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Proudly Present

“ADVANCEMENTS IN NON-DESTRUCTIVE TESTING”

By Peter Roosevelt, GE Inspection Services

Wednesday, February 8, noon @ Shaker Ridge Country Club, 802 Albany Shaker Rd, Loudonville

This is a technical presentation on inspection tools, techniques, standards and codes. The presentation will include a discussion of the capability of ultrasonic scanning devices to evaluate the integrity of tank shells, piping and welds. GE Inspection Services is bringing some of their field equipment for us to see.

RSVP through February 6 by registering on-line at <http://awmaneny.org/>
or by emailing Heather Fariello, AWMA Secretary, awmaneny@gmail.com

Students \$10, Members \$20, Guests \$25, Annual (**calendar**) dues: Individual \$25 or Corporation \$150 (Corp representatives pay Member fees)

Upcoming Events

March 8: Status of DEC Air regulations, by Bob Stanton, NYSDEC

Ultrasonic Testing Basics



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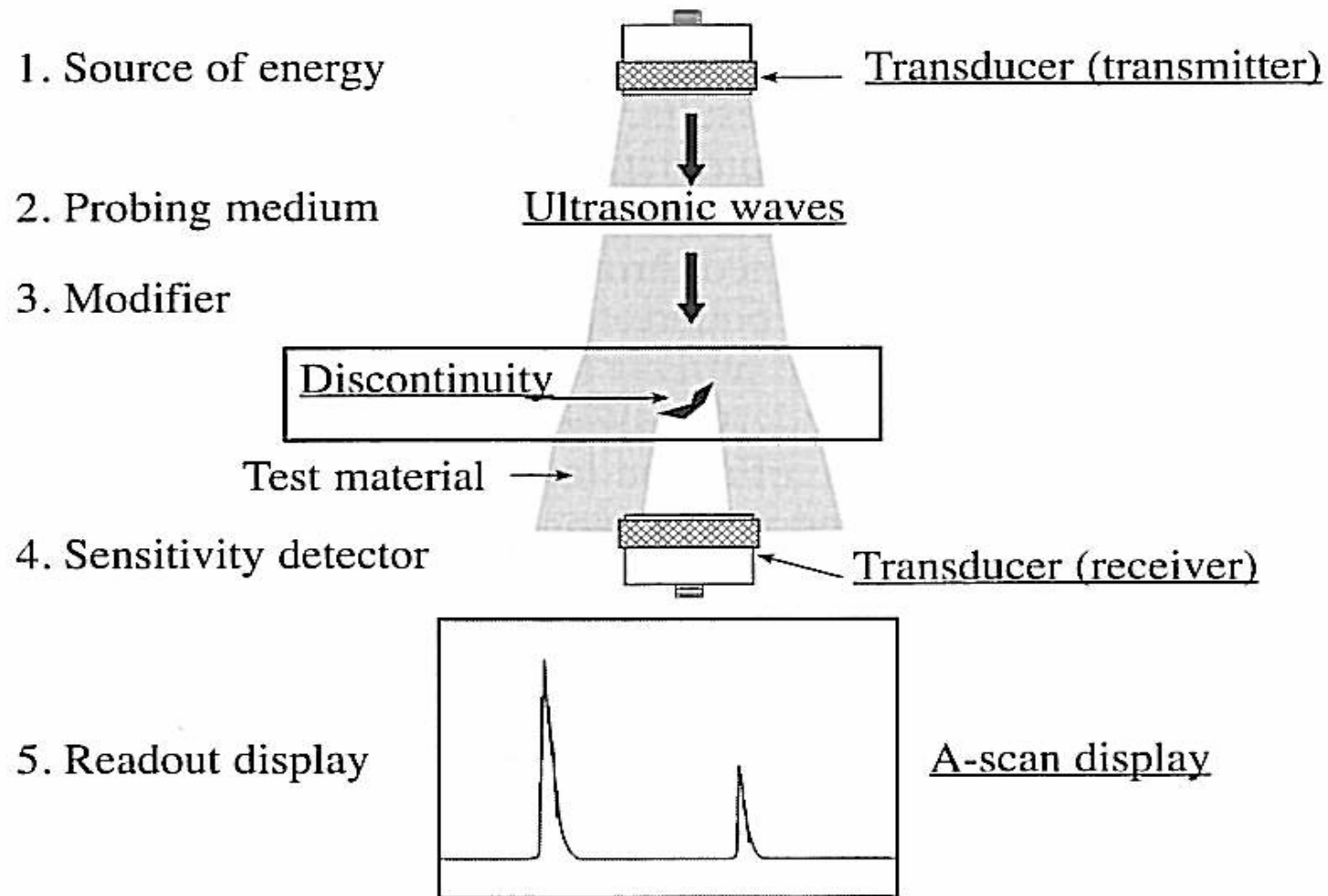


imagination at work

ULTRASONIC TESTING

- Review of Ultrasonic Testing Techniques
- Manufactured industrial materials sometimes have characteristics that adversely affect the product's intended use
- A small crack in steel used to build a bridge can grow to a size that reduces the steel's strength impairing safe operation
- Ultrasonic testing is one of the NDT methods used to detect cracks and other service threatening conditions
- These conditions can lead to premature failure

Figure 6.1: The five elements of nondestructive testing (numbered) used in an ultrasonic testing system (underlined).



ULTRASONIC TESTING

Figure 9.1: Ultrasonic test of parallel reflectors in products with parallel surfaces.

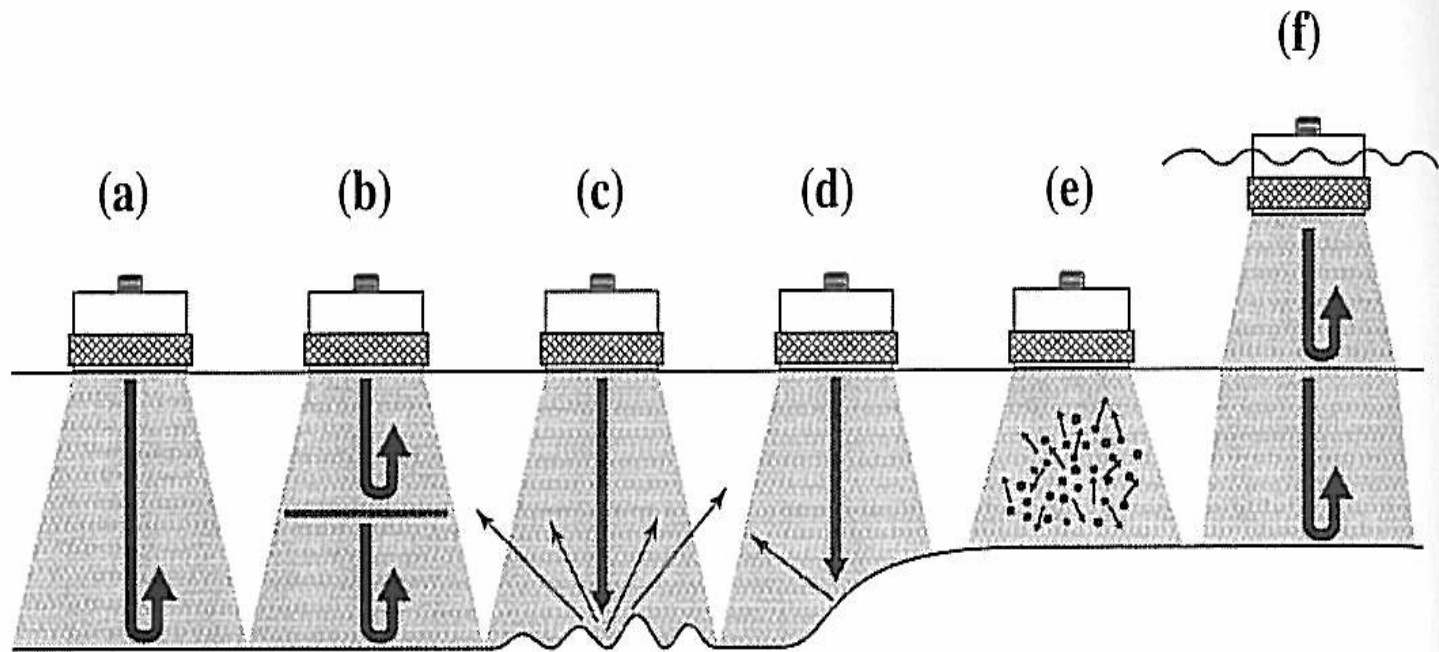


Figure 6.2: A-scan display for through transmission ultrasonic testing.

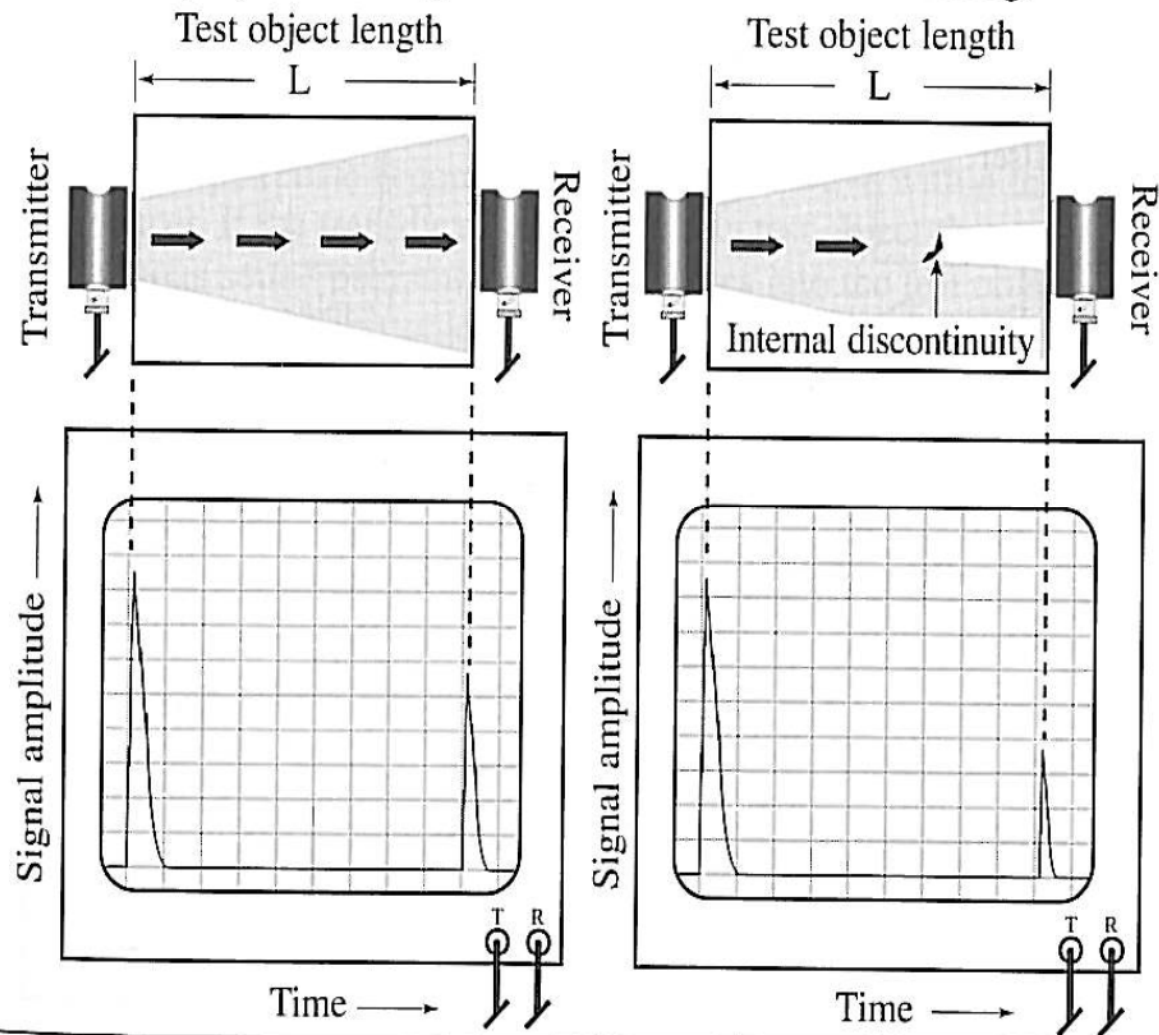
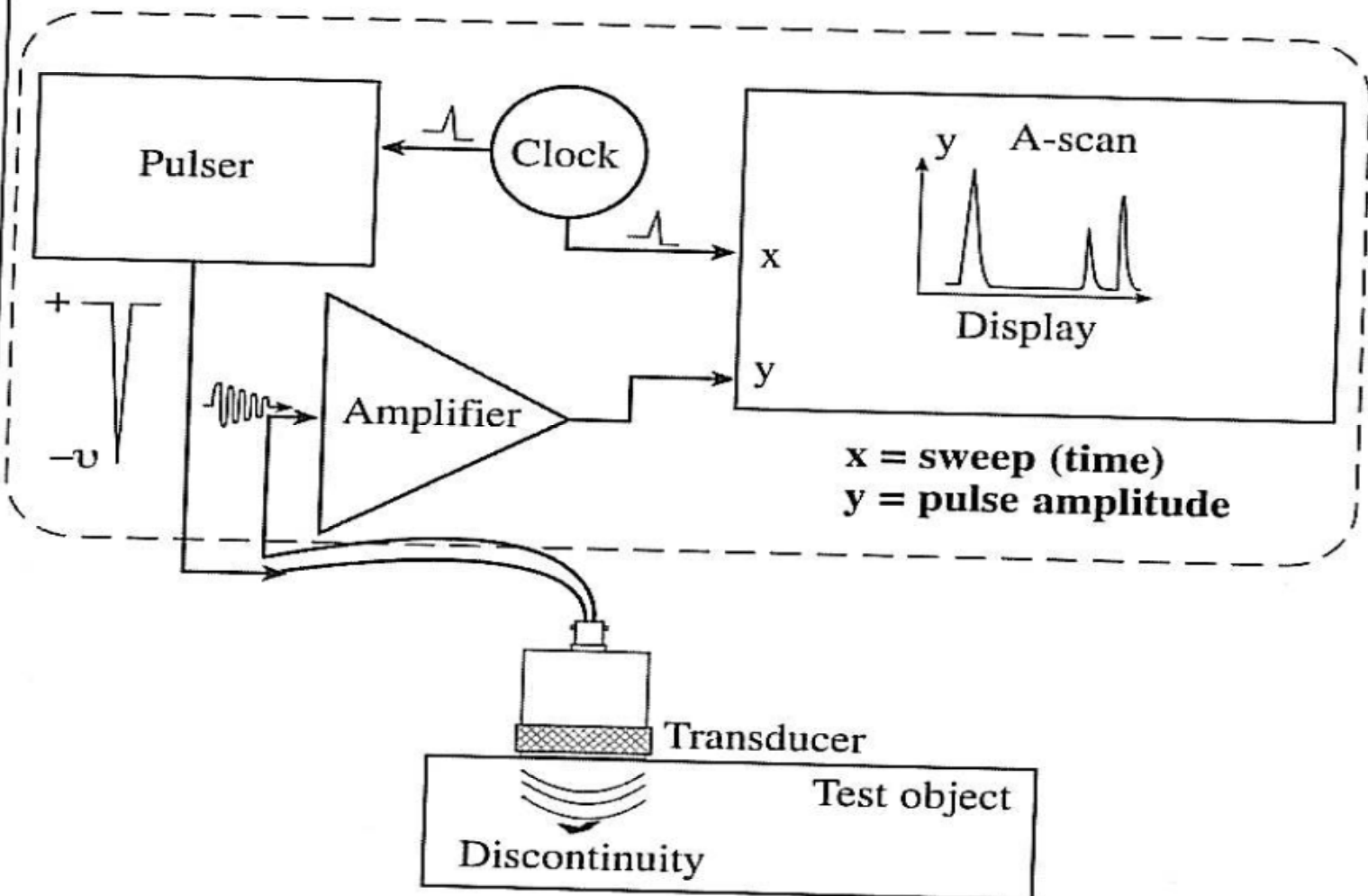


Figure 6.3: Components and interconnections of basic discontinuity detector.



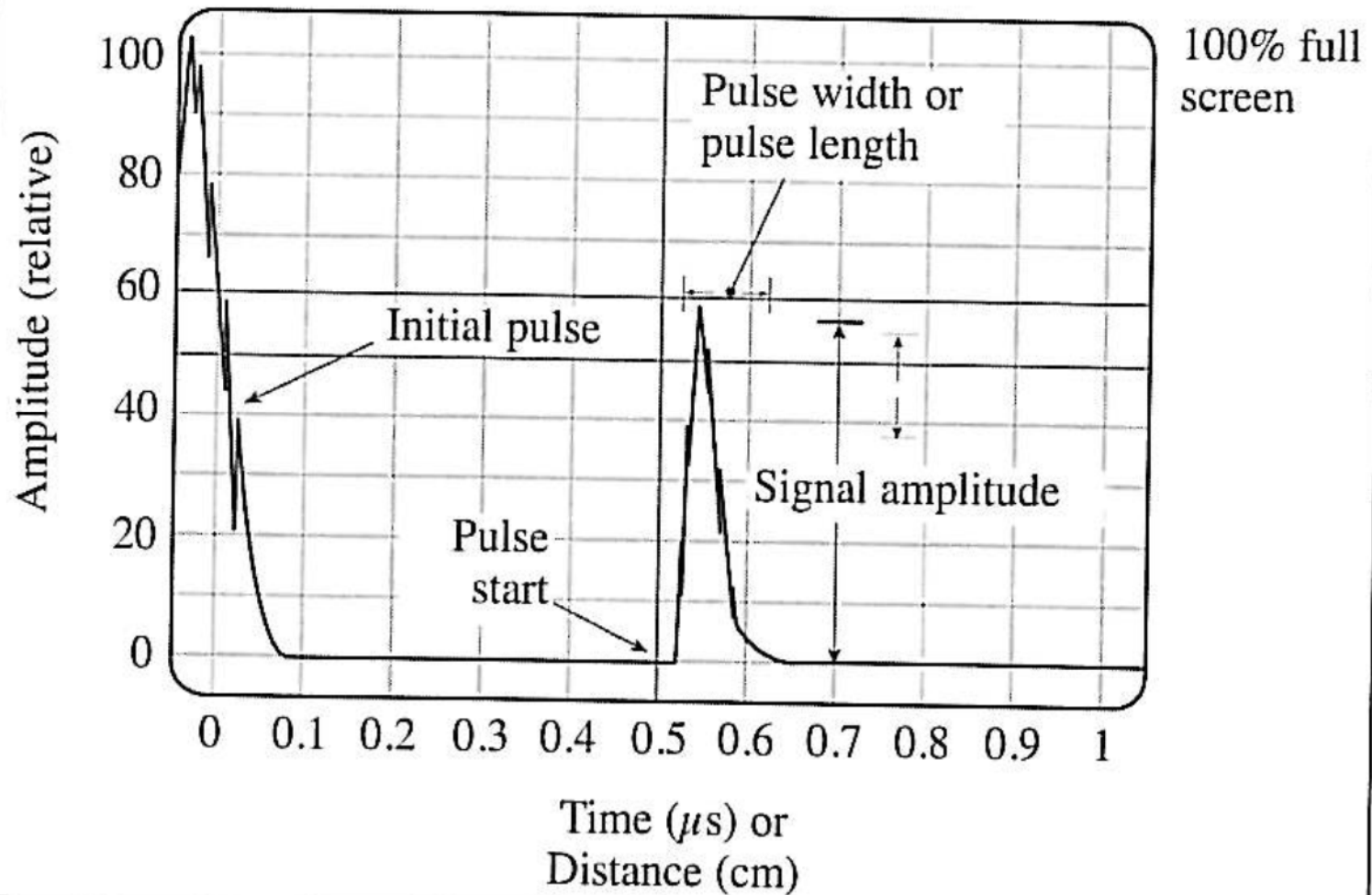
ULTRASONIC TESTING

- Display Unit
- Once echo signals have been amplified they are ready to be displayed in modes that provide information about the location and nature of echo surfaces within the test object
- Three general formats are commonly used:
 - A-scan
 - B-scan
 - C-scan

ULTRASONIC TESTING

- A-Scan
- Most common display is the A-scan
- The vertical axis represents signal strength
- The horizontal axis represents time and displays pulse signal amplitude variations with increasing time from a specific reference point
- The reference point at the left side of the display is usually the moment when the transducer is first excited with an electric pulse
- Sometimes called the *initial pulse* or *main bang*
- An alternate A-scan display called an *RF signal* presents the signal with both positive and negative peaks

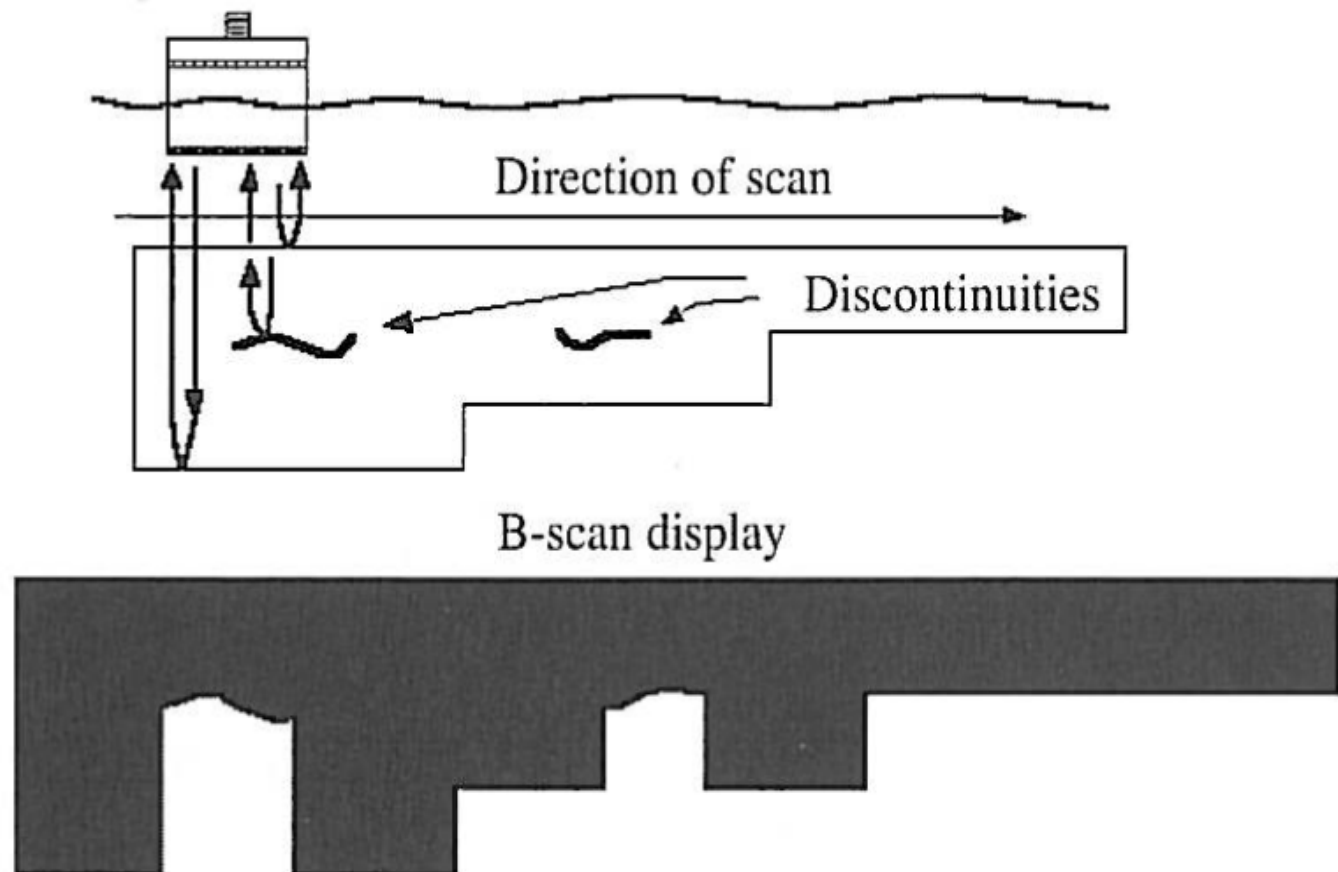
Figure 6.4: A-scan presentation.



ULTRASONIC TESTING

- B-Scan Display
- B-scan displays X-positional information in one direction and the time history of the horizontal scale of the A-scan in the other
- The result is a cross-sectional slice of the reflectors associated with the test object
- Since ultrasound reflects the strongest signal when it encounters a reflector surface at a right angle to its direction of propagation, the B-scan only shows horizontal components of the step wedge and internal reflectors
- Internal flaws reduce the strength of any ongoing ultrasonic waves
- A shadow of the internal reflector is often seen as a loss of signal in images of any subsequent reflecting surfaces
- Gaps can appear in the continuity of the lines representing the wedge item surfaces

Figure 6.5: B-scan representation of a step wedge with internal discontinuities.

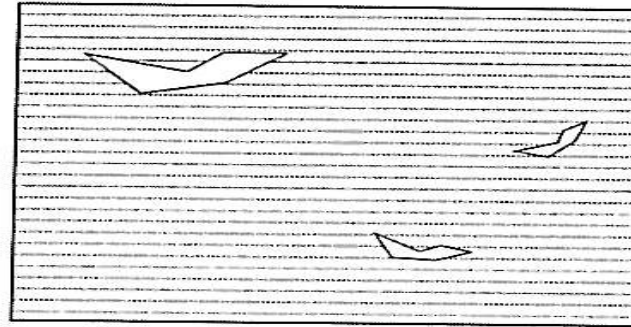


ULTRASONIC TESTING

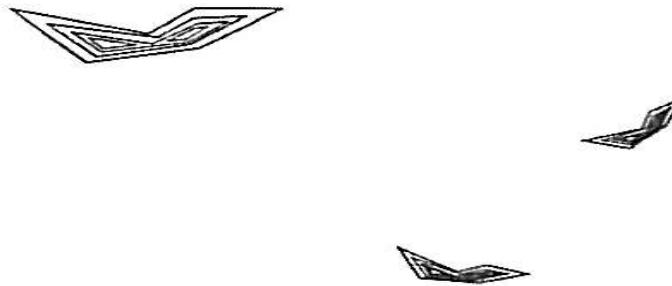
- C-SCAN
- In a C-scan display the transducer is scanned in a regular pattern of an area of interest
- Often uses automated mechanical positioning devices
- Received signals are converted to variations in color or grayscale density
- Created using A-scan data
- The plan view of the test object is generated using signal criteria based on pulse height and time of arrival to determine color or grayscale density at each X and Y location
- Similar to a floor plan of a house representing horizontal and vertical directions over which the transducer was scanned
- Resulting patterns tend to be directly correlated with the size and shape of the reflecting surfaces in the test object
- Easy to interpret
- Reflectors with sharply defined edges, the image is an accurate representation of the reflector size
- Key measure of a C-scan is its ability to distinguish between closely spaced reflectors that exist at the same depth
- The lateral resolution of the system is important and is related to the diameter of the sound beam at the depth of interest and the scanning step size
- When images are created with narrow acceptance ranges and carefully correlated with depth information the C-scan rendition becomes a slice of a three dimensional rendering of the reflectors contained within the test object

Figure 6.6: C-scan renditions of internal discontinuities in test plates: (a) threshold image; (b) contour image; and (c) system layout.

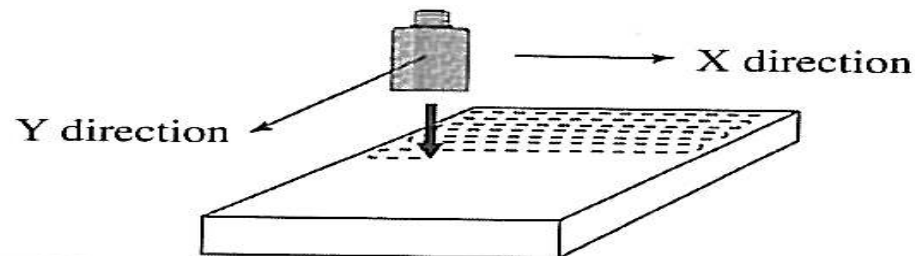
(a)



(b)



(c)



ULTRASONIC TESTING

TRANSDUCERS cont'd

- The frequency of a transducer is determined by the thickness of the piezoelectric element (crystal)
- The thinner the crystal the higher the frequency
- higher frequency sound beams produce higher levels of sensitivity and resolution
- Less ability to penetrate test objects to great depths

ULTRASONIC TESTING

- PENETRATION VERSUS SENSITIVITY AND RESOLUTION
 - A transducer is chosen to enhance the sensitivity (higher frequency) or provide greater ability to penetrate coarse grained materials or test objects of great depths (lower frequency)
 - Good penetrating ability in a transducer is provided by lower frequency (less 5.0 MHz). Lower frequencies produce longer wavelengths, countering the natural attenuation of the test material
 - Higher sensitivity and better resolution are achieved with higher frequencies (5 MHz and above)

ULTRASONIC TESTING

- ACOUSTIC COUPLING
- Ultrasonic waves require an intermediate medium to transfer the transducer's mechanical motion to the test object
- Coupling of the crystal to the test object is best done if the two are rigidly attached to each other
- If gas, such as air is trapped between the transducer and the test object surface, virtually all sound energy is reflected at the transducer/air boundary
- Liquid couplant is used as a transition medium between the two solid bodies
- The transducer is in direct physical contact with the test object in contact testing. Successful acoustic wave transfer is best performed when a thin layer of couplant is between the transducer and test object, providing acoustic energy transfer and lubricating the sliding surfaces of the transducer and test object

ULTRASONIC TESTING

- Welds
- Welding is the most commonly used metals joining method
- Most common structural item to be ultrasonically inspected in shop or field
- Important for the ultrasonic technician to have a basic knowledge of most commonly used welding processes and be familiar with welding terminology
- Prior to ultrasonic inspection of a weld the welding process used and the joint type (full or partial penetration) must be known to the technician. This information will give the technician an idea of what type of discontinuities may be present in the weld

ULTRASONIC TESTING

- Weld Testing
- Straight beam testing of welds can only be performed on welds that have had the weld reinforcement ground flush or from the back side of tee or corner welds
- Only if permitted by the governing code or specification
- Angle beam testing can be performed on
 - Full penetration butt welds
 - Corner and tee welds and pipe welds
- The first step is to determine accessibility to the area of interest
- Available distance back from the weld should be considered when selecting the wedge angle and determining the length of the scanning area
- Three common weld configurations; butt welds in a plate, a corner joint made by two plate ends set at 90° angles to each other, and a tee joint between two plates (as typically seen in a structural beam-column connection)

Figure 9.8: Shear wave (angle beam) transducer.

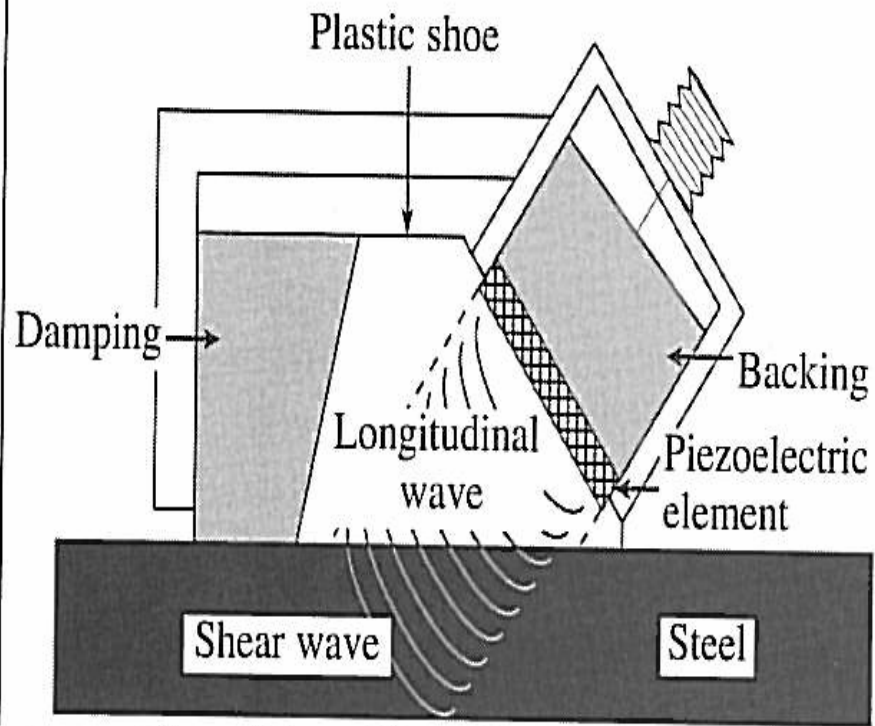


Figure 9.9: Ultrasonic test of perpendicular, surface connected reflectors: (a) flat pipe; and (b) heavy pipe.

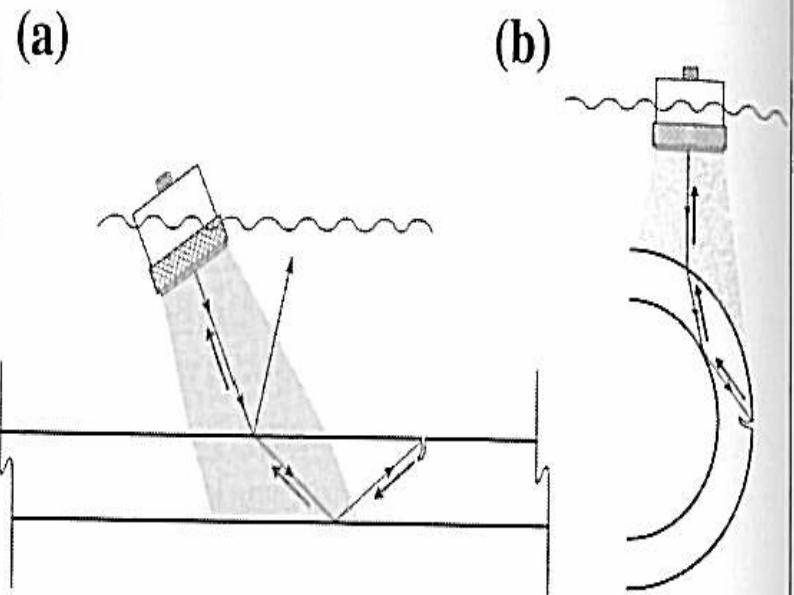


Figure 6.14: Scanning surfaces.

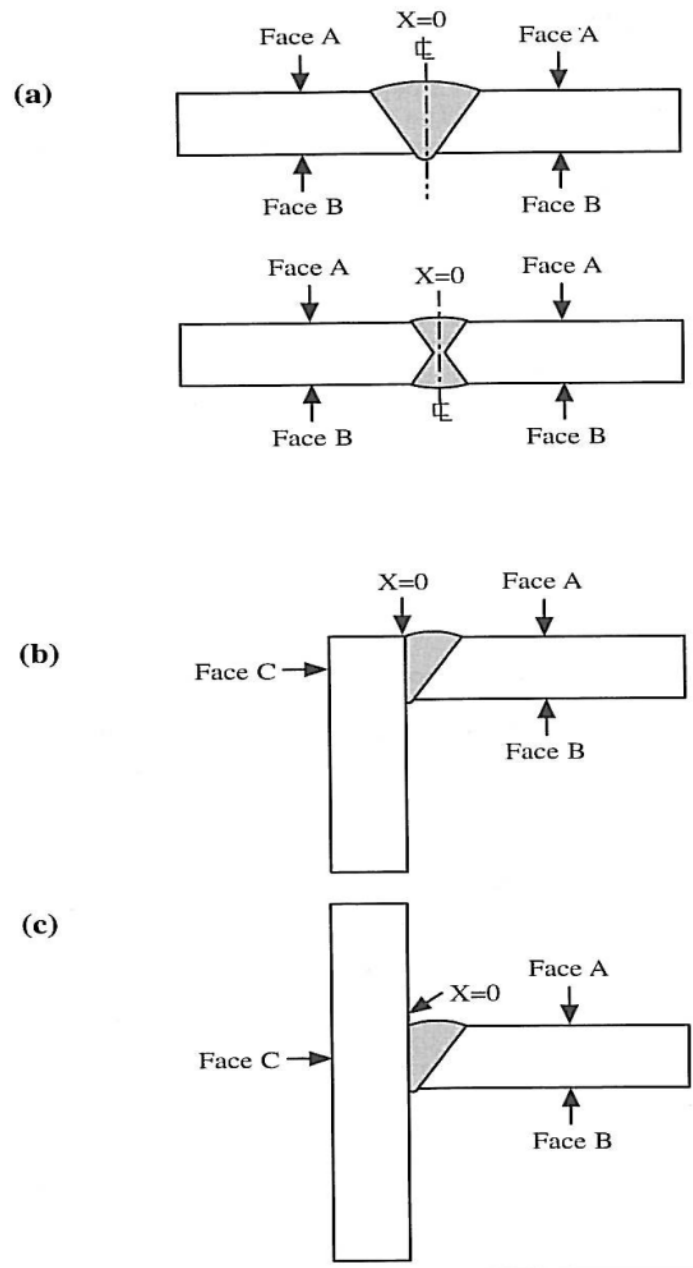


Figure 6.15: Minimum scanning distance.

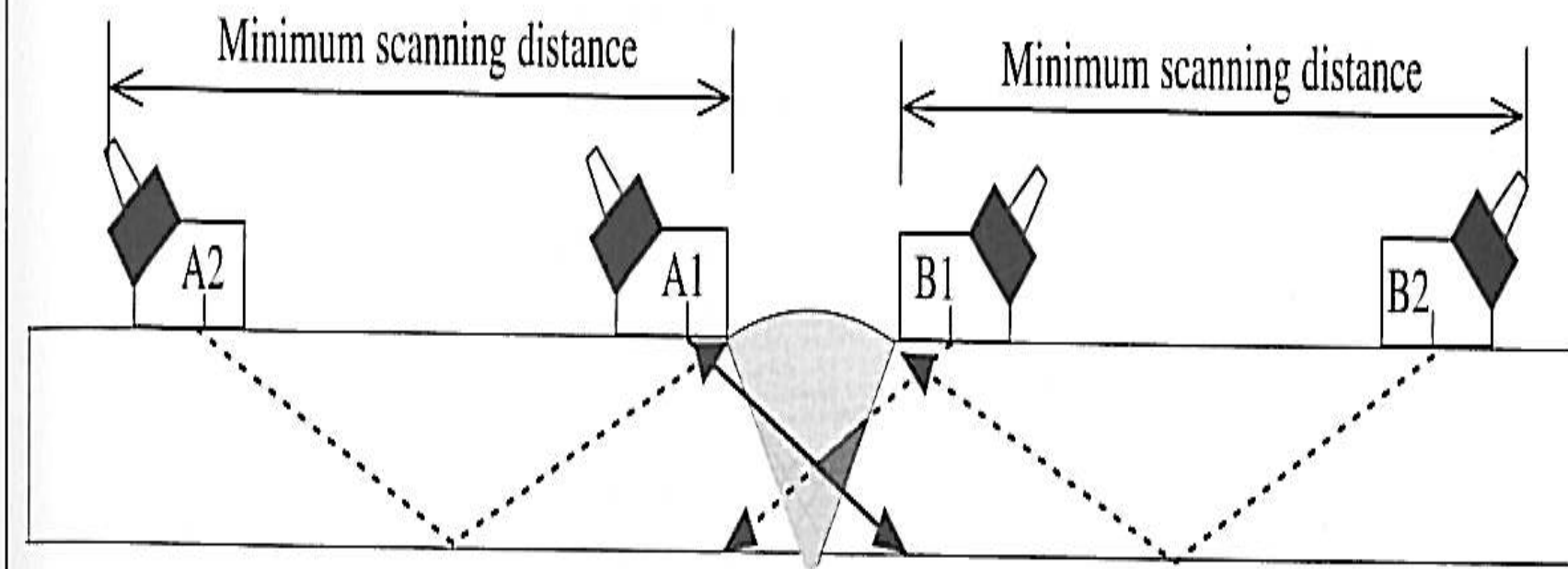


Figure 6.16: Angel beam scan patterns for welds.

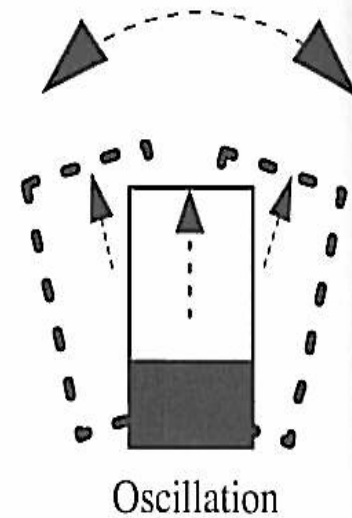
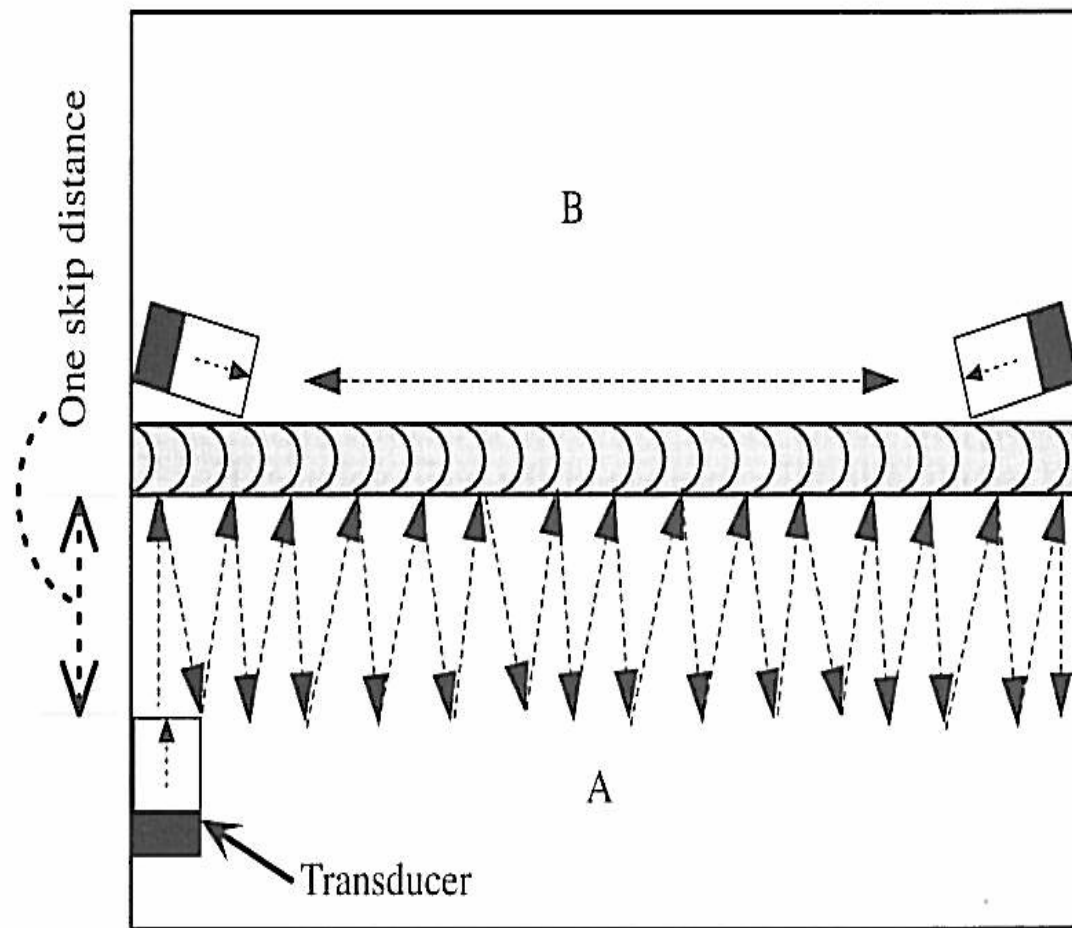


Figure 6.17: Scan overlap.

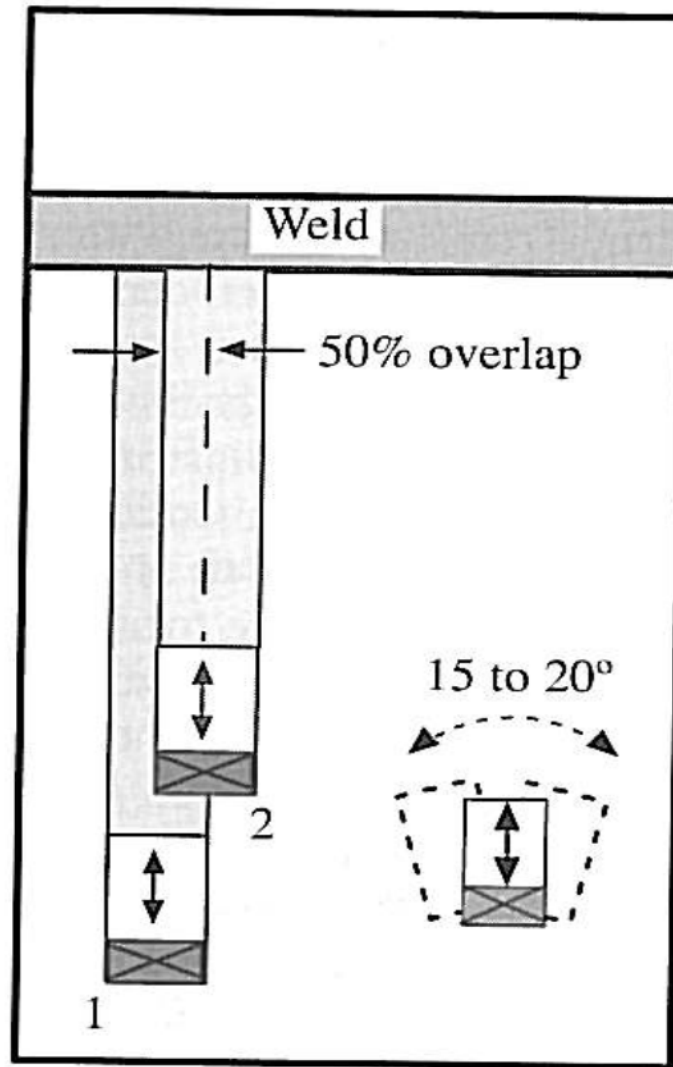
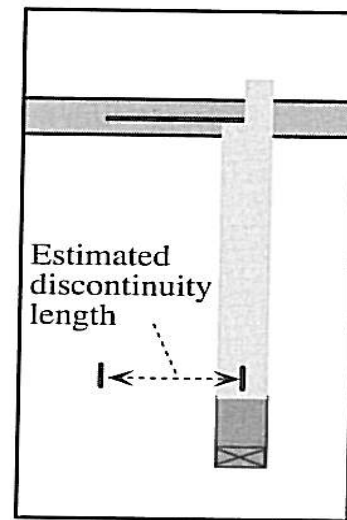
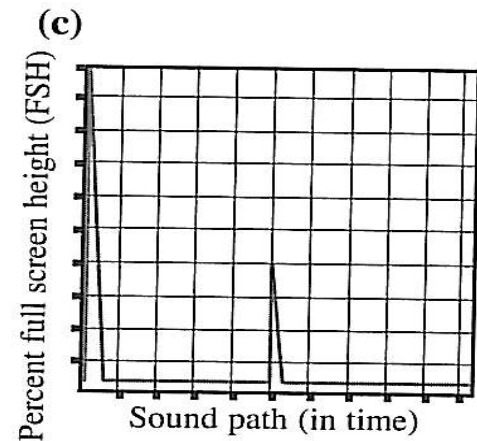
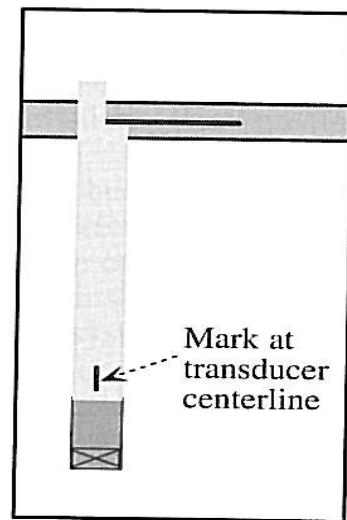
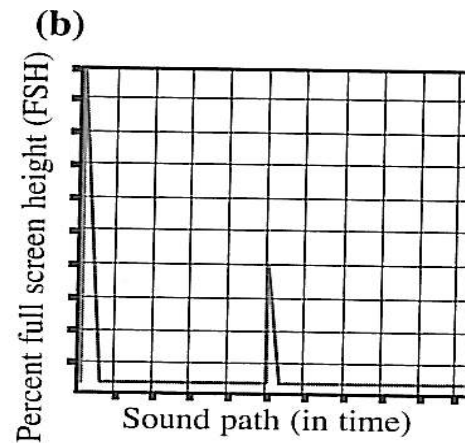
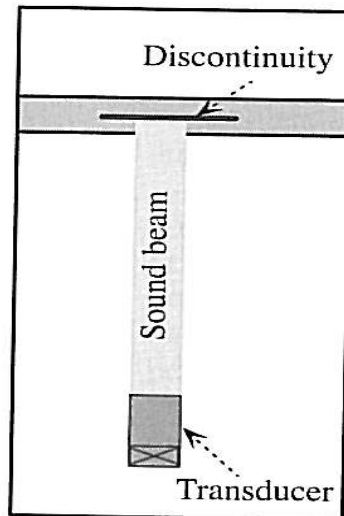
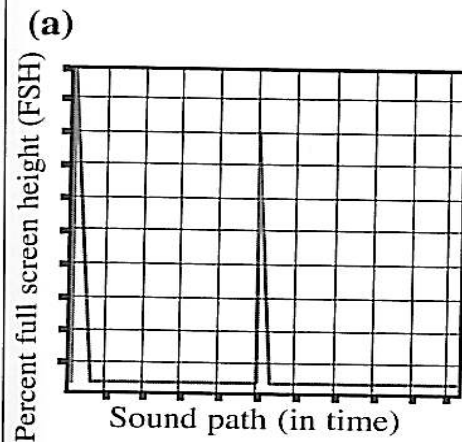


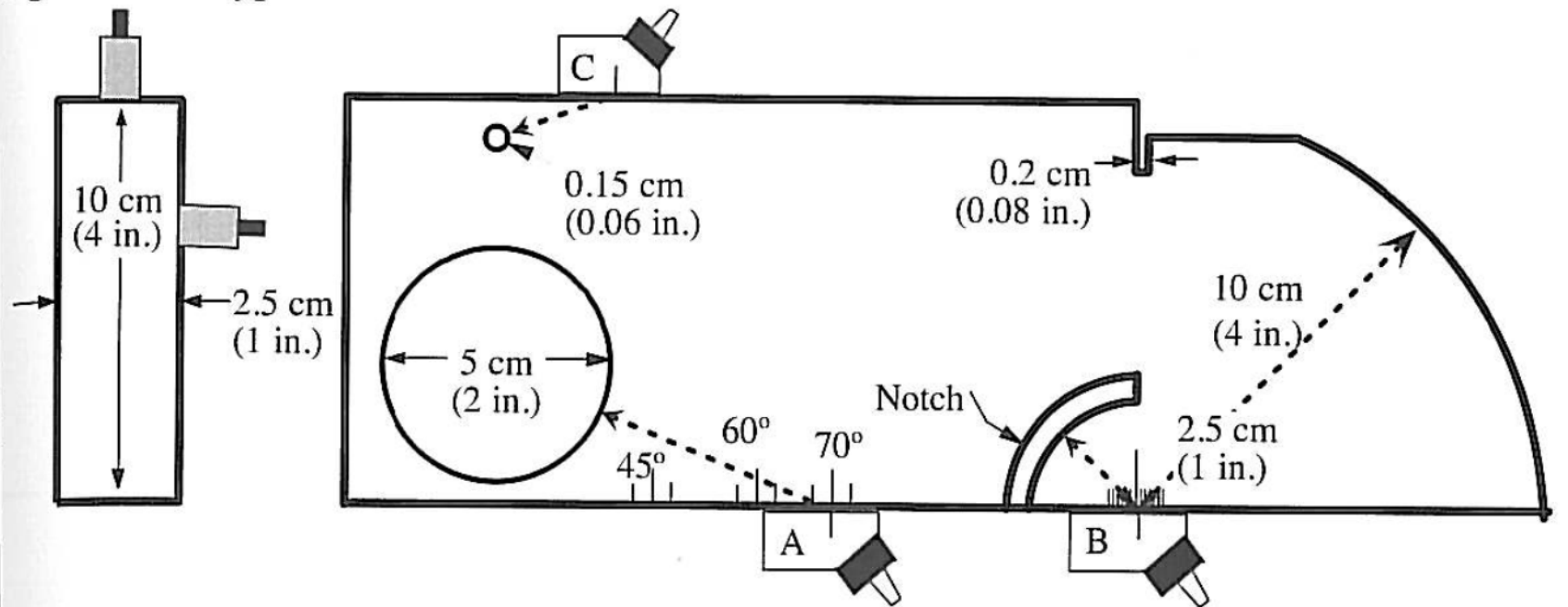
Figure 6.20: Sizing using 6 dB drop.



ULTRASONIC TESTING

- Equipment Calibration
- Equipment used in ultrasonic testing involves electronic and mechanical devices working together to accurately capture the way ultrasonic waves interact with various features of test materials
- This interaction is analyzed by measuring the strength and the nature of returning waves
- Location of reflectors is deduced by knowing the direction of the wave's propagation and the time elapsed in the wave's travel from the sending source to the receiving device
- The velocity of sound in the test object must be accurately known for distance estimations
- In simple test object geometries such as plate materials, the testing instrument can be used to interpret such features as thickness and presence of major discontinuities

Figure 7.11: Type 1 IIW block.

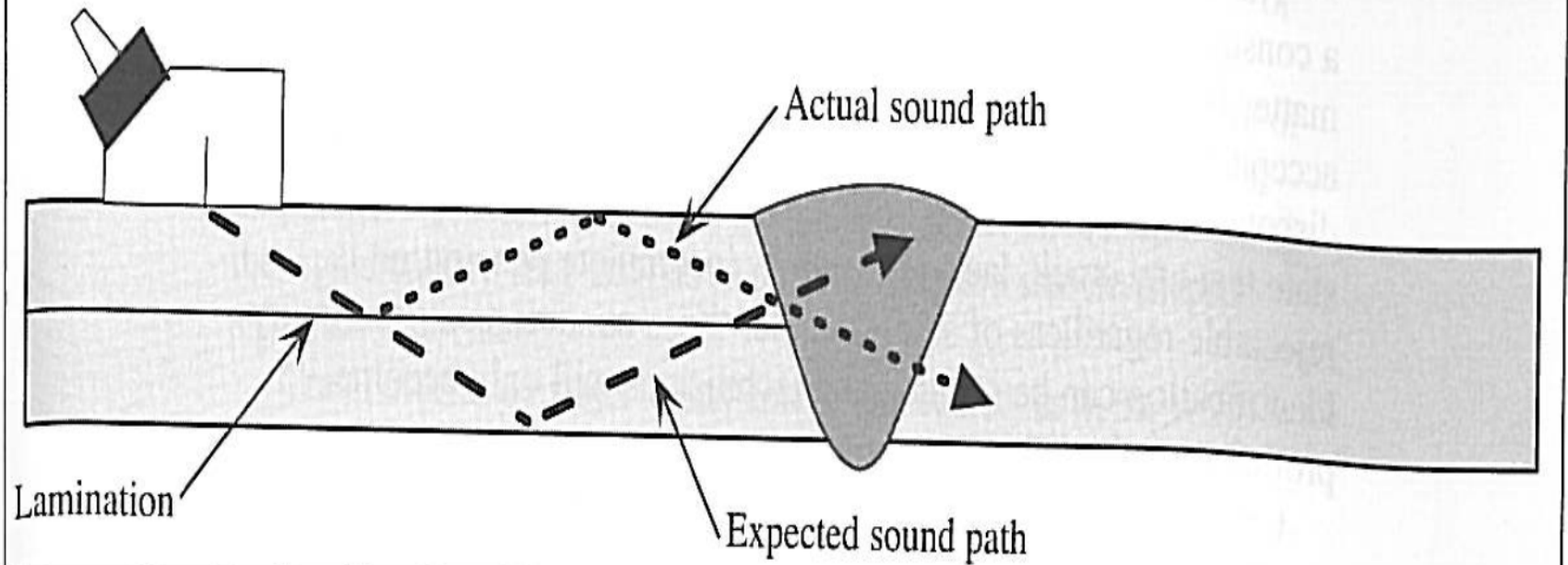


Straight beam and angle beam calibration using the IIW Block

ULTRASONIC TESTING

Weld Discontinuities

Figure 8.17: Scanning surface check.



ULTRASONIC TESTING

Weld Discontinuities

- Knowing the type of discontinuities that can occur in the various types of welds will help the technician understand what types of discontinuities may be expected in the weld

Table 8.1: Welding process discontinuities.

Welding Process	Discontinuity Type						
	Cracks	Incomplete penetration	Lack of fusion	Porosity	Slag inclusions	Tungsten inclusions	Undercut
Shielded metal arc welding (SMAW)	X	X	X	X	X		X
Submerged arc welding (SAW)	X	X	X	X	X		X
Gas tungsten arc welding (GTAW)	X	X	X	X		X	X
Gas metal arc welding (GMAW)	X	X	X	X			X
Flux-cored arc welding-self shielded (FCAW-S)	X	X	X	X	X		X
Flux-cored arc welding-gas shielded (FCAW-G)	X	X	X	X	X		X

ULTRASONIC TESTING

Weld Discontinuities

- The following slides show various discontinuities that can be found in the previously discussed weld processes, followed by various descriptions of the various discontinuity types and how they might appear during ultrasonic testing
- These descriptions are general in nature, but the screen displays are typical of the screen presentations that may be seen
- Screen displays will vary based on discontinuity size, orientation and location
- Interpretation of the screen signals is a learned art not a science
- There may be multiple discontinuity types at the same location
- The inability to be able to always identify a discontinuity type is a constant irritation to owners and contractors
- It doesn't matter what the discontinuity type is, if it exceeds the acceptance criteria it must be removed

ULTRASONIC TESTING

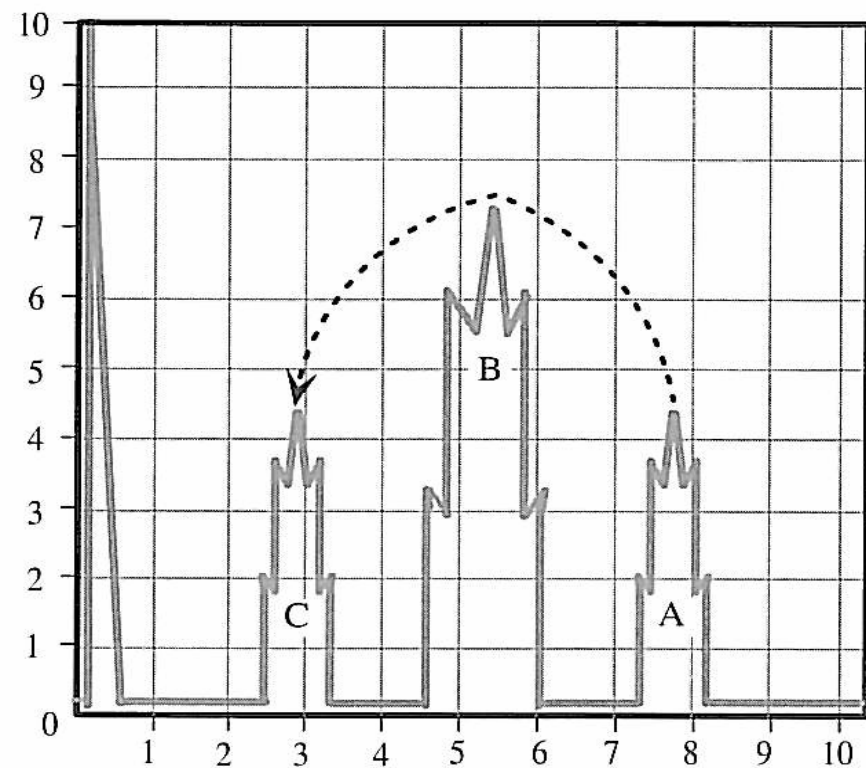
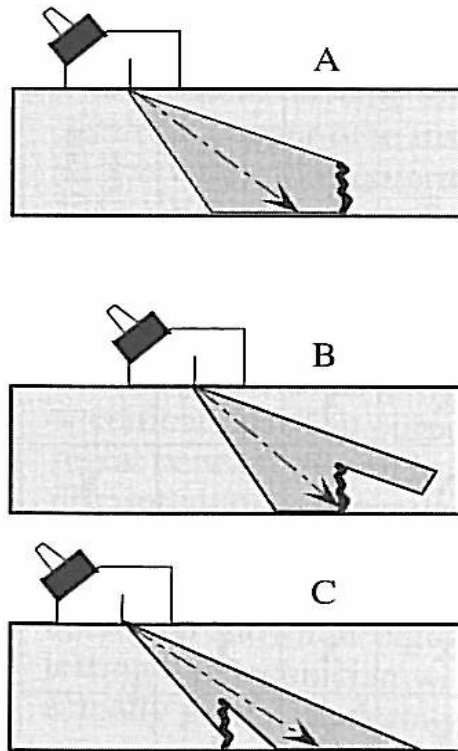
Weld Discontinuities

- Cracks occur when stresses exceed the strength of the material, resulting in a tear or rupture in the material that are usually irregularly shaped with jagged edges that make good ultrasonic reflectors
- Cracks generally initiate at a surface and propagate into the material
- If there is an internal discontinuity or stress riser it may create a focal point for those stresses and a crack may be initiated at that point
- Crater cracks are small shrink cracks occurring in the weld puddle (crater) at the end of a weld bead that has not been fully filled
- May be a single linear discontinuity or may have multiple cracks forming a star shaped indication
- This type of discontinuity is difficult to detect because they are shallow and on top of the weld

ULTRASONIC TESTING

Weld Discontinuities

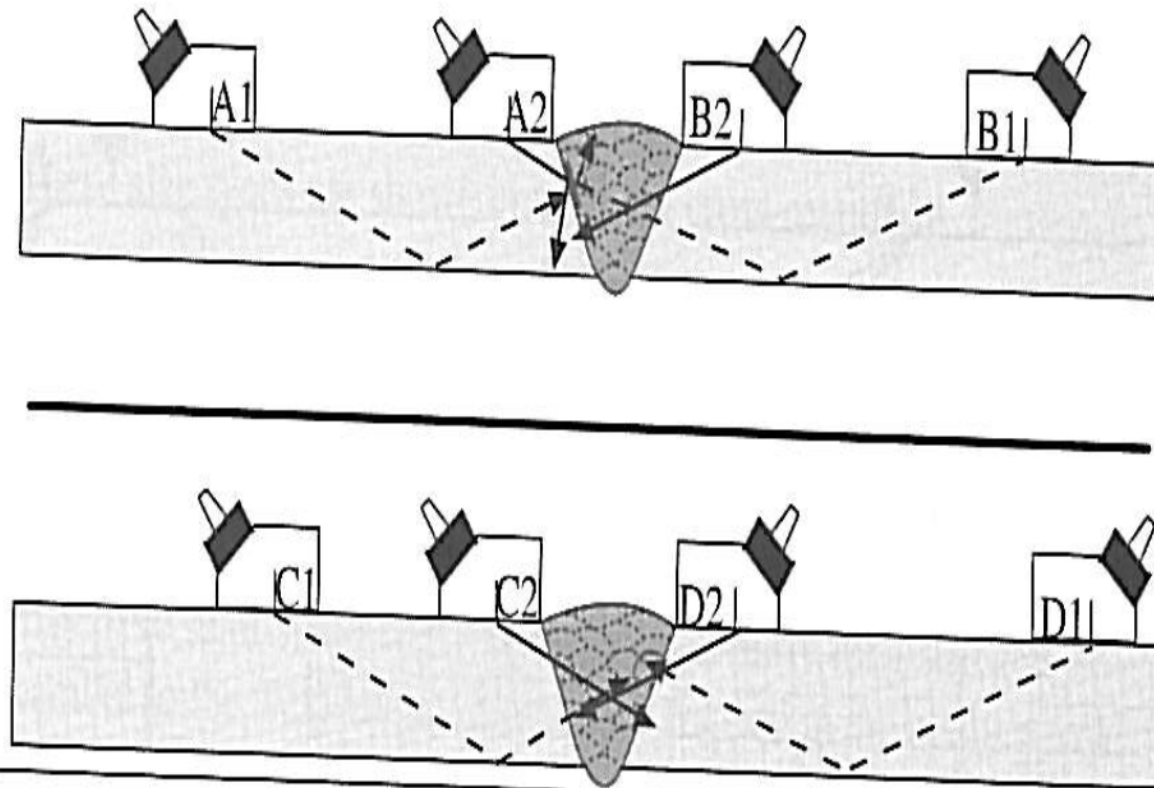
Figure 8.18: Crack indication.



ULTRASONIC TESTING

Weld Discontinuities

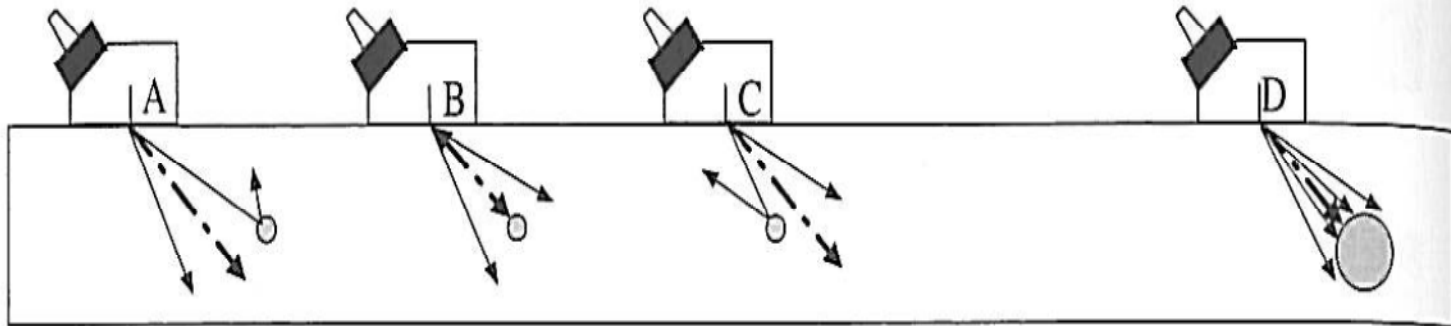
Figure 8.20: Lack of fusion.



ULTRASONIC TESTING

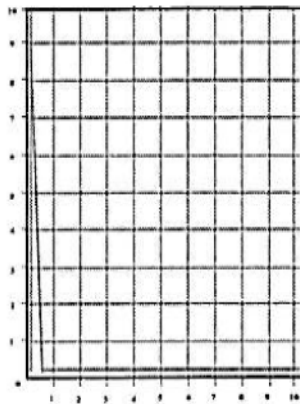
Weld Discontinuities

Figure 8.21: Porosity.

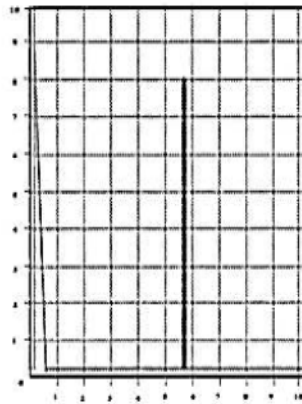


Small pores

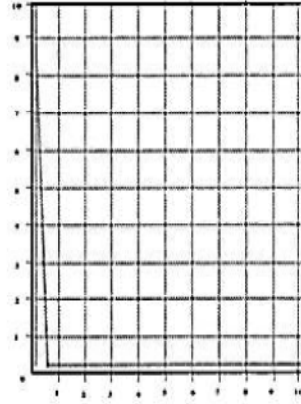
Large pores



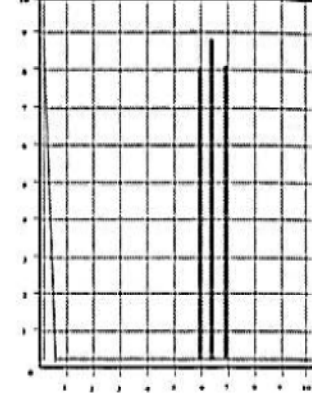
A



B



C

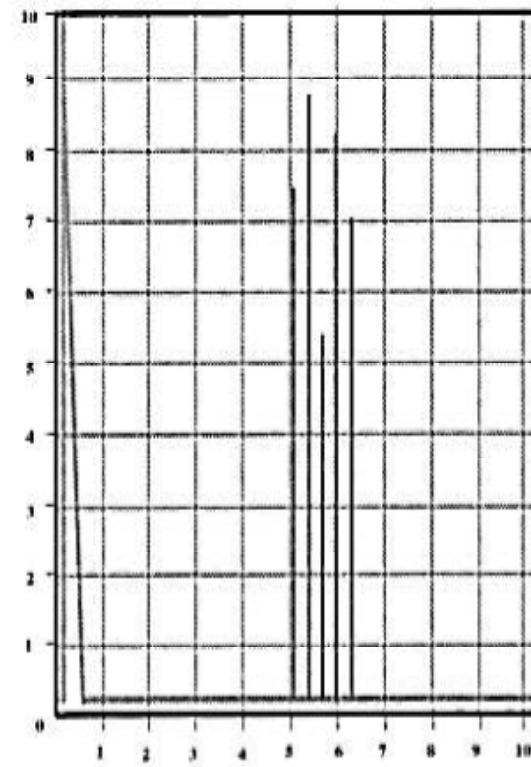
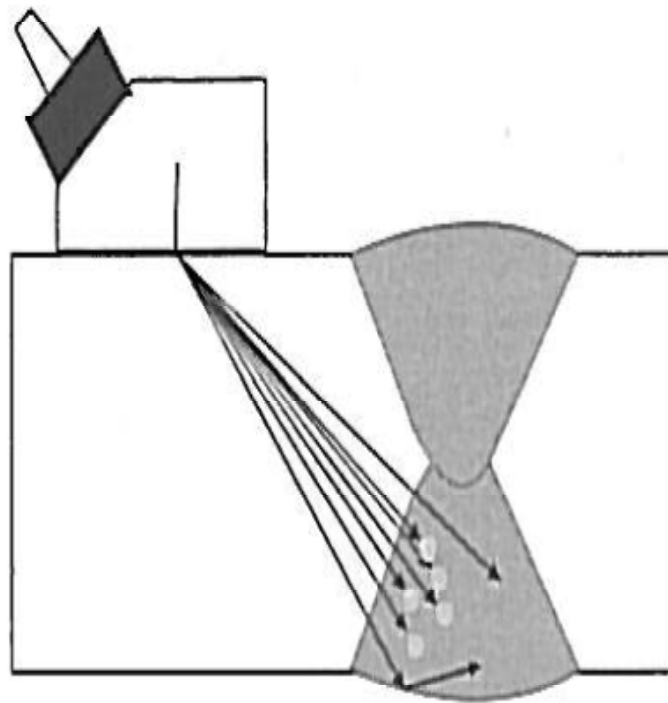


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ULTRASONIC TESTING

Weld Discontinuities

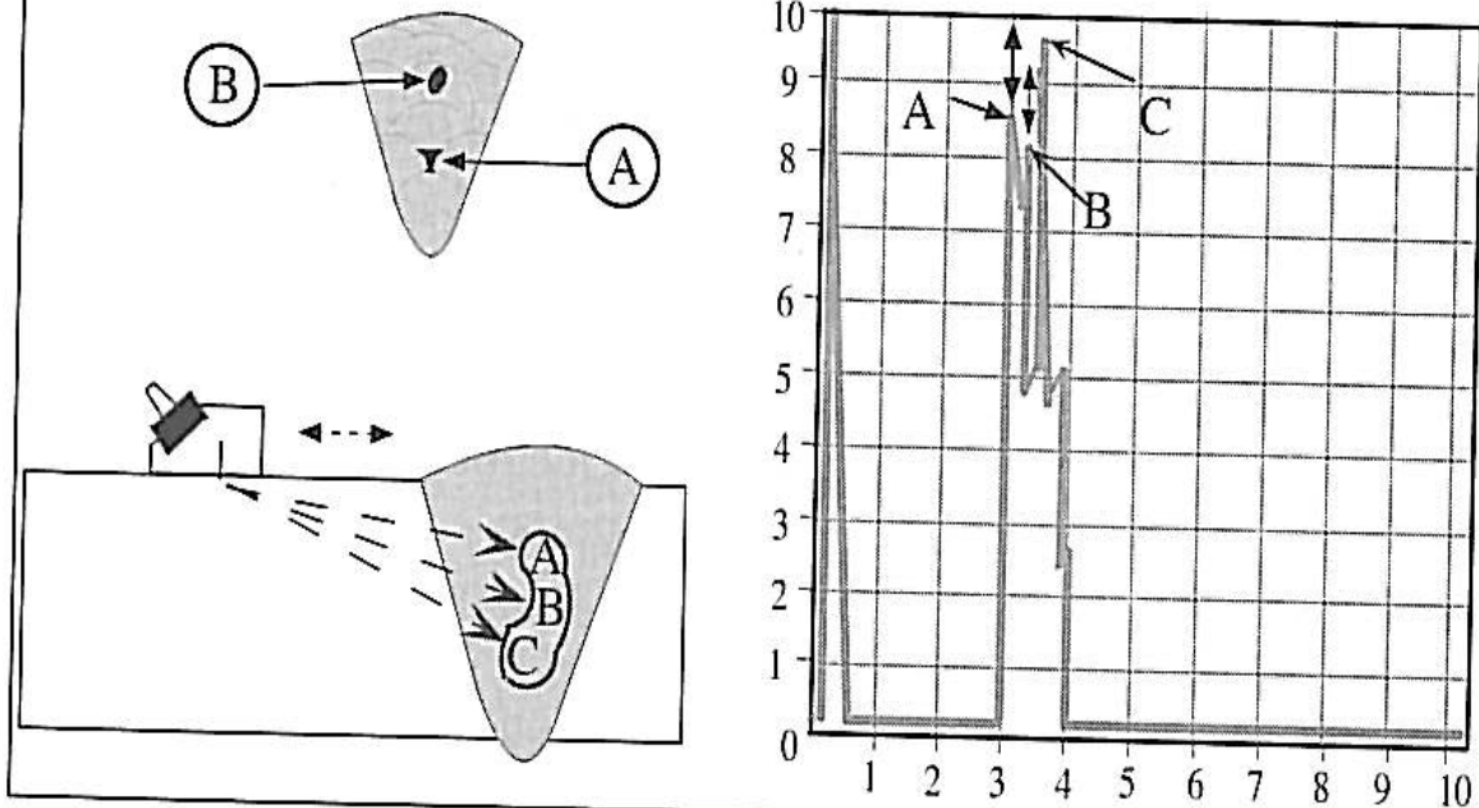
Figure 8.22: Cluster porosity.



ULTRASONIC TESTING

Weld Discontinuities

Figure 8.23: Slag inclusions.



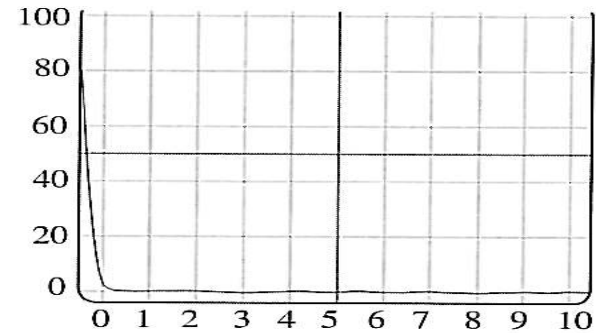
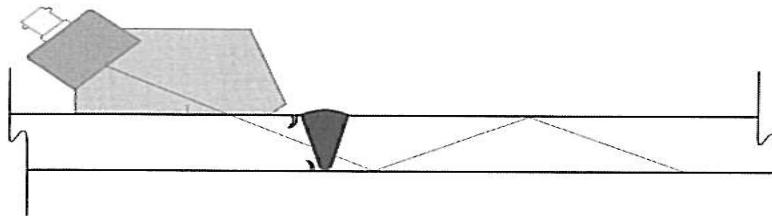
ULTRASONIC TESTING

- Because reflecting cracks are at some distance from the transducer, the orientation of the transducer is critical
- Rotation of the transducer by only a few degrees is enough to completely lose the signal
- The angle beam approach is the primary way cracks are detected in and around webs
- It does not have the convenience or comfort of the thickness mode because no back surface reference signal is present
- A signal is received only when the sound beam is reflected from a discontinuity or some geometrical reflector
- Geometric reflectors-
 - Corner at the plate edge
 - The crown or root area of the weld
 - The A-scan interpretation is further complicated since the location of the transducer, with respect to the weld, changes during scanning

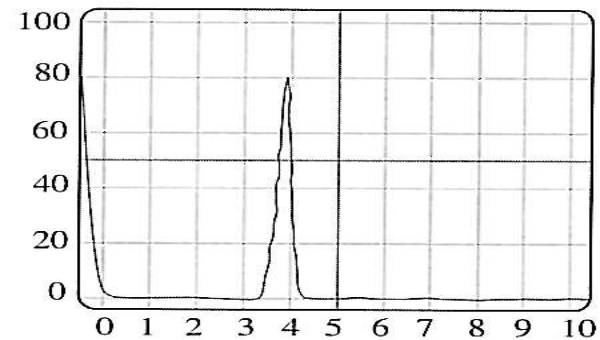
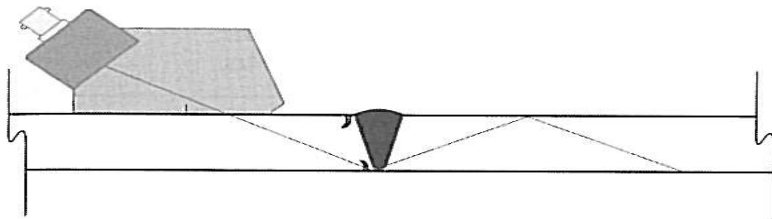
ULTRASONIC TESTING

Figure 9.10: Weld testing using contact shear waves that intersect: (a) the weld center; (b) the weld root; and (c) the weld crown.

(a)



(b)



(c)

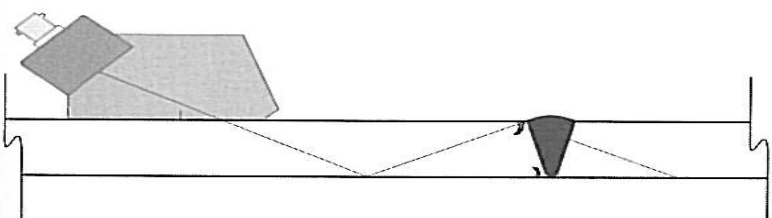
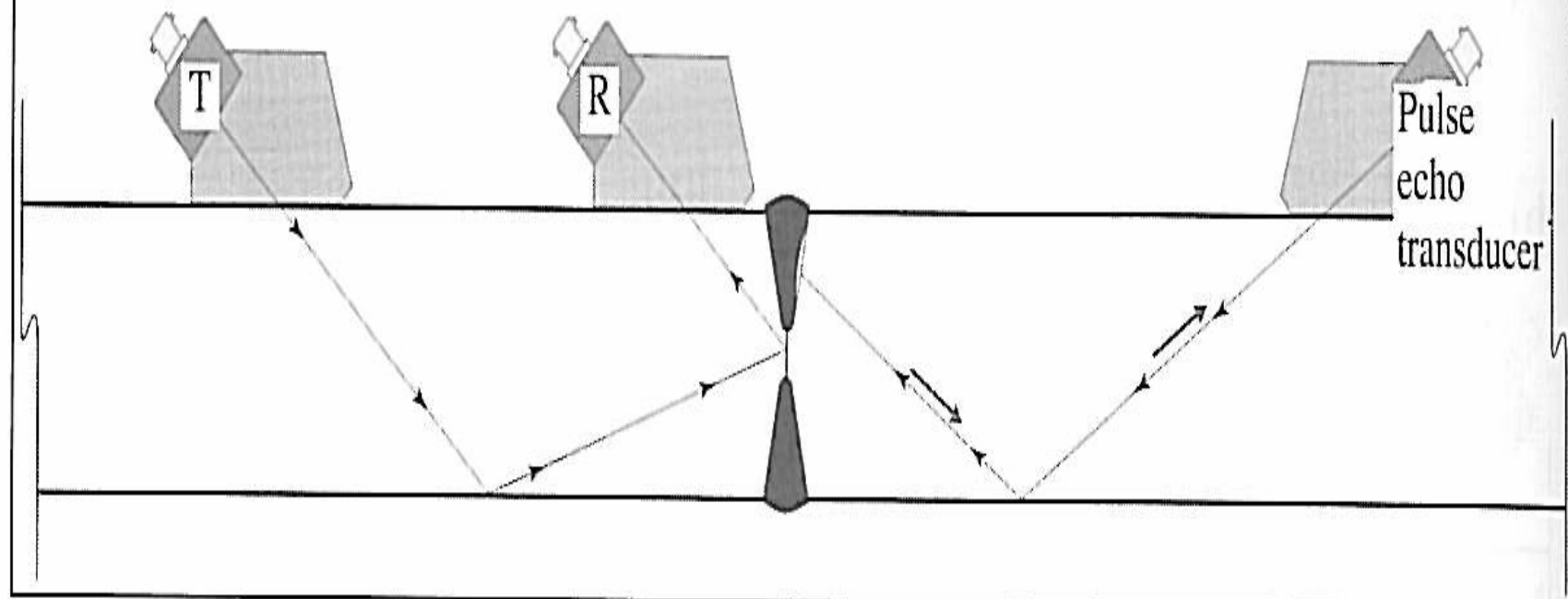


Figure 9.11: Double-vee weld with lack of root penetration and sidewall fusion.



Phased Array Inspection

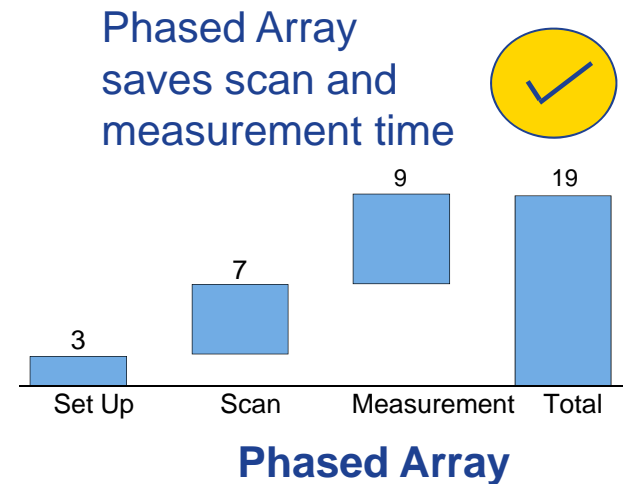
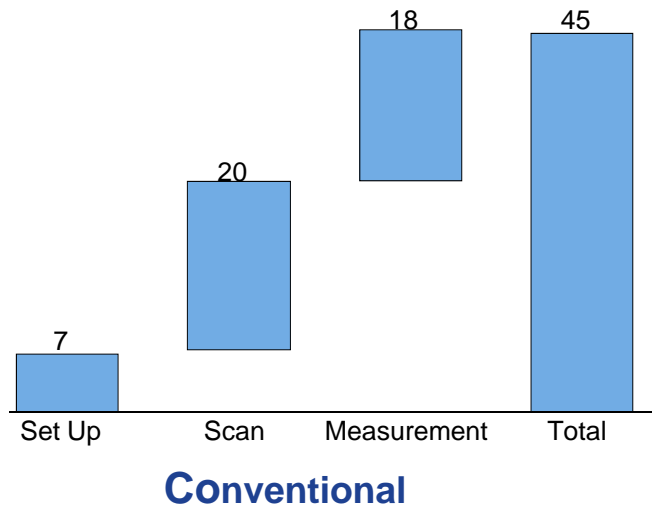
Alan Bloom
GE Inspection Technologies
518.424.5988



imagination at work

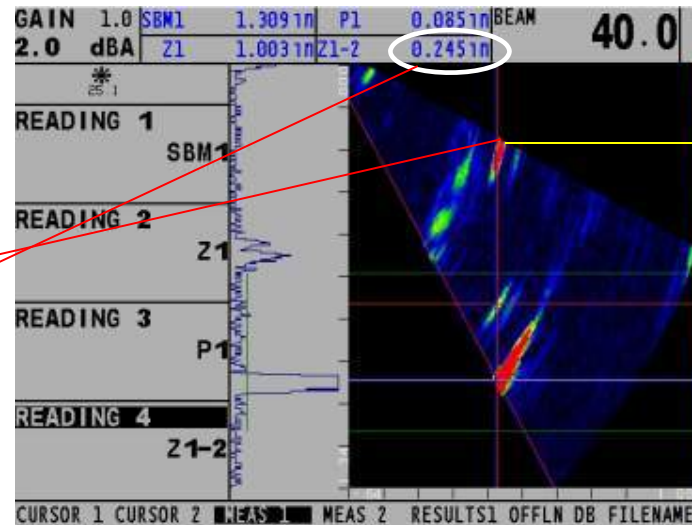
Value 2: Faster Inspections

Illustrative Weld Inspection Example (minutes)



Cut your inspection times by 50%

Value 3: Faster Measurement With Improved Precision



True depth
of side
drilled hole

- Improve precision by 40% (based on initial trials)
- Obtain reproducible and reportable proof of sizing calculation

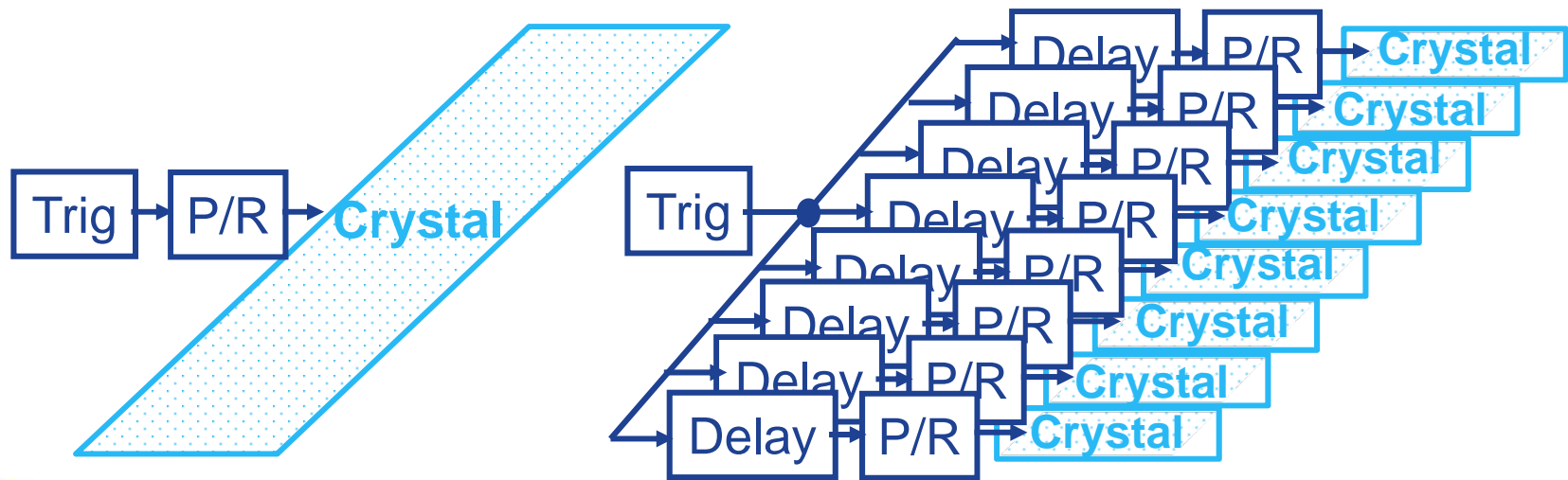
Phased Array Basics

Concepts of the Phased Array Technology

Conventional transducers are composed of a single crystal.

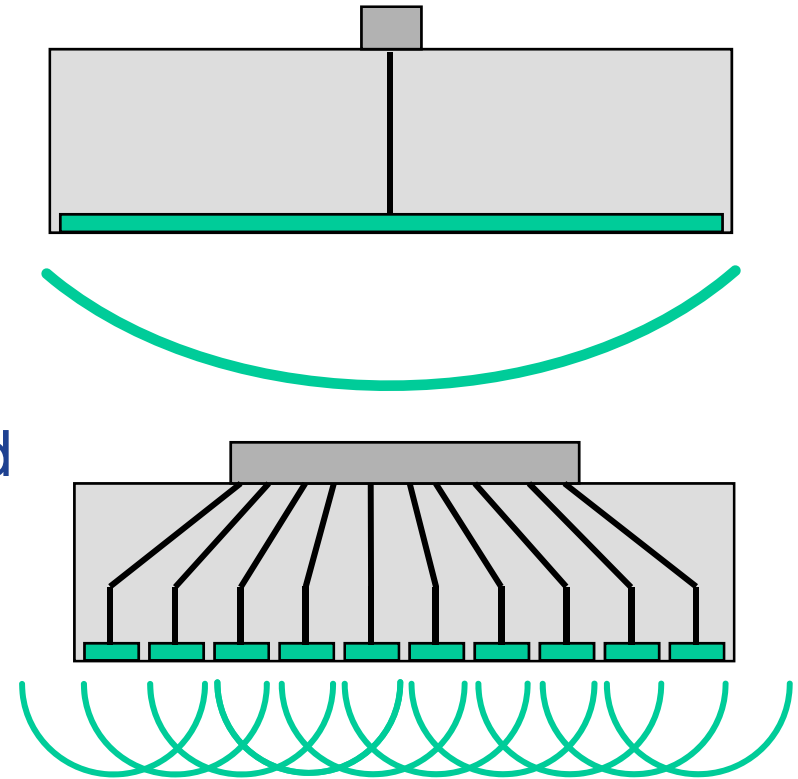
For Phased Array transducers, the crystal is cut in many part elements. Elements are individually driven with time-shifts called “Focal law”.

The aperture is controlled following the number of excited elements and the local law shape.



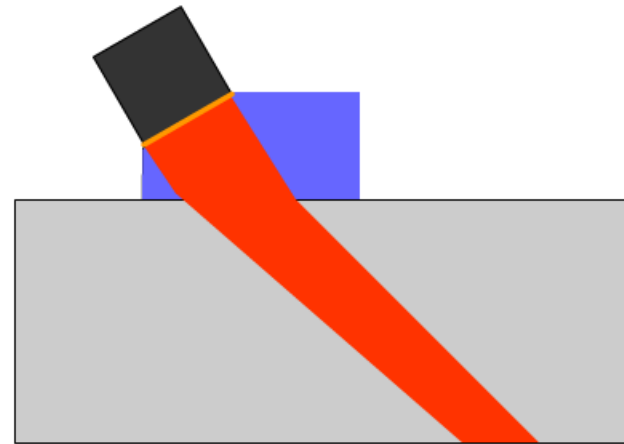
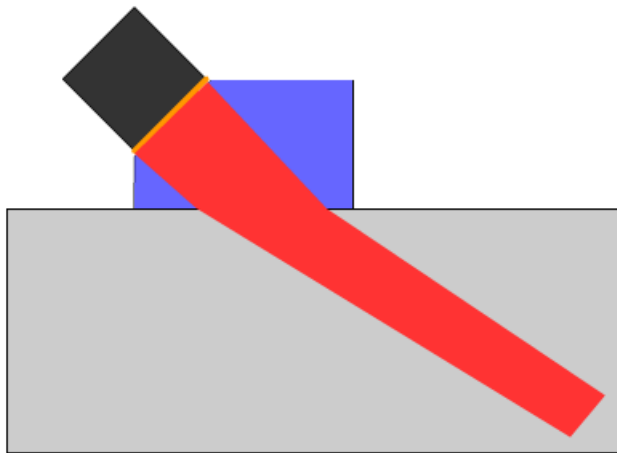
What is a Phased Array Transducer?

A phased array transducer can be compared to a large single-element transducer whose active area has been subdivided into small segments or elements. When connected to a phased array instrument, the direction and focus of the sound beam can be changed on each pulse repetition by pulsing individual elements at slightly different times or in different order.



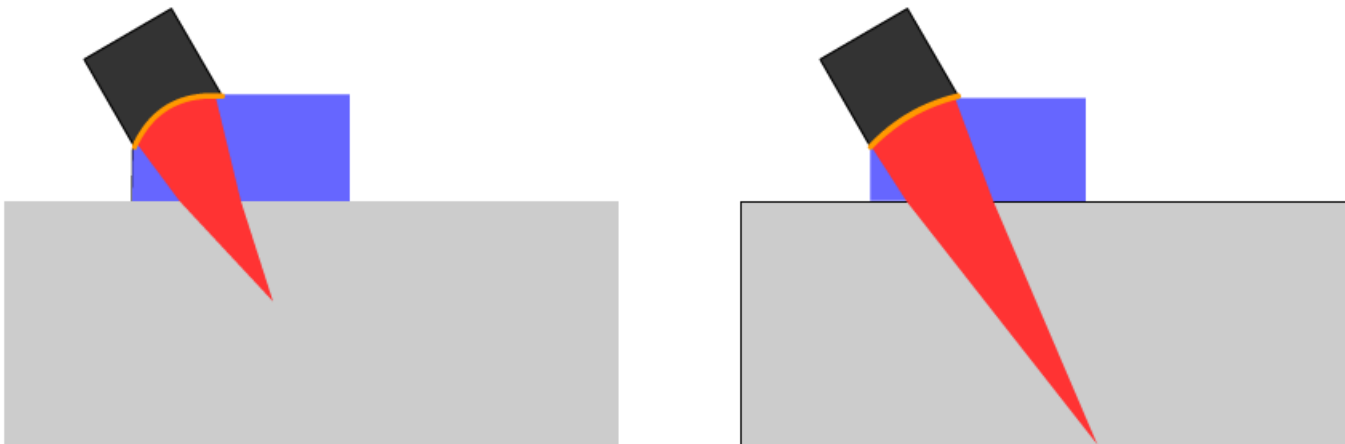
Phased Array Principles (1 of 6)

With conventional Ultrasound , we must change to a different transducer or wedge in order to change the sound angle .



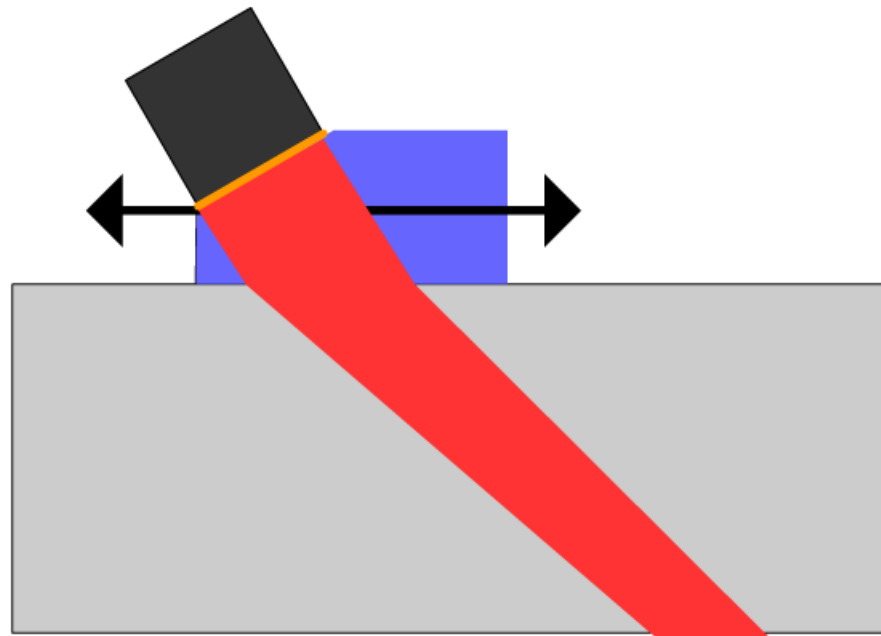
Phased Array Principles (2 of 6)

To focus we must use a lens or curved element.
To change the focus we must change the transducer.



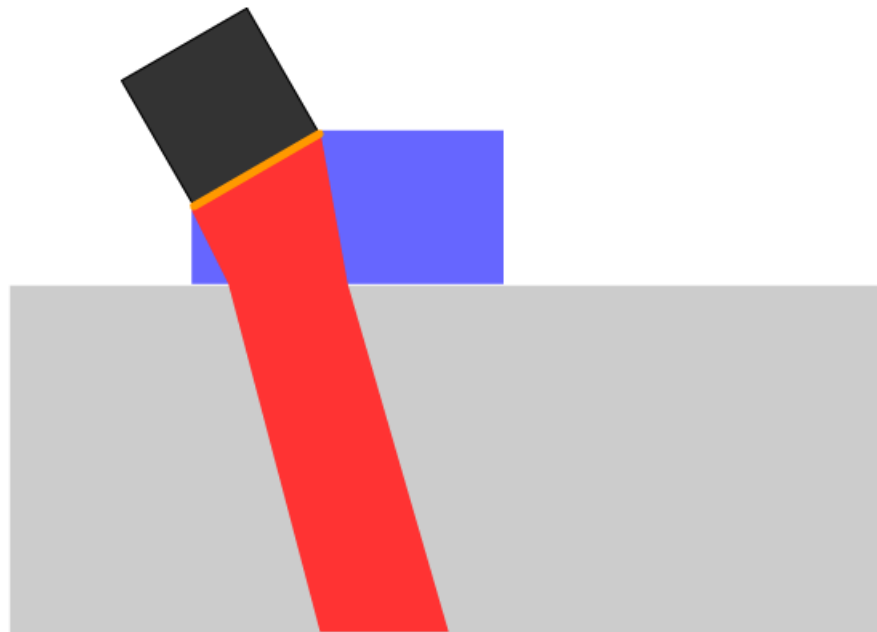
Phased Array Principles (3 of 6)

To scan the volume of a part - we must physically move the transducer.



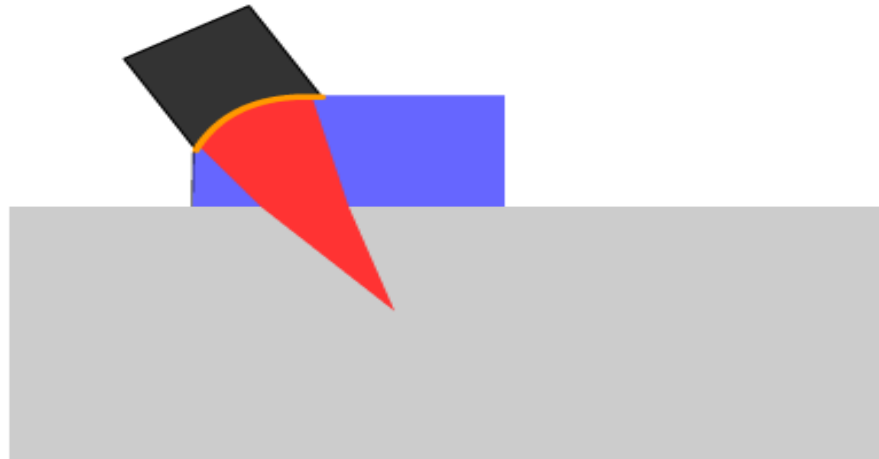
Phased Array Principles (4 of 6)

With a phased array system the sound angle can be changed electronically.



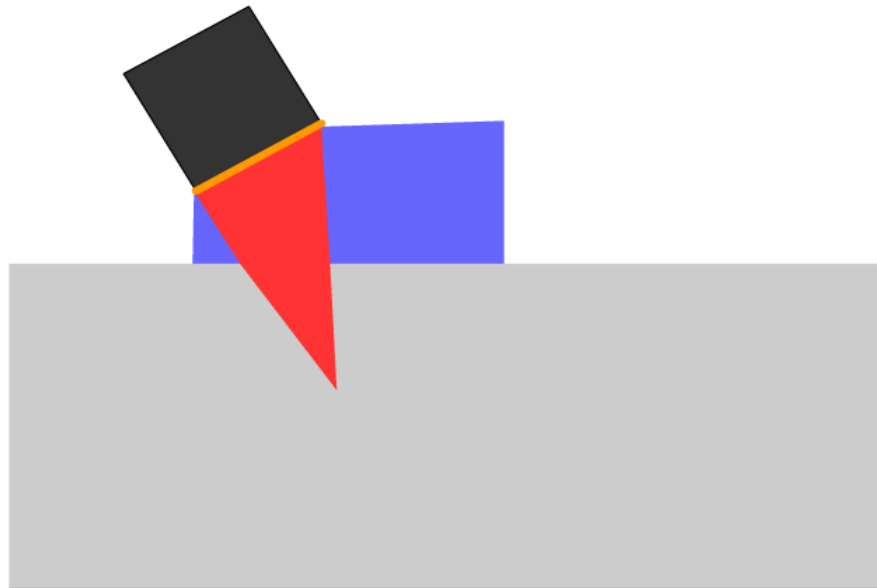
Phased Array Principles (5 of 6)

The focal point can also be changed electronically.



Phased Array Principles (6 of 6)

Steering and focus can be combined.



Advanced NDT Technologies

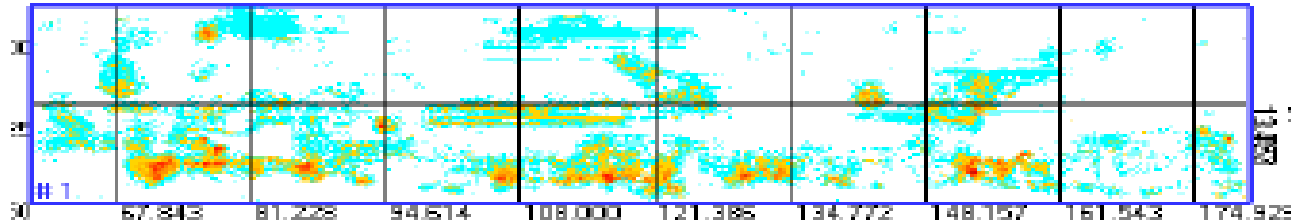


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imagination at work

Guided Wave Ultrasonics



Specialized Ultrasonics

- Ultrasonic “collar” pulses sound wave up to 300 feet along length of pipe to locate defects
- Effective screening tool
- Used for buried pipeline (under roadways, etc.)
- Examines insulated pipe with minimal insulation removal
- Guided Wave Ultrasonic Testing



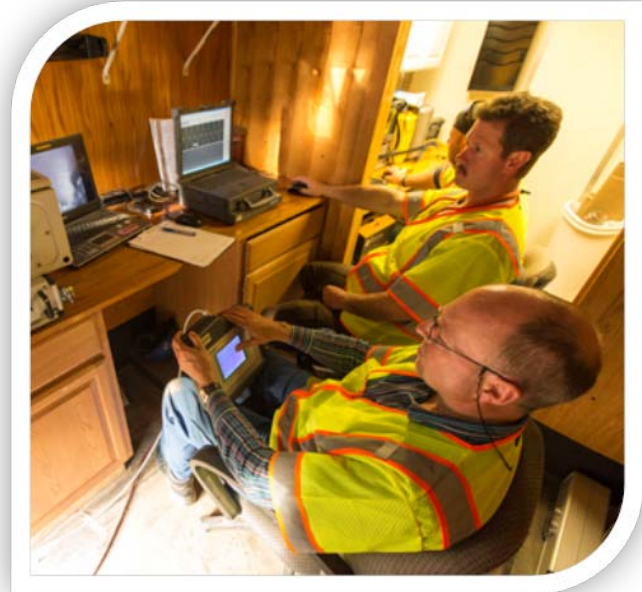
Collar with multiple UT transducers – Can pulse in both directions

Buried Piping Inspection

Solutions for “Unpiggable” Pipelines...

UT and SLOFEC corrosion detection and mapping

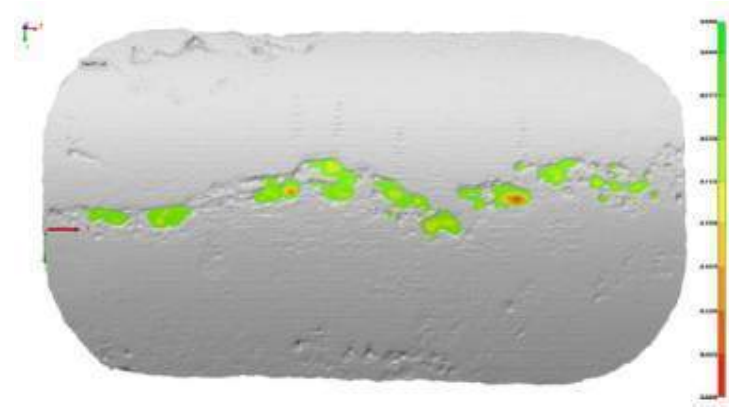
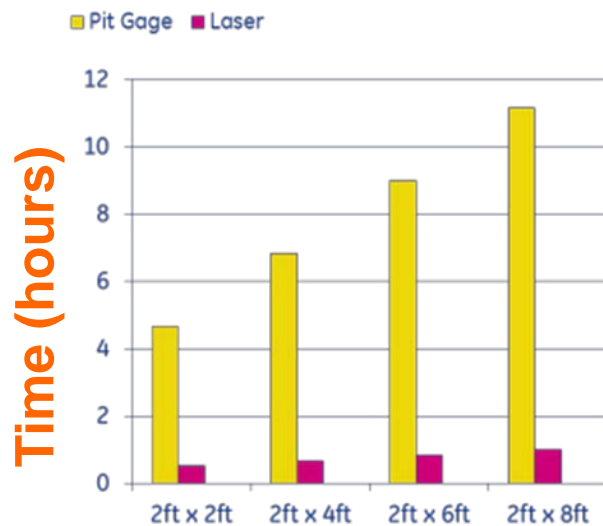
- Requires 1 access point
- Modular, flexible, & self propelled
- Able to traverse horizontal & vertical sections
- Navigates 1.5D bends
- Travels up to 1000 feet
- UT and SLOFEC technologies
- Video cameras and lights
- Real time data reporting



Laser Technology for Corrosion

3D Evaluation of External Surface Anomalies

- Digital fingerprints of External Wall Loss & Mechanical Damage
- Resolution Accuracy 0.002inches
- Comprehensive data collected in a fraction of the time to perform manual measurements



3D images of External Anomalies displaying depths and dimensions

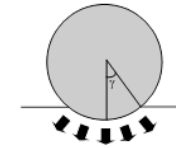
Tensile Property Measurement

Offerings

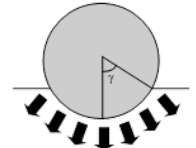
- Direct, non-destructive materials property determination
- Localized properties measured (e.g. base metal, weld or HAZ)
- Portable precision for in-field measurements
- Testing takes <20 minutes - 3 to 5 tests per location / segment
- Round indentations are non-injurious

Real World Benefits

- Establish tensile properties for unknown materials
- Avoid de-rating of operating pressure if lacking documentation
- Minimal service interruption for measurements



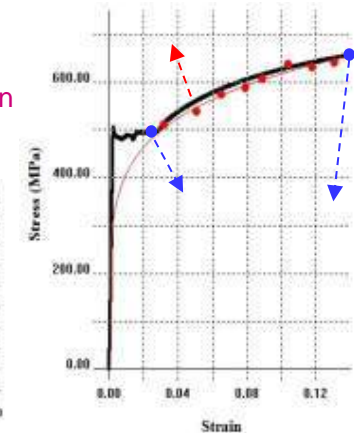
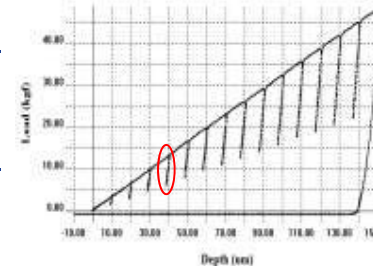
Indentation depth increases



Stress and strain increase

SS400 (Low-Strength Steel)	Tensile Test	Indentation Test	
	value	value	error
Yield Strength (MPa)	284.1	284.1	0.0%
Tensile Strength (MPa)	530.4	566.4	6.8%
Work-Hardening Index	0.228	0.222	2.4%

Stress, strain determination



Remote Visual Inspection

Video Borescopes

- Portable and rugged devices with measurement, video and image capture

Fiberscopes/Borescopes

- Portable and rugged devices for remote viewing

Large Diameter Cameras

- PTZ cameras for wide area inspection

Robotic Crawlers

- Remote controlled modular for multi-directional viewing



The End