19 mm to 57 mm);
(3) 3/4 in. (19 mm) for t over 21/4 in. (57 mm).

where t is the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses 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 .

ASME B 16.34 - Valves - Ultrasonic Testing

Acceptance Standards.

Straight Beam Examination

Indications which are equal to or exceed that obtained from a 6.4 mm (0.25 in.) diameter flat bottomed hole in a calibration test piece of thickness equal to the defect depth are unacceptable.

Angle Beam Examination

Indications which are equal to or exceed those obtained from a 60 deg V-notch, 25 mm (1.0 in.) long and having a depth not greater than 5% of the nominal wall thickness in a test piece are unacceptable.

ASME B 31.1 – Power Piping – Ultrasonic Testing

Acceptance Standards. Welds that are shown by ultrasonic examination to have discontinuities that produce an indication greater than 20% of the reference level shall be investigated to the extent that ultrasonic examination personnel can determine their shape, identity, and location so that they may evaluate each discontinuity for acceptance in accordance with (B.1) and (B.2) below.

(B.1) Discontinuities evaluated as being cracks, lack of fusion,. or incomplete penetration are unacceptable regardless of length.

(B.2) Other discontinuities are unacceptable if the indication exceeds the reference level and their length exceeds the following:

(B.2.1) ¼" (6.0 mm) for t up to ¾" (19.0 mm).

(B.2.2) 1/3 t for *t* from ¾" (19.0 mm) to 2 ¼ " (57.0 mm).

(B.2.3) ¾". (19.0 mm) for *t* over 2¼" (57.0 mm)

Where *t* is the thickness of the weld being examined. If the weld joins two members having different thicknesses at the weld, *t* is the thinner of these two thicknesses.

ASME B31.3 Process Piping – Ultrasonic Testing

Inspection of Weld Joints carried as per ASME Section V , Article 4

Pipe and Tubing

(a) Method. Pipe and tubing, required or selected in accordance with Table *K305.1.2* to undergo ultrasonic examination, shall pass a 100% examination for longitudinal defects in accordance with ASTM E213, Ultrasonic Testing of Metal Pipe and Tubing. Longitudinal (axial) reference notches shall be introduced on the outer and inner surfaces of the calibration (reference) standard in accordance with Fig. 3(c) of ASTM E213 to a depth not greater than the larger of 0.1 mm (0.004 in.) or 4% of specimen thickness and a length not more than 10 times the notch depth.

(b) Acceptance Criteria. Any indication greater than that produced by the calibration notch representation

ADVANCED QUALITY CENTRE

AWS D 1.1 Structural Steel Welding – Ultrasonic Testing Acceptance Criteria :

Table 6.2
UT Acceptance-Rejection Criteria (Statically Loaded Nontubular Connections)
(see 6.13.1 and C-6.26.6)

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	+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.

Notes:
1. Class B and C discontinuities shall be separated by at least 2L, L being the length of the longer discontinuity, except that when two 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 provisions of Class B or C, the discontinuity shall be considered a single acceptable discontinuity.
2. 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.
3. Discontinuities detected at "scanning level" in the root face area of CJP double groove weld joints shall be evaluated using an indication rating 4 dB more sensitive than described in 6.26.6.5 when such welds are designated as "tension welds" on the drawing (subtract 4 dB from the indication rating "d"). This shall not apply if the weld joint is backgouged to sound metal to remove the root face and MT used to verify that the root face has been removed.
4. ESW or EGW: Discontinuities detected at "scanning level" which exceed 2 in [50 mm] in length shall be suspected as being piping porosity and shall be further evaluated with radiography.
5. For indications that remain on the display as the search unit is moved, refer to 6.13.1.

For Statically loaded Non Tubular Connections:-

Class A (large discontinuities)
Any indication in this category shall be rejected (regardless of length).

Class B (medium discontinuities)
Any indication in this category having a length greater than 3/4 in [20 mm] shall be rejected.

Class C (small discontinuities)
Any indication in this category having a length greater than 2 in [50 mm] shall be rejected.

Class D (minor discontinuities)
Any indication in this category shall be accepted regardless of length or location in the weld.

Scanning Levels	
Sound path[b] in inches [mm]	Above Zero Reference, dB
through 2-1/2 [65 mm]	14
> 2-1/2 through 5 [65–125 mm]	19
> 5 through 10 [125–250 mm]	29
> 10 through 15 [250–380 mm]	39

[b] This column refers to sound path distance; NOT material thickness.

Table 6.3
UT Acceptance-Rejection Criteria (Cyclically Loaded Nontubular Connections) (see 6.13.2 and C-6.26.6)

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.

Notes:

1. Class B and C discontinuities shall be separated by at least 2L, L being the length of the longer discontinuity, except that when two 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 provisions of Class B or C, the discontinuity shall be considered a single acceptable discontinuity.
2. 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.
3. Discontinuities detected at "scanning level" in the root face area of CJP double groove weld joints shall be evaluated using an indication rating 4 dB more sensitive than described in 6.26.6.5 when such welds are designated as "tension welds" on the drawing (subtract 4 dB from the indication rating "d"). This shall not apply if the weld joint is backgouged to sound metal to remove the root face and MT used to verify that the root face has been removed.
4. For indications that remain on the display as the search unit is moved, refer to 6.13.2.1.

For Cyclically loaded Non Tubular Connections:-

Class A (large discontinuities)

Any indication in this category shall be rejected (regardless of length).

Class B (medium discontinuities)

Any indication in this category having a length greater than 3/4 in [20 mm] shall be rejected.

Class C (small discontinuities)

Any indication in this category having a length greater than 2 in [50 mm] in the middle half or 3/4 in [20 mm] length in the top or bottom quarter of weld thickness shall be rejected.

Class D (minor discontinuities)

Any indication in this category shall be accepted regardless of length or location in the weld.

Scanning Levels	
Sound path[b] in [mm]	Above Zero Reference, dB
through 2-1/2 [65 mm]	20
> 2-1/2 through 5 [65–125 mm]	25
> 5 through 10 [125–250 mm]	35
> 10 through 15 [250–380 mm]	45

[b] This column refers to sound path distance; NOT material thickness.

How to Interpret AWS D1.1 UT Acceptance Criteria

Your scanning levels:
Is determined by the length of your sound path and then you add the amount of gain required per the chart under Tables 6.2/6.3 to your reference level.

Scanning Levels

Sound path[b] in inches [mm]	Above Zero Reference, dB
through 2-1/2 [65 mm]	14
> 2-1/2 through 5 [65–125 mm]	19
> 5 through 10 [125–250 mm]	29
> 10 through 15 [250–380 mm]	39

[b] This column refers to sound path distance; NOT material thickness.

Your reference level is determined by the about of dBs that it took to get a peaked reflection off the 1.5mm side drilled hole up to 50%FSH.

ie. My Krautkramer is set with a reference level of 64 dBs(peaked up the signal from the 1.5mm side drilled hole on the IIW block to 50% FSH),
....then I add the number of dBs indicated in that chart to get to my scanning level.

ie. Soundpath is 2.5" - 5" add 19 dBs to my 64 dBs for a scanning level of 83 dBs.

Your Indication level:
When you find an indication and peak up on it.....you take out gain until your signal is at 50% FSH.....then you record the dB level.

Attenuation (item C on your test report) is attained by subtracting 1 inch from the sound path distance and then multiplying the remainder by 2. This factor can then be rounded out to the dearest db value.

Now that you have the level figured you will need to look at the appropriate Table and find where your indication level falls in.....then look at the chart to determine what classification the indication has....then determine from the Notes below the Tables if the indication is acceptable or rejectable.

Example:
if you found something that has an indication level of 78dB.....now to figure your attentuation...((sound path minus 1) times 2)

ie. Sound path= 2.8"...so... 2.8 -1 = 1.8 x 2 = 3.6 then rounded up to a 4.......(this depends on the type of machine you have)...if you had a reference level of +64 you work the attentuation formula of a-b-c=d.... so +78(a) minus+64(b) = +14 then subtract your attenuation factor of +4(c) to get your actual indication level of +10(d)...now since you had a sound path of 2.8" with a 70* transducer on 5/16"-3/4" material, look in the Table on 6.2/6.3 and see where you are in the table.....in Table 6.2 a +10 is a Class "D" indication and is acceptable regardless of length or location....but, in Table 6.3 a +10 is a Class "A" indication which is rejectable regardless of length or location....

Note: these figures were just made up to give us something to talk about.....use the actual numbers you have in your situation....
....my Krautkramer USN58L uses the forumla a-b-c=d.......see if yours has a gain control or an attentuation control, that determines which formula to use.

ASME Section IX – Welding Procedure & Welder Qualifciation – Ultrasonic Testing Acceptance

Welds over 6mm thick can be ultrasonically tested in reference with procedure given in ASME Sec V article 4.

Indications shall be sized using the applicable technique(s) provided in the written procedure for the
examination method. Indications shall be evaluated for acceptance as follows:

(a) All indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.
(b) Indications exceeding 1/8 in. (3 mm) in length are considered relevant, and are unacceptable when their lengths exceed
(1) 1/8 in. (3 mm) for *t* up to 3/8 in. (10 mm).
(2) 1/3*t* for *t* from 3/8 in. to 21/4 in. (10 mm to 57 mm).
(3) 3/4 in. (19 mm) for *t* over 21/4 in. (57 mm),
where "*t*" is the thickness of the weld excluding any allowable reinforcement.
For a butt weld joining two members having different thicknesses 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* .

API 1104 Welding of Pipelines & Related Facilities – Ultrasonic Testing – Acceptance level

9.6.2 Acceptance Standards 9.6.2.1 Indications determined to be cracks (C) shall be considered defects.

9.6.2.2 Linear surface (LS) indications (other than cracks) interpreted to be open to the I.D. or O.D. surface shall be considered defects should any of the following conditions exist:

a. The aggregate length of LS indications in any continuous 12”(300-mm) length of weld exceeds 1”. (25 mm).

b. The aggregate length of LS Indications exceeds 8% of the weld length.

9.6.2.3 Linear buried (LB) indications (other than cracks) interpreted to be subsurface within the weld and not I.D. or O.D. surface-connected shall be considered defects should any of the following conditions exist:

a. The aggregate length of LB indications in any continuous 12”(300-mm) length of weld exceeds 2” (50 mm).

b. The aggregate length of LB indications exceeds 8% of the weld length.

9.6.2.4 Transverse (T) indications (other than cracks) shall be considered volumetric and evaluated using the criteria for volumetric indications. The letter T shall be used to designate all reported transverse indications.

9.6.2.5 Volumetric cluster (VC) indications shall be considered defects when the maximum dimension of VC indications exceeds 1/2 “ (13 mm).

9.6.2.6 Volumetric individual (VI) indications shall be considered defects when the maximum dimension of VI indications exceeds 1/4 “ (6 mm) in both width and length.

9.6.2.7 Volumetric root (VR) indications interpreted to be open to the I.D. surface shall be considered defects should any of the following conditions exist:

a. The maximum dimension of VR indications exceeds 1/4“ (6mm).

b. The total length of VR indications exceeds 1/2 “ (13 mm) in any continuous 12” (300 mm) length.

9.6.2.8 Any accumulation of relevant indications (AR) shall be considered a defect when any of the following conditions exist:

a. The aggregate length of indications above evaluation level exceeds 2 “(50 mm) in any 12” (300 mm) length of weld.

b. The aggregate length of indications above evaluation level exceeds 8% of the weld length.