AC 43-7

ULTRASONIC NONDESTRUCTIVE TESTING FOR AIRCRAFT

1975

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

FLIGHT STANDARDS SERVICE

TABLE OF CONTENTS

Page

Chapter 1. INTRODUCTION

Chapter 2. TRANSDUCERS (SEARCH UNITS, PROBES, CRYSTALS)

Chapter 3. WAVE PROPAGATION

Chapter 4. ULTRASONIC VIBRATIONS

Chapter 5. ULTRASONIC SYSTEMS

Chapter 6. PRESENTATION

Chapter 7. RECORDERS

TABLE OF CONTENTS—Continued

Page

Chapter 8. ELECTRONIC GATING

Chapter 9. DELAY LINE

Chapter 10. COUPLANT

Chapter 11. ULTRASONIC REFERENCE BLOCKS

Chapter 12. TESTING METHODS

Chapter 13. INSPECTION OF INTEGRAL FUEL TANKS FOR CORRISON

Chapter 14. INSPECTION OF REPRESENTATIVE AIRCRAFT PARTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS—Continued

Chapter 1. INTRODUCTION

1. GENERAL. Ultrasonic inspection of aircraft plays an important role from both a safety and economic aspect. In order to accomplish the prescribed ultrasonic inspection, only minor aircraft open–up for accessibility is usually required. For example, in the case of the aircraft engine, inspections are performed "on the wing" with the engine still installed in the aircraft. For the airframe, ultrasonics required a minimum of disassembly and removal of interfering equipment. Aircraft inspections with ultrasonics can be performed "at the ramp" or "on the line" under circumstances entirely different from total disassembly. It is an extremely sensitive method of nondestructing testing. The limitations are few and when direct coupling (or contact) with the part being checked can be established, the resolving capabilities are excellent. However, interpretation by trained personnel is required.

2. USE OF ULTRASONICS. Ultrasonics employ electronically produced, high–frequency sound waves that will penetrate metals, liquids, composites, and other materials at speeds of several thousand feet per second. This technique can be used to:

a. Detect laps, seams, laminations, inclusions, cracks, corrosion, and other defects in installed parts.

b. Locate porosity, cupping, and nonmetallic inclusions in bar stock.

c. Locate cracks, blow holes, insufficient penetration, lack of fusion, and other discontinuities in welds.

d. Evaluate bond quality in brazed joints and honeycomb composites assemblies.

e. Inspect forgings such as turbine engine shafts, turbine engine discs, and landing gear structural members.

3. LIMITS ON APPLICATION OF ULTRASONIC TESTING. Among the factors which may limit the application of ultrasonic testing are:

a. Sensitivity. The ability of the instrument to detect the small amount of energy reflected from a discontinuity.

b. Resolution. The ability of the instrumentation to detect flaws lying close to the test surface or to separate and distinguish the indications from several defects occurring close together in the specimen.

c. Noise discrimination. The capacity of the instrumentation for differentiating between the signals from defects and the unwanted noise of either electrical or acoustics nature.

d. These factors are affected by others, such as frequency and pulse energy. For example, when frequency is increased, the sensitivity increases. With the increase in sensitivity, smaller inhomogeneties within the material will become detectable. This will increase the noise level, thus hindering signal discrimination. With an increase in pulse energy, material noise will increase and resolution will decrease.

4. ULTRASONIC INSPECTION FOR CORROSION DETECTION. Although ultrasonic inspections have been employed by the aviation industry for several years, it was not until recently that ultrasonics have been used as a means of corrosion detection. Presently, this method of corrosion detection is still in the early stages and certainly not infallible; but it has been demonstrated that, within limitations, ultrasonics can provide a fairly reliable indication of corrosion attack. Highly trained personnel must conduct the examination if any useful information is to be derived from the indicating devices. This is compounded by the fact that the results obtained vary, depending on the model and make of equipment used, and on the techniques used by the individual performing the examination.

5.–9. RESERVED.

Chapter 2. TRANSDUCERS (SEARCH UNITS, PROBES, CRYSTALS)

10. GENERAL. To understand how inaudible sound is used to reveal certain conditions which are not perceptible in the normal hearing range, it is first necessary to know how ultrasound is transmitted and received.

11. TRANSDUCER MATERIALS. Three transducer materials which can be used in the manufacture of ultrasonic search units are natural quartz crystals, lithium sulfate, and polarized crystalline ceramics.

a. Quartz. Principal advantages are: electrical and thermal stability, insolubility in most liquids, high mechanical strength, wear resistance, excellent uniformity and resistance to aging. A limitation of quartz is its comparatively low electromechanical conversion efficiency.

b. Lithium Sulfate. Principal advantages are: ease of obtaining optimum acoustic damping for best resolution, intermediate conversion efficiency, and negligible mode interaction.

c. Polarized Ceramics. Principal advantages are: high conversion efficiency which yields high search unit sensitivity. Because of lower mechanical strength and relatively high electrical capacitance, their use is generally restricted to frequencies below 15 Mega–Hertz (MHz). Another limitation is some interaction between various modes of vibration.

In order for a crystal to utilize its piezoelectric characteristics, it is placed in a circuit much like a condenser. That is, both faces are coated with a conducting material with no contact between the two faces. (See Figure 1.) Coatings for crystals may be of any conducting material such as aluminum, silver, gold, or chromium. However, coatings are difficult to deposit on lithium sulphate crystals so thin metallic foils are often cemented to the crystal.

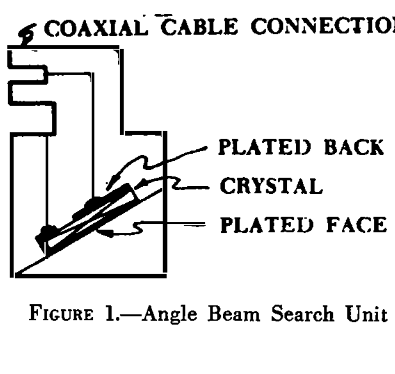


FIGURE 1.—Angle Beam Search Unit

12. PIEZOELECTRIC EFFECT. Ultrasonic testing may use the piezoelectric effect to generate ultrasonic vibrations. Crystals, when subjected to an alternating electric charge, expand and contract under the influence of these charges. Conversely, it was found that these materials when subjected to alternating compression and tension developed alternating electric charges on their faces. (See Figure 2.) This was named the piezoelectric effect.

The heart of an ultrasonic testing system is this method of converting electrical energy into mechanical vibrations, and converting the mechancial vibrations back into electrical energy.

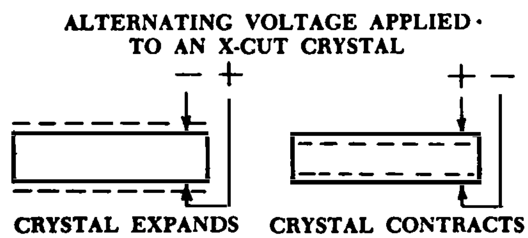


FIGURE 2.—Generation of Ultrasonic Vibration

Generation of the ultrasonic pulse is usually accomplished by producing a radio-frequency wave train of the desired frequency at a precise time and converting this into vibrations by means of piezoelectric transducers. Some ultraconsic instruments do not use a radio–frequency wave train, but instead, use a shock pulse and allow the search unit to select the frequency of operation.

13. TRANSDUCER TYPE SEARCH UNITS. The search unit consists of a shell for mechanical protection, a means to conveniently handle or mount the unit for use, the transducer element, electrical connections, and a backing material to dampen the backward directed energy that is transmitted by the crystal. (See Figure 3.)

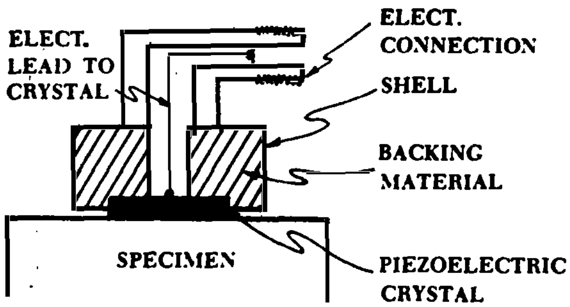


FIGURE 3.—Diagram of an Ultrasonic Search Unit

Transducers are available in a wide variety of types which include:

- **a.** X—Cut crystals for longitudinal-wave generation. (See Figure 4.)
- **b.** Y—Cut crystals for shear-wave generation. (See Figure 4.)
- **c.** Dual crystals with common holder.
- **d.** Mosaics–three or more crystals.
- **e.** High frequency, 50 MHz or more.
- **f.** Alternate crystal materials.
- **g.** Sandwich and tandem arrangements.
- **h.** Curved crysals to fit the specimen.
- **i.** Wheel search units.
- **j.** Focused search units.
- **k.** Temperature search units (for measuring wall thickness at temperature up to 1,100°F).

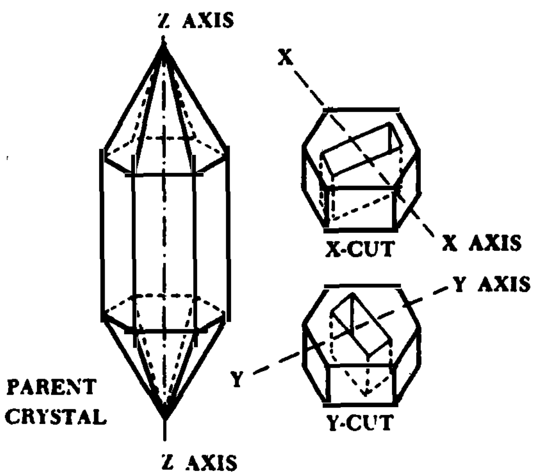


FIGURE 4.—Natural Quartz Crystal (X and Y Cut)

Transducers are available that are smaller than 1/8″ diameter and larger than 1″ x 4″. However, for most ultrasonic testing, standard diameters of 1/4″, 1/2″, and 1.0″ are used.

14. TRANSDUCER GROUPS. There are three general groups of transmitter-receiver search units:

a. Common Transmitter–Receiver (T–R). These search units employ a single crystal and have common connections to the transmitter and receiver amplifier units. (See Figure 5.)

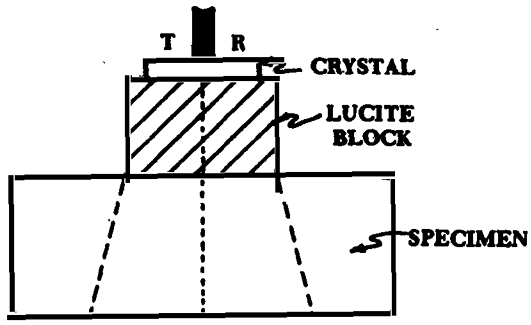


FIGURE 5.—Common Transmitter-Receiver Search Unit

Since the search unit acts as both transmitter and receiver, it transmits a pulse of 1 to 4 microseconds duration; then acts as a receiver for a period up to several thousand microseconds. This cycle of transmitting and receiving is repeated at a rate of 50 to 5,000 times per second, or higher if required for high-speed automatic scanning.

b. Combined Transmitter–Receiver (T–R). These search units have two transducers mounted on a single head and insulated acoustically from each other. One transducer is connected to the pulser and the other is connected to the receiver. The combined T–R search unit is used for testing close to the entry surface and for thickness measurements from .040″ to 2.0" when the opposite side is rough or corroded. The transmitting search unit projects a beam of vibrations into the material; the vibrations travel through the material and are re-

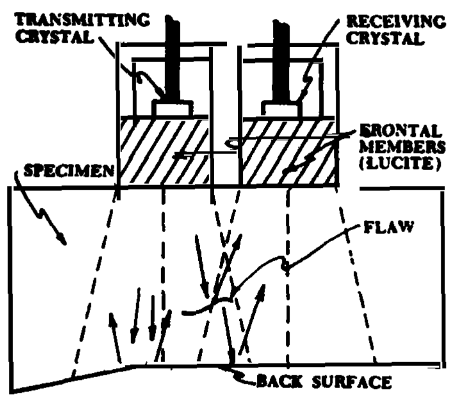


FIGURE 6.—Combined Transmitter-Receiver Search Unit

flected back to the receiving search unit from any discontinuities or from the opposite boundary if parallel to the entrant surface. (See Figure 6.)

c. Separate Transmitter–Receiver (T–R) or Pitch–Catch, Search Units. Two heads are employed in these units having separate electrical connections to the transmitter and the receiving units. One head is used as the transmitting unit while the other head is the receiving unit. (See Figure 7.)

Materials which are coarse grained tend to scatter the ultrasonic sound beam; these materials can be effectively inspected using separate T–R search units that are mounted on individual wedges of a suitable plastic solid. When separate wedges are used, the angle of incidence may be varied according to the section thickness to be examined.

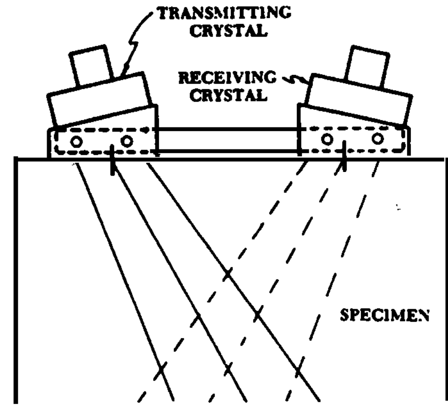


FIGURE 7.—Separate Transmitter–Receiver Search Unit

15.–20. RESERVED.

Chapter 3. WAVE PROPAGATION

21. ULTRASONIC WAVES. Ultrasonic waves can be propagated to some extent in any elastic material. This propagation occurs as a displacement of the successive elements of the material. If one part of a solid is distributed or displaced in some manner, molecules in other parts of the solid will be affected, but not instantaneously. As successive molecules in the medium are displaced, the disturbance is propagated away from its point of origin. (See Figure 8.) Since the lattice structure of all materials is elastic, a restoring force exists which tends to return each molecule to its original position. Because of inertia, these particles will tend to oscillate about their original undisturbed position until they come to rest. This molecule–to–molecule propagation results in a continuous train of disturbances called a compression–rarefaction wave. If the frequency of motion is above 20,000 cycles per second (cps) the waves are referred to as ultrasonic compressional waves. A small group of these waves, which occur together and are not preceded or followed by other waves, is called a wave train or a pulse. A pulse may have one of several different forms depending upon the individual wave amplitude, and the way the waves build up and decay. The most used modes of vibration are longitudinal, shear, surface, and plate waves.

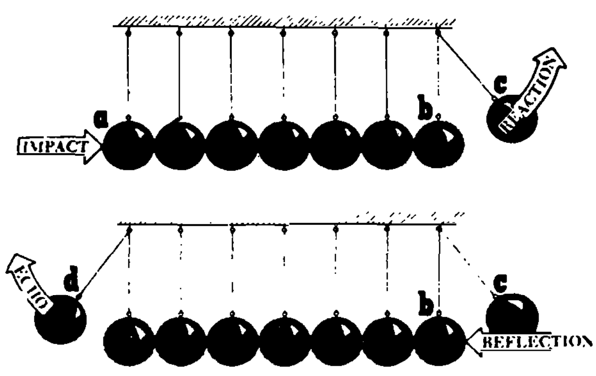


FIGURE 8.—Mechanical Analogy of Wave Propagation

22. LONGITUDINAL WAVES. The wave is said to be longitudinal (compressional) when the movement of the particles is parallel to the direction of the wave motion. (See Figure 9.)

The longitudinal mode of wave transmission is probably the most widely used in ultrasonic testing and is also the easiest to see with respect to the method of propagation. This wave is easily generated, detected, and has a high velocity of travel in most media.

Longitudinal waves are used for the detection and location of defects that present a reasonably large frontal area to the surface from which the test is being made.

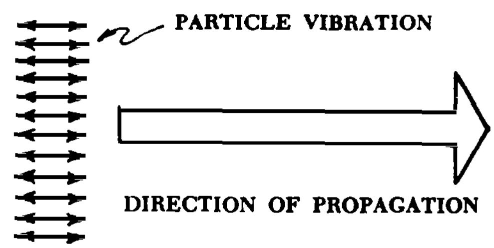


FIGURE 9.—Longitudinal Waves

23. SHEAR WAVES. The wave is said to be shear (transverse) when the movement of the particles are perpendicular to the direction of the wave motion. (See Figure 10.) These waves have a lower velocity than do longitudinal waves (in steel and other metals, about half). Because of their slower speed, shear waves have shorter wave lengths than those of longitudinal waves of the same frequency. This shorter wave length makes shear waves more sensitive to small inclusions, and consequently they are more easily scattered within the specimen.

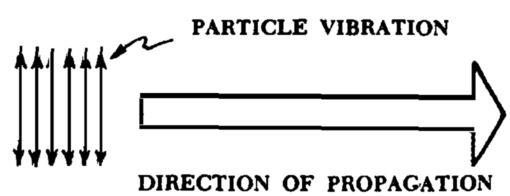


FIGURE 10.—Shear Waves

The principal advantage of these waves is in applications that require an ultrasonic beam to be transmitted into the test object at a small angle to the surface. (See Figure 11.)

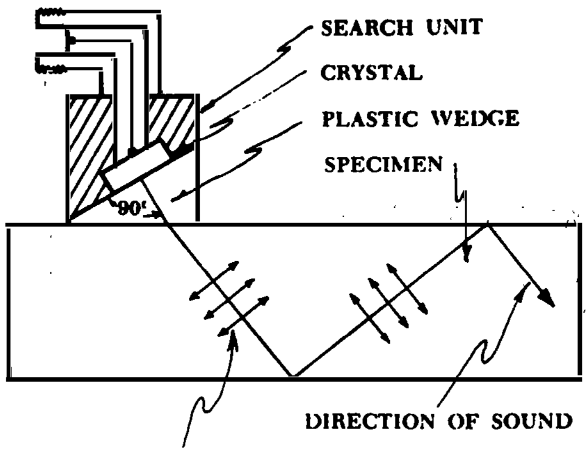


FIGURE 11.—Transmitting A Wave at a Small Angle

24. SURFACE (RAYLEIGH) WAVES. Surface waves travel with little attenuation in the direction of propagation, but their energy decreases rapidly as the wave penetrates below the surface. The particle displacement of the wave motion follows an elliptical orbit consisting of both the longitudinal and shear wave motion. (See Figure 12.)

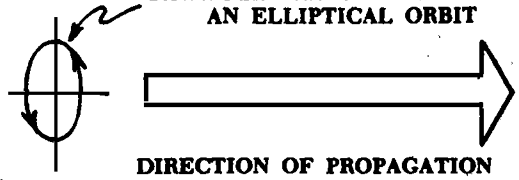


FIGURE 12.—Surface Waves

Velocity of surface waves depends upon the material and is about nine-tenths of the shear-wave velocity. Surface waves are likely to be affected, in their propagation, by variations in hardness, plated coatings, shot peening, or surface cracks, and are easily dampened by dirt or grease on the surface of the specimen. Surface waves can often be produced as an unwanted effect, especially when the contact surface is rough.

The waves are not limited to flat surfaces. They will travel around curves and surface contours. Sharp corners, such as the boundaries of plates or flaws, will reflect these waves. In fact, it is this characteristic or traveling around contours which makes surface waves so useful in surface flaw detection. (See Figure 13.)

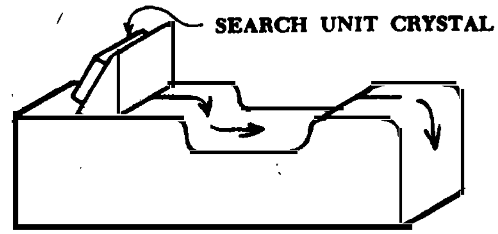


FIGURE 13.—Surface Wave Technique

25. PLATE (LAMB) WAVES. When ultrasonic vibrations are introduced into a relatively thin sheet, the energy propagates in the form of plate waves.

Unlike the longitudinal, shear, and surface modes, the plate wave velocity is dependent both on frequency and plate thickness. A complex particle motion exists somewhat like the elliptical orbits described for surface waves. Greatly simplified, they can be divided into two basic types: The symmetrical type are known as dilational waves and the asymmetrical type as bending waves.

Examples of these two modes are illustrated in Figure 14.

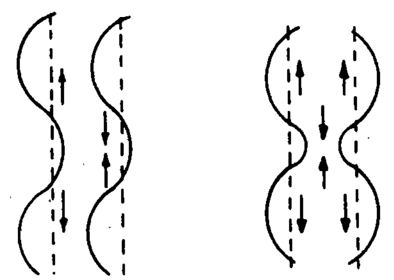


FIGURE 14.—Plate Waves

Plate waves can be used for detecting nonbonded areas in laminated structures such as sandwich panels. By sending waves along the outer surface, any areas of the top sheet that are not securely bonded in place can be made to vibrate in one of these modes. By sensing such local areas of vibration, lack of proper bonding can be detected.

26.–30. RESERVED.

Chapter 4. ULTRASONIC VIBRATIONS

31. TESTING METHODS. Ultrasonics employ low-amplitude stresses which do not permanently affect a specimen because of the short wave lengths and relatively low energy of the ultrasonic vibrations which are transmitted through the material. On the other hand, destructive mechanical tests, such as static physical tests and forced vibration fatigue testing involve high–amplitude stresses. These high–amplitude stresses may cause heating, nonlinear effects, permanent deformation, and eventual rupture of the specimen.

Sound waves beyond the hearing range of the human ear are referred to as ultrasonic vibrations. The term embraces all vibrational waves of a frequency greater than approximately 20,000 Hz. Ultrasonic vibrations of the lower frequencies act in essentially the same manner as do audible waves. Most commercial ultrasonic testing is done at frequencies from 200 KHz to 25 MHz; however, application exists for frequencies as low as 2 KHz and as high as 200 MHz.

In practical testing, selection of frequency depends on sensitivity desired and sound penetration required; high frequency for sensitivity and low frequency for penetration. In general, sound waves of all frequencies will penetrate fine-grain material. However, as the grain structure becomes more coarse, interference in the form of scattering may be expected when using higher frequencies (shorter wave lengths) and greater depth of penetration will be obtained by going to lower frequencies (longer wave lengths). The resonant frequency of a crystal is determined primarily by its thickness, the higher the frequency the thinner the crystal. For this reason, crystals with frequencies above 10 MHz are generally considered too fragile for contact testing. All testing frequencies, however, can be used in immersion testing.

Ultrasonic vibrations have several important characteristics:

a. They travel relatively long distances in solid materials.

b. They travel in well–defined sound beams.

c. The velocity of a specific vibrational wave mode is constant through a given homogenous material.

d. Most of the energy contained in one vibrational wave train is dissipated before the succeeding pulse is introduced to avoid confusing indications.

e. Vibrational waves will be reflected at boundaries of different elastic and physical properties.

f. Vibrational waves may change their mode of vibration when passing between materials having different elastic and physical properties or when reflected from boundaries at certain angles.

32. REFLECTION OF ULTRASONIC WAVES. Reflection of the ultrasonic vibrations will occur at the boundary between two different materials if a mismatch of acoustic impedance is encountered. The ultrasonic beam will be reflected at the interface exactly like light waves. For instance, the silvered back of a mirror has a high impedance mismatch to air, and light reflects from it at a very high efficiency. A plain piece of polished crystal has a very low impedance mismatch with air, and consequently, reflects very little.

When ultrasonic energy impinges upon the interface between two different mediums, part will

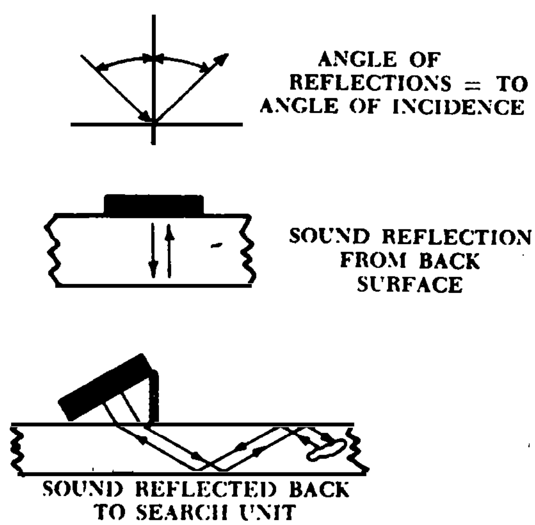


FIGURE 15.—Reflection of Ultrasound

be reflected, and the rest will be allowed to pass into the second medium, depending upon the impedance ratio between the two materials. Also, the path traveled by the vibrations and whether they return to their source depends upon the angles at which the beam impinges upon the reflecting surfaces, as well as the number and location of these surfaces. (See Figure 15.)

33. REFRACTION AND MODE CONVERSION OF ULTRASONIC WAVES. Ultrasonic beams introduced at an angle into a specimen are refracted. The velocities in the wedge material and the metal are different, therefore, the longitudinal vibrations will be refracted when passing into the metal. (See Figure 16.) At certain angles, conversion to other

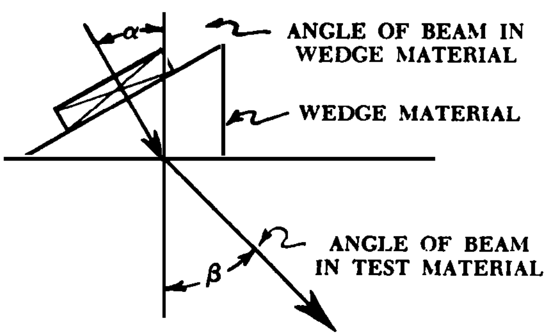


FIGURE 16.—Refraction of the Ultrasonic Beam

modes of vibration, such as shear (see Figure 17) and surface waves (see Figure 18) occurs.

WHERE: φ = angle normal to the beam in the wedge.

β = angle of refracted beam in specimen.

c_1 = velocity of incident vibrations in the wedge (usually the longitudinal velocity).

c_2 = velocity of vibration in the material under inspection for the desired wave mode.

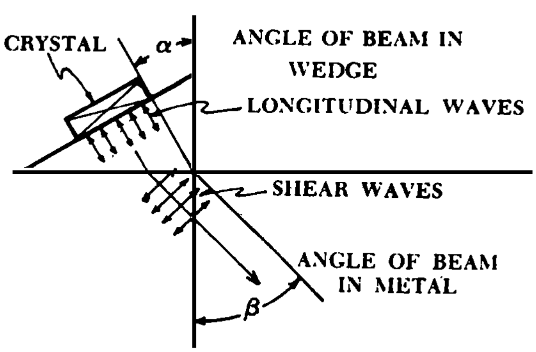


FIGURE 17.—Generating Shear Waves

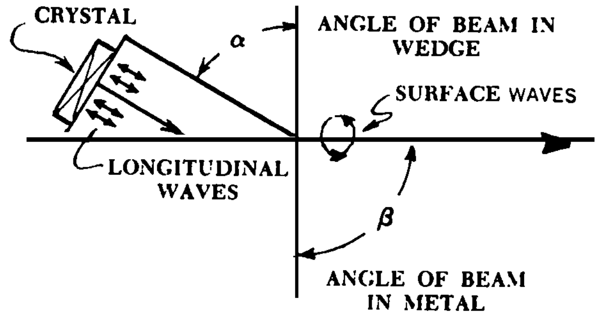


FIGURE 18.—Generating Surface Waves

34. BEAM DIVERGENCE. Beam divergence varies with frequency and crystal diameter. The higher frequencies give more directivity to the sound beam. Also, a large diameter crystal is more directive than one of a smaller diameter when operated at the same frequency. (See Figure 19 and 20.)

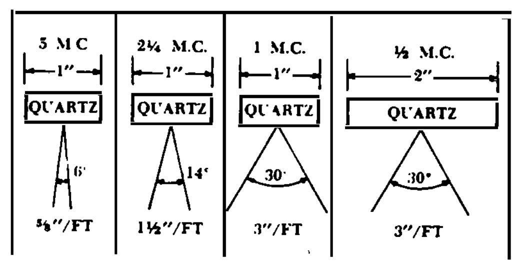


FIGURE 19.—Beam Divergence of Sound Waves in Steel

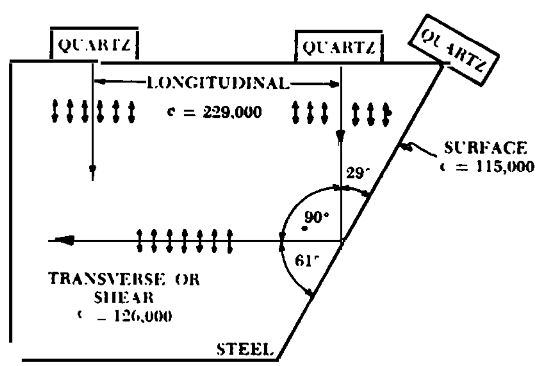


FIGURE 20.—Diagram of Longitudinal Sound Striking a Surface

35.–40. RESERVED.

Chapter 5. ULTRASONIC SYSTEMS

41. GENERAL. There are two basic ultrasonic systems: pulsed and resonance.

42. PULSED. The pulsed system may be either echo or through transmission. The pulse–echo is the most versatile of the two pulse systems and suitable for service and overhaul use.

a. Echo. Flaws are detected by measuring the amplitude of signals reflected and the time required for these signals to travel between specific surfaces and discontinuity. (See Figure 21).

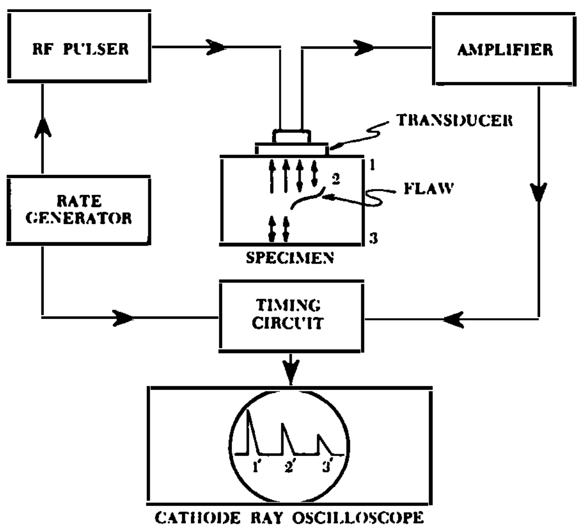


FIGURE 21.—Block Diagram of Basic Pulse–Echo System

The time base, which is triggered simultaneously with each transmission pulse, causes a spot to sweep across the screen of the CRT. The spot sweeps from left to right across the face of the scope 50 to 5,000 times per second, or higher if required for high–speed automated scanning. Due to the speed of the cycle of transmitting and receiving, the picture on the oscilloscope appears to be stationary.

A few microseconds after the sweep is initiated, the rate generator electrically excites the pulser and the pulser in turn emits an electrical pulse. The transducer converts this pulse into a short train of ultrasonic sound waves. If the interfaces of the transducer and the specimen are properly orientated, the ultrasound will be reflected back to the transducer when it reaches the internal flaw and the opposite surface of the specimen. The time interval between the transmission of the initial impulse and the reception of the signals from within the specimen is measured by the timing circuits. The reflected pulse that is received by the transducer is amplified, then transmitted to the oscilloscope where the pulse received from the flaw is displayed on the CRT screen in the same relationship to the front and back pulse as the flaw is in relation to the front and back surface of the specimen. (See Figure 22.)

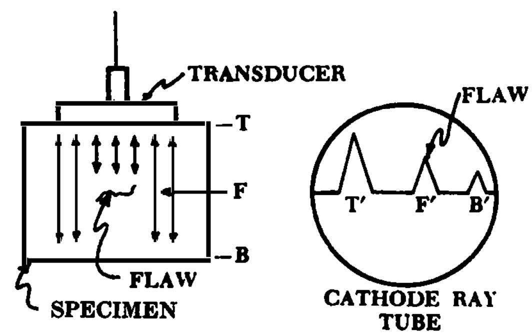


FIGURE 22.—Oscilloscope Display in Relationship to Flaw Detection

b. Through Transmissions. This system uses only amplitude information and operates on the principle that certain specific changes in the sample will produce significant changes in the intensity of an ultrasonic beam passing through it. This system requires two transducers placed on opposite sides of the specimen. (See Figure 23.) One transducer transmits the wave through the piece and the other picks up the signal. If there is a defect in the path of the wave, the received indication is reduced in size to the degree that the signal is blocked. This system is used extensively for bond testing of laminated and clad materials where the area of a laminar–type defect is of interest, and its probable depth is either known or of no importance.

This system is also useful in testing for metallurgical changes due to heat, pressure, stress, and fatigue.

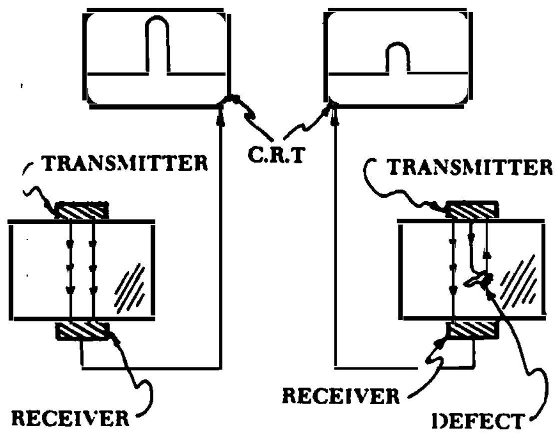


FIGURE 23.—Through–Transmission Technique

43. RESONANCE. This system differs from the pulse method in that the frequency of transmission is, or can be, continuously varied. The resonance method is principally used for thickness measurements when the two sides of the material under test are smooth and parallel. The point at which the frequency matches the resonance point of the material under test is the thickness determining factor.

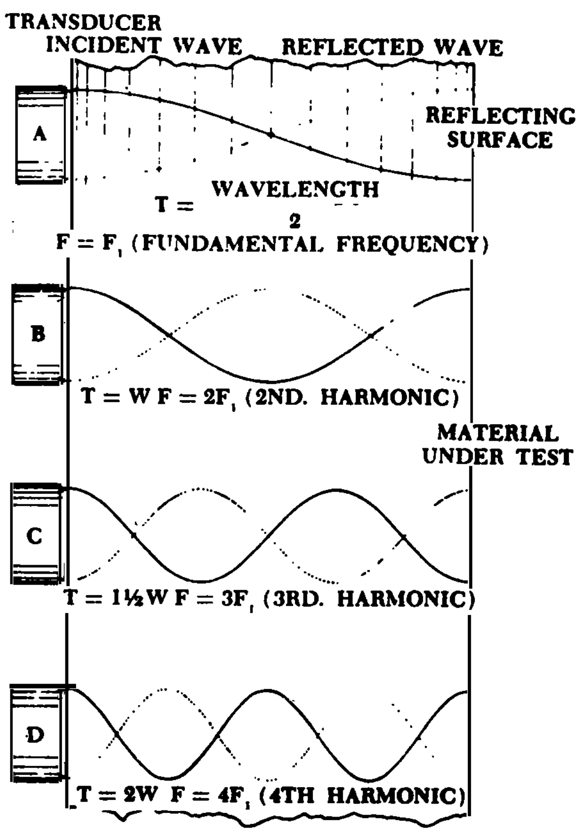


FIGURE 24.—Conditions of Ultrasonic Resonance in Metal Plate

It is necessary that the frequency of the ultrasonic waves, corresponding to a particular dial setting, should be accurately known. Checks should be made with standard test blocks to guard against possible drift of frequency. If the frequency of an ultrasonic wave is such that its wave length is just twice the thickness of a specimen, then the reflected wave will arrive back at the transducer in the same phase as the original transmission so that strengthening of the signal, or a resonance, will occur. If the frequency is increased so that three times the wave length equals four times the thickness, then the reflected signal will return completely out of phase with the transmitted signal and cancellation will occur. Further increase of the frequency, so that the wave length is equal to the thickness again, gives a reflected signal in phase with the transmitted signal and resonance occurs once more. By starting at the fundamental frequency, where the wave length equals twice the thickness and gradually increasing the frequency, the successive cancellations and reinforcements can be noted and the readings used to check the original or fundamental, frequency reading. (See Figure 24.)

In some instruments, the oscillator circuit contains a motor–driven capacitor which changes the frequency of the oscillator. (See Figure 25.) In other instruments, the frequency is changed by electronic means.

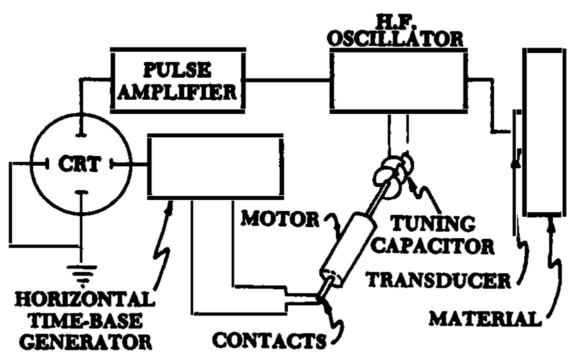


FIGURE 25.—Block Diagram of Resonance Thickness Measuring System

The change in frequency is synchronized with the horizontal sweep of a CRT. The horizontal axis thus represents a frequency range. If the frequency range contains resonances, the circuitry is arranged to present these vertically. Calibrated transparent scales are then placed in front of the tube and the thickness can be read directly. The instruments normally operate between 0.25 MHz and 10 MHz in four or five bands.

The resonant thickness instrument can be used to test the thickness of such materials as steel, cast iron, brass, nickel, copper, silver, lead, plastics, aluminum and magnesium. In addition, areas of corrosion on fuel tanks fuselage and wing skins can be located and evaluated.

44.–50. RESERVED.

Chapter 6. PRESENTATION

51. OBSERVING AND RECORDING RESPONSE PATTERNS. There are several methods of observing and recording ultrasonic response patterns such as a CRT, indicating lights, alarm lights, alarm devices (bells, buzzers, etc.), paint-spray markers, strip–chart and facsimile recorders, photographic representations, go/no–go monitors, and others. These methods may be used in combination to suit a particular need.

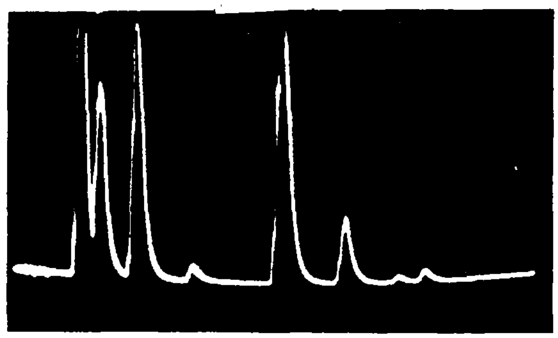
52. CATHODE-RAY TUBE (CRT).

a. Size: The screen sizes may vary from 3″ to 12″, however, there is usually no need for providing a signal larger than that which can be presented by a 5″ tube. The large screens do not provide any more picture information. Usually a small tube will have better contrast and definition. The primary purpose in using a large screen is in automated systems where the scanning transducer must be positioned some distance from the viewing screen of the test instrument.

b. Signal Trace. Figure 26 shows the two most common trace presentations. The Radio–Frequency (RF) presentation exhibits signals both above and below the sweep line. This type of presentation provides maximum resolution for locating defects close to the surface or for separating signals following closely upon one another. The video trace presentation is a cleaner and less cluttered signal than the RF presentation, however, it provides for less signal resolution because of its broader pulse characteristics. The video presentation is, in fact, an RF presentation with the bottom half electronically off and only the outline of the original pulses, added on to the top half, is shown. Therefore, larger signals are indicated, but flaw definition is more limited. Of the two traces, the video is most commonly used because it is easier to read.

c. Range Markers. To provide a means of measuring the depth of a flaw indication, square waves are electronically superimposed on, or beneath, the regular sweep line of the test presentation. The lengths of these waves can be adjusted to represent inches or feet of the material being tested. Figure 27 shows three of the most commonly used types of wave markers.

RF



VIDEO

FIGURE 26.—Radio–Frequency Trace and Video Trace

The square–wave markers shown at the top are easy to distinguish from the spike–like echo signals. They generally provide the most precise means of measuring flaw depth. The pyramidal markers (center) are especially useful in an angle-beam test where the sonic energy is sent into a piece at an angle and bounces back and forth between the walls as it travels on through the part under test. These markers simulate the actual path of the search beam passing through the piece, making it easier to determine the flaw depth with respect to the top and bottom surfaces of he specimen. The bottom marker illustrated differs from the other two types in that it does not have equal positive and negative values. These markers are a compressed negative wave and deflect in the opposite direction to the echo signals.

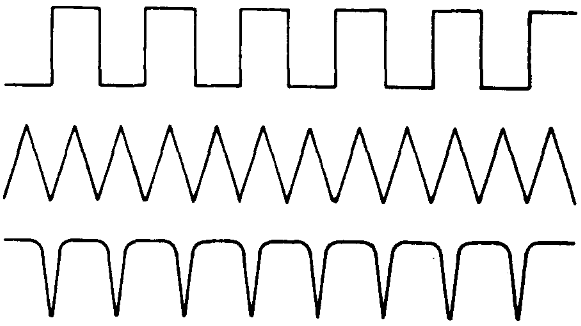


FIGURE 27.—Types of Marker Systems

53. SCAN PRESENTATIONS. The ultrasonic echoes are electronically translated into visual presentations on the CRT. There are three different presentations available; the A–scan; B–scan; and C–scan.

a. A-scan. In the A–scan presentation, the horizontal base line on the screen indicates elapsed time (from left to right) and represents the depth of the test specimen. The vertical deflection shows response amplitude. The signal amplitude represents the intensities of transmitted or reflected beams. This may be related to flaw size, sample attenuation, or other factors. (See Figure 28.)

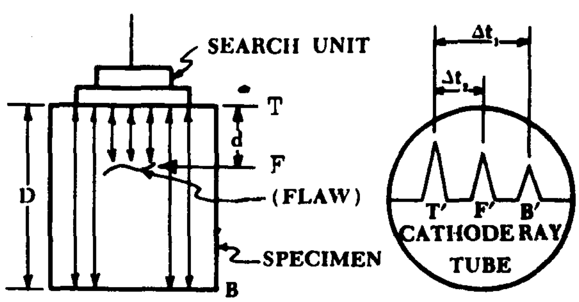


FIGURE 28.—A–Scan Presentation

b. B–scan. The B–scan takes the same signal received by the A-scan and presents them in a different pattern. The location and depth of the flaw can be determined as in the A–scan, but, in the case of small defects, only a rough estimation of the flaw size can be obtained. (See Figure 29.) The B–scan presentation has been used in the testing of plate stock for laminations.

c. C–scan. The C–scan presentation is a plan view of the part under test; a flaw is indicated in a manner similar to that given when a radiograph is made of a part. The electronic beam follows the movement of the probe and traces a true–to–scale reproduction on the CRT. However, accurate flaw depth cannot be determined from the C–scan presentation. (See Figure 30.)

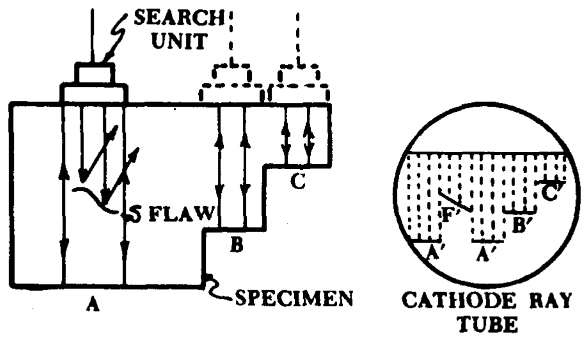


FIGURE 29.—B–Scan Presentation

Since the C–scan presentation is a true–to–scale reproduction of the flaw, the CRT is used only for calibration, tuning, and visual monitoring of the test. The use of facsimile–type paper recorders are currently supplementing the CRT.

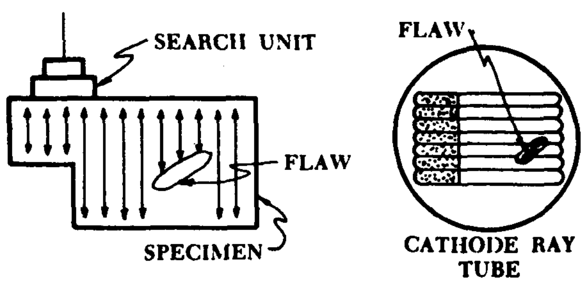


FIGURE 30.—C–Scan Presentation

The recorders provide excellent resolution, a permanent record, and are available with paper widths up to 36″ by several hundred feet in length. By varying intensities ranging from black to light grey, the depth of a defect can be approximated on the facsimile recorder.

54. INDICATIONS. It is possible to illustrate in this circular every variation of displays presented by the CRT. Fortunately, the great majority of patterns will fall into one or another of ten basic types which are illustrated and explained in the following paragraphs. Before the ultrasonic system can give results, as outlined in the following figures, it must, of course, have been properly set up and adjusted using standard reference blocks (see Figures 31 through 40).

a. Figure 31 represents a smooth-surfaced rectangular or round block with parallel surfaces placed directly under the search tube and at right angles to it. In such a case, clear pips representing the front and back surfaces of the material will be seen, and any flaw pips which are present will appear between these two.

The echo from the front surface of the metal returns first and is located at the left-hand side of the screen. The echo from the back surface of the sample arrives last and so is located at the extreme right of the screen. A pip which is located two-thirds of the distance from the front echo to the back echo indicates a flaw which is two-thirds of the thickness of the sample below its upper surface. For instance, if the sample is 3″ thick, and the pip appears on the right-hand side of the screen at two-thirds of the distance between the pips, measured from left to right, then the flaw is located 2″ below the surface. If the flaw is sufficiently large, all of the remaining sound may be reflected from it. In this case, the back echo will disappear, and the flaw will cast an ultrasonic shadow on the back surface.

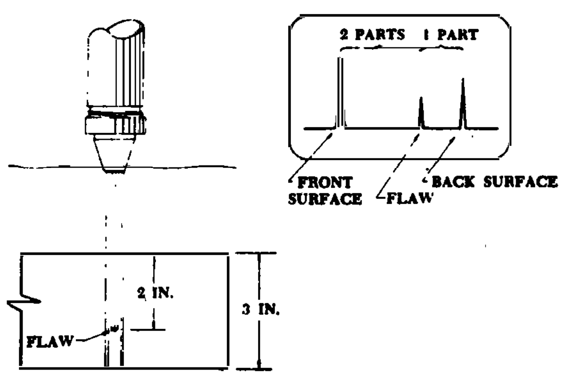


FIGURE 31.—Immersion Crystal Focused on Test Block and Indications to be Expected

b. ***Figure 32*** illustrates a situation in which the back surface of the sample to be tested is not parallel to the front surface. Under these circumstances, when the sound waves reach the back surface they will be reflected at an angle in the same manner as a beam of light would be reflected, and so they will not return to the crystal. This means, of course, that the pattern on the screen will not have a right-hand pip, which represents an echo from the back surface. If a second pip does appear, it probably represents a flaw. If any question exists as to whether this second pip is a flaw or an echo from the back surface, a distance measurement will indicate which it is. Any flaws will, of course, appear on the screen at a distance less than the actual thickness of the material being tested.

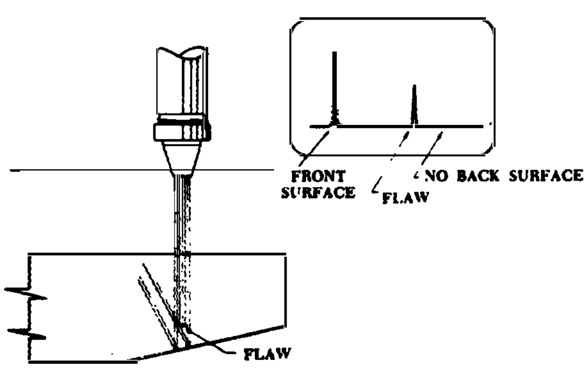


FIGURE 32.—Immersion Crystal Focused on Block with Defect and Non-parallel Surface

c. ***Figure 33*** indicates a situation where the depth of the metal through which the sound waves have to pass is so great and the nature of the metal is such that all of the sound waves are absorbed so that the echo, if any, from the back surface of the material is unable to get through. Again, of course, any pip to the right of the one representing the front surface will represent a flaw. In such a case, a distance measurement will clearly indicate that the flaw is close to the front surface.

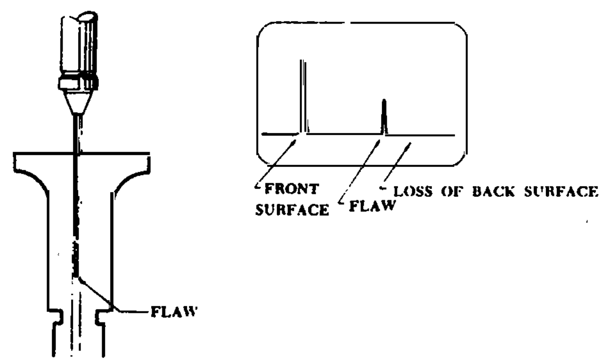


FIGURE 33.—Immersion Crystal Focused on Shaft too Long for Back Reflection of Return

d. ***Figure 34,*** the item being tested is a seam weld on a piece of thin-walled tubing. Behavior characteristics of ultrasound at an acute angle of approach are such that some of the sound waves will be reflected from the surface and be lost. The rest of the waves will become trapped in the circular path of the metal, and very little echo will be received from either the front surface or the back surface. Those waves which are proceeding through the wall of the tubing will strike any obstruction in the wall at approximately right angles, and will return an echo from such an obstruction. If the tube has been inspected prior to welding and found to be free of flaws, then any flaw which shows up after welding must be in the weld or the weld bead.

e. ***Figure 35*** represents the inspection of a welded tube with a wall thickness in excess of 0.125″. Refraction conditions are such that pips

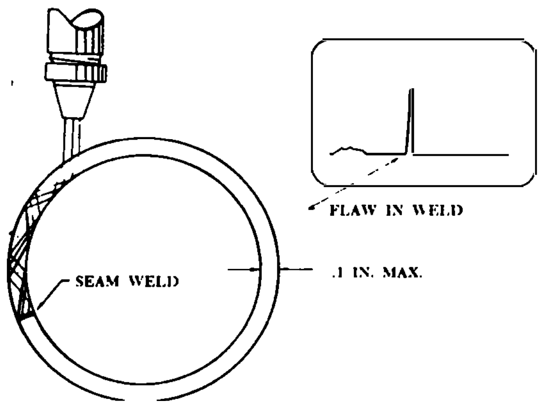


FIGURE 34.—Angle Beam Penetrating a Weld Bead

may be obtained representing both the outer and inner surfaces of the tube together with pips from any flaws which may be in the tube. The differences between the results received in Figures 34 and 35 situations are due to the beam angles.

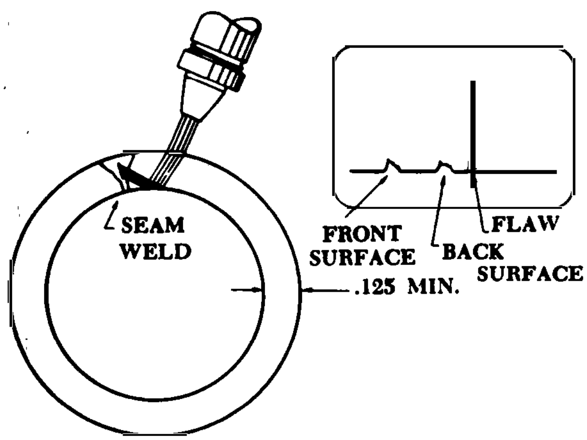


FIGURE 35.—Angle Beam Penetrating a Weld Bead

f. ***Figure 36*** represents the inspection of a weld in a heavy plate. The rough surface of the weld bead prevents a direct overhead inspection of the weld zone because the ultrasound beam cannot enter near the surface of the rough bead. Therefore, the transducer must be directed so the sound beam will be refracted to strike the flaw at right angles. The ultrasound, when it leaves the couplant and enters the metal, will refract in such a way that the beam will be bouncing between the surfaces of the material.

When an ultrasonic beam enters metal at some angle other than normal to the surface, the internal angle will change rapidly with small changes in the external angle. If the internal deviation angle exceeds approximately 15°, both shear and longitudinal waves will result. Above 33°, longitudinal waves will disappear. Shear waves will produce the same indications on the screen as longitudinal waves. To produce shear waves in steel, set the transducer to some angle above 33°.

In shear-wave inspection, a rather small and poorly defined echo is obtained from the front surface of the specimen. However, a strong echo will be returned from vertical fissures, or cracks, in the material being inspected. If the searching tube is moved horizontally without changing its angle, the flaw pip will move toward or away from the surface pip. This is because the acoustic path between the front surface and the flaw is made stronger or longer by the motion of the screening tube.

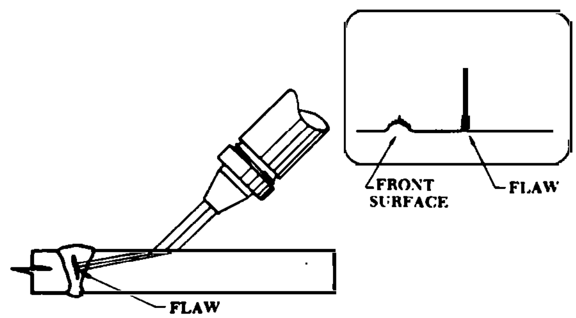


FIGURE 36.—Angle Beam Penetrating a Flat Plate

g. ***Figure 37*** represents a situation in which the front surface of the metal is so rough that a complete scattering of the sound waves results. In such a situation, no appreciable penetration into the metal will occur and any echoes that ordinarily appear on the screen will also be dissipated by the roughness and will not be received. The only possible solution to such a problem is either to have the

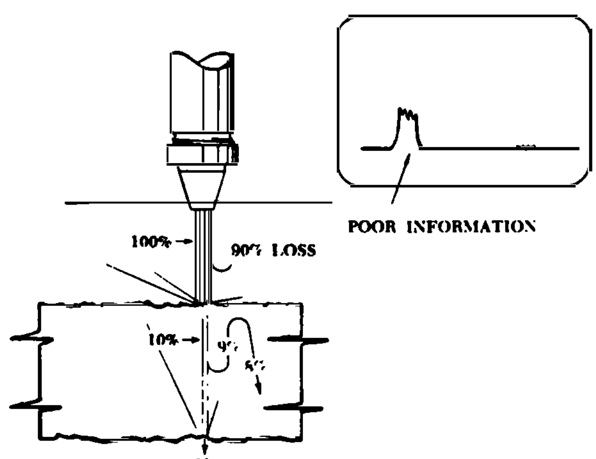


FIGURE 37.—Results of a Rough Front and Back Surface

surface smoothed sufficiently, or to conduct the test through a smoother surface from another angle. It is also suggested that the lowest frequency possible be used.

h. Figure 38 represents a typical reading from two different materials that have been brazed or welded face–to–face. Where a good uniform bonding has been obtained, a clear reading will be received with normal front and back pips, and a series of very small ridges. These ridges represent the uneveness of the bonded surfaces. If, however, the bonding is faulty and a void exists between the two surfaces, the sound waves will be unable to penetrate the void, and the pip from the bottom plate will be lost entirely, and a series of pips like tall grass will appear after the front surface indication, which represents reverberations of the sound waves within the top plate.

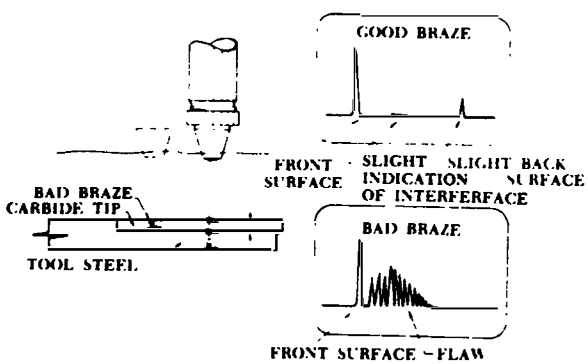


FIGURE 38.—Evaluating Braze of Carbide Tip to Steel

i. Figure 39 represents an inspection of relatively porous material. The front pip will be clear, but the back pip will be either very small or nonexistent because the ultrasonic waves have either been absorbed or dissipated by the porous nature of the material. The clear pip of the front surface will probably be followed by a long series of bumps, or very short "grass", which represents tiny echoes received from the porous structure itself and do not actually represent flaws. If a significant flaw is located within the material, it should create a pip of sufficient size to be recognized. Ultrasound will not, however, penetrate deeply into exceptionally porous material. As shown in Figure 37, lower frequencies penetrate more readily than higher frequencies. As shown in Figure 32, distance measuring will ascertain that pips are not actually an echo from the back surface.

It may be necessary to inspect a sample involving complex curved surfaces which do not fit any of the preceding illustrations. In such cases, the sound should be directed to hit the flash-line zone or grain flow at right angles since flaws would be oriented along the flash line or the grain flow direction. As shown in Figure 40, the probes are improperly positioned, therefore, any indication received would be erroneous.

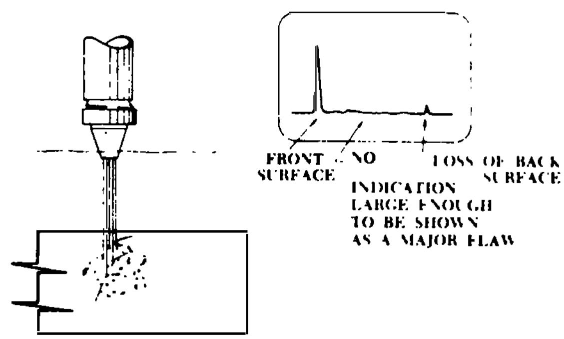


FIGURE 39.—Indication Received from Porous Material

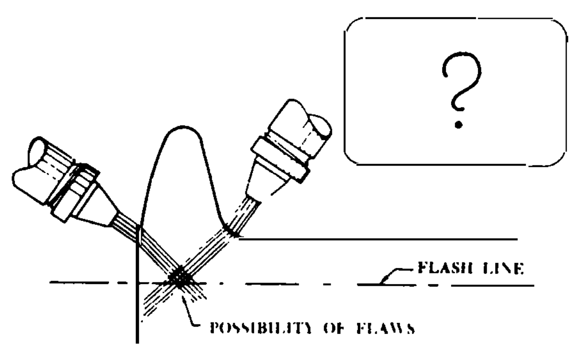


FIGURE 40.—Irregular Part

55.–60. RESERVED.

Chapter 7. RECORDERS

61. TYPES. The recording of flaws may be either by deflection modulation or intensity modulation.

62. DEFLECTION MODULATION, CONVENTIONAL PEN-CHART RECORDERS. In the deflection modulation method of recording, a pen draws a continuous line on a chart. (See Figure 41.) When a flaw is detected, the line is deflected from its true path in proportion to the flaw amplitude.

63. INTENSITY MODULATION, C-SCAN METHOD OF FACSIMILE RECORDING. A true-to-scale reproduction of defects or a change in material density is indicated by various intensities ranging from black to light grey. (See Figure 42.) When testing plate or other relatively flat specimens, the recorder prints a plan view of the test piece showing defect location and relative defect size. When testing material on a rotating mechanism, a true position along the X axis of defects detected is shown. When testing cylindrical components on a turntable, the true position along the Z axis of flaws detected is shown. When conducting a spiral scan of a disc which is mounted on the testing turntable, the recording chart is also mounted on a turntable that rotates in synchronism with the testing turntable.

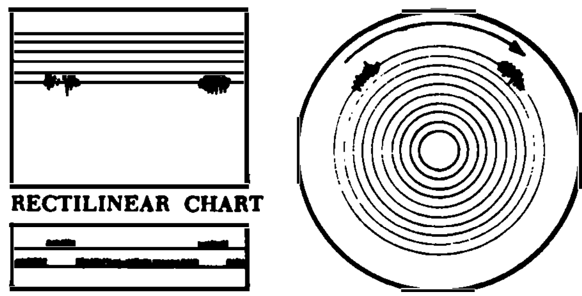


FIGURE 41.—Various Recording Charts

64.–70. RESERVED.

FIGURE 42.—Ultrasonic Recording of Brazed Honeycomb Panel

Chapter 8. ELECTRONIC GATING

71. FUNCTIONS. One of the most important functions required in a high-speed ultrasonic testing system with automatic readout or control, is the selection and processing of only those signals from discontinuities which occur within particular zones or areas of the test piece. This is accomplished by establishing a specific controllable gated zone within the test piece. (See Figure 43.) Signals above a pre-test amplitude occurring within the gate, can be monitored automatically and used to operate visual or aural alarms, sorting deflectors, or paint-spray markers.

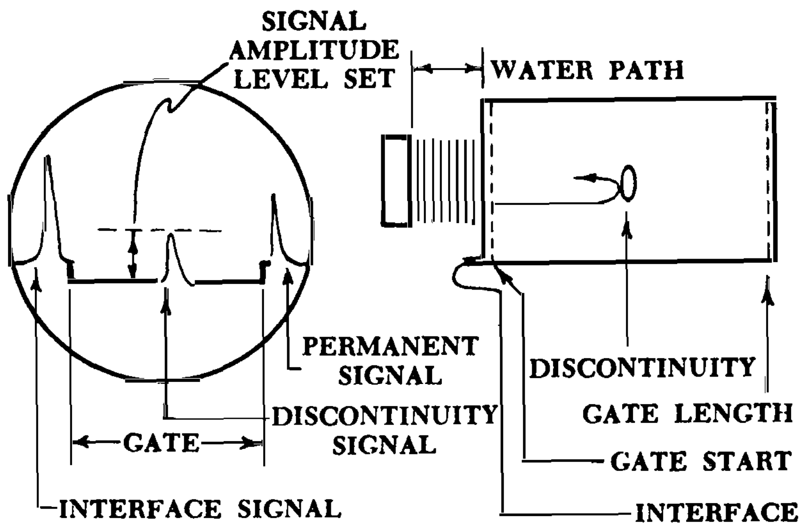


FIGURE 43.—Controllable Gated Zone in Test Piece

72. BASIC OPERATING PRINCIPLES OF GATES. A gate is a device having several inputs and one output. Some of the inputs may be called signal inputs and others may be designated as control or selector inputs, although often the inputs are indistinguishable from one another.

There are two general classes of gates. The first, called the transmission or linear gate, is defined as one in which the output is approximately a replica of one of the inputs, but the output occurs only during times selected by the control inputs. Thus the gate transmits the signal from input to output in a linear manner during selected times.

The second class of gate, called the switching or logical gate, is defined as one in which the ouput is a pulse which may have no resemblance to any of the inputs, except that the pulse occurs during the interval selected by the control voltage.

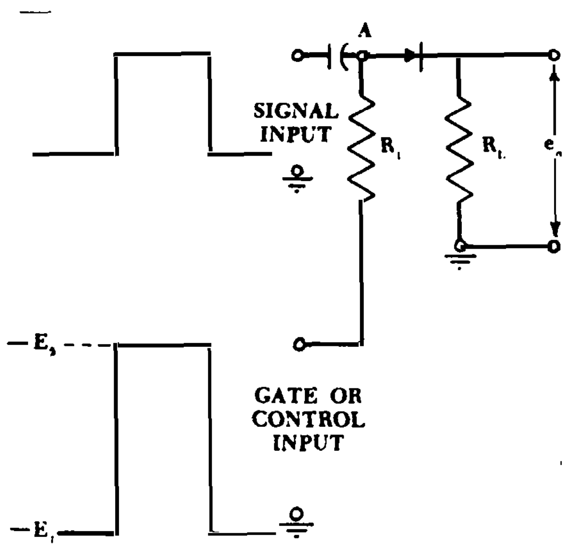


FIGURE 44.—Threshold Gate Circuit Diagram

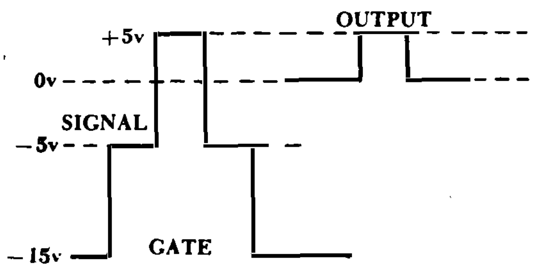


FIGURE 45.—Threshold Gate Wave Form

The gate of Figure 44 is suitable for a positive-going input signal. The gate signal (also called a control pulse, a selector pulse, or an enabling pulse) is a rectangular wave form which makes abrupt transitions between the negative levels $-E_1$ and $-E_2$.

In Figure 45, $-E_2$ is assigned a value of minus 5 volts, and for a 10-volt input pulse, a 5-volt output pulse appears. When used in this manner, the circuit is referred to as a threshold gate.

73.–75. RESERVED.

Chapter 9. DELAY LINE

76. DESCRIPTION. By using a delay unit to increase resolution power, "close–to–surface" defects, such as those normally found in spot welds, may be investigated and evaluated.

The basic operation of a delay line depends on the fact that acoustic signals travel much slower than electrical signals. At the input end of the line, the electrical signal to be delayed is converted to an acoustical signal by a transducer.

The signal travels along the delay line as an acoustic wave, requiring a specific time to travel to the output end. At the output end, the signal is converted back to its electrical form by another transducer. Figure 46 illustrates one of a number of methods which may be used to delay or slow down the electrical signal by converting it to the slower traveling sound waves.

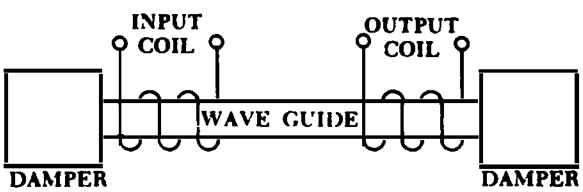


FIGURE 46.—Ultrasonic Delay Time

The ultrasonic delay line shown employs an input and an output transducer coil with a magnetostrictive core which is attached to a sonic wave guide. At the input end, the flux changes in the coil caused by the electrical input signal set up mechanical stress (vibrations) in the score. These vibrations travel down the line to the output coil. Acoustic absorbers (dampers) are used at both ends of the line to prevent reflections along the wave guide, which would introduce a form of distortion. A given amount of delay can be accomplished by using different lengths of line.

77.–80. RESERVED.

Chapter 10. COUPLANT

81. GENERAL. A couplant is a liquid having good wetting properties to transmit ultrasonic vibrations from the transducer to test surfaces.

82. DESCRIPTION. Ultrasound generated by the piezoelectric effect, for all practical purposes, will propagate in air due to its high frequency and short wave length. The actual movement of a piezoelectrical crystal vibration is in the micron range; it is often described as acceleration without motion. To transmit such energy into a material, use a fluid couplant between the search unit face and the material surface. A film of oil, glycerine, or water is generally used. (See Figures 47 and 48.) When water is used as the couplant, a wetting agent should be used to eliminate surface tension and facilitate "wetting" of the surface. When it is either impracticable or undesirable to use oil or water, a couplant paste is used.

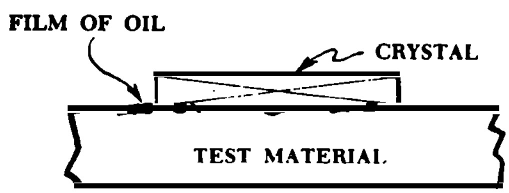


FIGURE 47.—Couplant (Contact Testing)

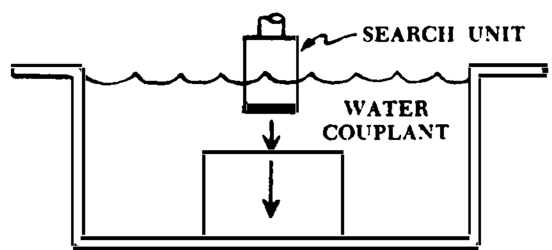


FIGURE 48.—Couplant (Immersion Tesing)

83.–85. RESERVED.

Chapter 11. ULTRASONIC REFERENCE BLOCKS

86. INTRODUCTION. Ultrasonic testing should not be accomplished without first calibrating the equipment to the proper reference standard. Standard Reference Blocks are used to standardize the ultrasonic equipment, set the sensitivity, and evaluate the discontinuities in the material being inspected. These blocks provide the comparison for any combination of crystal size, frequency, or test instrument used to inspect materials. The evaluation of the discontinuities within the material is accomplished by comparing the ultrasonic response from the discontinuity with the known artificial defects (flat-bottomed holes or notches) in the Standard Reference Blocks. The test instrument should be adjusted to indicate the hole representing the smallest defect it is desired to pick up. When making a test set-up, care should be taken to assure that the test block is of the same formulation alloy with similar surface conditions as the material under test. This precaution is necessary to assure that distance calibration is correct. If any adjustments are made on the apparatus, or if the probes are changed during the test, the probe and apparatus should be checked again on the reference blocks for sensitivity and proper functioning before resuming test.

87. DISTANCE-AMPLITUDE COMPARISON BLOCKS.

a. Hitt Blocks. Ultrasonic Standard Reference Blocks designed to be used for distance amplitude comparisons have a specific size flat-bottomed hole placed at varying depths below the surface of the material. The three sets have $3/64''$, $5/64''$, or $8/64''$ size flat-bottomed holes. The metal distance of the blocks normally used varies from $1/16''$ to $6.0''$ (See Figure 49.)

b. Calibration of ultrasonic thickness measurement equipment may be accomplished by using a "step-block." For exact calibration, it is always best to have a block whose thickness will give five

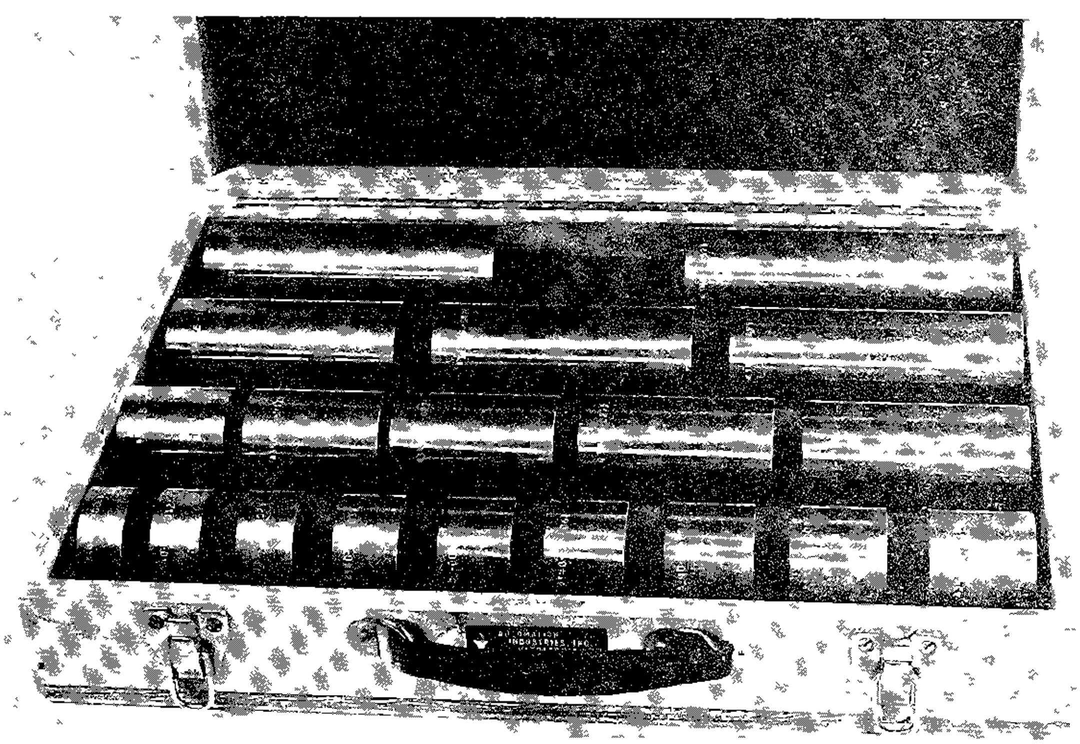


FIGURE 49.—Distance-Amplitude Comparison

signals on the screen for the range selected. (See Figure 50.)

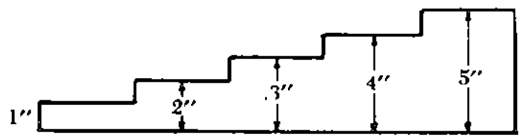


FIGURE 50.—Step Block

88. AREA-AMPLITUDE COMPARISON BLOCKS (ALCOA BLOCKS). A set consists of eight Ultrasonic Standard Reference Blocks. Each set contains one block with the following flat-bottomed holes: 1/64", 2/64", 3/64", 4/64", 5/64", 6/64", 7/64", and 8/64" The holes are placed at a depth of 3.0" below the surface of the material. Area-amplitude relationships at the 3-inch metal distance are obtained by intercomparison of the blocks within the set. (See Figure 51.)

89. I.I.W. WELDING BLOCK. The I.I W. Welding block was developed through the International Institute of Welding (I.I.W.). The block has gained wide acceptance as a reference standard in distance calibration and in the calibration of the angle of sound beam propagation from angle-beam search units (See Figure 52.)

90. ASME WELD REFERENCE PLATE. This standard ultrasonic reference plate is required to check the performance and sensitivity of the ultrasonic equipment and ultrasonic search units used in the inspection of welded joints under the ASME code requirements. This block provides three reproducible levels of instrument sensitivity for both longitudinal and shear-wave inspections and insures re-examination at the same level of sensitivity. (See Figure 53.)

91. SPECIAL REFERENCE STANDARDS. Many applications in ultrasonic inspections require special reference standards or blocks. The application may involve the use of standard sizes of blocks but employing a special type material or it may involve the use of special shaped blocks. A convex or concave entry surface as applicable is required when the test specimen has a curved entry surface. Many users of ultrasonic equipment prepare special reference blocks from a sample of the material under test that contains a known defect to represent the standard that is acceptable.

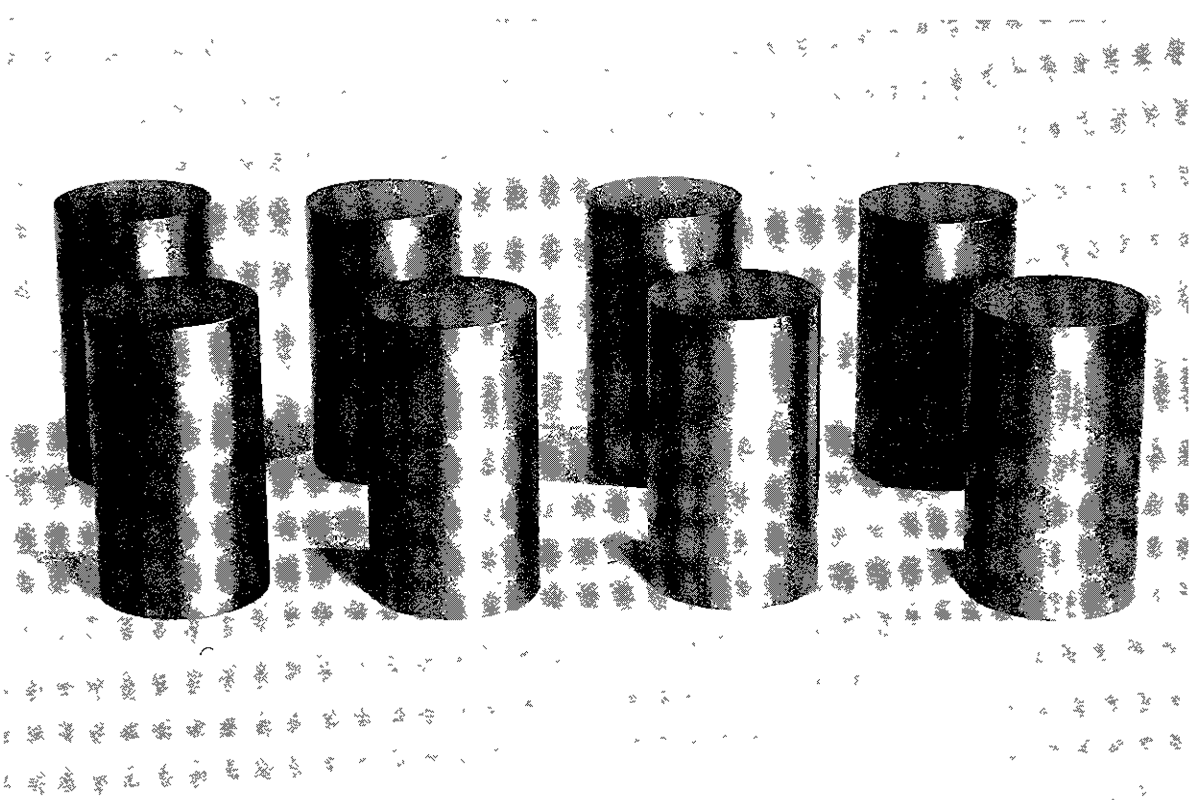


FIGURE 51—Area Amplitude Comparison Blocks

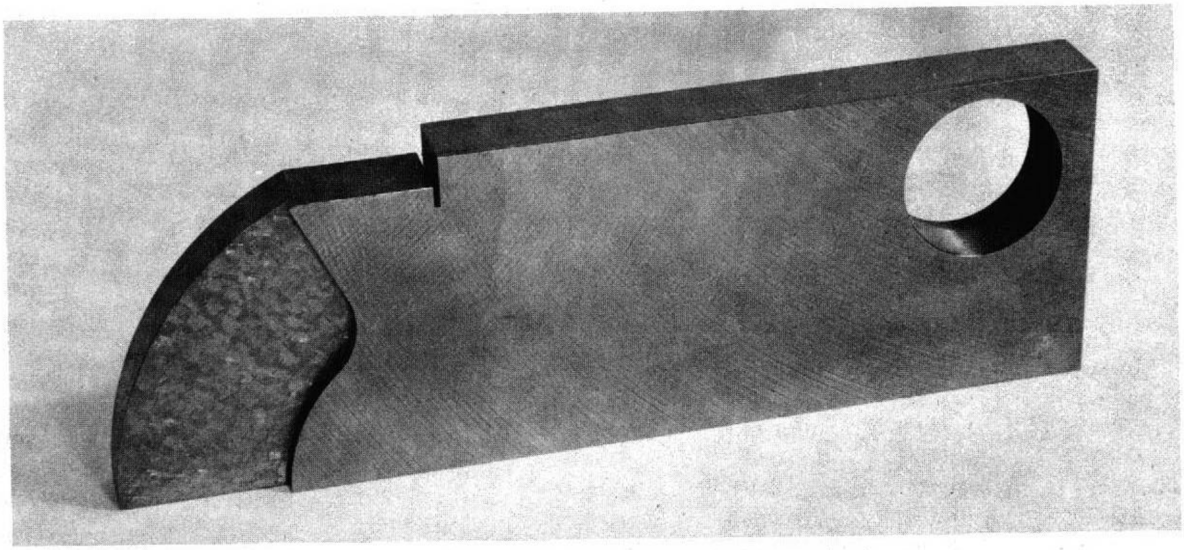


FIGURE 52.—I.I.W. Weld Block

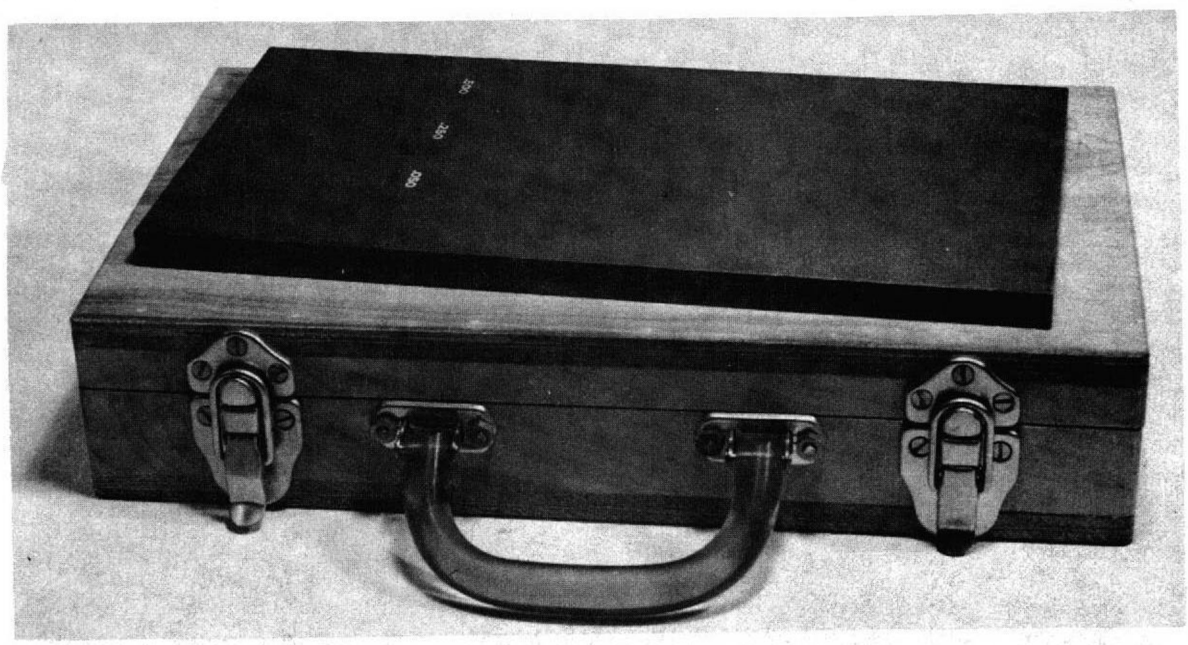


FIGURE 53.—ASME Weld Reference Plate

92.–95. RESERVED.

Chapter 12. TESTING METHODS

96. DESCRIPTION. Contact and immersion are the two basic methods used for ultrasonic nondestructive inspection The instrumentation of one method can be adapted, in a limited way, to the other

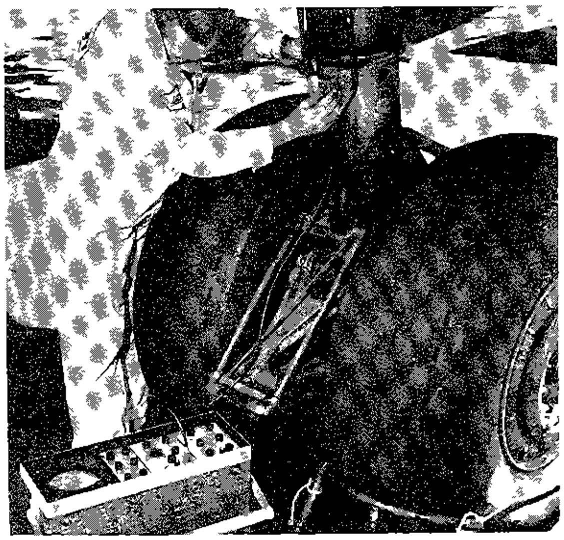


FIGURE 54—Contact Angle-Beam Test into Hidden Weld Region of a Landing Gear Oleo Strut

97. CONTACT TESTING. This method of testing can be used when the aircraft is on the line or ramp since the test equipment can be handcarried directly to the work area (See Figures 54, 55, and 56.) The principle of contact testing is illustrated in Figure 57.

Scanning of the test specimen is accomplished by manually moving the search unit over the test surface. A couplant, such as oil, is required between the face of the probe and the entrant surface of the specimen to exclude the air gap and couple the sound waves into a specimen.

98. IMMERSION TESTING. This method transmits sound into an inspection specimen through a water path or column The immersion search unit is usually of waterproof construction. Repetitive inspections provide a pre-programmed fully automated system Forgings, castings, and non-symmetrical parts with fillets, rough surfaces radii, etc , that cannot be tested by the contact mehod may be immersion tested with a manually operated scanning system Inspection is accomplished by:

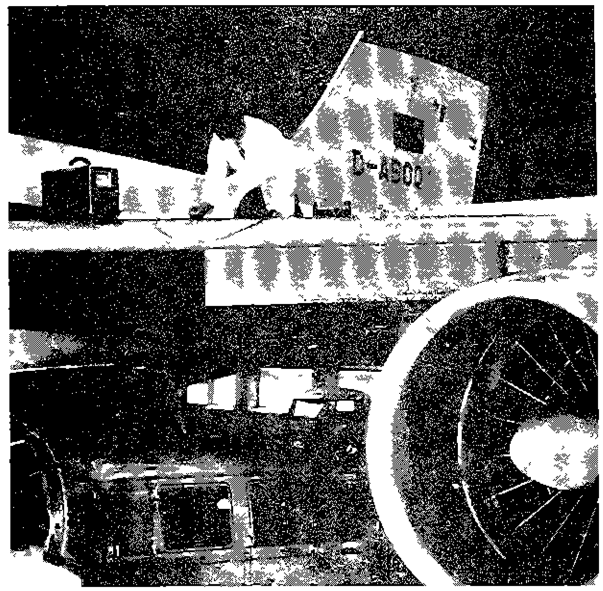


FIGURE 55.—Ultrasonic Inspection of a Wing Front Spar

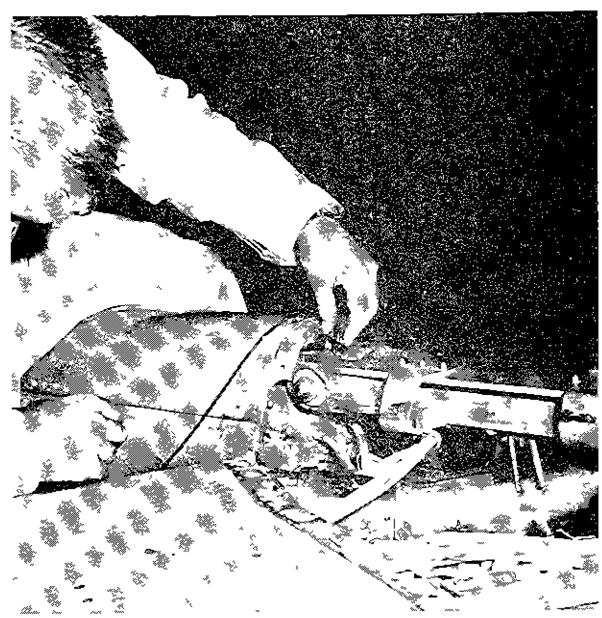


FIGURE 56—Ultrasonic Inspection of a Pylon Structural Member

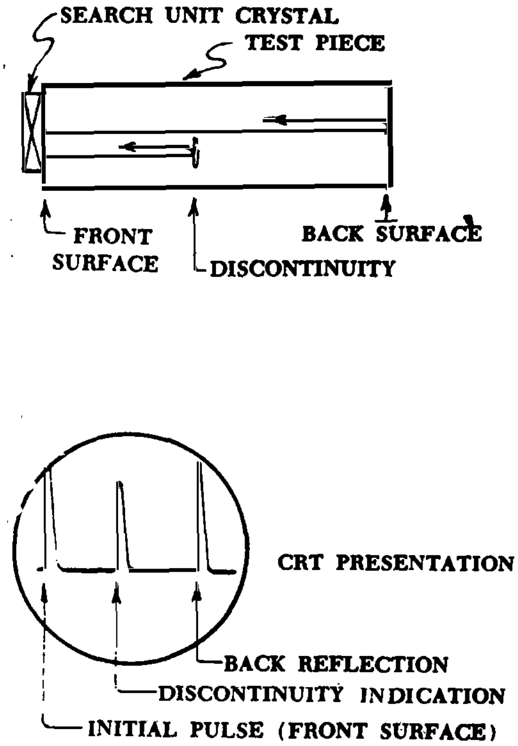


FIGURE 57.—Principle of Ultrasonic Testing (Contact)

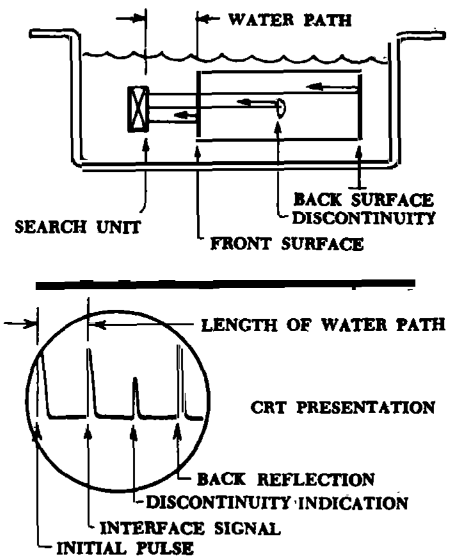


FIGURE 58.—Principle of Ultrasonic Testing (Immersion)

a. Immersing both the search unit and the material in a liquid couplant, normally water. (See Figure 58.)

b. By a squirter or bubbler which directs a column of flowing water to form a couplant between the face of the transducer and the surface of the specimen. (See Figure 59.)

c. By a wheel-search unit in which the transducer is mounted in a liquid-filled tire. The tire is operated in direct contact with the material. (See Figure 60.)

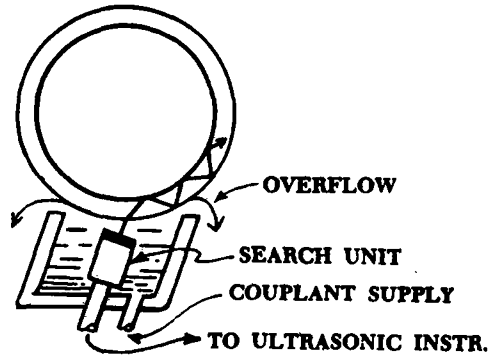


FIGURE 59.—Bubbler Angle-Beam Testing (Pipe)

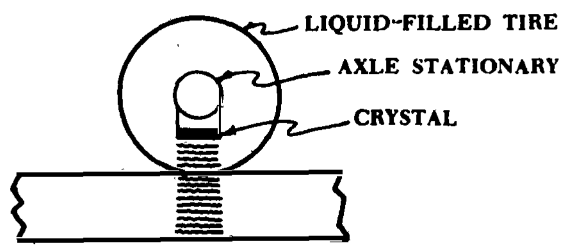


FIGURE 60.—Wheel Scanning Method

99. IMMERSED SCANNING TECHNIQUE. Both the search unit and the part to be tested are totally immersed in water. The sound beam is directed into the material normally by a straight-beam search unit. Angle-beam techniques such as shear or plate waves are accomplished through control and direction of the sound beam. (See Figures 61, 62, and 63.)

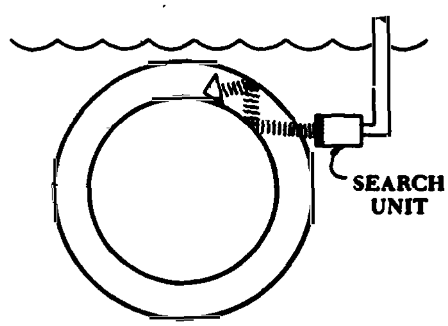


FIGURE 61.—Immersed Angle-Beam Technique (Pipe or Tube)

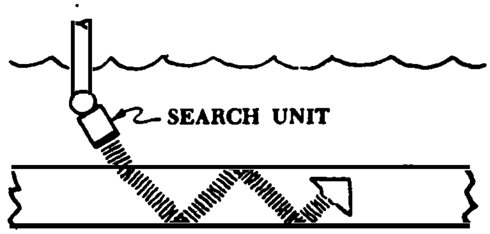


FIGURE 62.—Immersed Angle-Beam Technique (Plate or Sheet)

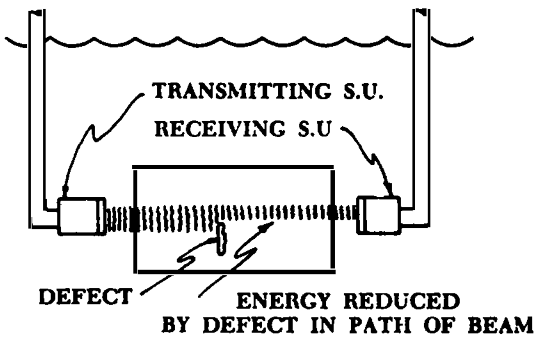


FIGURE 63.—Immersed Through-Transmission Technique

In immersion testing by the straight-beam technique, the water path distance (search unit to front surface of the test piece) is generally set longer in time than the length of scan (front surface to back surface) so that the first multiple of the interface signal will appear further along the CRT sweep than the back reflection. This is done to clear the test area of signals which may cause misinterpretations. This is particularly important when the test area is gated for automatic signalling and recording operations. (See Figure 64.)

a. Focused Search Unit. The high-frequency mechanical vibrations of the sound beam can be focused through acoustic lens structures in a manner similar to that achieved by glass lenses in optics. The acoustic lens is an integral of the focused search unit assembly and is designed to provide a well-defined and directed sound beam pattern. The energy propagated from the search unit can be concentrated through spherical lens structure into cone-shaped beams with high intensity. (See Figure 65.)

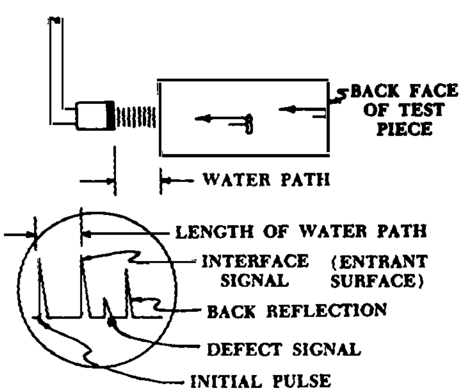


FIGURE 64.—Removing First Multiple of Interface Indication From Test Area

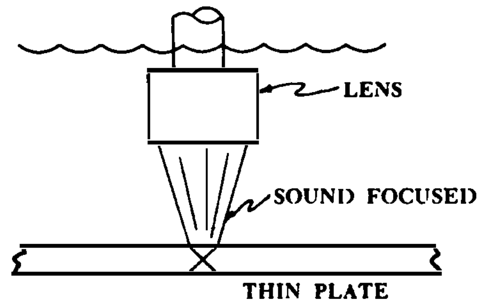


FIGURE 65.—Focused Search Unit

b. Beam Collimator. Beam divergence varies with frequency and crystal diameter. The higher frequencies give more directivity to the sound beam and a 1″ diameter crystal at any frequency is more directive than a ½″ diameter crystal operating at the same frequency. Therefore, to obtain more directivity (which results in a better definition of the defect) the frequency must be increased or a larger diameter crystal must be used.

Increasing the frequency to obtain a better definition of the defect often defeats the purpose of the test, since the increase in frequency is also an increase in sensitivity. The higher sensitivity discloses irrelevant factors such as surface scratches, nicks, and dents which make the defect evaluation difficult.

Therefore, to obtain more directivity of the sound beam without increasing the frequency, a larger diameter crystal is used. Since the defect under examination may occupy only a small portion of the

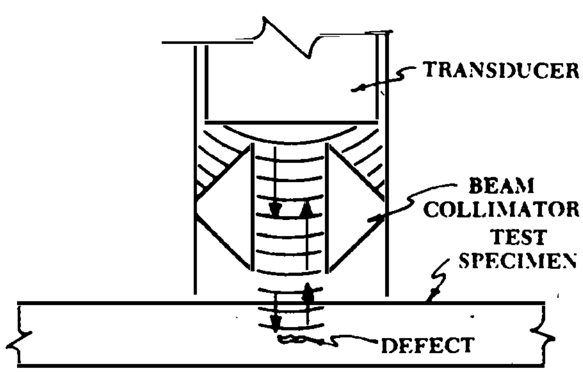


FIGURE 66.—Beam Collimator

total area of the beam spread, a beam collimator is used to reduce the area of the sound beam entering the test piece to cover only the area under inspection.

The sound–carrying shaft in the center of the collimator conducts the straight center rays of the transducer into the specimen. The remainder of the beam is prevented from reaching the test piece or returning a signal to the transducer by the acoustical block. (See Figure 66.)

100. WATER COLUMN TECHNIQUE (BUBBLER, SQUIRTER). The water column scanning technique operates on the immersion principle where a beam of high–frequency sound is projected through a water path into the test material. This technique is adapted to high-speed scanning of plate, sheet, strip, cylindrical forms and other regularly shaped parts. The sound beam is projected into the material through a column of flowing water. The sound beam can be directed into the material either perpendicular to the test surface (Figure 67) or at an angle (Figure 68).

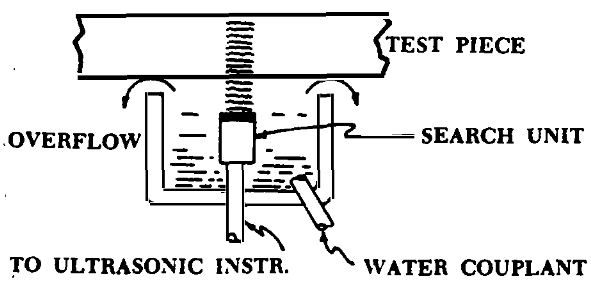


FIGURE 67.—Bubbler Scanning Method

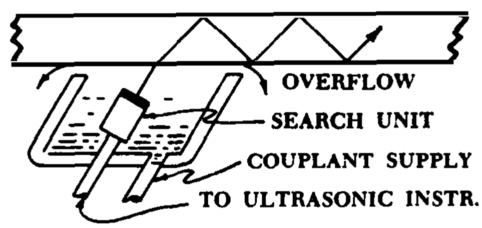


FIGURE 68.—Bubbler Angle–Beam Technique (Plate)

101. WHEEL SEARCH UNIT. The wheel search unit operates on the immersion principle in that a beam of high-frequency sound is projected through a liquid path into the test material. The search unit, mounted on the axle of a wheel with a liquid-filled rubber tire, is held in a fixed position relative to the test surface while the wheel rotates freely. The wheel search unit may be mounted on a stationary fixture, in which case the material moves past it (see Figure 69) or it may be mounted on a mobile fixture which runs over the material. (See Figure 70.)

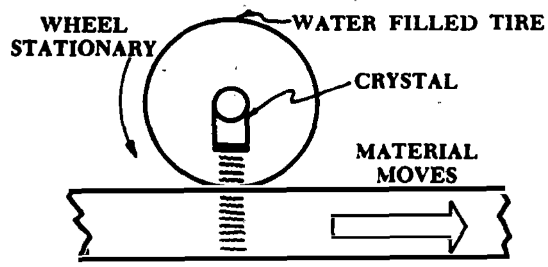


FIGURE 69. Wheel Search Unit in a Fixed Position

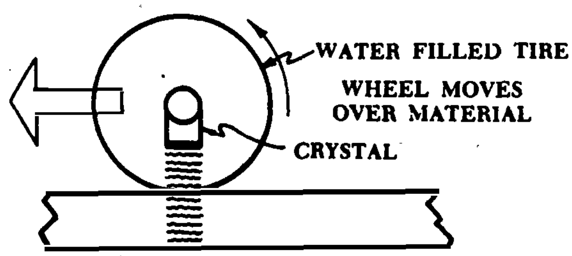


FIGURE 70.—Wheel Search Unit over the Material

The wheel is used in a wide variety of applications, and is especially useful for high-speed automated ultrasonic flaw detection systems since it combines advantages of both contact and immersion testing methods. The wheel eliminates the need for immersion tanks by coupling the transducer to the specimen through a water path and the resilient material of the tire–shaped casing.

Rusty, scaled, pitted, rough machined and asforged are successfully scanned with the wheel search unit.

The position and angle of the crystal mounting on the axle are determined by the test method and technique to be used; i.e., straight beam or angle beam.

102. ULTRASONIC IMAGE CONVERTER. The ultrasonic image converter is an evacuated tube having a piezoelectric quartz window, and contains an electron gun and multiplier. (See Figure 71.) When ultrasonic energy is impressed upon the quartz window, a piezoelectric voltage is produced whose magnitude at any one point corresponds approximately to the ultrasonic intensity at that point. These voltage variations influence the secondary emission generated by the scanning electron beam. The produced signal is then amplified and displayed using conventional closed–circuit television techniques.

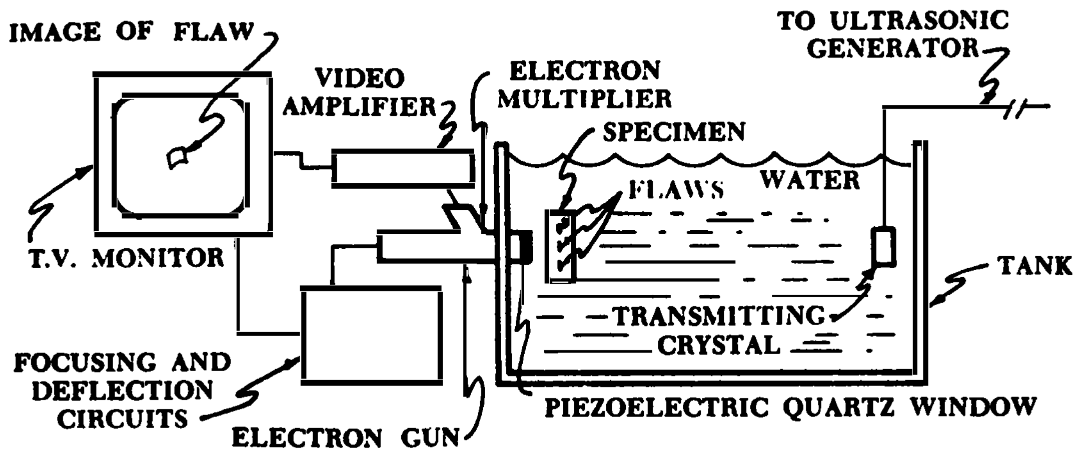


FIGURE 71.—Schemaic-Ultrasonic Image Converter System

103.–110. RESERVED.

Chapter 13. INSPECTION OF INTEGRAL FUEL TANKS FOR CORROSION

111. GENERAL. The existence of micro organisms in the fuel used in turbine-powered aircraft, results in failure of integral fuel tank coatings and corrosion of the wing skins.

Ultrasonic nondestructive testing provides a method of inspection for the detection and degree of corrosion in integral wing fuel tanks.

112. METHOD. Ultrasonic inspection techniques are used for determining and recording the condition of the interior surfaces of wet–wings. Longitudinal waves should be used since shear and plate waves will not accurately establish the definition or extent of corrosion pits.

113. EQUIPMENT. To scan the underneath surface of an aircraft wing, the following equipment is utilized:

a. ***A wheel search unit.*** To assure a satisfactory coupling, the surface to be scanned is moistened.

b. ***An oscilloscope*** with a fast pulse repetition rate. This is necessary to conduct a rapid scan of 500 square inches or more in 15 minutes.

c. ***A C–scan*** facsimile recorder.

d. ***An automatic and manually*** controlled scanning bridge and carriage.

e. ***A positioning mechanism,*** scanner support structure, and lift platform. This equipment places the sheel search unit in a position to scan the lower surface of the wing and provides the apparatus necessary to relate the motion of the search unit to the facsimile recorder. This equipment also permits a rapid engagement of the scanner with the aircraft and requires no jacking or other handling of the aircraft, nor is it necessary to drain the fuel tanks.

114. INDICATIONS. Intergranular corrosion appears on the C–scan recording as a solid area projecting outward from fastener holes or other locations where there is a transverse cut exposing the edge of the plate. Large or small areas of pit type corrosion may appear anywhere on the recording with high-density areas giving a mottled appearance to the recording. Thus, the extent and the kind of corrosion can be determined from the recording.

115.–120. RESERVED.

Chapter 14. INSPECTION OF REPRESENTATIVE AIRCRAFT PARTS

121. GENERAL. A few representative inspections by the contact method are discussed.

122. MAIN AND NOSE LANDING GEAR WHEELS. Figure 72 illustrates the part to be examined. A surface–wave probe is used to scan around the wheel web for cracks occurring adjacent to the bosses of the tie–bolt holes. The surface wave is able to detect cracks which are not always shown up by other methods of examination. The frequency used is 2.5 MHz and the depth of penetration is approximately 0.060″.

For cracks occurring in the zone of the tire areas, a second probe, having an angle of 30° refraction, is sometimes employed for testing the bead seat radius where the test is carried out without disassembly of the wheel. The angle is necessary to direct the beam away from any reflecting surfaces, such as changes in contour, into the zone where defects occur.

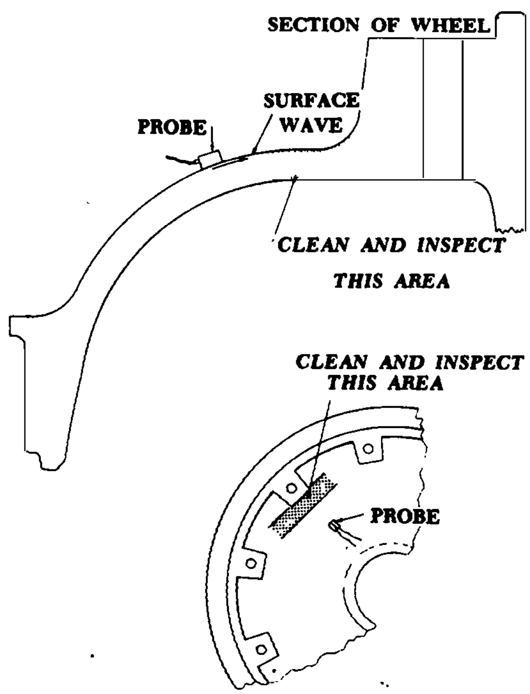


FIGURE 72.—Main and Nose Landing Gear Wheels

123. MAIN LANDING GEAR TORSION LINK. A 2.5 MHz surface–wave probe is applied to the member on its surface with the beam directed towards suspected zones. It is normal to scan most of the surface of the torsion link for fatigue cracks in any position occurring from the highly stressed areas. (See Figures 72 and 73).

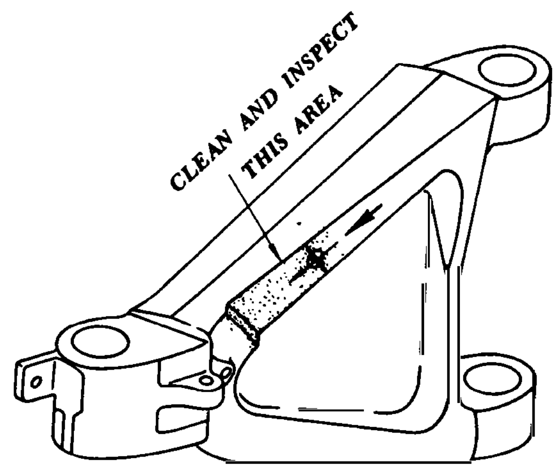


FIGURE 73.—Main Landing Gear Torsion Link

124. MAIN LANDING GEAR TORSION LINK LUGS. A surface-wave probe is used on the lug surfaces and on the thickened boss section for fatigue cracks occurring in random directions. It is necessary to direct the ultrasonic sound beam towards the crack at an angle of 90° in order to

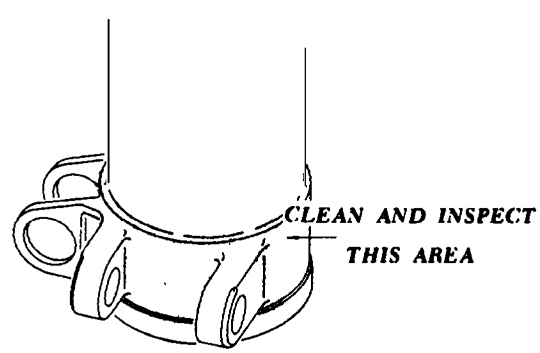


FIGURE 74.—Main Landing Gear Torsion Link Lugs

obtain the optimum reflection. This means that careful scanning in all directions and in all positions around the bosses and lugs is necessary to ensure complete coverage of the suspected area. (See Figure 74.)

125. MAIN LANDING GEAR OLEO OUTER CYLINDER. Figure 75 indicates the zone in which high stresses produce fatigue cracks. The whole of the section concerned needs to be scanned, using a 2.5 MHz surface-wave probe. Scanning is undertaken from the cylinder towards the fork ends, where the surface wave will travel around the changes in contour to locate defects in the zone indicated. Careful scanning is needed around the whole of the cylinder to find defects in any position around the base of the fork.

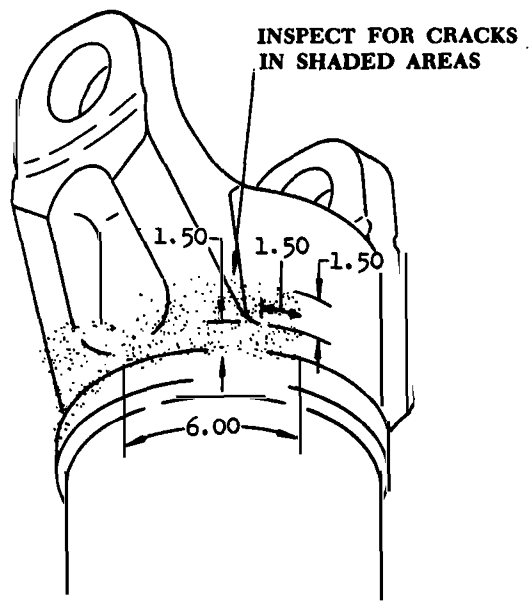


FIGURE 75.—Main Landing Gear Oleo Outer Cylinder

126. MAIN LANDING GEAR TRUNNION SUPPORT STRUCTURE. This examination is particularly difficult due to the geometry of the section to be inspected and due to its location on the aircraft. Very little space is available to apply the probe to the surface of the trunnion support. Figure 76 indicates the areas to be inspected but does not give a true picture of the complexity of this examination.

The probe is a complex arrangement producing a beam at an angle of 30° to the surface and having locating "wings" which align the probe in the correct position by insertion of the wing between the support structure and trunnion. Before undertaking this examination, the area needs to be cleaned and the grease removed from around the bearings. This can be done without removing any parts from the aircraft. Because left- and right-handed parts are to be examined, the probe is made in such a way that it can be located by either of two "wings" to suit the position of the part to be examined.

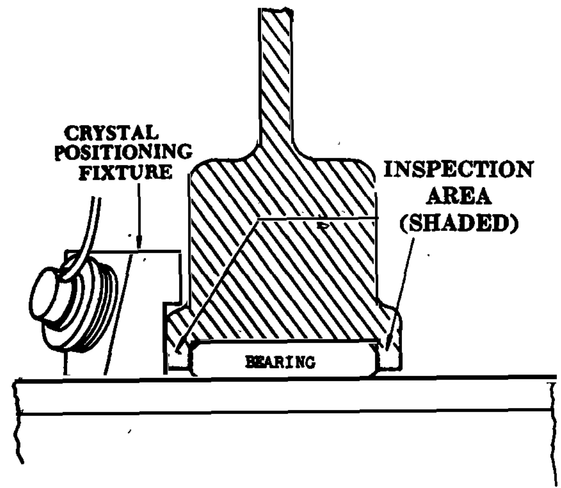


FIGURE 76.—Main Landing Gear Trunnion Support Structure

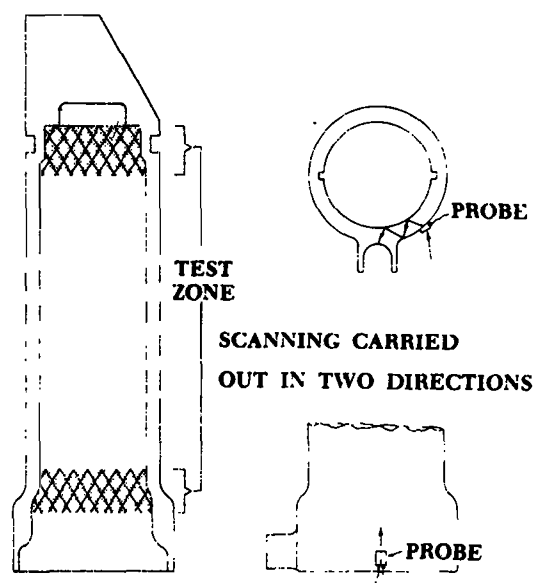


FIGURE 77.—Nose Landing Gear Outer Cylinder

127. NOSE LANDING GEAR OUTER CYLINDER. A 45° transverse-wave probe, 2.5 MHz frequency, is used to scan the upper and lower sections of this cylinder in the areas shown in Figure 77. The scanning is undertaken in two directions for the detection of cracks which normally occur on the inner surface but which can start on the outer surface. The two additional diagrams on the sketch show the method scanning.

128. INBOARD AND OUTBOARD NACELLE STRUT FRONT SPAR FITTINGS. Most of the examination of these components is undertaken on the curved sections of the lugs. The angle of the beam is approximately 20° from the tangent of the circle. To obtain this angle, the probe must have an incident angle of approximately 9°. Inspection is undertaken around the whole of the curved surface which gives more or less complete coverage of the bolt hole by moving a probe in two directions. In order to direct the beam towards any position of the hole in the lug, the probe has to be moved across the lug section from side to side while being rotated around the curved surface. This leaves a small section of the hole at the back of the lug which is not inspected. This is undertaken by a probe having a smaller angle and a slight taper on the lug surface. Both upper and lower parts of the lug have to be inspected by this method so that the entire bolt-hole section is examined. To facilitate examination from the curved surface, the probe surface is also curved. On some aircraft, this radius differs so that two probes would normally be necessary. Practice has indicated that a probe having a larger radius can be used on lugs of the smaller radius. (See Figure 78.)

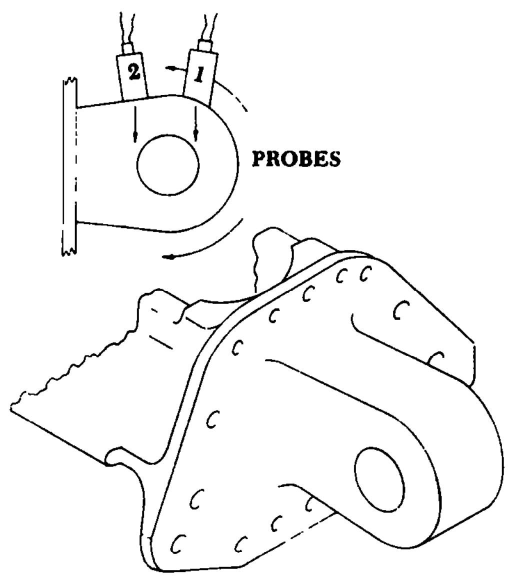


FIGURE 78.—Inboard and Outboard Nacelle Strut Front Spar Fitting

129. NOSE LANDING GEAR OUTER CYLINDER. Figure 79 shows the area of test undertaken using surface-wave probe with a frequency of 2.5 MHz. The probe is applied to the curved surface of the cylinder and the beam directed towards the lug. The sound wave follows the surface of the material and penetrates the flat surface of the lug for detection of defects from the corner of the sections into the lug zones marked on the sketch.

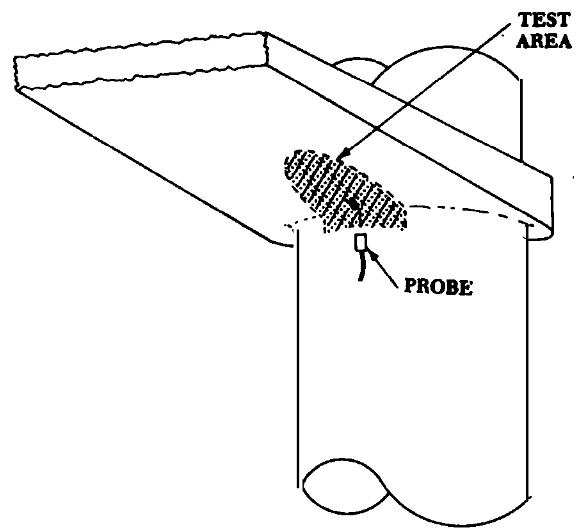


FIGURE 79.—Nose Landing Gear Outer Cylinder

130–135. RESERVED.