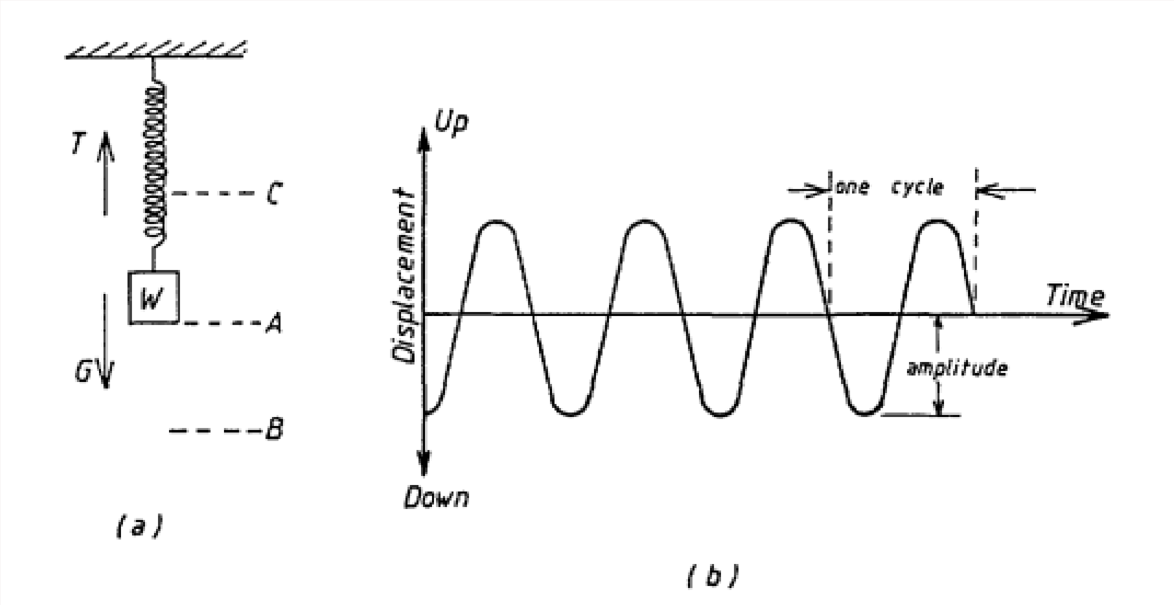
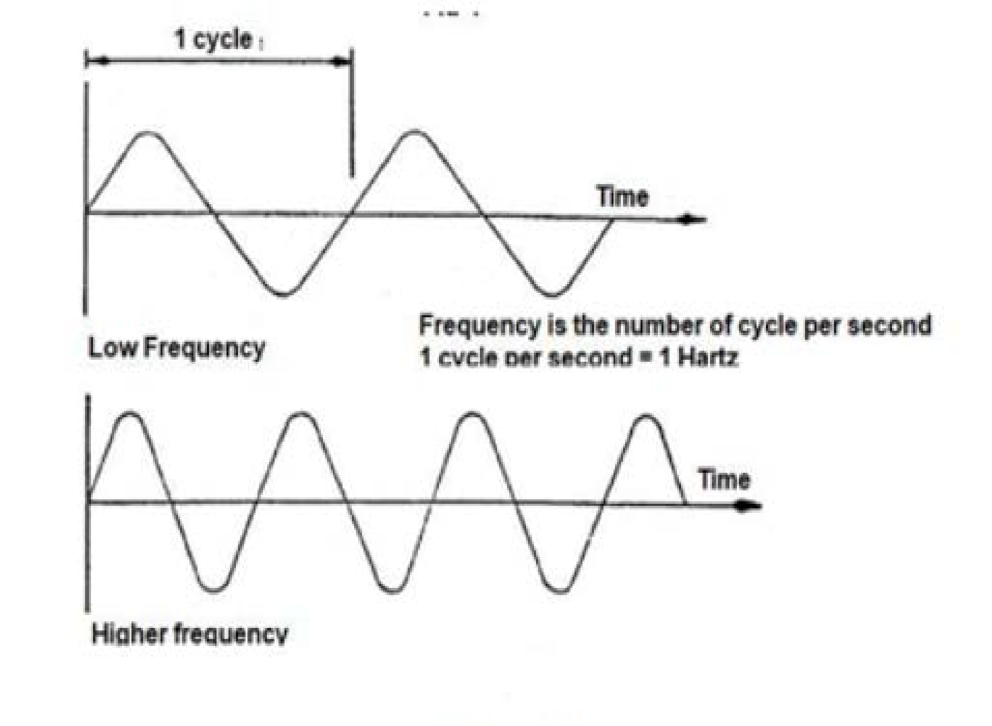
ULTRASOUND BASIC

Manual UT Principal & Working

The nature of ultrasonic waves

- To understand how ultrasonic wave motion occurs in a medium, it is necessary to understand the mechanism which transfer the energy between two points in a medium. This can be understood by studying the vibration of a weight attached to a spring





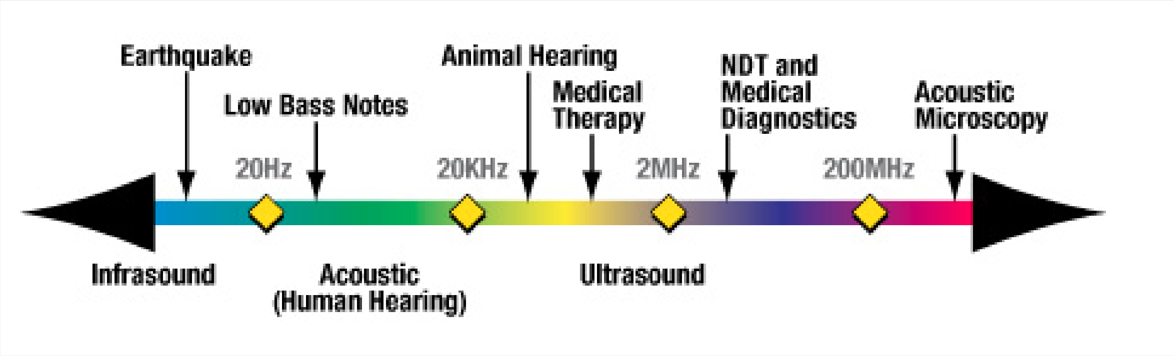
frequency vs time

Characteristics of wave propagation

- **Frequency :**
- The frequency of a wave is the same as that of the vibration or oscillation of the atoms of the medium in which the wave is travelling. It is usually denoted by the letter f and until recently was expressed as the number of cycles per second. The International term for a cycle per second is named after the physicist H . Hertz and is abbreviated as Hz
- 1 H z =1 cycle per second
- 1 KHz = 1000 Hz = 1000 cycles per second
- 1 MHz = 1000000 Hz = 1000000 cycles per second

Sound Wave

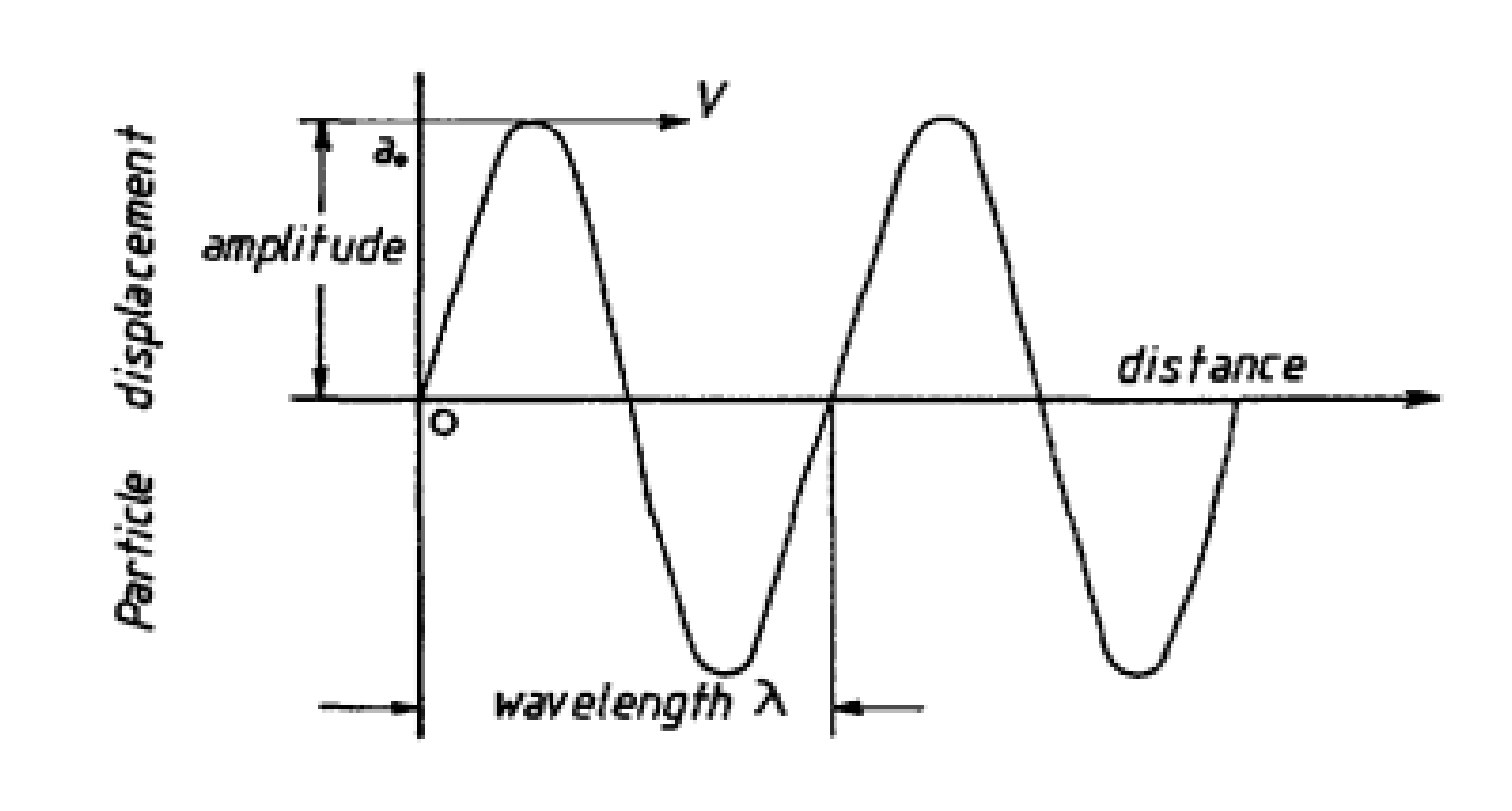
- Sound waves are all around us, as mechanical vibrations carried by a medium such as air or water. Ultrasonic testing involves frequencies beyond the upper limit of human hearing, higher than 20 KHz and most commonly in the range from 500 KHz to 20 MHz, although higher and lower frequencies are sometimes used as well. The exact test frequency will be selected with respect to the specific application at hand. All ultrasonic thickness gauges work by very precisely measuring how long it takes for a sound pulse that has been generated by a probe called an ultrasonic transducer to travel through a test piece. Sound waves will reflect from boundaries between dissimilar materials, such as the air or liquid on the inside of a steel pipe wall, so this measurement can normally be made from one side in a "pulse/echo" mode.

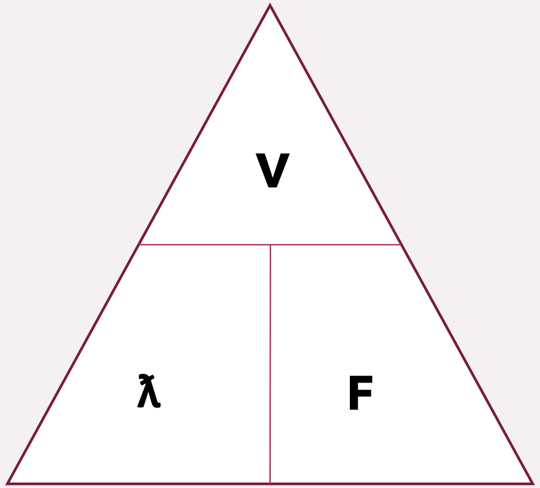


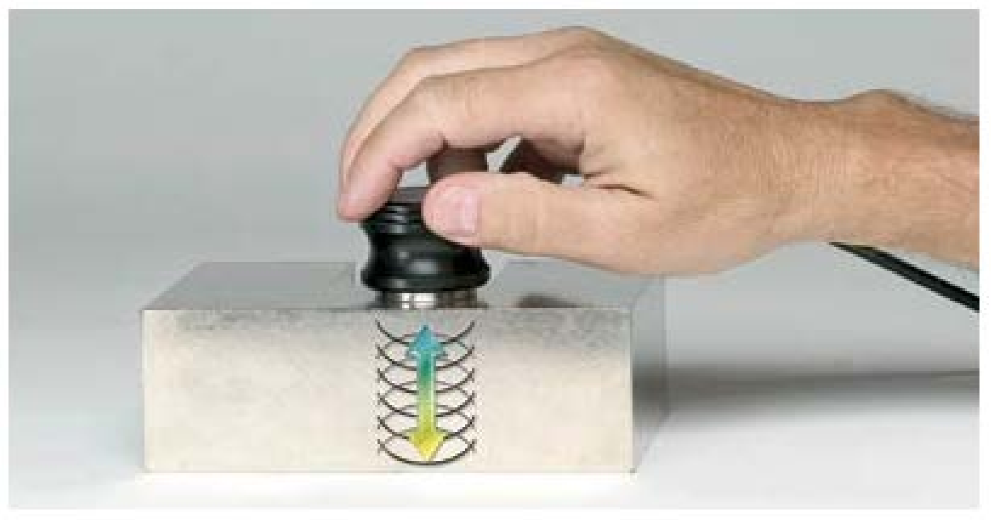
Wavelength:

$\lambda = (V/F)$

- The speed with which energy is transported between two points in a medium by the motion of waves is known as the velocity of the waves. It is usually denoted by the letter V.







Transducer Selection:

- The transducer contains a piezoelectric element which is excited by a short electrical impulse to generate a burst of ultrasonic waves. The sound waves are coupled into the test material and travels through it until they encounter a back wall or other boundary. The reflections then travel back to the transducer, which converts the sound energy back into electrical energy. In essence, the gauge listens for the echo from the opposite side. Typically, this time interval is only a few millionths of a second. The gauge is programmed with the speed of sound in the test material, from which it can then calculate thickness using the simple mathematical relationship
- $T = (V) \times (t/2)$
  were
  T = the thickness of the part
  V = the velocity of sound in the test material
  t = the measured round-trip transit time
- In some cases, a zero offset is also subtracted to account for fixed delays in the instrument and sound path.

Ultrasonic Waves

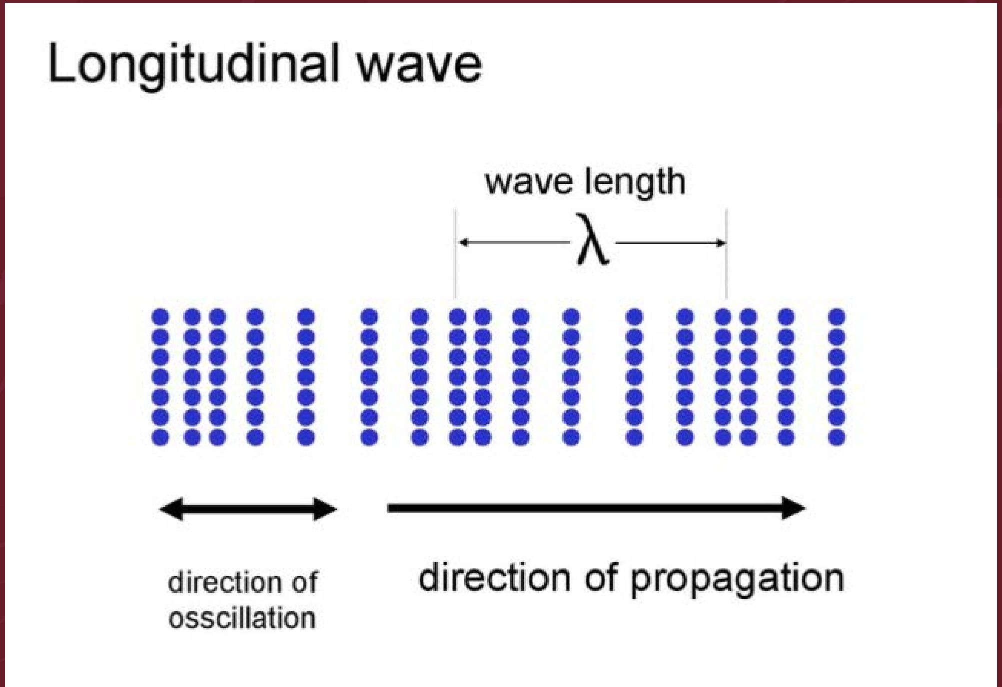
- Sound waves are vibrations of particles of gases, solids or liquids. The audible sound range of frequencies is usually taken from 20 Hz to 20 KHz . Sound waves with frequencies higher than 20 KHz are known as ultrasonic waves. In general, ultrasonic waves of frequency range 0.5 MHz to 20 MHz are used for the testing of materials. The most common range for testing metals is from 2 MHz to 5 MHz

Types of ultrasonic Waves

- Ultrasonic waves are classified based on the mode of vibration of the particles of the medium with respect to the direction of propagation of the waves, namely longitudinal, transverse, surface and Lamb waves.

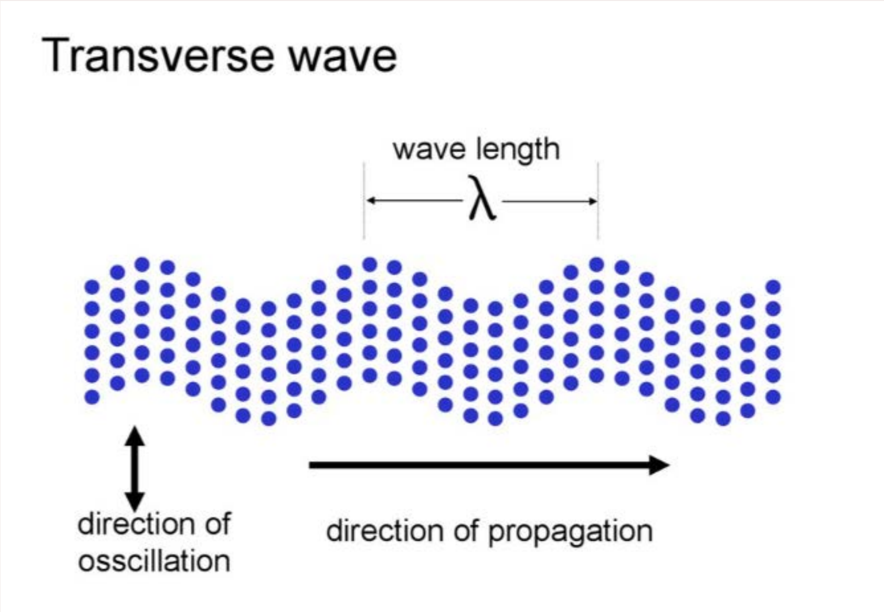
Longitudinal Waves

- These are also called compression waves. In this type of ultrasonic wave alternate compression and rarefaction 29 zones are produced by the vibration of the particles parallel to the direction of propagation of the wave



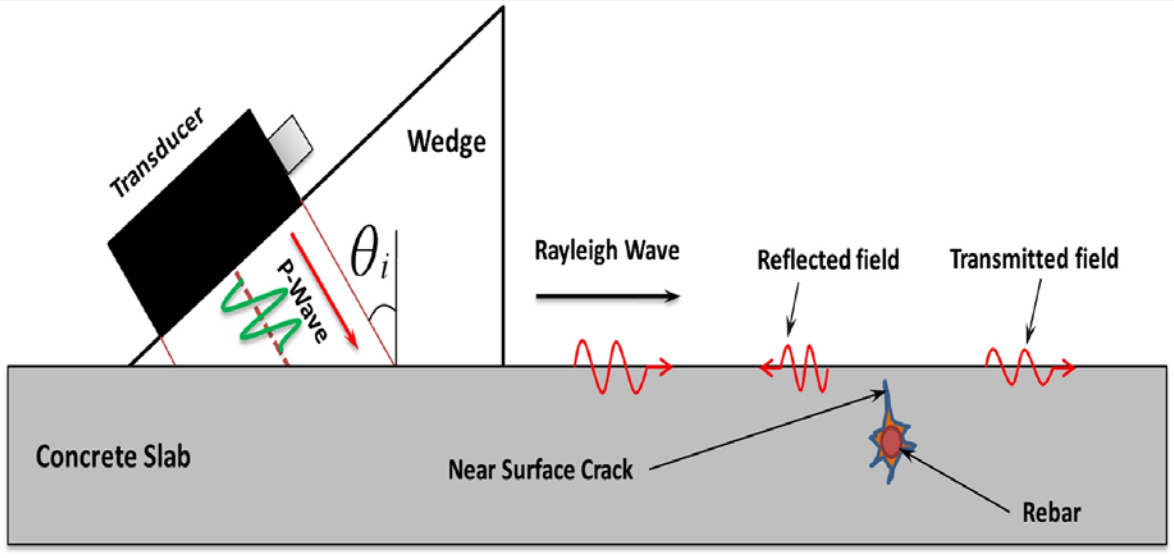
Transverse or Shear Waves

- This type of ultrasonic wave is called a transverse or shear wave because the direction of particle displacement is at right angles or transverse to the direction of propagation



Surface or Rayleigh Waves

- Surface waves were first described by Lord Rayleigh and that is why they are also called Rayleigh waves. These type of waves can only travel along a surface bounded on one side by the strong elastic forces of the solid and on the other side by the nearly nonexistent elastic forces between gas molecules. Surface waves, In surface waves, particle vibrations generally follow an elliptical orbit



$$R = \frac{I_r}{I_i} = \left(\frac{Z_2 - Z_1}{Z_1 + Z_2}\right)^2$$

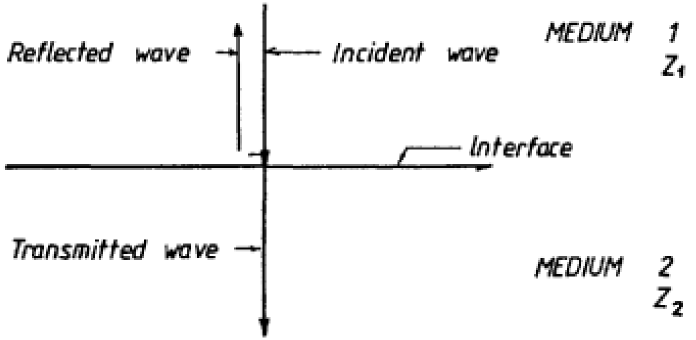
Where R = Reflection Co-efficient

Z_1 = Acoustic impedence of medium 1.

Z_2 = Acoustic impedence of medium 2.

I_r = Reflected ultrasonic intensity.

I_i = Incident ultrasonic intensity.

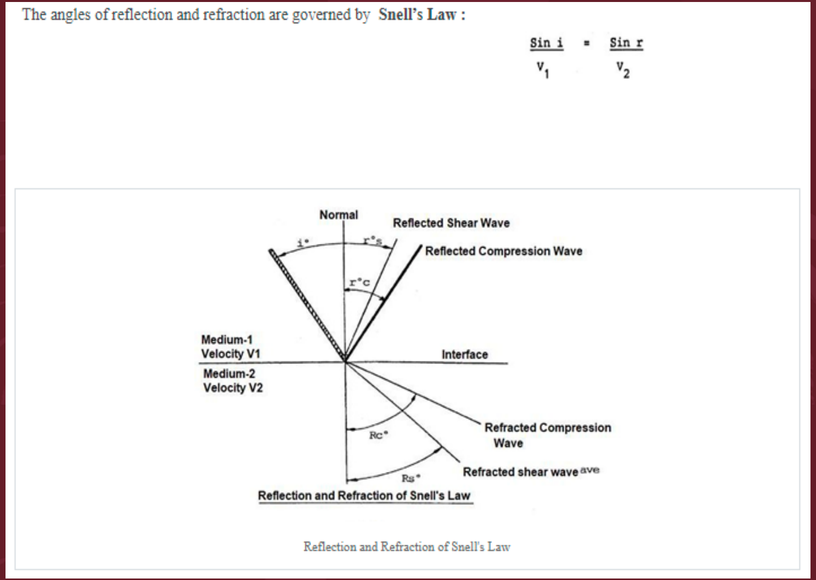


Reflected And Transmitted

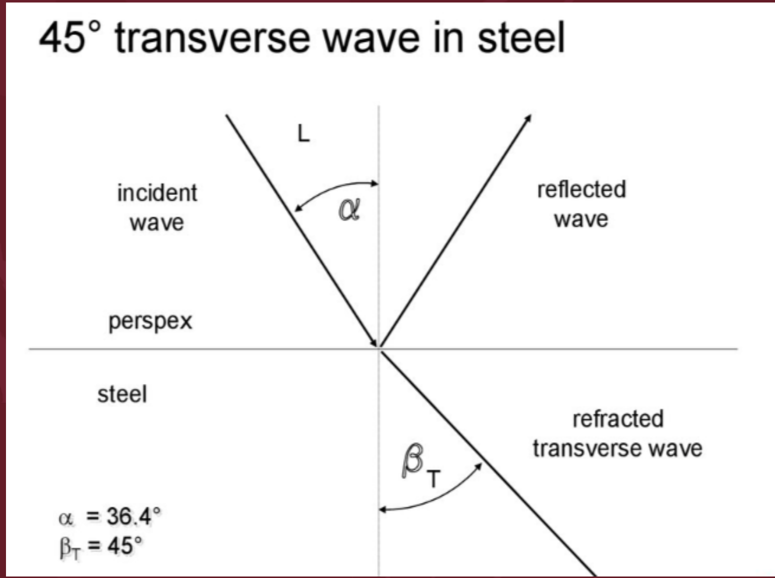
- When ultrasonic waves are incidence at right angles to the boundary { i.e., normal incidence) of two media of different acoustic impedances, then some of the waves are reflected and some are transmitted across the boundary. The amount of ultrasonic energy that is reflected or transmitted depends on the difference between the acoustic impedances of the two media. If this difference is large, then most of the energy is reflected and only a small portion is transmitted across the boundary. While for a small difference in the acoustic impedances most of the ultrasonic energy is transmitted and only a small portion is reflected Back

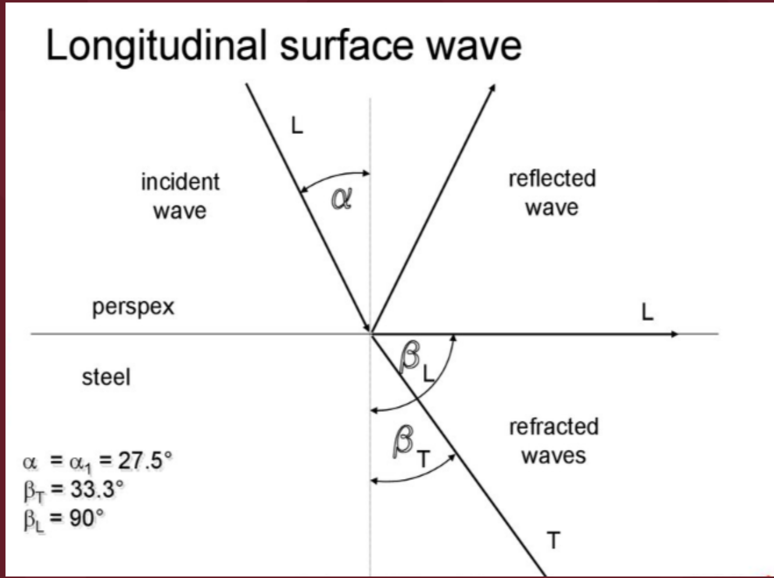
Snell's Law

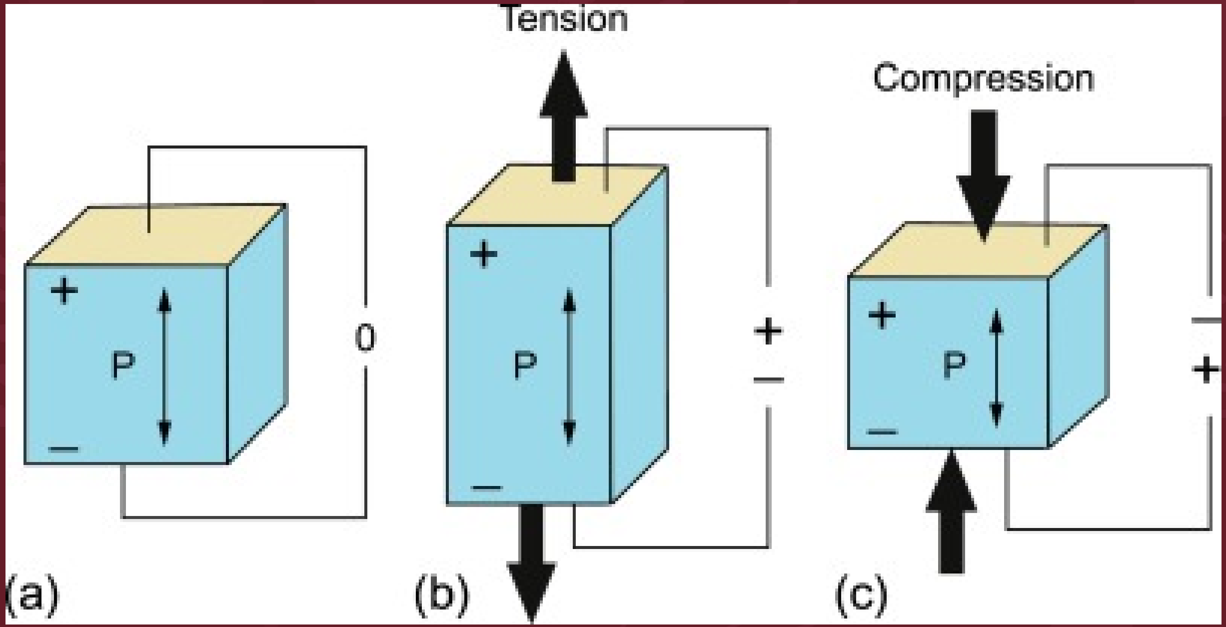
- The general law that, for a certain incident ultrasonic wave on a boundary, determines the directions of the reflected and refracted waves is known as Snell's Law. According to this law the ratio of the sine of the angle of incidence to the sine of the angle of reflection or refraction equals the ratio of the corresponding velocities of the incident and reflected or refracted waves.



Reflection and Refraction of Snell's Law

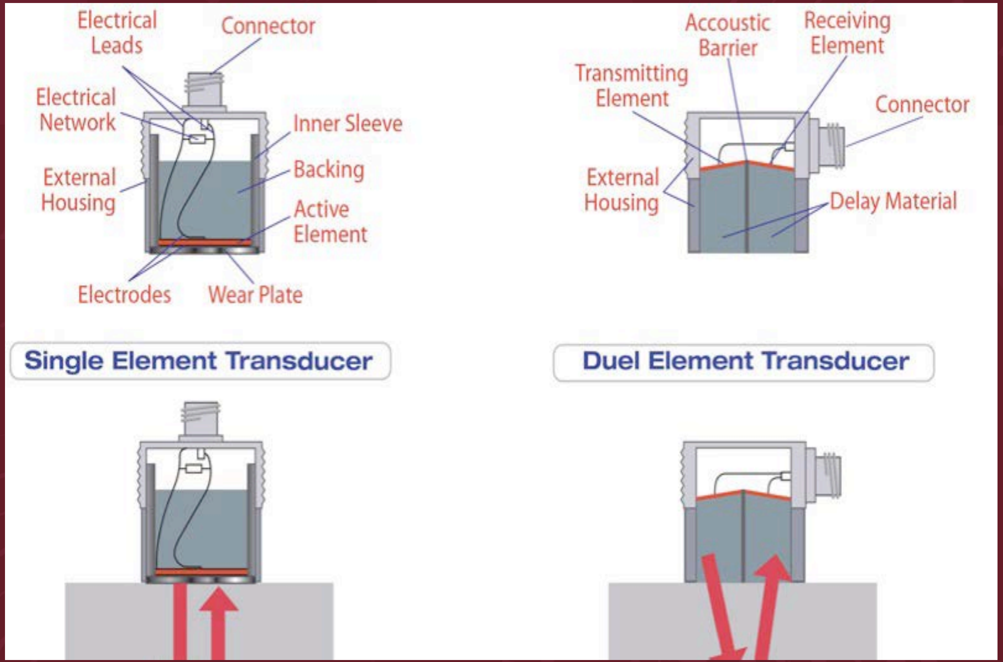






Piezoelectric Effect

- A transducer is a device which converts one form of energy into another. Ultrasonic transducers convert electrical energy into ultrasonic energy and vice versa by utilizing a phenomenon known as the piezoelectric effect. The materials which exhibit this property are known as piezoelectric materials



Piezoelectric Transducers

- Ultrasonic transducers for thickness gauging come in a wide variety of sizes, frequencies, and case styles, but most have a common internal structure. Typically, the active element of the transducer is a thin disk, square, or rectangle of piezoelectric ceramic that converts electrical energy into mechanical energy (ultrasonic vibrations), and vice versa. When it is excited by an electrical pulse, it generates sound waves, and when it is vibrated by returning echoes, it generates a voltage. The active element, which is often referred to informally as the crystal, is protected from damage by a wear plate or acoustic lens and backed by a block of damping material that quiets the transducer after the sound pulse has been generated. This ultrasonic subassembly is mounted in a case with appropriate electrical connections. All common contact, delay line, and immersion transducers utilize this basic design. Dual element transducers, commonly used in corrosion survey applications, differ in that they have separate transmitting and receiving elements separated by a sound barrier, no backing, and an integral delay line to steer and couple the sound energy, rather than a wear plate or lens.

Types Of Transducer:

- **Contact transducers:**
- As the name implies, contact transducers are used in direct contact with the test piece. A thin, hard wear plate protects the active element from damage in normal use. Measurements with contact transducers are often the simplest to implement, and they are usually the first choice for most common thickness gauging applications other than corrosion gauging.

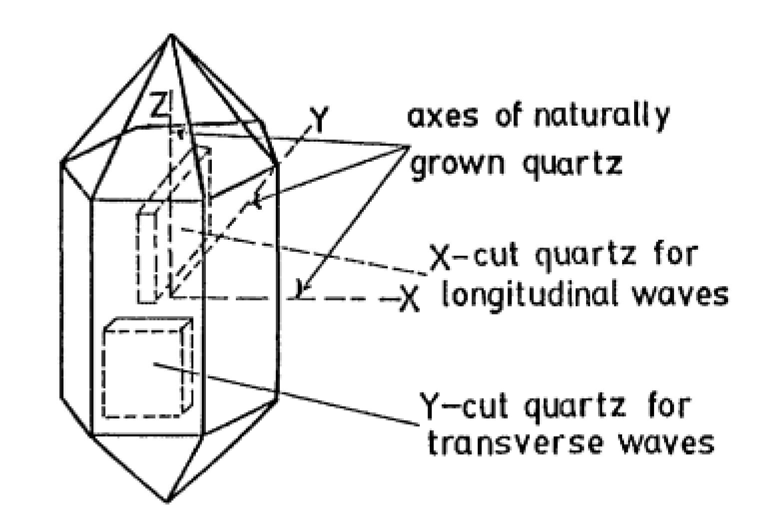
  Delay line transducers:
- Delay line transducers incorporate a cylinder of plastic, epoxy, or fused silica known as a delay line between the active element and the test piece. A major reason for using them is for thin material measurements, where it is important to separate the excitation pulse recovery from back wall echoes. A delay line can be used as a thermal insulator, protecting the heat-sensitive transducer element from direct contact with hot test pieces, and delay lines can also be shaped or contoured to improve sound coupling into sharply curved or confined spaces.

  Immersion transducers:
- Immersion transducers use a column or bath of water to couple sound energy into the test piece. They can be used for in-line or in-process measurement of moving product, for scanned measurements, or for optimizing sound coupling into sharp radiuses, grooves, or channels.

  Dual element transducers:
- Dual element transducers, or simply "duals," are used primarily for measurements involving rough, corroded surfaces. They incorporate separate transmitting and receiving elements mounted on a delay line at a small angle to focus sound energy a selected distance beneath the surface of a test piece. Although measurement with duals is sometimes not as accurate as with other types of transducers, they usually provide significantly better performance in corrosion survey applications.

Quartz:

- Naturally or artificially grown quartz crystals have a certain definite shape which is described by crystallographic axes, consisting of an X-, Y- and Z-axis
- **Advantage:**
- i) It is highly resistant to wear,
- ii) It is insoluble in water.
- iii) It has high mechanical and electrical stability,
- iv) It can be operated at high temperatures.



- **Limitation:**
- i) It is comparatively expensive.
- ii) It is the least efficient generator of ultrasonic energy.
- iii) It suffers from mode conversion when an Xcut quartz is used besides generating longitudinal waves it also generates transverse 44 waves. Transverse waves are generated because an X-cut crystal when compressed, elongates in the Y-direction also. Production of transverse waves gives rise to spurious signals after the main pulse.
- iv) It requires a high voltage for its operation

Transducer Properties:

- Transducers of the kind most used for ultrasonic gauging will have these fundamental functional properties, which, in turn, affect the properties of the sound beam that they will generate in each material:
- **Type** - The transducer will be identified according to its design and function as a contact, delay line, or immersion type. Physical characteristics of the test material such as surface roughness, temperature, and accessibility, as well as its sound transmission properties and the range of thickness to be measured, will all influence the selection of transducer type.
- **Diameter** - The diameter of the active transducer element, which is normally housed in a somewhat larger case. Smaller diameter transducers are often most easily coupled to the test material, while larger diameters may couple more efficiently into rough surfaces due to an averaging effect. Larger diameters are also required for design reasons as transducer frequency decreases.
- **Frequency** - The number of wave cycles completed in one second, normally expressed in kilohertz (KHz) or megahertz (MHz). Most ultrasonic gauging is done in the frequency range from 500 KHz to 20 MHz, so most transducers fall within that range, although commercial transducers are available from below 50 KHz to greater than 200 MHz Penetration increases with lower frequency, while resolution and focal sharpness increase with higher frequency.
- **Bandwidth** - Typical transducers for thickness gauging do not generate sound waves at a single pure frequency, but rather over a range of frequencies centered at the nominal frequency designation. Bandwidth is the portion of the frequency response that falls within specified amplitude limits. Broad bandwidth is usually desirable in thickness gauging applications involving contact, delay line, and immersion transducers.

Transducer Selection:

- election of the proper transducer is an essential factor for ensuring optimum performance in any ultrasonic gauging application. It is necessary to consider the material being measured, the range of thickness that must be covered, part geometry, and part temperature. A wide variety of transducers with various acoustic characteristics have been developed to meet the needs of industrial applications. Typically, lower frequencies of 2.25 MHz and below will be used to optimize penetration when measuring thick, highly attenuating, or highly scattering materials, while higher frequencies of 5 MHz and above will be recommended to optimize resolution in thinner, non-attenuating, non-scattering materials.
- **Material:**
- The type of material and the range of thickness being measured are the most important factors in selecting a gauge and transducer. Many common engineering materials including most metals, ceramics, and glass transmit ultrasound very efficiently and can easily be measured across a wide thickness range. Most plastics absorb ultrasonic energy more quickly and thus have a more limited maximum thickness range but can still be measured easily in most manufacturing situations. Rubber, fiberglass, and many composites can be much more attenuating and often require high penetration gauges with pulser/receivers optimized for low frequency operation.
- **Thickness:**
- Thickness ranges will also dictate the type of gauge and transducer that should be selected. In general, thin materials are measured at high frequencies and thick or attenuating materials are measured at low frequencies. Delay line transducers are often used on very thin materials, although delay line (and immersion) transducers will have a more restricted maximum measurable thickness due to potential interference from a multiple of the interface echo. In some cases, involving broad thickness ranges and/or multiple materials, more than one transducer type may be required.
- **Geometry:**
- As the surface curvature of a part increases, the coupling efficiency between the transducer and the test piece is reduced, so as radius of curvature increases the size of the transducer should generally be decreased. Measurement on very sharp radiuses, particularly concave curves, may require specially contoured delay line transducers or non-contact immersion transducers for proper sound coupling. Delay line and immersion transducers may also be used for measurement in grooves, cavities, and similar areas with restricted access.
- **Temperature:**
- Common contact transducers can generally be used on surfaces up to approximately 125° F or 50° C. Use of most contact transducers on hotter materials can result in permanent damage due to thermal expansion effects. In such cases, delay line transducers with heat-resistant delay lines, immersion transducers, or high-temperature dual element transducers should always be used

Lithium Sulphate

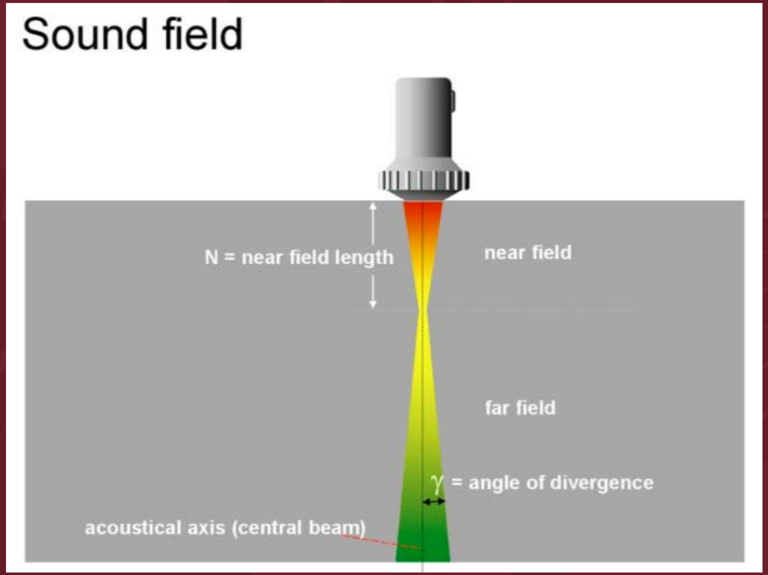
- Lithium sulphate is another piezoelectric crystal which is commonly used for the manufacture of ultrasonic transducers. Some of the advantages and limitations of a lithium sulphate transducer are as follows.
- **Advantages**
- i) It is the most efficient receiver of ultrasonic energy.
- ii) It can be easily damped because of its low acoustic impedance.
- iii) It does not age.
- iv) It is affected very little from mode conversion.
- **Limitations**
- i) It is very fragile.
- ii) It is soluble in water.
- iii) It is limited in use to temperatures below 75 C.

Polarized Ceramic Transducers

- Polarized ceramic transducers have nearly completely replaced quartz and are on their way to replacing artificially grown crystals as transducer elements. Polarized ceramic transducer materials are ferroelectric in nature
- **Advantages**
- i) They are efficient generators of ultrasonic energy.
- ii) They operate at low voltages.
- iii) Some can be used for high temperature applications e.g., lead metaniobate Curie point o 550 C.
- **Limitations**
- i) Piezoelectric property may decrease with age.
- ii) They have low resistance to wear,
- iii) They suffer from mode conversion.

The ultrasonic Beam

- The region in which ultrasonic waves are propagated from an ultrasonic transducer is known as the ultrasonic beam. Two distinct regions of the beam exist and are classified as the near field region and far field region
- **Near Field:**
- A piezoelectric transducer can be a collection of point sources, each of which is emitting spherical ultrasonic waves to the surrounding medium These spherical waves interfere with each other and result in a system of maxima and minima in intensity in the region close to the transducer. This region is known as the near field region
- **Far Field:**
- The intensity in the far field along the axial distance from the transducer beyond three near field lengths, falls off with distance in accordance with the inverse square law i.e., the intensity decreases inversely with the square of the distance. The intensity in the transition region of the far field



$$N = \frac{D^2}{4\lambda} = \frac{D^2 f}{4V}$$

Where

N = Near field length.

D = Diameter of transducer.

V = Velocity of sound in material.

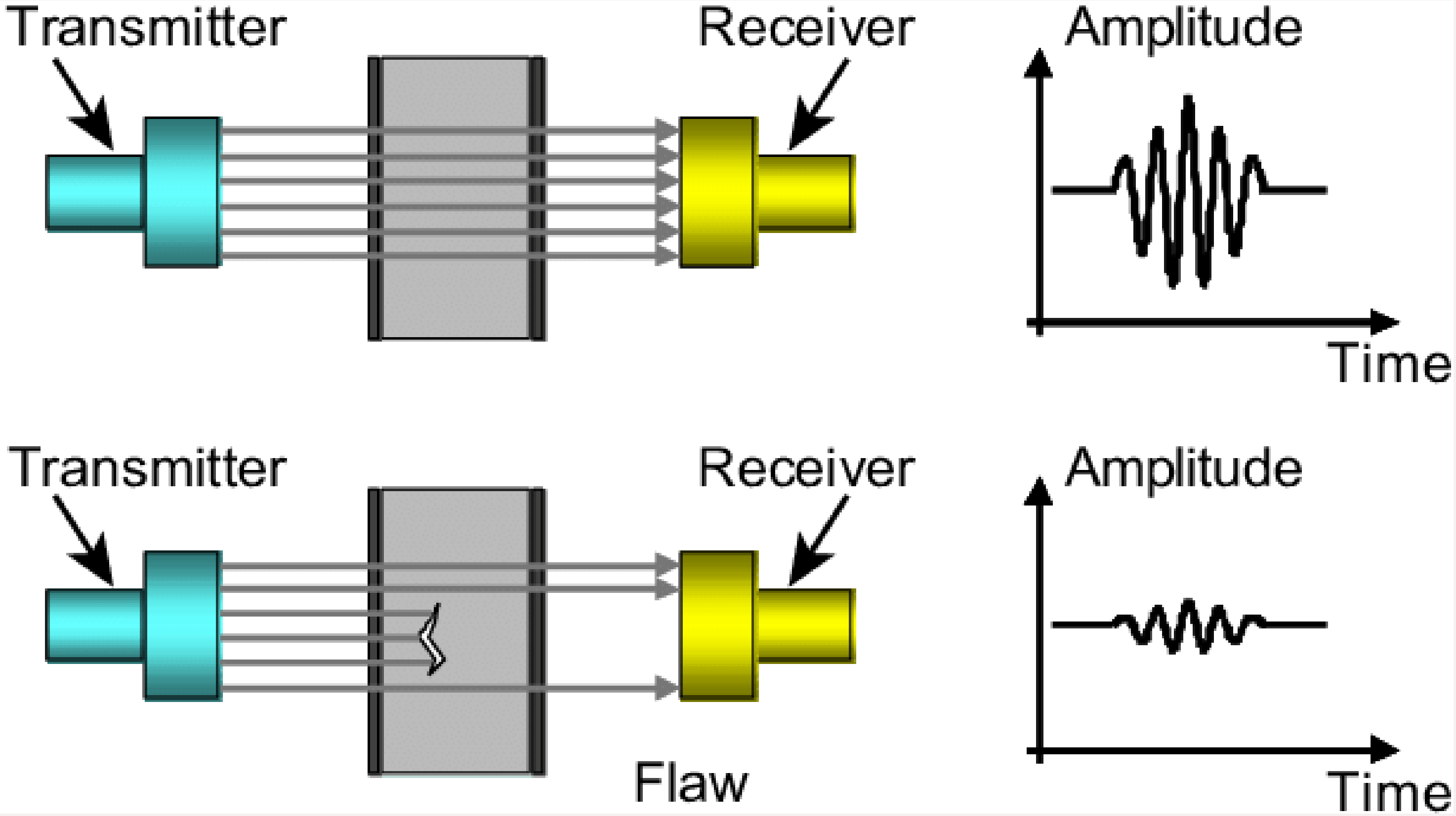
f = Frequency.

Basic ultrasonic Test Methods

- ultrasonic waves arriving at an interface between two media are partially reflected into the medium from which they are incident and partially transmitted in to the other medium. The method of ultrasonic testing which utilizes the transmitted part of the ultrasonic waves is the through transmission method while that which make use of the reflected portion of the waves is classified as the pulse echo test method. Another method which is used for the ultrasonic testing of materials is the resonance method.

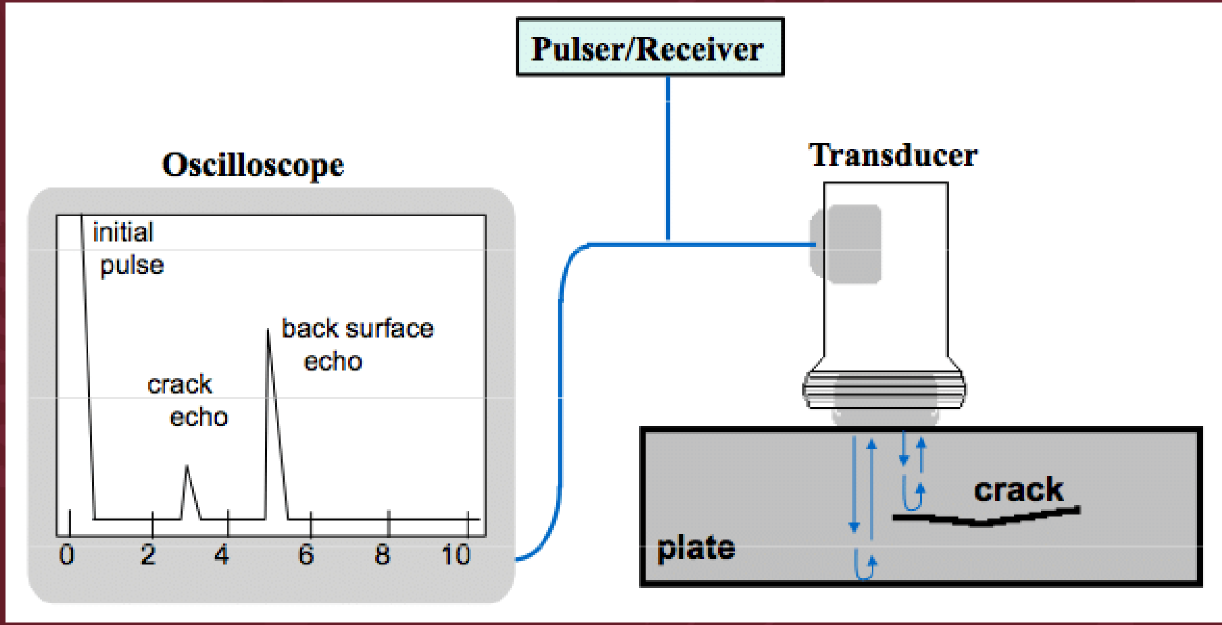
Through Transmission Method

- In this method two ultrasonic probes are used. One is the transmitter probe, and the other is the receiver probe. These probes are situated on opposite side of the specimen



Pulse Echo Method:

- This is the method most utilized in the ultrasonic testing of materials. The transmitter and receiver probes are on the same side of the specimen and the presence of a defect is indicated by the reception of an echo before that of the back wall echo. The CRT screen is calibrated to show the separation in distance between the time of arrival of a defect echo as against that of the back wall echo of the specimen, therefore, the location of a defect can be assessed accurately



Piezoelectric Transducers

- An ultrasonic probe is generally excited by a voltage pulse of less than 10 microsecond duration. A short voltage pulse consists of a band of frequencies. Among these frequencies, the transducer vibrates with maximum amplitude at the frequency known as the resonance frequency of the transducer, which is related to its thickness as follows

$$f_r = \frac{V}{2t} \qquad (3.3)$$

Where

f_r = resonance frequency of the transducer.

t = thickness of the transducer.

V = longitudinal wave velocity of ultrasound in the transducer .

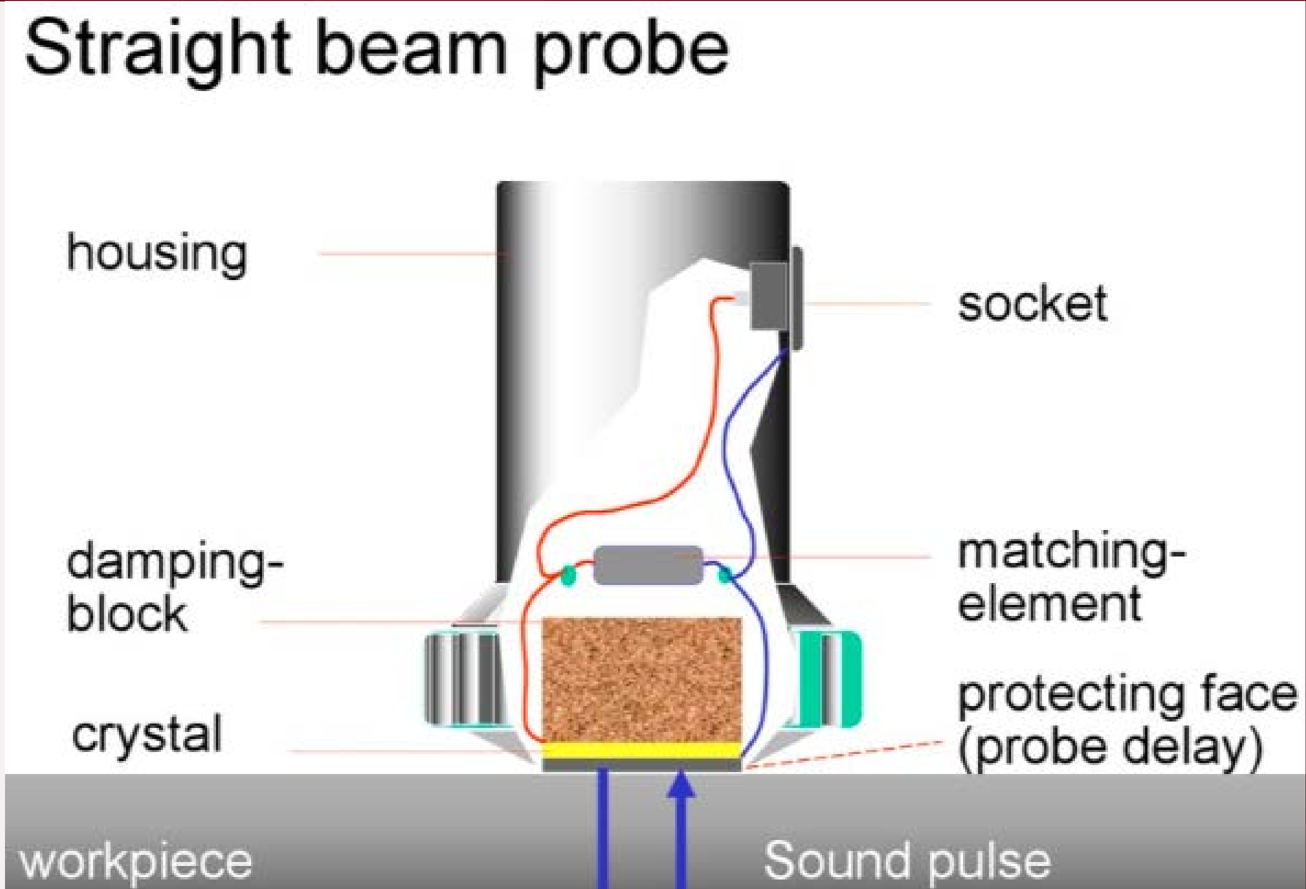
- **Backing Material**
- The backing material in a probe is used to control the two basic performance characteristics of the probe - resolution and sensitivity.
- **Resolution** of a probe is its ability to separate the echoes from two flaws which are close together in depth. **Sensitivity** of a probe is defined as the probe to detect echoes from small flaws.
- To have a **high-resolution** probe, the vibration of the transducer of the probe should be damped as quickly as possible. But to have a **high sensitivity probe**, the damping of the transducer vibration should be as low as possible

Types Of Probe:

- **Contact Type Probes:**
- Contact type probes are scanned in direct contact with the surface of the test specimen. In normal probes of this type a wear plate is often used to protect the transducer from wear. When using protected probes, a thin layer of an appropriate couplant usually light oil is always required between the transducer and the wear plate to obtain transmission of ultrasound energy across the interface. Different contact type probes
- **Normal Beam Contact Type Probes**
- probes transmit ultrasonic waves, usually longitudinal , into the test specimen in a direction perpendicular to the surface of the test specimen.

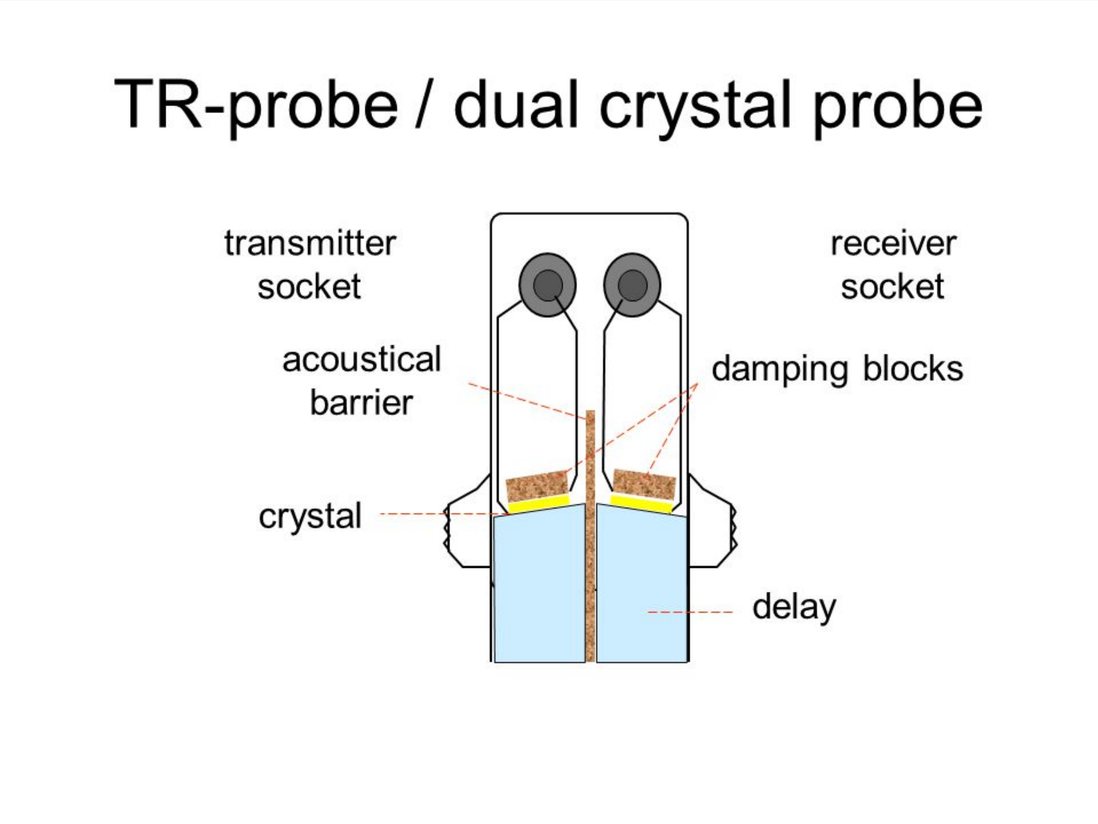
Single Transducer (Single Crystal) Normal Beam Probe

- These probes use a single transducer as a transmitter and receiver of ultrasound. This transducer has a common connection to the transmitter and amplifier units of the flaw detector. Because of this common connection to the transmitter and receiver unit, the single transducer probes have a large transmission pulse which results in a large dead zone for the probe generally making the probe useless for near surface flaw detection and thin wall thickness measurements. Short pulse length probes are now available which have shorter dead zones thus making them more useful for testing thin material.



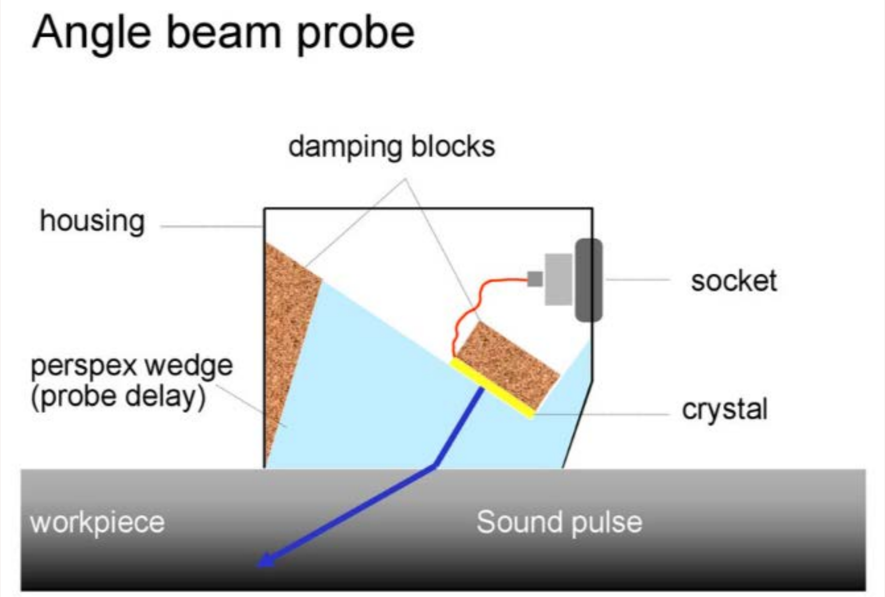
Double Transducers (Twin Crystal) Probes

- To avoid the limitations encountered in the use of single transducer normal beam probes for thin wall thickness

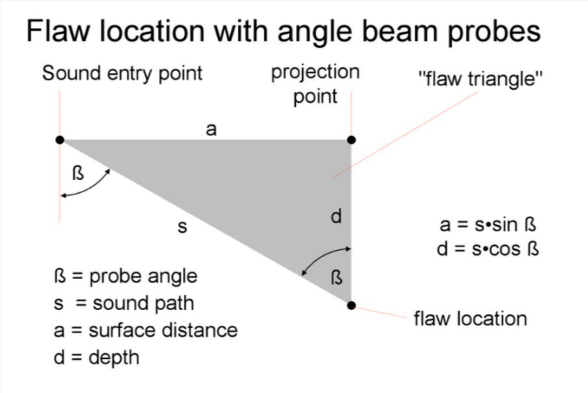


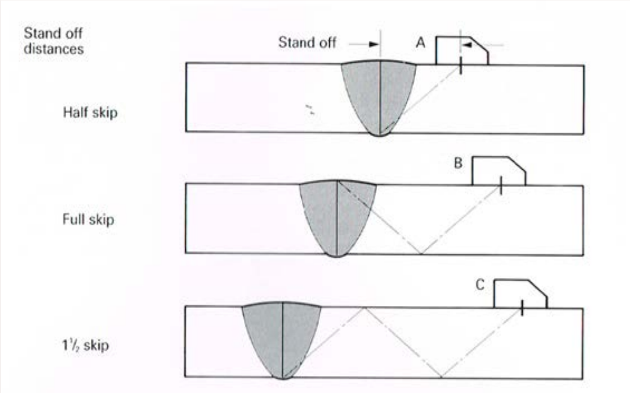
Angle Beam Contact Type Probes

- An angle probe transmits longitudinal waves through a Perspex delay block at a definite angle of incidence to the surface of the specimen. The angle of incidence chosen is greater than the first critical angle so that only transverse waves enter the specimen. The longitudinal portion is reflected back into the probe and is attenuated by the damping block and thus spurious indications that may arise due to the presence of the longitudinal waves are avoided



Angle Beam Skip Distance-(SD)



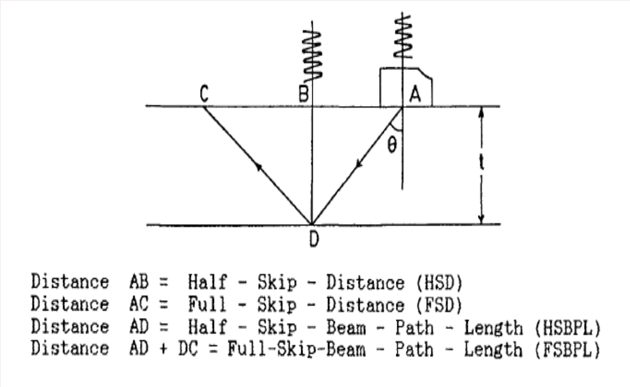


$$HSD = t \times \tan\theta \ldots\ldots\ldots\ldots$$

$$FSD = 2 \times t \times \tan\theta \ldots\ldots\ldots$$

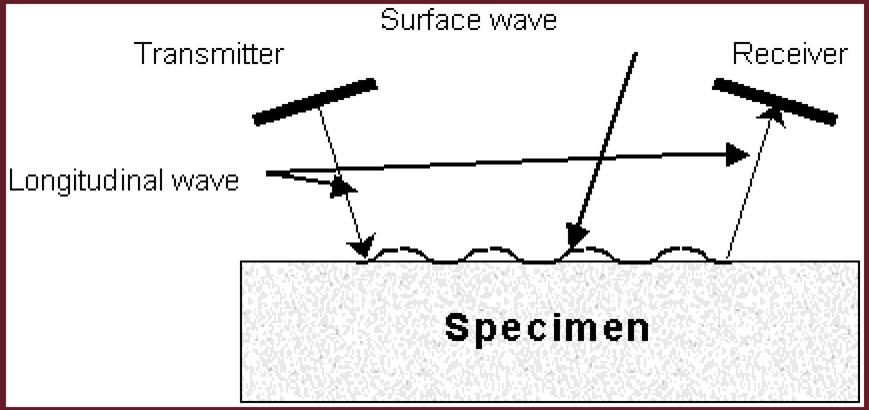
$$HSBPL = t/\cos\theta \ldots\ldots\ldots\ldots$$

$$FSBPL = 2t/\cos\theta \ldots\ldots\ldots\ldots$$



Surface Wave Techniques

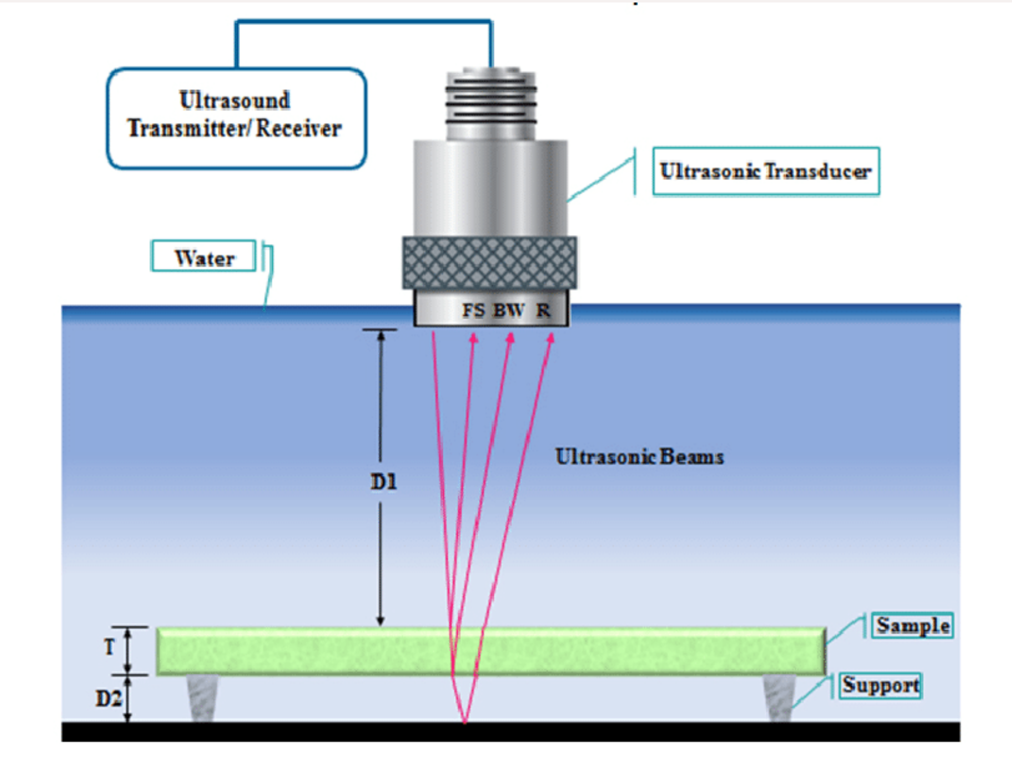
- Surface wave techniques have been used very successfully for a great number of applications, particularly in the Aircraft Industry. However, it is not so common in the steel industry because surface finishes are often less smooth, and magnetic flaw detection will find most defects detectable by surface waves. The main advantage of surface waves is that they follow gentle contours and are reflected sharply only by sudden changes in contour, thus making it a very useful tool for the examination of complex shaped components. The main limitation of these waves is that they are almost immediately attenuated if the surface finish is rough, is covered in scale or a liquid (such as the couplant), or if any pressure is applied by another object (such as the hand of the operator).



Immersion Testing Techniques

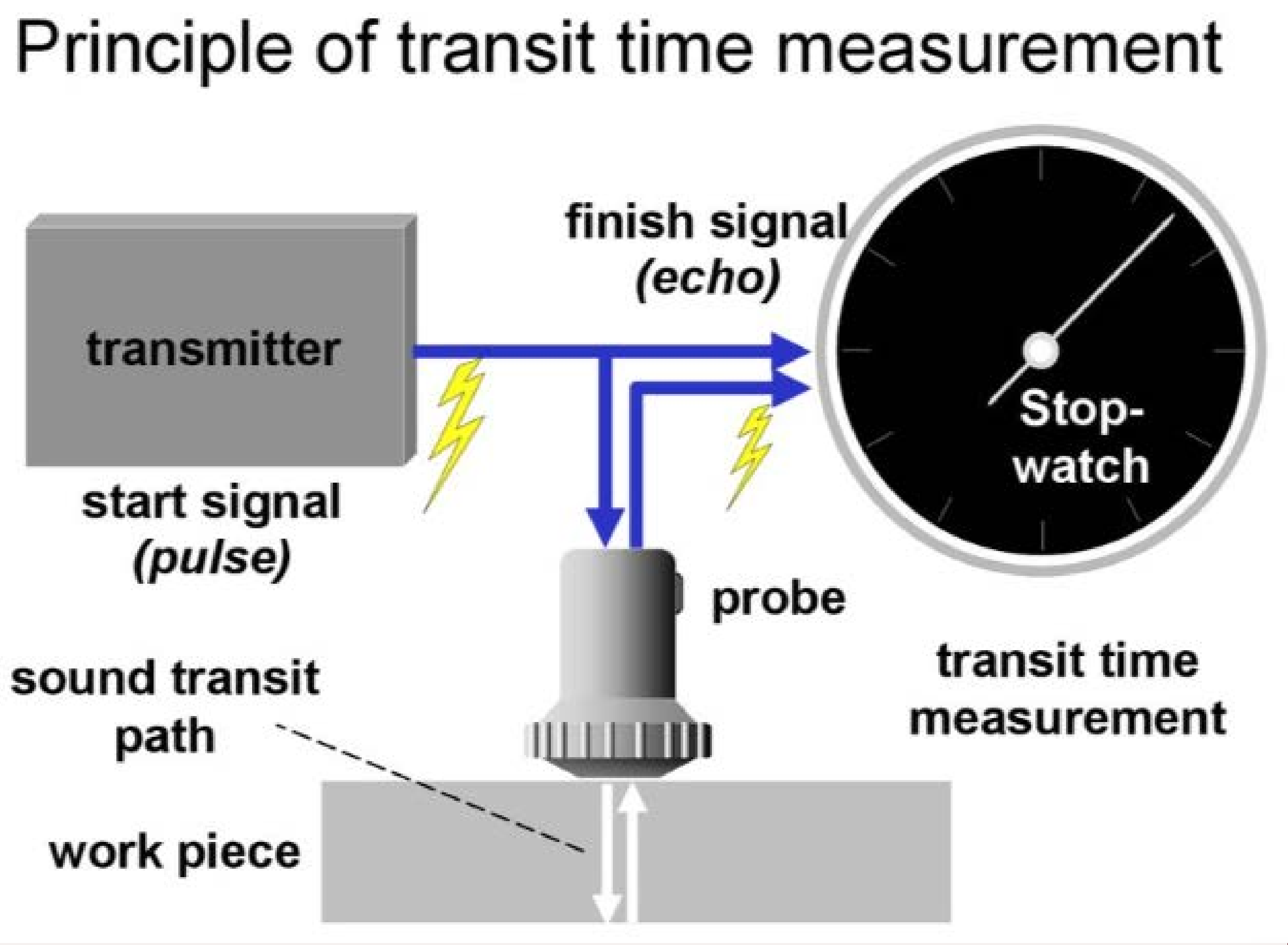
- Immersion testing techniques are mainly used in the laboratory and for large installations doing automatic ultrasonic testing. It has the advantage that uniform couplant conditions are obtained and longitudinal and transverse waves can be generated with the same probe simply by changing the incident beam angle. The three basic techniques used in immersion testing are the immersion technique, the bubbler technique and the wheel transducer technique. In the immersion technique both the probe and the test specimen are immersed in water. The ultrasonic beam is directed through the water into the test specimen, using either a normal beam technique

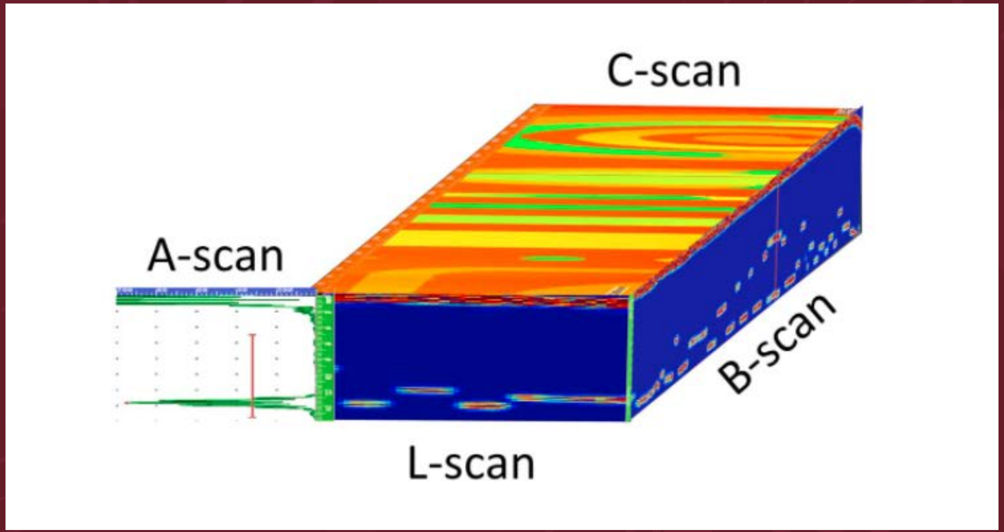
- $$S = \frac{\text{Thickness specimen} \times \text{sound velocity in water}}{\text{sound velocity in specimen}}$$



PULSE ECHO TYPE ULTRASONIC FLAW DETECTOR

- The cathode ray. tube. QE SEX (Figure 4.2) contains a heater coil H which heats the cathode C to make it emit electrons. These electrons are accelerated by a voltage applied between the cathode C and anode A . The resultant electron beam is focused by the focusing cylinder F to make it appear on the fluorescent screen S as a spot. As the electrons travel towards the CRT screen S they pass two pairs of deflecting plates X and Y . A voltage applied to the X plates deflects the electron beam horizontally while a voltage applied to the Y - plates deflects the beam vertically. The list of the CRT controls together with some of the names used by different manufacturers is given below
- i) Brightness control Brightness, Brilliance,
- intensity.
- ii) Focus control Focus.
- iii) Astigmatism Astigmatism, Auxiliary focus.





Scan Presentation

- The ultrasonic echoes are electronically translated into visual presentations on the CRT screen or other recording devices. The three basic presentation arc known as A-scan, B-scan and C-scan.
- **A-scan Presentation** **(AMPLITUDE)**
- The most used presentation is the A-scan presentation. In this presentation, the horizontal line on the screen indicates the elapsed time and the vertical deflection shows the echo amplitude. From the location and amplitude of the echo on the screen the depth of the flaw in the material and an estimate of the size of the flaw can be made
- **B-scan Presentation** **(SIDE VIEW)**
- This presentation gives a cross sectional view of the material being tested and will show the length and depth of a flaw in the test material. The B-scan presentation shows the reflection of the front and back surfaces of the test material and the flaw
- **C-scan Presentation** **(TOP VIEW)**
- C-scan equipment is designed to provide a permanent record of the test when high speed automatic scanning is used, A C- scan presentation displays the flaws in a plan view but provides no depth or orientation information.

Echo amplitude and its control

- Most pulse echo flaw detectors have an attenuator control fitted sometimes called a calibrated gain control. By turning this control one way the echo height increases and by turning the other way, the height decreases. The control is calibrated in decibel (dB) steps, usually 2dB although some flaw detectors have steps of 0.5 dB or 1 db. Because the echo height on the cathode ray tube is directly proportional to the setting on the attenuator control it is possible to compare the echo heights from two reflectors in the specimen.
- **Decibel (dB) Unit**
- The decibel unit is 1/10 of a bel which is a unit based on logarithms to the base 10. If there are two ultrasonic signals which must be compared, and they have intensities I0 and I1 then these signals will vibrate the transducer and produce electrical signals whose power will be P0 and P1 respectively .The ratio of these signals I will equal the electrical power ratio.

i.e. $$\frac{I_o}{I_1} = \frac{P_o}{P_1}$$

Since $P \propto V^2$

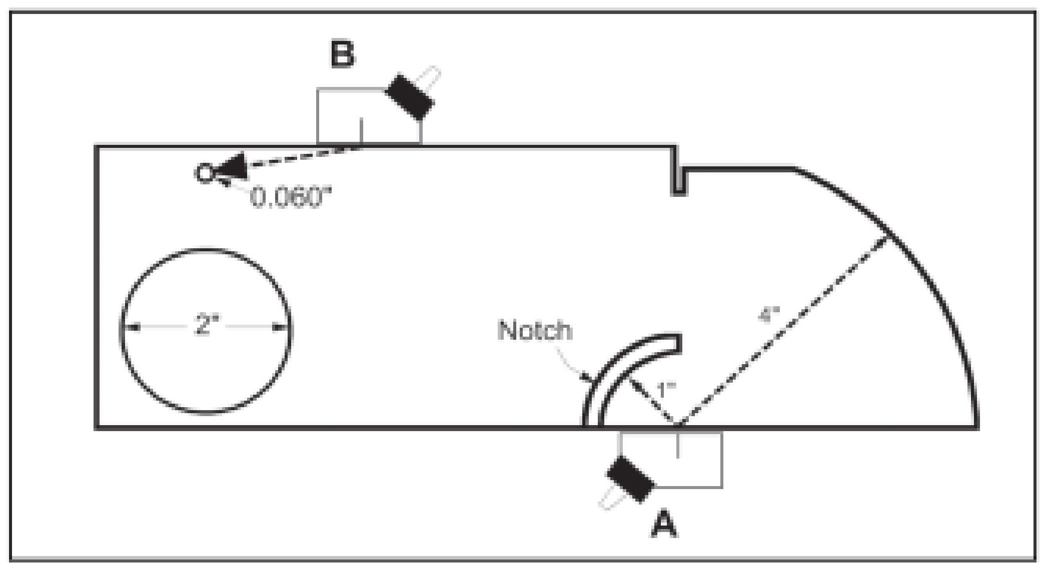
$$\frac{I_o}{I_1} = \frac{P_o}{P_1} = \frac{V_o^{2}}{V_1}$$

Calibration And Reference Test Blocks

- In ultrasonic pulse echo testing test blocks containing notches, slots or drilled holes are used to :
- (i) determine the operating characteristics of the flaw detector and probes.
- (ii) establish reproducible test conditions.
- (iii) compare the height or location of the echo from a flaw in the test specimen to that from an artificial flaw in the test block.
- The blocks used for the first two purposes are termed calibration blocks, while test blocks used for the third purpose, are known as reference blocks. The same test block may be used as a calibration or reference block. Test blocks whose dimensions have been established and sanctioned by any of the various groups concerned with material testing standards are called standard test blocks.

Commonly Used Cal Block:

- **I.I.W (VI) Calibration Block**
- The most versatile calibration block is the block described by the International Institute of Welding (I.I.W.) and proposed by the International Standard Organization (I.S.O.). This block, called the I.I.W
- This block is generally used for :
- (i) the calibration of the time base.
- (ii) the determination of probe index.
- (iii) the determination of probe angle.
- (vi) the checking of performance characteristics (time base linearity, resolution, dead zone etc.) of the ultrasonic flaw detector.



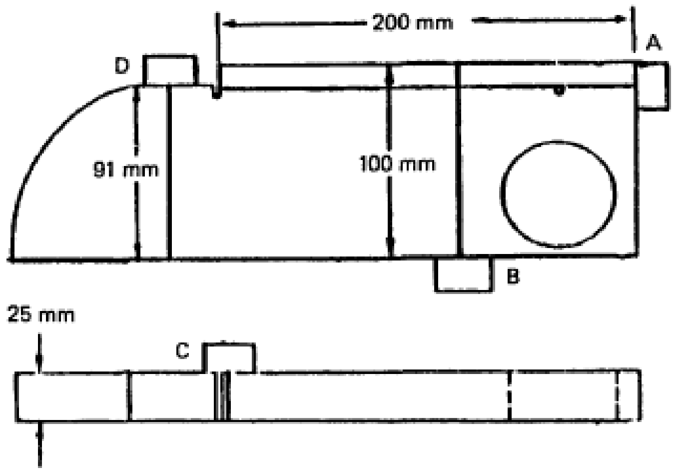
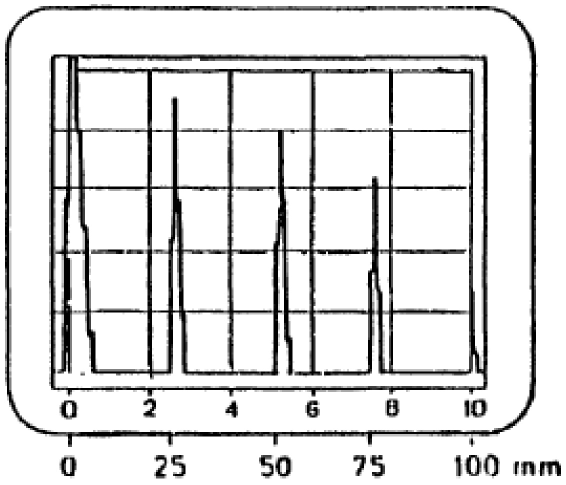


Figure 5.2



Calibration Of Time Base

- **(a) With normal beam probes**
- For calibration of the time base with a normal beam probe for a range of up to 250 mm, the probe is placed at position C (Figure 5.2) and multiple back wall echoes are obtained and adjusted to the appropriate scale division of the CRT screen using the delay and fine material, testing range controls. Figure 5.3 show the CRT screen display for a 100 mm calibrated CRT screen. The points where the rising back wall echoes leave the base line have beam adjusted to the appropriate scale divisions to give the time base calibrations.
- For time base calibration of more than 250 mm with normal beam probe, the probe is placed at position A or B (Figure 5.2) and multiple back wall echoes are obtained and adjusted to the appropriate scale divisions. Figure 5.4 shows the CRT screen display for a one-meter range.
- Multiple back wall echoes are used for time base calibration because the distance between the transmission pulse and the first back wall echo is somewhat larger than the distance between two consecutive multiple echoes. This zero error is caused by the ultrasound travelling in the transducer, probe protective layer (if any) and the layer of the couplant before entering the specimen.

(b) With angle beam probes

- For a range of 200 ram or more the most direct method is to get multiple back wall echoes from the 100 mm quadrant by placing the probe at position E (Figure 5.5 a). A CRT screen display for a range of 200 mm is shown in Figure 5.5b

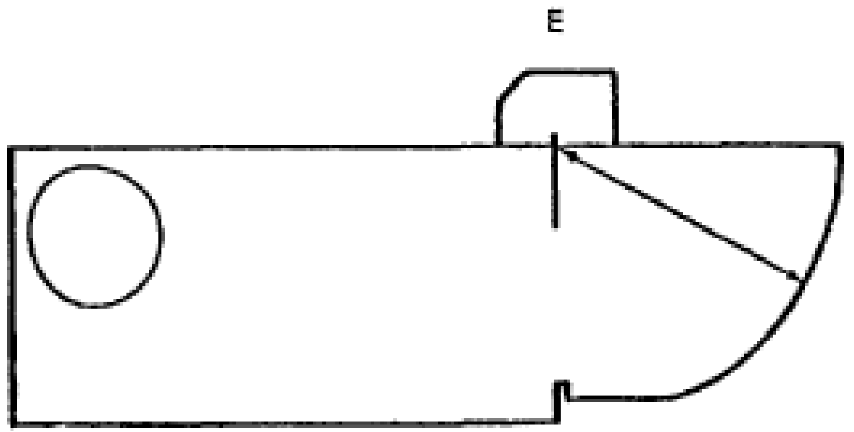
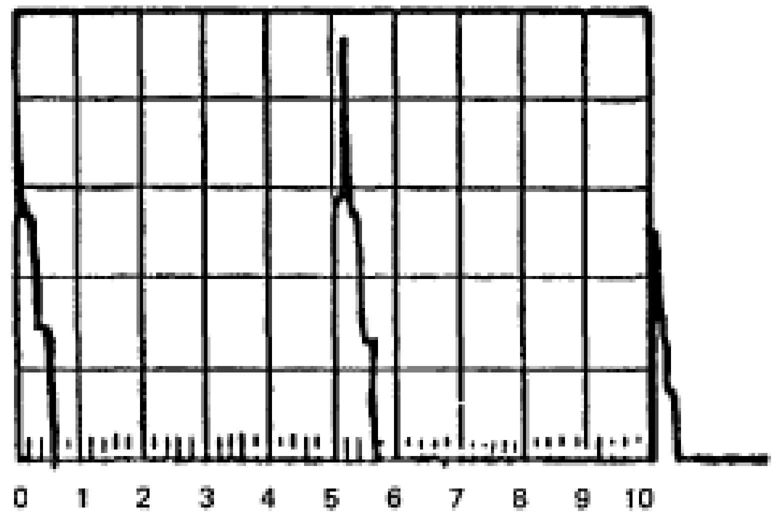
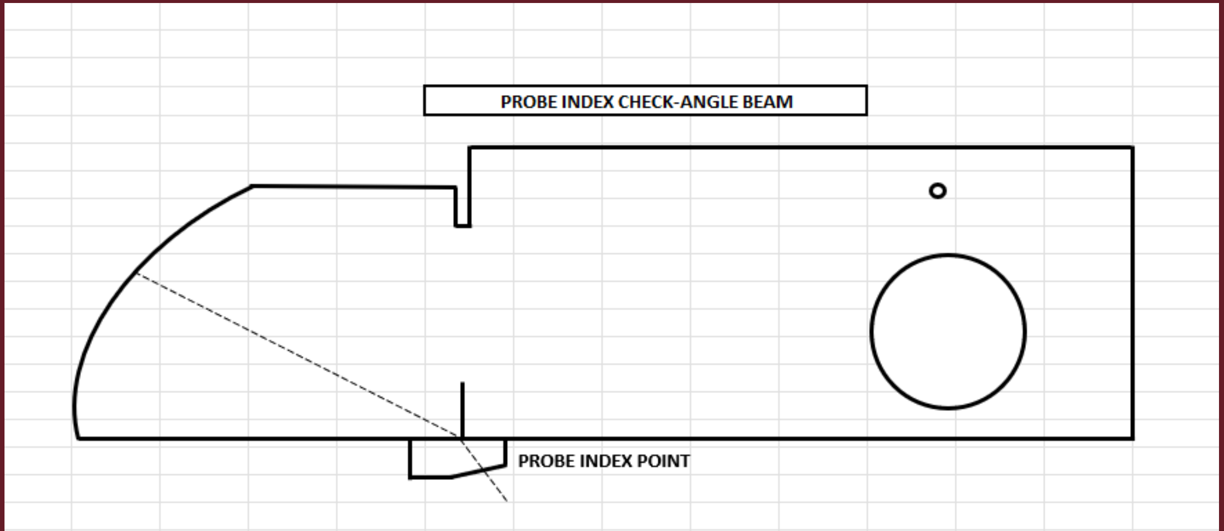


Figure 5.5 a.



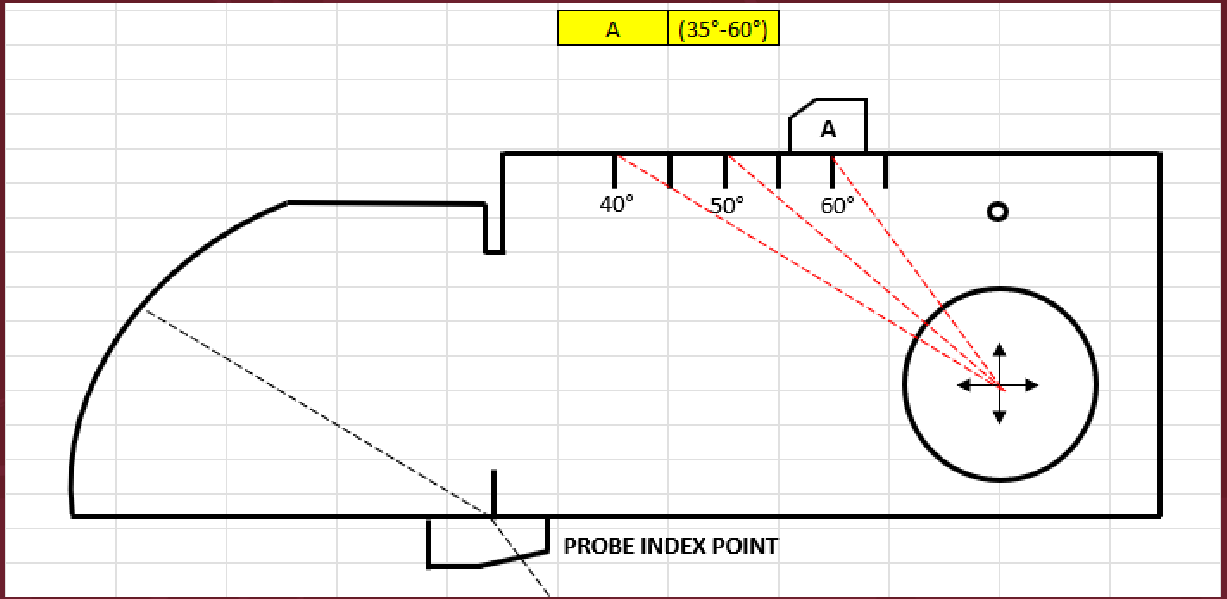
Determination of the probe index

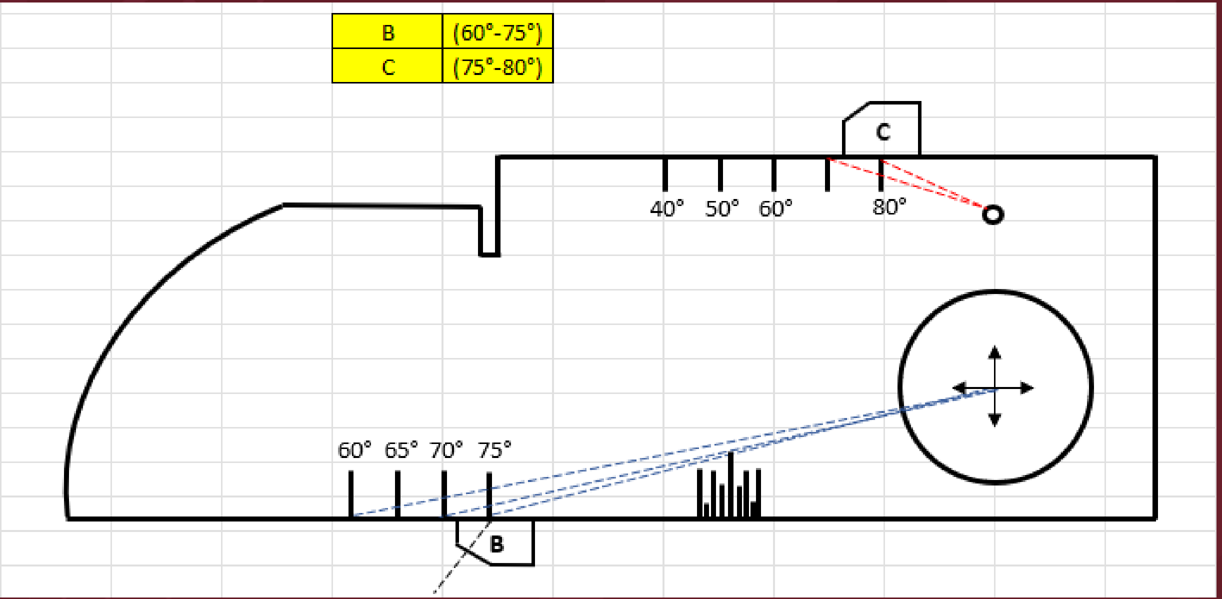
- The probe is placed at position L on the calibration block(Figure 5,8) and a back wall echo from the 100 mm quadrant is obtained. The maximum amplitude of this back wall echo is determined by moving the probe to and froth about the position L. When the maximum amplitude is found then the point on the probe which corresponds to the point 0 on the block is the probe index.

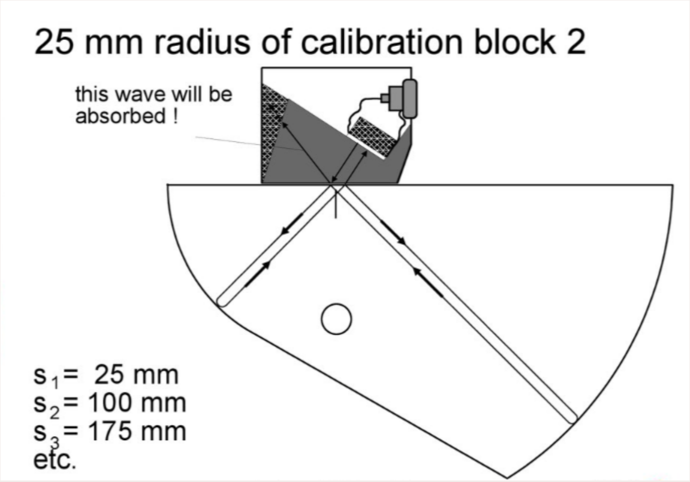


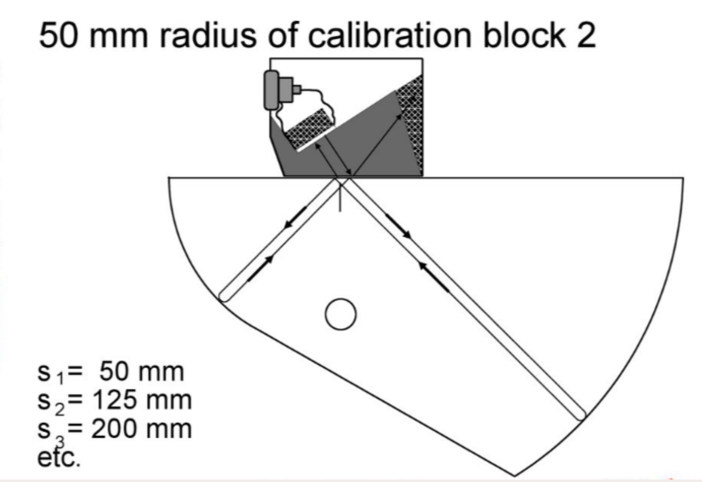
Determination of the probe index

- To determine the probe angle, the probe is moved too and FRO according its angle either at position
- A-(35°to 60°), B-(60 to 75°) or C- (75° to 80°) until the amplitude of the echo from the Perspex insert or 1.5 mm diameter hole is maximum. The angle of the probe is the one at which the index of the probe meets the angle scale on the block when the echo amplitude is maximum.





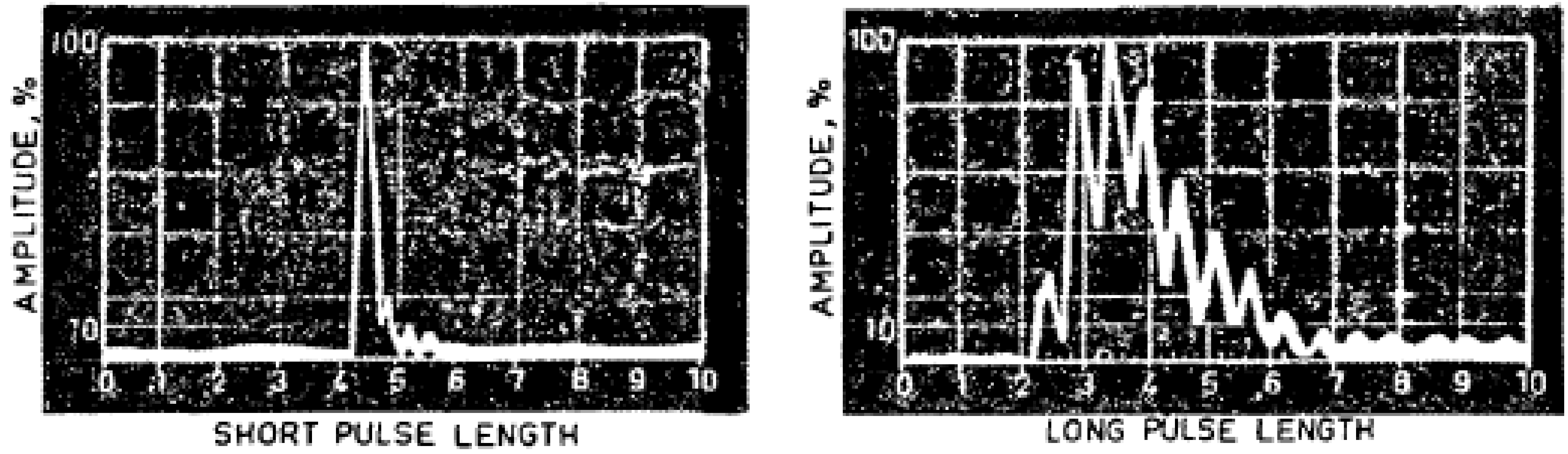




V2 BLOCK

- to calibrate the sweep of the flaw detector by the ultrasonic wave velocity for the straight beam piezoelectric transducers
- to calibrate the sweep of the flaw detector by the ultrasonic wave velocity for the angle beam piezoelectric transducers
- to set a conditional level of sensitivity of the UT flaw detectors with the straight and angle beam transducers
- to determine the probe index and X-value of the angle beam transducers
- to determine the UT wave entry angle in steel.

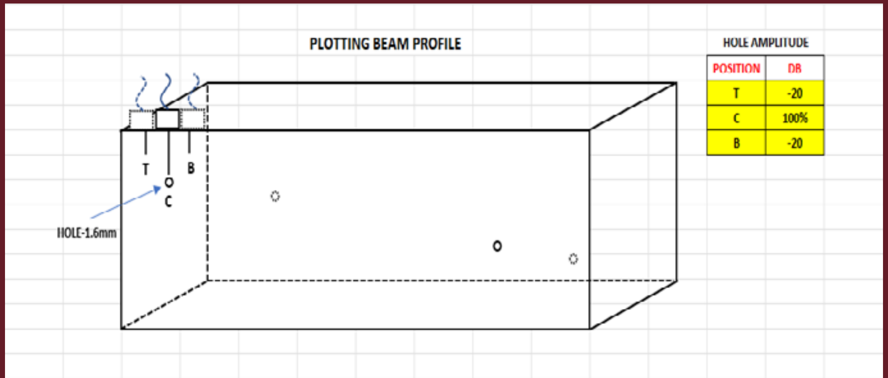
Determining the pulse length

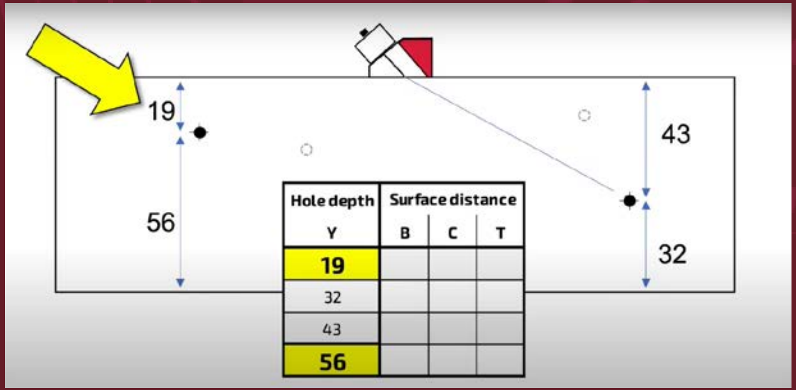


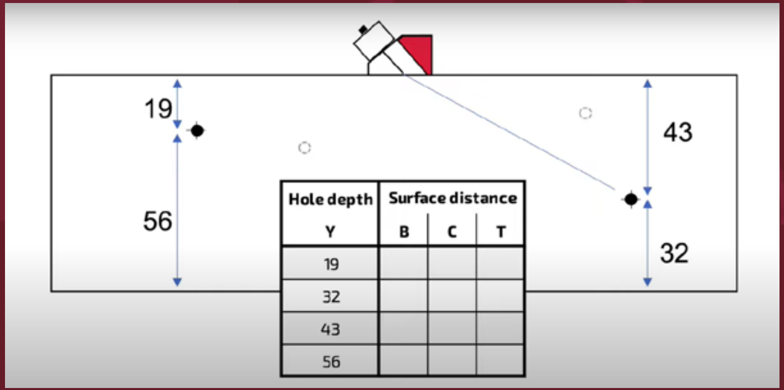
TYPICAL RECTIFIED DISPLAY

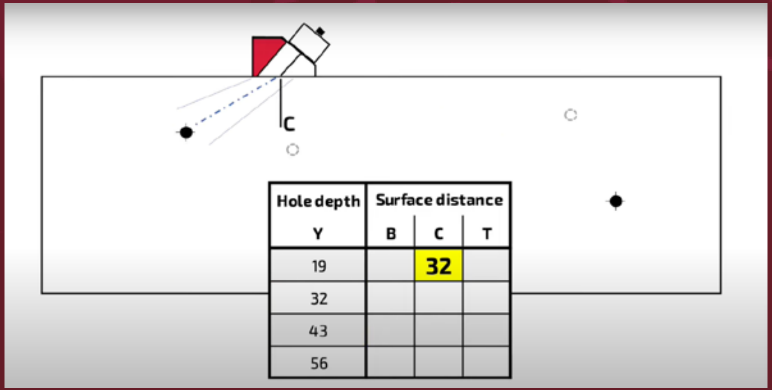
Plotting of Beam Profile

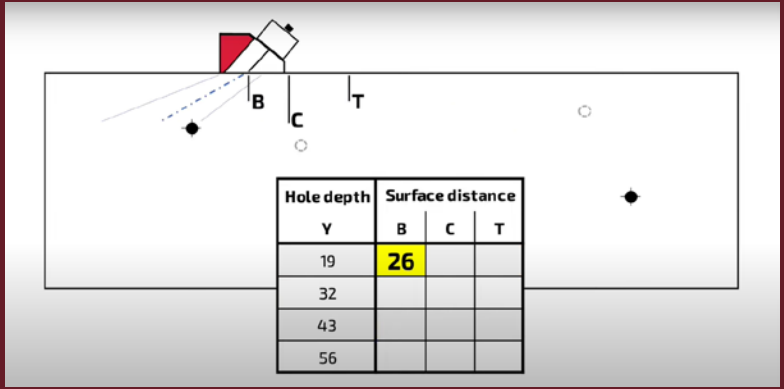
- The 1.5 mm target holes are sighted in succession from surfaces t , c & b of the 1OW block. For each case, the position of the probe index corresponding to the maximum echo amplitude is marked on the block (C). The probe is then moved to and fro so that the target is swept by the beam, the extremes of displacement being reached when the position of the probe index corresponds to a decrease of 20 dB, or 10 % of the original height of the echo, from the maximum echo amplitude. These positions are marked as b and T with mark a representing the position of the probe for maximum amplitude. With the probe in its forward position at position b the bottom edge of the beam strikes the target hole while in the backward position T the top edge of the beam strikes the target hole.
- **The beam profile is then plotted as follows**
- Draw the probe angle with the probe index as its starting point. At the appropriate hole depth plot the reading C & b (forward position) behind the beam axis while the reading C & T (backward position) is plotted in front of the beam axis. Repeat the procedure for holes at other depths and join the points.

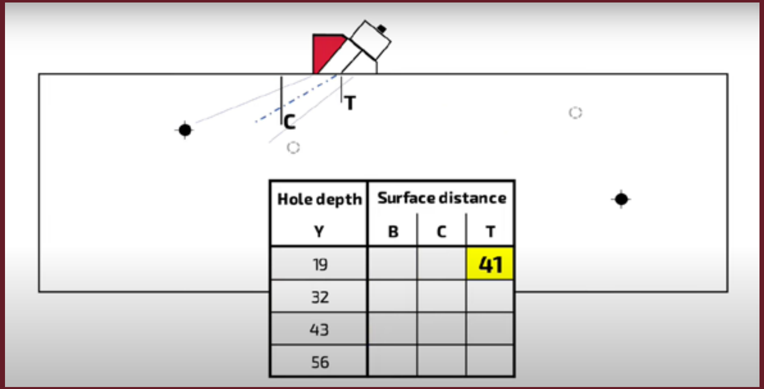


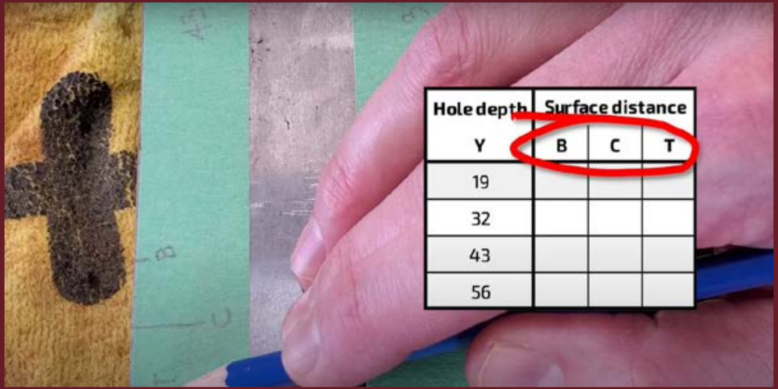

19
56
43
32
Hole depth
Surface distance
Y
B C T
19
32
43
56

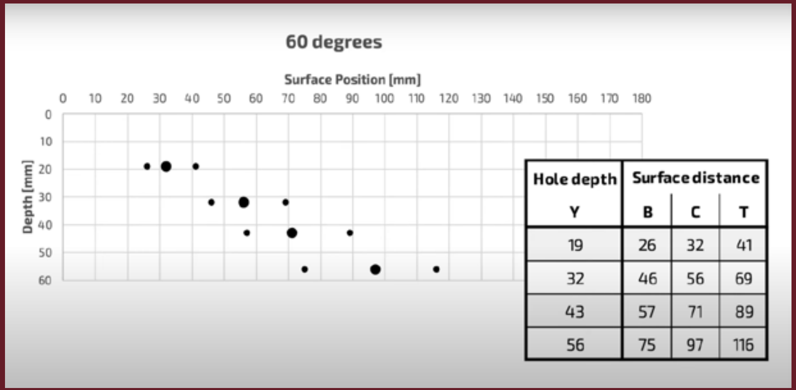

19
56
43
32
Hole depth
Surface distance
Y
B C T
19
32
43
56

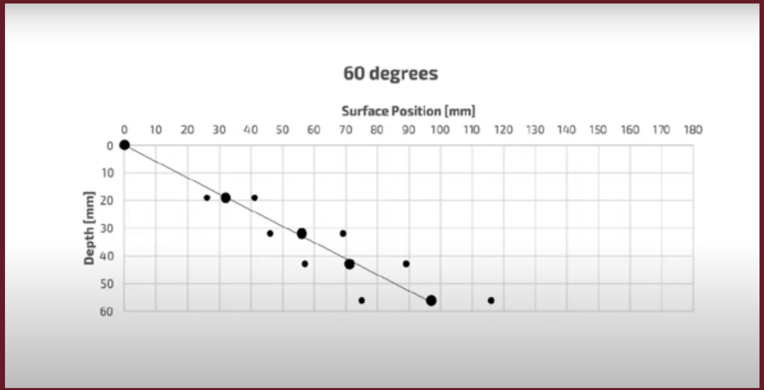

C
Hole depth
Surface distance
Y
B C T
19 32
32
43
56

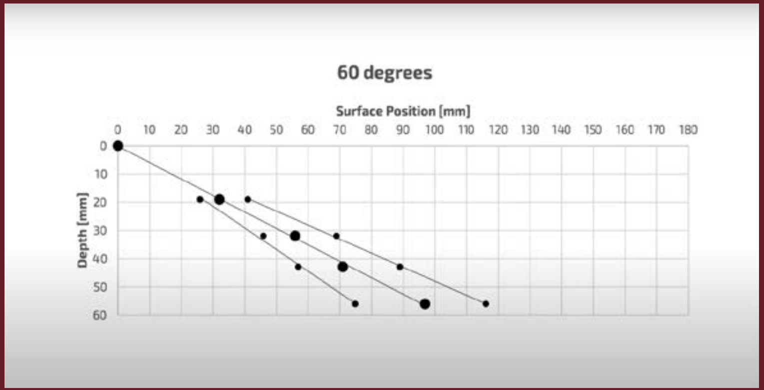

B
C
T
Hole depth
Surface distance
Y
B C T
19 26
32
43
56

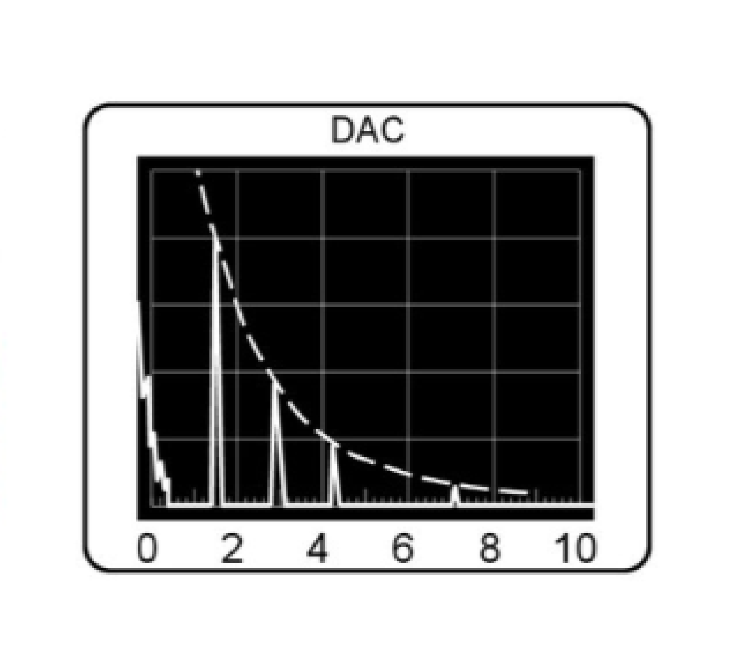

C
T
Hole depth
Surface distance
Y
B C T
19 41
32
43
56

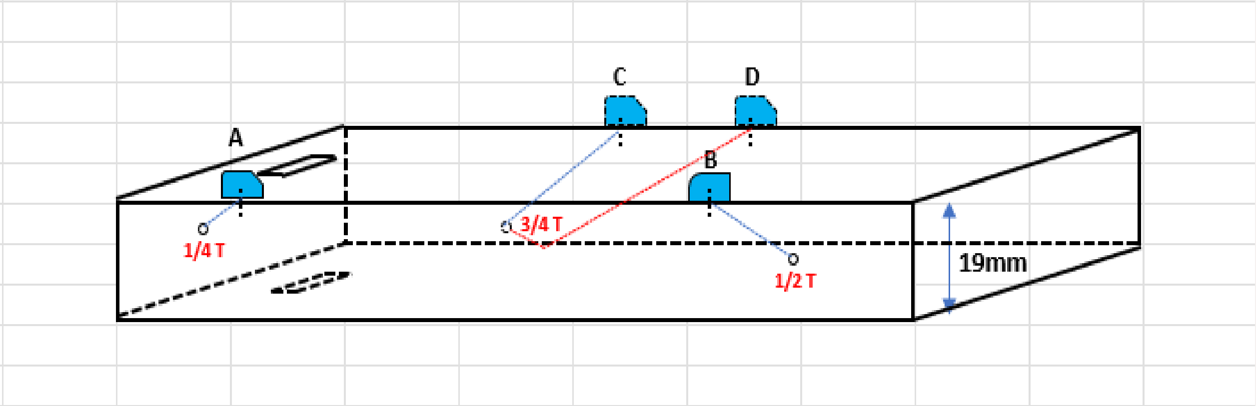

Hole depth
Surface distance
Y
B C T
19
32
43
56


60 degrees
Surface Position [mm]
Depth [mm]
Hole depth
Surface distance
Y
B C T
19 26 32 41
32 46 56 69
43 57 71 89
56 75 97 116


60 degrees
Surface Position [mm]
Depth [mm]


60 degrees
Surface Position [mm]
Depth [mm]

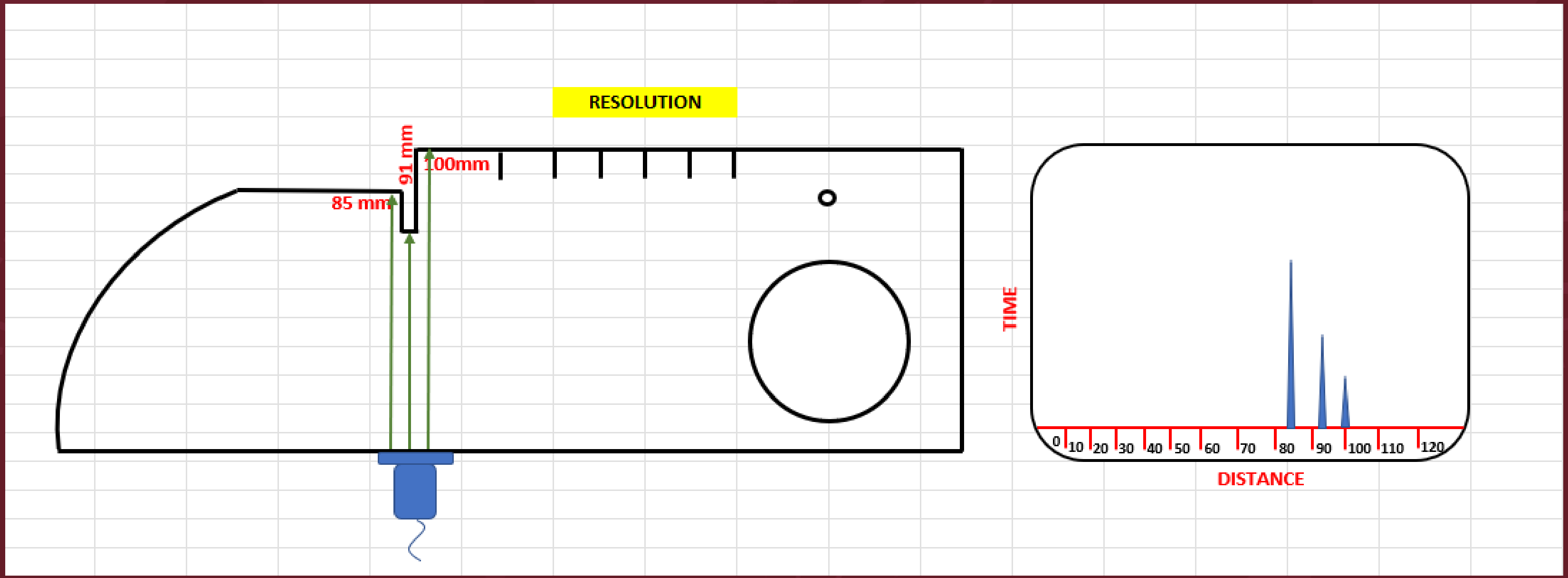




DAC (Distance Amplitude Curve)

- **DAC** – **D**istance **A**mplitude **C**urve – is a method of compensating for the fact that the pulse-echo response of a reflector will decrease as the distance of the reflector from the ultrasonic probe increases. This occurs because the transmitted ultrasonic beam spreads out as it travels from the probe to the reflector and so the further the reflector is from the probe the lower the energy of the sound that hits the reflector. Similarly, the further the reflected pulse must travel the lower the energy that is received back at the probe.

  The DAC is generated by plotting the amplitude of a known calibration reflector at different distances from the probe. Generally, the gain of the flaw detector is set so that the amplitude of the nearest reference reflector (the one at the shallowest depth) is at 80% FSH (see last month for description of FSH). The amplitudes of the same calibration reflector at further depths are then plotted on the flaw detector screen whilst the gain setting is maintained constant. The DAC is generated by plotting a curve through these amplitudes

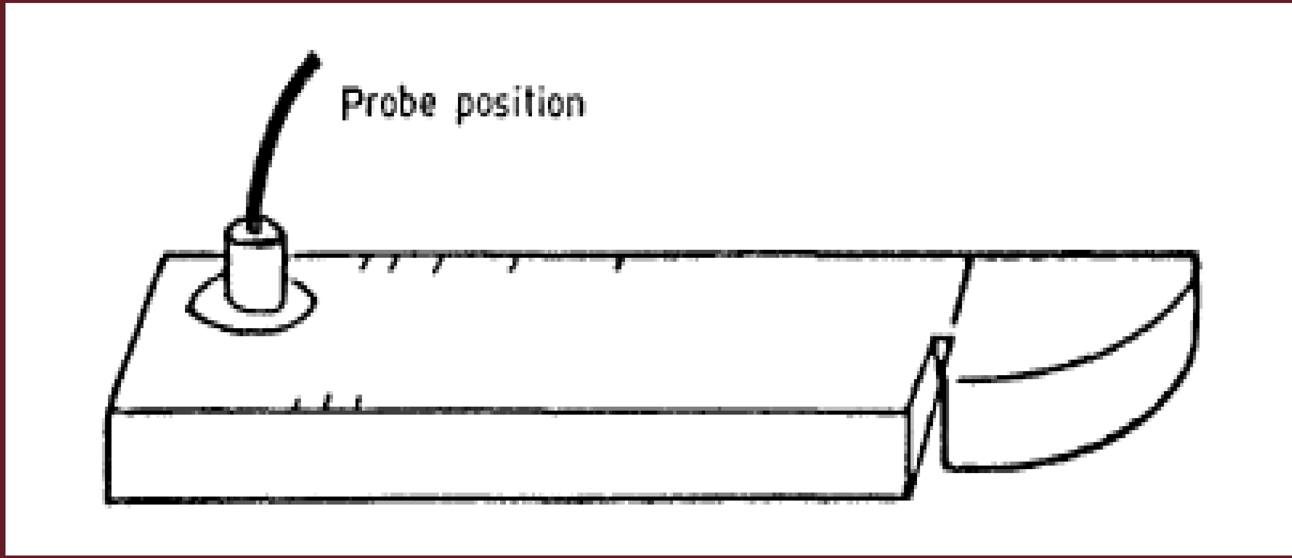


Resolution of the Flaw Detector

- The I.I.W. VI block is used to determine the resolution of a flaw detector using a normal beam probe. This block has three target reflectors at ranges of 85 mm, 91 mm and 100mm.a and echoes from the three reflectors are obtained. The separation of the echoes from each other indicates the degree of resolution of the flaw detector for that probe. Shows the degree of resolution for flaw detectors using two different normal beam probes.

Maximum Penetrative Power

- **The check is carried out as follows :**
- A longitudinal wave probe is placed on the Plastic insert of the I.I.W. block (Figure) and the gain of the instrument is set to its maximum. The number of multiple echoes and the amplitude of the last echo are noted and are used to express the maximum penetrative power of the set and the probe.



METHODS OF SETTING SENSITIVITY

- An ultrasonic flaw detector must be set at a minimum level of sensitivity since this is the only means whereby echoes of otherwise uncertain significance can be translated into meaningful information. In principle the choice of a sensitivity level is based on the reflectivity of the smallest flaw that is to be found at the maximum test range.
- Two sensitivities are used during an inspection the evaluation sensitivity and the scanning sensitivity.
- **Evaluation sensitivity (or reference sensitivity)**
- These are the instrument settings which produce a reproducible signal amplitude from a reference artificial reflector with which the instrument settings relating to a discontinuity echo can be compared. The evaluation sensitivity can also be called the Primary Reference Echo (PRE) level
- **Scanning Sensitivity**
- This sensitivity is used during the preliminary scanning of a test piece to locate all discontinuity echoes which have to be assessed at the evaluation sensitivity. It is set by increasing the amplification of the instrument from the evaluation sensitivity instrument settings by a specified amount e.g., 6dB. The commonly used methods of setting- evaluation sensitivity are :
- i. The Distance Amplitude Correction (DAC) method which is used for instance in the ASME code in which echo heights from similar size artificial reflectors in a reference block are plotted on the CRT screen to compensate for attenuation of the signals with increasing distance from the probe.
- ii. The echo height from a flaw is compared to a disc type reflector in the form of a flat-bottomed hole. This method was developed by Krautkrarner and is called the DGS method (D - distance, G - gain, S - size)
- iii. The grain response on the time base at the maximum testing range.
- iv. The echo height from a 1.5 mm drilled hole in a reference block (such as the I.O.W beam profile block).120

MEASUREMENT OF ATTENUATION

- **Longitudinal Wave Attenuation**
- The procedure for measurement of attenuation for longitudinal waves is based on the fact that the amplitude of reflection from an infinite reflector (i.e., back wall of the specimen) is inversely proportional to distance if the back wall is situated at a distance equal to or greater than 3 near field lengths from the probe. The procedure for measuring the attenuation of longitudinal waves in a specimen is as follows :
- i. Determine the near field length N of the probe
- N=(d2/4ƛ)
- D = diameter of probe crystal and ^ is the wavelength of the longitudinal waves).
- ii. Find three near fields. Place the probe on the specimen and obtain a number of back wall echoes on a calibrated CRT screen.
- iv. Choose two consecutive back wall echoes which lie beyond the 3 near field lengths.
- v. Adjust the gain control of the flaw detector to bring the height of the first back wall echo, selected into a predetermined mark on the CRT screen, say,2/5 th full screen height and note the reading of gain control. Let it be A db.
- vi. Now bring the height of the second selected back wall echo to 2/5 th screen height and note through reading of the gain control. Let it be B db.
- vii. Find the difference C = { B - A) dB,
- viii. Subtract 6 dB from the difference found in
- (vii) i.e. (C - 6) db.
- ix. Divide (C - 6) dB by twice the thickness of the specimen i.e. (C - 6) dB / 2T mm (where T is the thickness of the specimen). This gives the required attenuation per mm of path travelled in the specimen by the longitudinal waves.

Transverse Wave Attenuation

- Select two identical angle beam probes - one to be used as a transmitter and the other as a receiver of ultrasonic waves.
- ii. Calculate the skip - distance and half-skip-beam path-length.
- iii. Calibrate the time base for sufficient range for at least one full-skip-beam-path-length.
- iv. Use a guide to align the transmitter and the receiver probes.
- v. Position the probes at one-skip-distance apart(Positions T and Rl
- vi. Adjust the gain-control to bring the received echo to half screen height. Note the gain-control reading. Let it be AI db.
- vii. Move the receiver to two skip distances (Position R2).
- viii. Bring the height of the received echo to half screen height and note the gain-control reading. Let it be A2 db.
- ix. Calculate the difference (A2 - AI) db.
- x, Calculate the attenuation in dB/mm from
- Attenuation - $\dfrac{(a2\text{-}a1)}{\text{Half-skip-beam-path-1ength}}$ DB/mm

COUPLANTS

- In ultrasonic testing a couplant in the form of a liquid or paste is used to eliminate air between the probe and the specimen surface. If there is air between the probe and the specimen no transmission of ultrasonic waves into the specimen will take place because of the very low acoustic impedance of air as compared to the acoustic impedances of the specimen and the probe. Commonly used couplant in ultrasonic testing are glycerin, water, oils, petroleum greases, silicone grease, wallpaper paste and various commercial paste like substances. For the selection of a suitable couplant for a particular
- **ultrasonic inspection task the following points should be taken into consideration :**

i .Surface finish of the test specimen,

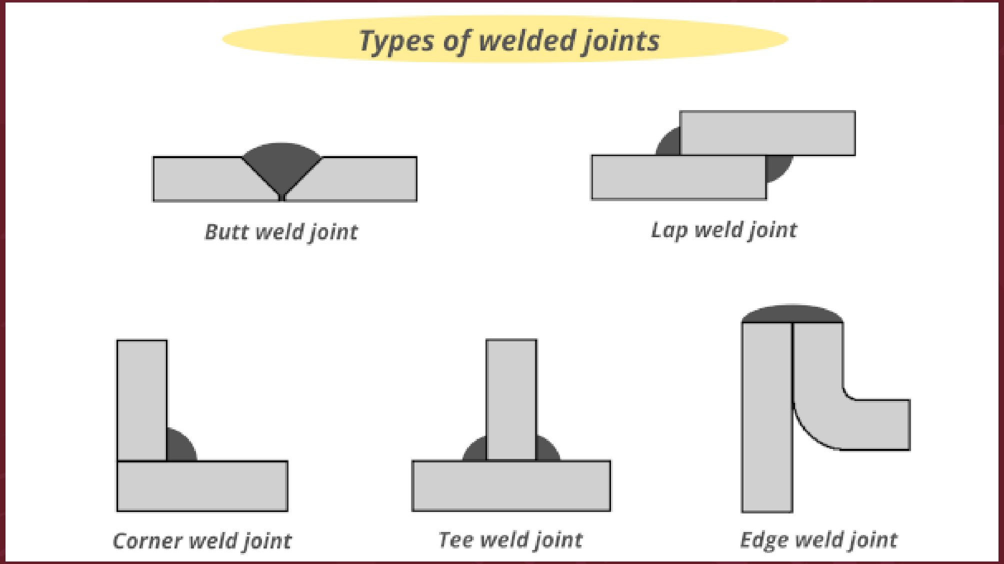
ii. Temperature of the test specimen.

iii.Possiblity of chemical reactions between the test specimen and the couplant.

iv. Cleaning requirement - some couplant are difficult to remove.

INFLUENCE OF THE TEST SPECIMEN ON THE ULTRASONIC BEAM

- 1.**Surface Roughness**
- Loss of sensitivity because of scattering due to refraction at the top surface and due to reflection at the rear surface (i.e., back wall). This is a maximum when the roughness of the surface is equal to or greater than the wavelength of the ultrasonic waves used for inspection. Loss of near surface resolution of the inspection system by lengthening in the transmission pulse. This lengthening is caused by the reflection of the side probe energy back into the probe by the roughness of the surface. The side lobe energy is not normally reflected into the probe.
- i.   By smoothing the surface.
- ii. By increasing the gain of the amplifier.
- iii. By using a probe with a lower frequency.
- iv. By using a probe with high ultrasonic output.



Types of Weld Joints

- In the welding process, two pieces of metal are joined together. Molten "filler" metal from a welding rod blends with molten parent metal at the prepared fusion faces and fuses the two pieces together as the weld cools and solidifies. Most welds fall in to one of the following categories :
- i. Butt weld,
- ii. T-weld .
- iii. Nozzle weld.

Weld Defects

- **LACK OF FUSION:**
- 1.Lack of side wall fusion
- 2.lack of root fusion
- 3.lack of inter run fusion
- **INCLUSION:**
- 1.slag inclusion
- 2.tungsten inclusion

OTHER DEFECT:

1.POROSITY

2.CRACK

3.UNDERCUT

4.EXCESS PENETRATION

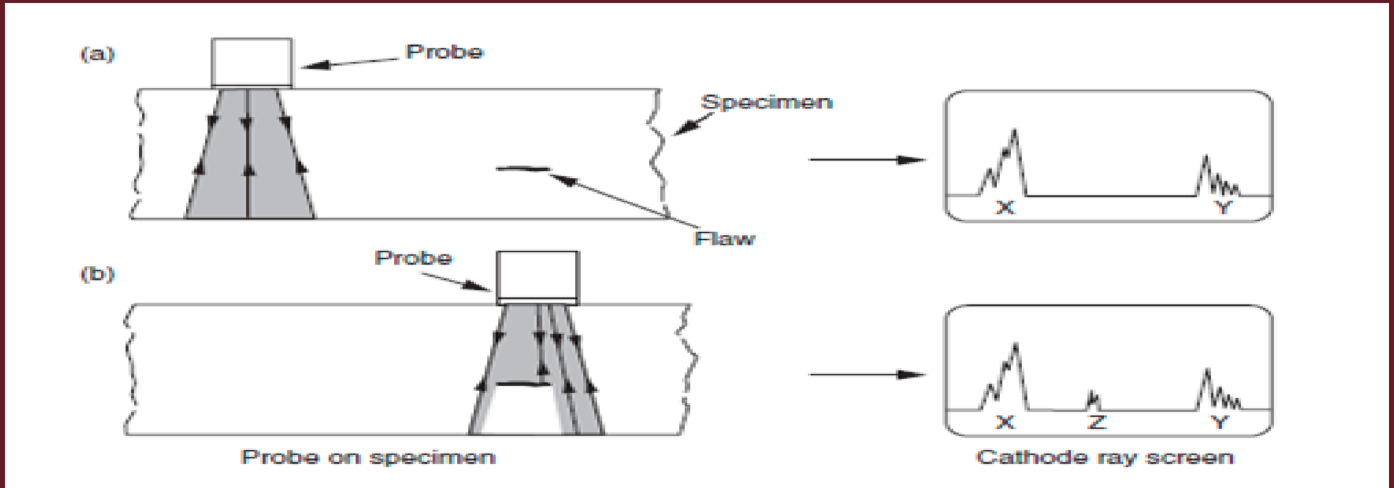
5.LAMINAR TEARING

6.Concavity at the Root of the Weld

Material Defects

- **0 Deg:**

Probes that project the beam into the test piece at an angle normal (90degs) to the plate surface are known as compression probes and are ideally suited to the detection of defects such as plate laminations or for the measurement of plate/pipe thickness

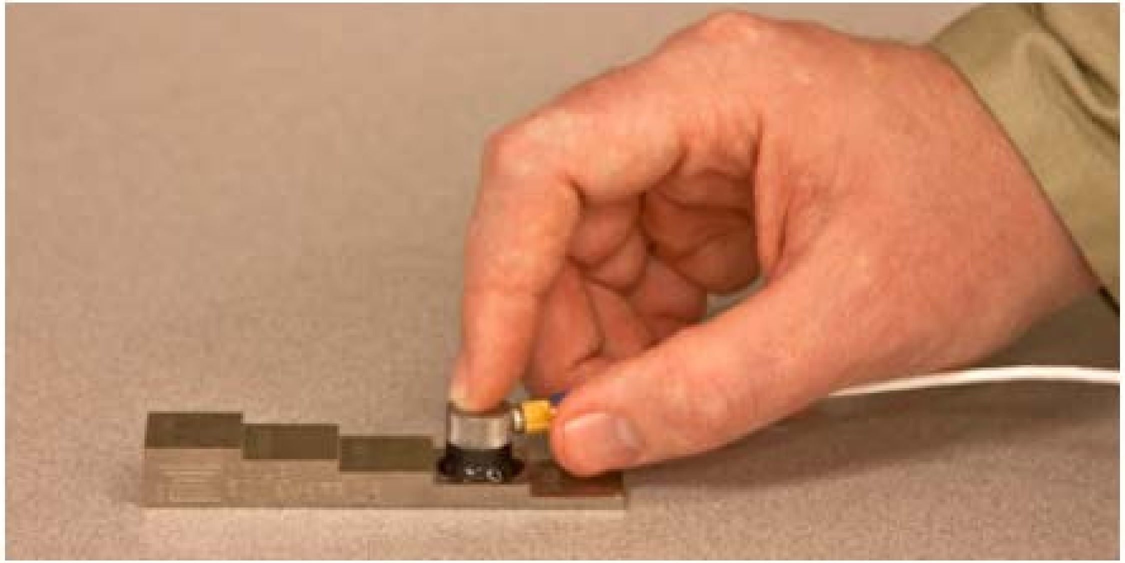


Benefits Of Thickness Gauging:

- **Measurement from one side:** Ultrasonic gauges require access to only one side of pipes, tanks, tubing, containers, hollow castings, large metal or plastic sheets, and other test pieces where the inside surface is impossible or difficult to reach.
- • **Completely nondestructive:** No cutting or sectioning of parts is required, saving scrap and labor costs.
- • **Highly reliable:** Modern digital ultrasonic gauges are highly accurate, repeatable, and reliable.
- • **Versatile:** All common engineering materials can be measured with appropriate gauge setups, including metals, plastics, composites, fiberglass, ceramics, and rubber. Most instruments can be pre-programmed with multiple application setups.
- • **Wide measurement range:** Ultrasonic gauges are available for measurement ranges as broad as 0.08 mm (0.003 in.) minimum to 635 mm (25 in.) maximum, depending on material and transducer selection. Resolution can be as fine as 0.001 mm or 0.0001 in.
- • **Easy to use:** Most ultrasonic gauging applications use straightforward pre-programmed gauge setups and require only a small amount of operator interaction. While this tutorial discusses a number of advanced techniques and challenging measurements, advanced training in ultrasonics is not required in most cases.
- • **Instant response:** Measurements usually take only one or two seconds per point and are displayed as a digital readout.

Zero and Velocity Calibration

- (1) Couple the transducer to the thick reference sample.
  (2) Using the keypad, enter the "calibrate velocity" command.
  (3) When the thickness reading is stable, press ENTER.
  (4) Using the keypad, adjust the displayed value to correspond to the actual thickness of the thick reference sample.
  (5) Couple the transducer to the thin reference sample.
  (6) Using the keypad, enter the "calibrate zero" command.
  (7) When the thickness reading is stable, press ENTER.
  (8) Using the keypad, adjust the displayed value to correspond to the actual thickness of the thin reference sample.
  (9) Press the MEASURE key to complete the process.



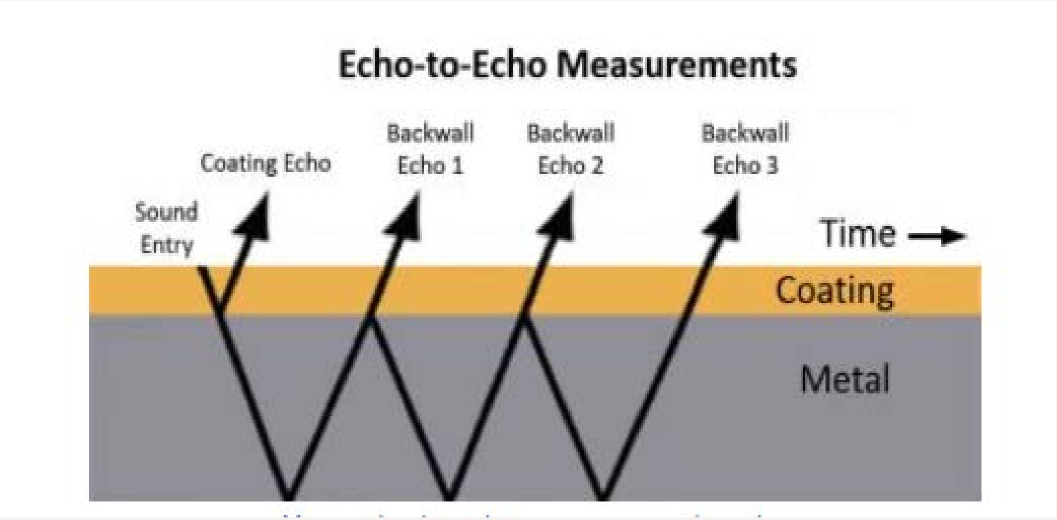
Precision Ultrasonic Gauging for Measuring Coatings

- Coating thickness has a significant effect on product quality, process control, and cost control. Two factors help ensure a coating performs its intended function: the quality of the paint and the thickness of the coating. Accurately measuring a coating can guarantee that requirements are met across a range of industries. Ultrasonic gauges are nondestructive and can accurately take thickness measurements of coatings that require access of only one side of a material’s surface.
- Ultrasonic Coating Thickness Measurement Techniques
- Two techniques to measure the thickness of coated pipes and parts are **echo-to-echo** and **THRU-COAT™** measurement. Each technique has strengths and weaknesses:

1.Echo-to-Echo Measurement

The echo-to-echo measurement technique, available on the 38DL PLUS™ and 45MG (optional) thickness gauges, enables you to measure the remaining wall thickness of pipes or other metal structures while removing the coating from the measurement. This technique times the interval between two successive back wall echoes to provide an accurate representation of the metal material's thickness without the coating (as multiple back wall echoes can exist in metal but not commonly in coatings).

- **The advantages of using the echo-to-echo technique include:**
- Works with a variety of common transducers
- Often works through rough-surfaced coatings
- Can be performed at high temperatures up to approximately 500 °C (930 °F) with the appropriate transducers
- The limitations of the echo-to-echo technique include:
- Requires multiple back wall echoes, which might not exist in severely corroded metals
- Thickness range is sometimes more limited than with a THRU-COAT measurement



THRU-COAT Measurement:

- The **THRU-COAT** measurement technique enables separate measurement of thin nonmetallic coatings like paint over metal and the metal thickness. This technique uses patented software to identify the time interval represented by one round trip in the coating. By subtracting this time interval from the total measurement, the metal substrate's thickness can be calculated. THRU-COAT measurement may not work properly if the coating's thickness is below 0.125 mm (0.005 in.) or if the external coated surface is rough or irregular. For more details on THRU-COAT measurement, see our guide on thickness gauge
- **The advantages of using THRU-COAT technology over the echo-to-echo technique include:**
- Works over a wide range of metal thicknesses, typically from 1 mm (0.04 in.) to greater than 50 mm (2 in.) in steel
- Requires only one back wall echo
- May measure minimum remaining metal thickness more accurately when there is pitting in the metal
- Some of the disadvantages of using THRU-COAT technology are:
- Coating must be nonmetallic and at least 0.125 mm (0.005 in.) thick
- Coating surface must be relatively smooth
- Requires you to use one of two special transducers
- Can only be used on surfaces with a maximum temperature of 50 °C (125 °F)

What Metals Can Be Measured Using Ultrasonic Gauges?

- **Pipes and tanks:** There is corrosion measurement involving metal pipes and tanks, but precision thickness measurement during the manufacturing process is also possible.
- **Sheets and coils:** Metal sheet and coil stock can normally be measured to very high accuracy at any point where the operator has access to one side of the material. Ultrasonic gauging is especially useful for wide products that are difficult to measure with mechanical gauges except at the edges.
- **Automotive sheet metal:** The complex shape and large size of many automotive sheet metal fabrications can make mechanical measurement challenging, but ultrasonic gauging can be performed at any point where there is access to one side, including reduction rate measurement at bends.
- **Small-diameter tubing:** Wall thickness and concentricity of precision metal tubing as small as 2 mm or 0.080 in. in diameter can be measured using focused transducers.
- **Gun drilling:** Drill drift during gun drilling operations can result in holes whose position varies with depth. An ultrasonic gauge can locate and measure the depth of holes from the outside surface at any point along the length of a part.
- **Castings:** Wall thickness of hollow ferrous and nonferrous castings can be measured ultrasonically, even those with complex shapes like engine blocks. Ultrasonic gauges can also be used to check nodularity in cast iron.
- **Turbine blades:** The wall thickness of hollow turbine blades for aircraft engines and similar critical applications can be measured with small focused transducers, both to detect core shift during manufacturing and to gauge wear in service.
- **Machined parts:** During machining operations, sometimes inspectors need to check the wall thickness of parts to ensure that they are within specification. Ultrasonic gauges are helpful tools for this application when the inside surface of the part is difficult or impossible to reach.

Testing On Corrosion:

- Why Is It Important to Inspect Metals for Corrosion?
- Structural steel beams, particularly bridge supports and steel pilings, are also subject to corrosion that reduces the original thickness of the metal. If undetected over time, corrosion will weaken walls and can cause dangerous structural failures. Both safety and economic considerations require that metal pipes, tanks, or structures that are susceptible to corrosion are inspected regularly. Ultrasonic thickness gauges enable you to accurately detect potential internal corrosion without damaging the metal and while accessing one side of the surface.
- How Do Ultrasonic Thickness Gauges Detect Corrosion?
- All gauges designed for corrosion applications will measure the round-trip transit time interval to the first back wall echo. Advanced instruments can also measure the interval between successive multiple echoes. They use signal processing techniques that are optimized for detecting the minimum remaining thickness in a rough, corroded test piece. This allows these gauges to calculate the specific thickness of corrosion, without being affected by the metal or its coating.
- The irregular surfaces that are frequently encountered in corrosion applications give dual element transducers an advantage over single element transducers. Dual element transducers incorporate separate transmitting and receiving elements, mounted on delay lines that are usually cut at an angle to the horizontal plane (the roof angle), so that the transmitting and receiving beam paths cross beneath the surface of the test piece. This crossed-beam design of duals provides a pseudo-focusing effect that optimizes the measurement of minimum wall thickness in corrosion applications.
- Duals will be more sensitive than single element transducers to echoes from the base of pits that represent the minimum remaining wall thickness. Also, duals are often more effective on rough outside surfaces. Couplant trapped in pockets on rough sound entry surfaces can produce long, ringing surface echoes that interfere with the thin material resolution of single element transducers. With a dual, the receiver element is unlikely to pick up this false echo. Finally, most duals can make high-temperature measurements that would damage single element contact transducers.

0 Degree Typical A-SCAN