Ultrasonic Testing
Module 4

Introduction

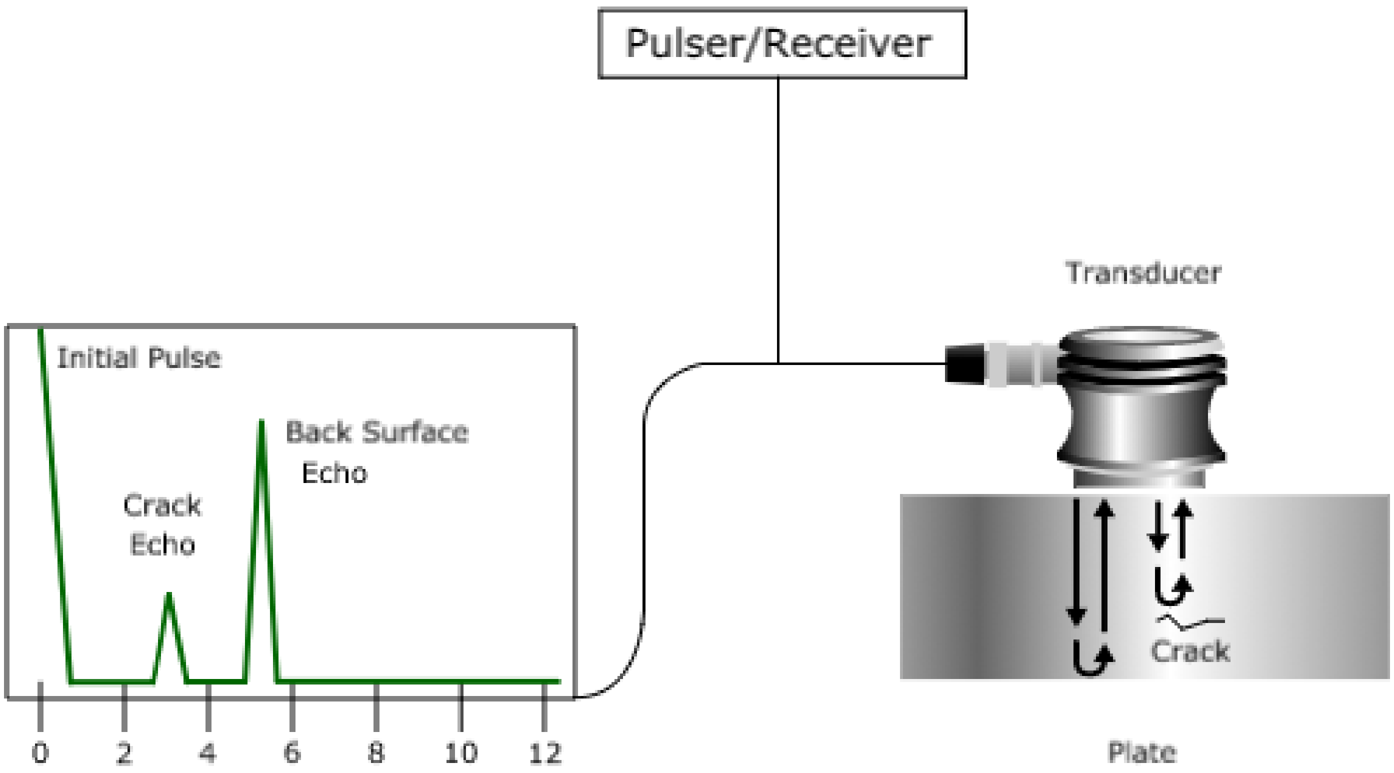
✓Ultrasonic techniques are very widely used for the detection of internal defects in materials, but they can also be used for the detection of small surface cracks.

✓Ultrasonic non-destructive testing, also known as ultrasonic NDT or simply UT, is a method of characterizing the thickness or internal structure of a test piece through the use of high frequency sound waves.

- ✓ Ultrasonic's are used for the quality control inspection of part processed material, such as roiled slabs, as well as for the inspection of finished component. The techniques are also in regular use for the in-service testing of parts and assemblies.
- ✓ Sound is propagated through solid media in severa1 ways and the nature of sound will be considered first.

✓The frequencies, or pitch, used for ultrasonic testing are many times higher than the limit of human hearing, most commonly in the range from 500 KHz to 20 MHz.

Principle of Operation



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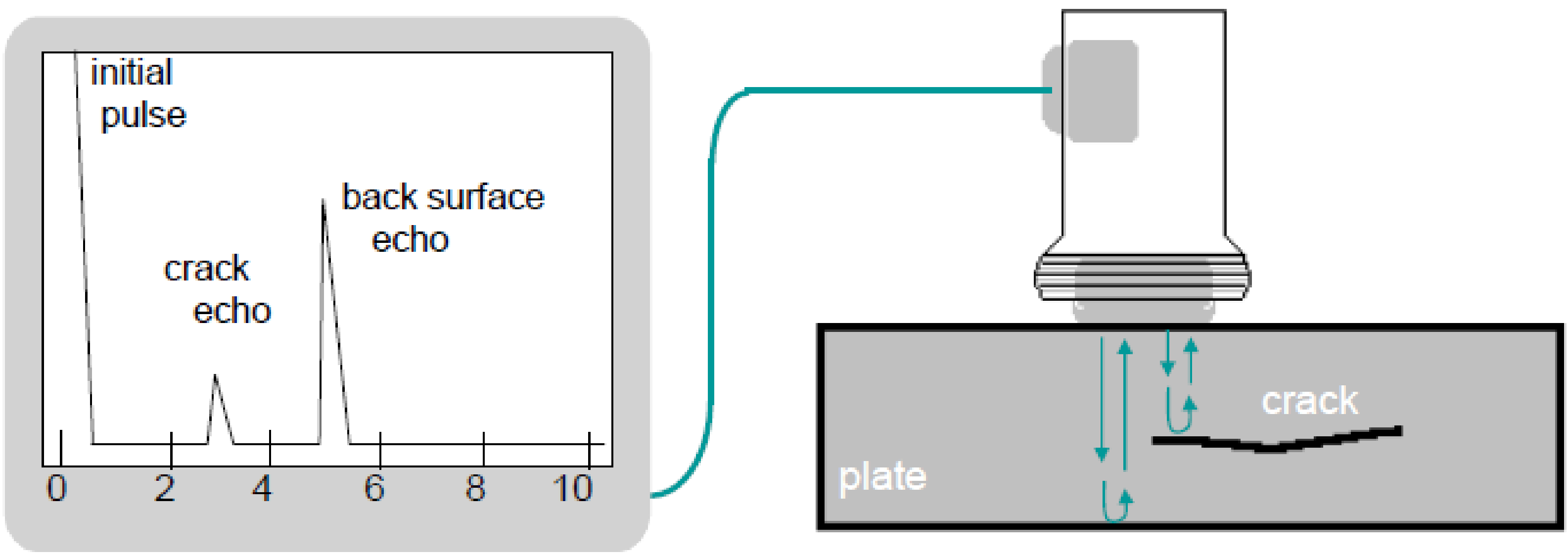
Ultrasonic Inspection (Pulse-Echo)

High frequency sound waves are introduced into a material and they are reflected back from surfaces or flaws.

Reflected sound energy is displayed versus time, and inspector can visualize a cross section of the specimen showing the depth of features that reflect sound.

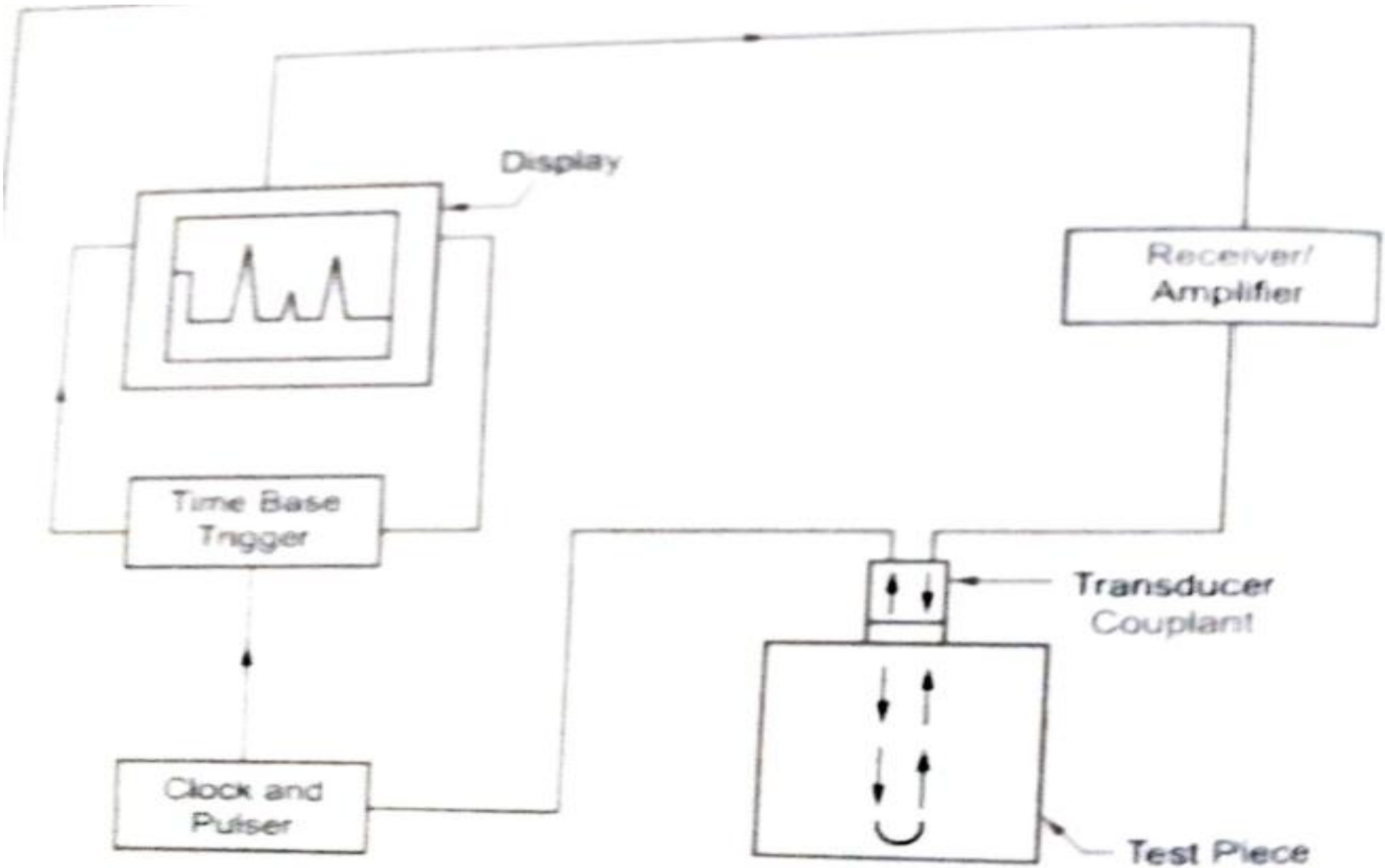


Oscilloscope, or flaw detector screen

Instruments used in Ultrasonic Testing

- Pulser/Receiver
- Ultrasonic Transducer
- Couplant
- Display Screen
- Receiver/Amplifier

Instruments used in UT



- A typical UT inspection system consists of several functional units, such as the pulser /receiver, transducer, and display devices.
- A pulser /receiver is an electronic device that can produce high voltage elec trical pulses.
- Driven by the pulser, the transducer generates high frequency ultrasonic en ergy. The sound energy is introduced and propagates through the materials i n the form of waves.
- When there is a discontinuity (such as a crack) in the wave path, part of the energy will be reflected back from the flaw surface. The reflected wave sig nal is transformed into an electrical signal by the transducer and is displaye d on a screen. In the applet below, the reflected signal strength is displayed versus the time from signal generation to when a echo was received.
- Signal travel time can be directly related to the distance that the signal trave lled. From the signal, information about the reflector location, size, orientat ion and other features can sometimes be gained.

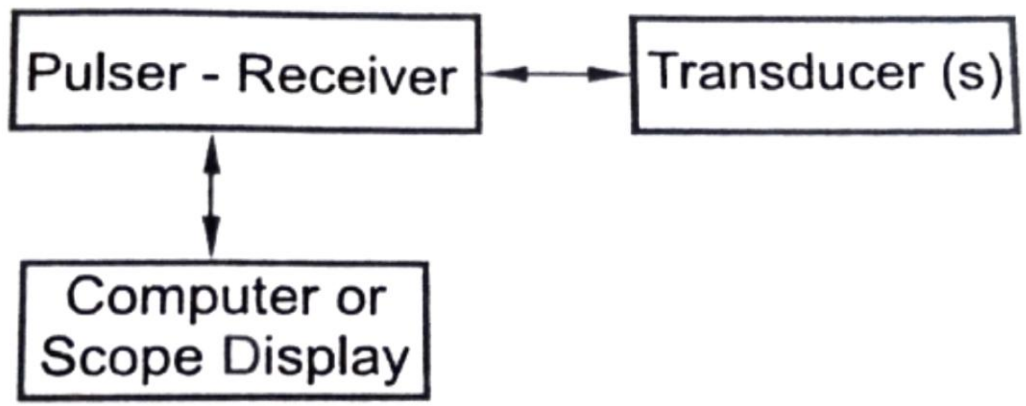


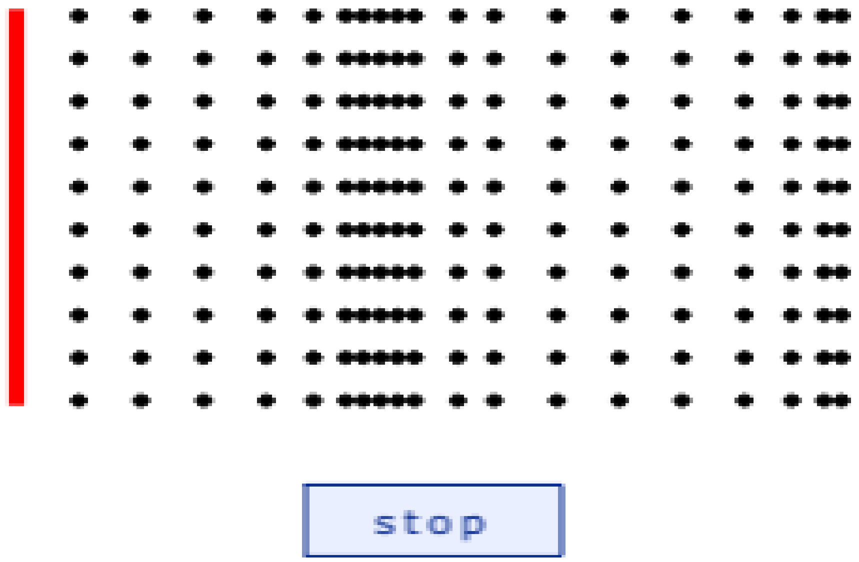
Fig. 4.22: Pulser - Receivers

Types of Waves

- In solids, sound waves can propagate in four principle modes that are based on the way the particles oscillate. Sound can propagate as longitudinal wav es, shear waves, surface waves, and in thin materials as plate waves. ***Longit udinal and shear waves are the two modes of propagation most widely us ed in ultrasonic testing.***
- The particle movement responsible for the propagation of longitudinal and shear waves is illustrated below.

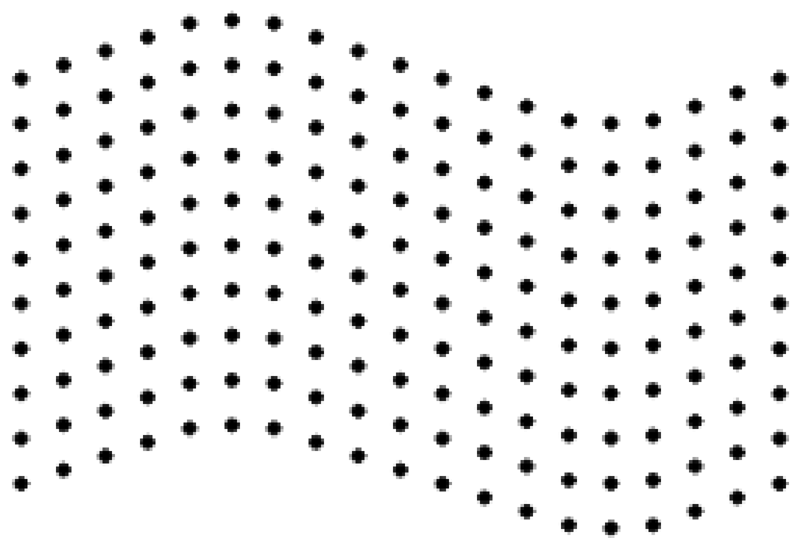
Longitudinal Wave

In longitudinal waves, the oscillations occur in the longitudinal direction or the directio n of wave propagation. Since compressional and dilational forces are active in these wa ves, they are also called pressure or compressional waves. They are also sometimes call ed density waves because their particle density fluctuates as they move. Compression w aves can be generated in liquids, as well as solids because the energy travels through th e atomic structure by a series of compressions and expansion (rarefaction) movements.



Transverse Wave

In the transverse or shear wave, the particles oscillate at a right angle or transverse to the direction of propagation. Shear waves require an acoustically solid material for effective propagation, and therefore, are not effectively propagated in materials such as liquids or gasses. Shear waves are relatively weak when compared to longitudinal waves. In fact, shear waves are usually generated in materials using some of the energy from longitudinal waves.



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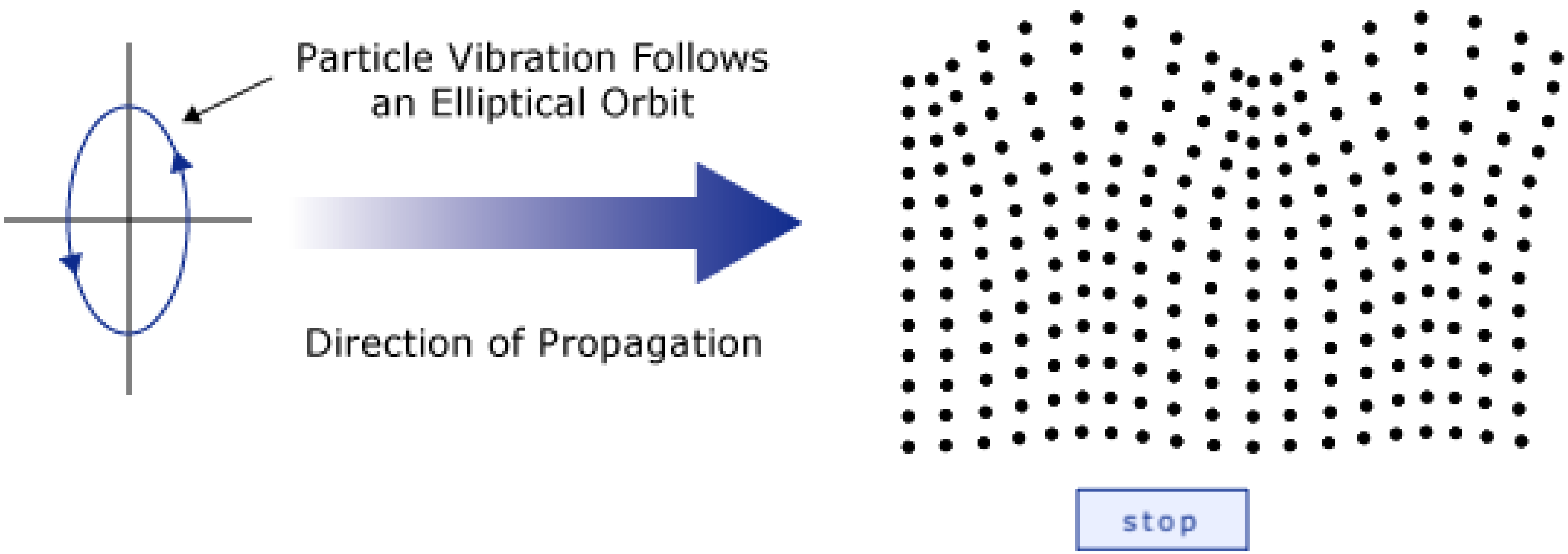
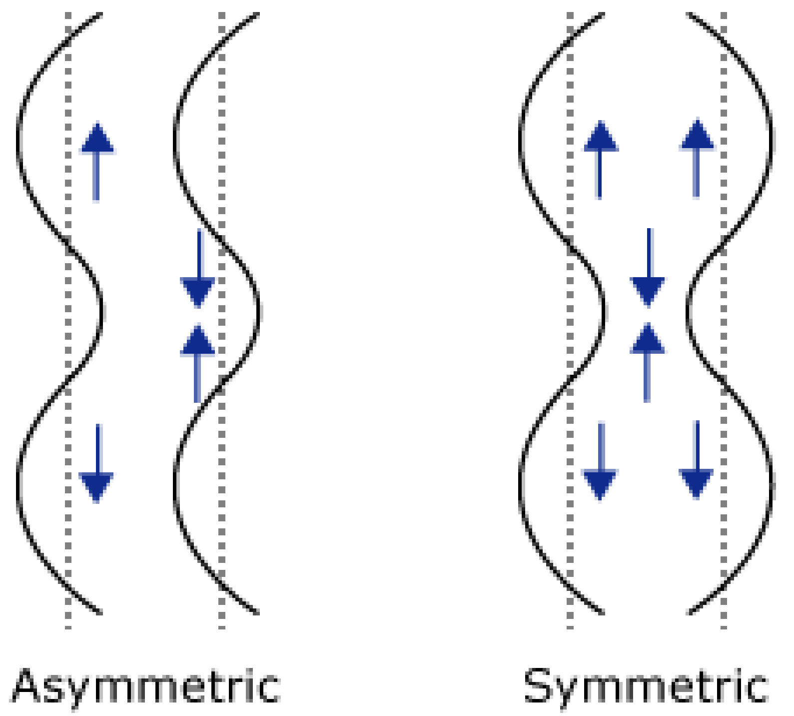
Surface Wave

Surface Wave: Surface wave is also called as Rayleigh Waves represent an oscillating motion that travels along the surface of a teat specimen to a depth of one wavelen gth. Surface wave can be used to detect breaking cracks in a test specimen.



Lamp Wave

Lamp Wave: Lamp wave are surface waves propagate parallel to the test surface and have a particle motion that is elliptical. They occur when the thickness of the test material is only a few wavelength at the test frequency and where the test specimen is of uniform thickness



Wave Types in Solids	Particle Vibrations
Longitudinal	Parallel to wave direction
Transverse (Shear)	Perpendicular to wave direction
Surface - Rayleigh	Elliptical orbit - symmetrical mode
Plate Wave - Lamb	Component perpendicular to surface (extens ional wave)

Terminologies Used in Ultrasonic Testing

Wavelength: The distance travelled by a wave during a particle of the medium completes one vibration is called wavelength. It is also defined as the distance between any two nearest on the wave having same phase

Time Period: The time period of a wave is the time taken by the wave to travel a distance equal to its wavelength

Frequency: This is defined as the number of waves produced in one second.

Sensitivity and Resolution: Sensitivity and resolution are two terms that are often used in ultrasonic inspection to describe a technique's ability to locate flaws. ***Sensitivity*** is the ability to locate small discontinuities. Sensitivity generally increases with higher frequency (shorter wavelengths). ***Resolution*** is the ability of the system to locate discontinuities that are close together within the material or located near the part surface. Resolution also generally increases as the frequency increases.

Scattering and Attenuation: Scattering is the reflection of the sound in directions other than its original direction of propagation. Absorption is the conversion of the sound energy to other forms of energy. The combined effect of scattering and absorption is called **attenuation**. Ultrasonic attenuation is the decay rate of the wave as it propagates through material.

Acoustic impedance: Sound travels through materials under the influence of sound pressure. Because molecules or atoms of a solid are bound elastically to one another, the excess pressure results in a wave propagating through the solid.

The acoustic impedance (Z) of a material is defined as the product of its density (p) and acoustic velocity (V).

$$Z = pV$$

Mode Conversion in UST

When sound travels in a solid material, one form of wave energy can be transformed into another form.

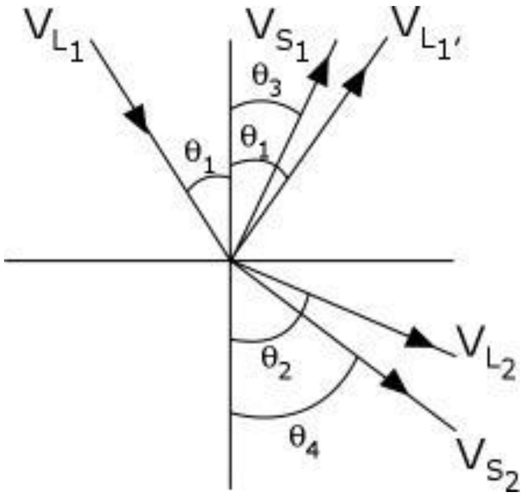
For example, when a longitudinal waves hits an interface at an angle, some of the energy can cause particle movement in the transverse direction to start a shear (transverse) wave. Mode conversion occurs when a wave encounters an interface between materials of different acoustic impedances and the incident angle is not normal to the interface.

it was pointed out that when sound waves pass through an interface between materials having different acoustic velocities, refraction takes place at the interface. The larger the difference in acoustic velocities between the two materials, the more the sound is refracted. ***Notice that the shear wave is not refracted as much as the longitudinal wave.*** This occurs because shear waves travel slower than longitudinal waves. Therefore, the velocity difference between the incident longitudinal wave and the shear wave is not as great as it is between the incident and refracted longitudinal waves.

Also note that when a longitudinal wave is reflected inside the material, the reflected shear wave is reflected at a smaller angle than the reflected longitudinal wave. This is also due to the fact that the shear velocity is less than the longitudinal velocity within a given material.

Snell's Law holds true for shear waves as well as longitudinal waves and can be written as follows.

Where:



VL1 is the longitudinal wave velocity in material 1.

VL2 is the longitudinal wave velocity in material 2.

VS1 is the shear wave velocity in material 1.

VS2 is the shear wave velocity in material 2.

$$\frac{\sin\theta_1}{V_{L_1}} = \frac{\sin\theta_2}{V_{L_2}} = \frac{\sin\theta_3}{V_{S_1}} = \frac{\sin\theta_4}{V_{S_2}}$$

Ultrasonic Testing Methods

Ultrasonic testing is a very versatile inspection method, and inspections can be accomplished in a number of different ways.

Ultrasonic inspection techniques are commonly divided into three primary classifications.

–**Pulse-echo and Through Transmission (**Relates to whether reflected or transmitted energy is used)

–**Normal Beam and Angle Beam** (Relates to the angle that the sound energy enters the test article)

–**Contact and Immersion (**Relates to the method of coupling the transducer to the test article)

Transmission Through Method

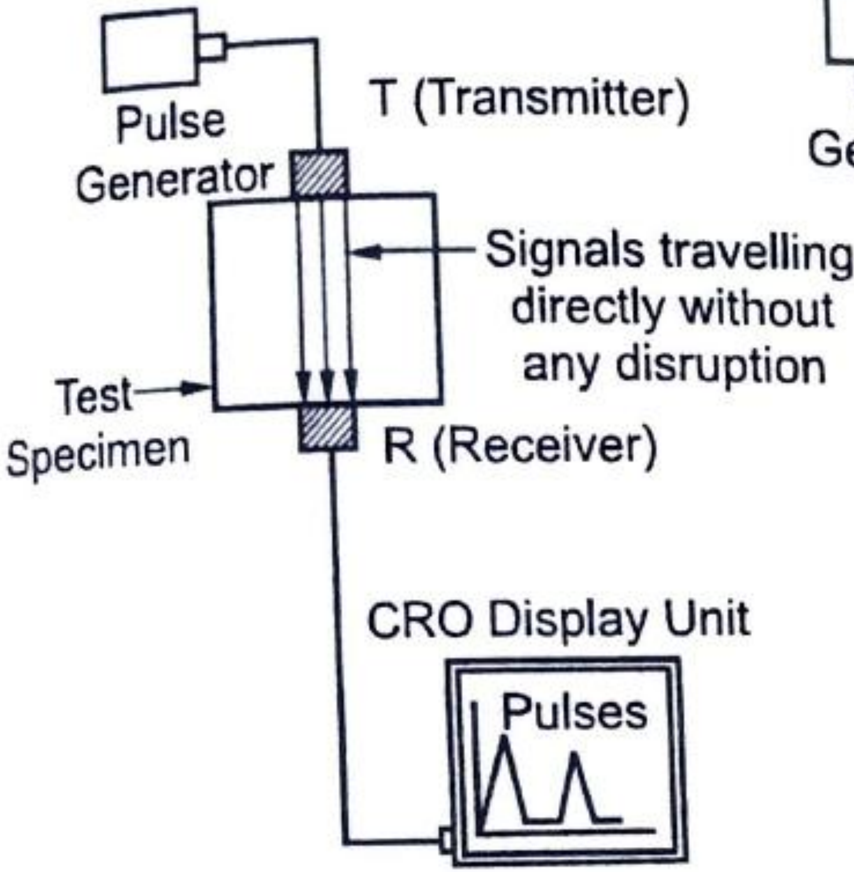
In this method, the defect can be identified on quantifying the rec eived sound waves.

Test Procedure:

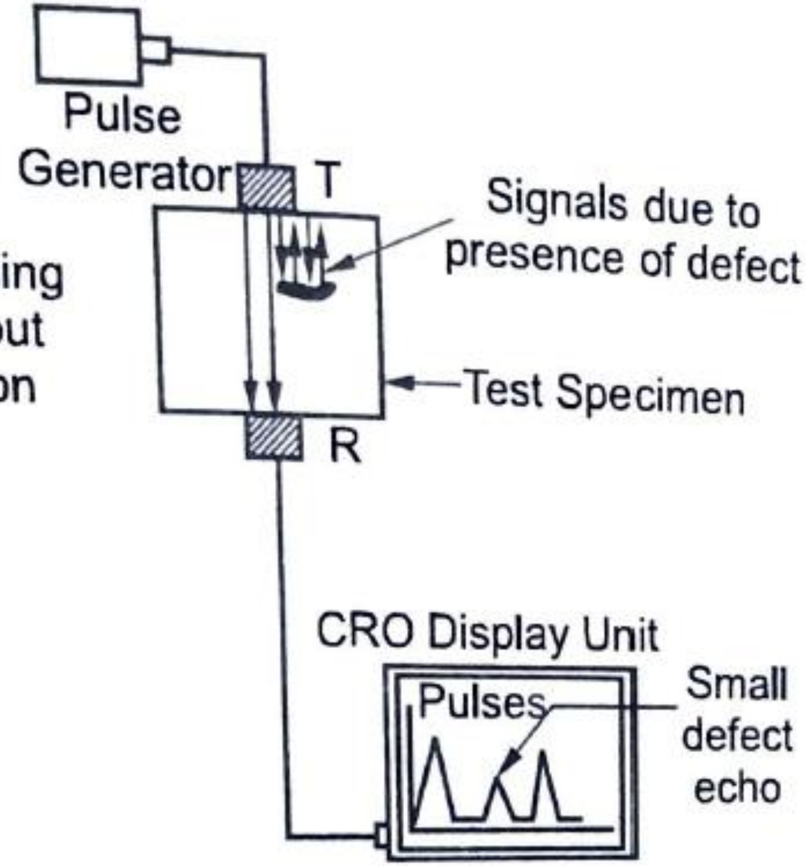
Two transducers located on opposing sides of the test specimen ar e used. One transducer acts as a transmitter, the other as a receive r.

Discontinuities in the sound path will result in a partial or total lo ss of sound being transmitted and be indicated by a decrease in th e received signal amplitude.

Through transmission is useful in detecting discontinuities that ar e not good reflectors, and when signal strength is weak. It does n ot provide depth information.

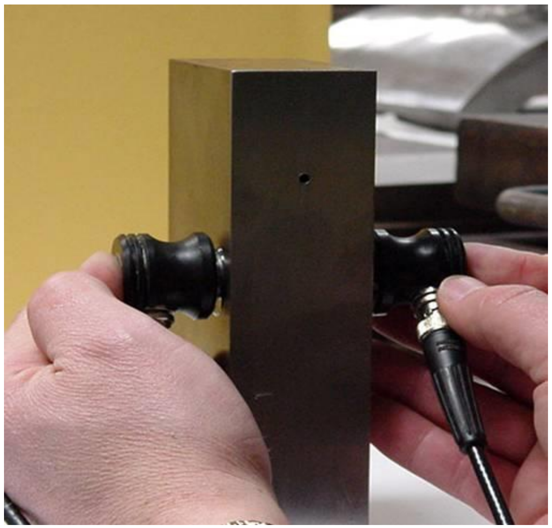


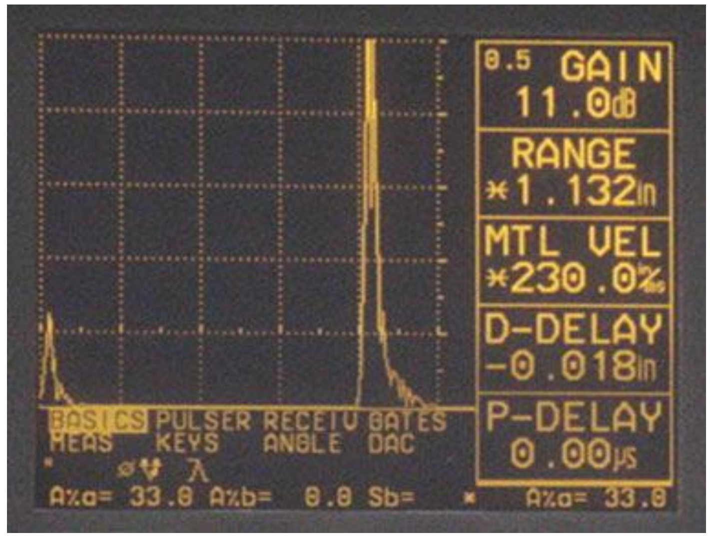
(a) Transmission of waves through defect free Specimen



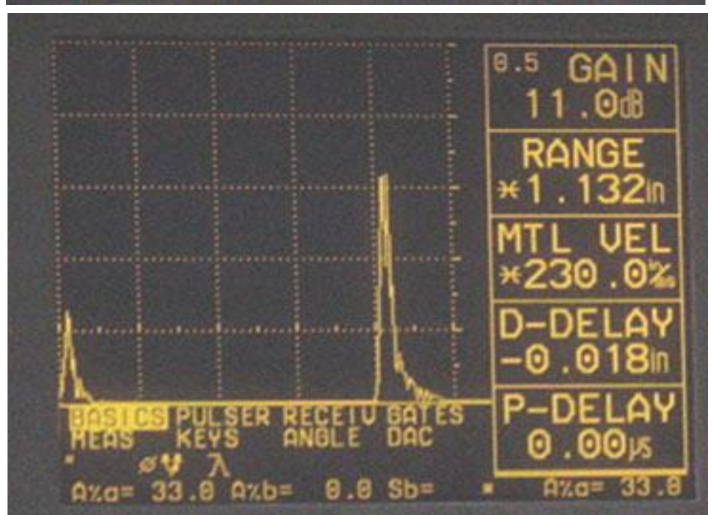
(b) Transmission of waves through specimen with defect

The result can be seen through CRT screen display





Digital display showing received sound through material thickness.



Digital display showing loss of received signal due to presence of a discontinuity in the sound field.

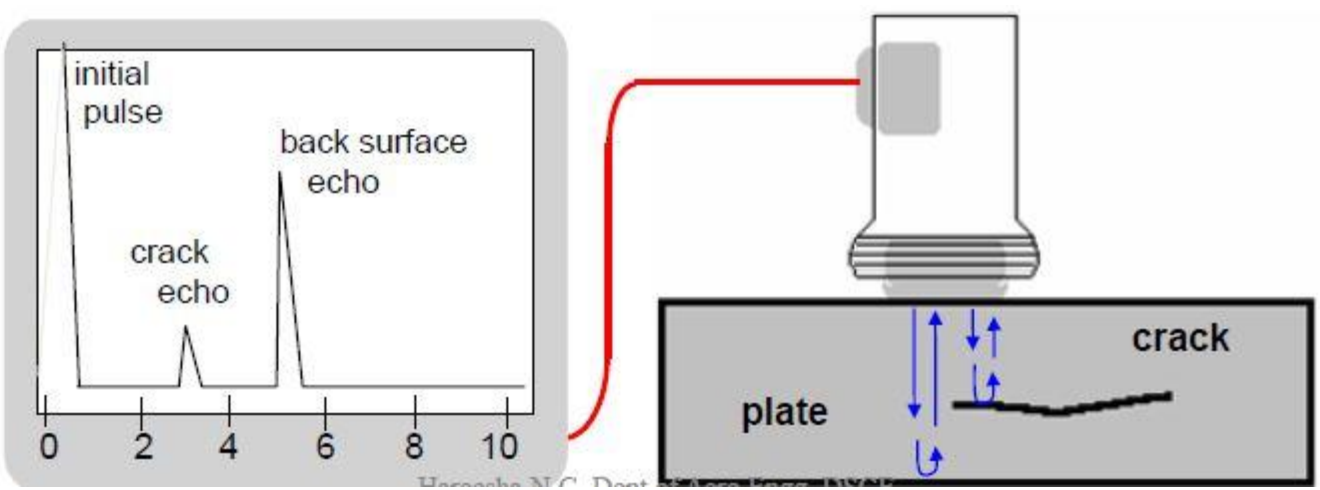
Pulse-Echo Testing Methods

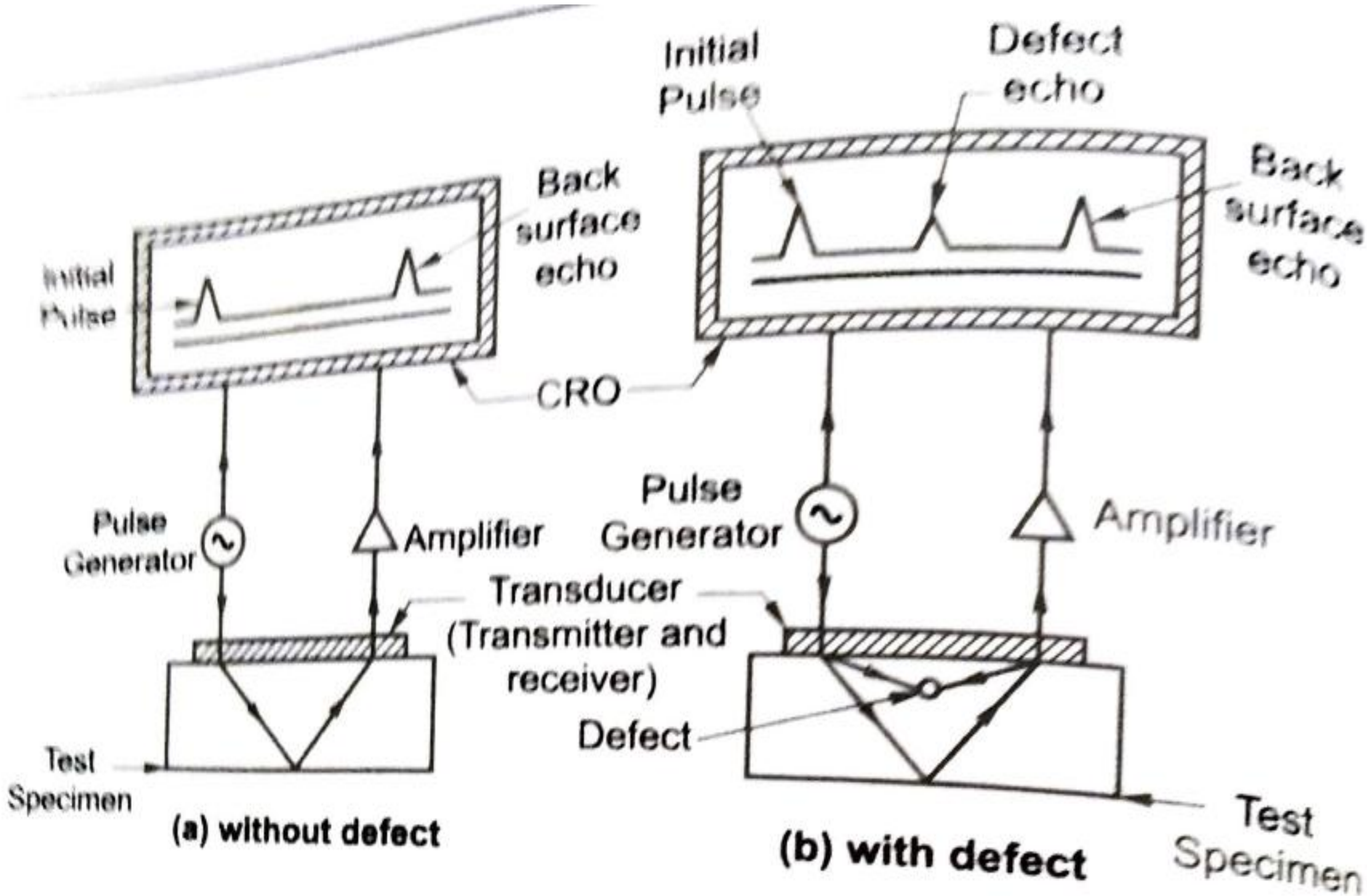
Test Procedure:

In pulse-echo testing, a transducer sends out a pulse of energy and the same or a second transducer listens for reflected energy (an echo).

Reflections occur due to the presence of discontinuities and the surfaces of the test article.

The amount of reflected sound energy is displayed versus time, which provides the inspector information about the size and the location of features that reflect the sound.

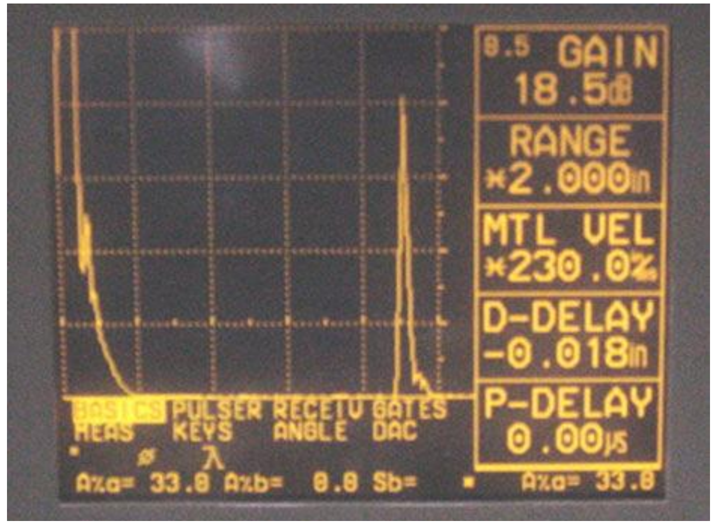




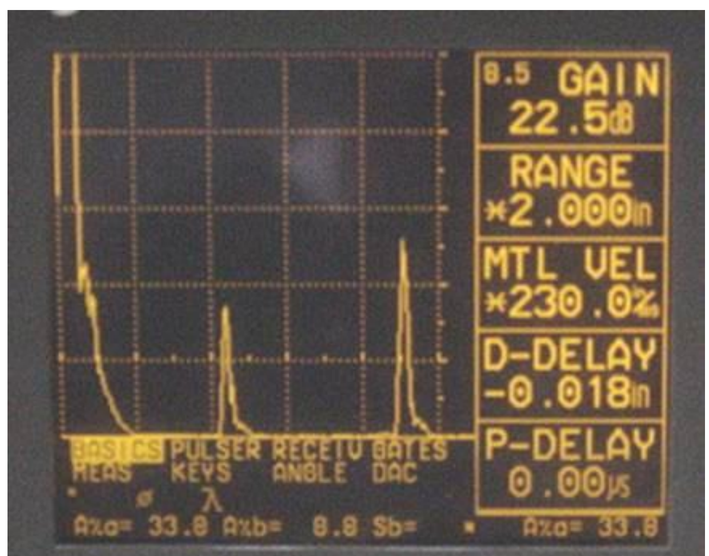
(a) without defect

(b) with defect

The pulse-echo technique allows testing when access to only one side of the material is possible, and it allows the location of reflec tors to be precisely determined.



Digital display showin g signal generated fro m sound reflecting off back surface.



Digital display showing t he presence of a reflector midway through material , with lower amplitude ba ck surface reflector.

Contact Testing Technique

Contact testing are used for direct contact inspections, and are manipulated manually. As the name suggests , this transducer has direct contact with this specimen.

These transducers are designed in such a manner so that it is easy to grip and move along a surface.

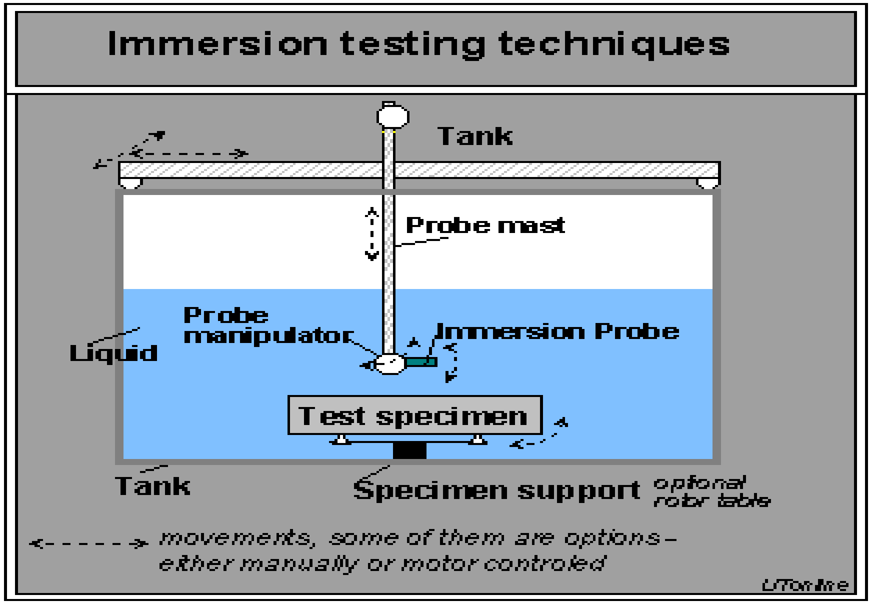
To get useful levels of sound energy into a material, the air between the transducer and the test article must be removed. This is referred to as coupling.

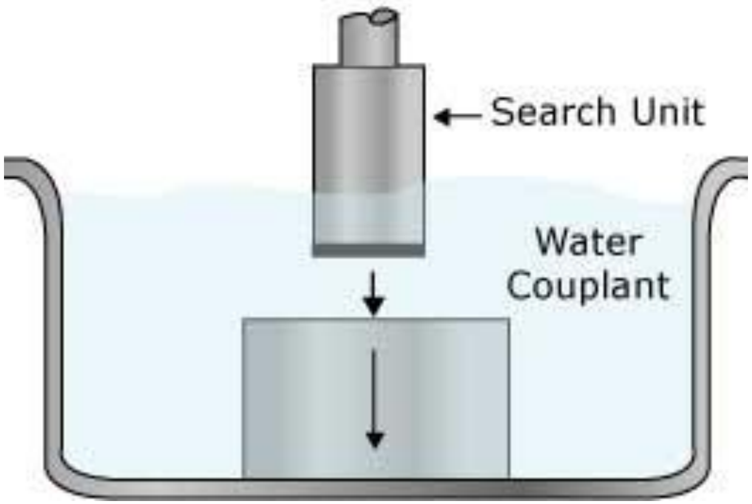
In contact testing, a couplant such as water, oil or a gel is applied between the transducer and the part.

Immersion Testing Technique

In immersion testing, the part and the transducer are place in a water bath. This arrangement allows better movement of the transducer while maintaining consistent coupling.

Immersion technique is typically used inside a water tank





Dual – crystal testing

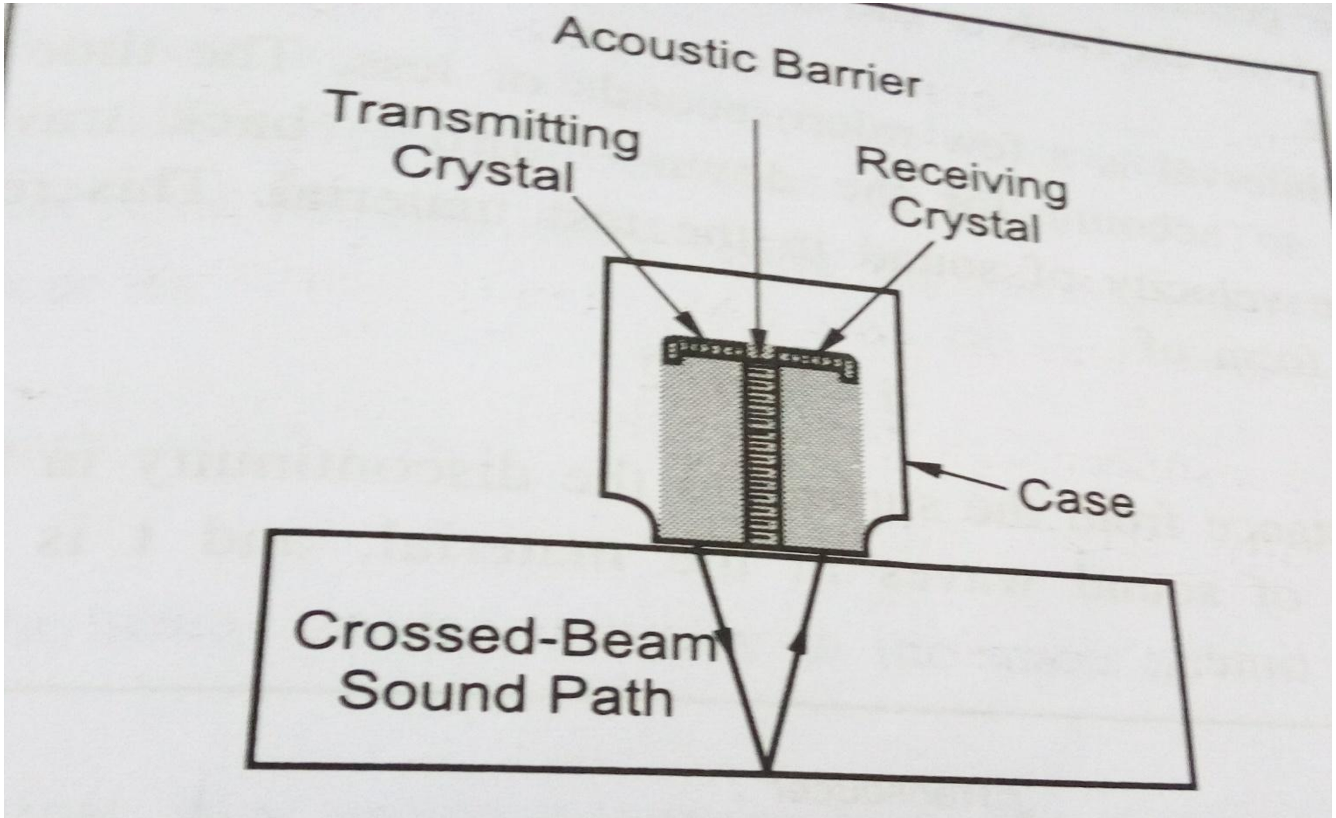


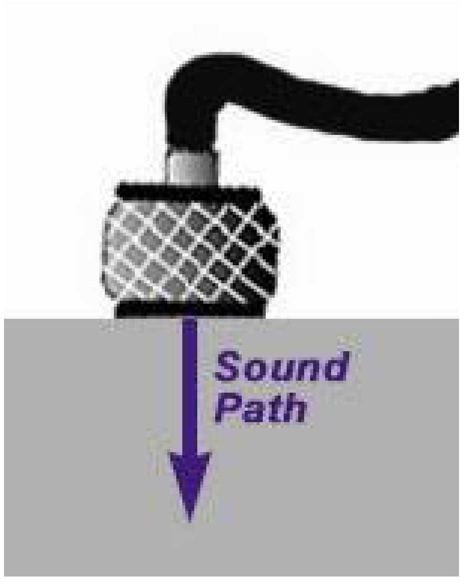
Fig. 4.15: Dual element transducer technique

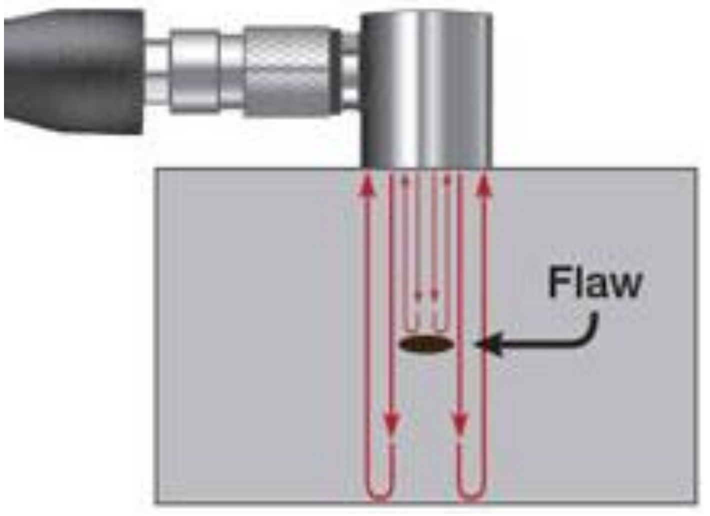
Straight Beam testing Methods

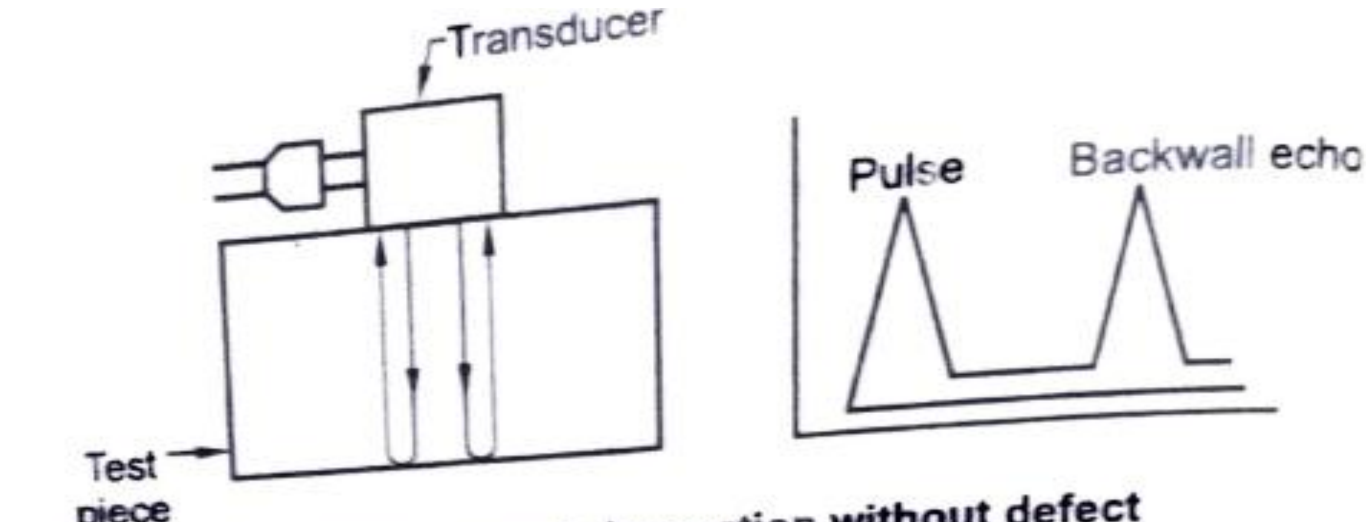
In normal beam testing, the sound beam is introduced into the test article at 90 degree to the surface.

It is also called straight beam technique. In this technique, mostly transducer is in direct contact with specimen.

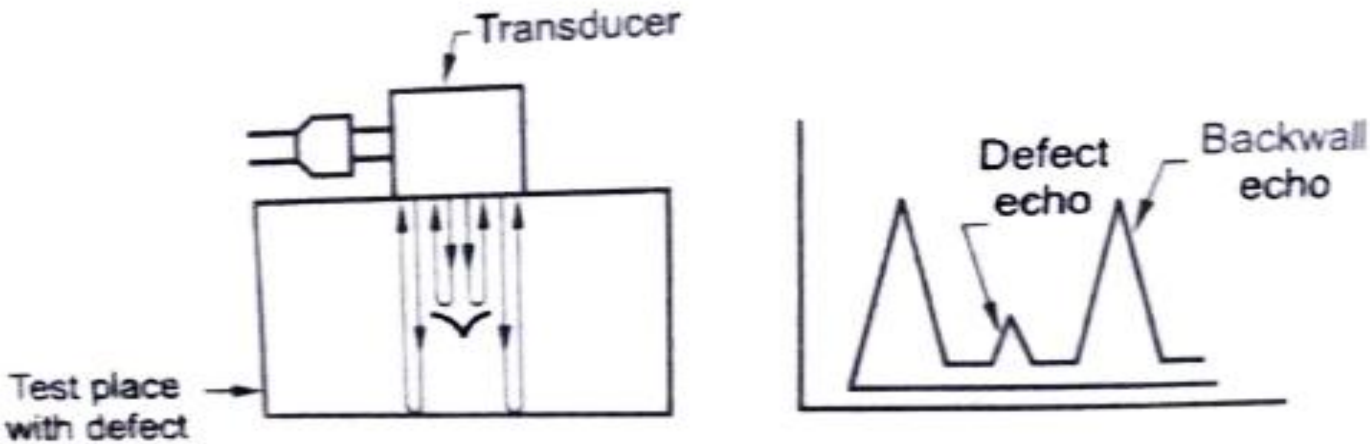
In this technique, determination of the location of a discontinuity in a part or st ructure is done accurately measuring the time required for SHORT Ultrasonic pulse generated from the or the surface of a discontinuity and be returned to th e transducer.







(a) Ultrasonic inspection **without defect**



(b) **Ultrasonic** inspection **with defect**

Angle Beam Testing

In angle beam testing, the sound beam is introduced into the test article at some angle other than 90.

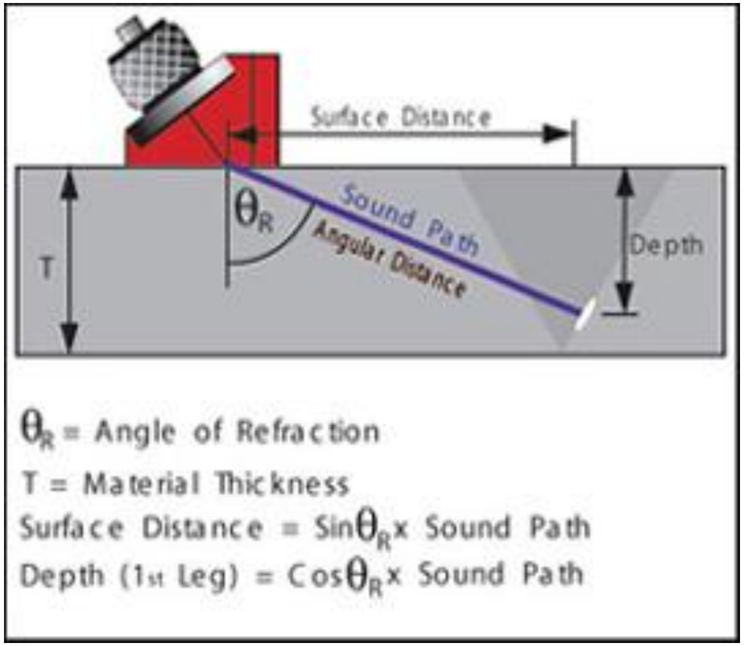
In this technique, the refracted beam is used to inspect angle beam transducers and wedges are used to introduce a refracted shear wave in to the test material.

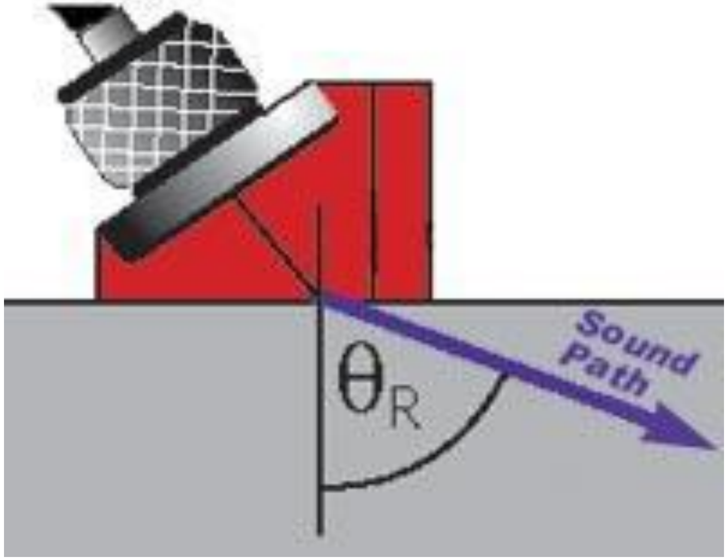
An angles sound path allows the sound beam to come in from the side thereby improving detectability of deflects and flaws in and around test specimen.

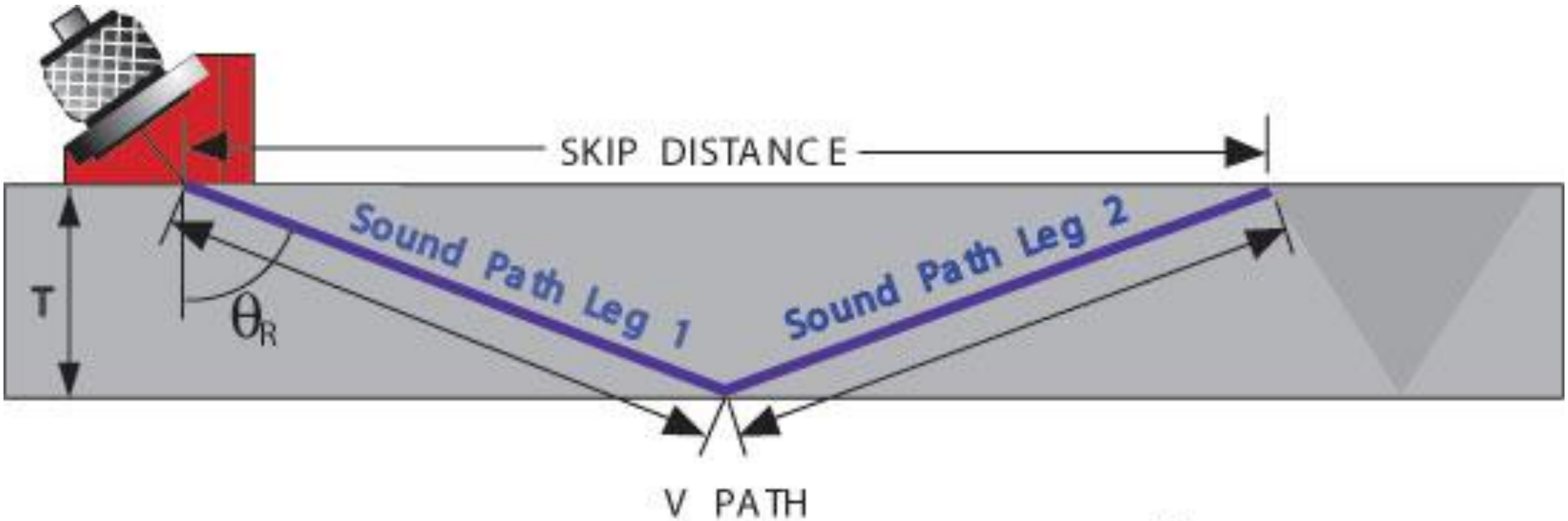
The choice between normal and angle beam inspection usually depends on two considerations:

-The orientation of the feature of interest – the sound should be directed to produce the largest reflection from the feature.

-Obstructions on the surface of the part that must be worked around.







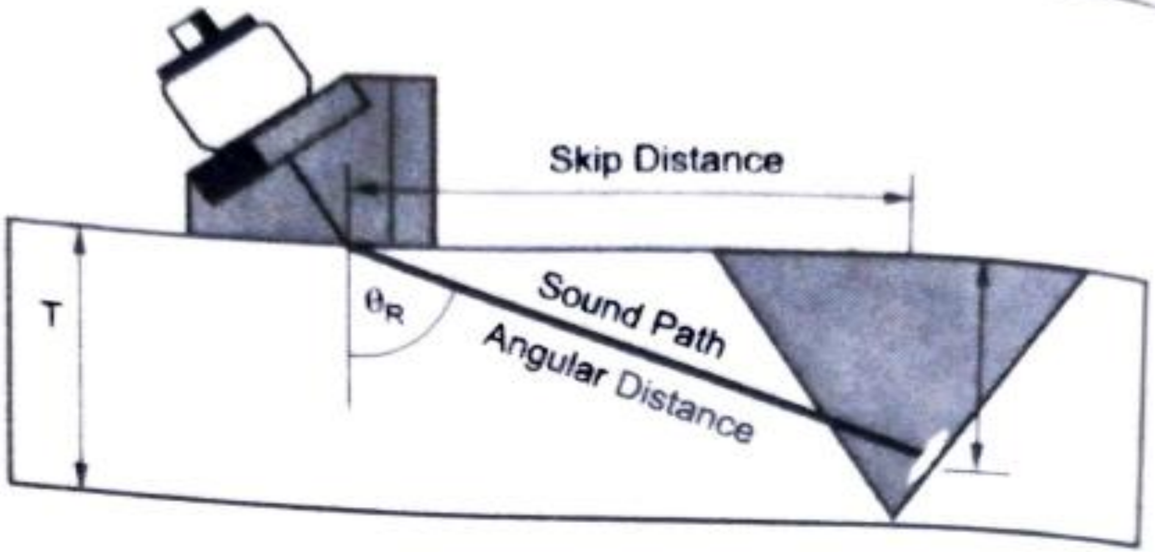
θ_R = Refracted Angle

T = Material Thickness

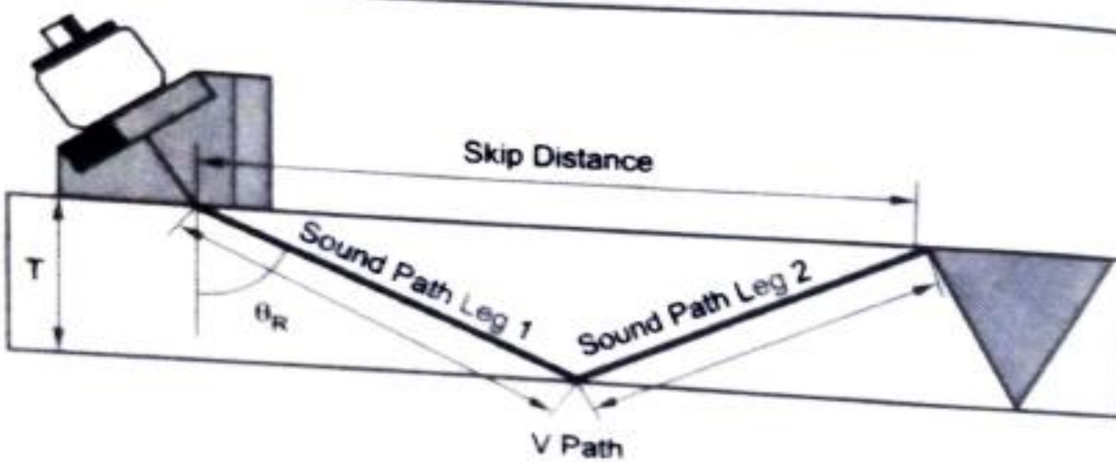
Skip Distance = $2T \times \tan\theta_R$

$$\text{Leg} = \frac{T}{\cos\theta_R}$$

$$\text{V-Path} = \frac{2T}{\cos\theta_R}$$



(a) First leg reflection



(b) Second leg reflection

Resonance testing

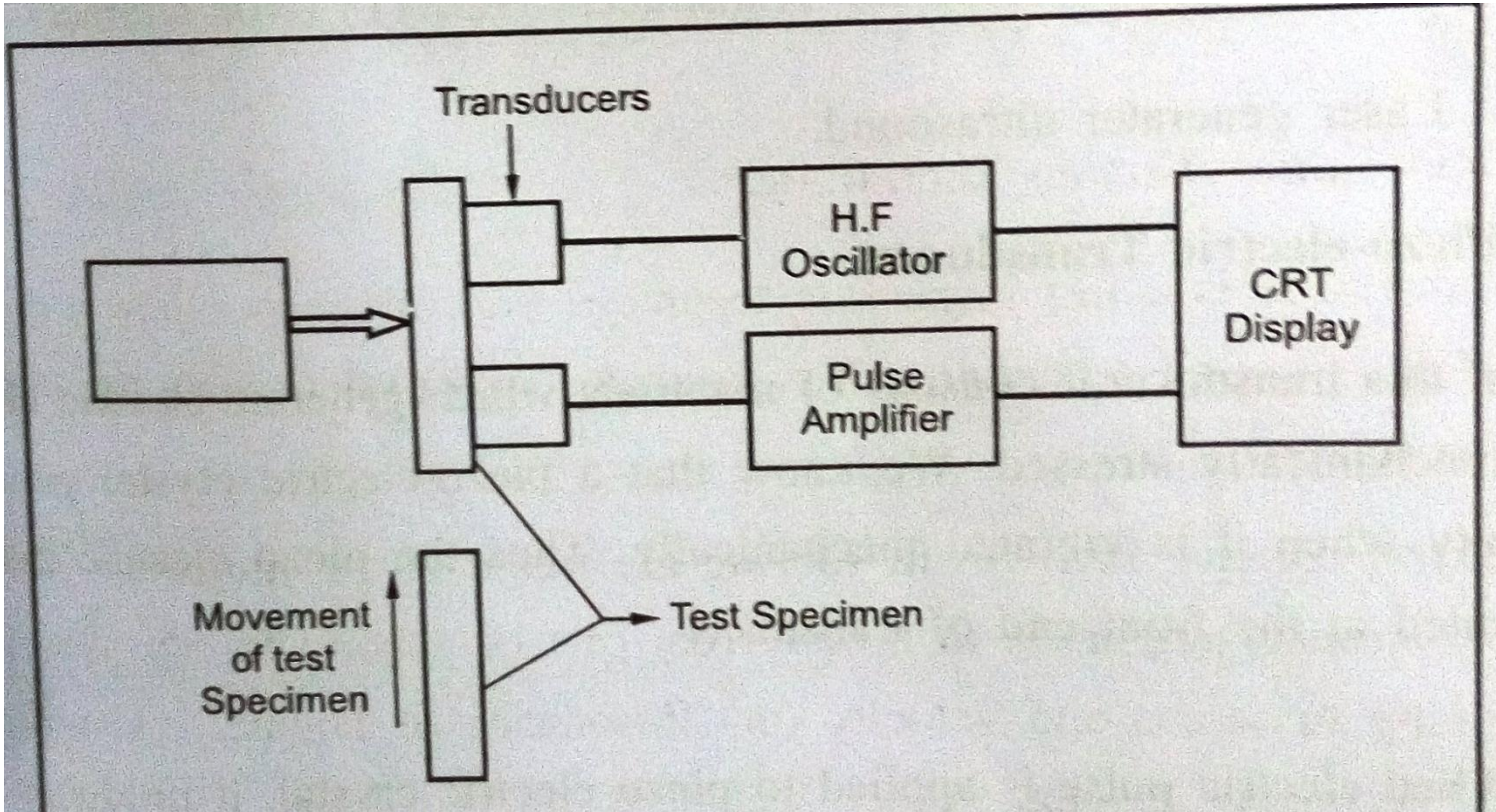


Fig. 4.18: Resonance testing Technique