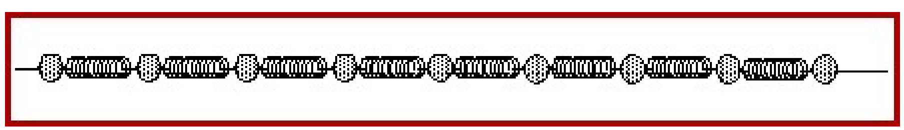
ULTRASONICS

Ultrasonic waves-properties-generation - piezo electric effect -magnetostriction effect – acoustic grating- detection Kundt's tube-flaw detection - NDT-scanning techniques A,B,C

Sound waves
Mechanical waves

Require medium
Generated by vibrating object
Pushing and pulling on its nearest neighbors
Displacement of particles from its equilibrium position

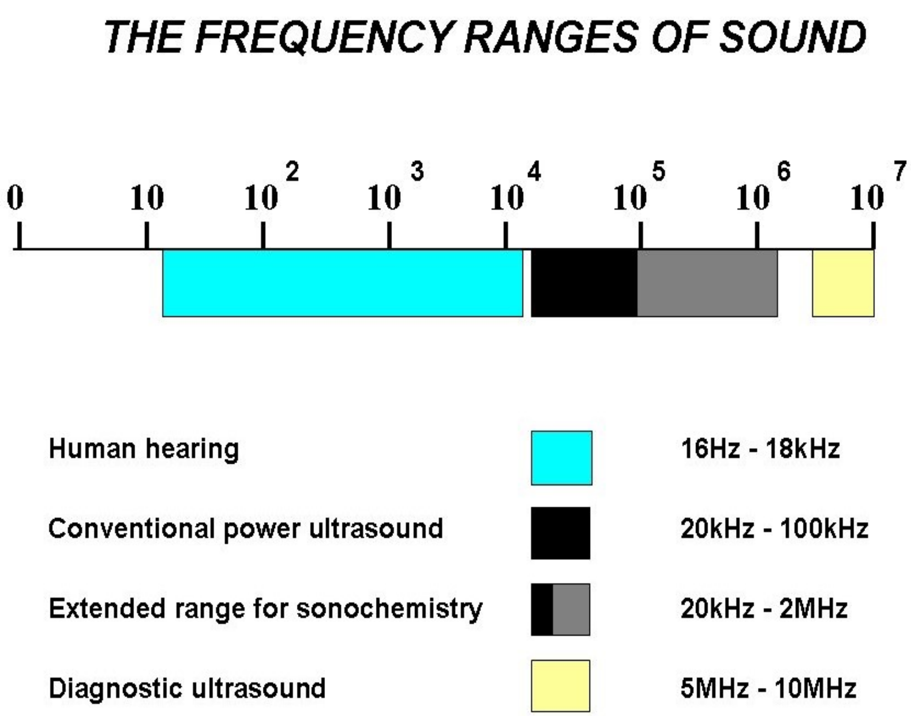
Propagation of disturbance through the medium



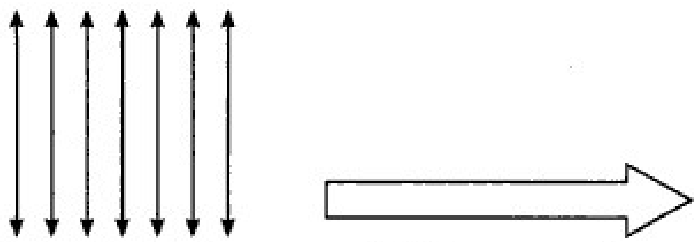
http://www.physicsclassroom.com/mmedia/waves/tfl.cfm

Sound waves: classification

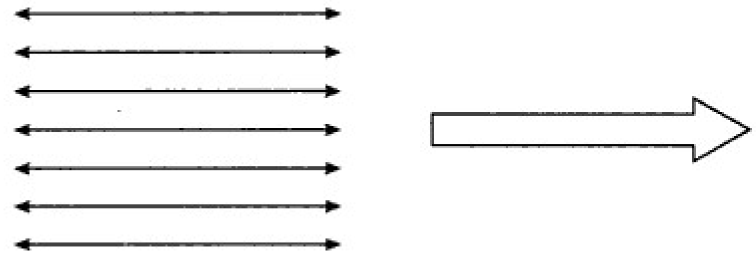
Infrasonic : <20 Hz waves generated by Earthquake
Sonic :20-20 kHz audible, understood by human
Ultrasonic: 20 KHz to 10 MHz bat, dog, dolphins, whales and some birds sense



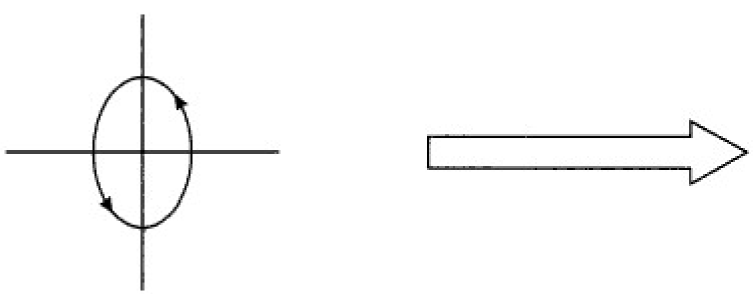
Supersonic!



Transverse ultrasonic waves.



Longitudinal ultrasonic waves.



Surface waves.

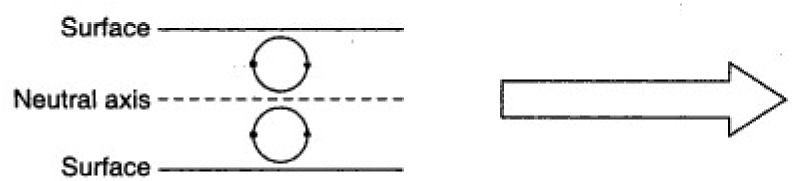
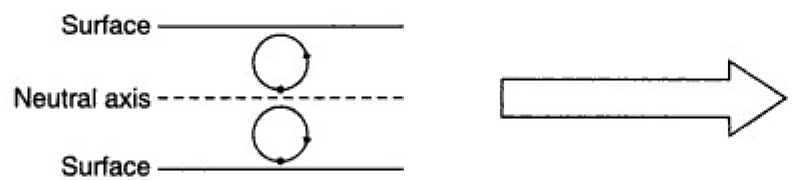
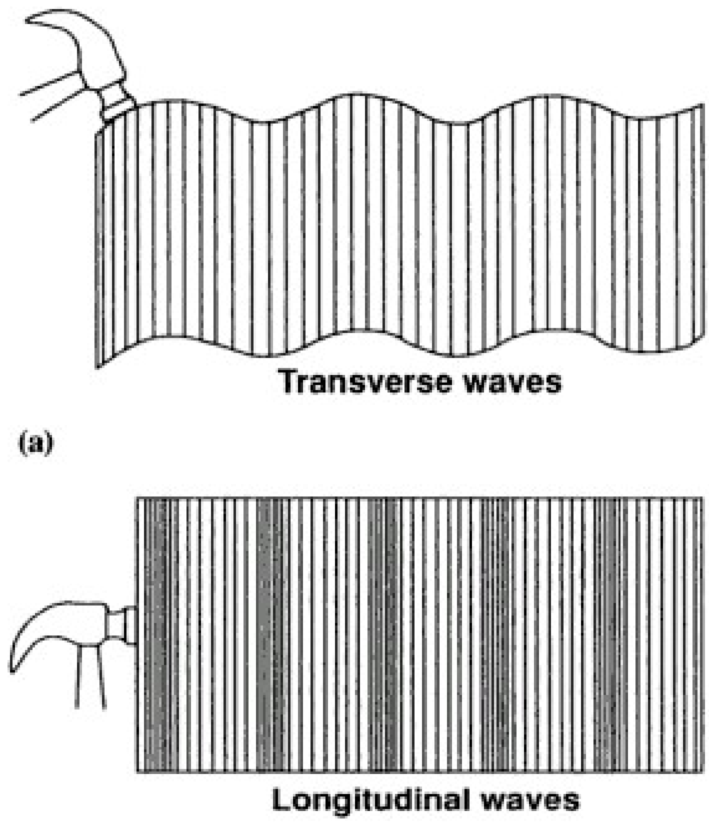


Figure 1.6 Symmetrical Lamb wave.



Asymmetrical Lamb wave.


Transverse waves
(a)
Longitudinal waves

Ultrasonic waves: Properties

❖They are Mechanical waves. They need material medium to propagate

❖The resistance offered by the medium to the propagation of ultrasonic wave is known as acoustic impedance.

$$\text{acoustic impedance} = \rho v$$

❖Velocity of propagation is proportional to the physical properties of materials

$$v^2 = E / \rho$$

❖Difference in elastic modulus of materials are higher than those in density. So v is determined mainly by E.

❖Ultrasonic waves undergoes reflection, refraction ,scattering and diffraction as light waves

❖Ultrasonic waves get attenuation while travelling through medium.

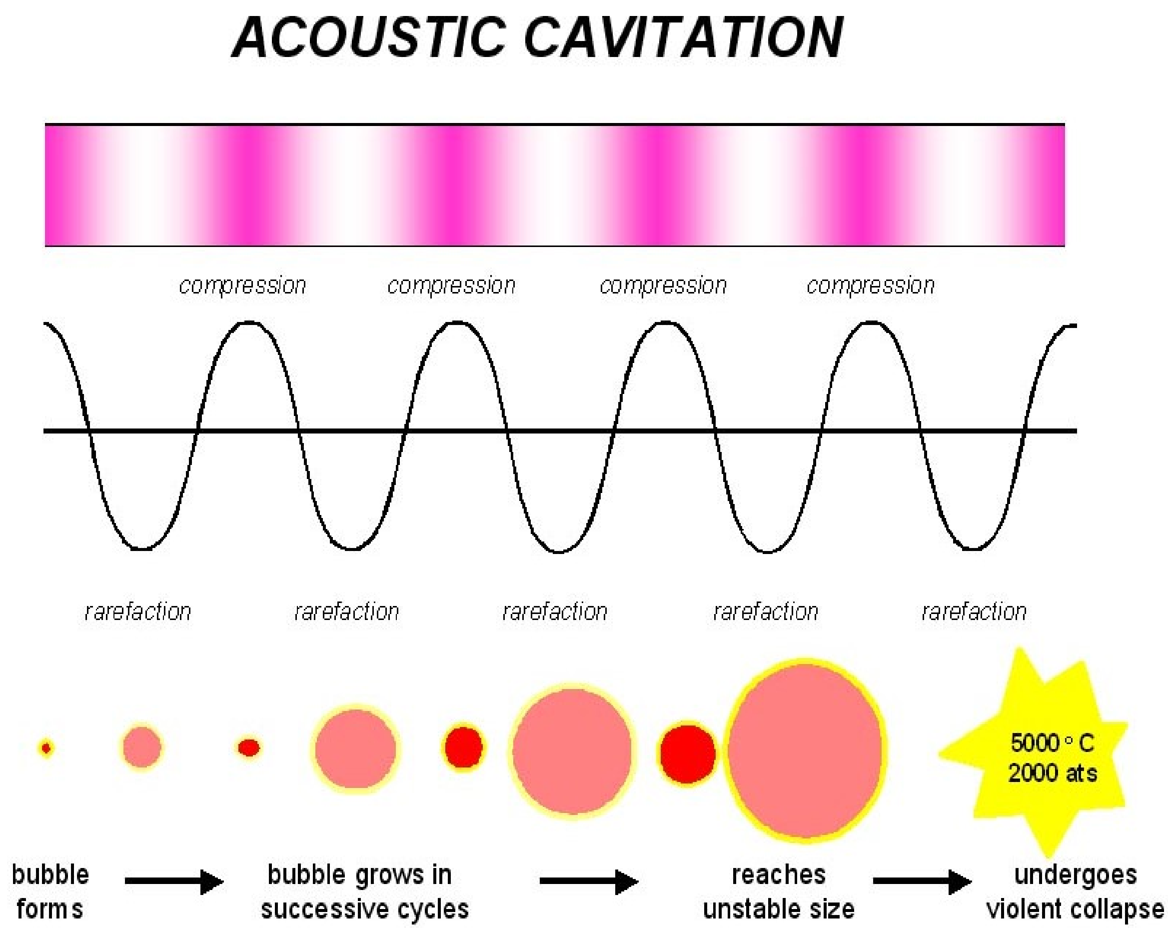
$$A = A_0 e^{-\alpha x}$$

A- amplitude of the wave, x – distance travelled, α- attenuation coefficient

At sufficiently high power the rarefaction cycle may **exceed the attractive forces of the molecules** of the liquid and cavitation bubbles will form.

The bubbles **grow over the period** of a few cycles to an equilibrium size for the particular frequency applied

when they collapse in succeeding compression cycles which **generates the energy for chemical and mechanical effects**



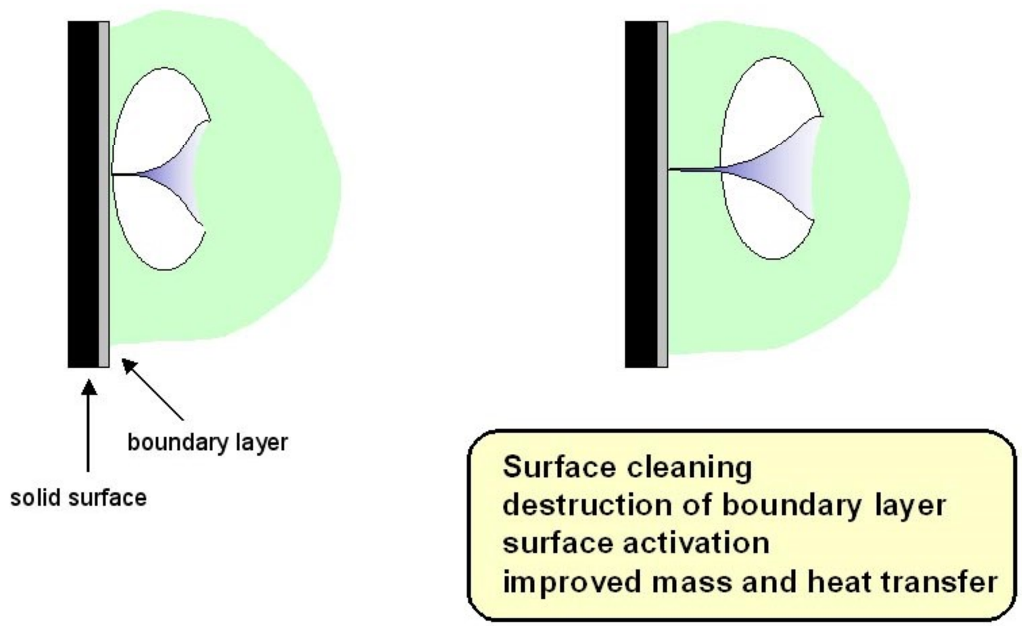
http://www.sonochemistry.info/introdution.htm

Ultrasound cleaning

ACOUSTIC CAVITATION

Collapse at or near a solid surface

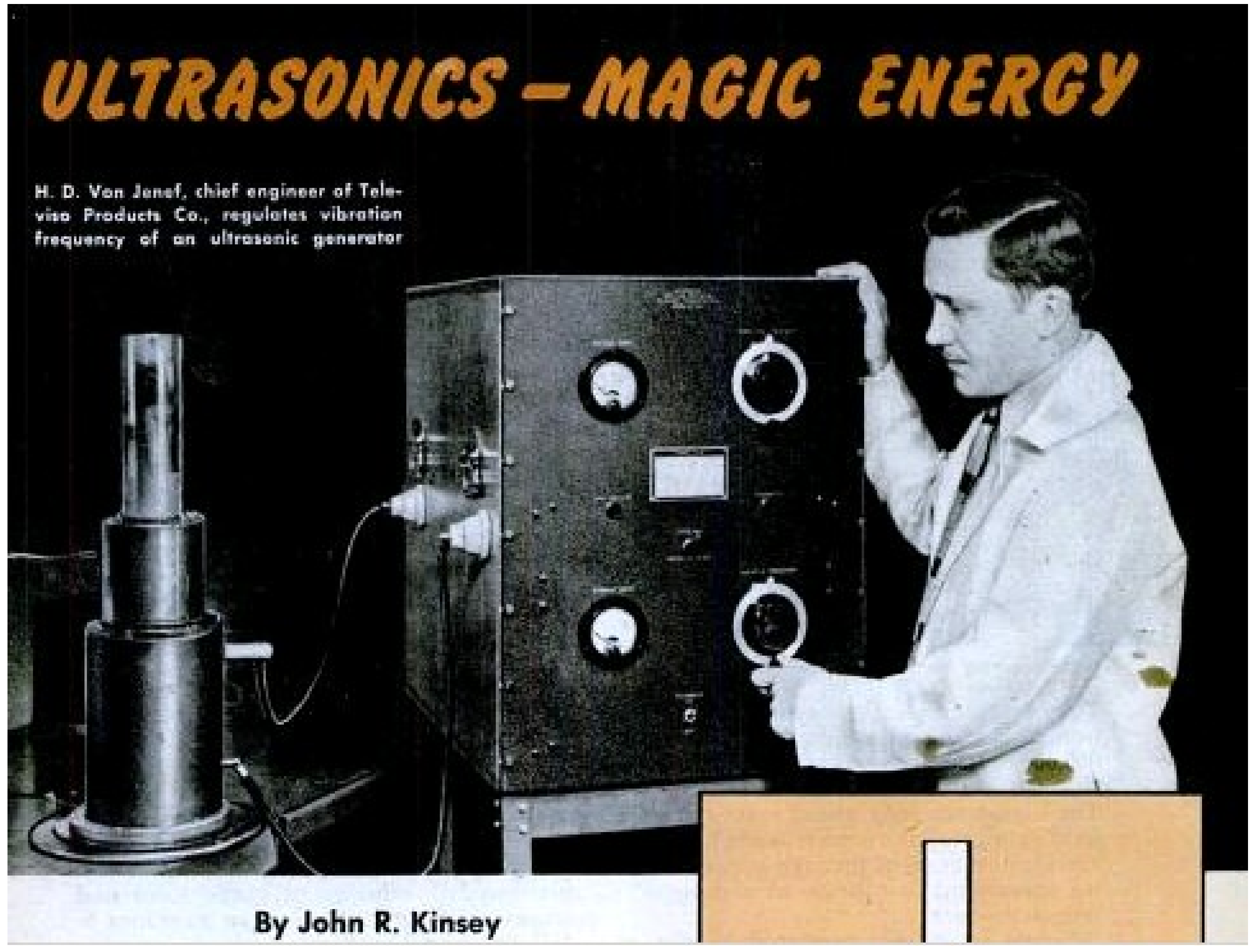
Inrush of liquid from one side of the collapsing bubble produces powerful jet of liquid targeted at surface



Popular Mechanics May 1947

Speeds of Sound in Various Media

Medium	v (m/s)
Gases	
Air (0°C)	331
Air (100°C)	386
Hydrogen (0°C)	1 290
Oxygen (0°C)	317
Helium (0°C)	972
Liquids at 25°C	
Water	1 490
Methyl alcohol	1 140
Sea water	1 530
Solids	
Aluminum	5 100
Copper	3 560
Iron	5 130
Lead	1 320
Vulcanized rubber	54



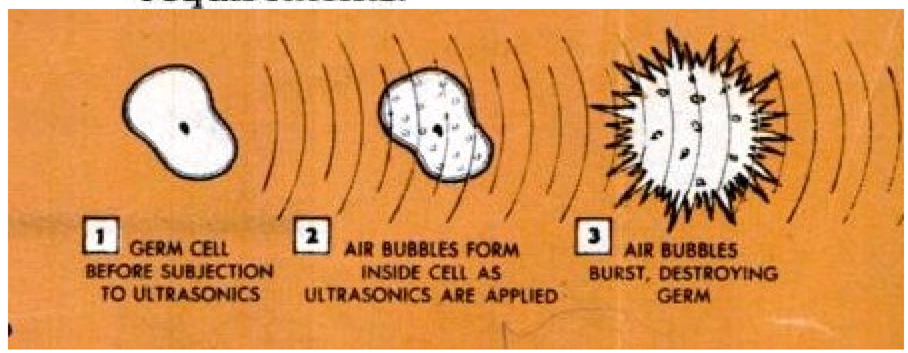
SOUND that can't be heard is science's newest "wonder tool."

It pierces tin and steel, sterilizing and preserving uncooked foods without marring their taste. It kills insects, offering the farmer a possible new attack on crop pests. It disperses smoke and soot and may help keep cities clean. It transforms fog into rain so pilots can see well enough to land planes.

Tobacco growers are experimenting with ultrasonics to kill insects that infest tobacco during its curing. Flour mills may use it to exterminate weevils in wheat, and germs which sometimes mature in flour after it is processed. Producers of grape juice and wines are testing sound wave machines to kill acetic acid bacteria.

Sound waves kill germs by producing and rupturing microscopic air bubbles inside a microbe cell, according to H. D. Von Jenef, chief engineer of Televiso Products Company of Chicago. Von Jenef directs the ultrasonic research which guides his company's manufacture of high-frequency sound wave generators.

The dairy industry is testing ultrasonics to emulsify cream cheese mixes and pasteurize milk at low temperature. The Raytheon Manufacturing Company makes a sonic oscillator which homogenizes milk; as the liquid passes over a vibrating steel diaphragm, milk particles are made microscopically fine, producing a soft-curd milk suitable for stringent dietetic requirements.



Ultrasonic Generation

14.1 Generators

14.1.1 Galton's Whistle Galton's whistle is similar to a boy scout's whistle. It differs in that it has a piston provided with a screw and a milled head (Fig.14.1). The screw operates through a nut provided in the back plate of the whistle. The piston is moved so as to shorten its effective length. The pitch of the sound emitted increases as the effective length is shortened. Eventually a stage is reached when no sound is heard, when, in fact, the whistle is emitting ultrasonic sound. Dogs are able to hear sound frequencies far beyond the human audibility limit. This is the reason why Galton's whistles are used to train dogs for patrol duty and reconnaissance operations.

Oscillations And Waves By K.R. Reddy, S. B. Badami, V. Balasubr

If the end correction for the wave extending outside the pipe is 'e', then the wavelength of the vibrating wave is given by

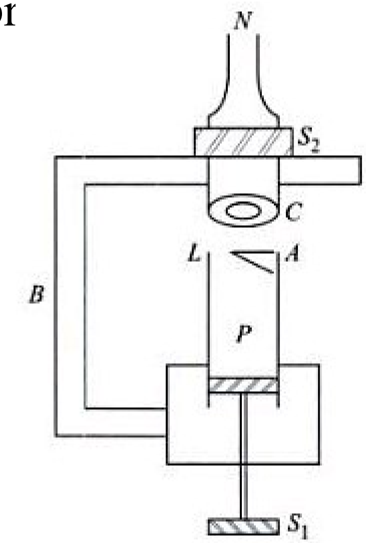
$$\frac{\lambda}{4} = (l+e)$$

$$\lambda = 4(l+e)$$

The frequency of the sound 'f', with a velocity 'v' is

$$f = \frac{v}{\lambda}$$

$$f = \frac{v}{4(l+e)}$$



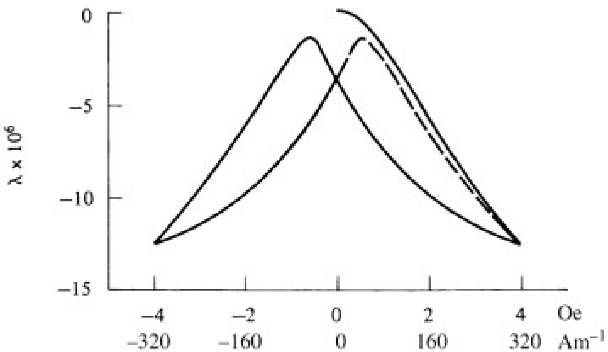
Galton whistle.

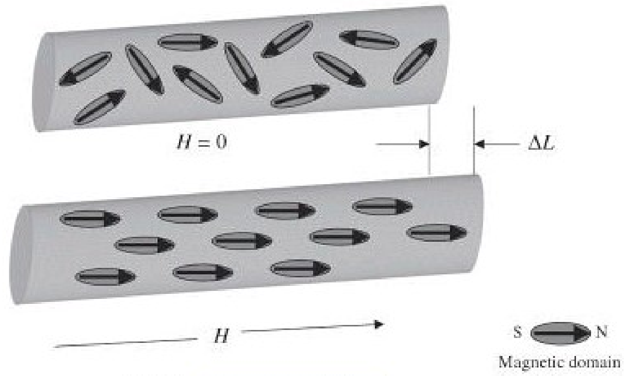
Ultrasonic Generation

Magnetostriction

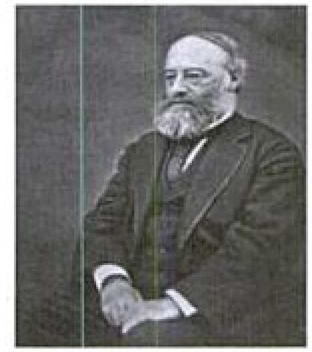
Discovered in 1842 by Joul

Nickel, cobalt, iron and their alloys





Positive magnetostriction



James Prescott Joule (1818–1889)

James Prescott Joule, an English physicist, studied the nature of heat, and discovered its relationship to mechanical work. The SI derived unit of energy, the joule, is named after him. He made observations on magnetostriction, and found the relationship between the current through a resistance and the heat dissipated, now called the Joule's law.

This process is non linear
Reversible

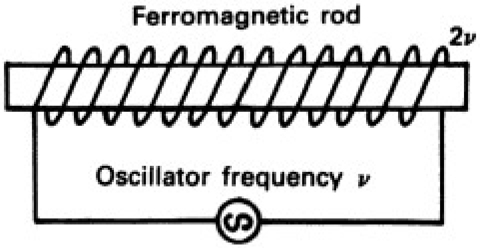
When field is reversed , no change in the direction of magnetostrictive strain
Butterfly loop
Material vibrates at twice the frequency of the field.
Example: humming sound in transformer

Positive Magnetostriction

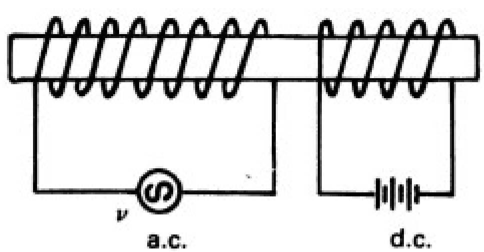
IRON

Negative Magnetostriction

Nickle



The magnetostriction frequency is 2ν when the applied a.c. frequency is ν.



By polarizing the field direction magnetostriction frequency is reduced to applied frequency

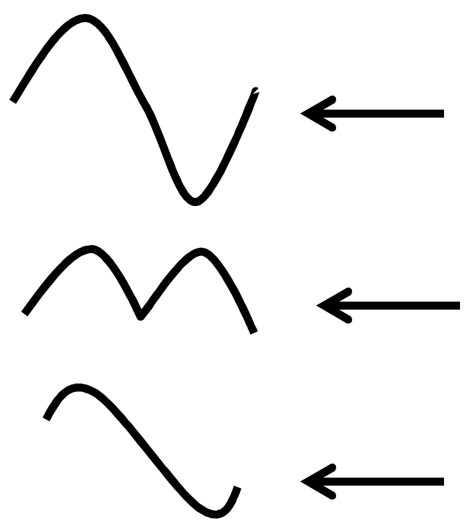
Oscillations And Waves By K.R. Reddy, S. B. Badami, V. Balasubramanian

Ultrasonic Generation

Magnetostriction

In the design of magnetostrictive transducer for real-time applications, the problem of the material straining in only one direction in the presence of both positive and negative currents is addressed by introducing a biasing field. The bias is usually accomplished either by placing a permanent magnet around the material or by introducing a DC bias field into the circuit. Due to the magnetic field from the permanent magnet, the material experiences an initial expansion or strain. The design size of the permanent magnet is suitably chosen so that the initial expansion is about one half the total expansion limit of the magnetostrictive material used. When the positive cycle of the AC current is presented, the field from the magnet and the field from the coil gets added, resulting in positive expansion of the material. When the negative cycle of the current is presented, the two fields cancel each other, and the material shrinks. Through the use of biasing, the actuator can be used to control the oscillating structures. If the use of the magnetostrictive actuator is limited to positive strain, a bias is not required for the application.

Mechatronics System Design: SI By Devdas Shetty, Richard A. Kolk



Input ac field by LC oscillator, ν

Magnetostriction frequency, 2 ν

Magnetostriction frequency, ν, after the application of polarizing field

Ultrasonic Generation

Magnetostriction

Major components

1. LC oscillator
2. Transistor or triode to make oscillator circuit

LC oscillator is tuned to match with the natural frequency of the magnetostrictive vibration of the rod of given dimension

(LC circuit) is set into oscillation with a frequency of vibration given by

$$f = \frac{1}{2\pi\sqrt{L_1C_1}}$$

The frequency of the ultrasonic waves produced is

$$f = \frac{1}{2l}\sqrt{\frac{Y}{\rho}}$$

By using oscillator circuit, oscillation in the tank circuit is maintained by positive feedback

Field applied by L1C1 make the rod into oscillation which induce opposite field in L2 and induced field is coupled to the input of the transistor or triode.

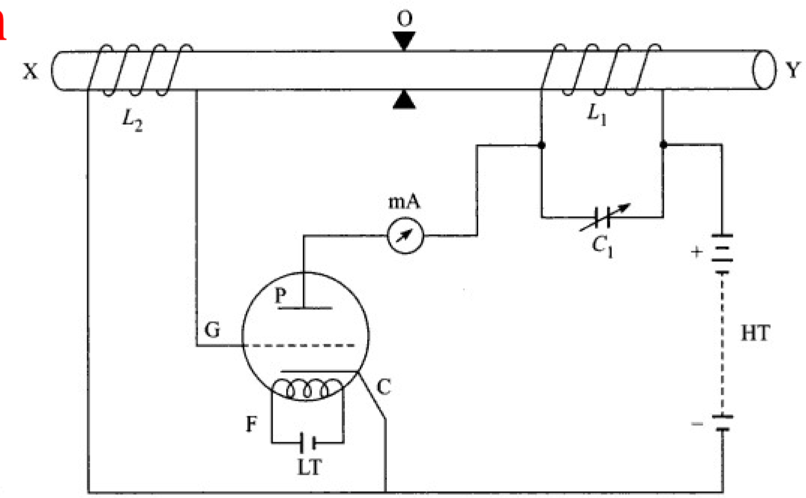
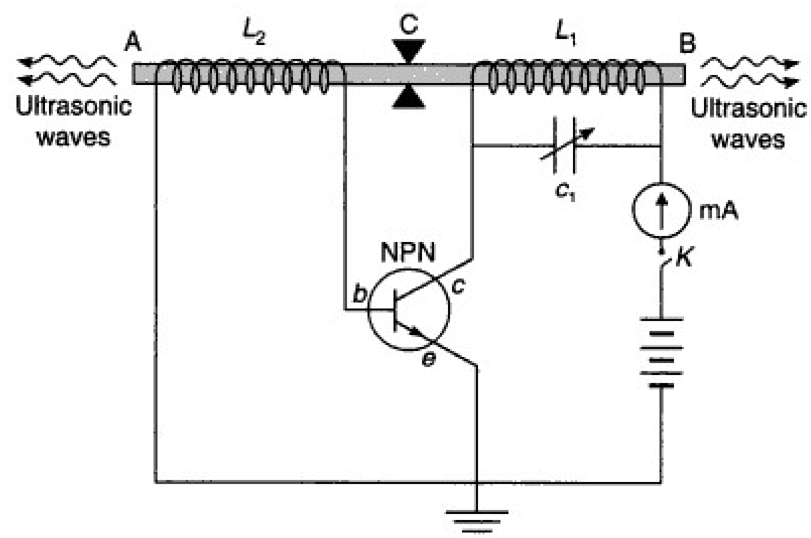
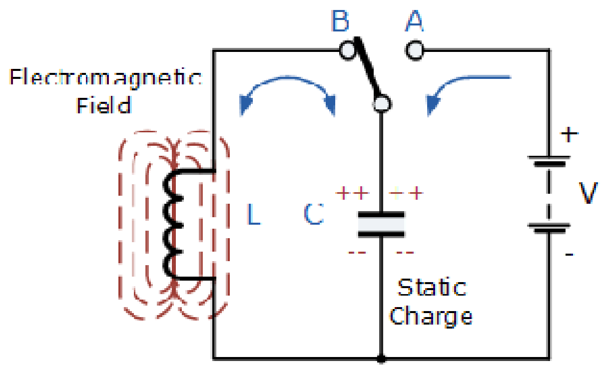


Figure 5.6 Magnetostriction oscillator.



Magnetostriction oscillator.

LC oscillator & Transistor amplifier



$$X_L = 2\pi f L \quad \text{and} \quad X_C = \frac{1}{2\pi f C}$$

$$\text{at resonance:} \quad X_L = X_C$$

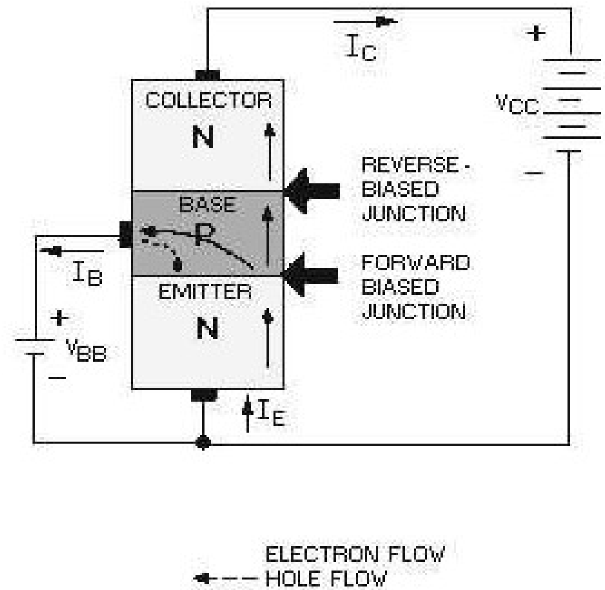
$$\therefore \; 2\pi f L = \frac{1}{2\pi f C}$$

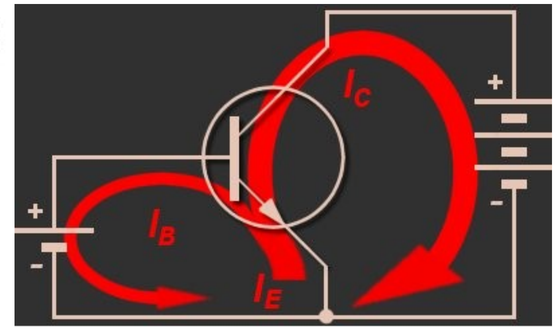
$$2\pi f^2 L = \frac{1}{2\pi C}$$

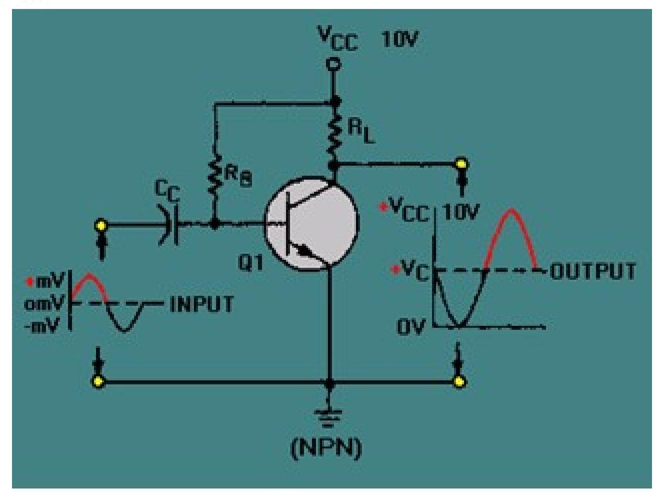
$$\therefore \; f^2 = \frac{1}{(2\pi)^2 LC}$$

$$f = \frac{\sqrt{1}}{\sqrt{(2\pi)^2 LC}}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$



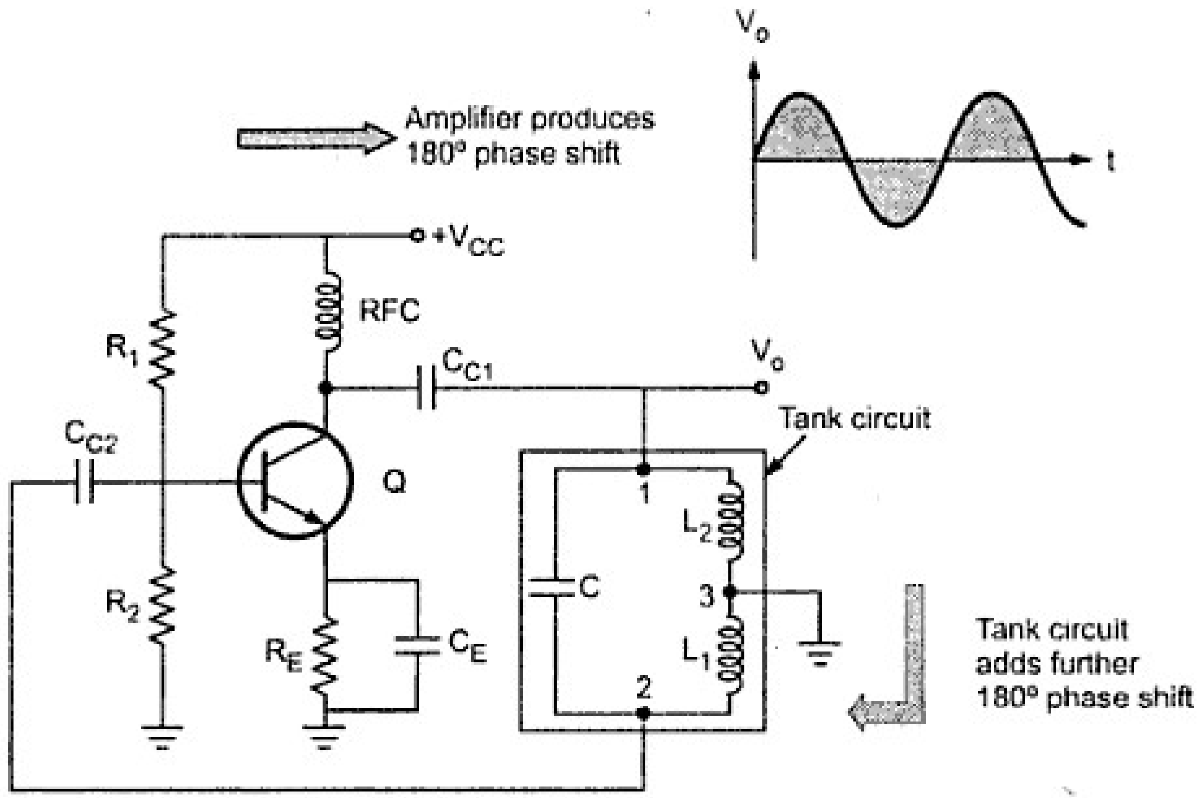




http://www.tpub.com/content/neets/14179/css/14179_70.htm

http://www.radartutorial.eu/21.semiconductors/hl19.en.html

HARTLEY oscillator



The resistances R_1 and R_2 are the biasing resistances. The RFC is the radio frequency choke. Its reactance value is very high for high frequencies, hence it can be treated as open circuit. While for d.c. conditions, the reactance is zero hence causes no problem for d.c. capacitors.

Hence due to RFC, the isolation between a.c. and d.c. operation is achieved. R_E is also a biasing circuit resistance and C_E is the emitter bypass capacitor. C_{C1} and C_{C2} are the coupling capacitor.

The common emitter amplifier provides a phase shift of 180°. As emitter is grounded, the base and the collector voltages are out of phase by 180°. As the centre of L_1 and L_2 is grounded, when upper end becomes positive, the lower becomes negative and viceversa. So the LC feedback network gives an additional phase shift of 180°, necessary to satisfy oscillation conditions.

HARTLEY oscillator

The fixed bias circuit is modified by attaching an external resistor to the emitter. This resistor introduces negative feedback that stabilizes the Q-point. From Kirchhoff's voltage law, the voltage across the base resistor is

$V_{Rb} = V_{CC} - I_e R_e - V_{be}$.

From Ohm's law, the base current is

$I_b = V_{Rb} / R_b$.

The way feedback controls the bias point is as follows. If V_{be} is held constant and temperature increases, emitter current increases. However, a larger I_e increases the emitter voltage $V_e = I_e R_e$, which in turn reduces the voltage V_{Rb} across the base resistor. A lower base-resistor voltage drop reduces the base current, which results in less collector current

Ultrasonic Generation

Magnetostriction

(d) Advantages

1. Using this method, the ultrasonic waves having frequency up to 300 kHz can be produced.
2. The construction of the oscillator circuit is very simple.
3. The cost of construction is low.

(e) Drawbacks

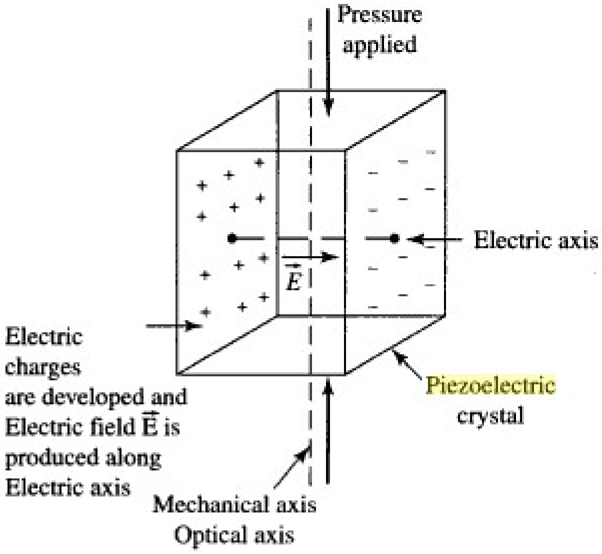
1. The output frequency is affected by temperature.
2. Since the frequency of vibration depends on the length of the rod, different ferromagnetic rod has to be used to produce different frequencies.
3. It is not possible to produce ultrasonic frequency higher than 300 kHz using this method.
4. The breadth of the resonance curve is large because the variation of the elastic constant. So it is not possible to produce stable and single output frequency.

Ultrasonic Generation

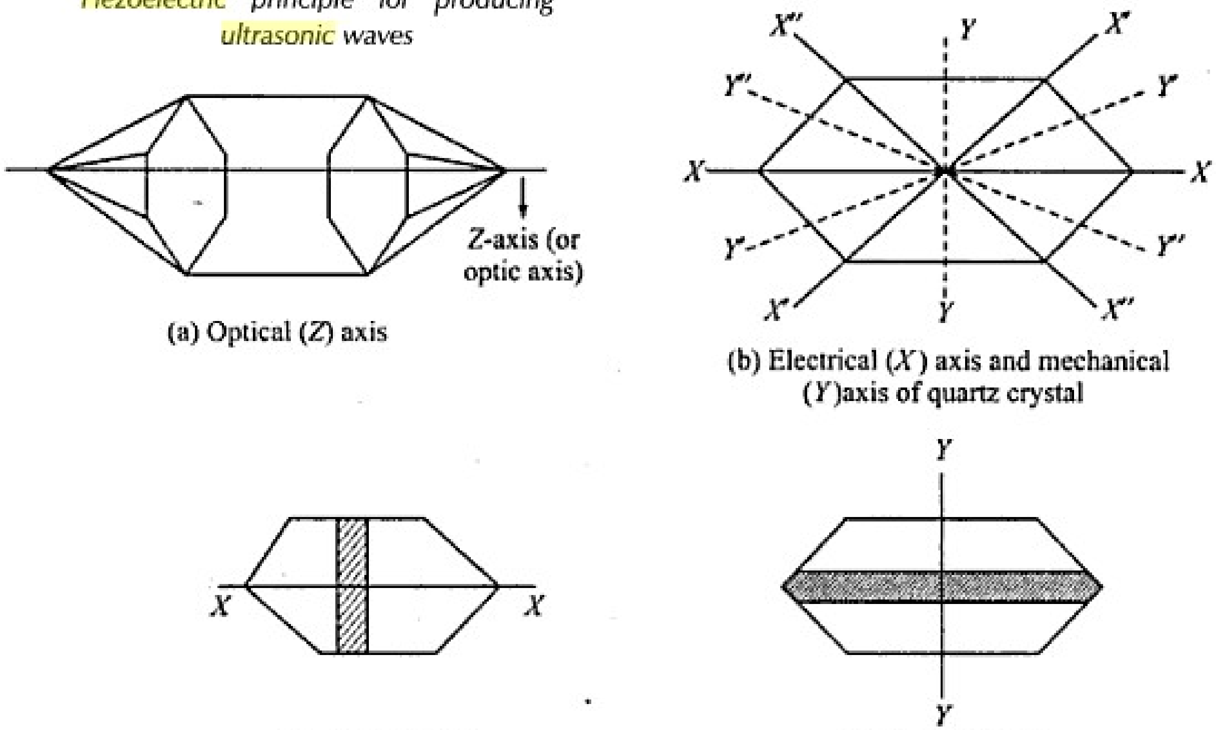
Piezoelectric effect

Discovered in 1880 by two brothers Pierre and Jacques curie

Rhombohedra crystal structure



Piezoelectric principle for producing ultrasonic waves



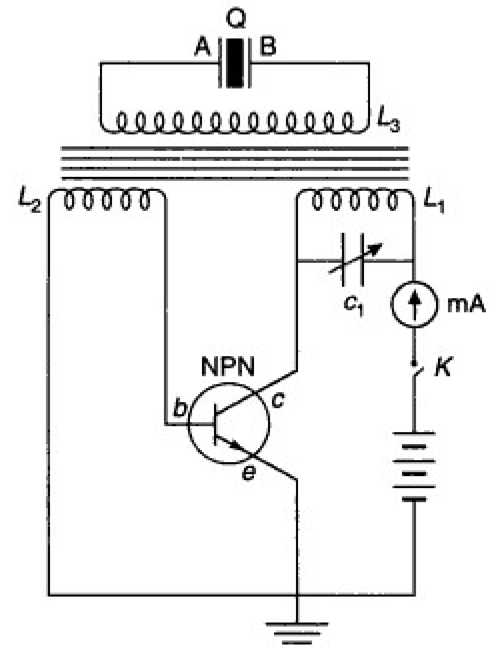
(a) Optical (Z) axis

(b) Electrical (X) axis and mechanical (Y) axis of quartz crystal

(c) X-cut crystal

(d) Y-cut crystal

Quartz crystal.



Piezoelectric oscillator.

$$f = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

$$f_1 = \frac{p}{2t}\sqrt{\frac{Y}{\rho}}$$

Piezoelectric effect

(d) Advantages

1. The maximum frequency of the ultrasonic wave produced using this method is 500 MHz.
2. The output frequency is independent of temperature and humidity.
3. A stable and constant output frequency is produced because the breadth of the resonance curve is small.
4. It is more efficient than magnetostriction oscillator.

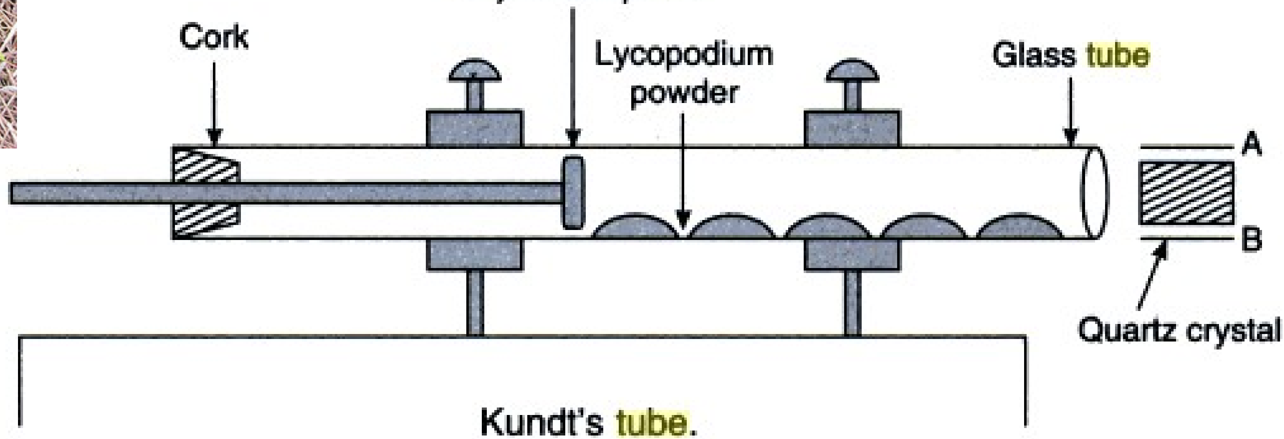
(e) Drawbacks

1. The piezoelectric oscillator is costly.
2. The cutting and shaping of the piezoelectric crystal is difficult.

Lycopodiopsida

Ultrasonic wave detection

KUNDT'S TUBE



Kundt's tube.

The distance between any two nodal or antinodal points is measured and hence the wavelength of the ultrasonic wave (λ_0) is determined using the relation,

$$\lambda_0 = 2d$$

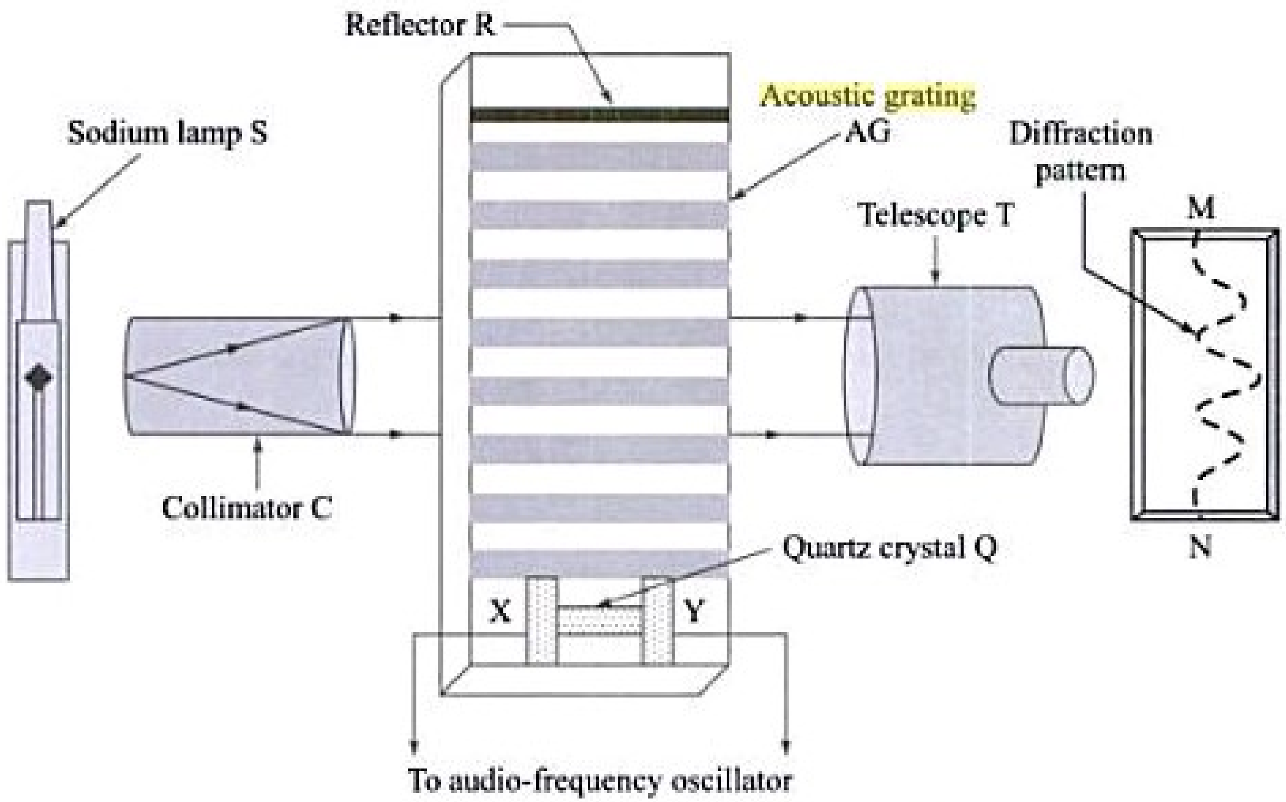
where d is the distance between any two adjacent nodals or antinodal points. By measuring the wavelength of the ultrasonic wave, its velocity is determined using the relation,

$$v = \lambda f$$

where λ is the wavelength and f is the frequency of the ultrasonic waves.

Acoustic Grating

The acoustic grating is based on the principle of diffraction of light by ultrasonic waves passing through a liquid. This phenomenon was discovered by Debye and Sears in 1932. When ultrasonic waves are propagated in a liquid, the density of liquid varies from layer to layer due to periodic variation of pressure. Hence the liquid behaves like a diffraction grating. Such a grating is known as acoustic grating as shown in Figure



Experimental set-up of acoustic grating.

$$d \sin \theta_n = n \lambda \qquad (1)$$

where n = 0, 1, 2, 3, ... is the order of diffraction, λ is the wavelength of light used and d is the distance between two adjacent nodal or anti-nodal planes.

Knowing n, θ_n and λ, the value of d can be calculated from eqn. (1). If λ_u is the wavelength of the ultrasonic waves through the medium, then

$$d = \lambda_u/2$$

$$\text{or} \qquad \lambda_u = 2d \qquad (2)$$

If the resonant frequency of the Piezo-electric oscillator is N, then the velocity of ultrasonic wave is given by

$$v = f \lambda_u = 2fd \qquad (3)$$

This method is useful in measuring the velocity of ultrasonic waves through liquids and gases at various temperatures. From these measurements, many parameters of the liquid such as free volume, compressibility, etc., can be calculated.

SONAR

Environmental Impact Statement

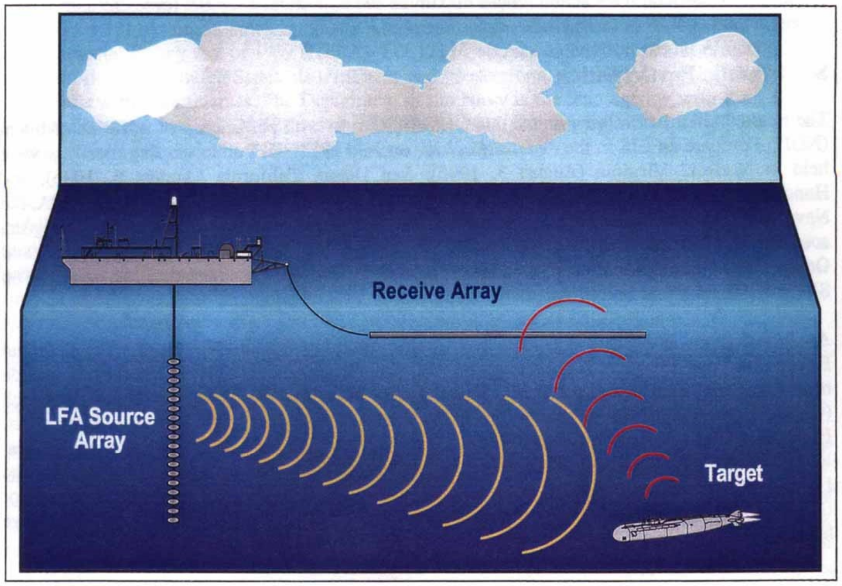
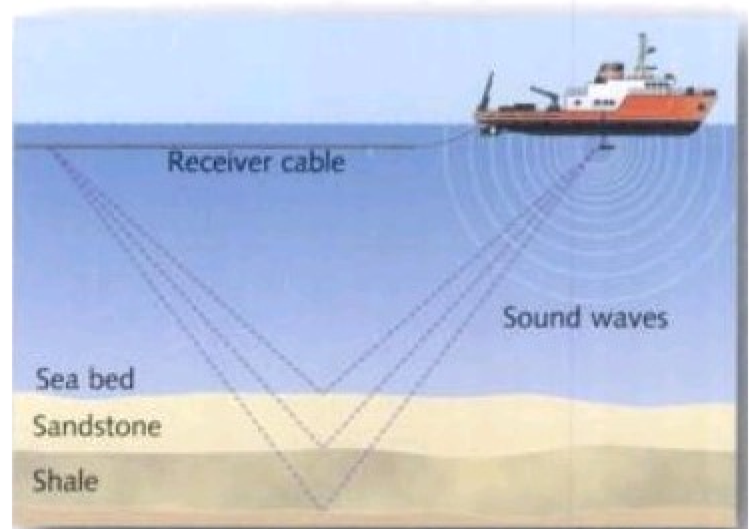


Figure S-2. SURTASS LFA Sonar System.



▲ Seismic surveying can detect different rock layers at sea.

Suppose T is the time interval between the transmission of the ultrasonic wave and receipt of the echo and v the velocity of sound waves through sea water, then the depth of the sea is given by

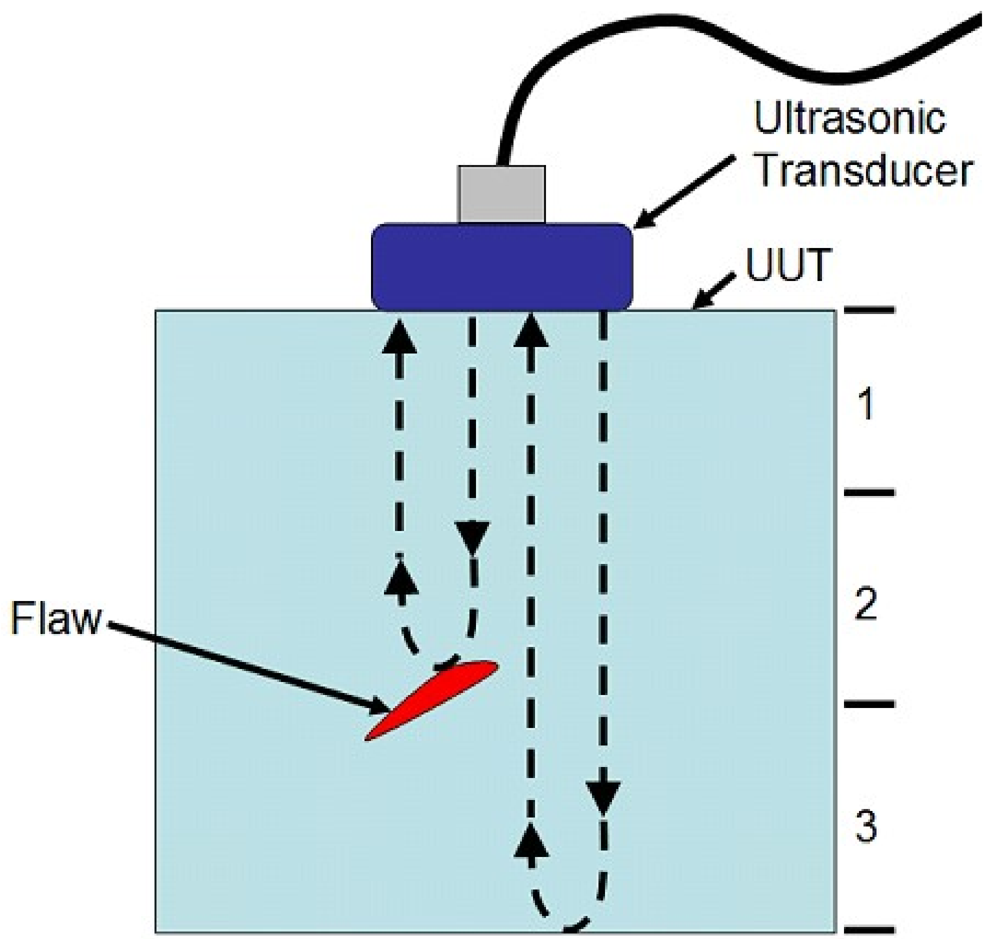
$$2d = vT \qquad d = \frac{v \times T}{2}$$

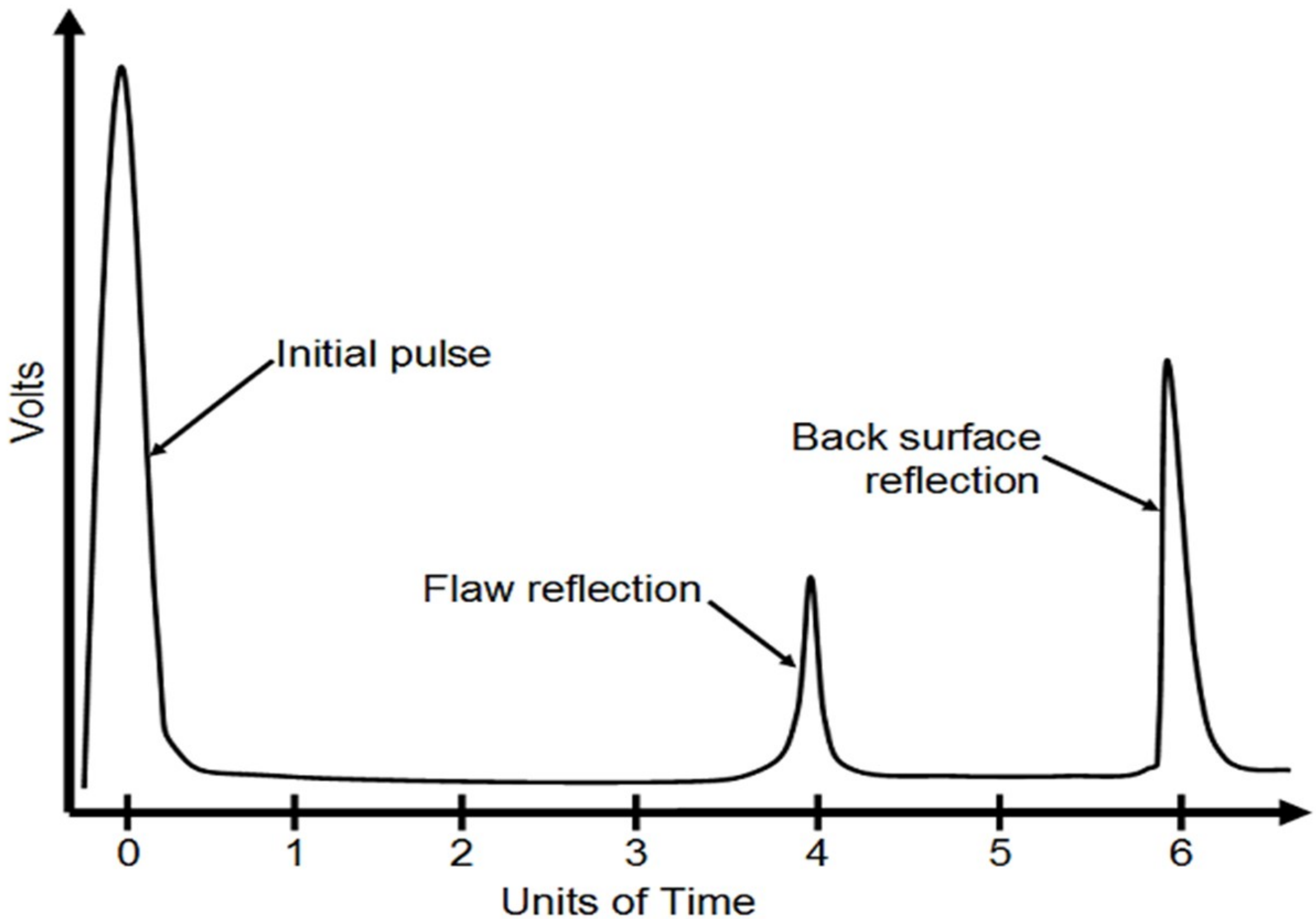
Ultrasonic NDT

Principle:

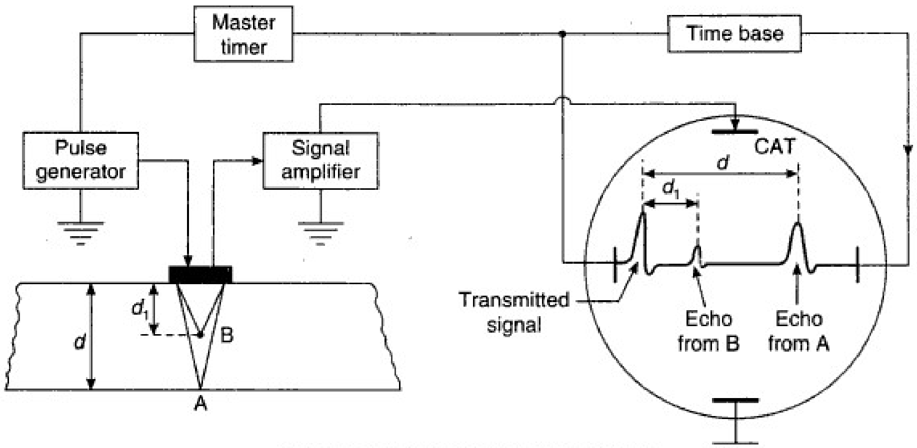
Whenever there is a change in the medium, the ultrasonic sound waves will be reflected.

Non-Destructive testing

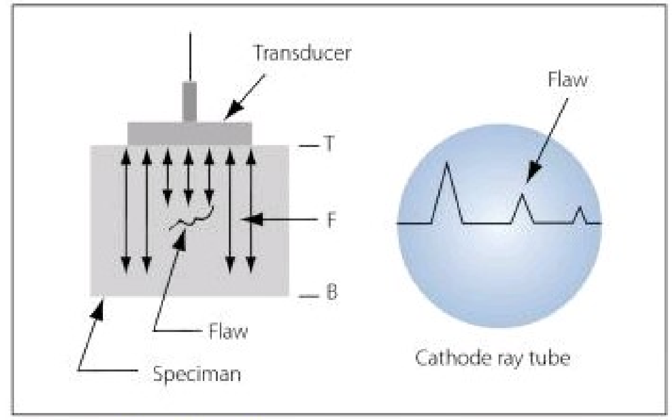



Initial pulse
Volts
Back surface
reflection
Flaw reflection
0
1
2
3
4
5
6
Units of Time

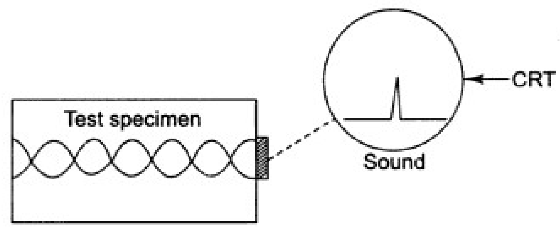
Ultrasonic flaw detection
Non destructive testing (NDT)



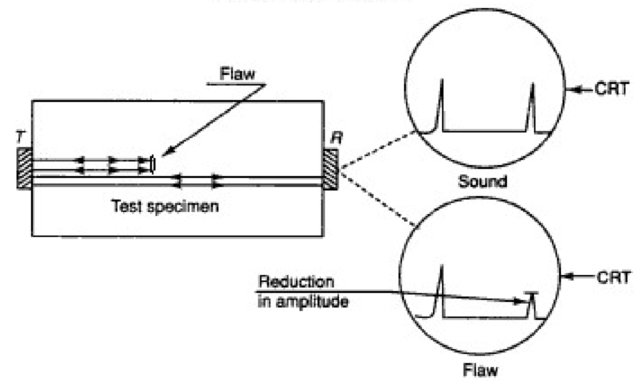
Non-destructive testing of specimen.



Pulse-echo display in relationship to flaw detection.



Resonance System



Through Transmission System

Since resonance can occur at any of the harmonic frequencies and the difference between any two adjacent harmonies gives the fundamental frequency, the following relationship is used to calculate thickness.

$$t = \frac{V}{2(f_{n+1} - f_n)}$$

where f_{n+1} = resonant frequency at the $(n+1)^{th}$ harmonic and f_n = resonant frequency at the n^{th} harmonic.

(a) Advantages of ultrasonic NDT

1. The ultrasonic testing can be made from any accessible surface.
2. The ultrasonic test can be made in a small specimen.
3. Ultrasonic equipment is compact and portable.
4. The testing provides result immediately. It should be interpreted carefully and decision should be taken accordingly.
5. It is one of the cheapest methods.
6. Permanent records can be maintained.

(b) Drawbacks of ultrasonic NDT

1. The skilled operators are needed to interpret the results.
2. Irregular shape and rough specimen cannot be studied.
3. Flaw estimation requires some standard specimen.

Ultrasonic Scanning

- The principle, construction and working are same as ultrasonic flaw detector.

- Based on the position of the transducer and the output displayed in CRO, we can classify scanning methods into 3 types.

- A Scan – Amplitude mode display
- B Scan- Brightness mode display
- C Scan or T-M Scan [Time Motion mode]

A-Scan is like looking at the screen with range/ distance on the X-axis and Gain/ Amplitude on Y-axis.

B-Scan is like a cross sectional view. Here, Range / distance is on the top of the screen, and backwall is at the bottom of the screen. It has a problem of Shadow effect.

C -Scan is like a top view. Depth is not seen in this view.

Scanning - Introduction

- Any discontinuity in the medium of propagation of an ultrasonic pulse gives rise to back-reflection which travels back to the input and is called the echo of the launched pulse.

- Ultrasonic pulse-echo data therefore comprises of (i) time elapsed between the launch of the pulse and the received echo and (ii)intensity /energy of the received echo.

- There are different ways in which this data can be presented for visualization/measurement. The three most common formats are known in the NDT(Non-Destructive Testing) world as A-scan, B-scan and C-scan presentations.

- Each presentation mode provides a different way of looking at and evaluating the region of material being inspected. Modern computerized ultrasonic scanning systems can display data in all three presentation forms simultaneously.

A- Scan [Amplitude mode display]

A display in which the received pulse amplitude is represented as displacement along one axis (usually the y-axis) and the travel time of the ultrasonic pulse is represented as a displacement along the other axis (usually the x-axis).

A-Scan

- In the A-scan presentation, the depth from which the reflection is obtained can be determined by the position of the signal on the horizontal sweep.
- Let us look at the sample piece with discontinuities as indicated in the figure 1 given below at B and C.
- Let the piece have a different depth, A in the initial region when compared to the rest.

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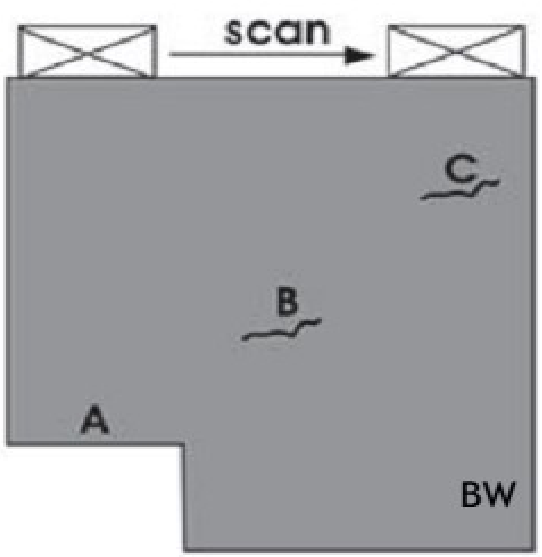
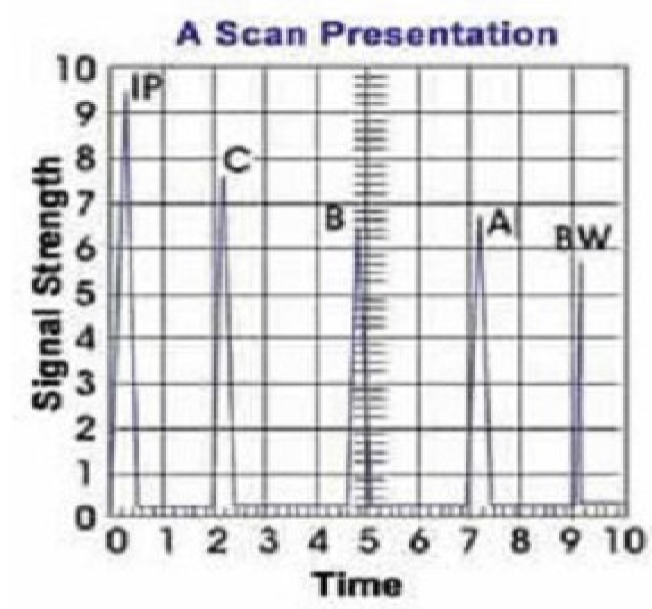
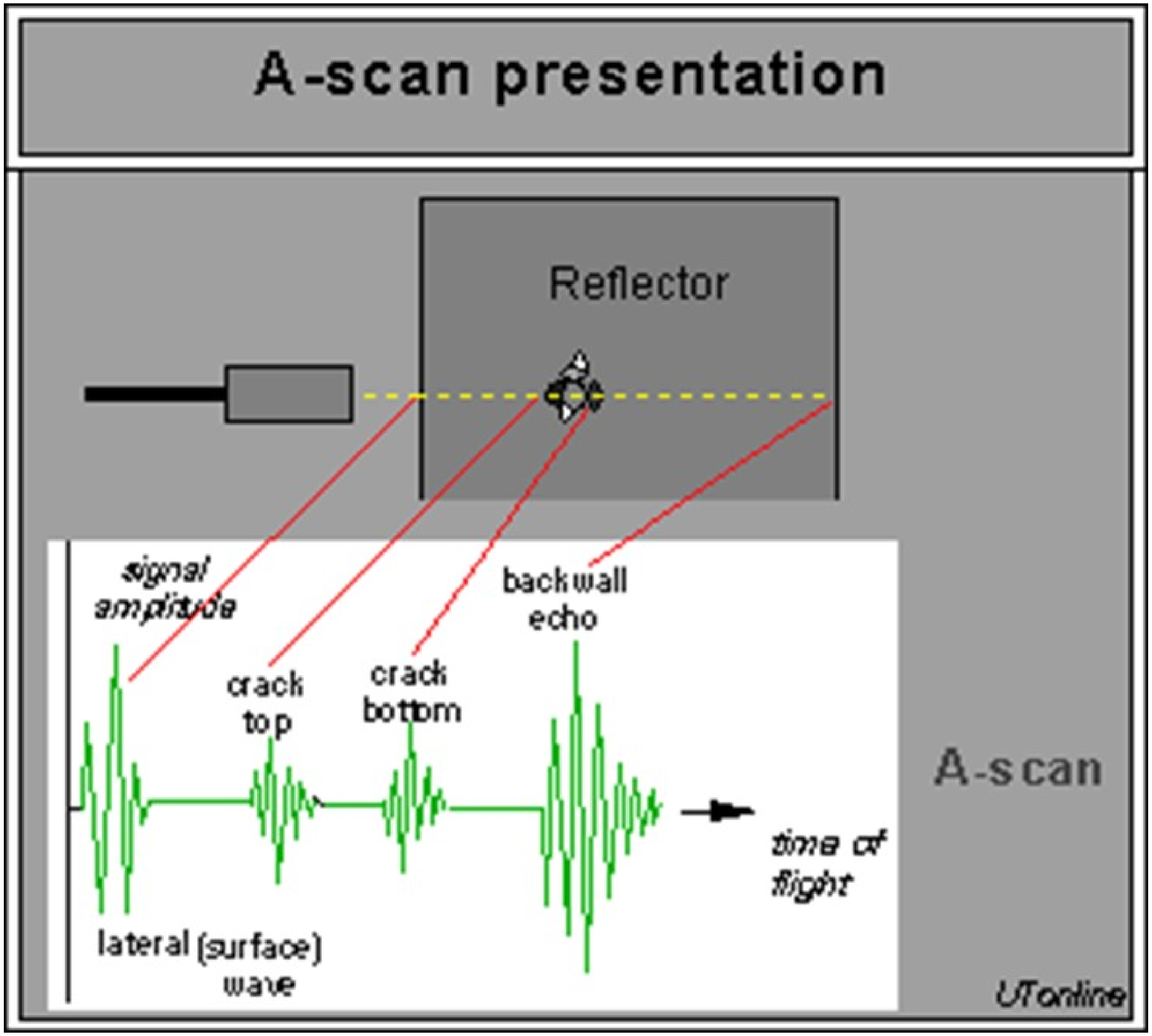


Fig 1 Sample test piece

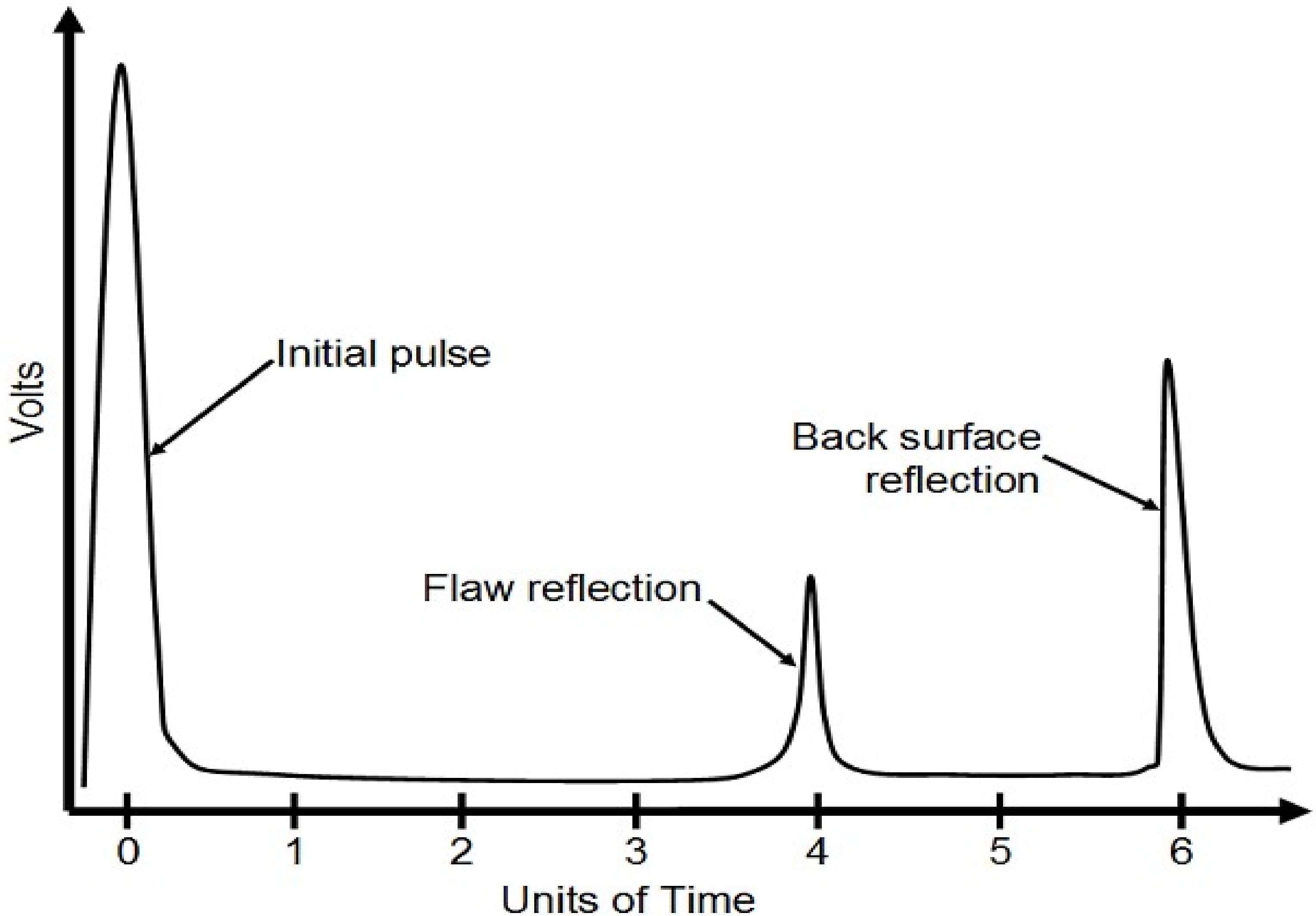


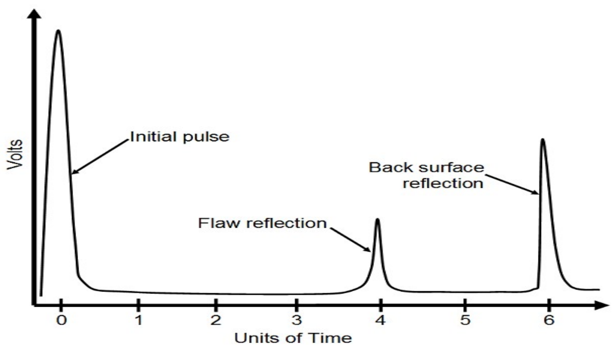
A-Scan



A-scan presentation
Reflector
signal amplitude
backwall echo
crack top
crack bottom
A-scan
time of flight
lateral (surface) wave
UTonline

A-Scan


Initial pulse
Volts
Back surface
reflection
Flaw reflection
0
1
2
3
4
5
6
Units of Time



- The height of the vertical spikes corresponds to the strength of the echo from the specimen.
- The position of the vertical spike from left to right along x-axis corresponds to the depth of penetration i.e., it gives the total time taken by the ultrasonic sound to travel from transmitter to the specimen and from the specimen to the receiver.

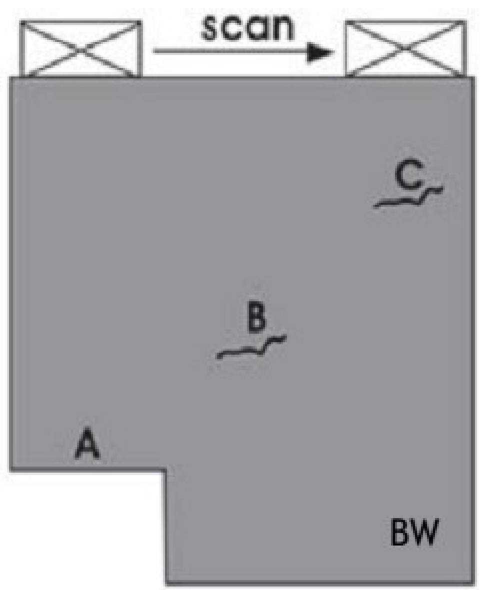
In the illustration of the A-scan presentation to the right, the initial pulse generated by the transducer is represented by the signal ***IP*,** which is near time zero. As the transducer is scanned along the surface of the part, four other signals are likely to appear at different times on the screen.

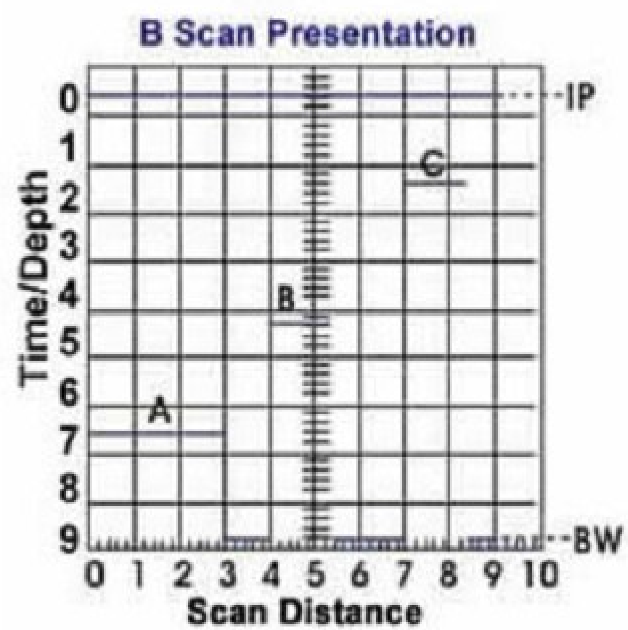
- When the transducer is in its far left position, only the ***IP*** signal and signal ***A***, the sound energy reflecting from surface ***A*,** will be seen on the trace.
- As the transducer is scanned to the right, a signal from the backwall ***BW*** will appear later in time, showing that the sound has traveled farther to reach this surface.
- When the transducer is over flaw ***B***, signal ***B*** will appear at a point on the time scale that is approximately halfway between the ***IP*** signal and the ***BW*** signal. Since the ***IP*** signal corresponds to the front surface of the material, this indicates that flaw ***B*** is about halfway between the front and back surfaces of the sample.
- When the transducer is moved over flaw ***C*,** signal ***C*** will appear earlier in time since the sound travel path is shorter and signal ***B*** will disappear since sound will no longer be reflecting from it.

If the input pulse is of sufficiently high energy and the size of discontinuity in the direction of propagation is small, then along with the signal from B or C , we may be able to observe the echo from the backwall BW also.

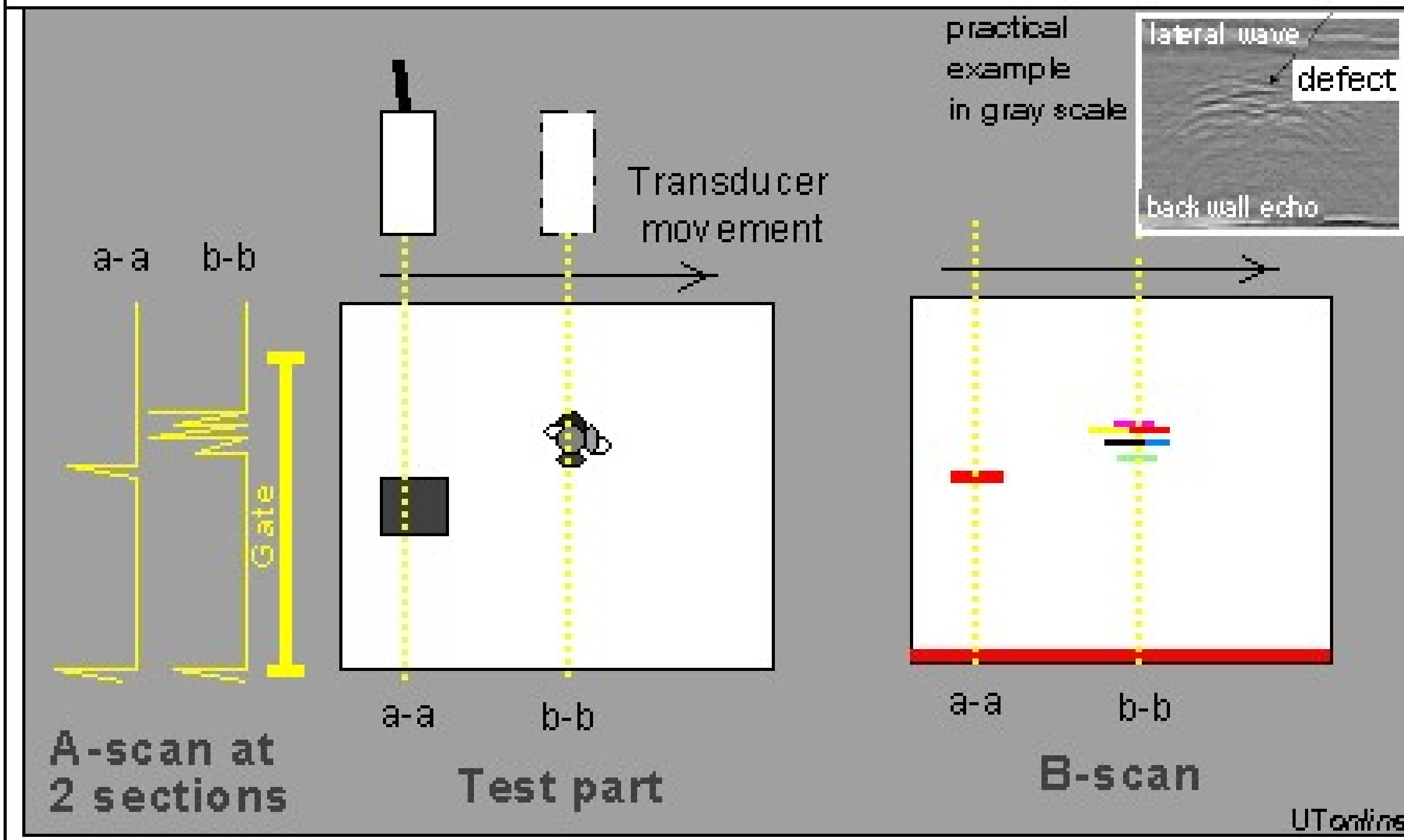
B-Mode

In the B-mode or **B**rightness mode of display, the **time-of-flight (travel time) of the sound energy is displayed along the vertical axis with zero of the time scale at the top left corner and the linear position of the transducer is displayed along the horizontal axis.** This format reveals the depth of the discontinuity and its approximate linear dimensions in the scan direction. The B-scan presentation is hence like a profile (cross-sectional) view of the test specimen.



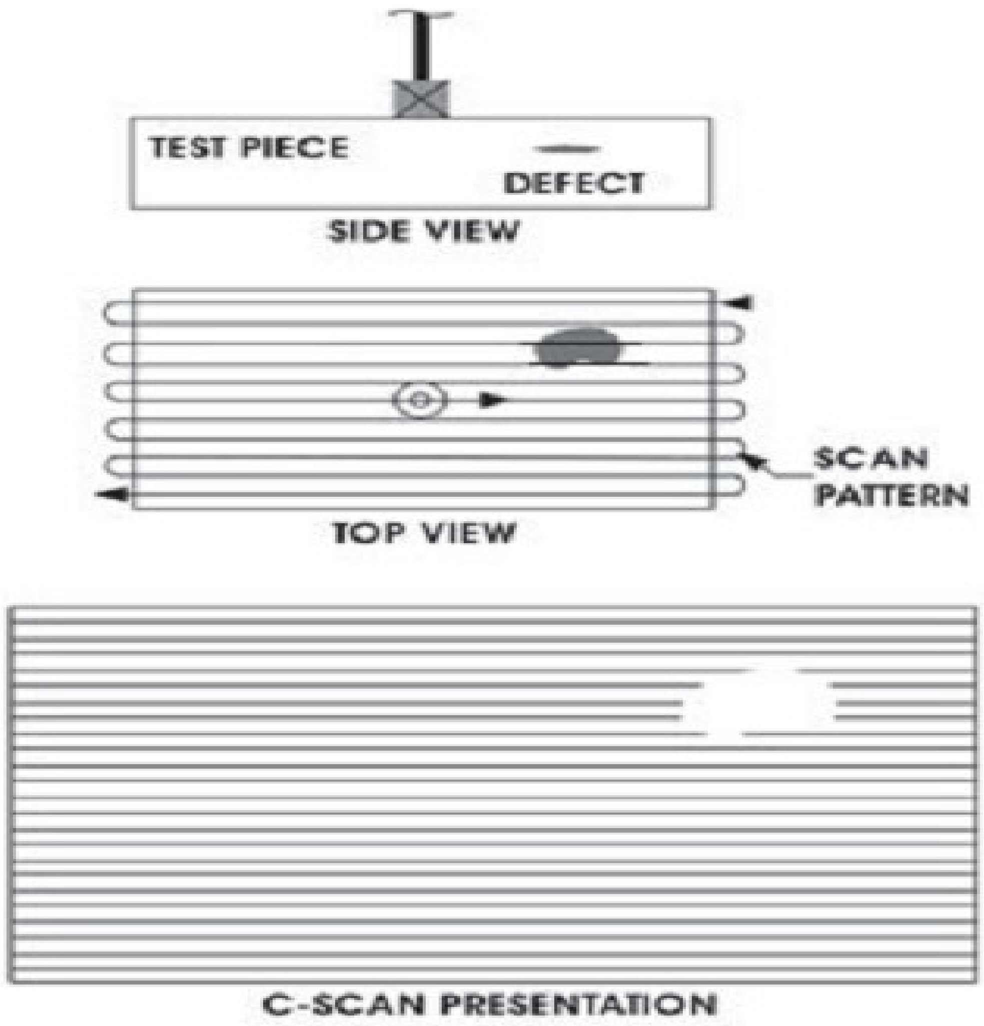


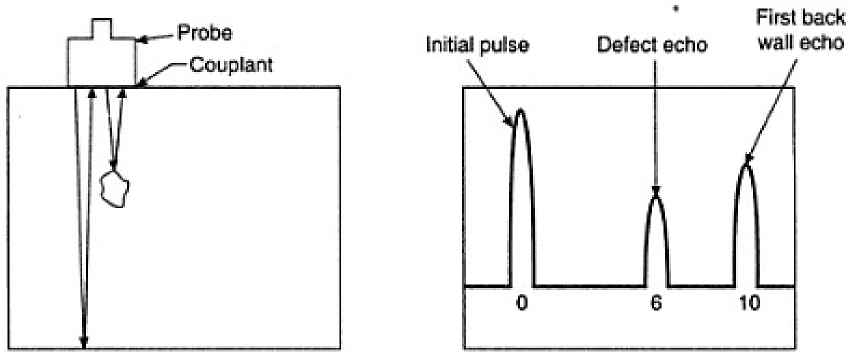
B-scan presentation



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, a point with appropriate brightness is produced on the B-scan. The gate is triggered by the sound reflecting from the backwall of the specimen and by smaller reflections from the discontinuities within the material. Thus each reflection is represented by a spot and the intensity or energy of the reflection in represented by the brightness of the spot.In the B-scan image above, line ***A*** is produced as the transducer is scanned over the reduced thickness portion of the specimen. When the transducer moves to the right of this section, the backwall line ***BW*** is produced. When the transducer is over flaws ***B*** and ***C***, lines that are similar to the length of the flaws and at similar depths within the material are drawn on the B-scan. It should be noted that a limitation to this display technique is that discontinuities may be masked by larger reflections near the surface.

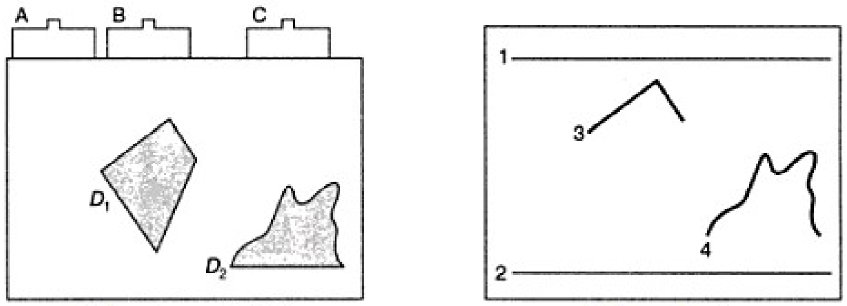
C-Scan


TEST PIECE
DEFECT
SIDE VIEW
SCAN
PATTERN
TOP VIEW
C-SCAN PRESENTATION



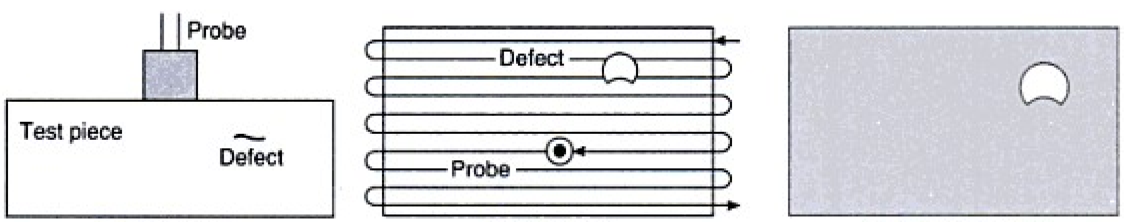
(a) Specimen under test (b) A-scan display

A-scan display.



(a) Specimen under test (b) B-scan display

B-scan display.



(a) Side view (b) Top view (c) C-scan display

C-scan display.

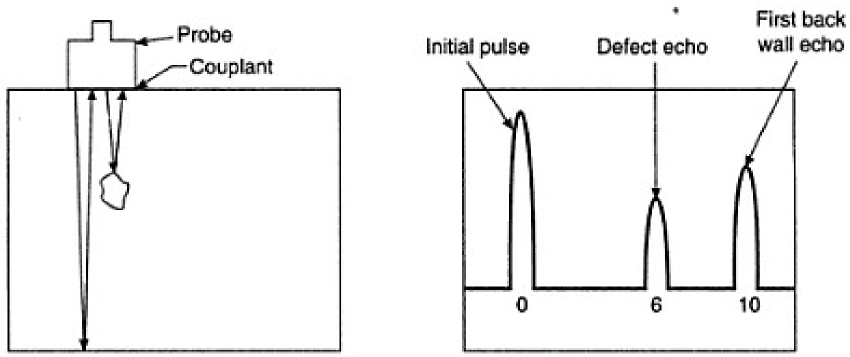
C-Scan

- The C-scan presentation provides a plan-type (2D) 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 produced with an automated data acquisition system, such as a computer controlled immersion 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.
- Planar images can be generated on flat parts by tracking data to X-Y position, or on cylindrical parts by tracking axial and angular position.

C-Scan

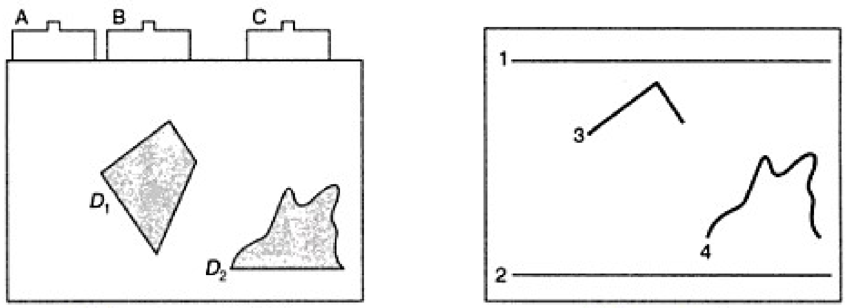
- For conventional ultrasound, a mechanical scanner with encoders is used to track the transducer's coordinates to the desired index resolution The relative signal amplitude or the time-of-flight is displayed as a shade of grey or a colour (b-mode representation) for each of the positions where data 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.
- Let us consider that the test piece has a discontinuity as shown in figure. The top view of the piece showing the direction of movement of the transducer i.e the scan pattern and the image constructed by plotting the brightness of the reflections at each of those scan points is also shown.

Again , it is to be noted that if the pulse strength is high and the depth of the discontinuity is small, then a 3D view of the discontinuity can also be obtained.



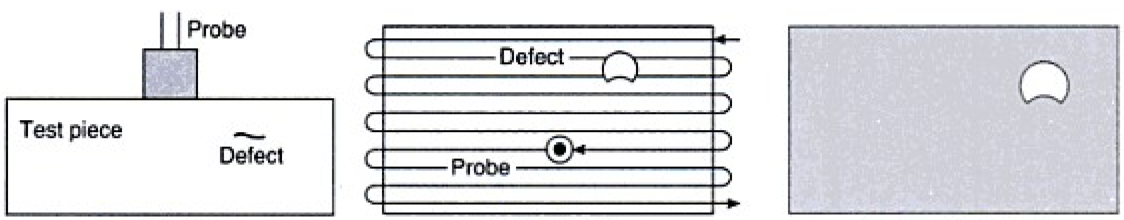
(a) Specimen under test (b) A-scan display

A-scan display.



(a) Specimen under test (b) B-scan display

B-scan display.



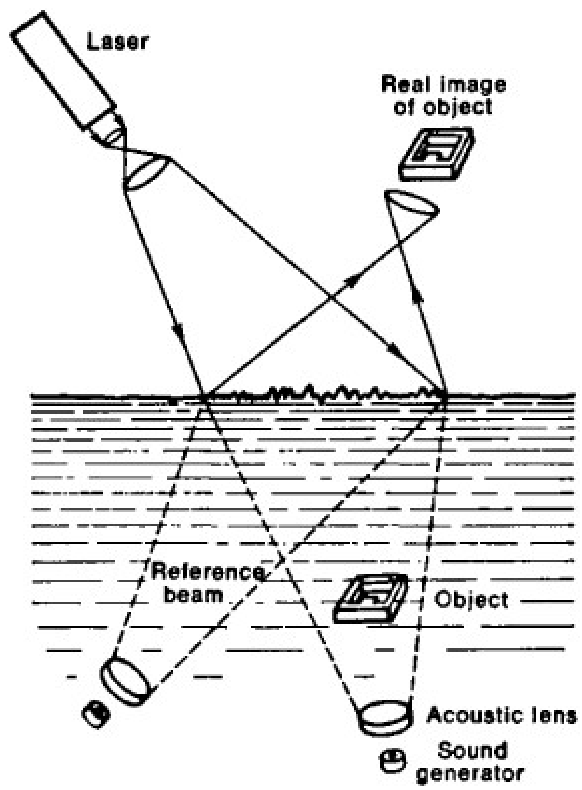
(a) Side view (b) Top view (c) C-scan display

C-scan display.

Ultrasound scanning

- Based on the principle of pulse echo method
- High frequencies sound waves produce echo which is used to detect tissue boundaries.
- The nature of sound wave travelling through tissues varies with density. It is used to construct the image
- It is a safest and a harm less method u
medical field.

Acoustic hologram



Other applications

Ultrasonic soldering:

1. mechanical vibrations remove the oxide layer and clean the surfaces to be soldered.
2. So soldering is done without flux.

Ultrasound drilling:

Used to drill holes in brittle materials like glass.

Ultrasound energy - make suspended abrasive materials (SiC or Boron carbide powder) beneath the cutting tool into vibration due to the bursting of cavitation bubbles.

Ultrasound welding:

20 kHz to 40 kHz signals are used.

Vibration produce heat at the joint interface which is kept at high pressure (2-15 MPa)

Melting at the interface causing welding

Advantage:

Fast, economical and easily automated and suited for mass production

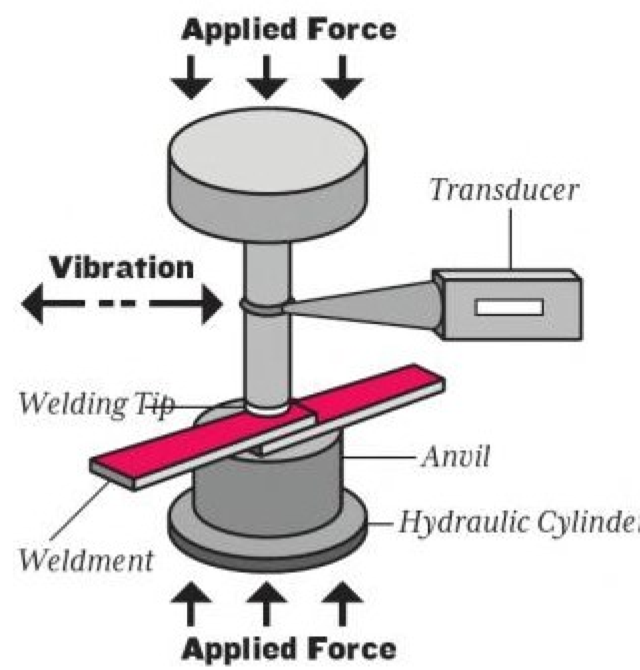
Clean (no fumes, no chemicals, no health hazard) and reliable weld in both polymer and metals at low operating temperature

High efficiency with large productivity with low cost

Disadvantage

Limited to the joining of thin materials

Ultrasonic vibration may damage the electronic components during welding. Choosing a correct frequency is important.



Handbook of Plastics Joining: A Practical Guide By Michael J. Troughton
Materials and Design: The Art and Science of Material Selection in Product ... By M. F. Ashby, Kara Johnson

Calculate the fundamental frequency of vibration when a quartz crystal of thickness 0.15 cm is vibrating at resonance. Given that Young's modulus is 7.9×10^{10} Nm^{-2} and its density is 2650 kg m^{-3}.

The frequency of vibration $f_1 = \frac{p}{2t}\sqrt{\frac{Y}{\rho}}$

Given data

Thickness of the quartz crystal = 0.15 cm

Young's modulus of quartz = 7.9×10^{10} N m^{-2}

Density of quartz = 2650 kg m^{-3}

Solution

The fundamental frequency of vibration

$$f = \frac{1}{2t}\sqrt{\frac{Y}{\rho}}$$

$$= \frac{1}{2 \times 0.15 \times 10^{-2}}\sqrt{\frac{7.9 \times 10^{10}}{2650}}$$

$$= 1.8199 \text{ MHz}$$

The fundamental frequency of vibration of the crystal is 1.8199 MHz.

Calculate the fundamental frequency and the first overtone emitted by a quartz crystal of thickness 1 mm in a piezoelectric oscillator. Given, Young's modulus for quartz $= 7.9 \times 10^{10}$ N m^{-2} and $\rho = 2650$ kg m^{-3}.

The frequency of vibration $f_1 = \frac{p}{2t}\sqrt{\frac{Y}{\rho}}$

The frequency of vibration

$$f_1 = \frac{p}{2t}\sqrt{\frac{Y}{\rho}}$$

For the fundamental frequency, $p = 1$ and for the first overtone, $p = 2$.

$$= \frac{1}{2 \times 1 \times 10^{-3}}\sqrt{\frac{7.9 \times 10^{10}}{2650}}$$

$$= 2.7299 \times 10^6 \text{ Hz}$$

The frequency of the first overtone

$$f_2 = \frac{p}{2t}\sqrt{\frac{Y}{\rho}}$$

$$= \frac{2}{2 \times 1 \times 10^{-3}}\sqrt{\frac{7.9 \times 10^{10}}{2650}}$$

$$= 5.459 \times 10^6 \text{ Hz}$$

The fundamental frequency of vibration of the crystal is 2.7299 MHz.
The frequency of the first overtone of the crystal is 5.459 MHz.

Determine the velocity of the ultrasonic wave produced by a piezoelectric oscillator. The density of quartz crystal is 2650 kg m^{-3} and the Young's modulus of quartz is 7.9×10^{10} N m^{-2}.

$$v = \sqrt{\frac{Y}{\rho}}$$

Given data

Young's modulus of quartz = 7.9×10^{10} N m^{-2}

Density of quartz = 2650 kg m^{-3}

Solution

The velocity of the ultrasonic waves

$$v = \sqrt{\frac{Y}{\rho}}$$

$$= \sqrt{\frac{7.9 \times 10^{10}}{2650}}$$

$$= 5459.97 \text{ m s}^{-1}$$

The velocity of the ultrasonic waves = 5459.97 m s^{-1}.

Calculate the velocity of the ultrasonic wave passing through an acoustic grating experiment using the following data: Wavelength of the light used is 589.3 nm, frequency of the ultrasonic transducer is 100 MHz, and the angle of diffraction in the first order is 2°15′.

$$2d \sin \theta = n\lambda \qquad \lambda_0 \sin \theta = n\lambda$$

$$2d = \lambda_0 \qquad v = \lambda_0 f$$

Given data

Wavelength of the light used, $\lambda = 589.3$ nm $= 5.893 \times 10^{-7}$ m

Frequency of the ultrasonic transducer = 100 MHz = 1×10^{8} Hz

Order of diffraction = 1

Angle of diffraction = 2°15′

Solution

The Bragg's equation is

$$2d \sin \theta = n\lambda$$

Substituting the values, we get

$$2d \sin 2°15' = 5.893 \times 10^{-7}$$

$$d = 7.505\ \mu\text{m}$$

The wavelength of the ultrasonic wave

$$\lambda = 2d = 2 \times 7.505 \times 10^{-6} = 1.501 \times 10^{-5}\ \text{m}$$

The velocity of the ultrasonic wave

$$v = f\lambda = 1 \times 10^{8} \times 1.501 \times 10^{-5}$$

$$= 1501\ \text{m s}^{-1}$$

The velocity of the ultrasonic wave = 1501 m s^{-1}.

Calculate the frequency of 40 mm length of pure iron rod. Given the density of pure iron is 7.25×10^3 kg/m^3 and its Young's modulus is 115×10^9 N/m^2. Can you use it in magnetostriction oscillator to produce ultrasonic waves?

$$f = \frac{1}{2l}\sqrt{\frac{E}{\rho}}$$

Solution: Length of the rod $l = 40$ mm $= 40 \times 10^{-3}$ m

We know that

$$f = \frac{1}{2l}\sqrt{\frac{E}{\rho}}$$

$$f = \frac{1}{2 \times 40 \times 10^{-3}}\sqrt{\frac{115 \times 10^9}{7.25 \times 10^3}}$$

$$= 49.784 \times 10^3 \text{ Hz}$$

$$= 49.784 \text{ kHz}$$

Since, its frequency is greater than audible range, it can be used to produce ultrasonic waves.

Given that the velocity of ultrasonic waves in sea water is equal to 1440 m/s. Find the depth of submerged submarine if an ultrasonic pulse reflected from the submarine is received 0.33 s after sending out ultrasonic waves.

$$v = \frac{h}{t/2}$$

Solution: We know that

$$v = \frac{h}{t/2} \quad \text{or} \quad h = \frac{vt}{2}$$

$$= 1440 \times \frac{0.33}{2}$$

$$= 237.6 \text{ m}$$