## PART 1 - GENERAL

## ULTRASONIC

NOTE: Ultrasonic inspection is divided into two main areas: Ultrasonic Flaw Detection and Ultrasonic Bond Inspection. Ultrasonic Bond Inspection is divided to cover metallic and composite structures.

### 1. Ultrasonic Flaw Detection

A. General

(1) Ultrasonic inspection can be performed on virtually all types of material used in aircraft structure. It is an extremely sensitive method of detecting flaws, both surface and subsurface. The Boeing Company has become increasingly interested in its use, both in material quality control and in aircraft maintenance programs. In relation to aircraft maintenance and overhaul, the company has concentrated mainly on the landing gear systems and the areas around fastener holes. Inspection techniques have been developed for all major components of the landing gear systems of Boeing jet transport aircraft: wheels, cylinders, torque link lugs, and trunnion supports. Other areas are now being investigated, and individual operators are urged to experiment also for possible use of ultrasonic testing in other areas of the aircraft.

(2) There are three basic methods of ultrasonic testing: (1) pulse-echo, (2) resonance, and (3) through transmission. Of the three, pulse-echo is the method most commonly used.

B. Description of Pulse-Echo Method

(1) In this method, pulsed, ultra-high-frequency sound waves are transmitted through a part with a piezoelectric transducer (crystal). When these sound waves are reflected from surfaces of the part or a flaw, the reflected sound waves are detected by the transducer. These reflected waves and the time required for the sound to travel between the surfaces or flaw are displayed on the face of a cathode ray tube. The size of the flaw can be determined by measuring the amplitude of these reflections. The location on the cathode ray tube will determine the location of the flaw in the part.

(2) Three wave modes are used in the pulse-echo method; (1) longitudinal, (2) shear, and (3) surface, or Rayleigh. These modes are illustrated in Fig. 1, and are described as follows:

## PART 1 - GENERAL

## ULTRASONIC

## ULTRASONIC FLAW DETECTION

(a) Longitudinal - These waves usually are transmitted into a part at right angles to the surface. Of the three wave forms, longitudinal obtains the highest velocity through the part. This mode can be used to measure thickness of a part as well as detect discontinuities. (See figure 2.)

(b) Shear, or Transverse - To induce a shear wave into a part, a plastic wedge is placed between a longitudinal wave transducer and the surface of the part. The velocity of the shear wave is about one-half that of the longitudinal wave. Also, shear waves are shorter in length than longitudinal waves. They are especially useful in finding a flaw in a hidden area of a part. Figure 3 gives data for fabricating lucite wedges for any desired angle.

(c) Surface, or Rayleigh - Surface waves travel over the surface of a part without any appreciable penetration into it. Their velocity and wave length are about nine-tenths those of the shear wave. A plastic wedge also is used between the transducer and the surface of the part to generate this type of wave. The optimum angle for producing a surface wave in aluminum is 64 degrees. This mode is used to detect surface flaws.

(3) The response pattern from any of the three wave modes can be shown on a cathode ray tube in any one of three patterns: (See figure 4.)

(a) A-Scan - The most common and widely used. Shows the signal as a peak on a straight line across the face of the cathode ray tube.

(b) B-Scan - Seldom used. Presents picture on face of the cathode ray tube in block form.

(c) C-Scan - Requires special equipment. Presents picture on a paper chart.

C. Equipment

(1) Because of constantly changing inspection techniques, and the necessity for detecting small defects, The Boeing Company recommends that the following factors be considered in evaluating ultrasonic equipment for aircraft maintenance inspection.

## PART 1 - GENERAL

## ULTRASONIC

## ULTRASONIC FLAW DETECTION

(a) The apparatus should ensure uniform, controlled operation, and should incorporate features for both contact and immersion testing with single or double search unit techniques.

(b) The equipment should be capable of dependably covering the standard frequencies (2.25 MHz, 5 MHz, and 10 MHz).

(c) For contact, single crystal work, the equipment should nave the following minimum capabilities within working depth of a part.

1) When using a frequency of 2.25 MHz, a 5/64-inch diameter, flat-bottomed hole should be resolved at a depth of 1.0 inch below the top surface of a sample part.

2) At 5 MHz, a 5/64-inch diameter hole should be resolved at a depth of 3/4 inh below the top surface.

3) At 10 MHz, a 5/64-inch diameter hole should be resolved at a depth of 1/2 inch below the top surface.

(d) Response should be displayed on a cathode ray tube that will present a relatively noise-free picture. Boeing recommended procedures normally will require the response from a simulated crack in a standard to be 70% of saturation as presented on the cathode ray tube.

(e) The instrument should have either integral or accessory constant voltage equipment to ensure adequate regulation of line voltage.

(2) Refer to Part 1, 51-01-00 for a partial list of ultrasonic flaw detection equipment manufacturers.

D. Preparation of Aircraft for Inspection

(1) For ultrasonic inspection it is not generally necessary to disassemble or remove part from the aircraft. However, it usually is necessary that access doors, fairing, or some items of equipment be removed to gain access to the inspection area.

(2) After gaining access to the inspection area, the following preparations must be made before performing an ultrasonic inspection.

(a) Rough scale or a limited amount of corrosion must be removed from parts to provide a smooth surface. A rough surface, with numerous pits and bumps, is difficult to inspect because of the unsteady pattern of response. Satisfactory results cannot generally be expected on finishes rougher than 250 microinches.

(b) Heavy paint and dirt should be removed. Heavy paint may absorb most of the sound energy.

(3) Specific preparation instructions are given with each procedure in Part 4.

E. Technique

(1) Techniques for ultrasonic inspection vary with the size, material, and shape of the part. Each technique is specific, and complete instructions are given for its accomplishment in Part 4 of this manual. Observing the following suggestions carefully when performing a specific test will enable operator to obtain acceptable results.

(a) Fabricate lucite transducer shoes, as closely as possible to dimensions given in individual procedure.

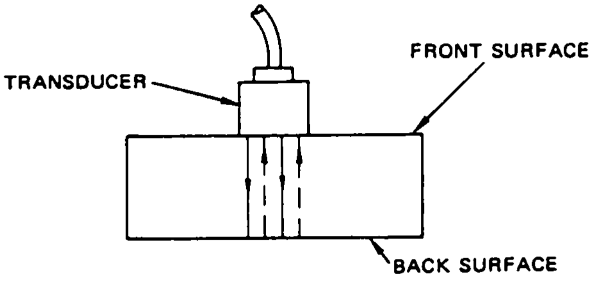
(b) Fabricate reference standards as closely as possible to given dimensions from material specified in individual test procedure. Electric discharge machining (EDM) may be substituted for jeweler's sawcuts in notch fabrication.

(c) Select couplant oil or grease as suggested by individual test procedure.

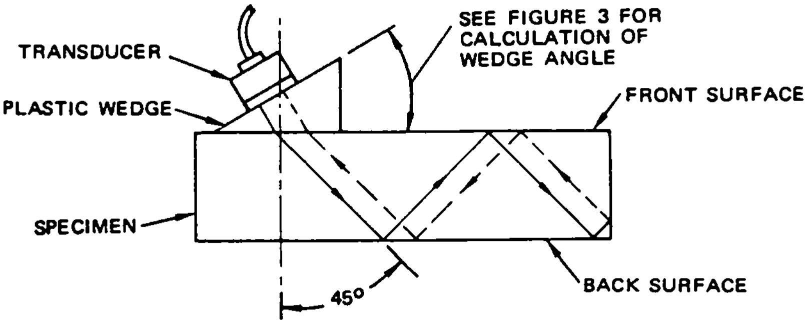
(d) Identify all tooling or fabrication holes before inspecting parts. The response of ultrasonic equipment does not differentiate between tooling holes and defects.

## ULTRASONIC

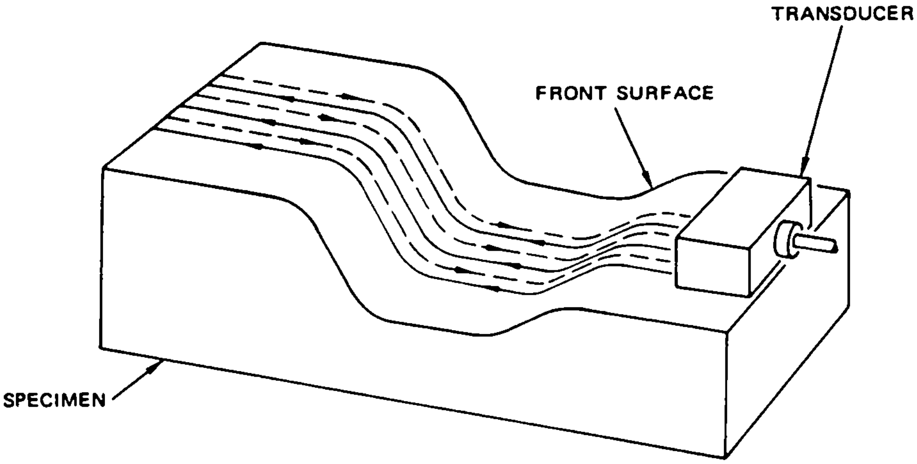
## ULTRASONIC FLAW DETECTION



LONGITUDINAL WAVE MODE



SHEAR WAVE MODE

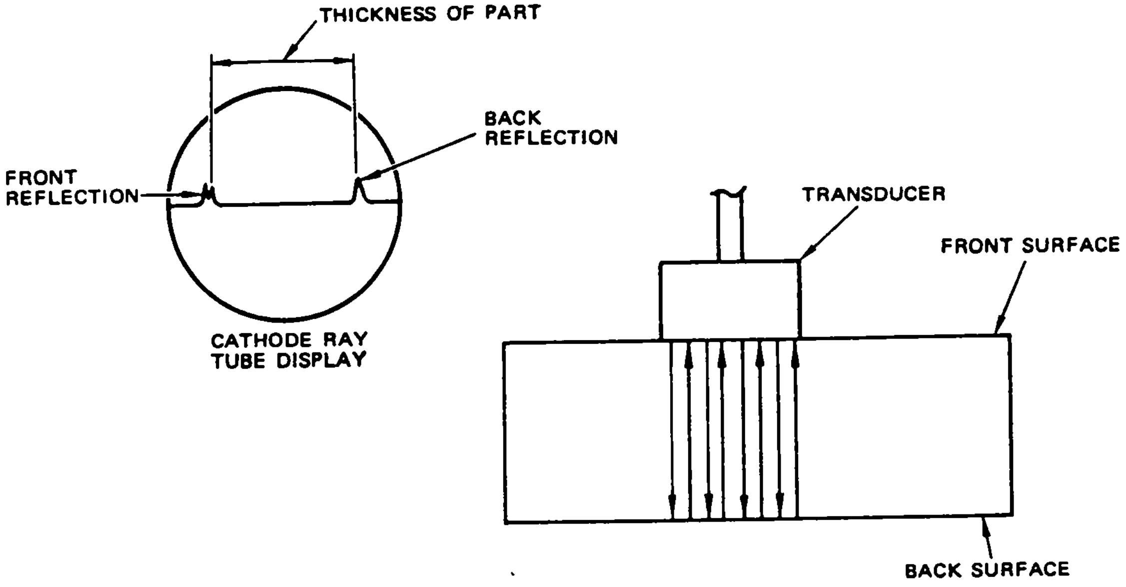


SURFACE WAVE MODE

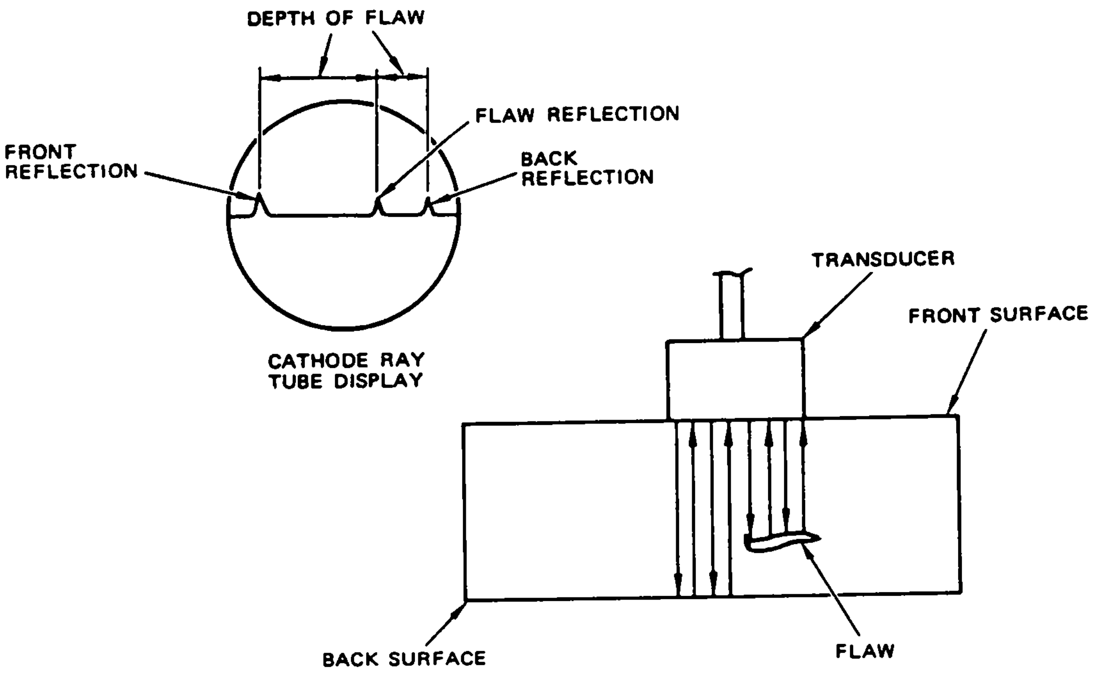
Waves Modes
Figure 1

## ULTRASONIC

## ULTRASONIC FLAW DETECTION



THICKNESS MEASUREMENT



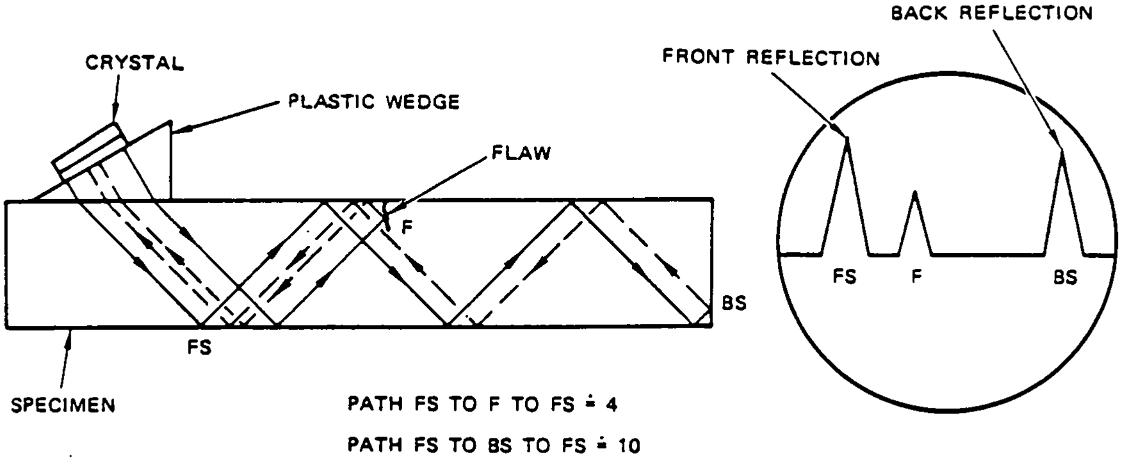
LONGITUDINAL WAVE MODE

Display of Flaw on Oscilloscope
Figure 2 (Sheet 1)

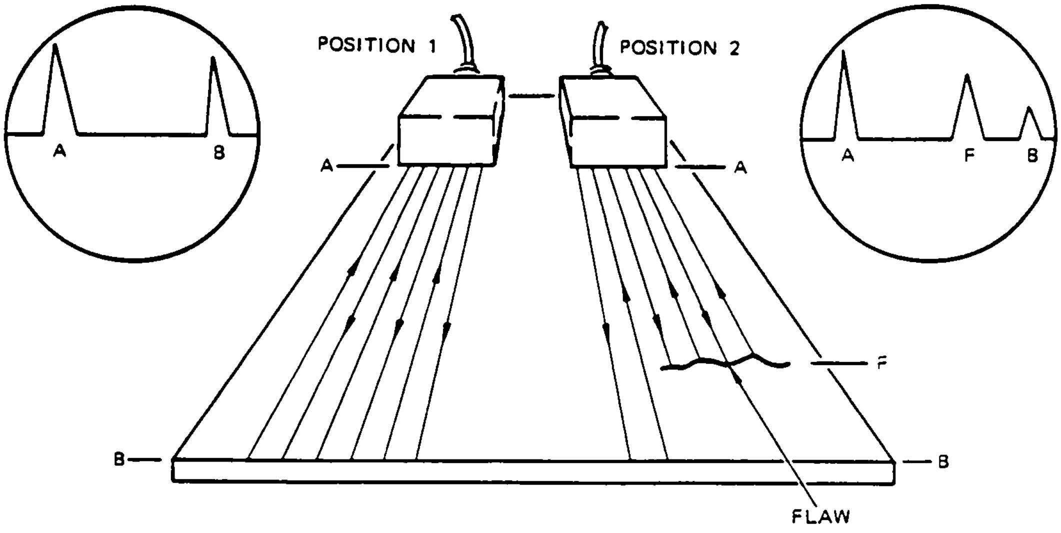
## PART 1 - GENERAL

## ULTRASONIC

## ULTRASONIC FLAW DETECTION



DETECTION OF FLAW WITH SHEAR WAVE MODE



DETECTION OF FLAW WITH SURFACE WAVE MODE

Display of Flaw on Oscilloscope
Figure 2 (Sheet 2)

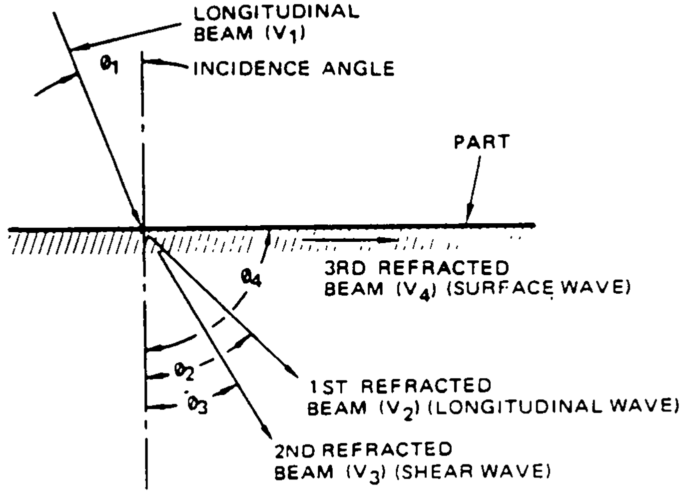
## ULTRASONIC FLAW DETECTION

| MATERIAL | ACOUSTIC VELOCITIES (CM/SEC) X $10^5$ | | |
|---|---|---|---|
| | $V_1$ AND $V_2$ LONGITUDINAL WAVE | $V_3$ SHEAR WAVE | $V_4$ SURFACE WAVE |
| ALUMINUM 2SO | 6.35 | 3.10 | 2.90 |
| ALUMINUM 17ST | 6.25 | 3.10 | 2.79 |
| BERYLLIUM | 12.80 | 8.71 | 7.87 |
| BRASS (NAVAL) | 4.43 | 2.12 | 1.95 |
| BRONZE, PHOSPHOR (5%) | 3.53 | 2.23 | 2.01 |
| COPPER | 4.66 | 2.26 | 1.93 |
| LEAD, PURE | 2.16 | 0.70 | 0.63 |
| LEAD, ANTIMONY (6%) | 2.16 | 0.81 | 0.74 |
| MAGNESIUM (AM35) | 5.79 | 3.10 | 2.87 |
| MERCURY | 1.42 | | |
| MOLYBDENUM | 6.29 | 3.35 | 3.11 |
| NICKEL | 5.63 | 2.96 | 2.64 |
| INCONEL (WROUGHT) | 7.82 | 3.02 | 2.79 |
| MONEL (WROUGHT) | 6.02 | 2.72 | 1.96 |
| SILVER-NICKEL (18%) | 4.62 | 2.32 | 1.69 |
| STEEL | 5.85 | 3.23 | 2.79 |
| STAINLESS 302 | 5.66 | 3.12 | 3.12 |
| STAINLESS 410 | 7.39 | 2.99 | 2.16 |
| TITANIUM (TI 150A) | 6.10 | 3.12 | 2.79 |
| TUNGSTEN | 5.18 | 2.87 | 2.65 |
| NONMETALS | | | |
| AIR | 0.33 | | |
| OIL, TRANSFORMER | 1.38 | | |
| PLASTIC (LUCITE) | 2.67 | 1.12 | |
| QUARTZ (NATURAL) | 5.73 | | |
| WATER | 1.49 | | |
| FUSED, QUARTZ | 5.93 | 3.75 | 3.39 |
| PYREX | 5.57 | 3.44 | 3.13 |
| PLATE GLASS | 5.77 | 3.43 | 3.14 |
| ICE | 3.98 | 1.99 | |

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{V_1}{V_2}$$

SNELLS LAW

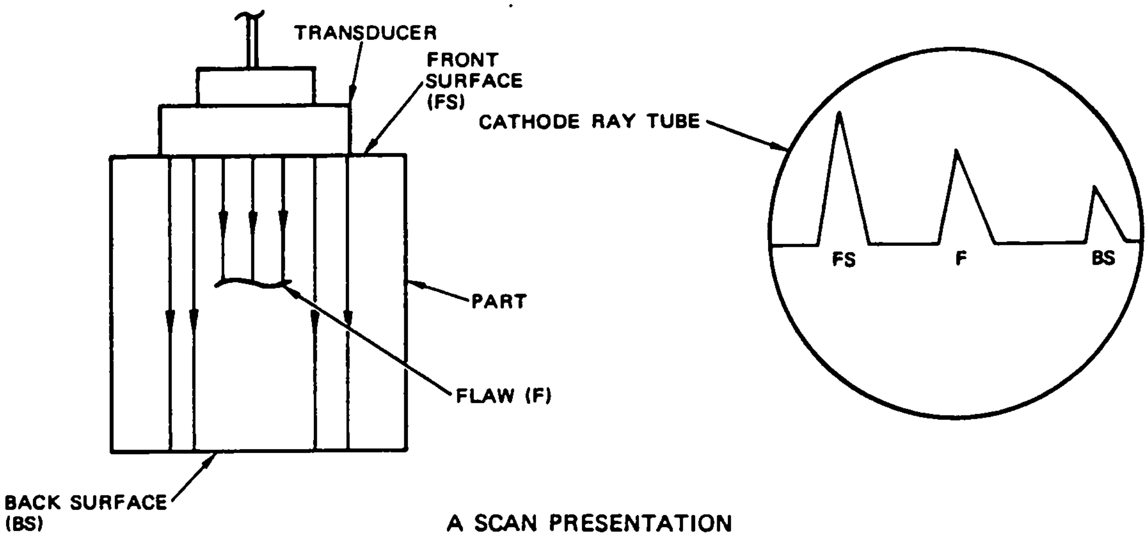
NOTE: FABRICATE WEDGE FROM LUCITE



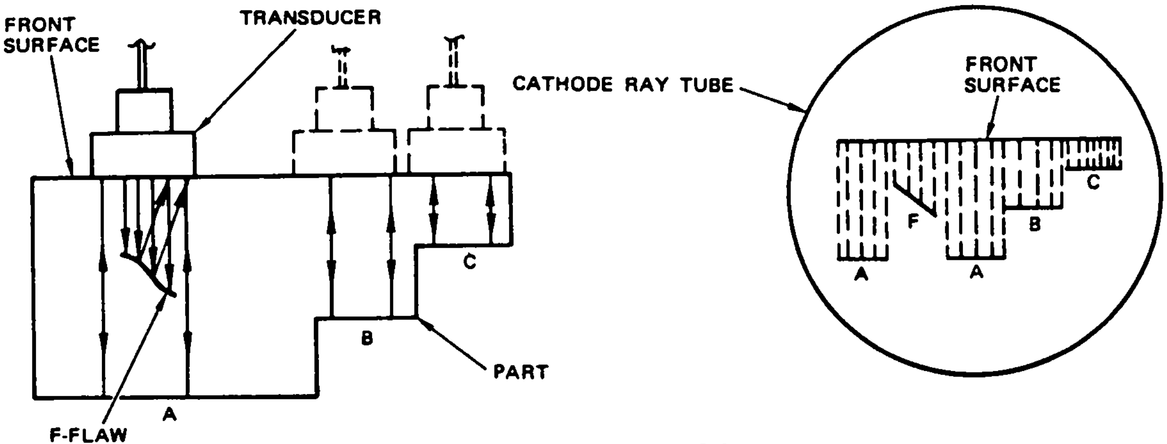
Refraction Data for Fabrication of Wedges
Figure 3

## ULTRASONIC

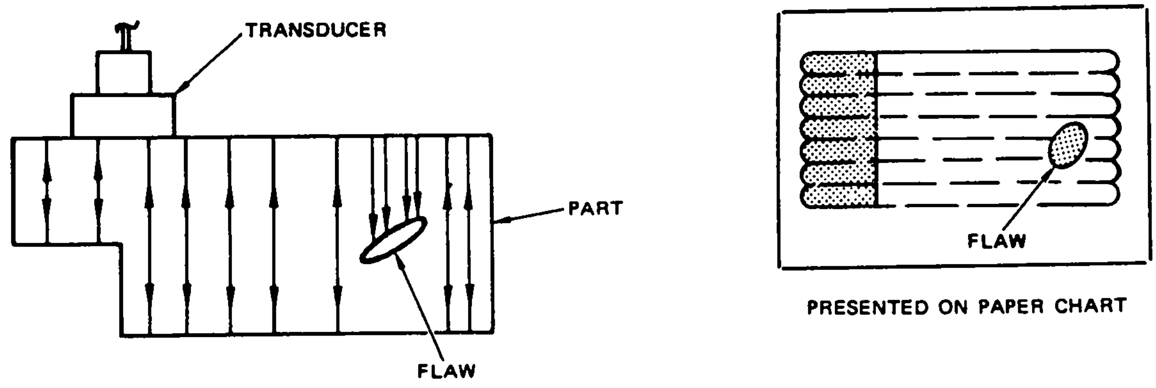
## ULTRASONIC FLAW DETECTION



A SCAN PRESENTATION



B SCAN PRESENTATION



PRESENTED ON PAPER CHART

C SCAN PRESENTATION

Data Presentation Patterns
Figure 4

## 2. Ultrasonic Bond Inspection of Metal-to-Metal Bonding and Honeycomb Structures

### A. General

(1) Inspections required to ensure structural integrity on today's commerical airplanes encompass varying degrees of complexity. Some inspections require no more than a visual appraisal. Inspections in other areas are comparatively simple through the use of such methods as eddy current or dye penetrant techniques.

(2) Structural configurations that have resisted any simple method of inspection were those of metal-to-metal bonding and honeycomb panels. When two pieces of metal are bonded together, as when a doubler is bonded to a skin to provide additional strength, bonding separation (delamination) is difficult to detect easily. The same situation exists with regard to bonding of face sheets on honeycomb structure.

(3) Since bonding is finding increasing application in airplane construction, the ability to detect bonding delamination becomes increasingly important. Surveillance of these bonds should be encompassed in airline standard maintenance practices.

### B. Description of Method

(1) Several methods of adhesive bond testing have been available for some time, and their application is generally well understood. All of these methods involve portable testing devices. These devices include the Sondicator S-2, S-2B and S-1A, Audible Bondtester, Acoustic Flaw Detector, Harmonic Bondtester, Fokker Bondtester, 210 Bondtester and Bondscope 2100. All induce some form of vibration into the part that is being inspected, then react to and display or record a response.

(2) In general, operation of all four types of adhesive bond testers is similar. The test probe is moved over the surface in smooth, overlapping strokes. Direction of the stroke with regard to the surface is generally immaterial. However, when using the Sondicator models, direction of the stroke becomes critical when the test probe is operated near a surface edge. Edge effects on vibration paths give test reading that may be misinterpreted. To avoid edge effects, the test probe should be moved so that the inspection path follows the surface edge, giving a constant edge for the test probe to inspect. Edge effects are more pronounced in thicker material. In addition, the operator should determine whether there are variations in the thickness of the material to interpret meter readings correctly.

(3) With the exception of the Sondicator models, the test probes of the testers noted above emit a sending signal that radiates in a full circle. The sending signal of Sondicator probe is polarized (travels from one transducer tip to the other). For this reason, the test probe should be held so that the transducer tips are at right angles to the inspection path.

(4) When inspecting honeycomb panels with a Sondicator model, the transducer tips should be moved consistently in the direction of the ribbon of the honeycomb or at right angles to the ribbon so that a constant subsurface is presented.

C. Equipment

(1) The Sondicator, S-2, S-2B, and S-5 contain two meters and associated electronic circuitry, and a test probe containing two teflon-tipped transducers that are mounted approximately 0.75 inch apart. One transducer imparts vibration at 25 kHz into the surface. Vibrations travel laterally through the material to the other transducer. The second transducer detects the amplitude and phase relationship of the vibrating surface, directing the associated signals to the two meters of the equipment. If the probe encounters a delaminated area where the bond has separated, it will, in effect, be introducing a vibration into a part that is thinner than the part it had been inspecting. The amplitude of the vibration will then increase and the phase of vibration will shift as the thinner section vibrates more vigorously. Needles on the two test equipment dials will dip toward one another. The Sondicator is equally effective on metallic or nonmetallic surfaces and requires no liquid couplant. The model S-2B is battery powered.

(2) The Sondicator S-1A is similar to the Sondicator S-2B in operating principle, but is larger than the S-2B, and battery power is not available. The probes are similar to the S-2B probes and are interchangeable. The most significant instrument difference is the method of information presentation. The instrument employs a CRT, or scope, and offers a choice of two information modes. One is the waveform presentation. Amplitude and phase changes can be observed directly on the screen. The other is the "flying dot", or polar presentation. Amplitude and phase difference are shown, in this presentation, by distance of the dot from screen center, and radial position, respectively.

(3) The S-3 Audible Bondtester uses the same probe as the Sondicator S-2B and S-1A. It is a small, light-weight unit that produces an audible tone via an operator-worn headset (earphones) to indicate disbonds. This instrument offers simplicity of operation and low cost, and is capable of detecting disbonds in aluminum-honeycomb or aluminum-aluminum adhesive bonded joints and non-mental composites.

The instrument operates by activating the transmit tranducer 100 times per second to produce a pulse of 25 kHz sound energy. The receiving element is capacitance coupled to maximize detection of 25 Kkz return signal. The operator discriminates between acceptable and unacceptable areas through amplitude changes in the audio signal.

(4) The S-9 Sondicator bondtester is a variable frequency, pulsed, ultrasonic instrument that can be used to test metallic and non-metallic bonded structure.

The basic operating principle of the S-9 bondtester is mechanical impedance which measures the impedance (stiffness) of the structure with low frequency, pulsed ultrasonic energy which is transmitted into the structure by a contact probe.

The contact probe contains a transmitting and a receiving piezoelectric element transducer. The transmitting transducer converts electrical energy to mechanical energy which enters the structure through a vibrating torlon (plastic material) tip that requires no couplant. A complex waveform is generated and travels (vibrates) laterally through the structure to a second torlon tip which is connected to a receiving transducer that changes mechanical energy back into electrical energy. The received signal is then amplified and displayed on a liquid crystal display screen. Any change in the structure will cause a change in the amplitude and/or phase signal which can then be compared to a known condition signal.

The instrument has two frequency selection modes, internal and external. The internal frequency selections are 7, 14, 25, 40, 54, 84, and 130 kHz. The external frequency will require an external tuning module for any other selected frequency.

(5) The Acoustic Flaw Detector is a compact, light-weight, battery-powered instrument. The single probe contains two transducers, for transmission and receipt of acoustic energy. As opposed to the Sondicator's, these transducers are oriented in a tandem arrangement, with a lucite sound column separating the two. The probe has a single contact point and requires no couplant. Information presentation is provided by two meters, whose indicators show phase and amplitude information. Material structure changes indicated either by amplitude change, or simultaneous amplitude and phase shift, may be interpreted as flaws. The Acoustic Flaw Detector has adjustments for power and frequency. These adjustments enable the range of instrument use to be expanded to match structural conditions, and to enhance the instrument's sensitivity.

(6) The Harmonic Bondtester utilizes a test probe with an electromagnetic coil that induces eddy currents into metal. As the current in the coil alternates, the eddy currents in the skin are alternately attracted and repulsed, causing the skin to vibrate. This vibration emits a sound that is picked up by a microphone mounted coaxially above the electromagnetic driving coil. The sound is then amplified, and filtered to block the driving frequency but pass its harmonics. This signal is then read on a meter. As the test probe is passed over the surface, the signal remains constant if the section is bonded. Delaminated sections will vibrate at a different amplitude from bonded sections, and this amplitude difference will be shown on the equipment meter. This tester requires no liquid couplant.

(7) The Fokker Bondtester utilizes the resonating frequency of a transducer to detect delamination. This device induces ultrasonic vibration into the surface by means of a liquid-coupled transducer. The surface impedance changes the resonant frequency of the transducer. Responses are displayed on a scope. Initially, the scope is adjusted so that the resonant frequency peak displayed on the scope is centered. This is done by placing the transducer on a skin as thick as the skin to be tested simulating a delamination. When a bonded assembly is then tested, the resonant frequency peak on the scope will shift right or left. The peak will recenter on the scope when delamination is detected. The Fokker Bondtester requires careful interpretation of the readings displayed on the scope to enable the operator to determine when he encounters delamination.

(8) The 210 Bondtester is a compact, light-weight, battery-powered instrument. It employs a small probe with a single piezoelectric transducer. In operation, the instrument energizes the transducer, which vibrates the inspection part through its entire thickness. The structures overall acoustic impedance is presented as a meter reading. A change in the inspection parts structure, including discontinuities or flaws, will result in a detectable change in acoustic impedance, which will cause an upswing of the instrument meter. The instrument requires liquid couplant.

(9) The Bondascope 2100 is similar to the 210 Bondtester in operating principle. It utilizes a small, fluid-coupled probe in detecting changes in structure through acoustic impedance differences. The instrument is larger and heavier that the 210 Bondtester, however, it has several notable features, and offers improved performance, repeatability and information presentation.

This instrument uses microprocessors to simplify standardization. It uses a CRT screen presentation of information, using a "flying dot". The scope has a storage feature whereby up to eight dot locations, representing flaw depths can be stored for comparison to instrument active response. This instrument is easier to use, more consistent, and presents more information than the 210 Bondtester.

(10) The US-5200C Bond Flaw Detector uses an eddy-sonic method of detection. It is almost the same as the Harmonic bondtester in operation and principle but it is smaller in size and has a LED (light emitting diode) barograph (light bar) that displays ultrasonic signals received from the structure surface.

The low frequency eddy-sonic metallic probe uses a coil that electromagnetically vibrates the metal face with a single transducer that operates at a fixed 12.5 kHz transmitting frequency and 25 kHz receiving frequency. It basically excites the structure by pulsing 12.5 kHz of electromagnetic packet into the part. Each packet consists of five 12.5 kHz pulses that occur every 16.6 milliseconds. These pulses induce eddy current into the part that opposes the main field. This opposition to the main field causes the part to vibrate. As the part vibrates, waves of energy radiate from the surface of the part, and the predominate rectified wave will have a frequency of 25 kHz. This wave is received and analyzed by the receiver circuitry through a piezoelectric element mounted in a microphone in the probe. The signal is then amplified and displayed on the LED barograph.

The non-metallic probe operates at a fixed 25 kHz frequency and has two Teflon contact tips located at a fixed distance from each other. Its operating principle is basically mechanical impedance which measures the impedance (stiff-ness) of the structure. No liquid couplant is necessary for the operation of the metallic and the non-metallic probes.

(11) The Bondmaster is a low/high frequency ultrasonic instrument that has four test methods of operation: the MIA, pitch/catch swept, pitch/catch impulse, and the resonance methods. All four methods can be used to test metallic and non-metallic bonded structure.

The basic operating principle for the MIA (Mechanical Impedance Analysis) and two pitch/catch methods (swept and impulse) is mechanical impedance which measure the impedance (stiffness) of the structure by using low frequency ultrasonic energy to generate vibration into the structure surface. The MIA probe is a single contact probe with two piezoelectric element transducers located in tandem within the probe. This single contact point probe can easily be used to examine small, irregularly curved surfaces. The receiver transducer will detect the effect of loading as the frequency is swept in the range of 500 to 10,000 Hz. It is not necessary to use a liquid couplant to do the MIA test method.

The pitch/catch swept method and impulse method use the same two Teflon contact tips probe. The probe and operating principle are almost the same as the Sondicator probe and its operation principle. The probe has one transmitting and one receiving piezoelectric element transducer located at a fixed distance from each other in contact with the structure surface through the Teflon tips.

The swept test method sweeps the frequency range and the impulse test method uses a burst of energy several cycles in duration to drive the transducer element. Both pitch/catch methods do not require liquid couplant.

The resonance high frequency test method operates on a principle of electrically monitoring the impedance changes of the transducer piezoelectric element. In this test method, the transducer is operated near its resonant frequency and is sensitive to small changes in mechanical loading (pressure changes) on the transducer element face. These changes come from small variation in the structure that change the mechanical loading (particle vibration) on the transducer face which in turn changes the transducer electrical impedance.

(12) Figure 5 is a brief comparison of the characteristics of adhesive bond testing devices.

D. Preparation of Aircraft for Inspection

(1) The following preparations must be made before performing an ultrasonic bond inspection.

(a) Loose dirt, paint flakes or blisters, heavy oil or grease buildup must be removed from the area to be inspected.

(2) Specific preparation instructions are given with each procedure in Part 4.

E. Technique

(1) The technique for performing any given test is necessarily a specific procedure to fit the job being performed. Procedures are given in Part 4 of this manual.

## 3. Ultrasonic Bond Inspection of Graphite/Epoxy, Aramid/Epoxy and Hybrid/Epoxy Laminate and Honeycomb Structures

A. General

(1) Ultrasonic testing has proven to be a reliable and accurate method for detecting internal flaws in both simple and complex composite structures. A variety of ultrasonic testing methods and instruments are available for adaptation to specific inspection problems.

B. Inspection for the detection of interply and skin-to-core delaminations/disbonds where both surfaces of part are accessible.

(1) For these conditions a through-transmission ultrasonic inspection is most effective. This method uses a water stream consisting of two impinging water columns to transmit sound between two yoke-mounted transducers that are positioned on opposite sides of the part. Ultrasonic sound waves produced by the sending transducer are transmitted along the water column, through the inspection panel and continue along the water column on the opposite side to the receiving transducer mounted on the opposite arm of the yoke. Any delaminations in the panel will cause a reduction in transmitted sound and will consequently produce a greatly reduced signal response on the CRT screen. The maximum size of the part that can be inspected using this method is determined by the configuration of the yoke fixture used in the inspection system.

C. Representative instruments for the detection of interply delaminations/disbonds in laminate structures when access is limited to only one surface.

(1) An inspection using existing standard pulse-echo instrumentation may be performed on laminate panels. It is desirable that the resolution of the instrument/transducer combination be great enough to discern single ply delaminations. To achieve adequate near surface resolution, the use of a delay line transducer may be necessary. The distance/amplitude display used in pluse-echo testing gives an accurate indication as to which laminate bondline is defective.

(2) Sondicator S-2, S-2B, and S-5. See par. 2.C.(1).

(3) Sondicator S-1A. See par. 2.C.(2).

(4) S-3 Audible Bondtester. See par. 2.C.(3).

(5) Sondicator S-9. See par. 2.C.(4).

(6) Acoustic Flaw Detector. See par 2.C.(5).

(7) Fokker Bondtester, Model 70. See par. 2.C.(7).

(8) Bondascope 2100. See par. 2.C.(9).

(9) US-5200C. See par. 2.C.(10).

(10) Bondmaster, MIA, Pitch Catch Swept and Impulse and Resonance Methods. See par. 2.C.(11).

D. Representative instruments for the detection of skin-to-core delaminations/disbonds

(1) Sondicator S-2, S-2B, and S-5. See par 2.C.(1).

(2) Sondicator S-1A. See par. 2.C.(2).

(3) S-3 Audible Bondtester. See par. 2.C.(3).

(4) Sondicator S-9. See par. 2.C.(4).

(5) Acoustic Flaw Detector. See par 2.C.(5).

(6) Harmonic Bondtester, Model Mark II B. See par 2.C.(6).

(7) Figure 5 is a brief comparison of the characteristics of adhesive bond testing devices.

(8) US-5200C. See par. 2.C.(10).

(9) Bondmaster, MIA, Pitch Catch Swept and Impulse and Resonance Methods. See par. 2.C.(11).

E. Preparation of Aircraft for Inspection

(1) The following preparations must be made before performing an ultrasonic bond inspection.

(a) Loose dirt, paint flakes or blisters, heavy oil or grease buildup must be removed from the area to be inspected.

(2) Specific preparation instructions are given with each procedure in Part 4.

F. Inspection for the detection of water contamination in honeycomb cells.

(1) Pulse-echo inspection is effective in accurately locating and evaluting areas of water contamination in honeycomb structures. In order to be detectable, the water in the cells must have internal contact with the same skin that the transducer is placed on externally. The relative amount of water within each cell can be accurately determined through appropriate instrument calibration.

G. Technique

(1) The technique for performing any given test is necessarily a specific procedure to fit the job being performed. Procedures are given in Part 4 of this manual.

H. Calibration Guides

(1) Composite honeycomb and laminate calibration guides have been developed to assist the inspector with initial instrument set-up and with the evaluation of instrument responses obtained from in-service honeycomb and/or laminate composite components. These calibration guides are in kit ST8870. You can make an order for kit ST8870 through Boeing Spares.

Two honeycomb calibration guides, one with a 0.25-inch core (Fig. 6) and one with a 1.0-inch core (Fig. 7), incorporate a number of simulated defects representing potential disbonds in the skin-to-core bondline of the component being inspected. By comparing instrument responses obtained at bonded and disbonded areas along the calibration guide with those obtained on the panel being inspected, defect evaluation may be accomplished.

A set of three graphite/epoxy laminate step wedges with steps ranging from one to 30 plies of cured graphite fabric in one ply increments may be used in conjunction with a variety of bond testers in the evaluation of interply defects in composite skins and laminate components (see Fig. 8). Each step is labeled with the nominal cured step thickness for the type of material and resin system used in these particular wedges. This makes it possible to utilize these wedges even when the panel being inspected contains material of a different type i.e. Kevlar, fiberglass, graphite tape, etc., as long as the overall cured thickness of the skin/laminate is known.

The specific use of both the honeycomb and laminate calibration guides will be detailed in the appropriate composite inspection procedures found in Part 4. All five calibration guides are in kit ST8870. You can make an order for this kit through Boeing Spares. The calibration guides in kit ST8870 are equivalent to the calibration guides identified before in this manual as guides 1, 1A, 1B, 1C and 2.

| | INSTRUMENT<br>INSTRUMENT CHARACTERISTICS | SONDICATOR S-1A | SONDICATOR S-2, S-2B | S-3 AUDIBLE BOND TESTER | ACOUSTIC FLAW DETECTOR | HARMONIC BONDTESTER MODEL MARK IIB | FOKKER BONDTESTER MODEL 70 | 210 BONDTESTER | BONDASCOPE 2100 |
|---|---|---|---|---|---|---|---|---|---|
| METAL STRUCTURES | DETECTS SKIN-TO-CORE DISBONDS | YES | YES | YES | YES | YES | NOT RECOMMENDED | NO | NO |
| | DETECTS SKIN-TO-SKIN DISBONDS | YES | YES | YES | YES | YES | YES | YES | YES |
| | MAXIMUM FACESHEET THICKNESS | 0.10 | 0.10 | 0.063 | 0.071 | 0.080 | 0.30 | 0.25 | 0.25 |
| | DETECTABLE DEFECT SIZE | 1.0 | 1.0 | 1.0 | 0.5 | 1.0 | 0.5 | 0.5 | 0.5 |
| NON-METAL STRUCTURES | DETECTS SKIN-TO-CORE DISBONDS | YES | YES | YES | YES | YES | NO | NO | NO |
| | DETECTS INTERPLY DISBONDS | YES | YES | YES | YES | NOT RECOMMENDED | YES | NOT RECOMMENDED | YES |
| | MAXIMUM FACESHEET THICKNESS/MAXIMUM LAMINATE THICKNESS | 0.070/0.050 | 0.060/0.050 | 0.050/0.050 | 0.085/0.050 | 0.050/- | -/0.060 | -/0.25 | -/0.25 |
| | DETECTABLE DEFECT SIZE | 1.0 | 1.0 | 1.0 | 0.5 | 1.0 | - | 0.5 | 0.5 |
| | INFORMATION DISPLAY FORMAT | SCOPE/METER | METER | AUDIBLE TONE | METER | METER | SCOPE/METER | METER | SCOPE/METER |
| | TYPE OF COUPLANT | DRY | DRY | DRY | DRY | DRY | WET | WET | WET |
| | POWER SOURCE | AC | AC/BATTERY | AC/BATTERY | AC | AC/BATTERY | AC | AC/BATTERY | AC |
| | VENDOR | AUTOMATION INDUSTRIES<br>DANBURY, CT<br>(203) 748-3581 | AUTOMATION INDUSTRIES<br>DANBURY, CT<br>(203) 748-3581 | ZETEC, INC.<br>1320 N.W. MALL<br>ISSAQUAH, WA 98027 | BALTEAU ELECTRIC CORP.<br>63 JEFFERSON ST.<br>STANFORD, CT 06902<br>(203) 324-6118 | SHUR-LOK CORP.<br>2541 WHITE RD.<br>P.O. BOX 19584<br>IRVINE, CA 92713<br>(714) 474-6000 | HALO INSTRUMENTS, INC.<br>6807 COOLRIDGE DR<br>TEMPLE HILLS, MD<br>20748<br>(301) 868-7888 | NDT INSTRUMENTS INC.<br>15622 GRAHAM ST.<br>HUNTINGTON BEACH, CA<br>92649<br>(714) 893-2438 | NDT INSTRUMENTS INC.<br>15622 GRAHAM ST.<br>HUNTINGTON BEACH, CA<br>92649<br>(714) 893-2438 |

ALL DIMENSIONS ARE IN INCHES

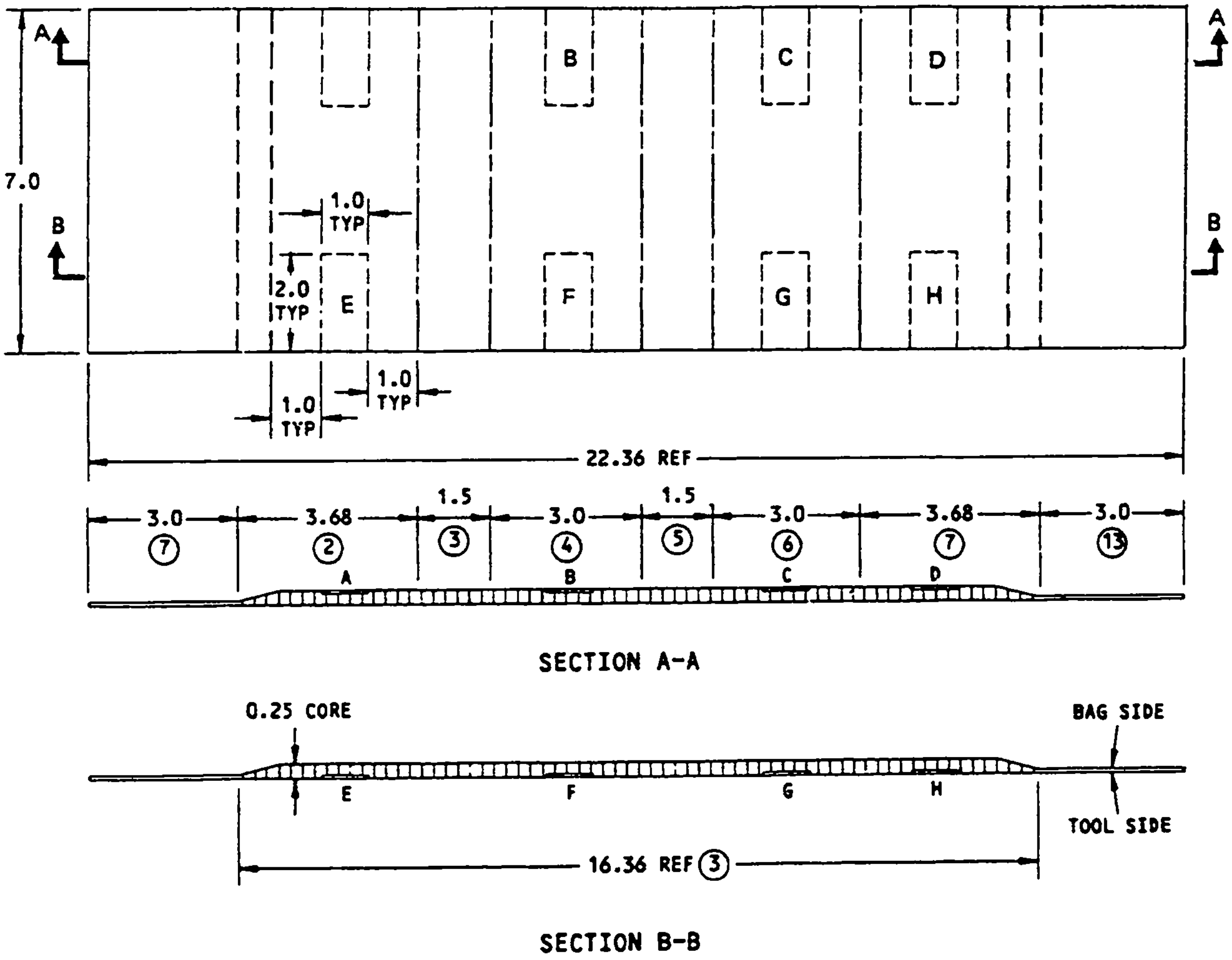
Comparison of Characteristics of Bond Testing Devices
Figure 5 (Sheet 1)

| | INSTRUMENT CHARACTERISTICS \ INSTRUMENT | BONDMASTER | | | | SONDICATOR S-5 | SONDICATOR S-9 | UNIWEST US-5200C | MITSUI WOODPECKER |
|---|---|---|---|---|---|---|---|---|---|
| | | RESONANCE | PITCH CATCH SWEPT | PITCH CATCH IMPULSE | MIA | | | | |
| METAL STRUCTURE | DETECTS SKIN-TO-CORE DISBONDS | NO | YES | YES | YES | YES | YES | YES | YES |
| | DETECTS SKIN-TO-SKIN DISBONDS | YES | YES | YES | YES | YES | YES | YES | YES |
| | MAXIMUM FACESHEET THICKNESS OVER CORE / MAXIMUM FACESHEET THICKNESS OVER SKIN | -/0.31<br>(-/7.8) | 0.040/0.10<br>(1.01/2.5) | 0.060/0.10<br>(3.14/2.5) | 0.090/0.125<br>(2.28/3.17) | 0.10/0.125<br>(2.5/3.17) | 0.10/0.20<br>(2.5/5.0) | 0.10/0.15<br>(2.5/3.8) | 0.040/0.040 |
| | NEAR SIDE DETECTABLE DEFECT DIAMETER SIZE - SKIN TO CORE / SKIN TO SKIN | -/0.375<br>(-/9.52) | 1.0/1.0<br>(25/25) | 1.0/1.0<br>(25/25) | 1.0/0.75<br>(25/19) | 1.0/1.0<br>(25/25) | 1.0/1.0<br>(25/25) | 0.75/0.50<br>(19/12.7) | 1.0/1.0 |
| | FAR SIDE SKIN TO CORE - MAXIMUM FACESHEET THICKNESS / MAXIMUM CORE THICKNESS | - | - | 0.040/1.0<br>(1.01/25) | - | - | 0.050/1.0<br>(1.27/25) | 0.050/1.0<br>(1.27/25) | - |
| | FAR SIDE DETECTABLE DEFECT DIAMETER SIZE | - | - | 1.0<br>(25) | - | - | 1.0<br>(25) | 1.0<br>(25) | - |
| NON-METAL STRUCTURE | DETECTS SKIN-TO-CORE DISBONDS | NO | YES | YES | YES | YES | YES | YES | YES |
| | DETECTS INTERPLY DISBONDS | YES | YES | YES | YES | YES | YES | YES | YES |
| | MAXIMUM FACESHEET THICKNESS OVER CORE / MAXIMUM LAMINATE THICKNESS | -/0.438<br>(-/11.12) | 0.032/0.056<br>(0.81/1.42) | 0.056/0.056<br>(1.42/1.42) | 0.064/0.056<br>(1.62/1.42) | 0.112/0.040<br>(2.84/1.01) | 0.128/0.056<br>(3.25/1.42) | 0.064/0.080<br>(1.62/2.0) | 0.050/0.040 |
| | DETECTABLE DEFECT DIAMETER SIZE - NEAR SIDE SKIN TO CORE/ FAR SIDE LAMINATE | -/0.50<br>(-/12.7) | 1.0/1.0<br>(25/25) | 1.0/1.0<br>(25/25) | 1.0/0.50<br>(25/12.7) | 1.0/1.0<br>(25/25) | 1.0/1.0<br>(25/25) | 1.0/1.0<br>(25/25) | 1.0/1.0 |
| | FAR SIDE SKIN TO CORE - MAXIMUM FACESHEET THICKNESS / MAXIMUM CORE THICKNESS | - | - | - | 0.048/1.0<br>(1.21/25) | - | 0.048/1.0<br>(1.21/25) | - | 0.032/0.5 |
| | FAR SIDE DETECTABLE DEFECT DIAMETER SIZE | - | - | - | 1.0<br>(25) | - | 1.0<br>(25) | - | 1.0 |
| | INFORMATION DISPLAY FORMAT | SCOPE | SCOPE | SCOPE | SCOPE | METER | SCOPE | LIGHT BAR | LIGHT BAR |
| | TYPE OF COUPLANT | WET | DRY | DRY | DRY | DRY | DRY | DRY | DRY |
| | POWER SOURCE | AC/BATTERY | | | | | | | BATTERY |
| | VENDOR | STAVELEY INSTRUMENT INC.<br>421 NORTH QUAY ST.<br>KENNEWICK, WA<br>99336 | | | | ZETEC INC<br>1370 NW MALL<br>P.O. BOX 140<br>ISSAQUAH, WA<br>98027 | | UNIWEST<br>1021 N.<br>KELLOGG<br>KENNEWICK,<br>WA<br>99336 | MITSUI<br>TSUKIJI<br>5-6-4<br>CHUO-KU<br>TOKYO 104<br>JAPAN |

NOTES:

- ALL DIMENSIONS ARE IN INCHES (MILLIMETERS IN PARENTHESES)

Comparison of Characteristics of Bond Testing Devices
Figure 5 (Sheet 2)



## NOTES

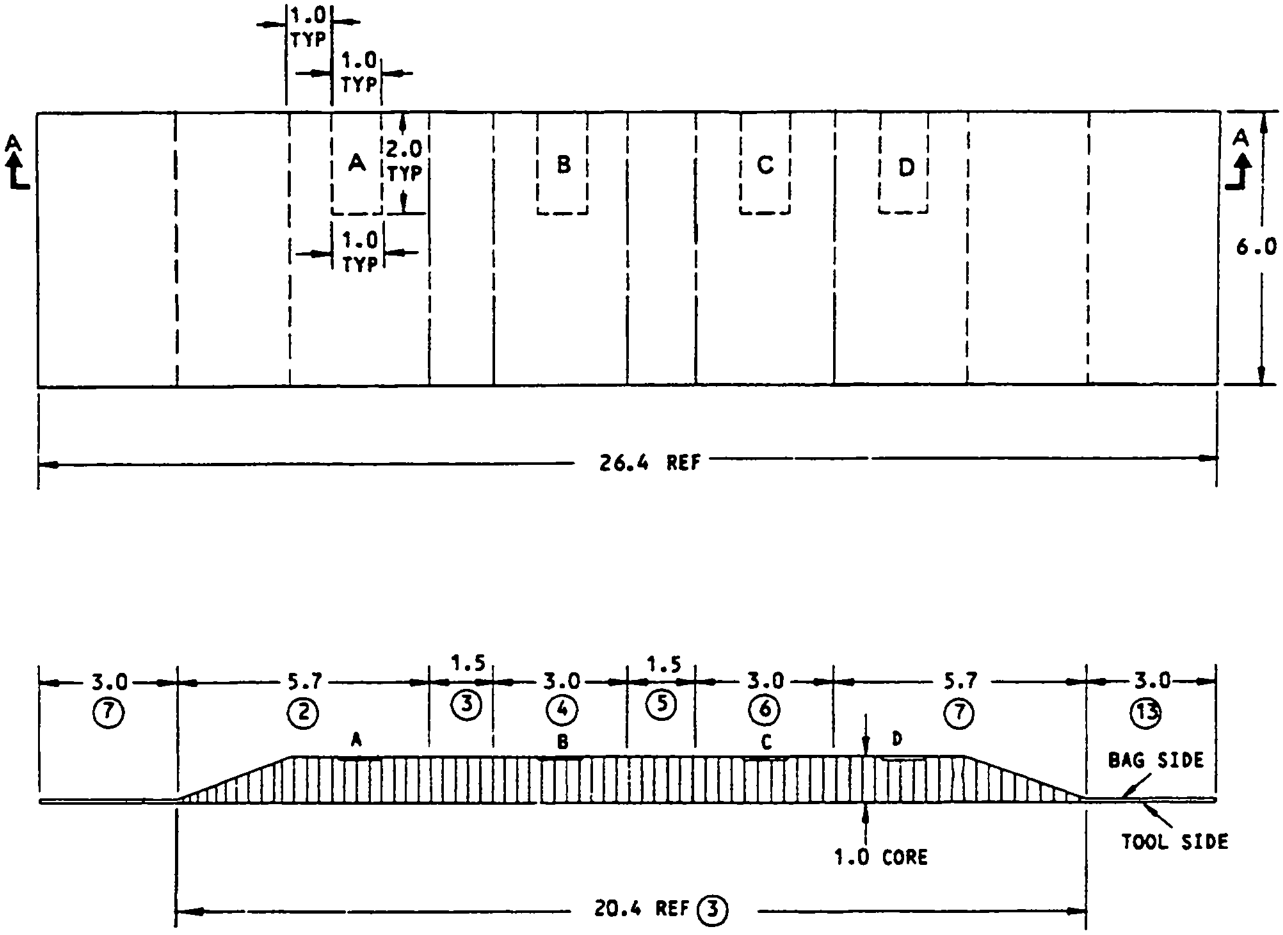
- ALL DIMENSIONS IN INCHES
- MATERIAL-
  SKIN- STYLE 3K-70-PW GRAPHITE FABRIC
  CORE- (NOMEX REINFORCED) BMS 8-124,
  CLASS IV, TYPE V, GRADE 3.0
- DEFECT LOCATIONS-
  -DEFECTS A THROUGH D LOCATED AT JUNCTION OF BAGSIDE SKIN AND CORE

  -DEFECTS E THROUGH H LOCATED AT JUNCTION OF TOOLSIDE SKIN AND CORE
- YOU CAN GET THIS CALIBRATION GUIDE FROM BOEING SPARES AS PART OF KIT ST8870.
- THIS CALIBRATION GUIDE WAS IDENTIFIED AS GUIDE 1 BEFORE KIT ST8870 WAS MADE (GUIDE 1 IS EQUIVALENT TO GUIDE ST8870-4).

○ TOTAL NUMBER OF SKIN PLIES

Honeycomb Calibration Guide ST8870-4
Figure 6

A82997



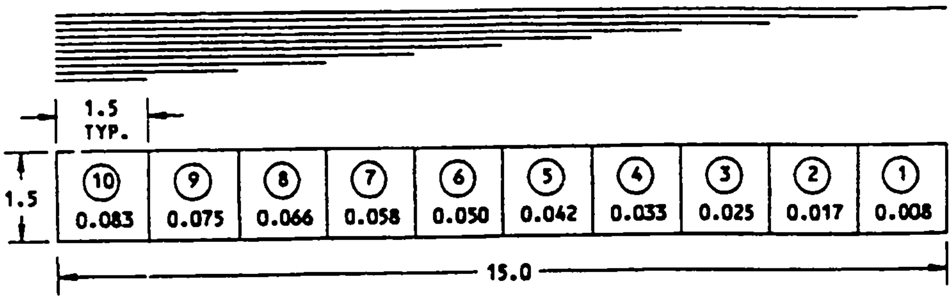
SECTION A-A

NOTES

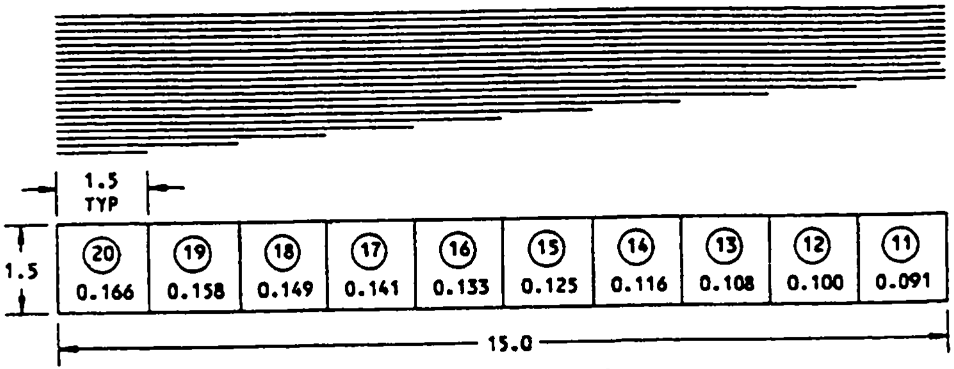
- ALL DIMENSIONS IN INCHES
- MATERIAL-
  SKIN- STYLE 3K-70-PW GRAPHITE FABRIC
  CORE- (NOMEX REINFORCED) BMS 8-124,
  CLASS IV, TYPE V, GRADE 3.0
- DEFECT LOCATIONS-
  -DEFECTS A THROUGH D LOCATED AT JUNCTION OF BAGSIDE SKIN AND CORE
- YOU CAN GET THIS CALIBRATION GUIDE FROM BOEING SPARES AS PART OF KIT ST8870.
- THIS CALIBRATION GUIDE WAS IDENTIFIED AS GUIDE 2 BEFORE KIT ST8870 WAS MADE (GUIDE 2 IS EQUIVALENT TO GUIDE ST8870-1).

○ TOTAL NUMBER OF SKIN PLIES

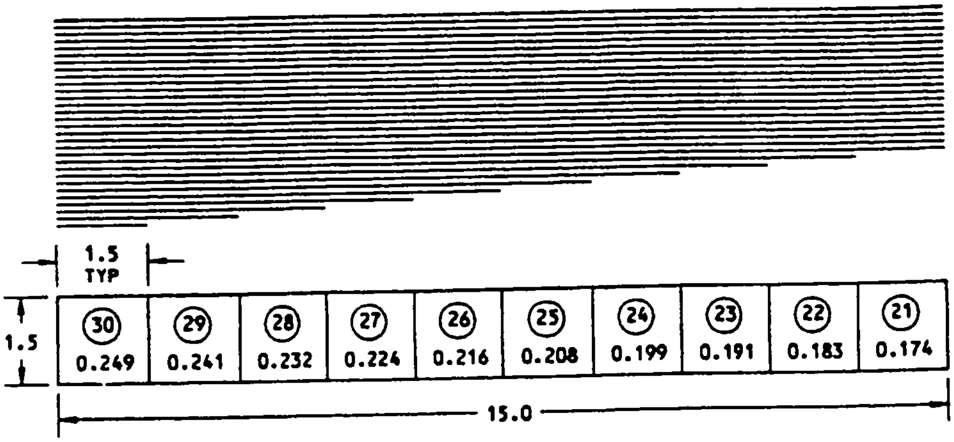
Honeycomb Calibration Guide ST8870-1
Figure 7



GUIDE ST8870-7



GUIDE ST8870-8



GUIDE ST8870-9

NOTES

- ALL DIMENSIONS IN INCHES
- TOLERANCE: ±0.02
- MATERIAL: BMS 8-212, 3K-70-PW, TYPE 4, CLASS 2
- PROCESS PER BAC 5317-1
- NOMINAL CURED PLY THICKNESS (0.0083 INCH PER PLY) USED TO CALCULATE STEP THICKNESS
- ○ TOTAL NUMBER OF PLIES
- YOU CAN GET THESE CALIBRATION GUIDES FROM BOEING SPARES AS PART OF KIT ST8870.
- THESE CALIBRATION GUIDES WERE IDENTIFIED AS GUIDES 1A, 1B AND 1C BEFORE KIT ST8870 WAS MADE (GUIDE 1A IS EQUIVALENT TO ST8870-7; GUIDE 1B IS EQUIVALENT TO ST8870-8; GUIDE 1C IS EQUIVALENT TO ST8870-9).

Laminate Calibration Guides ST8870-7, -8 and -9
Figure 8