PART 4 - ULTRASONIC

BONDTEST INSPECTION OF METAL BONDED PARTS AND NON-METAL LAMINATES

1. **General**

   A. This procedure uses high frequency bondtest equipment to find a bondline delamination in metal to metal and non-metal to non-metal parts. This procedure will also find interply delaminations in non-metal laminates.

   NOTE: High frequency bondtesters are those that use a transducer and couplant. They can find smaller defects than low frequency (no couplant) bondtesters.

   B. This procedure must not be used to do the inspection of honeycomb sandwich assemblies. To do the inspection of skin-to-core disbonds and core damage in honeycomb sandwich assemblies, refer to Part 4, 51-00-05.

   C. This procedure can be used to find voids or bond separation only. It cannot be used to measure bond strength.

2. **Equipment**

   A. General

   (1) Use inspection equipment that can be calibrated on the reference standard as specified Paragraph 4.

   (2) Refer to Part 1, 51-01-00, for data about the equipment manufacturers.

   B. Bondtest Instrument

   (1) The instruments that follow can be used to do this procedure:

   (a) 210 Bondtester; NDT Instruments

   NOTE: Because of its display limit, use the 210 Bondtester to do metal bond inspections only.

   (b) Bondascope 2100; NDT Instruments

   (c) Model 70 and Model 80; Fokker Bondtester

   (d) Bondmaster; Staveley Instruments

   (e) MIZ-21SR and S9-R; Zetec, Inc.

   (2) Transducers

   (a) The transducers used for high frequency bondtesters are supplied with the inspection instrument.

   (3) Couplant

   (a) Use a thin couplant with properties as follow:

   1) Thin as possible.

   2) Does not damage the structure or contaminate the surfaces to be bonded.

   NOTE: Do not use a couplant that has a silicone base.

   3) Does not have an effect on the bondtester indication.

   (4) Reference Standards

   (a) For metal parts:

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1) Make a reference standard which has the same skin and doubler thicknesses as the inspection area. If the same skin and/or doubler thickness is not available, use a thickness that is one gage more. Example: the inspection area has a skin and doubler thickness of 0.036 inch (0.91 mm). Use 0.040 inch (1 mm) thickness material if 0.036 inch (0.91 mm) is not available. Include in this reference standard, a 0.50 inch (12.7 mm) diameter disbond area. This disbond area can be made if you drill a spotface to the adhesive bondline.

2) A reference standard for general uses can be made from strips of the aluminum skin thicknesses used in your airplanes Figure 1. See reference standard NDT1033-n shown in Figure 1. You can also buy this reference standard from the NDT Engineering Corp. Refer to Part 1, 51-01-00.

3) A discarded part can be used as an alternative to a reference standard if you drill spotfaces to the correct bondline locations.

(b) For non-metal parts:

1) For graphite parts, make a laminate step wedge or get one from Boeing Spares. Refer to Part 1, 51-04-00, Fig. 8.

2) For fiberglass or Kevlar parts, make a laminate step wedge as shown in Part 1, 51-04-00, Fig. 8.

3) For inspection of repairs, you can use the repair reference standards given in Part 1, 51-01-01, to cause example indications. Use of these reference standards is optional.

3. Prepare for the Inspection

A. Get the engineering drawings, if possible, that show the structure and thicknesses in the inspection area.

B. Clean loose dirt, paint flakes, or blisters from the inspection surface.

4. Calibrate the Instrument

A. Get the correct transducer for the inspection material thickness and structure. Refer to the instrument instruction manual.

B. Set the instrument frequency as specified in the instrument instruction manual.

C. Calibrate the instrument to examine metal-to-metal bonded parts for disbonds at the bondline as follows:

(1) Put couplant on the reference standard in a bonded area and in the disbonded area.

(2) Calibrate the instrument to get a clear signal from the bonded and the disbonded areas.

(3) Lift the transducer off of the reference standard to identify the lift-off signal. Make sure the lift-off signal is easily identified.

NOTE: The lift-off signal is used to identify a loss of coupling between the transducer and the part during the scan inspection.

(4) Put the transducer back on the bonded area and make a scan across the disbond area to find a scan speed that will give a clear disbond signal. Use the same speed during the scan inspection.

(5) Do Paragraph 4.C.(1) thru Paragraph 4.C.(4) again for each material thickness, if parts with multiple thicknesses are to be examined.

D. Calibrate the instrument to examine non-metal to non-metal bonded parts for disbonds at the bondline and/or interply delaminations in a non-metal laminate as follows:

(1) Put couplant on all the thicknesses of the reference standard that are equal to the total thickness of the part to be examined and the steps within the total thickness of the part to be examined.

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(2) Calibrate the instrument on the reference standard to get clear signals from the full thickness of the part to be examined to steps within the thickness range of the part to be examined as follows:

(a) To find disbonds at the bondline of two laminate parts bonded together, get a signal that equals the total thickness of the bonded part and a signal from the thickness of the single layer laminate that the transducer is put on.

(b) To find interply delaminations in a laminate, identify the signals from the steps of the reference standard, from the total thickness of the part to the minimum thickness (one ply thick of the part).

(3) Lift the transducer from the reference standard to identify the lift-off signal. Make sure the lift-off signal is easily identified.

NOTE: The lift-off signal is used to identify a loss of coupling between the transducer and the part during the scan inspection.

5. Examine metal-to-metal and non-metal to non-metal bonded parts for disbonds at the bondline and/or interply delaminations

A. Examine metal-to-metal bonded parts for disbonds at the bondline as follows:

(1) Calibrate the instrument as specified in Paragraph 4.C.

(2) Put couplant on and adjacent to the inspection area.

(3) Put the transducer on an area adjacent to the inspection area that is bonded to get a signal from the total thickness. Make sure the material thicknesses for each part in the adjacent area is the same as the inspection area to be examined. The signal can be different from the signal you got from the reference standard if:

NOTE: It is not important that the signal from the total thickness be the same as the signal from the reference standard because of the conditions that follow. It is very important that the transducer is not on a disbond area.

(a) The material thickness is not the same as the reference standard.

(b) The adhesive type and/or thickness in the inspection area can be different than that in the reference standard.

(c) The back surface of the inspection area has structure attached and/or sealant.

(d) The quality of the bond (porosity in the adhesive) is not as good as the bond in the reference standard.

(4) Move the transducer away from the bonded area to a single thickness area to get a signal. The signal from the single thickness identifies how a disbond signal will look. The signal can be different from the signal you got from the reference standard if the material thickness is different.

NOTE: It is not important that the signal from the single thickness be the same as the signal from a disbond area of the reference standard.

(5) Examine the inspection area as follows:

(a) Make slow scans along areas that are of a constant thickness.

(b) For areas where it is necessary to do more than one scan, use a transducer scan increment that is one third the diameter of the disbond.

(c) When possible, it is recommended to use a guide or a straightedge to control the movement of the transducer during the inspection.

(d) During the scan inspection, monitor the instrument display for a sudden change which is not caused by structural changes in the part.

NOTE: It is important to monitor for coupling loss (lift-off signal) during the scan.

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B. Examine non-metal to non-metal bonded parts for disbonds at the bondline and/or interply delaminations in a laminate as follows:

(1) Calibrate the instrument as specified in Paragraph 4.D.

(2) Put couplant on and adjacent to the inspection area.

(3) Put the transducer on an area adjacent to the inspection area to get a signal from the total thickness. Make sure the thicknesses of the laminate(s) in the adjacent area are the same as the inspection areas to be examined. The signal can be different from the signal you got from the reference standard if:

NOTE: It is not important that the signal from the total thickness be the same as the signal from the reference standard because of the conditions that follow. It is very important that the transducer is not on a disbond area or an area with delaminations.

(a) The laminate(s) and/or adhesive thickness (bondline disbond inspection) is different than that in the reference standard.

NOTE: Porosity in laminates can cause the instrument to give an indication that the part is thicker than the actual part to be examined.

(b) The back surface of the area has structure attached and/or sealant.

(4) To do a bondline disbond inspection, move the transducer away from the bonded area to a single laminate area to get a signal. The signal from the single laminate identifies how a disbond signal will look. The signal can be different from the signal you got from the reference standard if the material thickness is different.

NOTE: It is not important that the signal from the single thickness be the same as the signal from a disbond area of the reference standard.

(5) Examine the inspection area as follows:

(a) Make slow scans along areas that are of a constant thickness.

(b) For areas where it is necessary to do more than one scan, use a transducer scan increment that is one third the diameter of the disbond.

(c) When possible, it is recommended to use a guide or a straightedge to control the movement of the transducer during the inspection.

(d) During the scan inspection, monitor the instrument display for a sudden change which is not caused by structural changes in the part.

NOTE: It is important to monitor for coupling loss (lift-off signal) during the scan.

6. Make an Analysis of the Inspection Results

A. An indication of a sudden thickness decrease that occurs on the instrument display which is not caused by a structural change in the part is a possible disbond or delamination. This area must be examined some more.

B. Slow changes on the instrument display can be caused by conditions such as:

(1) Small changes in the part thickness (tapered skins).

(2) Change in the quality of the bond (porosity in the adhesive) and/or adhesive thickness.

(3) Changes in the thickness of coatings and/or sealants on the back surface of the part.

C. Refer to the engineering drawings to make sure of the configuration of the structure. If necessary, get access to the back surface to do a visual examination to help identify the causes of slow changes.

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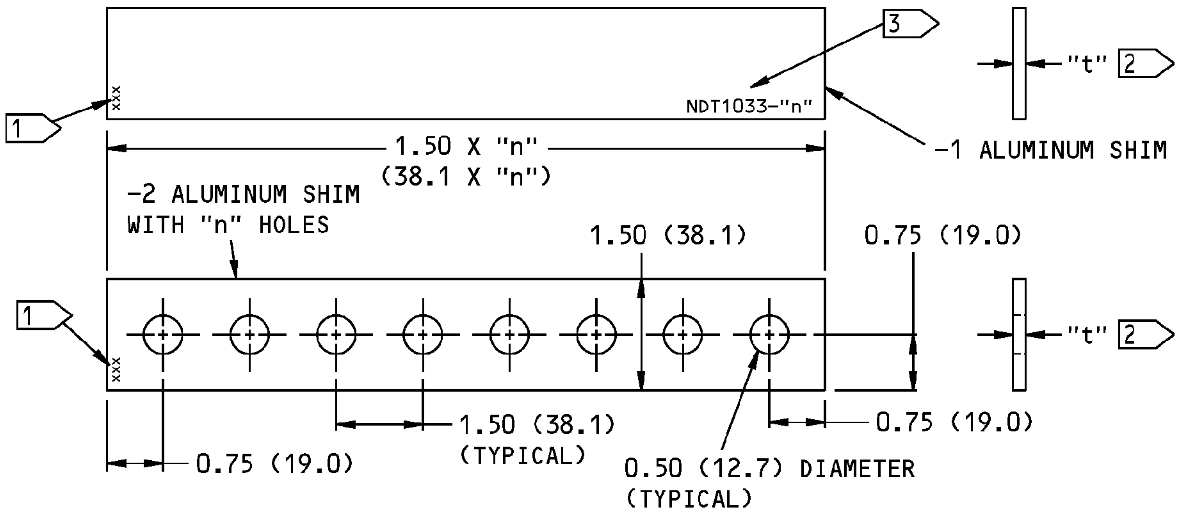

NOTES

- ALL DIMENSIONS ARE IN INCHES (MILLIMETERS ARE IN PARENTHESES).
- TOLERANCES:

INCHES	MILLIMETERS
X.XXX = ±0.005	X.XX = ±0.10
X.XX = ±0.025	X.X = ±0.5
X.X = ±0.050	X = ±1

- SURFACE ROUGHNESS: 125 R_a OR BETTER
- MATERIAL: 2000, 6000 OR 7000 SERIES ALUMINUM

1 ETCH OR STEEL STAMP THE SHIM THICKNESSES.

2 USE THE TABLE BELOW TO HELP YOU IDENTIFY THE ALUMINUM SHIMS NECESSARY TO MAKE YOUR REFERENCE STANDARD. CHOOSE A -1 AND -2 SHIM FOR EACH SKIN GAGE USED ON YOUR AIRPLANES FOR A TOTAL OF "n" PAIRS OF ALUMINUM SHIMS. USUAL BOEING SKIN GAGES ARE IDENTIFIED IN THE TABLE BELOW. NOT ALL GAGES ARE LISTED.

SKIN GAGE	-1 SHIM	-2 SHIM
"t" = 0.016 (0.41)		
0.020 (0.51)		
0.025 (0.64)		
0.032 (0.81)		
0.040 (1.02)		
0.050 (1.27)		
0.063 (1.60)		
0.080 (2.03)		
0.100 (2.54)		
0.125 (3.18)		
	TOTAL: "n"	TOTAL: "n"

3 ETCH OR STEEL STAMP THE REFERENCE STANDARD NUMBER AND DASH NUMBER ("n") EQUAL TO THE NUMBER OF STEPS.

Metal Bond Reference Standard NDT1033-n
Figure 1 (Sheet 1 of 3)

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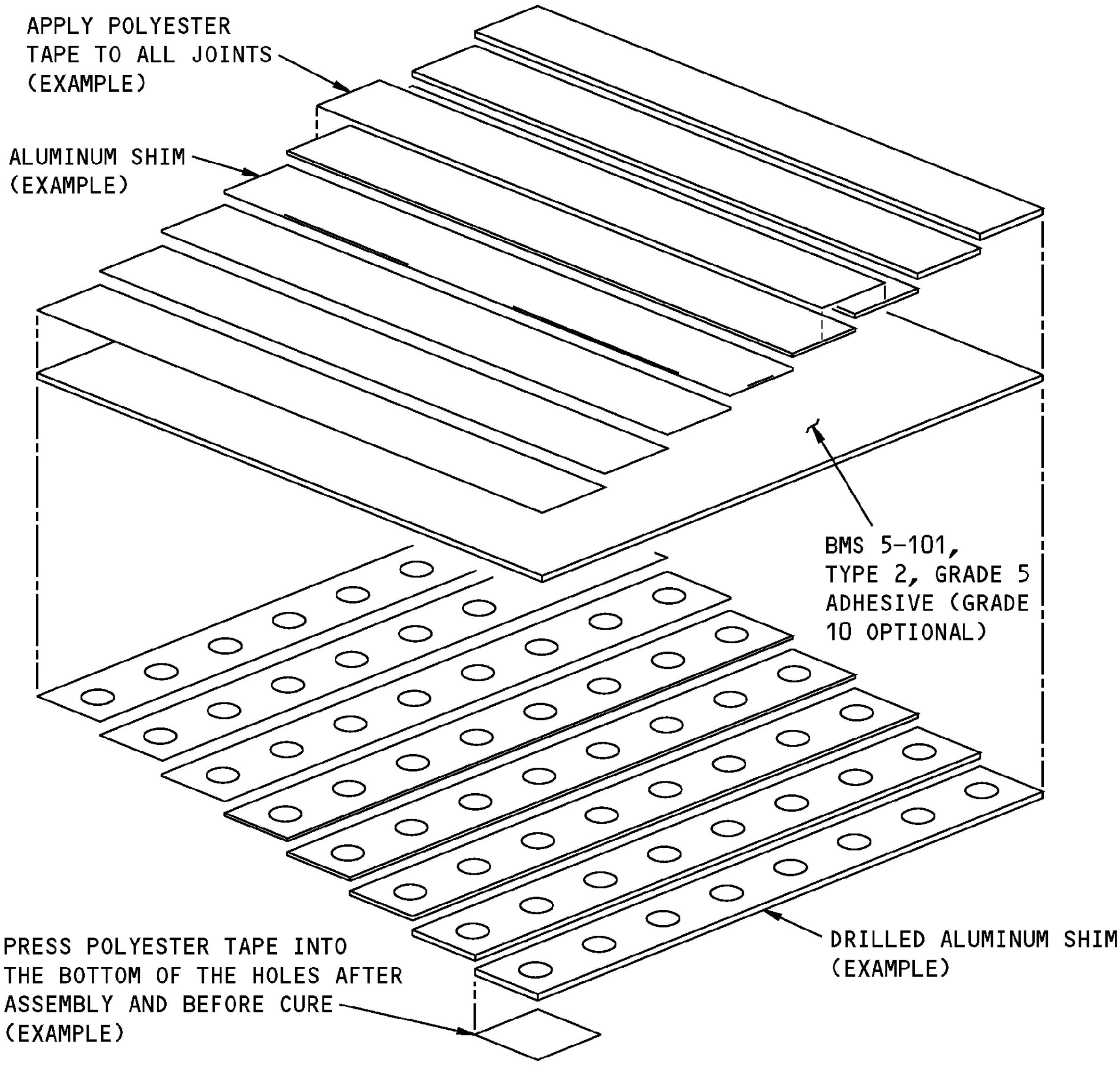

NOTE:
- THIS DETAIL SHOWS THE ALUMINUM SHIMS TURNED 90° RELATIVE TO THE DRILLED ALUMINUM SHIMS.
- USE THE ENVELOPE BAG PROCEDURE (NO TOOL) TO BOND THE SHIMS TOGETHER.
- USE POLYESTER ("FLASH") TAPE TO SEAL AROUND THE EDGES OF THE HOLE AND ALONG THE EDGES OF THE SHIMS.
- USE ABRASIVES OR EPOXY REMOVER TO TRIM THE EXCESS CURED ADHESIVE FROM THE INTERIOR OF THE HOLE. GRADE 5 ADHESIVE IS RECOMMENDED SO THAT THERE IS LESS ADHESIVE TO REMOVE.

SHIM ORIENTATION
A

Metal Bond Reference Standard NDT1033-n
Figure 1 (Sheet 2 of 3)

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PROCEDURE TO MAKE THE REFERENCE STANDARD:

1. CUT "n" PAIRS OF ALUMINUM SHIMS. SEE 2 .
2. DE-BURR THE EDGES.
3. SOLVENT CLEAN THE PARTS.
4. PREPARE THE SURFACES TO BE BONDED BY PHOSPHORIC ACID ANODIZING OR HF/CHEMICAL CONVERSION COATING AS SPECIFIED IN SRM 51-70-09.
5. APPLY PRIMER TO ONE SIDE OF EACH SHIM AS SPECIFIED IN SRM 51-70-09.
6. CUT A SQUARE OF BMS 5-101, TYPE 2, GRADE 5 (GRADE 10 OPTIONAL) ADHESIVE SO THAT THE SIDES OF THE SQUARE ARE EQUAL TO THE LENGTH OF THE SHIMS (1.50 X "n" INCHES OR 38.1 X "n" MM).
7. APPLY THE SIDES OF THE ALUMINUM SHIMS THAT HAVE THE PRIMER TO THE ADHESIVE SO THAT THE THICKNESS OF THE SHIMS INCREASES.
8. APPLY THE DRILLED ALUMINUM SHIMS TO THE OPPOSITE SURFACE OF THE ADHESIVE SO THEY ARE TURNED 90° TO THE ALUMINUM SHIMS (SEE DETAIL A).
9. TRIM THE ADHESIVE FROM THE HOLES WITH A SHARP KNIFE.
10. SEAL ALL THE JOINTS WITH POLYESTER TAPE.
11. PRESS THE POLYESTER TAPE INTO THE BOTTOM OF ALL THE HOLES TO CONTAIN THE ADHESIVE FLASH.
12. ENVELOPE BAG AND CURE AT 250° FOR 120 MINUTES AS SPECIFIED IN SRM 51-70-09.
13. REMOVE THE CURED ADHESIVE FLASH FROM THE BOTTOM OF THE HOLES WITH ABRASIVES OR EPOXY REMOVER.
14. DO A THROUGH-TRANSMISSION INSPECTION TO EXAMINE FOR DISBONDS. REFER TO PART 4, 51-00-03. DISBONDS 0.375 (9.5) IN DIAMETER OR LARGER ARE NOT PERMITTED.

Metal Bond Reference Standard NDT1033-n
Figure 1 (Sheet 3 of 3)

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PART 4 - ULTRASONIC

PULSE-ECHO INSPECTION OF LAMINATE STRUCTURES

1. **General**

   A. Use this procedure to do an inspection for interply delaminations in graphite/epoxy solid laminate structure and honeycomb structures with skins less than 0.25 inch (6.4 mm) thick that is not BMS 8-276 structure. Refer to Part 4, 51-00-06 (for 777 airplanes) or Part 4, 51-00-07 and/or Part 4, 51-00-08 (for 787 airplanes) to examine BMS 8-276 solid laminates and skins.

   B. Access to only one surface of the part is necessary.

   C. To do an inspection of solid laminate structure which is more than 0.25 inch (6.4 mm) thick, refer to Part 4, 51-00-06 (for 777 airplanes) or Part 4, 51-00-07 and/or Part 4, 51-00-08 (for 787 airplanes).

2. **Equipment**

   A. General

      (1) Use inspection equipment that can be calibrated on the reference standard as specified in Paragraph 4.

      (2) Refer to Part 1, 51-01-00, for data about the equipment manufacturers.

   B. Instrument

      (1) Use an ultrasonic instrument that can display a half waveform of a signal.

      (2) The instrument specified below was used to prepare this procedure.

         (a) USL 48; Krautkramer-Branson

   C. Transducer

      (1) Use an alpha transducer that:

         (a) Operates at 10 MHz

         (b) Has a 0.25 inch diameter

         (c) Has a Lucite delay line

   D. Reference Standards

      (1) Use Laminate Calibration Guides, part numbers ST8870-7,-8,-9, which are shown in Part 1, 51-04-00, as applicable.

      (2) For inspection or repairs, you can use the repair reference standards given in Part 1, 51-01-01, to cause example indications. Use of these reference standards is optional.

   E. Couplant

      (1) Use a couplant that is permitted for use with graphite epoxy structure.

3. **Prepare for the Inspection**

   A. Get access to the inspection area.

   B. Remove loose paint, dirt and sealant from the surface of the inspection area.

4. **Calibrate the Instrument**

   A. Do a test of the instrument sensitivity.

      (1) Put a thin layer of couplant on the surface of the reference standard (laminate calibration guides).

      (2) Make the initial instrument adjustments. Refer to the operators manual, if necessary, for the instrument operation instructions.

      (3) Make sure that the instrument reject and signal suppression is off for calibration and inspection.

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(4) Put the negative and positive half waveforms on display, if it is possible (see Figure 1) and use the waveform with only one signal.

(5) Put the transducer on step 30 of calibration guide ST8870-9, or calibration guide 1C.

(6) Use the delay and range controls to put the front surface signal at the left edge of the screen and the back surface signal at 90 percent screen width (see Figure 2).

NOTE: The screen range is now set to examine a maximum of 0.250 inch thick graphite epoxy laminate.

(7) Put the transducer on step 15 of calibration guide ST8870-8, or calibration guide 1B. The instrument and transducer sensitivity must permit a back surface signal to be identified from each ply step on the calibration guide.

(8) Put the transducer on the 30 ply step on the calibration guide.

(9) Monitor the signal on the display as you move the transducer from ply step 30 to ply step 1.

B. Do a calibration check in the inspection area.

(1) Identify the thickness of the laminate in the inspection area. Use a drawing or a specific procedure.

(2) Put the transducer on the calibration guide thickness that is as close as possible to the thickness of the laminate in the inspection area.

(3) Monitor the horizontal position of the back surface reflection on the display.

(4) Adjust the gain so the back surface reflection is 100 percent of the display height.

5. Examine the Laminate Structures that are Less than 0.25 inch (6.4 mm) Thick for Interply Delaminations

A. Apply couplant to the inspection surface.

B. Put the transducer on the inspection surface. The horizontal location of the back surface signal on the display must be at approximately the same location as the signal from the calibration guide.

C. Adjust the gain to get a back surface signal of approximately 60 percent of the display height.

NOTE: See Paragraph 6.C. if the signal is less than 60 percent of the display height.

D. Make a scan of all inspection areas with the same laminate thickness.

(1) A change in the amplitude that is between 20 and 100 percent of the display height of the back surface signal is permitted.

(2) Examine the drawings to identify the locations of the ply steps. During the inspection, make sure you do not identify these ply steps as delamination indications.

(3) Make a record of all areas where:

(a) The back surface signal falls below 20 percent of the display height.

(b) You are not sure what caused the signal.

E. For inspection of areas with other laminate thicknesses, do Paragraph 4.B. thru Paragraph 5.D. again.

6. Make an Analysis of the Inspection Results

A. Signals caused by structure or material changes must not be identified as defect signals. Use Table 1 as an aid to help identify the causes of the signals.

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Table 1 Identification of Signals

Signal Display Examples	Figure No.	Refer to Paragraph
100 percent decrease of the back surface signal from the usual display location and the addition of a new signal that occurs to the right of the usual back surface signal location.	Figure 3	Paragraph 6.B.
100 percent decrease of the back surface signal from the usual display location and the addition of a new signal(s) to the left of the usual back surface signal.	Figure 4	Paragraph 6.C.
80 to 100 percent decrease of the back surface signal. There can also be the same 80 to 100 percent (approximate) decrease in all the other signals.	Figure 5	Paragraph 6.D.

B. A signal that occurs to the right of the usual signal can be caused by an increase in the laminate thickness or a defect. See Figure 3. Identify the cause of the signal as follows:

(1) Examine the part drawings to identify the areas where there are increases in the number of plies.

(2) Identify if a ply overlap has caused the signal. Ply overlaps usually increase by one ply. The ply overlaps are usually not more than 1 inch wide and extend in a straight line.

(3) Identify if the area is a repaired area. Repaired areas can be identified by:

(a) A round or rectangular patch on the skin surface.

(b) A one ply signal change between a good area and the edge of a possible repair.

C. A signal that shows a decrease in the laminate thickness that is not shown in the part drawings must be identified as a defect (see Figure 4).

(1) Use the same gain level as used during the inspection to identify the area where a 100 percent decrease in the back reflection occurs. This area is the defect area.

(2) To identify the type of defect, make a scan of the defect area with the transducer.

(3) Decrease the gain to adjust the defect signals so they are at 50 percent of the display height.

(a) Only one signal that is to the left of the usual full thickness signal is an indication of a delamination.

1) To identify the depth, compare the horizontal position on the display caused by the defect signal with the horizontal position on the display caused by the signal from the reference standard.

(b) More than one signal on the display is a sign of a fracture in the laminate (see Figure 4 Detail C).

D. A signal where the back reflection falls below 20 percent of the display height is a sign of a defect (see Figure 5, Details A and B). Do the steps below to make sure of a defect:

(1) Increase the gain to get a back surface signal of 50 percent of the display height.

(a) If you can see a back surface reflection then:

1) Examine the part drawing to identify if the structure contains faying surface sealant. Faying surface sealant can cause a back surface signal to occur at a higher gain level (usually 12 to 15 dB). The signal amplitude will change as the transducer is moved on the inspection surface in an area where there is faying surface sealant.

2) Examine the surface to identify areas that contain an increase in paint thickness or mylar decals.

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3) Thick paint or mylar can cause a back surface signal at a higher gain level to occur to the right of the display.

NOTE: Paint and decal disbonds can cause defect signals. If necessary, remove the paint or decals in the inspection area.

4) Continue the inspection as specified in Paragraph 5. as long as a back surface signal can be seen. Use an increased gain.

(b) If a back surface signal cannot be seen, it is possible that it is caused by high signal attenuation. Graphite epoxy laminates with high signal attention can cause large noise signals. It may not be easy to identify the back surface signal with graphite epoxy laminates, (See Figure 5, Detail C).

(c) Use a lower frequency transducer to make the inspection. If you are still not able to get a back surface signal, a detailed visual inspection is necessary. In addition to the visual inspection, do an inspection with a bondtester if possible.

(2) The list below identifies the type of defects that have been found on in-service airplanes.

NOTE: Visual aids that can be used to help find these defects include a 10 power magnifying glass, a mirror that extends, a flashlight and a borescope.

(a) Indications of impact damage include:

1) Cracked, crazed or chipped paint

2) Dents on the surface of the structure

3) Cracked or fractured plies, missing plies, or complete ply removal that shows internal damage to the honeycomb structure

(b) Indications of lightning strike include:

1) Blistered, scorched or chipped paint

2) Frayed fibers

3) Some missing plies

4) Delamination

5) Complete removal of the plies

6) Signs of stress around the fasteners

(c) Indications of erosion include:

1) Chipped and/or missing paint

2) Worn and/or frayed plies

3) Missing plies

(d) Indications of stress damage include:

1) Fastener hole damage such as:

a) Chipped, loose or lifted paint

b) Fasteners that have been pulled through the skin.

(e) Indications of possible crack damage includes:

1) Linear cracks in the paint

2) Structure movement or separation

(f) Indications of burn or overheating include:

1) Blistered and/or discolored paint

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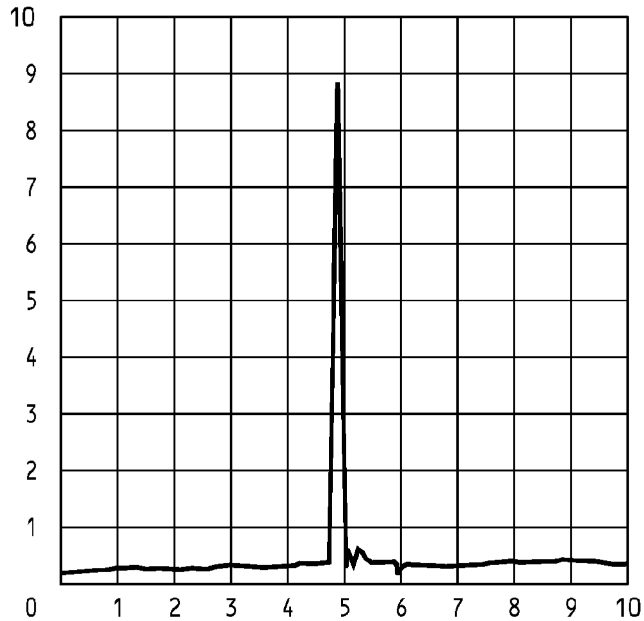
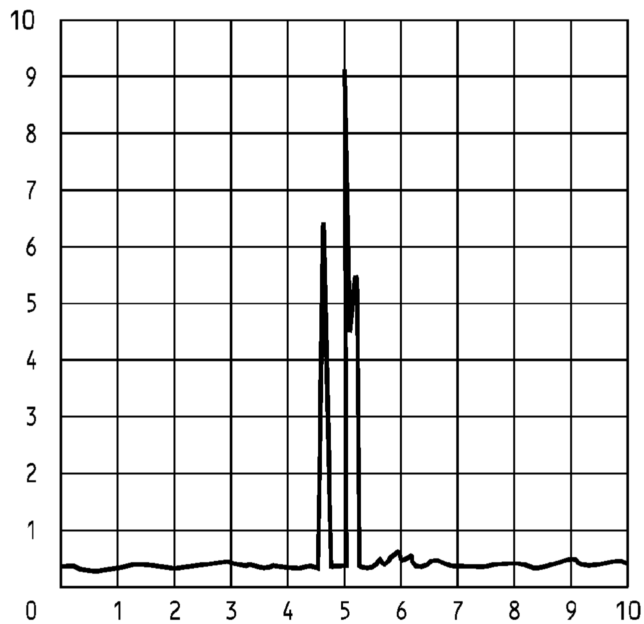


NEGATIVE HALF WAVEFORM [1]



POSITIVE HALF WAVEFORM [2]

NOTES

- SIGNALS CAN BE DIFFERENT FOR DIFFERENT TRANSDUCERS

[1] THE NEGATIVE HALF OF THE SIGNAL FROM A 10 MHZ TRANSDUCER THAT IS CAUSED BY THE END OF THE DELAY LINE.

[2] THE POSITIVE HALF OF THE SIGNAL FROM A 10 MHZ TRANSDUCER THAT IS CAUSED BY THE END OF THE DELAY LINE.

Positive and Negative Waveforms
Figure 1

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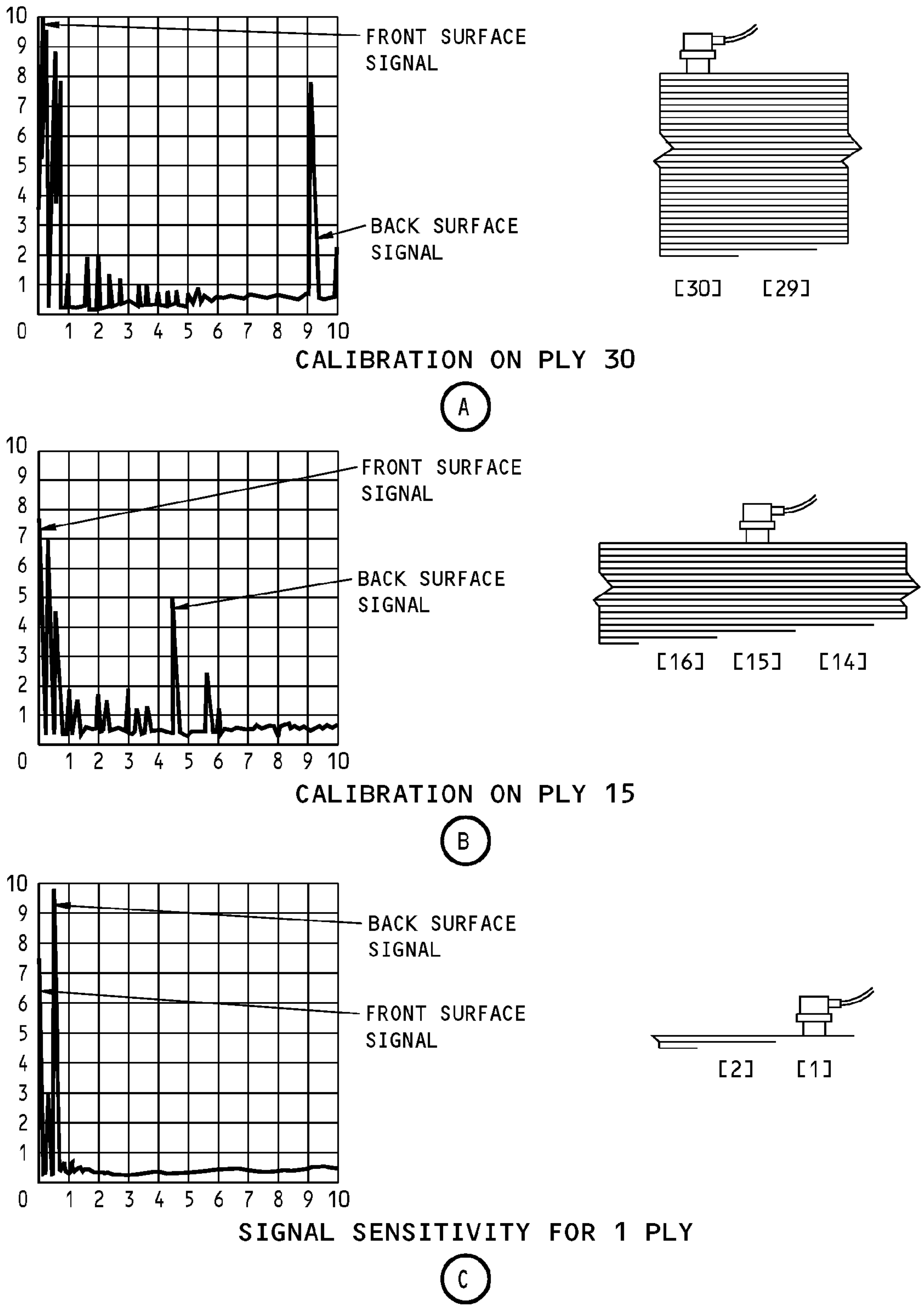

Calibration Signals
Figure 2

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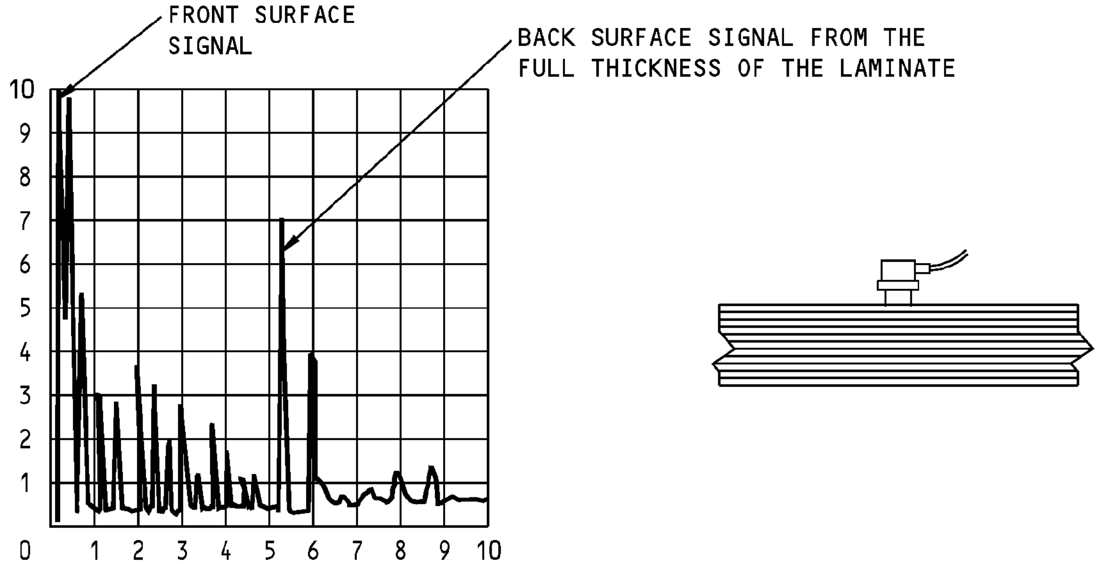
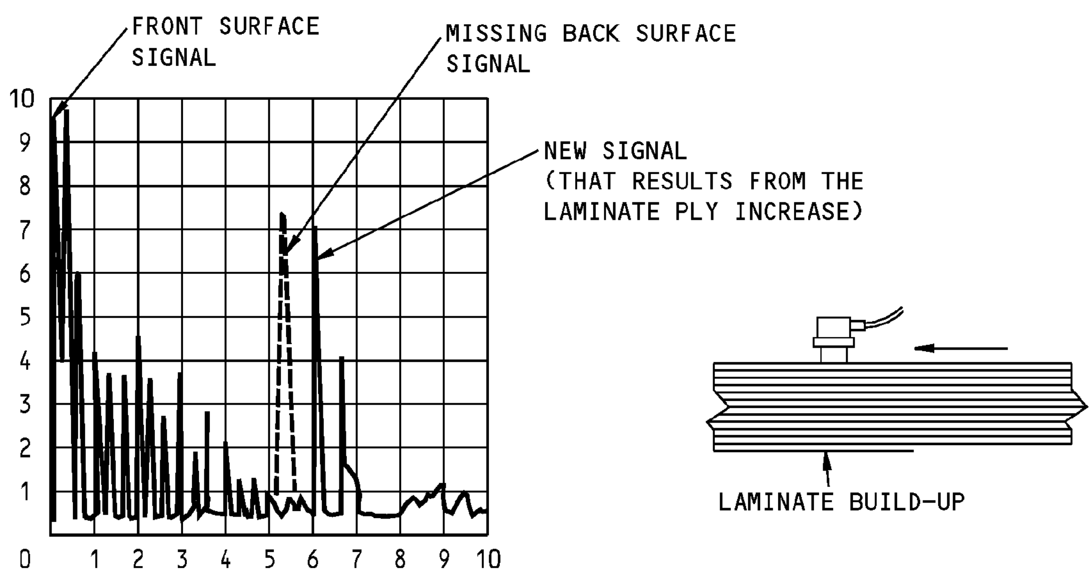


TYPICAL DISPLAY SIGNAL FROM THE FULL THICKNESS OF A LAMINATE

A



LAMINATE THICKNESS INCREASE SIGNAL

B

Laminate Thickness Signals
Figure 3

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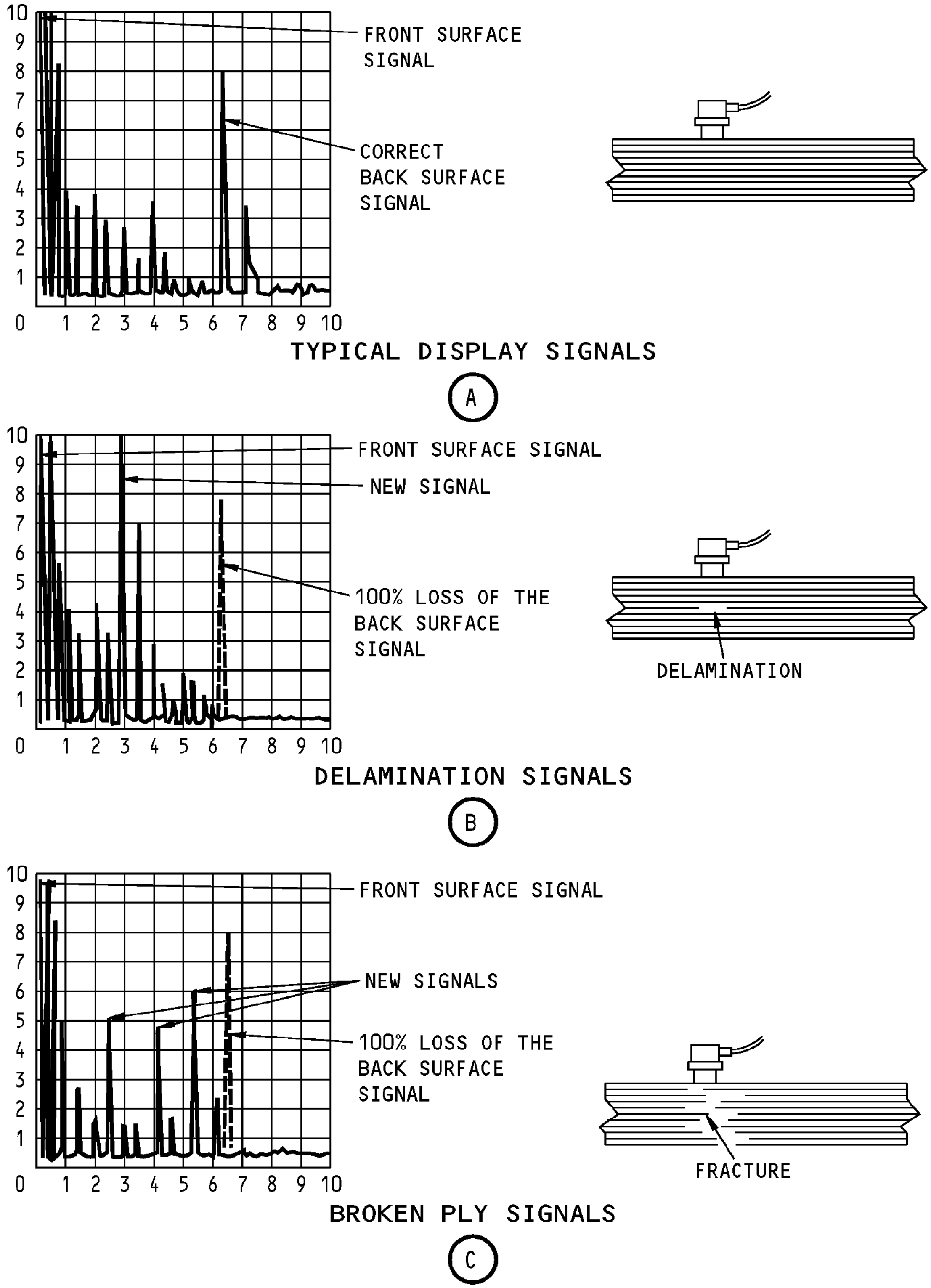

Defect Signals
Figure 4

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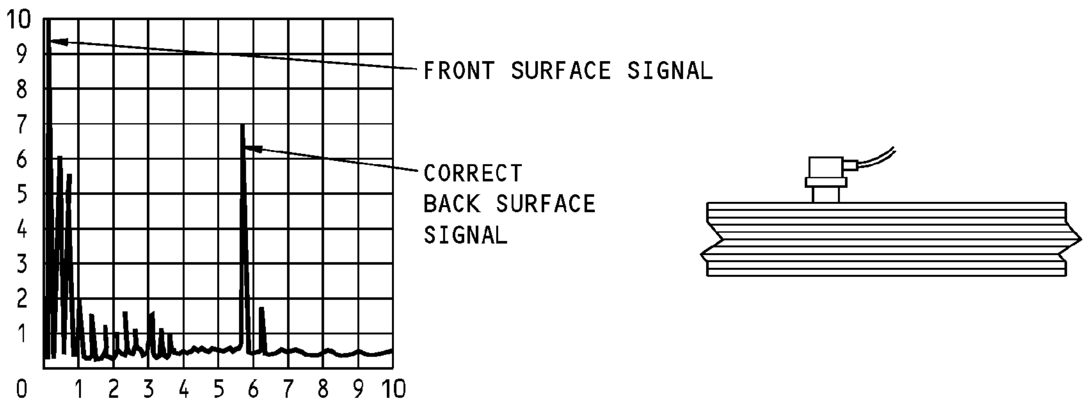
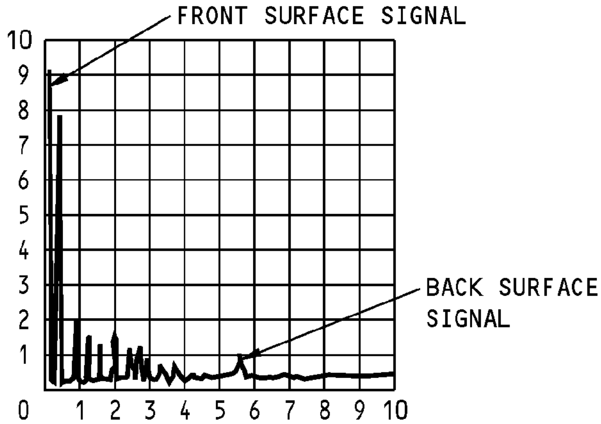


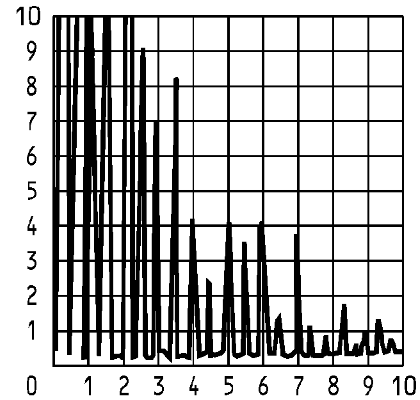
TYPICAL DISPLAY SIGNALS

A



LOSS OF
BACK SURFACE SIGNAL

B 1



UNSATISFACTORY INTERFERENCE
SIGNALS - "HASH"

C 2

NOTES

1 80 TO 100 PERCENT DECREASE IN THE AMPLITUDE OF THE BACK SURFACE SIGNAL. IT IS POSSIBLE FOR THE OTHER SIGNALS TO DECREASE ALSO.

2 THIS SHOWS THE DISPLAY THAT OCCURS IF YOU INCREASE THE GAIN BUT STILL CANNOT GET A BACK SURFACE SIGNAL.

Possible Display Signals
Figure 5

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PART 4 - ULTRASONIC

HONEYCOMB AND LAMINATE STRUCTURE - THROUGH-TRANSMISSION INSPECTION

1. **General**

   A. Use this Through-Transmission Ultrasonic (TTU) inspection procedure to examine metal and nonmetal composite parts. A TTU inspection is done to find bondline delaminations, skin-to-core disbonds and core damage.

   B. Use this procedure to do these inspections:

      (1) Computer-Aided Through-Transmission Ultrasonic (CATTU): A scan bridge and computer are used to make a C-scan. CATTU is the best procedure to use to examine composite parts. See Figure 1.

      (2) Manual Through-Transmission Ultrasonic (MTTU): A handheld water jet yoke is used to make a scan. Use MTTU if CATTU is not available. See Figure 2.

      (3) Wheel Transducer Through-Transmission Ultrasonic (WTTU): Wheel transducers in a portable yoke are used to make a scan. Use WTTU if MTTU and CATTU are not available. See Figure 3.

      (4) Contact Through-Transmission Ultrasonic (CTTU): A transducer is put on each side of the part by hand. One transducer transmits sound and the other receives the sound. Use CTTU if CATTU, MTTU and WTTU are not available. See Figure 4.

      (5) Air Coupled Through-Transmission Ultrasonic (ATTU): A hand held yoke with airborne transducers that do not touch the structure and for which couplant is not necessary. This inspection system can examine septumized parts. Refer to Part 4, 51-00-09 (for 777 airplanes) or Part 4, 51-00-04 (for 787 airplanes).

   C. C-scan equipment (CATTU inspection) is recommended for the inspection of septumized honeycomb. All other Through-Transmission Ultrasonic (TTU) systems that are used to examine septumized honeycomb must be calibrated on a reference standard that has septumized honeycomb or on a known good area of the structure to be examined.

2. **Equipment**

   A. General

      (1) Use inspection equipment that can be calibrated on the reference standard as specified in Paragraph 4.

      (2) Refer to Part 1, 51-01-00, for data about the equipment manufacturers.

   B. The scan equipment necessary to use to do a TTU inspection is related to the TTU procedure and inspection conditions. We recommend 5 MHz equipment for inspection of solid laminates and 1 MHz equipment for inspection of honeycomb structure. It is acceptable to use other frequencies if necessary.

   C. All ultrasonic instruments are permitted for use if they can do the calibration specified in this procedure. The ultrasonic instrument specified below was used to prepare this procedure.

      (1) USL 38 - Made by Krautkramer Branson

   D. The scan equipment necessary to do each TTU procedure is as follows:

      (1) CATTU - To do a CATTU inspection, it is necessary to use a through-transmission scan system with computer control of the transducer position and storage of the inspection data. The equipment specified below can be used.

         (a) Automated Ultrasonic Scanning System (AUSS) - Made by the McDonnell Aircraft Company

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(2) MTTU - To do a MTTU inspection, it is necessary to use a handheld water jet yoke and related items. The equipment that follows was used to help prepare this procedure.

(a) Yoke -- Part number JTW-36/8; Made by the NDT Engineering Corp.

(b) Yoke Nozzles -- Part number JTN 1.5x.75; Made by the NDT Engineering Corp.

(c) Yoke Transducers -- Part number JA4-1.0/.5 (1 MHz) or JA4-5.0/.5 (5 MHz); Made by the NDT Engineering Corp.

(d) External Preamplifier -- Model number ULP-90; Made by Sparta Technology (available through the NDT Engineering Corp.)

(e) Water Pump -- Part number 3E-12N; Made by the NDT Engineering Corp.

Drawings are also available from Boeing if you want to make an MTTU scan yoke. Ask for drawing numbers 65C22214 and 65C22093.

(3) WTTU - To do a WTTU inspection, it is necessary to use a handheld wheel transducer yoke and related items. The equipment that follows was used to help prepare this procedure.

(a) Yoke -- Part number RPTW-322A; made by the NDT Engineering Corp.

(b) Roller Probe Transducers -- Part number DCR-581 (1 MHz); made by the NDT Engineering Corp.

NOTE: We recommend that 1 MHz transducers be used to examine honeycomb and laminate parts.

(c) External Preamplifier -- Model number ULP-90; made by Sparta Technology (available through the NDT Engineering Corp.)

(4) CTTU - To do a CTTU inspection, it is necessary to use two handheld contact transducers, 0.50 inch (13 mm) or less in diameter. The equipment specified below was used to prepare this procedure.

(a) 0.50 inch (13 mm) contact transducer -- Part number 241-043 (1 MHz) or 244-043 (5 MHz); made by Krautkramer Branson

(b) External Preamplifier -- Model number ULP-90; made by Sparta Technology (available through the NDT Engineering Corp.)

E. Couplant - Use couplant as follows:

(1) For MTTU and CATTU use water as a couplant.

(2) For CTTU, use a couplant that can be removed with water. The couplant below was used to help prepare this procedure.

(a) Ultragel II - Made by Echo Laboratories, PO Box 552, Lewiston, PA, USA

F. Reference Standard - The reference standard structure must be the same or almost the same as the part you are to examine. Make a reference standard for this inspection as follows:

(1) Make a reference standard from a scrapped part which is the same as the part to be examined. Put foam tape on the part as specified in Paragraph 3.C.(2) or make knife cuts in the honeycomb core to make defects in the reference standard for calibration.

(2) If a scrapped part is not available, use an area of the part that does not have defects as the reference standard. Do a check as follows to make sure the areas are without defects.

(a) Compare the areas with the same areas on the other side of the airplane.

(b) Compare the areas with the same part on other airplanes.

(3) For inspection of repairs, you can use the repair reference standards given in Part 1, 51-01-01, to cause example indications. Use of these reference standards is optional.

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G. Foam Tape - Use foam tape that will cause the received signal to decrease at least 18 db. The foam tape identified below was used when this procedure was prepared.

(1) Vinyl Foam Tape - Part Number 4416; Made by the 3M Company, St. Paul, MN 55144, USA

3. Prepare for the Inspection

A. Remove the part from the airplane, if possible.

B. Wipe the scan area clean.

C. Apply foam tape to the part as follows:

(1) Cut 0.50 inch (12 mm) squares of foam tape and put them on the part at each corner of the scan area. These foam tape markers will mark the limits of the inspection location. They will help you to align the scan printout with the part surface when you do a CATTU scan.

(2) If the part is used as a reference standard, put 0.5 inch (12 mm) squares of foam tape in each area of the part that is structurally different. The foam tape will cause disbond signals and show that you have good sensitivity in these areas when you calibrate the equipment.

(3) If a scrapped part with defects is used as a reference standard, the use of foam tape is optional.

4. Calibrate the Instrument

A. Calibrate the equipment to do a Computer-Aided Through-Transmission Ultrasonic (CATTU) inspection Figure 1 as follows:

(1) Set the instrument frequency to the level recommended in Paragraph 2.B.

(2) Do a function check on the system. Refer to the operation instructions for your equipment.

(3) Put the part or reference standard between the water jets. Adjust the water pressure so that the lower water jet continuously touches the inspection surface.

(4) Align the water jets parallel to the honeycomb cell walls.

NOTE: Honeycomb cell walls are usually aligned perpendicular to the external surface. For panels with two external surfaces, such as an aileron, the honeycomb cell walls are usually aligned perpendicular to the surface of least curvature.

(5) Make a scan of the part or reference standard.

(6) If a reference standard is used, make sure the scan printout shows a sound decrease of at least 18 db when the water jets are moved across the defect. If the part is used as a reference standard, make sure the scan printout shows a sound decrease of at least 18 db when the water jets are moved across the foam tape. If the sound does not decrease by at least 18 db, use a higher inspection frequency.

B. Calibrate the equipment to do a Manual Through-Transmission Ultrasonic (MTTU) inspection Figure 2 as follows:

(1) Set the instrument frequency to the level recommended in Paragraph 2.B.

(2) Connect the yoke to the water supply tubing.

(3) Open the water valve to allow water to flow into the yoke.

(4) Remove the air bubbles in the yoke.

(5) Put the transducers in water and align the transducers to get a maximum signal. If it is not possible to put the transducers in water, align the water jets to get a symmetrical water pattern.

(6) Put the part or reference standard between the water jets so that the water jets are in an area without defects or foam tape.

(7) Adjust the water pressure so that the lower water jet continuously touches the inspection surface.

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(8) Align the water jets with the honeycomb cell walls.

NOTE: Honeycomb cell walls are usually aligned perpendicular to the external surface. For panels with two external surfaces, such as an aileron, the honeycomb cell walls are usually aligned perpendicular to the surface of least curvature.

(9) Set the reject control to the "off" position.

(10) Adjust the gain to set the received signal at 100 percent of full screen height.

(11) Adjust the range and delay controls to set the received signal at 50 percent screen width.

(12) Increase the gain by 12 db.

(13) Set the gate at 50 percent of full screen height.

(14) Set the alarm in the "on" position.

(15) Make a scan across the defect area of the reference standard or the foam tape (if the part is used as a reference standard). The alarm must operate when you make a scan across these areas.

C. Calibrate the equipment to do a Wheel Transducer Through-Transmission Ultrasonic (WTTU) inspection as follows:

(1) Set the instrument frequency to 1 MHz.

(2) Make sure that there are no air bubbles or "flat spots" in the transducer wheels as follows:

(a) Position a piece of Lucite, aluminum or other structure that has a constant thickness between the transducers.

(b) Set the received signal to 80 percent of full screen height.

(c) Make a scan.

(d) The received signal amplitude must not change more than 20 percent of full screen height when you make the scan.

(3) Connect the yoke to the instrument and supply power to the instrument.

(4) Put the yoke at a location on the part or reference standard that has no defects or foam tape.

(5) Align the transducer wheels so the sound beam is parallel to the honeycomb cell walls.

NOTE: Honeycomb cell walls are usually aligned perpendicular to the external surface. For panels with two external surfaces, such as an aileron, the honeycomb cell walls are usually aligned perpendicular to the surface of least curvature.

(6) Set the gain, range, delay and alarm as specified in Paragraph 4.B.(9) thru Paragraph 4.B.(15)

D. Calibrate the equipment to do a Contact Through-Transmission Ultrasonic (CTTU) inspection as follows:

(1) Set the instrument frequency to the level recommended in par. Paragraph 2.B.

(2) Put the transducers at an area on the part or reference standard that has no defects or foam tape.

(3) Move one transducer until the received signal is at a maximum.

NOTE: If possible, use a transducer holder to keep the transducers in the correct position. Figure 5 shows an example of a transducer holder.

(4) Set the gain, range, delay and alarm as specified in Paragraph 4.B.(9) thru Paragraph 4.B.(15)

(5) Put the transducers on a defect area, or a foam tape area (if the part is used as a reference standard). The alarm must operate when the transducers are at these areas.

NOTE: Some rubber-tipped transducers made for contact inspection are sensitive to pressure. Make sure to use the same contact pressure during the calibration and the inspection.

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5. **Examine the Honeycomb and Laminate Structure for Bondline Delaminations, Skin-to-Core Disbonds and Core Damage**

A. Examine a part with Computer-Aided Through-Transmission Ultrasonics (CATTU) as follows:

(1) Calibrate the CATTU equipment as specified in Paragraph 4.A.

(2) Position the part so the honeycomb core cells are aligned parallel to the water jets.

(3) Set the scan area so that each of the foam tape markers will show on the scan at the same time.

(4) Make a scan of the inspection area in increments of 0.125 inch (3 mm) or less.

B. Examine a part with Manual Through-Transmission Ultrasonics (MTTU) as follows:

(1) Calibrate the MTTU equipment as specified in Paragraph 4.B.

(2) Put foam tape on the part as specified in Paragraph 3.

(3) Put the transducers on each side of the part in an area with no defects or foam tape.

(4) Compare the signal from the part with the signal you got during calibration. If the signal is different that the calibration signal:

(a) Make a check of the water jet alignment.

(b) Make sure that the reference standard structure and the part structure are the same.

(5) Make scans of the inspection area as specified in these steps:

(a) Keep the transducers on areas of constant thickness.

(b) Make scans from the thin areas of parts to the thick areas.

(c) Recalibrate the equipment as specified in Paragraph 4.B. when the received signal from good structure falls below 100 percent of the full screen height.

(6) If the signal suddenly falls below 50 percent of the full screen height, calibrate the equipment and do the inspection again. During calibration, use the thickness on the reference standard that is the same as the part thickness. See Paragraph 4.B. for the calibration procedure.

NOTE: It is necessary to do the calibration again to make sure that you have the correct sensitivity for the local structure.

(7) Carefully mark all areas that cause the signal to fall below 50 percent of full screen height.

C. Examine a part with Wheel Transducer Through-Transmission Ultrasonics (WTTU) as follows:

(1) Calibrate the WTTU equipment as specified in Paragraph 4.C.

(2) Put foam tape on the part as specified in Paragraph 3.

(3) Put the transducers on each side of the part at an area with no defects or foam tape.

(4) Compare the signal from the part with the signal you got during calibration. If the signal is different than the calibration signal:

(a) Make a check of the transducer alignment.

(b) Make sure that the reference standard and the part structure are the same.

(5) Make scans of the part as specified in Paragraph 5.B.(5) thru Paragraph 5.B.(7)

D. Examine a part with Contact Through-Transmission Ultrasonics (CTTU) as follows:

(1) Calibrate the CTTU equipment as specified in Paragraph 4.D.

(2) Put foam tape on the part as specified in Paragraph 3.

(3) Make scans of the part as specified in Paragraph 5.B.(5) thru Paragraph 5.B.(7) Use a tool, if possible, to align the transducers. Figure 5 shows a transducer holder that is easy to make.

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6. **Make an analysis of the inspection results.**

A. Areas where the signal falls below 50 percent of full screen height that are larger than permitted for a defect must be examined more to identify the defect type. Use one of the inspection procedures specified below.

(1) Pulse-echo ultrasonic as specified in Part 4, 51-00-02.

(2) High-frequency bondtester as specified in Part 4, 51-00-01.

(3) X-ray inspection as specified in Part 2, 51-00-03.

NOTE: Use X-ray inspections to get data about the part structure only. Do not use X-ray to accept or reject parts with disbonds. X-ray inspections cannot find disbonds.

(4) Low-frequency bondtester as specified in Part 4, 51-00-05.

B. The conditions that follow can cause the sound to attenuate more than 18 db. Use X-ray inspection (refer to Part 2, 51-00-03) to identify these areas; or carefully mark the TTU indications on the part until you can see a pattern to identify the area.

(1) Core splices

(2) Core repairs

(3) Areas not sufficiently filled with potting compound

(4) Cracks in potted areas

C. Use pulse-echo to identify potted areas if X-ray is not available as follows:

(1) Put a 1 or 5 MHz transducer on the potted area.

(2) Use your finger to identify the back surface echo from the other side of the part. Touch the opposite side of the part at the transducer location to decrease the back echo signal.

(3) If you can identify a back surface reflection and damp it with your finger, the transducer is on a potted area.

D. Use a high frequency bondtester as specified in Part 4, 51-00-01, to examine the bond between the skin and potted areas for defects. Areas where there is a separation of the bond between the skin and potting will give a signal equivalent to areas where the skin is not above potting.

E. The conditions that follow can cause false defect signals that are not related to the part structure.

(1) Intermittent signal loss from too much scan speed

(2) Transducers that are out of alignment

(3) Decreased water pressure

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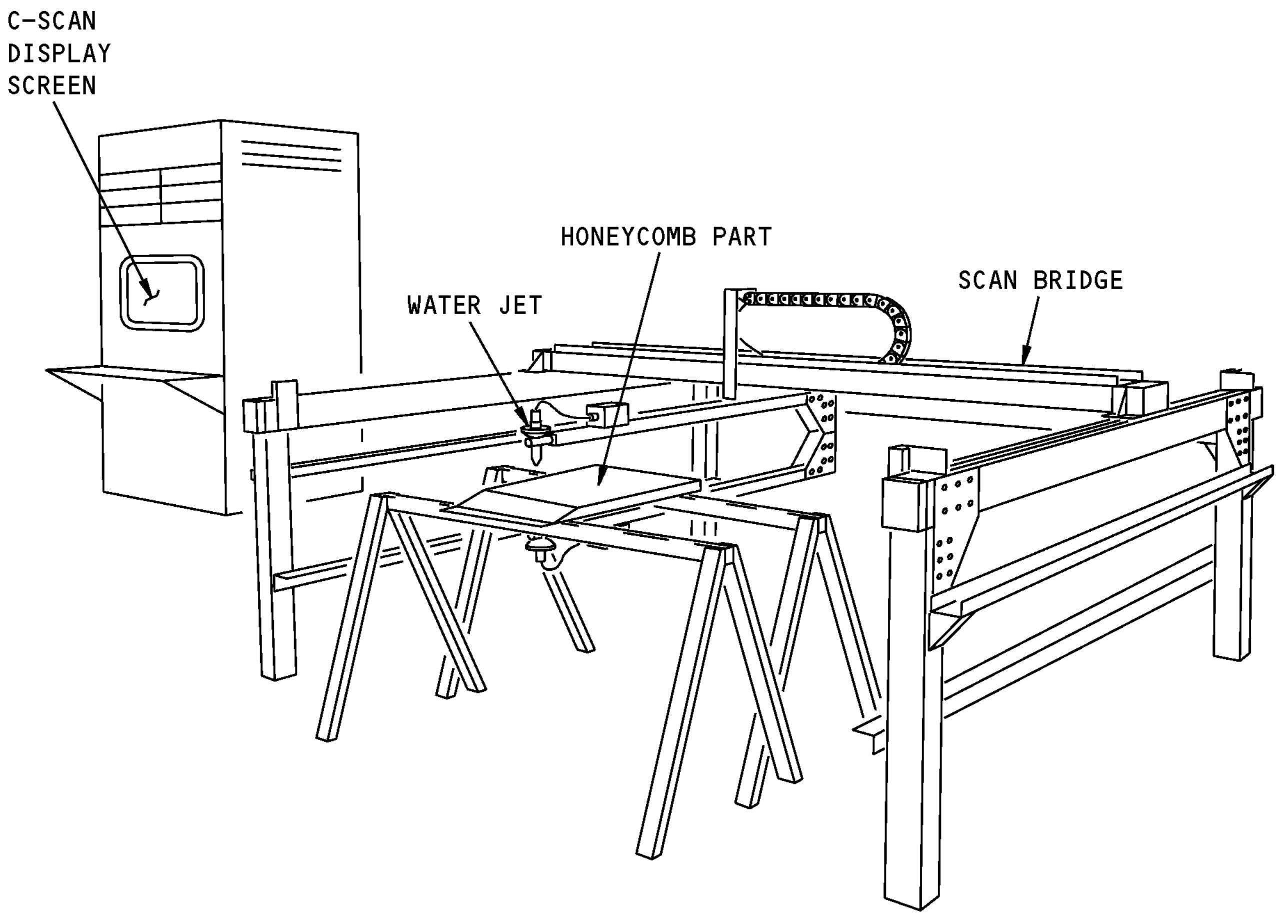

Computer-Aided Through Transmission Ultrasonics (CATTU)
Figure 1

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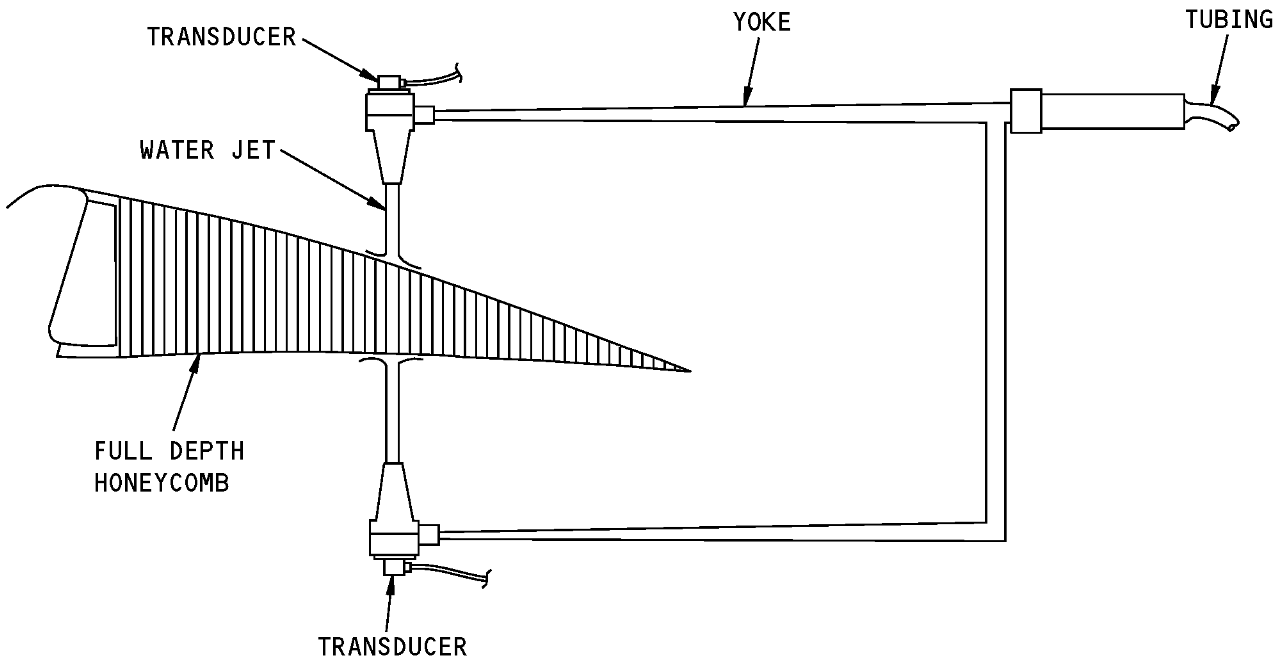

NOTE: • ALIGN THE WATER JETS WITH THE HONEYCOME CORE.

Manual Through-Transmission Ultrasonic (MTTU) Yoke
Figure 2

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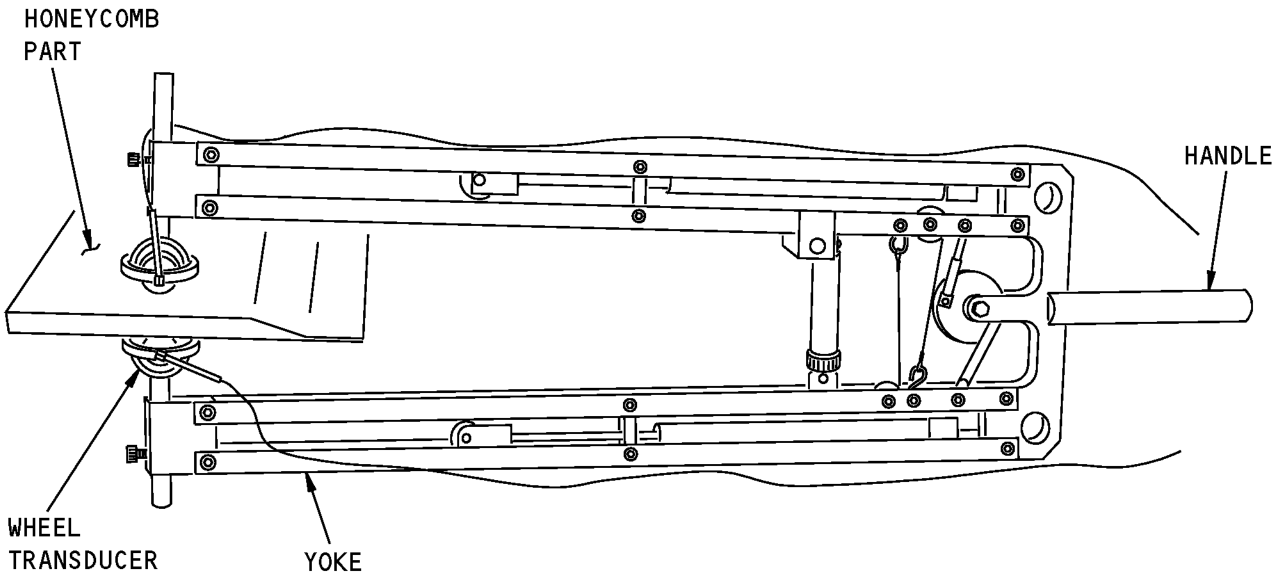

Wheel Transducer Through-Transmission Ultrasonics (WTTU)
Figure 3

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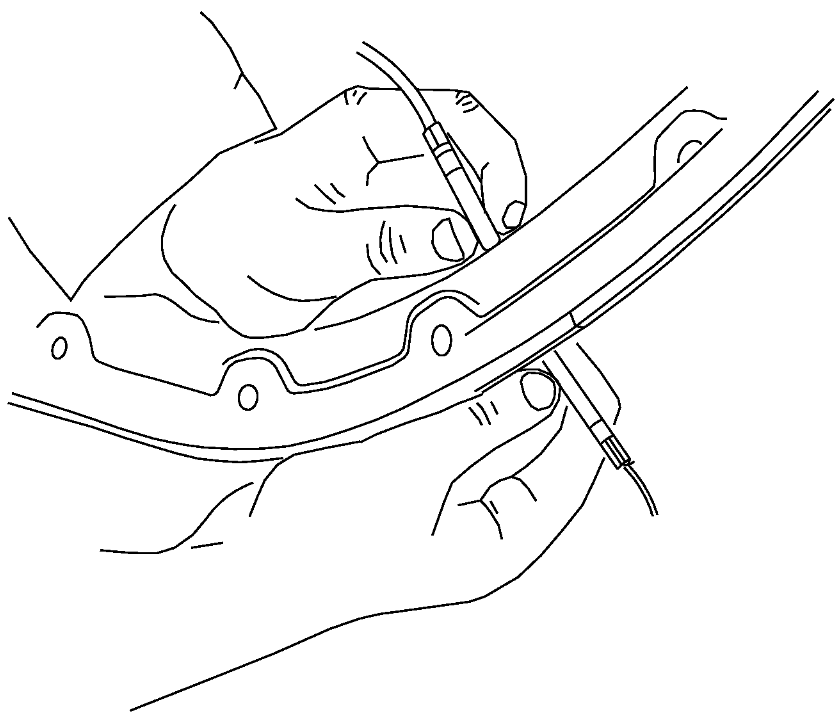

Contact Through-Transmission Ultrasonics (CTTU)
Figure 4

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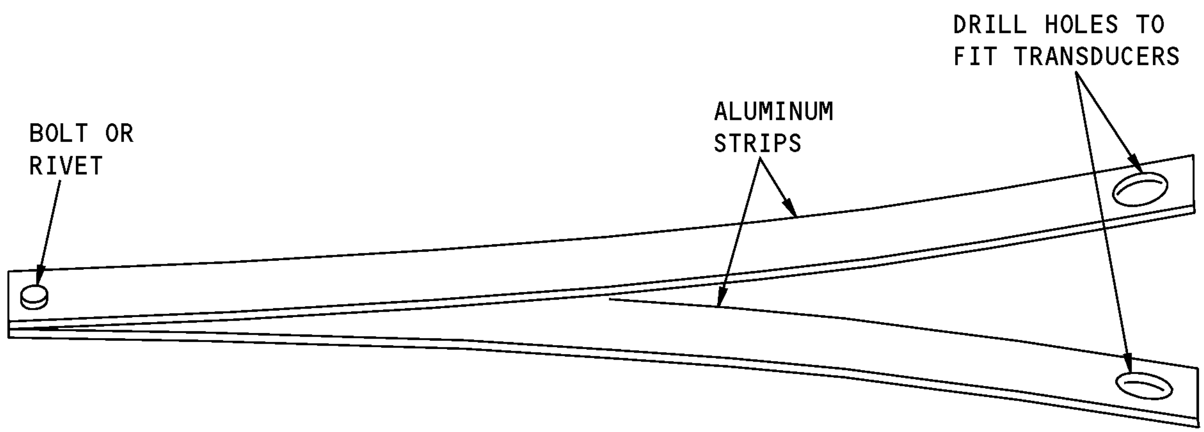

Transducer Holder
Figure 5

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PART 4 - ULTRASONIC

INSPECTION FOR WATER IN HONEYCOMB STRUCTURE

1. **Purpose**
   A. To detect water in honeycomb structures using ultrasound.
2. **Equipment**
   A. Any ultrasonic equipment which will satisfy the performance requirements of this procedure is suitable for this inspection. The following equipment was used in the development of this procedure and found acceptable.
      (1) Instrument - USL 38, Krautkramer/Branson Inc.
      (2) Transducer - 5-MHz longitudinal wave transducer with a 0.5-inch (1.28 cm) OD case, P/N 224-000 Krautkramer/Branson, Inc.

      NOTE: Larger or smaller diameter size transducer may be used. Larger diameter will provide greater area coverage.
      (3) Reference Standard - See Figure 1.
      (4) Couplant - Ultrasonic couplant compatible with structure being inspected.
3. **Preparation for Inspection**
   A. Identify area where water contamination is suspected and wipe surface clean.

   NOTE: Check for visible damage in general inspection area.
4. **Instrument Calibration**
   A. Connect transducer and make preliminary instrument adjustments.
   B. Place transducer on lower surface of reference standard directly below cells filled completely with water (see Figure 2, Position 1).
   C. Manipulate transducer to obtain maximum signal response.
   D. Adjust instrument gain to obtain 80 percent of full scale height response from water-filled cells.
   E. Position response from water-filled cells at approximately 50 percent of screen width as indicated in Figure 2.

   NOTE: This instrument calibration will detect completely filled cells in honeycomb core up to 2.0 inches thick. To inspect for completely filled cells in thicker honeycomb core composite structure compress the instrument time base line as required to compensate for the thicker section.
   F. Place transducer beneath honeycomb core cells containing approximately 0.5 inch (2.3 cm) and 0.25 inch (0.64 cm) of water and cells containing no water and note location of response signal (see Figure 2, flagnotes 2, 3, and 4).
5. **Inspection Procedure**
   A. Identify inspection area.
   B. Calibrate instrument per Paragraph 4.
   C. Apply a thin coat of couplant to inspection area.
   D. Place transducer on lower side of honeycomb structure being inspected (see Figure 3).

   NOTE: Water must be in contact with surface on which transducer is placed to be detected.
   E. Scan area of suspected water contamination and note signal response.
   F. Compare response signal received with response signal obtained from reference standard.

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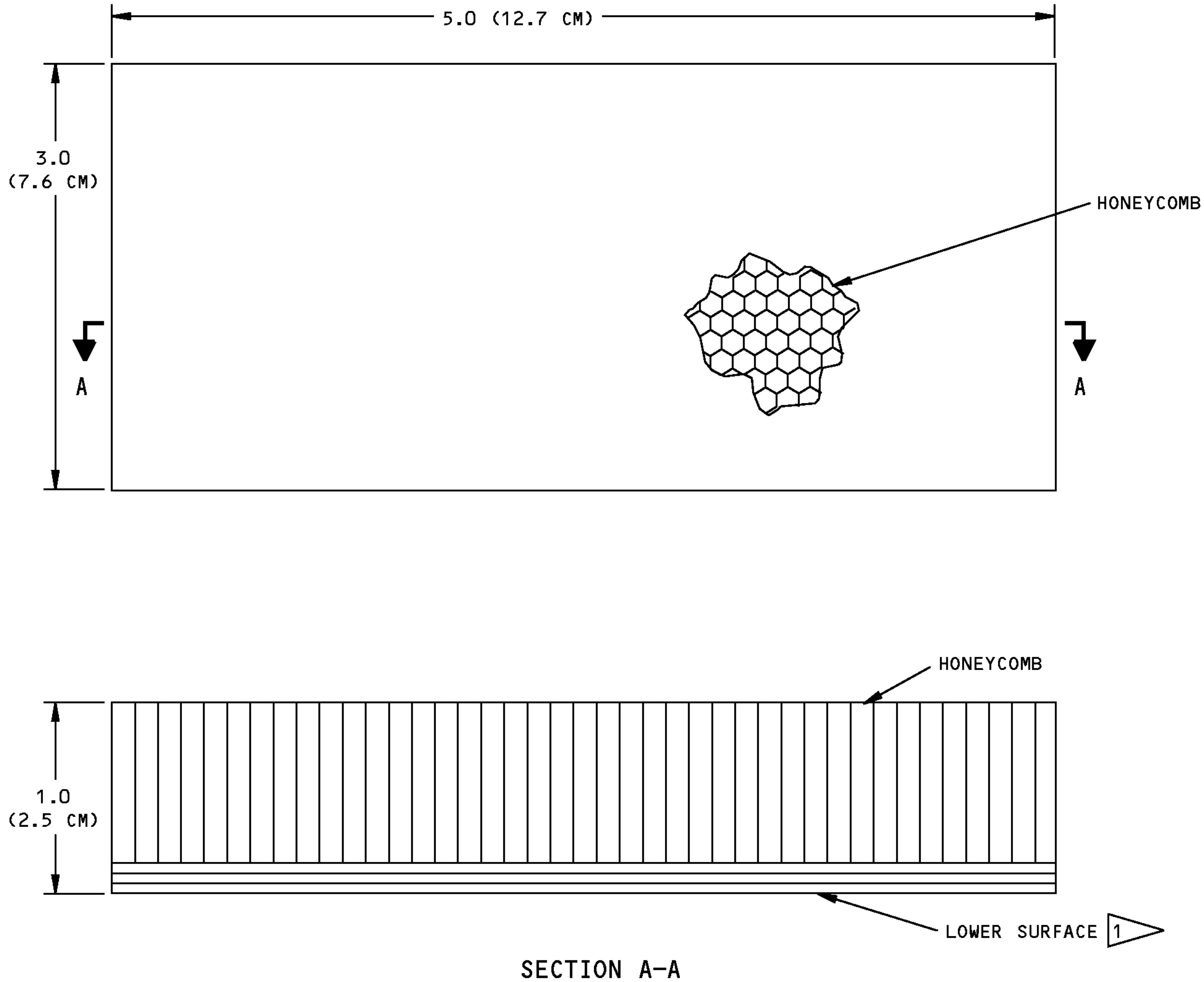

NOTES

- ALL DIMENSIONS ARE IN INCHES (CENTIMETERS IN PARENTHESES)
- TOLERANCE: ±0.1 (0.25 CM)
- FABRICATE FROM MATERIALS USED IN AIRPLANE CONSTRUCTION

1 THREE PLIES MINIMUM IF FABRICATED FROM NONMETALLIC COMPOSITE

Reference Standard
Figure 1

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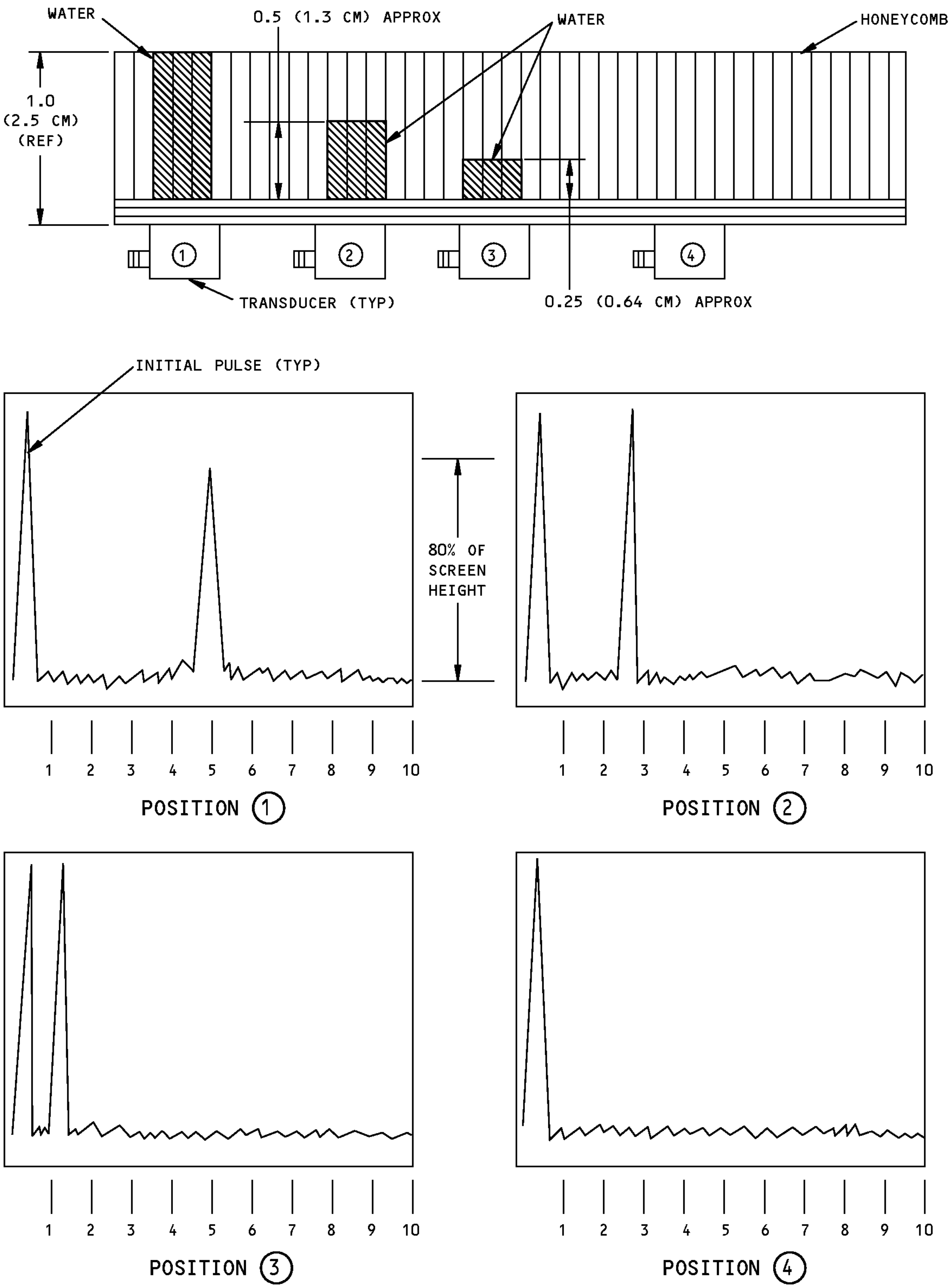

Instrument Calibration
Figure 2

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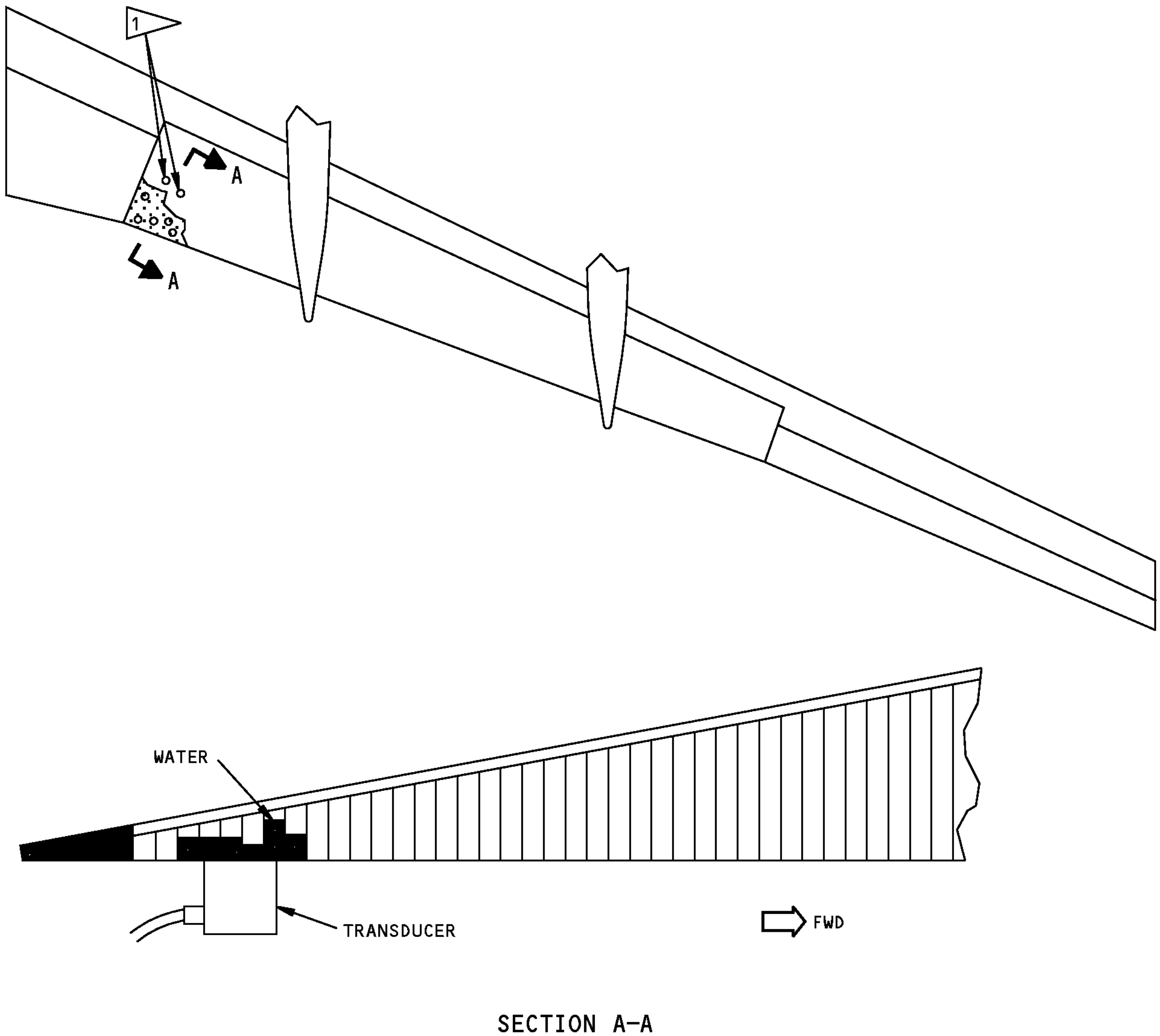

NOTES

- VIEW LOOKING UP
- PLACE TRANSDUCER ON LOWER SURFACE OF HONEYCOMB STRUCTURE AND SCAN AREAS OF SUSPECTED WATER CONTAMINATION

SUSPECTED WATER CONTAMINATION AREAS

1 COMPARE RESPONSE SIGNAL FROM AREAS OF SUSPECTED WATER CONTAMINATION WITH RESPONSES OF OTHER AREAS AND WITH REFERENCE STANDARD RESPONSE

Typical Surveillance Inspection of Honeycomb Structure for Water Contamination
Figure 3

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PART 4 - ULTRASONIC

BONDTEST INSPECTION OF HONEYCOMB STRUCTURE

1. **General**

   A. Use this procedure to find core damage and skin-to-core disbonds in metal and nonmetal honeycomb structure. A low frequency bondtester is necessary to do this procedure.

      NOTE: Low frequency bondtesters are those that operate without a liquid couplant.

   B. This procedure can also be used to find disbonds in metal laminates, but it is not as sensitive as inspection with high frequency bondtesters. For inspection of metal laminates with high frequency bondtesters, refer to Part 4, 51-00-01.

   C. This procedure can be used to find core damage and disbonds only. It cannot be used to measure bond strength.

   D. This procedure cannot tell the difference between disbonds and core crush.

2. **Equipment**

   A. General

      (1) Use inspection equipment that can be calibrated on the reference standard as specified in Paragraph 4.

      (2) Refer to Part 1, 51-01-00, for data about the equipment manufacturers.

   B. Instrument

      (1) All bondtest instruments are permitted for use if they can get satisfactory results on the reference standard used for this procedure. The equipment identified below was used to prepare this procedure:

         (a) S-2B Sondicator; Automation Industries

         (b) S-5 Sondicator; Zetec

         (c) S-9 Sondicator; Zetec

         (d) Bondmaster; Staveley Instruments (mechanical impedance and pitch-catch modes)

         (e) Acoustic Flaw Detector 1000; Staveley Instruments

         (f) US5200C; Uniwest

         (g) V95 Bondcheck; Rohmann GmbH

   C. Probes

      (1) The probes used with low frequency bondtesters are supplied with the inspection instrument.

   D. Reference Standards

      (1) For metal honeycomb sandwich parts:

         (a) Make a reference standard as shown in Figure 1. You can also buy this reference standard from NDT Engineering Corp. Refer to Part 1, 51-01-00, for data about the NDT Engineering Corp.

      (2) For graphite-epoxy honeycomb sandwich parts:

         (a) Honeycomb calibration guide ST8870-1 or ST8870-4. See Part 1, 51-04-00, Fig. 6 and Fig. 7.

         (b) For inspection of repairs, you can use the repair reference standards given in Part 1, 51-01-01, for calibration and to cause example indications. Use of these reference standards is optional.

      (3) For metal laminate parts:

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(a) Make a reference standard as shown in Figure 2. You can also buy this reference standard from NDT Engineering Corp. Refer to Part 1, 51-01-00, for data about the NDT Engineering Corp.

(4) A discarded part can be used as a reference standard if you drill a 1.0 inch (25 mm) diameter flat-bottomed hole to the correct bondline location. The discarded part must have the same structure as the inspection part.

3. **Prepare for the Inspection**

A. Get the Structural Repair Manual data or engineering drawings, if possible, that show the structure and thicknesses in the inspection area.

B. Clean loose dirt, paint flakes, or blisters from the inspection surface.

4. **Calibrate the Instrument**

A. Get the correct probe for the inspection material thickness and structure to be examined. Refer to the instrument instruction manual for data about probes.

B. Put the probe on the reference standard in a bonded area. This area must have the same skin thickness as the part to be examined.

C. Calibrate the instrument as specified in the instrument instruction manual or in an equivalent approved procedure.

D. Move the probe across the bonded area on the reference standard. Adjust the calibration as you move the probe until you get a stable signal.

E. Move the probe across a disbonded area on the reference standard.

F. Make sure that you get a disbond signal from the instrument when the probe is moved across the disbonded area. If not, do Paragraph 4.C. thru Paragraph 4.E. again until you get a clear disbond signal.

G. Adjust the instrument's alarm controls so that the alarm operates when the probe is moved across the disbond area.

5. **Examine the Honeycomb Structure for Core Damage and Skin-to-Core Disbonds**

A. Put the probe on known good structure in the inspection area.

B. Compare the signal from the part with the signal you got during calibration from the good structure of the reference standard. If the signal is different than the reference standard signal, do the steps specified below, as necessary:

(1) Check the honeycomb core ribbon direction of the part. If the probe is a pitch-catch probe, use the same probe-to-ribbon direction angle on the part as you did on the reference standard.

(2) Make a check to make sure that the reference standard structure and the part structure are the same or almost the same.

(3) Examine the same part on the other side of the airplane or on a different airplane to make sure that your probe is not on a disbond area.

(4) Make small adjustments to the instrument display if necessary. Small display adjustments are permitted if the instrument continues to find the reference standard disbond after the new adjustments.

C. Make scans of the inspection area as specified in these steps:

(1) Move the probe along areas of constant thickness.

(2) Move the probe slowly and look for sudden changes in the instrument display which are not caused by structural changes in the part.

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(3) Use a scan increment that is one-third of the permitted disbond diameter. For example: to find 1 inch diameter (25 mm) disbonds, use a scan increment of 0.30 inch (8 mm). We recommend that you use a guide or straightedge against the probe.

(4) Make a mark below the center of the probe at each location that you get a disbond signal.

6. Make an Analysis of the Inspection Results

A. Examine the areas that have been marked to identify the cause of the indication. One or more of the inspection procedures specified below can be used to make this examination:

(1) Through-transmission inspection as specified in Part 4, 51-00-03.

(2) X-ray inspection as specified in Part 2, 51-00-03.

NOTE: Use X-ray inspection to get data about the part structure only. Do not use X-ray to accept or reject parts with disbonds. X-ray inspection cannot be used to find disbonds.

(3) High-frequency bondtester as specified in Part 4, 51-00-01 (for metal laminate parts and nonmetal laminate areas).

B. The conditions that follow can cause indications. These areas will look like thicker structure on the bondtester display, while a disbond will look like thinner structure. Use X-ray inspection (refer to Part 2, 51-00-03) to identify these areas. Or, carefully make the indications on the part until you can see a pattern to identify the area. You can also refer to the SRM drawings or engineering drawings of the part if you have them. The conditions that can cause indications are:

(1) Core splices

(2) Core repairs

(3) Doublers

(4) Areas not sufficiently filled with potting compound. (Use X-ray inspection to examine these areas.)

C. To identify potted areas, use one of the procedures identified below:

(1) X-ray inspection as specified in Part 2, 51-00-03.

(2) High frequency bondtester as specified in Part 4, 51-00-01, as follows:

(a) Null the instrument on an area of skin that covers honeycomb.

(b) Move the probe across the area you think contains potting.

1) If the signal does not change, there is no potting below the skin, or there is a disbond between the skin and the potting. Use X-ray inspection as specified in Part 2, 51-00-03, to do a check for potting.

2) If the signal moves in the direction of thinner structure (nonmetal laminates only), there can be a disbond between the skin plies. Examine the skin with pulse-echo as specified in Part 4, 51-00-02.

3) If the signal moves in the direction of thicker structure, there is potting below the skin plies.

(3) Pulse-echo as follows:

(a) Put a 5 MHz transducer on the area that you think contains potting.

(b) If you can identify a back surface reflection and can dampen it when you touch the opposite side of the part at the transducer location, the transducer is on a potted area.

(c) If you cannot identify the back surface reflection, use a plastic block to make sure you have the correct screen range. The plastic block must be the same thickness as the part in the potted area.

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(d) If you are at the correct screen range and you cannot identify a back surface reflection, do Paragraph 6.C.(3)(a) thru Paragraph 6.C.(3)(c) again with a 1 MHz transducer.

(e) If you cannot identify a back surface reflection with a 1 MHz transducer, the honeycomb cells below the skin are not filled with potting.

D. To examine for disbonds in the bond between the skin and potted areas, use one of the procedures specified below:

(1) High frequency bondtester as specified in Part 4, 51-00-01. Areas where there is a separation of the bond between the skin and potting will give a signal equivalent to areas where the skin is not above potting.

(2) Pulse-echo as specified in Paragraph 6.C.(3)

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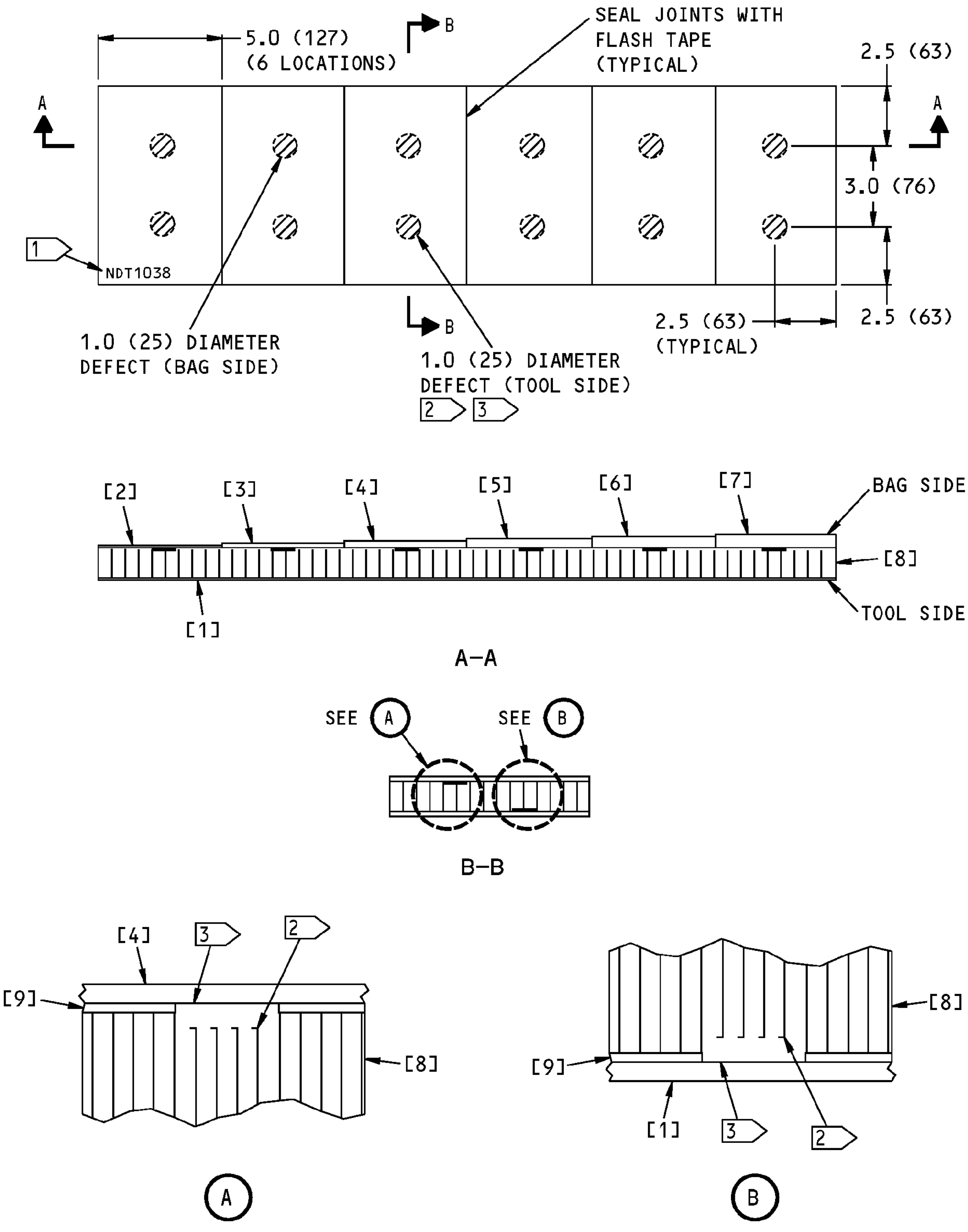

Reference Standard NDT1038
Figure 1 (Sheet 1 of 3)

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NOTES

- ALL DIMENSIONS ARE IN INCHES (MILLIMETERS ARE IN PARENTHESES).
- TOLERANCES:

INCHES	MILLIMETERS
X.XXX = ±0.005	X.XX = ±0.010
X.XX = ±0.025	X.X = ±0.5
X.X = ±0.050	X = ±1

- SURFACE ROUGHNESS = 125 Ra OR BETTER.
- TO MAKE THE REFERENCE STANDARD:
  1. PREPARE THE SURFACES AS SPECIFIED IN BAC 5514.
  2. APPLY A LAYER OF BMS 5-101, CLASS I, GRADE 10, TYPE II ADHESIVE TO THE SKIN SECTIONS. BMS 5-129, CLASS I, GRADE 10, TYPE 4 ADHESIVE IS AN ALTERNATIVE TO BMS 5-101.
  3. REMOVE CIRCULAR AREAS OF ADHESIVE IN THE LOCATIONS SHOWN.
  4. USE A KNIFE AND CIRCLE TEMPLATE TO CUT THE CORE CELL WALLS AROUND THE DEFECT LOCATIONS. CUT ONLY 0.10 (2.5) INTO THE CELL WALLS.
  5. USE A 1 INCH (25) DIAMETER SANDING WHEEL OR END MILL TO REMOVE OR BEND THE CORE WITHIN THE CUT AREA TO A DEPTH OF 0.10 (2.5).
  6. ASSEMBLE THE SKINS AND THE HONEYCOMB. SEAL THE JOINTS BETWEEN THE SKIN SECTIONS WITH FLASH TAPE.
  7. CURE AT 35 PSI (241 KPa) AS SPECIFIED IN BAC 5514-5101.

1 ETCH OR STEEL STAMP THE REFERENCE STANDARD NUMBER "NDT1038".

2 BEND OR REMOVE THE CORE TO A 0.10 (2.5) DEPTH TO MAKE DEFECTS.

3 REMOVE A CIRCULAR AREA OF THE ADHESIVE TO MAKE THE DEFECT AREAS.

4 2000,6000, OR 7000 SERIES ALUMINUM, CLAD OR UNCLAD.

Reference Standard NDT1038
Figure 1 (Sheet 2 of 3)

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• MATERIAL:

ID NO.	QUANTITY	DIMENSIONS	MATERIAL
[1]	1	8.0 (203) X 30.0 (762) X 0.025 (0.5)	ALUMINUM SHEET 4
[2]	1	8.0 (203) X 5.0 (127) X 0.016 (0.4)	ALUMINUM SHEET 4
[3]	1	8.0 (203) X 5.0 (127) X 0.020 (0.5)	ALUMINUM SHEET 4
[4]	1	8.0 (203) X 5.0 (127) X 0.025 (0.6)	ALUMINUM SHEET 4
[5]	1	8.0 (203) X 5.0 (127) X 0.032 (0.8)	ALUMINUM SHEET 4
[6]	1	8.0 (203) X 5.0 (127) X 0.040 (1.0)	ALUMINUM SHEET 4
[7]	1	8.0 (203) X 5.0 (127) X 0.050 (1.3)	ALUMINUM SHEET 4
[8]	1	8.0 (203) X 30.0 (762) X 1.0 (25)	BMS 4-4, TYPE 3-30N, ALUMINUM CORE (3-15,3-20, AND 3-25 CORE ACCEPTABLE AS SUBSTITUTES)
[9]	2	8.0 (203) X 30.0 (762)	BMS 5-101, CLASS 1, GRADE 10, TYPE II ADHESIVE FILM (BMS 5-129, CLASS I, GRADE 10, TYPE IV ACCEPTABLE AS SUBSTITUTE).

Reference Standard NDT1038
Figure 1 (Sheet 3 of 3)

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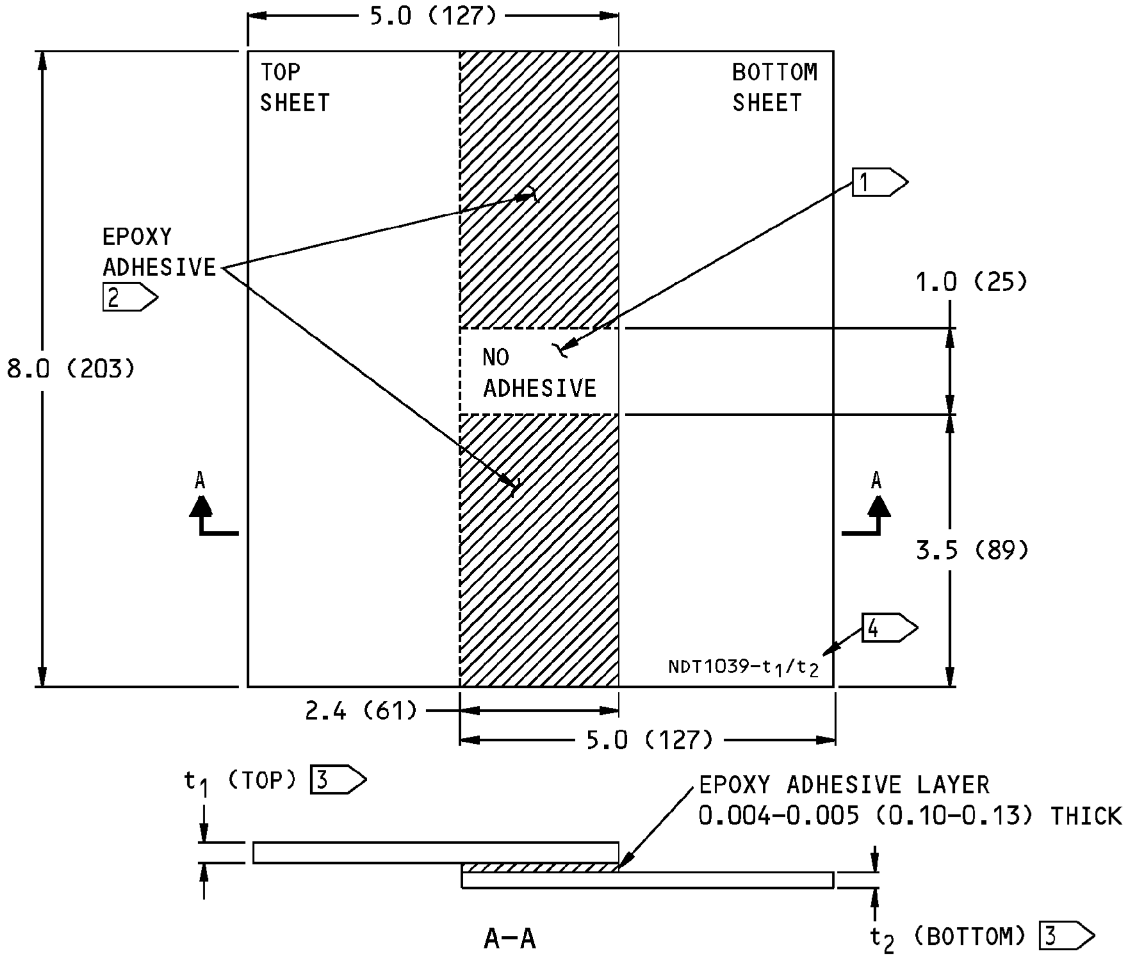

NOTES

- ALL DIMENSIONS ARE IN INCHES (MILLIMETERS ARE IN PARENTHESES).
- TOLERANCE:

INCHES	MILLIMETERS
X.XXX = ±0.005	X.XX = ±0.010
X.XX = ±0.025	X.X = ±0.5
X.X = ±0.050	X = ±1

- MATERIAL: 2000 SERIES ALUMINUM, CLAD OR UNCLAD

1 YOU CAN USE A TEFLON INSERT THAT HAS THE APPROXIMATE THICKNESS OF THE EPOXY ADHESIVE TO PREVENT ADHESIVE FLOW INTO THE "NO ADHESIVE" AREA

2 USE AN EPOXY ADHESIVE THAT IS 0.004-0.005 (0.10-0.13) THICK FOR SUFFICIENT STRENGTH

3 CHOOSE THE t_1 AND t_2 SKIN THICKNESSES TO EQUAL THE THICKNESSES OF THE STRUCTURE TO BE EXAMINED

4 ETCH OR STEEL STAMP "NDT1039-t_1/t_2" ON THE REFERENCE STANDARD WHERE t_1 IS THE THICKNESS OF THE TOP SHEET AND t_2 IS THE THICKNESS OF THE BOTTOM SHEET.

Reference Standard NDT1039-t1/t2
Figure 2

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PART 4 - ULTRASONIC

HONEYCOMB AND LAMINATE STRUCTURE - AIR COUPLED THROUGH-TRANSMISSION INSPECTION

1. General

   A. Use this Air Coupled Through-Transmission Ultrasonic (ATTU) inspection procedure to examine metal and nonmetal composite parts. This inspection can find interply delaminations and skin-to-core disbonds. This inspection system can examine septumized parts.

   B. It is not necessary to use couplant or touch the part with the transducer to use this inspection system. To do this inspection, you must access opposite sides of the part and the transducers must be perpendicular to each side of the part. The system can be used as follows:

      (1) Structure with parallel sides can be examined as follows:

         (a) The gimbaled transducer locked and the (two) transducers in air.

         (b) One transducer in touch with the structure.

      (2) Angled (ramp) structure can be examined as follows:

         (a) The gimbaled transducer locked and in air at the same angle of the inspection surface. The other transducer can be in air and must be perpendicular to the inspection surfaces.

         (b) The gimbaled transducer unlocked and in touch with the angled inspection surface. The other transducer can be in air and must be perpendicular to the inspection surfaces.

         NOTE: This is the recommended procedure to use to examine angled inspection surfaces.

         (c) With the two transducers removed from the yoke and in touch with the upper and lower surfaces. Transducers are handheld and must be aligned to each other.

2. Equipment

   NOTE: Refer to Part 1, 51-01-00, for data about the equipment manufacturers.

   A. The Curlin Air ATTU system parts that follow were used to help prepare this procedure.

      (1) Instrument - 150-10000-1

      (2) Airborne Transducers (2 each) - AT1

      (3) BNC to BNC Cables - (2 each) - BBB01-8

      (4) Yoke Assembly (1 fixed end, 1 gimbaled end) - 150-81000

   B. You can get the Curlin Air equipment from Dupont NDT Systems, Inc.

   C. Couplant - None

   D. Reference Standard - The reference standard structure must be the same or almost the same as the part you are to examine. Make a reference standard for the inspection as follows:

      (1) Make a reference standard from a scrapped part, which is the same as the part to be examined.

      (2) If a scrapped part is not available, use an area of the part that does not have defects as the reference standard. Do a check as follows to make sure the areas are without defects.

         (a) Compare the areas with the same areas on the other side of the airplane.

         (b) Compare the areas with the same part on other airplanes.

      (3) Make a 0.75 x 0.75 inch (19 x 19 mm) paper shim. The paper shim thickness must be sufficient so that the shim will lay flat on the part to be examined. A shim thickness of approximately 0.010 inch (0.25 mm) was used to help prepare this procedure.

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3. **Prepare for the inspection**

A. Remove all dirt and grease from the outer and inner surfaces of the part in the inspection area.

B. Lightly sand chipped paint from the inspection surfaces.

4. **Calibrate the Instrument**

A. Calibrate the air-coupled instrument to find interply delaminations and skin-to-core disbonds. Calibrate the instrument on the thickest area of the part if the part to be examined has more than one thickness and/or ramp inspection area.

(1) Connect the transducer to the instrument and the yoke.

(2) Adjust the gimbaled transducer so that it is in the locked position and at a right angle to the inspection surface.

(3) Adjust the distance between the transducers on the yokes to approximately 2 to 5 inches (50 to 127 mm) from each side of the part. Keep the transducers in air during calibration of the system.

(4) Energize the instrument.

(5) Set the primary instrument controls to the manufacturer's instructions or to the general positions as follows:

Parameter	Value
Energy	5
Blank	On
Reprate	25
Average	1
Gate	AMPL
Start	2.400
Width	6.700
Alarm Level	35% Full screen height
Range	22.40
Delay	0.000
Smooth	On
Tune	Norm
AlumTime	0.1

(6) Put the transducer on the part but away from the inspection area. See Figure 2, flag note 1.

(7) Make sure the structure you used to calibrate the inspection system is the same type of structure you will examine.

(8) Put a 0.75 x 0.75 inch (19 x 19 mm) paper shim on the upper side of the part.

NOTE: The paper shim simulates a disbond area. Other materials can be used to simulate a disbond if they are not attached to the structure with an adhesive. There must be air between the shim and the outer skin of the structure to simulate a disbond.

(9) Adjust the instrument to put the received signal at approximately 70% of full screen height (FSH) and approximately 20% of full screen width (FSW) as shown in Figure 1, flag notes 1 and 2.

NOTE: The receiver transducer can be above or below the part to be examined.

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(10) Slowly move the transducers across the paper shim. The signal on the instrument must go below 35% of FSH when the top transducer is above the paper shim. See Figure 1, flag notes 3, 4, and 7. Use this scan speed when you examine the inspection part.

5. Examine the different areas of a part in sequence for interply delaminations and skin-to-core disbonds as follows:

NOTE: The steps that follow are for parts with different thicknesses and shapes. Only Paragraph 5.A. is necessary to do to examine parts with a constant thickness and shape.

A. Examine the thickest area of the part first as follows:

(1) Calibrate the air-coupled instrument as specified in Paragraph 4.

(2) Unlock the gimbaled transducer and put the gimbaled transducer against the inner side of the part in a thick inspection area. See Figure 2, flag note 1.

NOTE: You do not have to have the gimbaled transducer in touch with the part if the upper and lower surfaces of the part are parallel.

NOTE: If the gimbaled transducer is not in touch with the part, it must be in the locked position.

(3) Slowly move the transducers in the constant thickness direction to examine the part. See Figure 2, flag note 2.

(a) Make sure to keep the transducers in the area that has the same approximate thickness.

(b) Monitor the instrument screen display:

1) To make sure the signal does not go above 80% of FSH. See Figure 1, flag note 2.

a) . If the signal goes above 80% of FSH, change the instrument gain to put the signal at 70% of FSH.

2) Stop the transducers and make a temporary mark on the part at locations that cause the signal to decrease to 35% of FSH or lower.

(4) Index the transducers approximately 0.40-inch (10 mm). See Figure 2, flag note 3.

(5) Do Paragraph 5.A.(3) and Paragraph 5.A.(4) again, a minimum of 3 times, to make sure the inspection area has been completely examined.

(6) Do Paragraph 5.A.(3) thru Paragraph 5.A.(5) again in all of the inspection areas that have the same approximate thickness.

(7) Make an analysis of the temporary marks as follows:

(a) If the temporary marks make a straight line, the straight line is an indication of a core splice or the start of a ramp area.

NOTE: You can do a visual check of the contour of the inner skin to identify where the ramp areas start.

(b) The temporary marks that do not make a straight line are possible disbond indications.

(8) Make a mark to identify all areas that have temporary marks that are not in a straight line.

NOTE: Make this mark a different color or shape.

B. Examine the ramp areas as follows:

(1) Put the gimbaled transducer on the thickest part of the ramp. Make sure its at the same angle as the ramp, touches the ramp and is unlocked. The other transducer must be held perpendicular to its inspection surface. See Figure 2, flag note 5.

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(2) Do Paragraph 5.A.(1) thru Paragraph 5.A.(8) again to do a scan in all inspection areas with the same thickness. Make sure you move the transducers in the ramps constant thickness direction.

(3) Keep the instrument gain so the signal from bonded areas is at 70% of FSH as you move the transducers to examine thinner sections of the ramp inspection areas.

NOTE: You can do a scan of concave and convex radii in the ramp inspection areas. Make sure you move the transducers in the same direction as the radius. Do not move the transducers through the radius.

C. Examine the thinner honeycomb areas as follows:

(1) Put the transducers on a thin honeycomb area to be examined and adjust the instrument gain to put the signal at 70% of FSH. SeeFigure 1, flag note 2 and Figure 2, flag note 6.

NOTE: The gain control is the only control necessary to adjust.

(2) Do Paragraph 5.A.(1) thru Paragraph 5.A.(8) again to do a scan in all inspection areas with the same thickness.

6. Make an Analysis of the Inspection Results

A. All inspection areas are satisfactory if they do not cause an interply delamination, disbond or water ingestion indication to occur. An interply delamination, disbond or water ingestion signal indication is shown on the air-coupled screen as:

(1) A decrease in the receive signal to 35% of FSH or lower.

(2) The signal is not from an area of the part where the temporary mark for the signal in question is in a straight line with other temporary marks. See Figure 1, flag notes 4 and 7.

(3) A water ingestion signal can be irregular as the transducers move through an inspection area. This can occur when all cells within the sound beam do not have water in them.

B. It is possible to get an incorrect interply delamination, skin-to-core disbond or water ingestion signal indication (a signal that is 35% of FSH or lower) if:

(1) The transducers are moved too fast.

(2) The yoke is angled more than 10 degrees.

(3) The transducers are not perpendicular to the surfaces.

(4) The transducers are above the start of the ramp area.

(5) The transducers are above a core splice.

(6) The transducers are moved into a different grade of honeycomb core areas.

(7) The transducers are moved too near to an edge.

C. Interply delamination, disbond and water ingestion can be missed if the instrument gain is set too high and the signal is above 80% of FSH.

D. Further investigation is necessary if the signal is at 35% of FSH or lower as follows:

(1) Laminate structure - Examine laminate structure for interply delamination with one of the two inspection procedures that follow:

(a) Ultrasonic pulse echo general procedure. Refer to Part 4, 51-00-02.

(b) Ultrasonic high frequency bondtester. Refer to Part 4, 51-00-01.

(2) Honeycomb structure - Examine each side of honeycomb structures for skin-to-core disbonds with the inspection procedure that follows:

(a) Low frequency bondtester. Refer to Part 4, 51-00-05.

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(3) Honeycomb structure - Examine honeycomb structure for water ingestion with one of the three inspection procedures that follow:

(a) X-ray inspection for water in honeycomb structure. Refer to Part 2, 51-00-01.

(b) Thermography inspection for water or ice in honeycomb structure. Refer to Part 9, 51-00-01 or Part 9, 51-00-02.

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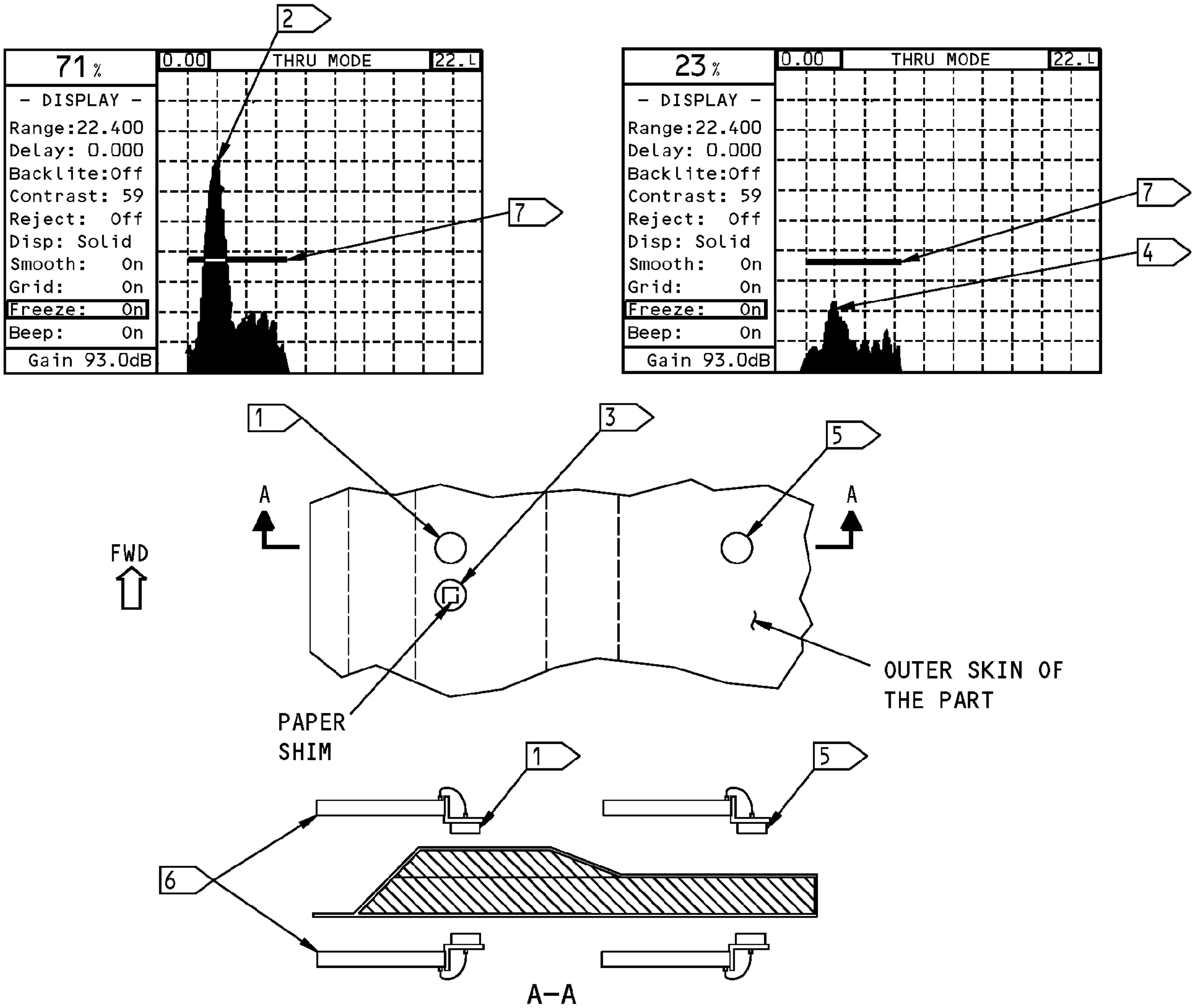

NOTES

1. PUT THE TRANSDUCERS IN A THICK AREA OF THE PART AND ADJACENT TO THE INSPECTION AREA.
2. SIGNAL THAT OCCURS FOR A BONDED AREA.
3. MOVE THE TRANSDUCERS ABOVE THE PAPER SHIM SO THAT THE PAPER SHIM IS BETWEEN THE TRANSDUCERS.
4. SIGNAL THAT OCCURS WITH THE PAPER SHIM ON THE OUTER SKIN OF THE STRUCTURE.
5. MOVE THE TRANSDUCERS ACROSS A THIN AREA ADJACENT TO THE INSPECTION AREA.
6. TRANSMIT AND RECEIVER TRANSDUCERS AND YOKE ASSEMBLY.
7. SET THE ALARM LEVEL TO 35% OF FULL SCREEN HEIGHT.

Instrument Calibration
Figure 1

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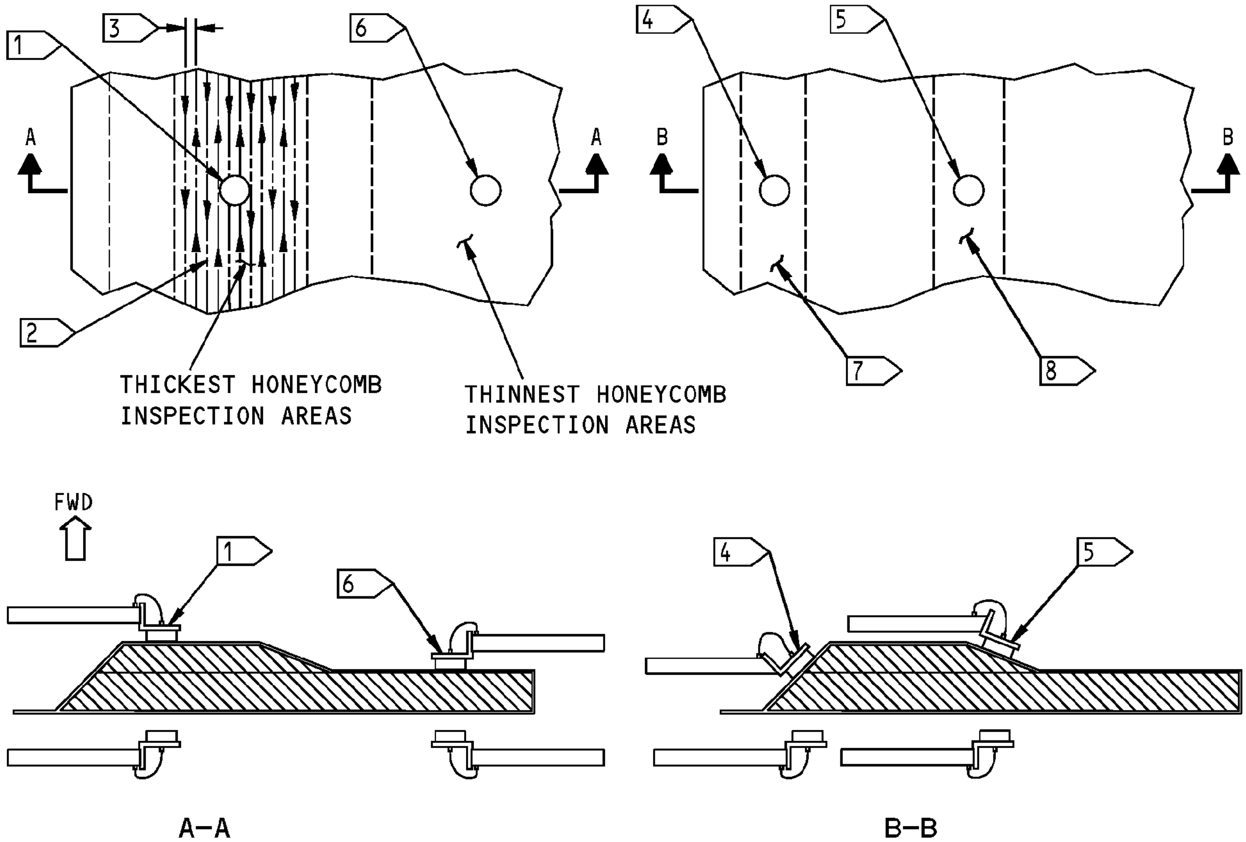

NOTES

- EXAMINE THE HONEYCOMB INSPECTION AREAS OF THE PART AS FOLLOWS: THE THICKEST AREAS FIRST, THE RAMP AREAS AND THEN THE THINNEST AREAS.

1 PUT THE GIMBALED TRANSDUCER ON THE INNER SURFACE OF THE PART AT THE THICK (OR THICKER) INSPECTION AREA.

2 SLOWLY MOVE THE TRANSDUCERS ALONG THE CONSTANT THICKNESS DIRECTION.

3 THE TYPICAL INDEX DISTANCE FOR ALL INSPECTION AREAS IS APPROXIMATELY 0.4 INCH (10 MM).

4 PUT THE GIMBALED TRANSDUCER ON THE LARGEST RAMP INSPECTION AREA AND MOVE THE TRANSDUCERS IN A CONSTANT THICKNESS DIRECTION IN THE RAMP INSPECTION AREA.

5 PUT THE GIMBALED TRANSDUCER ON THE SMALLEST RAMP INSPECTION AREA AND MOVE THE TRANSDUCERS IN A CONSTANT THICKNESS DIRECTION IN THE RAMP INSPECTION AREA.

6 PUT THE GIMBALED TRANSDUCER ON THE INNER SURFACE OF THE THINNEST INSPECTION AREA OF THE PART.

7 LARGEST RAMP INSPECTION AREA

8 SMALLEST RAMP INSPECTION AREA

Inspection Area on the Main Landing Gear Door
Figure 2

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PART 4 - ULTRASONIC

THICKNESS MEASUREMENT

THICKNESS MEASUREMENT - A-SCAN INSTRUMENT WITH DIGITAL THICKNESS DISPLAY

1. **General**

   A. Use this procedure to measure the thickness of parts with bare, painted or coated surfaces.

   B. An A-Scan instrument with a digital thickness display is used to do this measurement. To use an instrument with a digital display only, refer to Part 4, 51-00-10, Procedure 2.

   C. A transducer with or without a delay line can be used, but it is necessary to use a transducer with a delay line on thin parts. Refer to Paragraph 4.A.(1) for help to make a transducer selection.

   D. The parts examined must have parallel front and back surfaces to do this procedure.

   E. The precision of the thickness measurement is a function of the surface condition, shape, and material properties of the part to be measured.

2. **Equipment**

   A. General

      (1) Use inspection equipment that can be calibrated on the reference standard as specified in Paragraph 4.

      (2) Refer to Part 1, 51-01-00, for data about the equipment manufacturers.

   B. Instrument

      (1) Use an ultrasonic instrument that:

         (a) Has an ‘‘A-Scan’’ display with a digital display.

         (b) Operates at a frequency range of 5 MHz to 20 MHz.

      (2) The instruments that follow were used to help prepare this procedure.

         (a) USN 50; Krautkramer Inc.

         (b) 25DL Plus; Panametrics Corp.

         (c) DMS 2; Krautkramer Inc.

   C. Transducer

      (1) Use a highly damped, broadband transducer that:

         (a) Operates at a frequency range between 5 and 20 MHz.

         (b) Can be used with or without a delay line.

      (2) A delay line transducer has a maximum thickness limit. If the instrument cannot be calibrated on the thick reference standards, remove the delay line and do the calibration again, or use a longer delay line.

      (3) The longitudinal wave transducers that follow were used to help prepare this procedure.

         (a) KBA Alpha 20 MHz, 0.125 inch (3.18 mm) diameter crystal with a 0.187 inch (4.75 mm) mini delay line; Krautkramer Inc.

         (b) Aerotech 10 MHz, 0.25 inch (6.4 mm) diameter crystal with a 0.30 inch (7.6 mm) delay line; Krautkramer Inc.

         (c) Sonopen V260-SM 15/ 0.125; Panametrics Inc. (This is a pencil probe transducer used on blend out areas and pits on the front surface of the part).

   D. Reference Standards

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(1) Use calibration step wedges or blocks made from the same material (aluminum, steel, etc.) as the part to be measured.

NOTE: For parts that are more than 0.100 inch (2.54 mm) thick, we recommend a reference standard that is the same alloy as the part to be measured. Different alloys can have different sound velocities. The difference in the velocities between the reference standard and the part to be measured can cause incorrect thickness values.

(2) Make a reference standard with at least two thickness steps; one thicker and one thinner than the measured part. The thinner step must be at the minimum permitted thickness of the part (plus 0 to minus 25 percent). The thicker step must be at the part thickness shown in the drawing (plus 0 to 25 percent).

E. Couplant

(1) Use ultrasonic couplants that will not damage the airplane structure. Commercial grease or oil can be used if the equipment can be calibrated as specified in Paragraph 4.

3. Prepare for the Inspection

A. Identify and get access to the inspection surface.

B. Remove loose paint, coatings and dirt from the inspection surface. Rough texture coatings and thick paint must be sanded smooth (use caution to prevent damage to the part surface). If access is possible, do the same for the opposite (far) surface.

NOTE: Thin, well-bonded, primer and paint does not cause a problem for a thickness inspection when the instrument and search unit calibration is correctly done. But it is best to remove the paint. If the paint cannot be removed, use the multi-echo calibration procedure.

NOTE: The multi echo calibration procedure uses the gate(s) to be set between the back surface echoes of the reference standard - the gate is not to be set on the interface or the front surface signal when there is a paint or coating on the inspection surface.

NOTE: Refer to Figure 2 and Figure 3 for the gate locations in multi echo sensitivity calibrations done with two different instruments.

C. Get the thickness of the part to be measured from the approved drawings, along with the minimum and maximum permitted thickness.

4. Instrument Calibration

NOTE: Refer to the manufacturer's instrument manual during calibration. Calibration adjustments can be different for different instruments, so it is not possible to include all instructions for the calibration of each instrument in this procedure.

A. Connect the correct transducer to the instrument specified in Paragraph 2.B.(1). Do not use reject.

(1) An applicable range of thickness (in aluminum) is shown with the transducer types and waveforms in Figure 1. Use Figure 1 to help you make a selection of an applicable transducer (and delay line).

(2) If necessary, use a delay line made from Lucite or Plexiglas for the thin parts. Put a small drop of couplant on the surface of the transducer at the interface where the delay line and the transducer touch.

(3) For areas where there is removed material, a dent or an irregular front surface, use a pencil probe-type transducer which has a narrow point tip delay line.

B. Energize the instrument and set it for the pulse-echo mode.

C. Set the front surface signal to the left side of the instrument display as shown in Figure 2 and Figure 3. This is done automatically with some instruments.

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D. Adjust the damping, receiver frequency and other adjustments in the instrument manual, if available, to get the best signal. See Figure 4 for examples of satisfactory front surface signals.

E. Put couplant on the thickness reference standard to be used during calibration.

F. Put the transducer on the step of the reference standard that is thinner than the minimum permitted thickness of the part to be examined.

G. The delay line (front surface) to first back echo calibration procedure can be used if there is no paint or coatings on the front surface of the part.

(1) Refer to the instrument manual for this calibration procedure. A single gate is used to the right of the front surface signal that goes to the back wall signal for the thickness measurement. Refer to the waveform display in mode 2 of Figure 1.

H. The multi echo (echo to echo) procedure can be used when paint is on the surface of the part. This multi echo procedure can also be used on surfaces that are not painted.

(1) Refer to the instrument manual for this calibration procedure. This procedure uses one or two gates that measure between multiple back surface signals (echoes). See Figure 2 and Figure 3 for examples of the two different instruments that use the multi echo procedure for the calibration.

I. Adjust the instrument (the velocity or other available controls) so that the thickness value is the correct thickness (plus or minus 0.001 inch (0.03 mm)) of the reference standard. An alternative adjustment can be done on some instruments. Refer to the manufacturer's instrument manual.

J. Put the transducer on the step of the reference standard that is thicker than the actual thickness of the part to be examined.

K. Adjust the instrument, if necessary, so that the thickness value is the correct thickness (plus or minus 0.001 inch (0.03 mm)) of the reference standard.

L. Make sure that you get correct thickness values from the thin and the thick steps of the reference standard. If you don't get the correct values, go back to Paragraph 4.A. and calibrate the instrument again.

5. Inspection Procedure

A. Do the instrument calibration as specified in Paragraph 4.

B. Put couplant on the inspection surface. Then put the transducer on the same area.

C. Monitor the front surface signal and the back surface signal(s) to make sure the transducer satisfactorily touches the part. Also, monitor the digital display and compare the thickness with the values you get from the reference standard during calibration.

D. Take more than one thickness measurement on each area of the part to prevent errors.

E. After the thickness measurements are done, clean the couplant from the inspection area(s).

6. Inspection Results

A. A part whose thickness value is not equivalent to that identified in the applicable document or drawing for that part must be examined some more.

B. Errors in thickness values can be caused by changes in geometry and/or the sub-structure of the part. Figure 5 identifies possible inspection conditions that can occur with parts to be examined. Some of the conditions can cause incorrect measurements or no measurements. Some of these inspection conditions are as follows:

(1) See Figure 5 (Example I) for an example of an acceptable inspection condition.

(2) A part that does not have parallel front and back surfaces will not give a back surface signal. See Figure 5 (Example II).

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(3) An irregular back surface on a part can give incorrect thickness measurements or no measurements. See Figure 5 (Example III).

(4) Material removed from, or dents on, the front surface of the part can prevent good contact between the transducer and the part. This can weaken or prevent a back surface signal or cause incorrect measurements. See Figure 5 (Example IV). A pencil probe type transducer is recommended for these conditions. It will be necessary to tilt the pencil probe until the correct back surface signal is found with the lowest measurement. See Figure 5 (Example V).

(5) A transducer diameter that is too large for a curved surface (for example: a small hinge lug) can make it difficult to get a back surface signal. See Figure 5 (Example VI). Use a smaller transducer that fully touches the part. See Figure 5 (Example VII).

(6) Paint, sealant, a bushing or other items on the back surface of the part can give incorrect measurements or prevent a back surface signal. Figure 5 (Example VIII) shows the screen display from a lug that has a bushing and a pin inside. Compare the display from Example VIII with Example VII in Figure 5.

C. If measurement errors are caused by paint, sealant, or bushings, remove these conditions and examine the area again.

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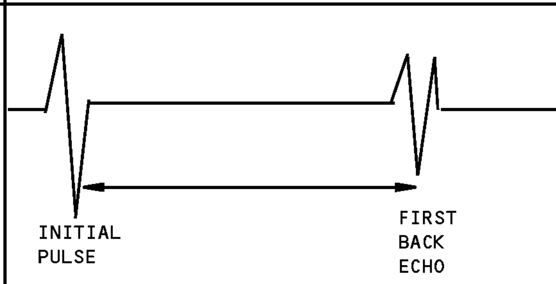
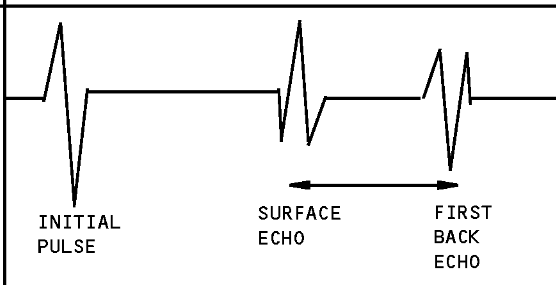
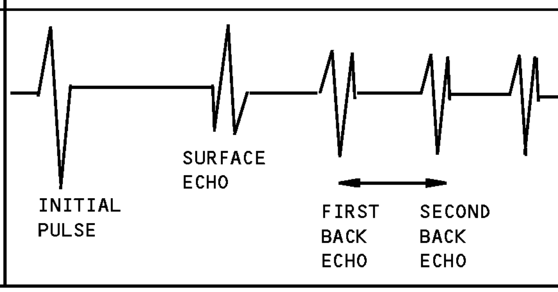
MODE	WAVEFORM	APPLICABLE TRANSDUCER TYPES	1 APPLICABLE RANGE OF THICKNESS MEASUREMENT (ALUMINUM)
1		DIRECT CONTACT	0.500 INCH TO 5 INCH (12.7 mm TO 127 mm)
2		DELAY LINE/ IMMERSION	0.020 INCH TO 2 INCH (0.50 mm TO 51 mm)
3		DELAY LINE/ IMMERSION	0.010 INCH TO 1 INCH (0.25 mm TO 25 mm)

NOTES:

- THREE USUAL MODES TO MEASURE THE TIME INTERVAL THAT SHOWS A SOUND WAVE'S TRAVEL THROUGH A TEST MATERIAL.

  MODE 1 - MEASURES THE TIME INTERVAL BETWEEN THE INITIAL PULSE OF THE TRANSDUCER AND THE FIRST BACK SURFACE ECHO OF THE TEST MATERIAL. THIS IS CALLED THE "CONTACT" MODE.

  MODE 2 - MEASURES THE TIME INTERVAL BETWEEN AN ECHO RETURNED FROM THE SURFACE AND THE FIRST BACK SURFACE ECHO OF THE TEST MATERIAL. THIS IS CALLED THE "DELAY LINE" OR "INTERFACE ECHO TO FIRST BACK ECHO" MODE.

  MODE 3 - MEASURES THE TIME INTERVAL BETWEEN TWO SUCCESSIVE BACK SURFACE ECHOES. THIS IS CALLED THE "MULTIECHO" OR "ECHO TO ECHO" MODE.

1 ALL THICKNESS RANGES ARE APPROXIMATE. THE ACTUAL MEASUREMENT RANGE FOR EACH THICKNESS MEASUREMENT WILL ALWAYS BE A FUNCTION OF THE INSTRUMENT, TRANSDUCER, AND THE MATERIAL PROPERTIES OF THE PART.

Waveform Displays
Figure 1

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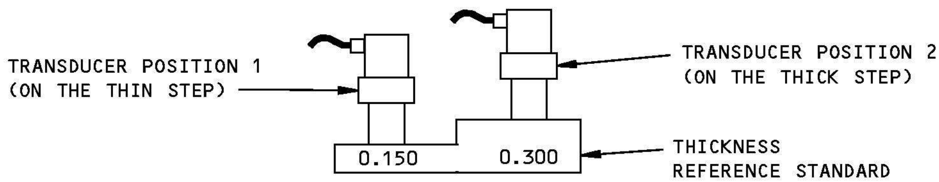
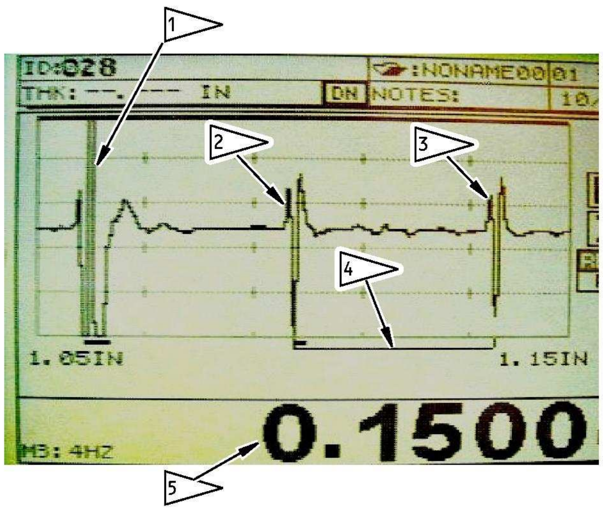
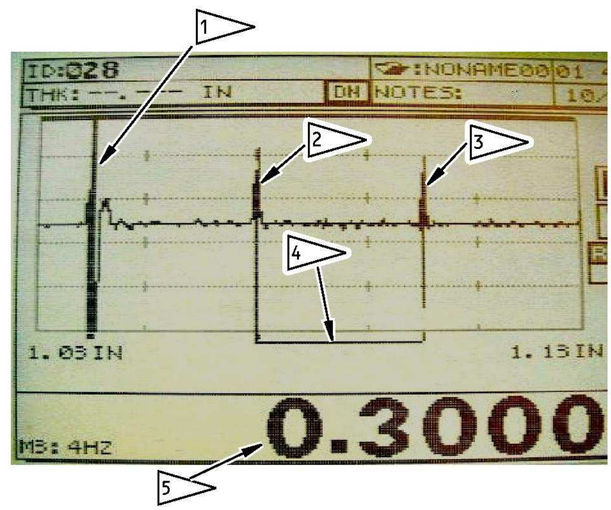




DISPLAY 1
(TRANSDUCER AT POSITION 1)



DISPLAY 2
(TRANSDUCER AT POSITION 2)

NOTES:

- DISPLAY 1 SHOWS AN A-SCAN DISPLAY AND THICKNESS READING WITH A REFERENCE STANDARD THICKNESS OF 0.150 INCH (3.81 mm).
- DISPLAY 2 SHOWS AN A-SCAN DISPLAY AND THICKNESS READING WITH A REFERENCE STANDARD THICKNESS OF 0.300 INCH (7.62 mm).
- GATES ARE SET TO MEASURE FROM THE FIRST BACK WALL SIGNAL TO THE SECOND BACK WALL SIGNAL.
- THE DISTANCE BETWEEN THE SIGNALS APPEARS LARGER IN DISPLAY 1 COMPARED TO THE DISTANCE BETWEEN THE SIGNALS IN DISPLAY 2 BECAUSE DISPLAY 1 SHOWS AN EXPANDED (ZOOM IN MODE) A-SCAN DISPLAY AND DISPLAY 2 SHOWS A NORMAL DISPLAY.
- THE SCREEN DISPLAYS ABOVE ARE EXAMPLES - THE SIGNALS CAN LOOK DIFFERENT WITH OTHER INSTRUMENT/TRANSDUCER MIXES.

1 INTERFACE OR FRONT SURFACE SIGNAL

2 FIRST BACK SURFACE SIGNAL

3 SECOND BACK SURFACE SIGNAL

4 GATE

5 THICKNESS READING IN INCHES

Multi-Echo Sensitivity Calibration - Example 1
Figure 2

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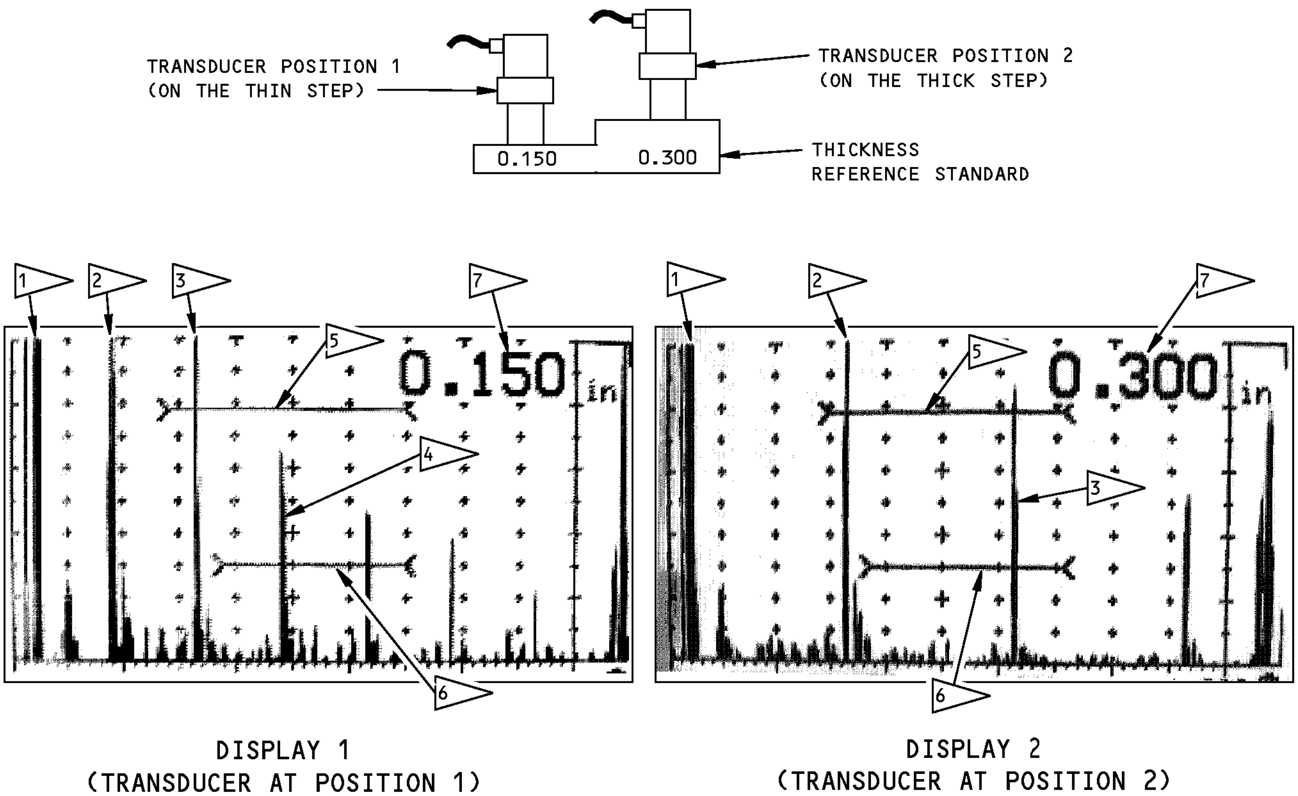

NOTES:

- DISPLAY 1 SHOWS AN A-SCAN DISPLAY AND THICKNESS READING WITH A REFERENCE STANDARD THICKNESS OF 0.150 INCH (3.81 mm)
- DISPLAY 2 SHOWS AN A-SCAN DISPLAY AND THICKNESS READING WITH A REFERENCE STANDARD THICKNESS OF 0.300 INCH (7.62 mm)
- THE LOCATIONS OF THE GATES ARE ADJUSTED TO LOCK ON THE MULTIPLE BACK WALL SIGNAL THAT YOU CHOOSE.
- THE INSTRUMENT DISPLAY IN DISPLAY 1 SHOWS THE SECOND BACK WALL SIGNAL IN GATE 1 AND THE THIRD BACK WALL SIGNAL IN GATE 2.
- THE INSTRUMENT DISPLAY IN DISPLAY 2 SHOWS THE FIRST BACK WALL SIGNAL IN GATE 1 AND THE SECOND BACK WALL SIGNAL IN GATE 2.
- SINCE THE THICKNESS MEASURED AT POSITION 2 IS TWICE THE THICKNESS MEASURED AT POSITION 1, THE DISTANCE BETWEEN THE SIGNALS IN DISPLAY 2 IS TWICE AS MUCH AS THE DISTANCE BETWEEN THE SIGNALS IN DISPLAY 1.
- THE SCREEN DISPLAYS ABOVE ARE EXAMPLES - THE SIGNALS CAN LOOK DIFFERENT WITH OTHER INSTRUMENT/TRANSDUCER MIXES.

1 INTERFACE OR FRONT SURFACE SIGNAL
2 FIRST BACK SURFACE SIGNAL
3 SECOND BACK SURFACE SIGNAL
4 THIRD BACK SURFACE SIGNAL
5 GATE 1
6 GATE 2
7 THICKNESS READING IN INCHES

Multi-Echo Sensitivity Calibration - Example 2
Figure 3

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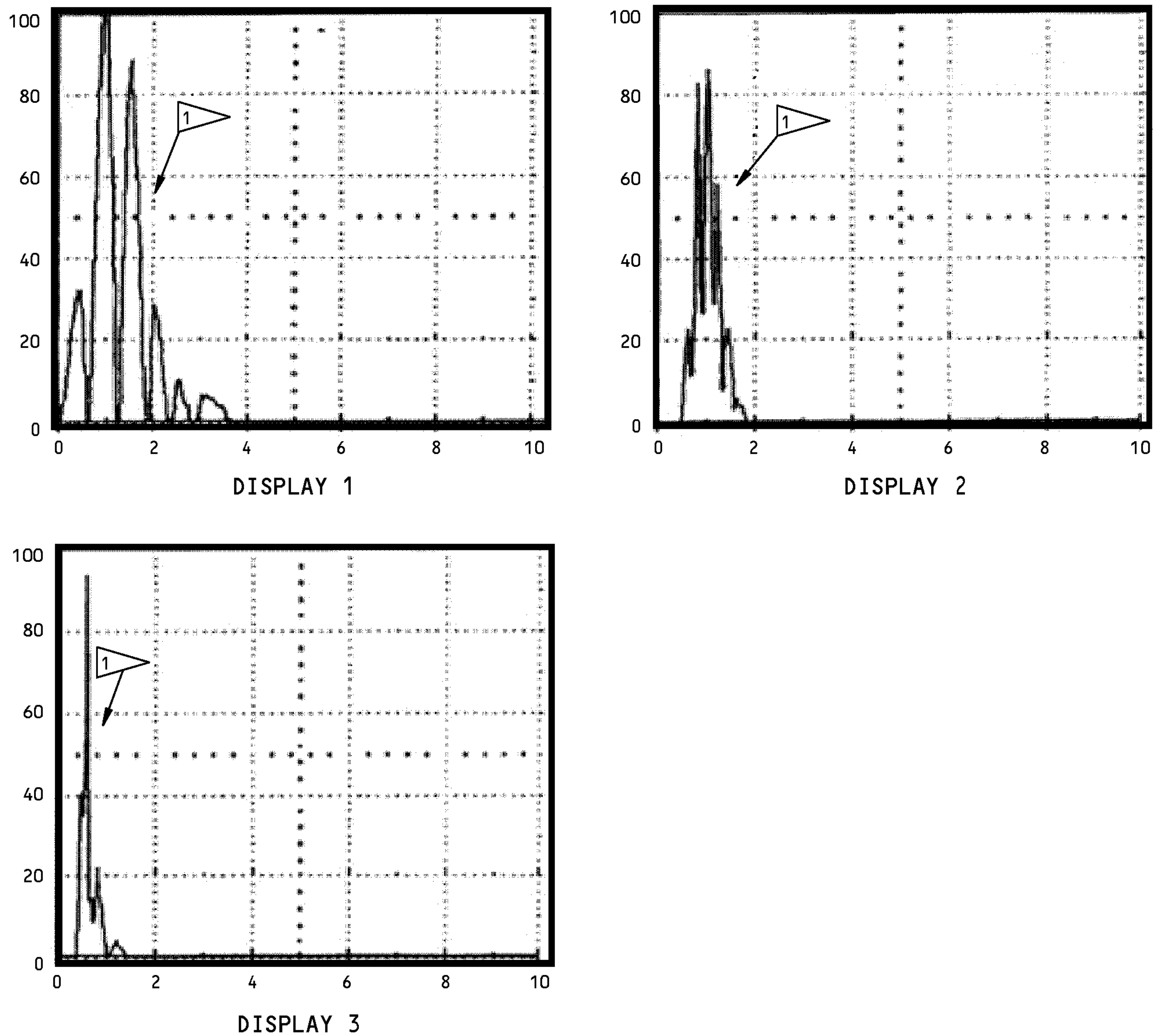

NOTES:

- USE A TRANSDUCER THAT RESULTS IN A FRONT SURFACE SIGNAL THAT IS NOT TOO WIDE. THE TRANSDUCER THAT CAUSES FRONT SURFACE SIGNALS ALMOST THE SAME AS THOSE SHOWN IN DISPLAY 3 WILL GIVE THE BEST THICKNESS VALUES.

  DISPLAY 1 - UNSATISFACTORY FRONT SURFACE SIGNAL

  DISPLAY 2 - BETTER FRONT SURFACE SIGNAL

  DISPLAY 3 - BEST FRONT SURFACE SIGNAL

1 FRONT SURFACE SIGNAL

Unacceptable and Acceptable Front Surface Signals
Figure 4

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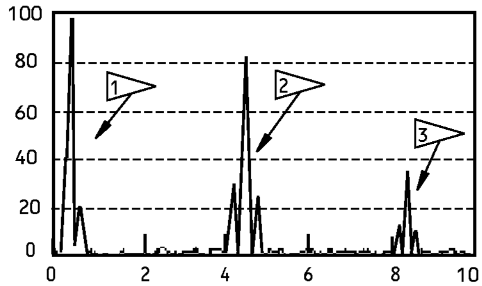
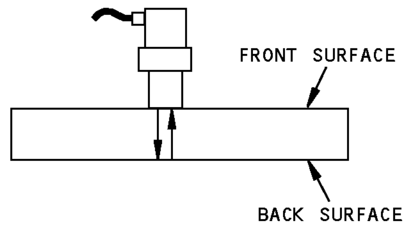


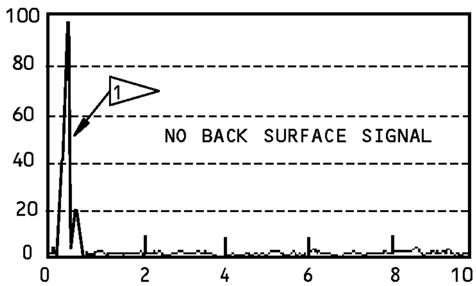
EXAMPLE I
(CORRECT SCREEN DISPLAY)



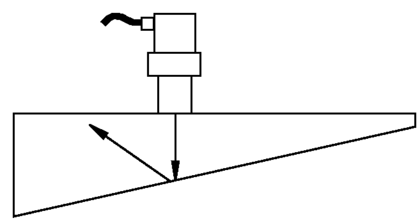
1 FRONT SURFACE SIGNAL
2 1ST BACK SURFACE SIGNAL
3 2ND BACK SURFACE SIGNAL

NOTES:

- EXAMPLE I SHOWS THE SCREEN DISPLAY THAT OCCURS WHEN A PART HAS A FRONT SURFACE THAT IS PARALLEL TO THE BACK SURFACE. YOU CAN GET THE CORRECT THICKNESS MEASUREMENT WITH THIS CONDITION.



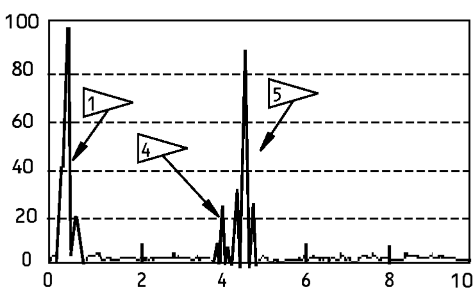
EXAMPLE II
(FRONT AND BACK SURFACES
THAT ARE NOT PARALLEL)



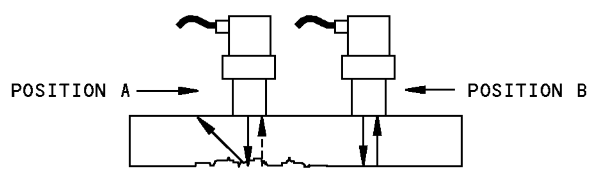
1 FRONT SURFACE SIGNAL

NOTES:

- EXAMPLE II SHOWS THE SCREEN DISPLAY WHEN THE BACK SURFACE OF A PART IS NOT PARALLEL TO THE FRONT SURFACE. THE REFLECTED SOUND DOES NOT COME BACK TO THE TRANSDUCER. A THICKNESS MEASUREMENT CAN NOT BE DONE WITH THIS CONDITION.



EXAMPLE III
(IRREGULAR BACK SURFACE)



1 FRONT SURFACE SIGNAL
4 SIGNAL FROM IRREGULAR BACK SURFACE WITH THE TRANSDUCER AT POSITION A
5 1ST BACK SURFACE SIGNAL WITH THE TRANSDUCER AT POSITION B.

NOTES:

- EXAMPLE III SHOWS THE SCREEN DISPLAY FROM AN IRREGULAR SURFACE AND A SMOOTH (AND PARALLEL) SURFACE. AN IRREGULAR BACK SUFACE FROM PITS, WEAR OR OTHER CONDITIONS CAN DECREASE OR PREVENT THE BACK SURFACE SIGNAL (A SECOND BACK WALL SIGNAL IS NOT SHOWN).
- FLAG NOTE 4 SHOWS A DECREASED BACK SURFACE SIGNAL WITH THE TRANSDUCER AT POSITION A. FLAG NOTE 5 SHOWS A CORRECT BACK SURFACE SIGNAL WITH THE TRANSDUCER AT POSITION B. THE THICKNESS MEASUREMENT CAN NOT BE DONE WITH THE TRANSDUCER AT POSITION A.
- THE SCREEN DISPLAYS ARE EXAMPLES - THE ACTUAL SIGNALS CAN LOOK DIFFERENT WITH OTHER INSTRUMENT/TRANSDUCER MIXES.

Possible Inspection Conditions
Figure 5 (Sheet 1 of 3)

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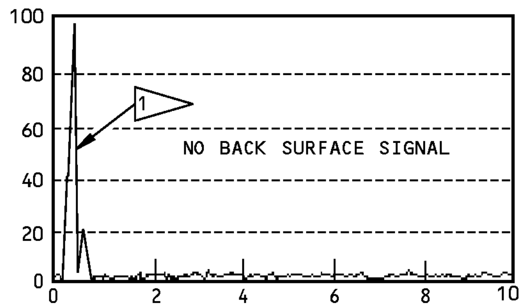
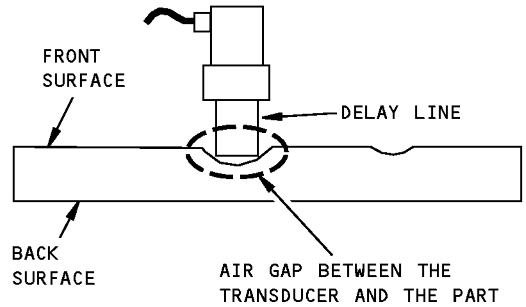


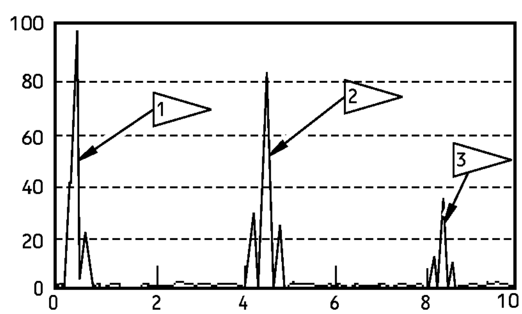


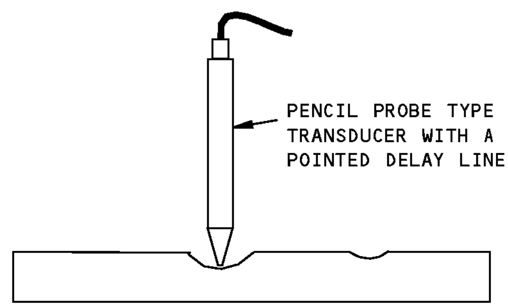
EXAMPLE IV
(IRREGULAR FRONT SURFACE)

NOTES:

- EXAMPLE IV SHOWS THE SCREEN DISPLAY WHEN THE TRANSDUCER IS ON A PART WHERE THE MATERIAL ON THE FRONT SURFACE HAS BEEN REMOVED OR HAS A DENT. THE SOUND CANNOT GO INTO THE PART IF THERE IS AN AIR GAP. THE THICKNESS MEASUREMENT CAN NOT BE DONE WITH THIS CONDITION.

1 SIGNAL FROM THE TIP OF THE DELAY LINE





EXAMPLE V
(PENCIL PROBE TRANSDUCER)

NOTES:

- EXAMPLE V SHOWS THE SCREEN DISPLAY THAT CAN OCCUR WHEN A PENCIL PROBE TYPE TRANSDUCER IS USED FOR A CONDITION IDENTIFIED IN EXAMPLE IV.
- THE SCREEN DISPLAYS ARE EXAMPLES - THE ACTUAL SIGNALS CAN LOOK DIFFERENT WITH OTHER INSTRUMENT/TRANSDUCER MIXES.

1 FRONT SURFACE SIGNAL
2 1ST BACK SURFACE SIGNAL
3 2ND BACK SURFACE SIGNAL

Possible Inspection Conditions
Figure 5 (Sheet 2 of 3)

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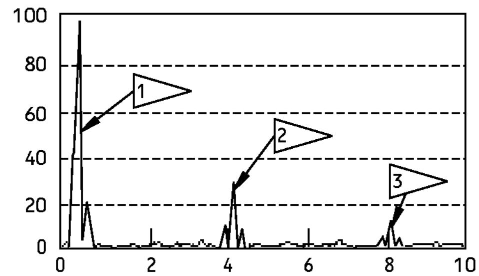
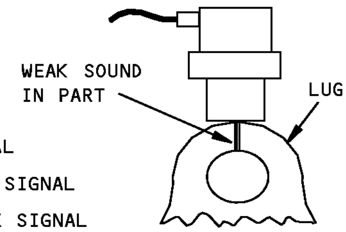


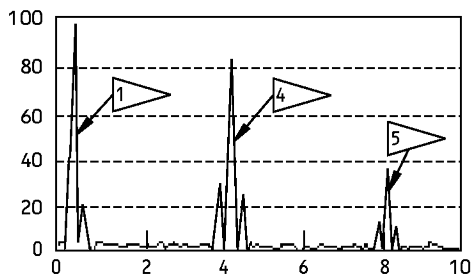
1 FRONT SURFACE SIGNAL
2 FIRST BACK SURFACE SIGNAL
3 SECOND BACK SURFACE SIGNAL



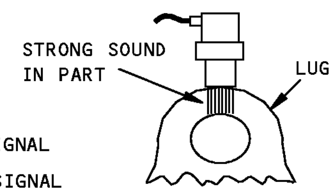
EXAMPLE VI
(INCORRECTLY SIZED TRANSDUCER)

NOTES:

- EXAMPLE VI SHOWS THE SCREEN DISPLAY WITH A LARGE DIAMETER TRANSDUCER ON THE PART. ONLY A SMALL AREA OF THE TRANSDUCER TOUCHES THE PART. THIS CAN CAUSE A WEAK SIGNAL AND AN INCORRECT VALUE TO OCCUR. THE THICKNESS MEASUREMENT CAN NOT BE DONE WITH THIS CONDITION.



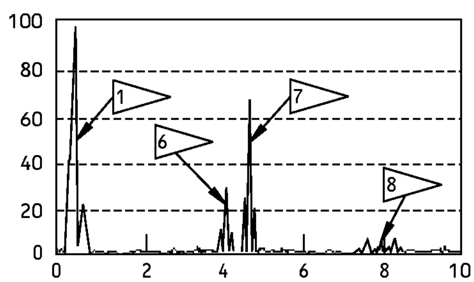
1 FRONT SURFACE SIGNAL
4 FIRST BACK SURFACE SIGNAL
5 SECOND BACK SURFACE SIGNAL

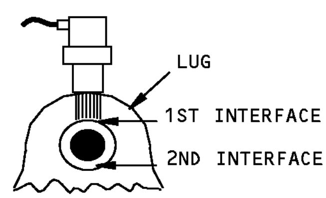


EXAMPLE VII
(CORRECT SCREEN DISPLAY)

NOTES:

- EXAMPLE VII SHOWS THE SCREEN DISPLAY WHEN A CORRECTLY SIZED (SMALL) TRANSDUCER IS ON THE PART AND THE TRANSDUCER FULLY TOUCHES THE PART. THE CORRECT THICKNESS MEASUREMENT CAN BE DONE WITH THIS CONDITION.





BUSHING PIN

1 FRONT SURFACE SIGNAL
6 SIGNAL FROM THE 1ST INTERFACE BETWEEN LUG AND BUSHING
7 SIGNAL FROM THE 1ST INTERFACE BETWEEN BUSHING AND PIN
8 SIGNALS FROM THE 2ND INTERFACES BETWEEN THE PIN AND THE BUSHING AND THE BUSHING AND THE LUG.

EXAMPLE VIII
(LUG WITH A BUSHING AND A PIN INSIDE)

NOTES:

- EXAMPLE VIII SHOWS THE SCREEN DISPLAY WHEN A BUSHING AND A PIN ARE INSIDE A LUG. A SMALL QUANTITY OF SOUND IS REFLECTED FROM THE INTERFACE BETWEEN THE LUG AND BUSHING, BUT A LARGE QUANTITY OF THE SOUND IS REFLECTED FROM THE INTERFACE BETWEEN THE BUSHING AND PIN. THE CORRECT THICKNESS MEASUREMENT CAN NOT BE DONE WITH THIS CONDITION.
- THE SCREEN DISPLAYS ARE EXAMPLES - THE ACTUAL SIGNALS CAN LOOK DIFFERENT WITH OTHER INSTRUMENT/TRANSDUCER MIXES.

Possible Inspection Conditions
Figure 5 (Sheet 3 of 3)

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PART 4 - ULTRASONIC

THICKNESS MEASUREMENT - DIGITAL DISPLAY INSTRUMENT

1. **Purpose**
   A. Use this procedure to measure the thickness of parts with a bare surface only.
   B. An instrument with only the digital thickness display is used to do this measurement. To use an A-scan instrument with a digital display, refer to Part 4, 51-00-10, Procedure 1.
   C. The range of thickness recommended for the contact transducer is from 0.500 to 5 inches (12.7 to 127 mm) and for the delay line transducer is from 0.020 to 2 inch (0.50 to 51 mm). The actual measurement range for each thickness measurement will be a function of the instrument, transducer, and the test material. Refer to the manufacturer's instrument manual for the correct range of thickness.
   D. The parts examined must have parallel front and back surfaces to do this procedure.
   E. The precision of the thickness measurement is a function of the surface condition, shape, and material properties of the part to be measured.
2. **Equipment**
   A. General
      (1) Use inspection equipment that can be calibrated on the reference standard as specified in Paragraph 4.
      (2) Refer to Part 1, 51-01-00, for data about the equipment manufacturers.
   B. Instrument
      (1) Use an ultrasonic instrument that:
         (a) Has a digital display for the thickness value.
         (b) Operates at a frequency range of 5 to 20 MHz.
      (2) The instruments that follow were used to help prepare this procedure.
         (a) CL3 DL; Krautkramer Inc.
         (b) T - MIKE E; StressTel Corp.
         (c) 25DL; Panametrics (Olympus)
   C. Transducers
      (1) Use a highly damped, broadband transducer that:

         NOTE: Some transducers are included with the instrument as a set and other transducers will not work with the instruments.

         (a) Operates at a frequency range between 5 and 20 MHz.
         (b) Can be used with or without a delay line.
      (2) A delay line transducer has a maximum thickness limit. If the instrument cannot be calibrated on the thick reference standards, use a longer delay line or a different instrument and do the calibration again.
      (3) The longitudinal wave transducers that follow were used to help prepare this procedure.
         (a) KBA Alpha 15 MHz, 0.25 inch (6.4 mm) diameter crystal with a 0.30 inch (7.6 mm) delay line; Krautkramer Inc.
         (b) Dual element transducers (specially made for T-MIKE E unit). The frequency and the crystal dimensions are not specified.

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(c) 5 MHz, 0.25 inch (6.4 mm) diameter crystal with a 0.42 inch (10.7 mm) delay line; Panametrics (Olympus)

D. Reference Standards

(1) Use calibration step wedges or blocks made from the same material (aluminum, steel, etc.) as the part to be measured.

NOTE: For parts that are more than 0.100 inch (2.54 mm) thick, we recommend a reference standard that is the same alloy as the part to be measured. Different alloys can have different sound velocities. The difference in the velocities between the reference standard and the part to be measured can cause incorrect thickness values.

(2) Make a reference standard with at least two thickness steps; one thicker and one thinner than the measured part. The thinner step must be at the minimum permitted thickness of the part (plus 0 to minus 25 percent). The thicker step must beat the part thickness shown in the drawing (plus 0 to 25 percent).

E. Couplant

(1) Use ultrasonic couplants that will not damage the airplane structure. Commercial grease or oil can be used if the equipment can be calibrated as specified in Paragraph 4.

3. Preparation for Inspection

A. Identify and get access to the inspection surface.

B. Remove paint, coatings and dirt from the part to get a clean, smooth and bare inspection surface. If access is possible, do the same for the opposite (far) surface.

NOTE: If you cannot remove the paint or coatings, we recommend you use a thickness instrument with the A-Scan display. Refer to Part 4, 51-00-10, Procedure 1.

C. Get the thickness of the part to be measured from the approved drawings, along with the minimum and maximum permitted thickness.

4. Instrument Calibration

NOTE: Refer to the manufacturer's instrument manual during calibration. Calibration adjustments can be different for different instruments, so it is not possible to include all instructions for the calibration of each instrument in this procedure.

A. Connect the correct transducer to the instrument.

B. Energize the instrument and make the necessary adjustments specified by the instrument manual (i.e. probe zero, etc).

C. Put couplant on the thickness reference standard to be used during calibration.

D. Put the transducer on the step of the reference standard that is thinner than the minimum permitted thickness of the part to be examined.

E. Adjust the instrument (the scroll keys or other available controls) so that the thickness value is the correct thickness (plus or minus 0.001 inch (0.03 mm)) of the reference standard.

F. Put the transducer on the step of the reference standard that is thicker than the actual thickness of the part to be examined.

G. Adjust the instrument (the scroll keys or other available controls) so that the thickness value is the correct thickness (plus or minus 0.001 inch (0.03 mm)) of the reference standard.

H. Make sure that you get correct thickness values from the thin and thick steps of the reference standard. If you don't get the correct values, go back to Paragraph 4.A. and calibrate the instrument again.

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5. **Inspection Procedure**

A. Do the instrument calibration as specified in Paragraph 4.

B. Put couplant on the inspection surface. Then put the transducer on the same area.

C. Monitor the digital display and compare the thickness of the part with the thickness set by the drawing.

D. Take more than one thickness measurement on each area of the part to prevent errors.

E. After the thickness measurements are done, clean the couplant from the inspection area(s).

6. **Inspection Results**

A. A part whose thickness value is not equivalent to that identified in the applicable document or drawing for that part must be examined some more.

B. Errors in thickness values can be caused by changes in geometry and/or the sub-structure of the part. Figure 1 identifies the possible inspection conditions that can occur with the part that is to be examined. Some of the conditions can cause incorrect or no thickness measurements. Some of these inspection conditions are as follows:

(1) A part that does not have parallel front and back surfaces will not give a thickness value. See Figure 1 (Example I).

(2) An irregular back surface (from pits, wear or other conditions) can give an incorrect or no thickness measurement as shown in Figure 1 (Example II - position A).

(3) Material removed from, or dents on, the front surface of the part can prevent good contact between the transducer and the part. This can cause an incorrect or no thickness measurement as shown in Figure 1 (Example III - position A). A pencil probe type transducer (shown in Example III - position B) is recommended for these conditions.

(4) A transducer diameter that is too large for a curved surface (for example: a small hinge lug) can make it difficult to get the correct thickness. See Figure 1 (Example IV).

(5) Paint, sealant, a bushing or other items on the back surface of the part can give incorrect measurements. In Figure 1 (Example V) the instrument can display the thickness of the lug and the bushing or the lug, bushing and pin.

C. Use a thickness gage instrument that has an A-Scan display to examine and identify the cause of thickness values thought to be incorrect. Refer to Part 4, 51-00-10, Procedure 1.

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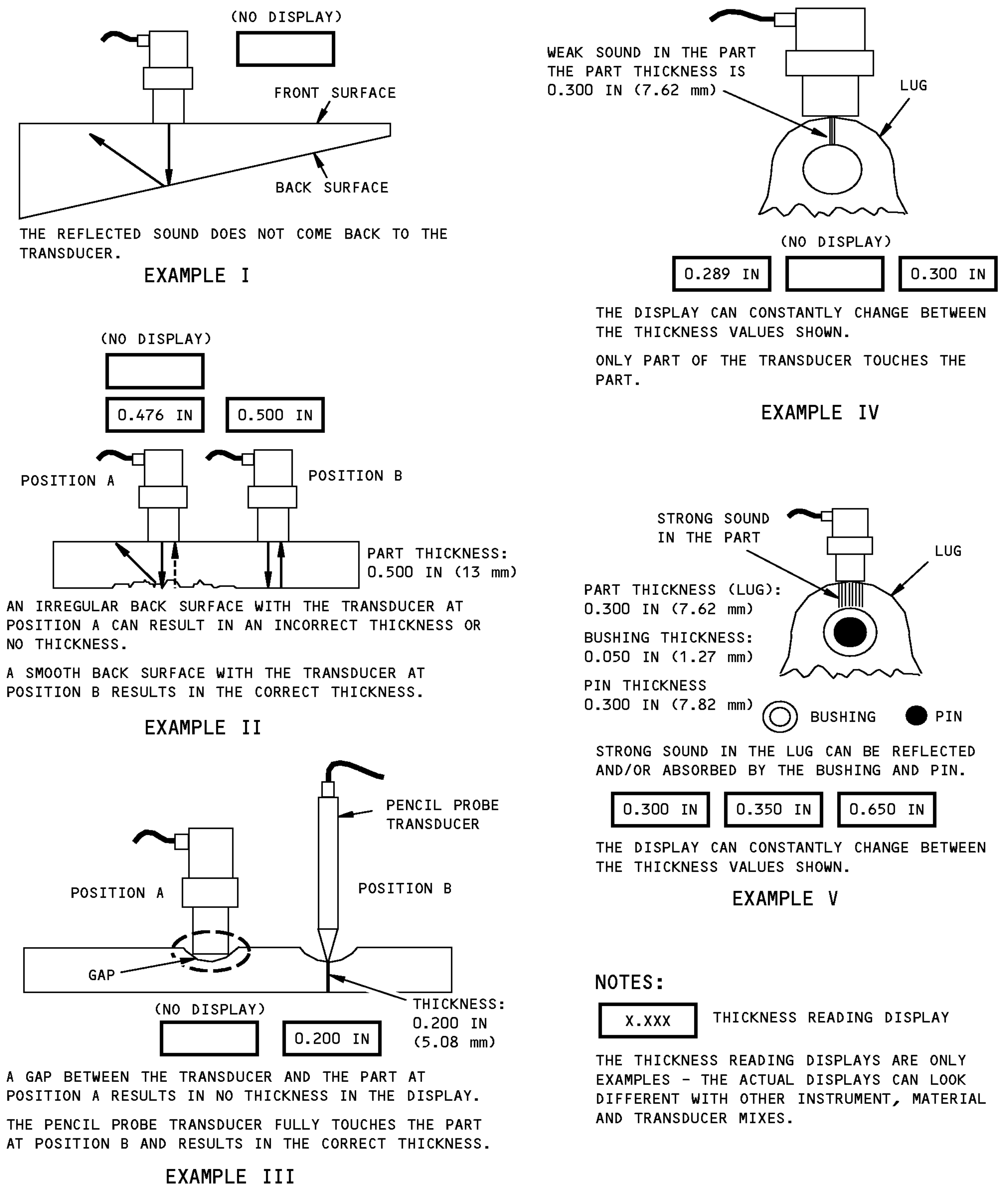

Possible Inspection Conditions
Figure 1

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