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PART 9 - THERMOGRAPHY

INSPECTION FOR ICE OR WATER IN HONEYCOMB PARTS

1. Purpose

- A. Use this procedure to do an inspection for ice or water in nonmetallic honeycomb structure with an infrared thermography camera.
- B. This procedure gives instructions for a flight line or a maintenance facility inspection.
- C. The Flight Line Procedure must be done within one hour after the airplane lands.
- D. It is necessary to heat the part if the Heat Source Procedure is used in the maintenance facility. There is no limit for the inspection time of the Heat Source Procedure if the heat source is frequently applied to the inspection area.

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 a thermography camera that:
 - (a) Displays a grayscale image on a video monitor (a color display is not necessary).
 - (b) Can find water or ice in reference standard NDT1046 as specified in this procedure.
 - (c) The instruments specified below were used to help prepare this procedure.
 - 1) Thermo Tracer TH1101; NEC San-ei Instruments Ltd.
 - 2) Thermo Tracer TH1100; Mikron Instruments
 - 3) 760; Inframetrics Inc.
- C. Heat Source
 - (1) Boeing recommends that quartz lamps, with 1000-watt outputs be used as the external heat sources for the Heat Source Procedure.

NOTE: A heat source is not necessary for the flight line inspection.
- D. Reference Standard
 - (1) Use reference standard NDT1046. See Figure 1 for data about the reference standard.

3. Preparation for Inspection

- A. Prepare the reference standard as follows:
 - (1) To do the "Flight Line Procedure":
 - (a) Fill the cells in reference standard NDT1046 with water as specified in Figure 2.
 - (b) Freeze reference standard NDT1046 until the water is solid.
 - (c) Remove the reference standard from the freezer immediately before the test.
 - (2) To do the "Heat Source Procedure":
 - (a) Fill the cells of reference standard NDT1046 with water as specified in Figure 2.
 - (b) Let the water come to room temperature.
- B. Prepare the airplane as follows:
 - (1) Get access to the inspection areas.

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- (2) Remove loose paint, dirt, or grease from the surface of the inspection area if it can affect the inspection.

4. Instrument Calibration

NOTE: Refer to the instrument instruction manual for the equipment operation instructions.

A. Approve the instrument for use as follows:

NOTE: It is necessary to approve the thermography camera only one time to make sure the camera can identify subsurface ice.

- (1) Prepare the reference standard as specified in Paragraph 3.A.
 - (2) Let the thermography camera cool to its operation temperature.
 - (3) Put the reference standard in front of the thermography camera.
 - (a) Make sure that the reference standard is the same distance from the camera that the inspection area will be during the inspection.
 - (4) Look at the reference standard with the thermography camera.
 - (a) Adjust the focus until the edge of the reference standard can be seen clearly.
 - (5) Adjust the instrument sensitivity and temperature level until you can clearly see the ice in the reference standard. Use the lowest temperature range that permits you to see the full reference standard.
 - (a) If you cannot see the ice in the reference standard, then:
 - 1) The sensitivity and temperature levels are not set correctly. Refer to the instrument instruction manual for the calibration instructions about how to set the sensitivity.
 - 2) The thermography camera is too far from the reference standard. Do the calibration again at a closer distance.
 - 3) If Paragraph 4.A.(5)(a)1 and Paragraph 4.A.(5)(a)2 cannot correct the problem, the thermography camera cannot be calibrated for this inspection procedure. You cannot use the thermography camera for this inspection.
 - (6) Make a record of how the thermography camera is set for use during the airplane inspection.
 - (7) Make a record of the distance between the reference standard and the thermography camera. This is the maximum distance that can be used during the inspection.
- B. Calibrate the equipment to do a thermography inspection with the airplane on the flight line as follows (this is the Flight Line Procedure):
- (1) Let the thermography camera cool to its operation temperature.
 - (2) Use the data in Paragraph 4.A.(5) and Paragraph 4.A.(6) to make the initial calibration adjustments.
 - (3) Make sensitivity and temperature level adjustments to the thermography camera.
 - (4) Calibrate the thermography equipment with the reference standard or the airplane inspection area, as applicable, as follows:
 - (a) If you use the frozen reference standard to calibrate the instrument:
 - 1) See Paragraph 3.A.(1) for the reference standard preparation instructions.
 - 2) Put the reference standard at a distance that is equivalent to the distance between the thermography camera and inspection area on the airplane.
 - 3) Adjust the sensitivity and the temperature levels to make sure the ice is clearly seen with the best contrast.
 - (b) If you use the airplane inspection area to calibrate the instrument:

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- 1) Align the thermography camera so its view is perpendicular (approximately) to the inspection area as Figure 3.
- 2) Adjust the sensitivity and temperature levels to make sure subsurface structure or areas with subsurface ice or water can be clearly seen with the best contrast.

NOTE: Do not make an inspection with the thermography camera at a larger distance from the inspection area than the distance found in Paragraph 4.A.(7).

- (c) Make a record of how the thermography camera controls are set.
- C. Calibrate the equipment to do a thermography inspection with a heat source as follows (this is the Heat Source Procedure):
- (1) Let the thermography camera cool to its operation temperature.
 - (2) Use the data in Paragraph 4.A.(5) and Paragraph 4.A.(6) to make the initial calibration adjustments.
 - (3) Calibrate the thermography equipment with the reference standard or the airplane inspection area, as applicable, as follows:
 - (a) To calibrate the thermography equipment with the reference standard:
 - 1) Make sure that the reference standard contains water at room temperature.
 - 2) Point the thermography camera at the reference standard.
 - a) Make sure the thermography camera is less than the distance found in Paragraph 4.A.(7) from the reference standard.
 - 3) Apply heat to the reference standard equally with a quartz lamp.
 - a) As you apply the heat, monitor the surface temperature of the reference standard with the thermography camera to make sure that all areas of the inspection surface are heated equally. Do not heat the surface more than 10 degrees Celsius (18°F).
 - 4) Immediately examine the reference standard and identify temperature differences caused by water.
 - 5) Adjust the thermography camera controls to get the best image contrast.
 - 6) Make a record of how the thermography camera is set.
 - (b) To calibrate the thermography equipment on the airplane:
 - 1) Get drawings of the inspection area.
 - 2) Point the thermography camera so it is perpendicular (approximately) to the calibration surface on the airplane in an area with subsurface structure.
 - 3) Apply heat to the inspection area equally with the quartz lamp.
 - a) As you apply the heat, monitor the surface temperature with the thermography camera to make sure that all areas of the inspection surface are heated equally. Do not heat the surface more than 10 degrees Celsius (18°F).
 - 4) Immediately examine the surface with the thermography camera and identify temperature differences caused by water.
 - 5) Adjust the controls to get the best image contrast.
 - 6) If no subsurface structure or water is seen, then:
 - a) Apply the heat several times and monitor the area for water. Permit the part surface to cool each time you apply heat.

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- b) If you do Paragraph 4.C.(3)(b)6)a) and you cannot see a subsurface structure or water, then look at an area with known subsurface structure to make sure the camera is set correctly as follows:

NOTE: It is necessary to see the subsurface structure or water to make sure the calibration is set correctly.

- < 1 > Set the camera in a position to view a known subsurface structure.
- < 2 > Apply heat to the subsurface structure.
- < 3 > Monitor the area for the subsurface structure (and/or water).

- c) If you cannot identify the subsurface structure (or water) during Paragraph 4.C.(3)(b)6)a) and Paragraph 4.C.(3)(b)6)b), do the calibration again on the reference standard.

- 7) Make a record of how the thermography camera is set.

5. Inspection Procedure

- A. Use the "Flight Line" or "Heat Source" procedures to examine the inspection area as follows:

- (1) Examine the Inspection area with the "Flight Line" procedure as follows:

- (a) Point the thermography camera so it is perpendicular (approximately) to the inspection part. For inspection areas that are larger than the cameras field of view, point the camera at one end (corner) of the inspection area. Figure 3 shows how to position the camera.
- (b) Monitor the video display for local areas that are colder than the adjacent inspection area. Make small contrast adjustments if necessary.
- (c) Make a record of the local cold areas in the inspection area. These cold areas are possible defects. It is necessary to do more analysis of these areas. Use one of the procedures that follow to make the record.
 - 1) Make a record of the defect data on a digital storage system (floppy disk drive or video cassette recorder) or,
 - 2) Make a record of the defect areas on the airplane with an approved pencil or marker.
- (d) Move the thermography camera to the next inspection area. If the inspection area is too large to fit in the camera's field of view, make sure that subsequent adjacent images overlap.
- (e) Make sure the thermography camera is perpendicular (approximately) to the inspection surface.
- (f) Do Paragraph 5.A.(1)(b) thru Paragraph 5.A.(1)(e) until the full inspection area is examined. Stop the inspection if one (or more) of these conditions occur.
 - 1) You cannot see the ice/water in the reference standard.
 - 2) You cannot see subsurface structure in the inspection area.
 - 3) One hour has passed since the airplane landed.

- (2) Examine the inspection area with the "Heat Source" Procedure in the Maintenance Facility as follows:

- (a) Point the thermography camera so it is perpendicular (approximately) to the inspection part. For inspection areas that are larger than the cameras field of view, point the camera at one end (corner) of the inspection area. Figure 3 shows how to position the camera.
- (b) Apply heat to the inspection area equally with the quartz lamp.

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- 1) As you apply the heat, monitor the surface temperature with the thermography camera to make sure that all areas of the inspection surface are heated equally. Do not heat the surface more than 10 degrees Celsius (18°F).
- (c) Immediately examine the part and identify temperature differences caused by water.
- (d) Adjust the thermography camera controls to get the best image contrast. If no subsurface structure or water is seen, then:
 - 1) Apply the heat several times and monitor the area for water. Permit the part surface to cool each time before you apply heat.
 - 2) If you do Paragraph 5.A.(2)(d)1) and you cannot see subsurface structure or water, then look at an area with known subsurface structure to make sure the camera is set correctly as follows:
 - a) Set the camera in a position to view a known subsurface structure.
 - b) Apply heat to the subsurface structure.
 - c) Monitor the area for the subsurface structure (and/or water).
 - 3) If you cannot identify the subsurface structure (or water) during Paragraph 5.A.(2)(d)1) and Paragraph 5.A.(2)(d)2), do the calibration again on the reference standard.
- (e) Make a record of the local cold areas in the inspection area. These cold areas are possible defects. It is necessary to do more analysis of these areas. Use one of the procedures that follow to make the record.
 - 1) Make a record of the defect data on a digital storage system (floppy disk drive or video cassette recorder) or,
 - 2) Make a record of the defect areas on the airplane with an approved pencil or marker.
- (f) Move the thermography camera to the next inspection area. If the inspection area is too large to fit in the camera's field of view, make sure the subsequent adjacent images overlap.
- (g) Make sure the thermography camera is perpendicular (approximately) to the inspection area.
- (h) Do Paragraph 5.A.(2)(b) thru Paragraph 5.A.(2)(g) until the full inspection area is examined.

NOTE: No time limit is applicable if the heat and examination cycle is continued.

6. Inspection Results

- A. Compare the defect indications with drawings of the inspection area.
 - (1) All high contrast areas that are not caused by structural material changes (fasteners, doublers, fittings) must be thought of as ice or water and the areas must be examined some more. Figure 4 shows example thermographs.
- B. Make sure that all of the surface contamination has been removed to make sure that the identified defect areas contain ice or water. Local surface conditions (chipped paint, grease, dirt) can cause incorrect defect indications.
- C. Use a different NDT procedure, if possible, to make sure of the results.

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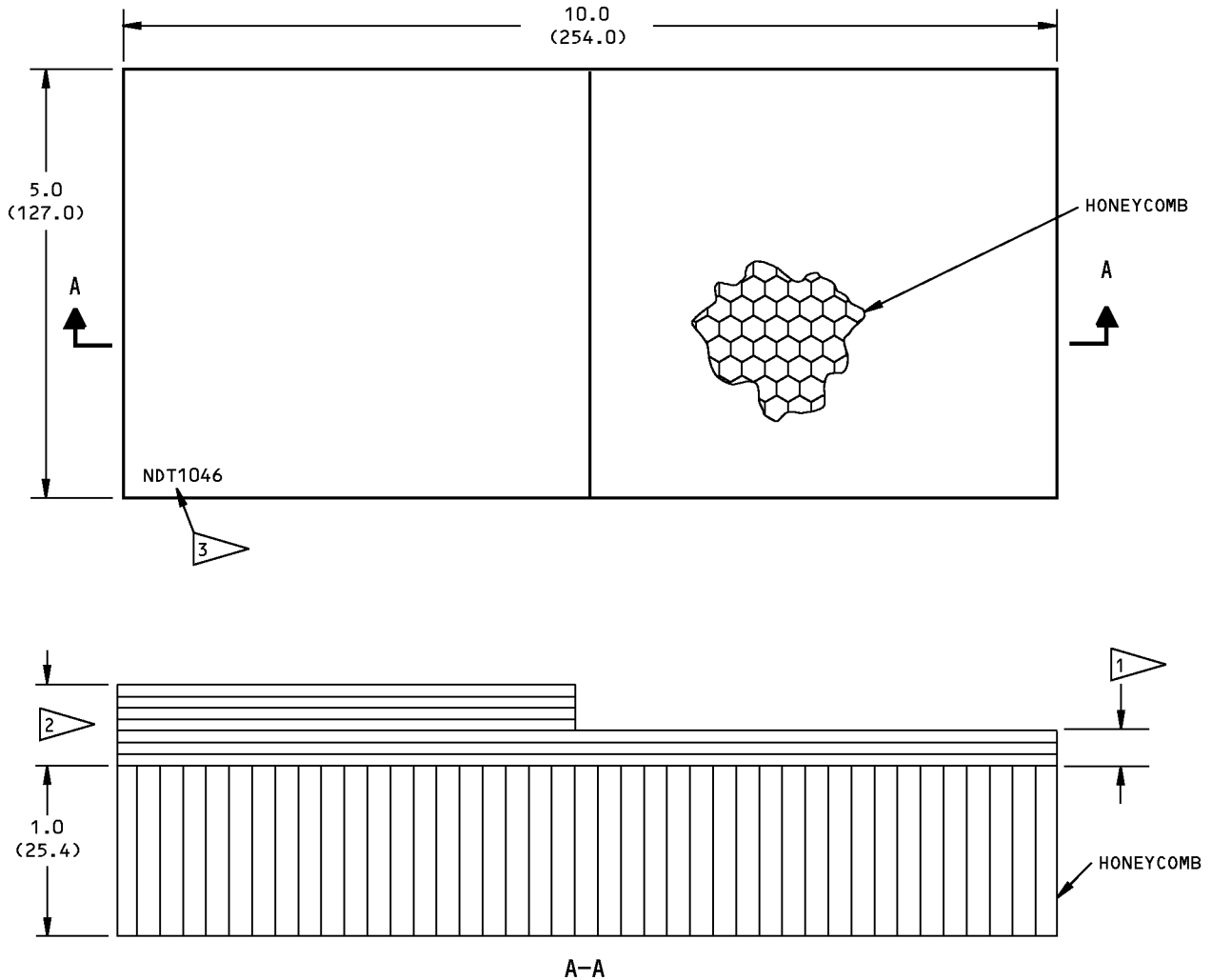
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NOTES:

- ALL DIMENSIONS ARE IN INCHES (MILLIMETERS ARE IN PARENTHESES)
- TOLERANCE: ± 0.1 (2.5)
- MAKE THE REFERENCE STANDARD FROM THE SAME MATERIALS THAT ARE USED IN THE INSPECTION AREA.

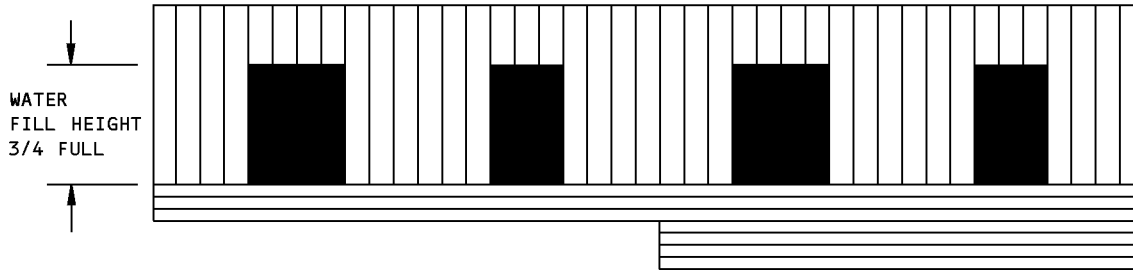
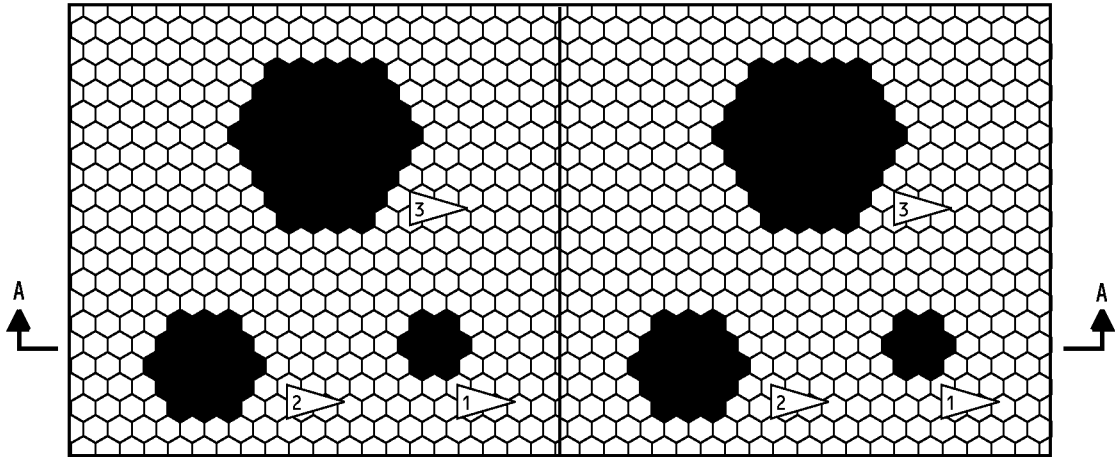
- USE THREE PLYS (MINIMUM) IF MADE FROM NONMETALLIC COMPOSITE. THE THICKNESS MUST BE EQUIVALENT TO THE MINIMUM THICKNESS IN THE INSPECTION AREA.
- THIS THICKNESS MUST BE EQUIVALENT TO THE MAXIMUM SKIN THICKNESS IN THE INSPECTION AREA.
- IDENTIFY THE REFERENCE STANDARD NUMBER "NDT1046" IN THIS AREA.

Reference Standard NDT1046
Figure 1

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


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A-A

NOTE:

FILL ADJACENT CELLS WITH WATER TO GET THE APPROXIMATE DIAMETERS SHOWN IN THE FLAGNOTES. THE ACTUAL SIZE WILL CHANGE WITH THE DIMENSIONS OF THE CORE CELLS. PUT TAPE ON THE CORE TO SEAL THE WATER.

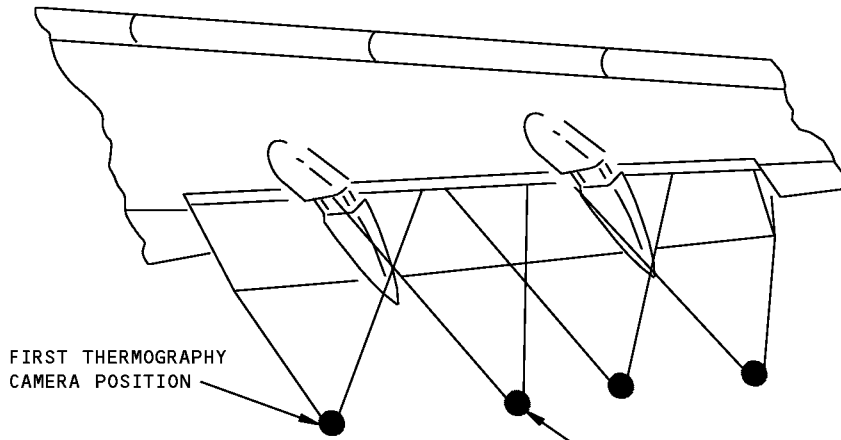
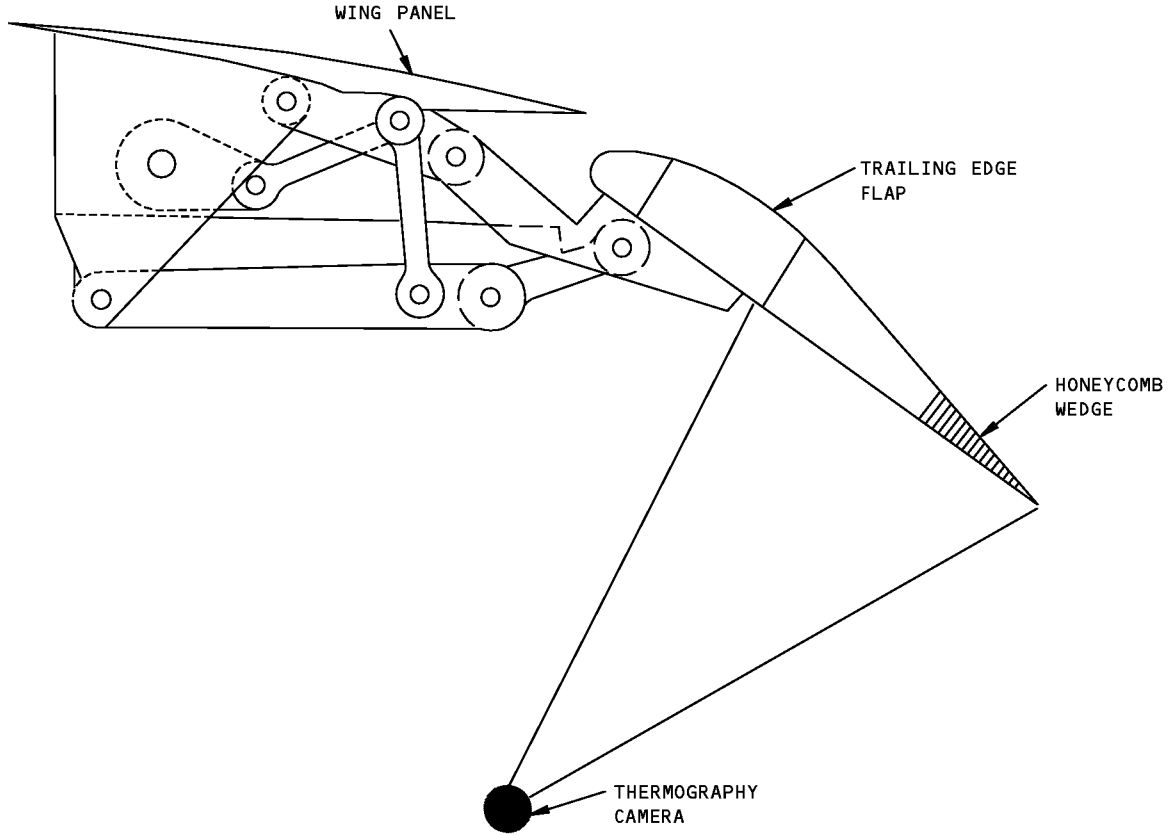
-  0.5 INCH (13 mm) DIAMETER
-  1.0 INCH (25 mm) DIAMETER
-  2.0 INCH (50 mm) DIAMETER

**Subsurface Water Preparation
Figure 2**

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NOTE

- THE THERMOGRAPHY CAMERA MUST BE PERPENDICULAR (APPROXIMATELY) TO THE INSPECTION SURFACE.

SUBSEQUENT CAMERA POSITIONS MUST CAUSE THE INSPECTION AREAS TO OVERLAP TO MAKE SURE THE FULL PART IS EXAMINED

Example of How to Position the Thermography Camera

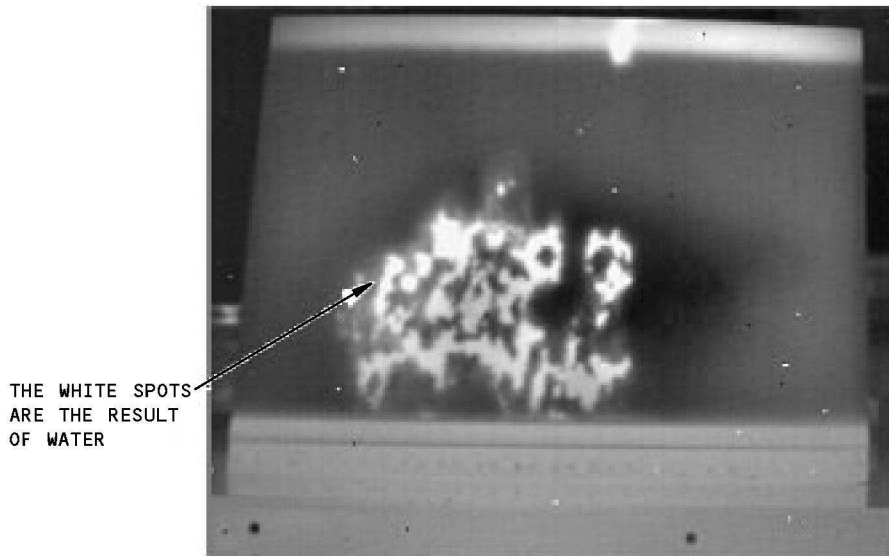
Figure 3

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SKIN HOTTER THAN THE WATER



WATER HOTTER THAN THE SKIN

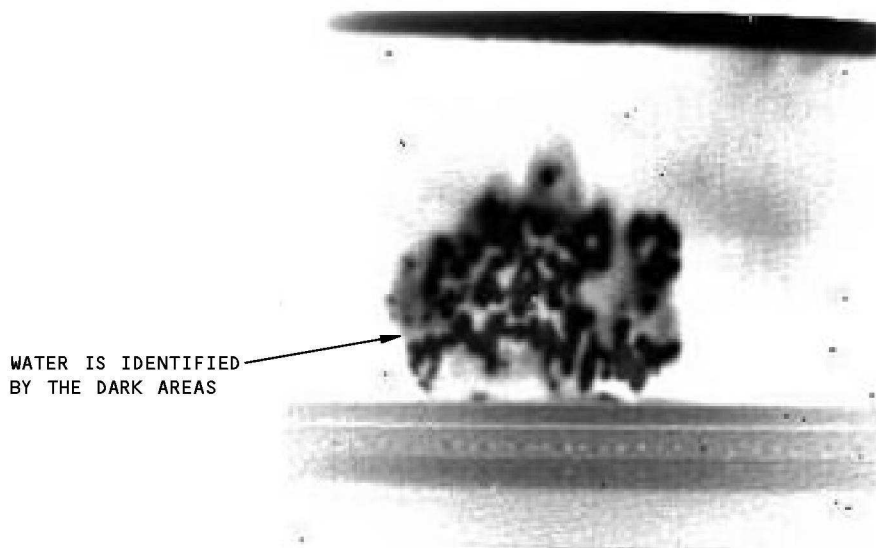
**Example Thermographs
Figure 4 (Sheet 1 of 2)**

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EXAMPLE OF SHADOW EFFECT
AROUND WATER FILLED CELLS

Example Thermographs
Figure 4 (Sheet 2 of 2)

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INSPECTION FOR WATER IN HONEYCOMB WITH LIQUID CRYSTAL SHEETS

1. Purpose

- A. Use this procedure to do an inspection for water in nonmetallic honeycomb structure with liquid crystal sheets that are sensitive to temperature differences. The liquid crystal sheets are used as an inexpensive alternative to an electronic thermography camera.
- B. It is necessary to heat the part. There is no limit to the number of heat cycles if the heat is applied frequently to the part through the liquid crystal sheet.
- C. This procedure gives instructions for inspection with one of these vacuum attachment methods:
 - (1) Vacuum bag
 - (2) Portable Vacuum chamber
 - (3) Couplant attachment
- D. This procedure can be used when the temperature of the part, before the inspection, is between 40°F (40°C) and 90°F (32°C).
- E. This is an alternative procedure to the X-ray and instrumented thermography procedures used to find water in composite honeycomb structures.

2. Equipment

- A. General
 - (1) Use liquid crystal sheets that can identify water in the cells of the honeycomb reference standard as specified in Paragraph 4.
- B. Liquid Crystal Sheets
 - (1) Use liquid crystal sheets made from micro-encapsulated liquid crystals attached to Mylar substrate.
 - (2) Use material that can identify subsurface water if the procedure specified in Paragraph 4. and Paragraph 5. is followed.
 - (3) The liquid crystal sheets specified below were used to help prepare this procedure (see Figure 1).
 - (a) BS14200; Biosynergy, Inc.
 - (b) R30C5W
R35C5W
R40C5W; Hallcrest
- C. Heat Source
 - (1) It is recommended that a quartz lamp, with a 1000-watt output be used as the heat source.
 - (a) The lamp specified below was used to help prepare this procedure:
 - 1) Model HL1
High intensity vertical heater
2-500-watt tubes
10 inches (254 mm) long, Eraser Luxtherm
 - (b) Other heat sources, such as heat guns, can also be used.
- D. Reference Standard

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- (1) Use reference standard NDT1046. See Figure 2 for data about the reference standard.

NOTE: A honeycomb part that you discard from an airplane can also be used as an alternative to reference standard NDT1046. To use a honeycomb part as the reference standard, it must have the same configuration and the same (or more) number of plies as the part to be examined.

E. Vacuum Bag

- (1) Use one of the types of bags that follow for the vacuum procedures.
 - (a) Nylon vacuum bag material with a "Tacky Tape" (extruded repair compound seal, refer to the SRM).
 - (b) Portable vacuum chamber: Model GL1620; Torr Technologies Inc.

F. Vacuum Source

- (1) Maintenance facility vacuum line
- (2) Maintenance facility compressed air with an aspirator
- (3) Electric vacuum pump

G. Couplant

- (1) Grease
- (2) Thick ultrasonic couplant
- (3) Honey

3. Preparation for Inspection**A. Prepare the reference standard as follows:**

- (1) Fill the cells of reference standard NDT1046 with water as specified in Figure 3.
- (2) Let the water and the reference standard come to room temperature.
- (3) Put tape on the core to seal the water.

B. Prepare the airplane as follows:

- (1) Get access to the inspection areas.
- (2) Remove loose paint, dirt and grease and moisture from the lower surface of the part to be examined. These can give incorrect indications.

C. Use the applicable liquid crystal sheet.

- (1) Measure the temperature of the part.
- (2) Use a liquid crystal sheet that has an "initial temperature change" that is at least 4 °F (2 °C) higher than the temperature of the part (Figure 1 for a list of tested material).

4. Instrument Calibration**A. It is necessary to do a check of the sensitivity of the liquid crystal sheet for each different type of honeycomb panel.**

NOTE: Examine the reference standard with the liquid crystal inspection procedure to make sure that you can easily identify the water indications.

- (1) Do a sensitivity check as follows (Figure 4):
 - (a) Prepare the reference standard. See Paragraph 3.A.
 - (b) Put the reference standard on a smooth surface with the skin side up (Figure 4).
 - (c) Put the liquid crystal sheet on the skin side of the reference standard. Make sure the shiny side of the liquid crystal sheet is away from the skin (you must be able to see the shiny surface). The liquid crystal sheet can be cut to the proper dimensions if necessary.

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- (d) Put a continuous ring of Tacky Tape around the reference standard. Permit enough room to attach a vacuum line fitting to the vacuum bag (Figure 4). Position the attach fitting as shown in Figure 4.
- (e) Put a transparent vacuum bag material over the reference standard and attach it to the Tacky Tape.
- (f) Apply a vacuum to the bag through the fitting.

NOTE: The vacuum permits close contact between the liquid crystal sheet and the part. This increases the heat transfer between the sheet and the part.

- (g) Apply heat to the surface of the reference standard (through the liquid crystal sheet) until the liquid crystal sheet becomes blue in color.

NOTE: The liquid crystals will continue to change color as heat is applied. As the temperature increases, the colors will progress through red, yellow, green and blue before the sheet becomes black again. Red identifies the coldest area and blue identifies the hottest.

NOTE: Do not apply enough heat to cause the liquid crystals to change from black, through the full color range and become black again. This could damage the liquid crystal sheet.

- (h) Monitor the liquid crystal sheet. View it through the bag to make sure that the heat is applied equally to all of the reference standard.
- (i) Identify the water-filled cells with the liquid crystal sheets. The liquid crystal sheets will be a different color in the areas where the sheet is adjacent to water-filled cells.
- (j) If a water indication is identified, continue to apply heat as you move the lamp away from the reference standard. At some separation distance between the reference standard and the lamp, a steady water indication can be seen.
- (k) Sweep the lamp back and forth above the part at this distance to keep the water indication visible.
- (l) Compare your results with those shown in Figure 5.

NOTE: This is the same procedure that will be used to examine honeycomb structure for water on the airplane.

5. Inspection Procedure

- A. Use a vacuum bag, portable vacuum frame or couplant attachment procedure to examine the inspection area as follows:

NOTE: Usually the underside of the part is examined so if water is in the honeycomb cells it is in contact with the inspection skin. If the inspection part is vertical, choose one side of the honeycomb panel for inspection. More than one of the liquid crystal inspection procedures can be necessary to permit a complete examination of the inspection area.

- (1) Examine the inspection area with the "Vacuum bag" procedure as follows:
 - (a) Apply a continuous ring of "Tacky Tape" to the underside of the part to be examined at the edge of the inspection area (Figure 6).
 - (b) Use an approved pencil to make an "X" at opposite corners of the inspection area. Make the marks within the Tacky Tape ring (Figure 6).

NOTE: This will permit alignment of the vacuum bag with the part. The vacuum bag can be used as a guide during the repair process.

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- (c) Attach the liquid crystal sheet(s), identified in Paragraph 3.C., to the inspection surface with a small piece of tape at each corner of the liquid crystal sheet(s). Make sure that the shiny side of the liquid crystal sheet is toward the vacuum bag.

NOTE: More than one liquid crystal sheet can be put adjacent to each other to decrease the number of times the sheets must be positioned to the next part of the inspection area.

- (d) Attach a single sheet of vacuum bag material to the Tacky Tape. Make sure the vacuum bag is attached smoothly to the Tacky Tape.
- (e) Attach a vacuum line connection fitting, or equivalent, to the vacuum bag near a corner of the inspection area. Use a breather cloth under the fitting.
- (f) Remove the air from the bag with the vacuum source (Paragraph 2.F.).
- (g) Use a grease pencil to make an "X" on the vacuum bag above the "X's" on the part. These marks will permit the bag and the part to be aligned if the bag is removed from the part before it is repaired.
- (h) Apply heat to the part through the bag and a liquid crystal sheet until the full liquid crystal sheet becomes blue in color.

NOTE: Do not apply enough heat to cause the liquid crystals to change from black, through its full color range and become black again. This could damage the liquid crystal sheets.

NOTE: If more than one liquid crystal sheet is use, then heat and monitor each sheet separately.

- (i) Monitor the liquid crystal sheet. View it through the bag to make sure that the heat is applied equally to all of the liquid crystal sheet.
- (j) If the liquid crystal sheet changes color equally over the full sheet, and no small areas of different color are visible, then do Paragraph 5.A.(1)(h) thru Paragraph 5.A.(1)(i) two more times to make sure that there is no water in the honeycomb. Permit the liquid crystal sheet to cool each time (change to the initial color).
- (k) Cells that contain water can be identified with the liquid crystal sheet as areas that are a different color than the liquid crystals around the water indication. (See Figure 5 for examples of liquid crystal defect indications caused by water in honeycomb.)
- (l) Continue to apply heat while you move the lamp away from the inspection surface. At some separation distance between the part and the lamp, a stable color pattern can be seen.
- (m) If areas of water are identified, then make a mark to identify the position of the indications. Use a felt pen or grease pencil to draw a line around the water indications directly on the vacuum bag.
- (n) If more than one liquid crystal sheet is used, do Paragraph 5.A.(1)(h) thru Paragraph 5.A.(1)(m) again for the other sheet(s).
- (o) Remove the vacuum from the vacuum bag and permit the bag to separate from the inspection surface as the air leaks back into the bag.
- (p) Move the liquid crystal sheet(s) to the next inspection position within the Tacky Tape boundary.
- 1) Quickly pull the edge of the vacuum bag so that the bag is removed from the Tacky Tape while the Tacky Tape remains on the inspection surface.
 - 2) Move the sheet(s) to the next inspection position. Make sure that the position of the liquid crystal sheet(s) partially overlap the last inspection position.

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- 3) Attach the vacuum bag to the Tacky Tape again.
 - 4) Apply the vacuum to the vacuum bag.
 - (q) Do Paragraph 5.A.(1)(h) thru Paragraph 5.A.(1)(p) again until all of the inspection surface has been examined.
 - (r) After the inspection area has been examined, the bag can be used as a guide to identify water-filled areas during the repair process.
- (2) Examine the inspection area with the "Portable Vacuum Chamber" procedure as follows:
- (a) Put the liquid crystal sheet (identified in Paragraph 3.C.) on the flexible window of the portable vacuum chamber so the shiny side is toward the window.
 - (b) Attach the vacuum source to the portable vacuum chamber.
 - (c) Position the portable vacuum chamber at the corner of the inspection area (Figure 7).
 - (d) Permit the vacuum chamber to attach to the inspection surface.
 - (e) Apply heat to the part through the window and the liquid crystal sheet until the full liquid crystal sheet becomes blue in color.
NOTE: Do not apply enough heat to cause the liquid crystals to change from black, through the full color range and become black again. This could damage the liquid crystal sheet.
 - (f) Monitor the liquid crystal sheet through the window. Make sure that the heat is applied equally to all of the liquid crystal sheet.
 - (g) If the liquid crystal sheet changes color equally over the full sheet, and no small areas of different color are visible, then do Paragraph 5.A.(2)(e) thru Paragraph 5.A.(2)(f) two more times to make sure that there is no water in the honeycomb. Permit the liquid crystal sheet to cool each time (change to the initial color).
 - (h) Cells that contain water can be identified with the liquid crystal sheet as areas that are a different color than the liquid crystals away from the water indication.
 - (i) Continue to apply heat while you move the lamp away from the inspection surface. At some separation distance between the part and the lamp, a steady color pattern can be seen.
 - (j) If areas of water are identified, then:
 - 1) Remove the portable vacuum chamber.
 - 2) Use an approved pencil to make a mark around the general position of the indications on the inspection part.
 - (k) Move the portable vacuum chamber to the next adjacent inspection position (Figure 7).
 - (l) Apply the vacuum to the portable vacuum chamber again.
 - (m) Do Paragraph 5.A.(2)(d) thru Paragraph 5.A.(2)(l) again until all of the inspection surface has been examined.
- (3) Examine smooth inspection areas (e.g., aerodynamic surfaces) with the "Couplant Attachment" procedure as follows:
- (a) Apply a small amount (1/8 inch (3 mm) diameter) of approved couplant (Paragraph 2.G.) to the corners and center of the liquid crystal sheet on the backside of the sheet (opposite the shiny side) as shown in Figure 8. A couplant that has the consistency of honey should be used.
NOTE: The couplant is used to hold the sheet in contact with the surface.
 - (b) Put the liquid crystal sheet at a corner of the inspection surface.

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- (c) Use a cylindrical roller (paint roller or equivalent) to remove air bubbles and make the liquid crystal sheet attach smoothly to the inspection surface.
- (d) Apply heat to the part through the liquid crystal sheet until the full liquid crystal sheet becomes blue in color.

NOTE: Do not apply enough heat to cause the liquid crystals to change from black, through its full color range and become black again. This could damage the liquid crystal sheet.

- (e) Monitor the liquid crystal sheet. Make sure that the heat is applied equally to all of the liquid crystal sheet.
- (f) If the liquid crystal sheet changes color equally over the full sheet, and no small areas of different color are visible, then do Paragraph 5.A.(3)(c) thru Paragraph 5.A.(3)(e) two more times to make sure that there is no water in the honeycomb. Permit the liquid crystal sheet to cool each time (change to the initial color).
- (g) Frequently use the roller to remove air bubbles that occur below the liquid crystal sheets.
- (h) Cells that contain water can be identified with the liquid crystal sheet as areas that are a different color than the liquid crystals away from the water indication.
- (i) Continue to apply heat while you move the lamp away from the inspection surface. At some separation distance between the part and the lamp, a stable color pattern can be seen.
- (j) The instructions that follow can be used if a map of the water indication is necessary for repair purposes:

- 1) Use an approved pencil to make a mark on the surface of the inspection part in the general area of the indication or,
- 2) Attach a transparent vacuum bag to the skin above the liquid crystal sheet.
 - a) Make alignment marks on the airplane and the vacuum bag with an approved pencil.
 - b) Heat the liquid crystal sheet as specified above.
 - c) Make a mark around the position of the indications on the vacuum bag.

NOTE: The areas of the liquid crystal sheet that have couplant on them will give indications that look like subsurface water. Make sure that you do not identify these as water indications. The inspection is not valid where the couplant attaches the liquid crystal sheet to the part.

- (k) Move the liquid crystal sheet to the next adjacent inspection position (Figure 8).
 - (l) Apply more couplant, if necessary. Make sure it is only applied to the corners and center of the liquid crystal sheet.
 - (m) Do Paragraph 5.A.(3)(c) thru Paragraph 5.A.(3)(k) again until all of the inspection surface has been examined.
- (4) Use the alternative inspection procedure for special inspection conditions:
- (a) Under the conditions that follow, it can be necessary to examine the opposite side of the inspection surface.
 - 1) Structure that interferes with the inspection area
 - 2) Complex curvature
 - 3) Septumized core
 - 4) Separate honeycomb panels (e.g., rudder) combined to make one structure.

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- (b) Use the instructions specified in Paragraph 5.A.(1), Paragraph 5.A.(2) or Paragraph 5.A.(3) to examine these areas.

NOTE: The liquid crystal sheets are very sensitive to small amounts of water. When the inspection is made from the top of a part it is possible to get indications from small amounts of moisture in the honeycomb. It is possible that these indications do not represent cells that have a large amount of water.

6. Inspection Results

- A. Compare the defect indications with drawings of the inspection area.
- (1) All high contrast areas that are not caused by structural material changes (fasteners, doublers, repairs, fittings) must be thought of as water.
- B. All surface contamination must be removed to make sure that the identified indication is caused by subsurface water. Local surface conditions (chipped paint, grease, dirt or moisture on the inspection surface) can cause incorrect defect indications.
- C. Typical water indications are shown in Figure 5. Compare your results with this figure. Look for irregular shapes and colors that are different than the area that surrounds the indication.
- D. Use a different NDT procedure, if possible (X-ray, electronic thermography), to make sure of the results.

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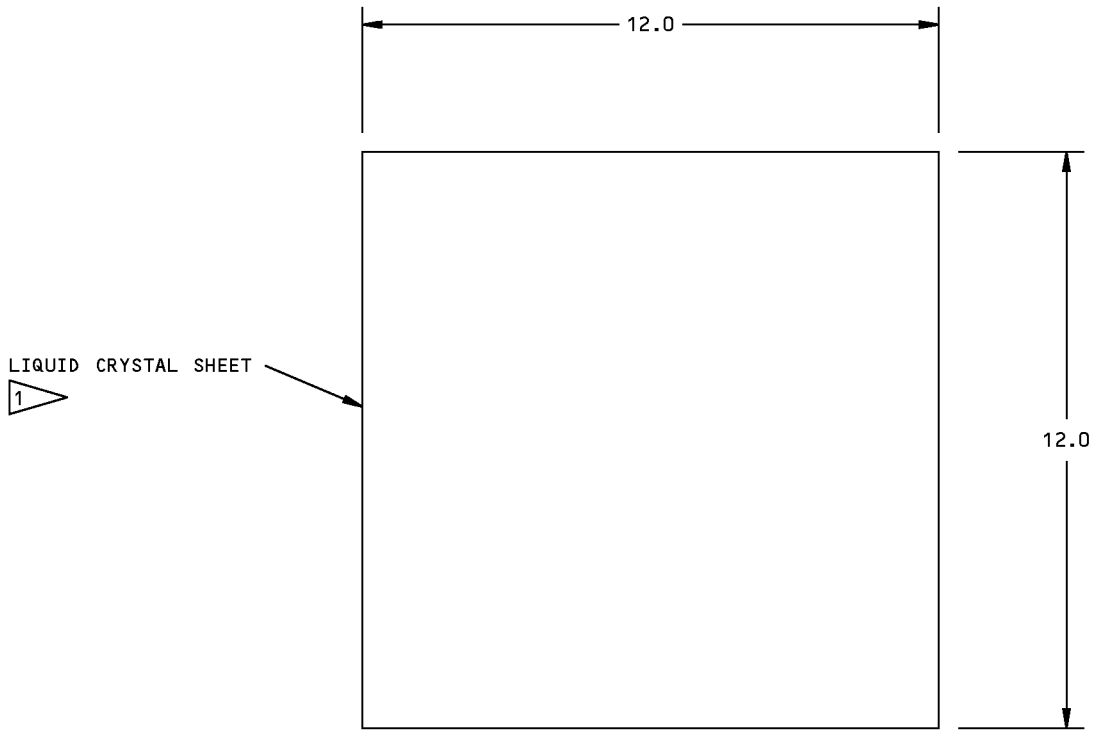
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MANUFACTURER/MODEL		INITIAL TEMPERATURE CHANGE	END TEMPERATURE CHANGE
HALLCREST:	R30C5W	30°C (86°F)	35°C (95°F)
	R35C5W	35°C (95°F)	40°C (104°F)
	R40C5W	40°C (104°F)	45°C (113°F)
BIOSYNERGY:	BSI 4200	27.2°C (81°F)	28.3°C (83°F)

HALLCREST: 1820 PICKWICK LANE, GLENVIEW, IL. 60025 USA
847-998-8580, FAX 847-998-8051

BIOSYNERGY: 1940 E. DEVON AVE., ELK GROVE VILLAGE, IL. 60007
847-956-0471, FAX 847-956-6050

- ALL DIMENSIONS ARE IN INCHES
- SUBSTRATE: 0.005 MYLAR

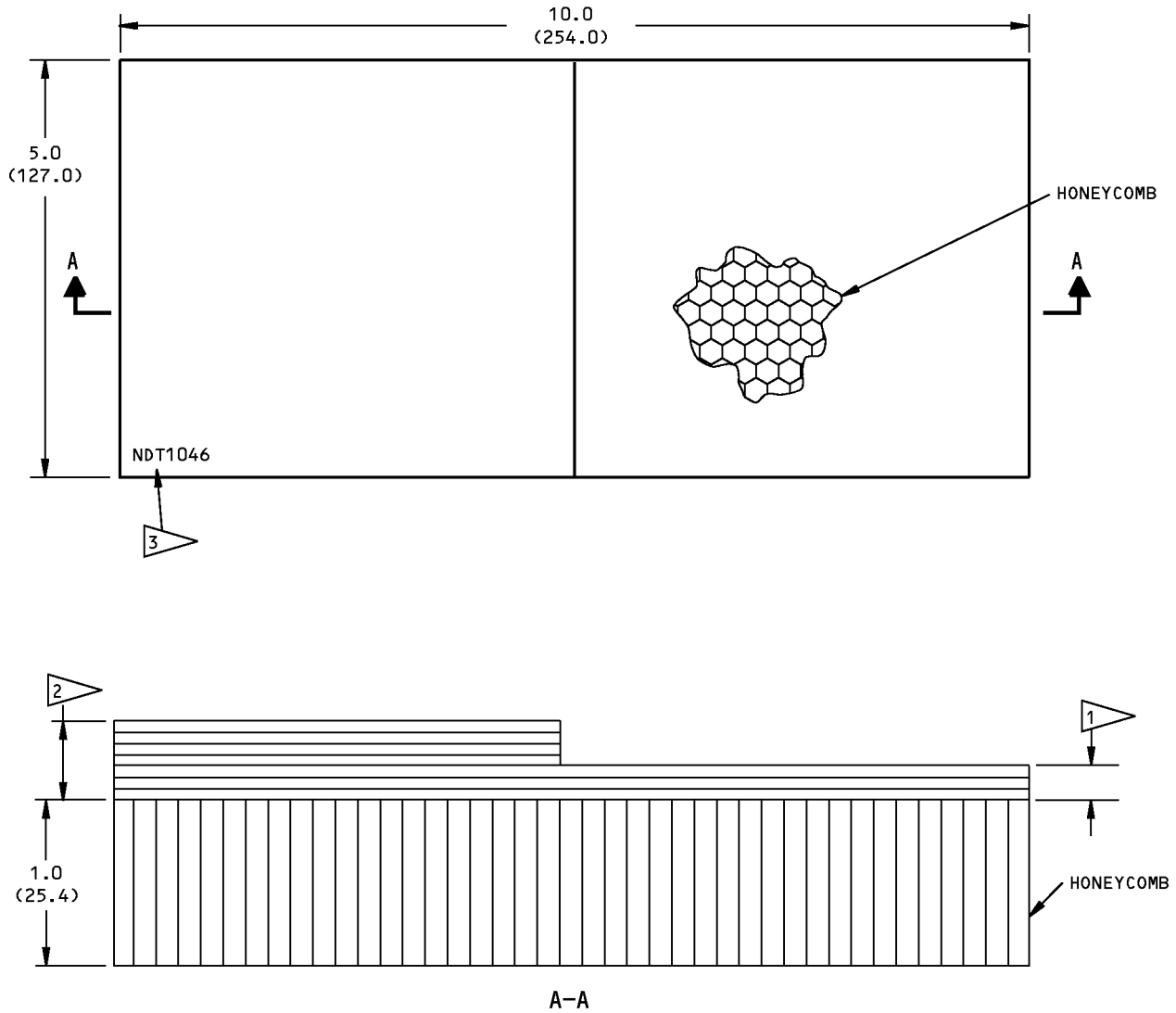
1 SHEETS CAN BE CUT TO MATCH THE SHAPE OF SPECIFIC PARTS

**Liquid Crystal Sheet Specifications
Figure 1**

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NOTES

- ALL DIMENSIONS ARE IN INCHES
MILLIMETERS ARE IN PARENTHESES
- TOLERANCE: ± 0.1 (2.5)
- MAKE THE REFERENCE STANDARD FROM
THE SAME MATERIALS THAT ARE USED
IN THE INSPECTION AREA

- 1** USE THREE PLYS (MINIMUM) IF MADE FROM
NONMETALLIC COMPOSITE. THE THICKNESS MUST
BE EQUIVALENT TO THE MINIMUM THICKNESS
IN THE INSPECTION AREA.
- 2** THIS THICKNESS MUST BE EQUIVALENT TO
THE MAXIMUM SKIN THICKNESS IN THE
INSPECTION AREA.
- 3** IDENTIFY THE REFERENCE STANDARD NUMBER
"NDT1046" IN THIS AREA.

Reference Standard NDT1046
Figure 2

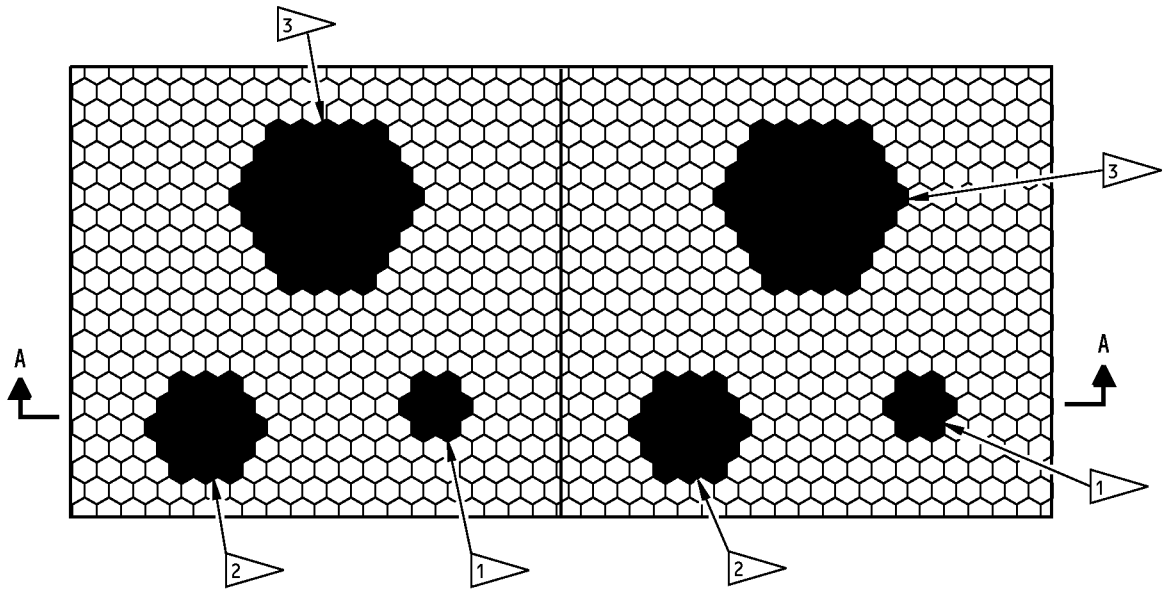
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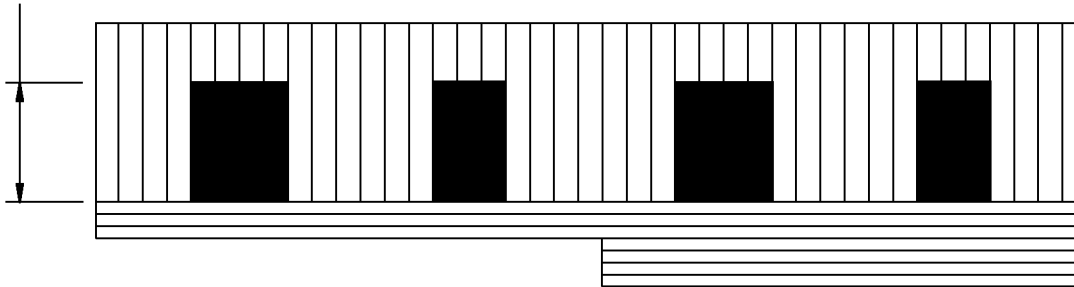
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WATER FILL HEIGHT
1/2 TO 3/4 FULL



A-A

NOTE

- FILL ADJACENT CELLS WITH WATER TO GET THE APPROXIMATE DIAMETERS SHOWN IN THE FLAGNOTES. THE ACTUAL SIZE WILL CHANGE WITH THE DIMENSIONS OF THE CORE CELLS. PUT TAPE ON THE CORE TO SEAL THE WATER.

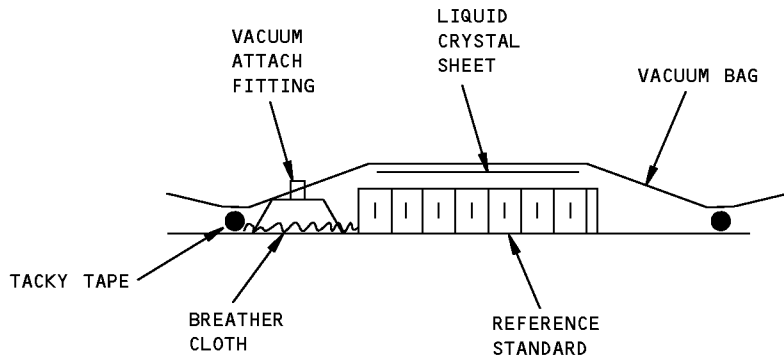
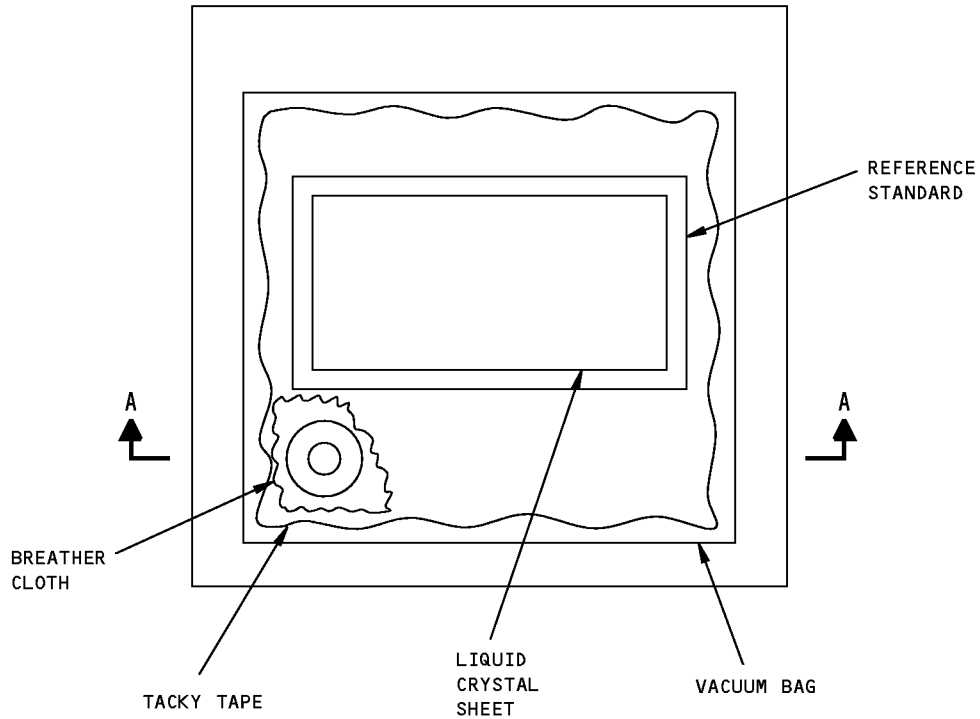
- 1 0.5 INCH (13 MM) DIAMETER
- 2 1.0 INCH (25 MM) DIAMETER
- 3 2.0 INCH (50 MM) DIAMETER

**Subsurface Water Preparation
Figure 3**

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**Reference Standard Calibration
Figure 4**

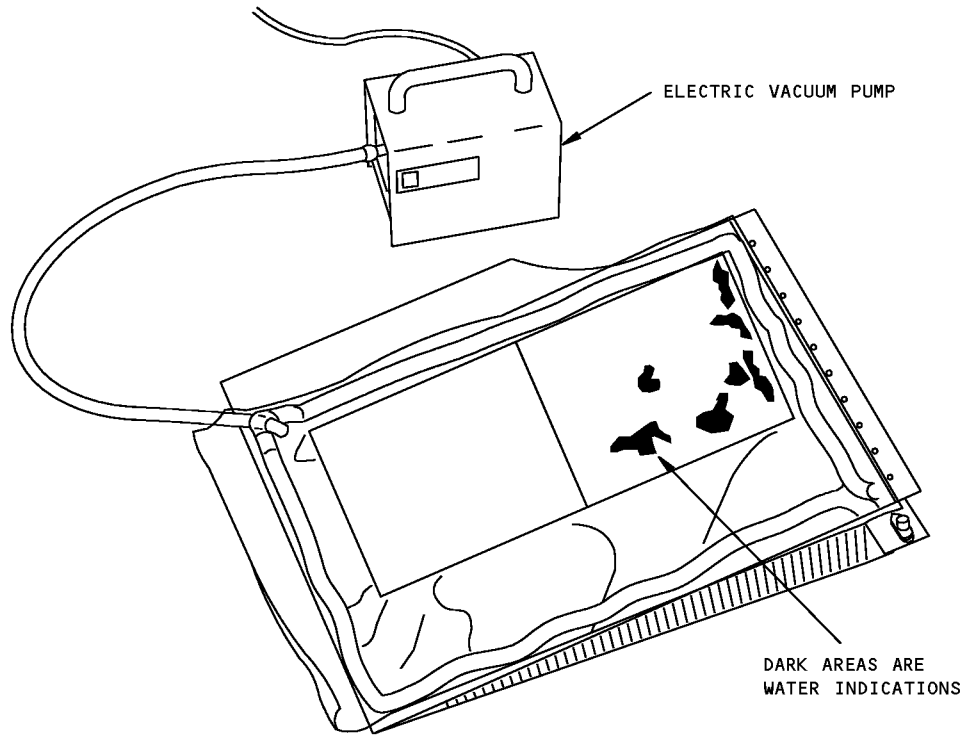
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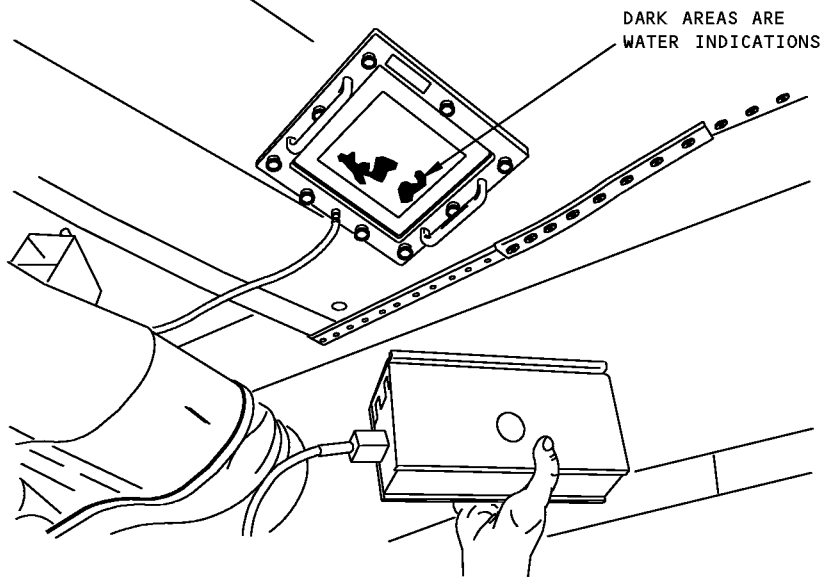
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**VACUUM BAG PROCEDURE
DETAIL I**

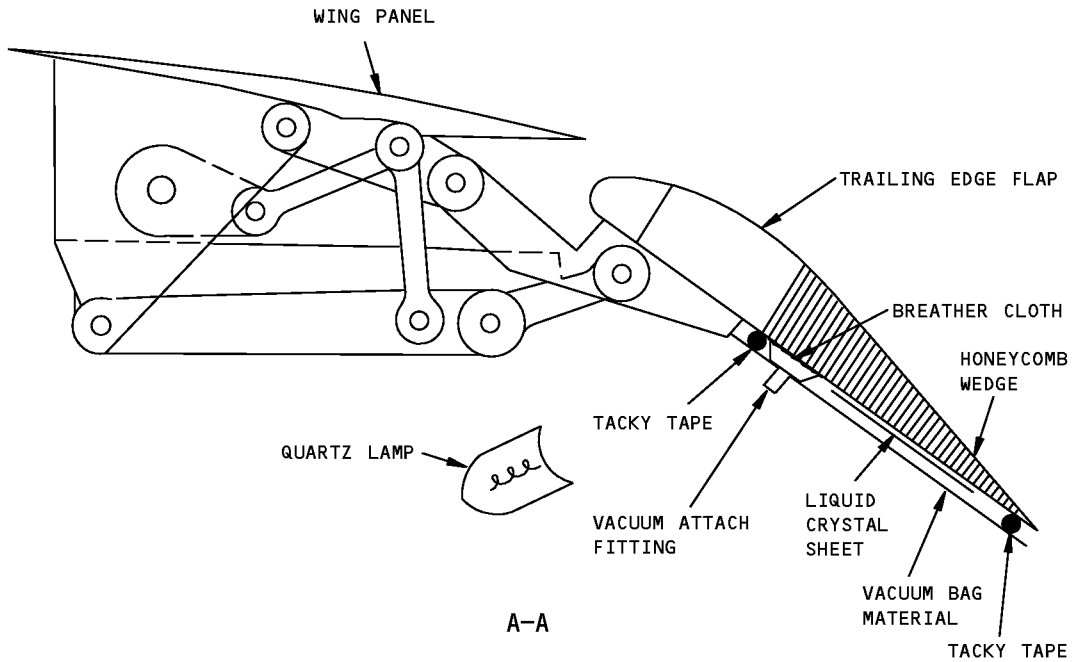
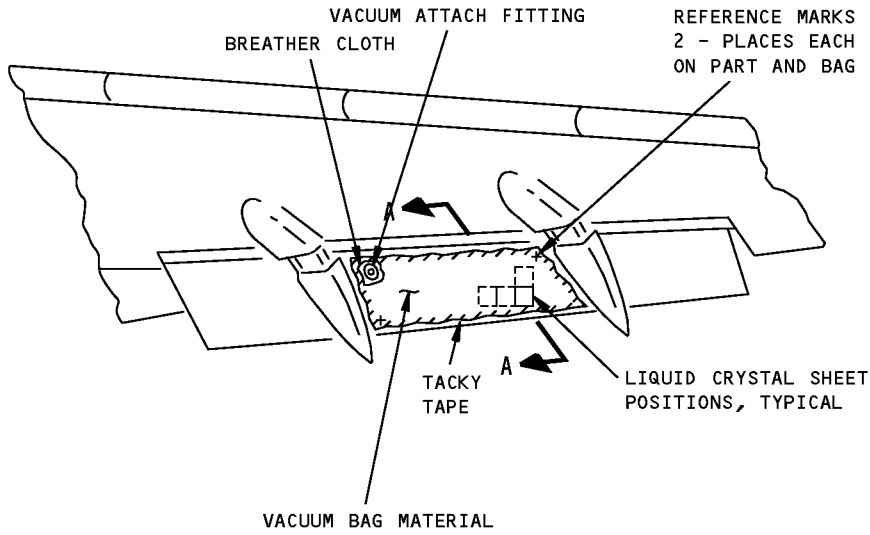


**PORTABLE VACUUM FRAME PROCEDURE
DETAIL II**

**Example Thermographs
Figure 5**

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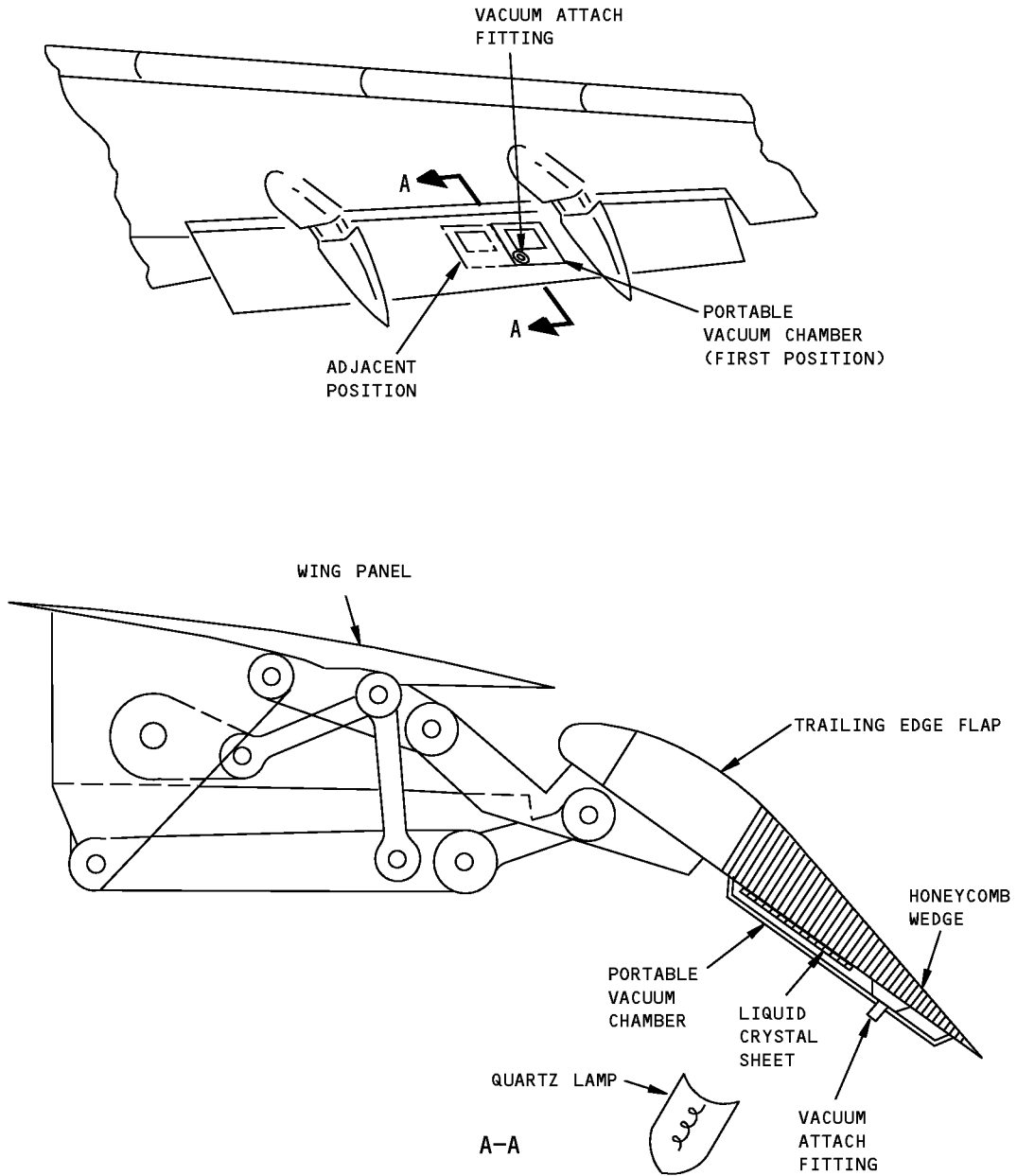
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**Example of How to Position Liquid Crystal Sheets and Vacuum Bag
Figure 6**

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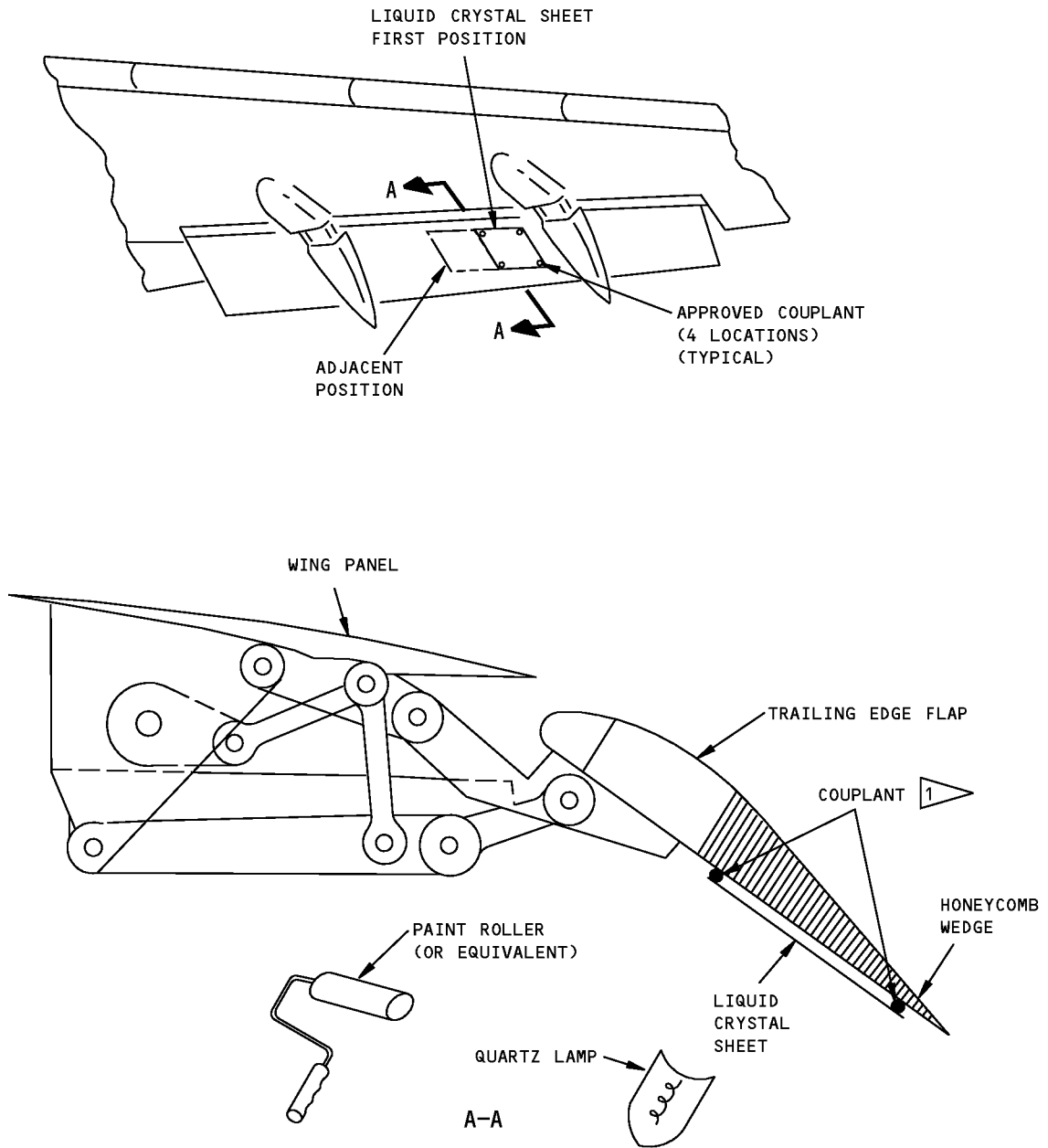


PORTABLE VACUUM FRAME MANUFACTURER: TORR TECHNOLOGIES INC.,
1-37TH ST NW UNITE, AUBURN, WA., 98001-1715, 206-735-9115,
FAX 206-735-0437

**Example of How to Position The Portable Vacuum Chamber
Figure 7**

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1 USE A SMALL AMOUNT OF COUPLANT SINCE THE INSPECTION IS NOT VALID AT THE COUPLANT LOCATIONS

**Example of How to Position the Liquid Crystal Sheet with the Couplant Attachment Procedure
Figure 8**

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PART 9 - THERMOGRAPHY

PULSED THERMOGRAPHY INSPECTION FOR DISBONDS IN BONDED ALUMINUM STRUCTURE

1. Purpose

A. Use this procedure to do an inspection to find disbonds in bonded aluminum structure.

NOTE: This procedure cannot be used to find skin-to-core disbonds.

B. An infrared camera and an imaging system are necessary to do this procedure.

C. This procedure can be used to find 1 x 1 inch (25.4 x 25.4 mm) disbonds below first layer skins that are 0.08 inch (2.0 mm) thick or less.

D. This procedure can only be used to find disbonds that are between the 1st and 2nd layers of aluminum.

2. Equipment

A. General

(1) Use an infrared camera and an imaging system 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. Instruments

(1) Use an infrared camera that:

(a) Has a temperature sensitivity (Noise Equivalent Temperature Difference - $NE\Delta T$) that is 0.1 °C, or less.

(b) Has a dynamic range of 12 bits or more and a digital output (RS-422) at 30 Hz or more.

(c) Gives a good thermal image with high spatial resolution (256 x 256 pixel arrays, or more, are recommended).

(d) Has a frame rate of 30 Hertz or more.

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

(a) Radiance 1; Amber, a Raytheon Co.

(b) Thermocam SC1000; FLIR/Inframetrics

(c) Merlin Mid; Indigo systems

(d) SC3000; FLIR

C. Heat Source

(1) Photographic flash lamps must be used as the heat source to make sure that a fast pulse of energy is supplied to the part.

(2) Two flash lamps with power supplies of at least 4000 Watt-seconds are recommended.

(3) The lamps that follow were used to help prepare this procedure.

(a) Power Supply 6400; Balcar

(b) Power Supply A4000-PS; Norman

(c) Lamps are contained in an Illumination Head Assembly; Thermal Wave Imaging Inc.

D. Image Acquisition and Processing System

(1) The system that follows was used to help prepare this procedure.

(a) EchoTherm (R) version 6.4; with Thermal Wave Imaging MOSAIQ (TM) version 3.1

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- (2) Thermal Wave Imaging, Image Acquisition and Processing System is necessary to do this procedure (Figure 1). It is used to:
 - (a) Make sure that the flash lamp energy is synchronized with the recorded infrared images.
 - (b) Make a record of the thermal images.
 - (c) Process the recorded images to identify disbonds.

E. Reference Standards

- (1) Use reference standard NDT1092-t₁/t₂ or NDT1093-t₁/t₂. See Figure 2 and Figure 3 for data about the reference standards.
- (2) Ultrasonic reference standards that were prepared for other procedures can be used if they agree with the conditions specified in Paragraph 3.A..

NOTE: If your airplane is painted, the reference standards must be painted with external airplane paint before they can be used with this inspection procedure.

NOTE: If the reference standard contains a Teflon insert, it can be difficult to identify the disbond. If you can see a disbond in a reference standard with a Teflon insert, it will be easy to see a disbond on the airplane.

F. Surface Finishes**(1) Paint**

- (a) If your airplane is not painted, water washable paint is applied to the inspection area of your airplane to increase the infrared energy emission from the inspection surface.
 - 1) Tempera Paint, available from the Crayola Company, was used to help prepare this procedure.

(2) Wax

- (a) External airplane wax can be used to decrease reflections from the inspection surface to make for a better inspection.

3. Preparation for Inspection

A. Make a selection of the correct reference standard. See Figure 2 or Figure 3. Use a reference standard with:

- (1) A first layer thickness (t₁) that is not less than 0.02 inch (0.5 mm) thinner than the first layer skin thickness on the airplane that you will examine.
- (2) A second layer thickness (t₂) that is not more than 0.01 inch (0.3 mm) thicker than the doubler on the structure that you will examine.

B. Prepare the reference standard for calibration as follows:

NOTE: With this procedure, it is not possible to examine aluminum surfaces that are not painted. You must prepare the reference standard and airplane surfaces to make sure that disbonds can be identified.

- (1) If your airplane is painted:
 - (a) Use a reference standard that is painted with the same paint that is on the airplane to be examined.
 - (b) You can apply a layer of external airplane wax, or an equivalent material, to the painted reference standard if reflections do not allow you to see the disbond image. Use a paint roller to apply a thick, even layer. This will keep the background reflections from the reference standard to a minimum and improve the inspection sensitivity.
- (2) If your airplane is not painted:

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- (a) Apply a smooth layer of black, water-washable paint to the reference standard. Make sure the layer is smooth and that its thickness is sufficient so that when you do the inspection on the airplane, you will not get reflections from the surface of the airplane. The paint that follows was used to help prepare this procedure:

1) Tempera Paint; Crayola Company

- (3) Let the wax or the paint dry before you do the inspection.

C. Prepare the airplane for the inspection as follows:

(1) Get access to the inspection area.

(2) Remove loose paint, dirt, or grease from the surface of the inspection area.

(3) If your airplane is painted, prepare the surface to be examined as specified in Paragraph 3.B.(1).

NOTE: Wax was used to decrease the reflections from the surface of the airplane because it will not damage the airplane surface and the airplane surface will be clean when it is removed after the thermography inspection.

(4) If your airplane is not painted, prepare the surface to be examined as specified in Paragraph 3.B.(2).

(5) Let the wax or the paint dry before you do the inspection.

4. Instrument Calibration

A. Make a selection of a reference standard that is identified in Paragraph 3.A.

B. Prepare the reference standard as specified in Paragraph 3.B.

C. Energize the Thermal Wave Imaging inspection system. Use the manufacturers' instructions and let the camera cool to its operation temperature.

D. Use the manufacturers' instructions to do a non-uniformity calibration on the infrared camera. Make sure that the auto gain mode is off.

E. Adjust the focus of the infrared camera until you get a good image of the surface.

F. Adjust the TWI system software as follows:

(1) Start the MOSAIQ software program.

(2) Click on the "New" button, then the Live button on the MOSAIQ 3.1 software to show the "Inspection Grid" menu. See Figure 4.

(3) Click OK on the Inspection Grid menu to show the "Live Capture" menu. See Figure 4.

(4) Click on the right arrow on the "Live Capture Control" menu. See Figure 4.

(a) Adjust the duration with the slider bar so that there is sufficient time for the heat to get to the back of the part. Make an estimate of the necessary time if you have not examined the material or thickness before. The log-log plot will be monitored during Paragraph 4.F.(5) to make sure the part is monitored for a sufficient quantity of time.

(b) Decrease the frame rate (make the fps smaller) from the pull down menu, if necessary, to increase the time necessary to get the images.

(c) Put the reference standard below the inspection head.

(d) Click "Run" on the Live Capture Control menu and OK on the pop-up dialog box to begin the test.

(e) Hold the inspection head stable (without movement) until the image has been recorded.

(5) Examine the image as follows:

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- (a) Use the log-log plot to make sure that the quantity of time you collected images with the camera was sufficient.
 - 1) Click on the "tool" pull down menu and select the T_T curve.
 - 2) Click on an area of the image that does not have a disbond to put a time/temperature cursor on the thickest area of the reference standard.
 - 3) Make sure that the curve shown on the log-log plot changes from the initial slope and becomes horizontal (see Figure 5, Detail II). If the curve does not become horizontal, you must increase the duration time to get more images and do Paragraph 4.F.(2) thru Paragraph 4.F.(5) again.
 - 4) Record the duration time that causes a horizontal T_T curve on the log-log plot to occur (see Figure 5). It is necessary to know this time when you start the inspection.
 - (b) Select the 1d or 2d buttons to view the first or second derivative images and adjust the time step slider bar and contrast until you get the best image of the disbond. You can look at the movie to help to identify the time where the disbond is easiest to identify.
- (6) Make a record of the time that is necessary to get the maximum contrast for the images processed with the 1d and 2d functions. The maximum contrast time can be different for the best 1d and 2d images. These time values will be used during the inspection and can be used during subsequent inspections to decrease the time necessary to calibrate the equipment.

5. Inspection Procedure

A. Examine areas of bonded aluminum structure for disbonds as follows:

- (1) Make sure that the TWI system is adjusted as specified in Paragraph 4. for the applicable skin thickness range.
- (2) Make the adjustments to the software that follow:
 - (a) Select "New" from the MOSAIQ main menu to show the "Inspection Grid" menu. See Figure 4.
 - (b) Identify the grid pattern you will use to examine the inspection area and adjust the rows and columns so it agrees with the inspection area you will examine. See Figure 4.
NOTE: It can be necessary to examine some areas that are smaller than the full inspection area.
 - (c) Set the grid pattern you will use to examine the inspection area and click OK.
 - (d) Click on the Auto Save Setup box in the Live Capture Control Menu.
 - (e) Click on the "Select Folder and Base Name" button in the Auto Save Setup menu.
 - (f) Make a new folder and name it to help identify the area you will examine.
 - (g) Put in a filename and click save.
 - (h) Put a number in the "starting with" box or click on append date and time.
 - (i) Click on the TSR filetype box and click OK.
 - (j) Adjust the duration on the Live Capture Control menu to the time you recorded in Paragraph 4.F.(5)(a)4).
- (3) Put the inspection head at one corner of the inspection area. See Figure 6.
- (4) Adjust the inspection system to examine the inspection area.
 - (a) During the inspection of a skin panel, it is necessary to record the infrared images that follow in the mosaic.
 - 1) Images from locations that are forward and aft of the butt splices (across adjacent butt splices).

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- 2) Images that are above and below the lap splices (across adjacent lap splices).
- (5) Press Run to begin the data inspection.
- (6) Hold the inspection head at the inspection location, without movement, until all images are recorded. This will take approximately 6 seconds.
- (7) Move the TWI system to the next adjacent inspection area. Make sure that subsequent inspection areas overlap each other by at least 1 inch (25.4 mm). It is necessary to calibrate the equipment again when the conditions that follow occur:
 - (a) The skin thickness (t1) in the inspection area is more than 0.02 inch (0.5 mm) thicker than the reference standard thickness (t1) used for calibration.
 - (b) The doubler thickness (t2) in the inspection area is more than 0.01 inch (0.3 mm) thinner than the reference standard thickness (t2) used for calibration.
 - (c) A different camera lens is used that changes the field of view.
- (8) Do Paragraph 5.A.(4) thru Paragraph 5.A.(7) until the inspection area is examined.
- (9) Do Paragraph 5.A.(2) thru Paragraph 5.A.(8) until the full inspection area is examined.
- (10) Make an analysis of the processed images identified at the times specified in Paragraph 4.F.(6) for the 1d and 2d processed images. The inspection area can have a disbond if:
 - (a) The shape of a doubler is gone.
 - (b) The brightness in the area above a doubler is the same as the single skin (See Figure 7 and Figure 8).
 - (c) The contrast or brightness in an area of the image looks different than an adjacent area with the equivalent thickness.
- (11) Make a record of the disbond data.
 - (a) Use the instructions that follow to identify the disbonds on the airplane or to make a record of each disbond image:
 - 1) Keep the disbond image on a digital storage system to use as a permanent record.
 - 2) Make a record of the disbond location on the airplane. Use an approved pencil or marker to identify the disbond area on the airplane surface.

NOTE: The color of the disbond is a function of how the image is processed and the time that the processed image is monitored. Refer to images of the reference standard to identify the time when the contrast is a maximum.

- (12) To do more operations on the MOSAIQ data, refer to the TWI EchoTherm System User Manual.

6. Inspection Results

- A. Local areas above the doubler that are a different color or gray scale level than other doubler images are disbond indications. Make sure that these areas that you identify do not occur in areas that do not contain doublers.
- B. Compare the disbond indications with drawings of the inspection area.
- C. Compare the disbond image with the image you recorded during calibration.
- D. Compare an area with a disbond indication to an adjacent area with an equivalent skin and doubler configuration. These areas must look equivalent.
- E. Use a different NDT procedure, if possible, to make sure of the results.

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- (1) Use Part 4, 51-00-05 (Low Frequency Bondtester) or Part 4, 51-00-01 (High Frequency Bondtester).

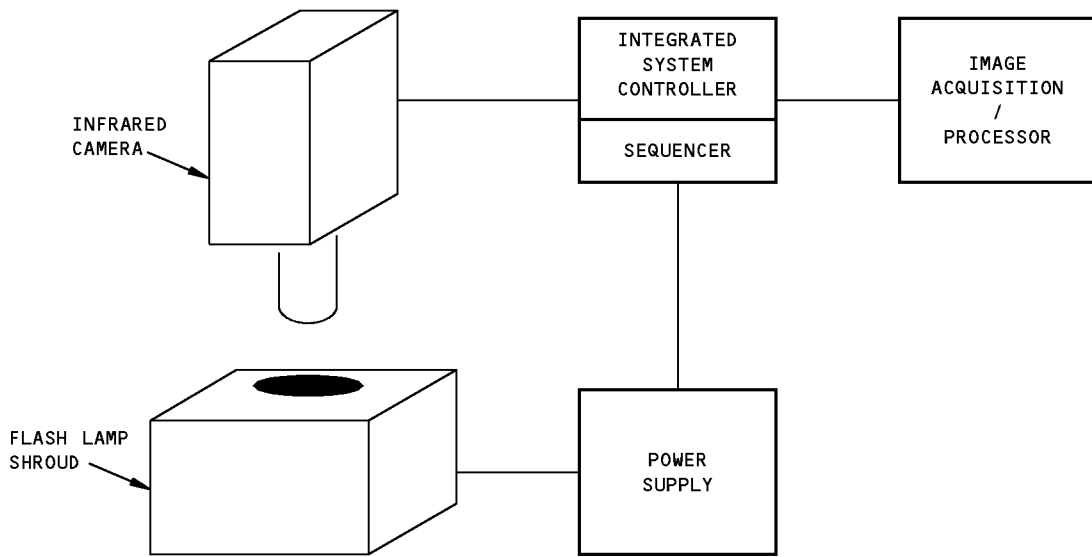
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**Infrared Disbond System Block Diagram
Figure 1**

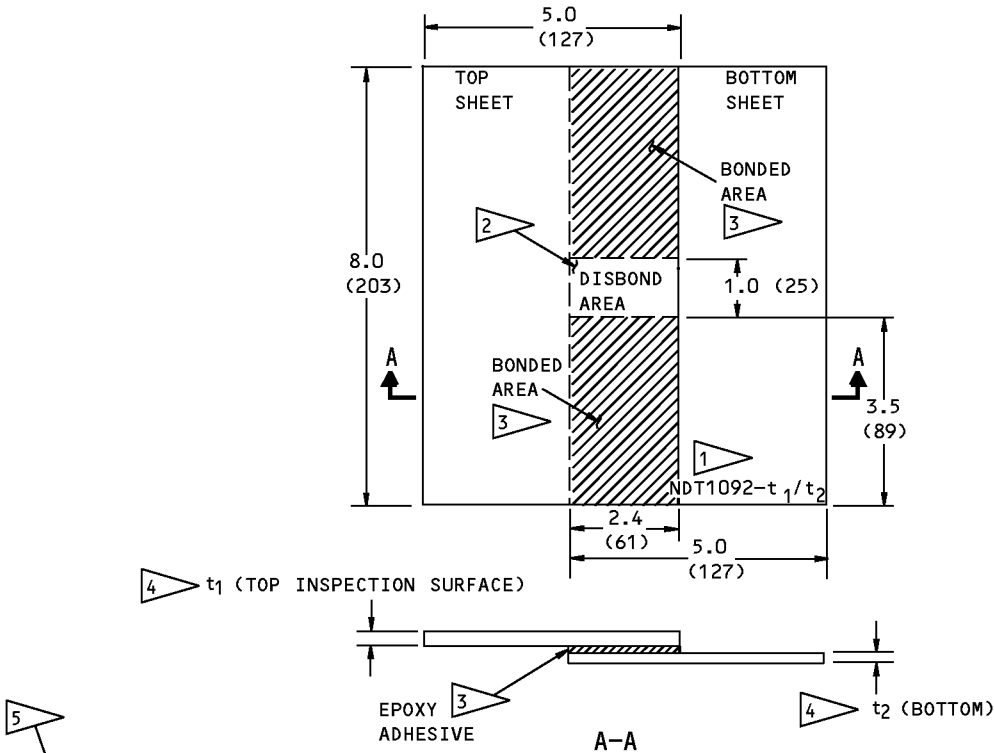
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t ₁ TOP	t ₂ BOTTOM	AIRPLANE SKIN THICKNESS RANGE (t ₁)	AIRPLANE DOUBLER MINIMUM THICKNESS (t ₂)
0.040 (1.02)	0.016 (0.4)	0.020 - 0.040 (0.51 - 1.02)	0.014 (0.36)
0.040 (1.02)	0.032 (0.8)	0.020 - 0.040 (0.51 - 1.02)	0.022 (0.56)
0.050 (1.27)	0.040 (1.02)	0.030 - 0.050 (0.76 - 1.27)	0.030 (0.76)
0.071 (1.80)	0.056 (1.42)	0.051 - 0.071 (1.30 - 1.80)	0.046 (1.17)

NOTES

• ALL DIMENSIONS ARE IN INCHES (MILLIMETERS ARE IN PARENTHESES)

• DIMENSION TOLERANCES:

<u>INCHES</u>	<u>MILLIMETERS</u>
X.XXX = ±0.005	X.XX = ±0.10
X.XX = ±0.025	X.X = ±0.5
X.X = ±0.050	X = ±1

• MATERIAL: 2000 SERIES ALUMINUM, CLAD OR BARE

1 ETCH OR SCRIBE THE REFERENCE STANDARD NUMBER NDT1092-t₁/t₂. t₁ IS THE THICKNESS OF THE TOP SHEET AND t₂ IS THE THICKNESS OF THE BOTTOM SHEET.

2 TO MAKE THE DISBOND AREA, DO NOT APPLY ADHESIVE IN THIS AREA. YOU CAN USE A TEFLON INSERT THAT IS THE APPROXIMATE THICKNESS OF THE EPOXY ADHESIVE. THE INSERT WILL NOT LET THE ADHESIVE FLOW INTO THE DISBOND AREA.

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

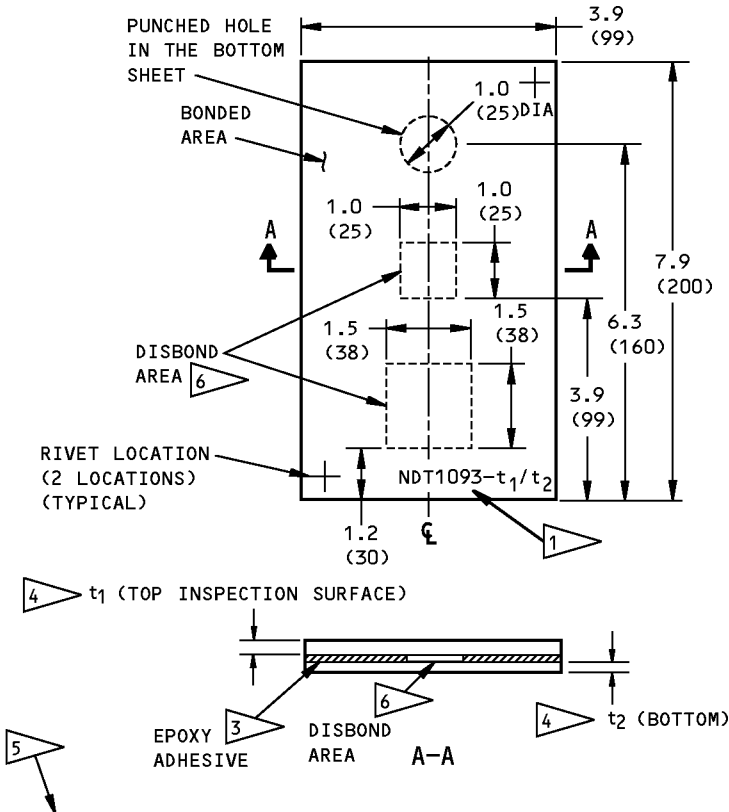
4 CHOOSE THE t₁ AND t₂ SHEET THICKNESSES FROM TABLE 1 ABOVE FOR THE STRUCTURE THICKNESSES TO BE EXAMINED.

5 THE TABLE IDENTIFIES SOME SKIN THICKNESS CONFIGURATIONS. OTHER t₁ AND t₂ CONFIGURATIONS CAN BE MADE AS NECESSARY. THE RANGE IDENTIFIES THE SKIN THICKNESSES ON THE AIRPLANE THAT CAN BE EXAMINED WITH THE SPECIFIED t₁ AND t₂ THICKNESS OF THE REFERENCE STANDARD.

Reference Standard NDT1039-t₁/t₂
Figure 2

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PROCEDURE TO MAKE THE REFERENCE STANDARD:

- PUNCH THE 1 INCH DIAMETER (25 mm) HOLE IN THE BOTTOM ALUMINUM SHEET
- APPLY A SHEET OF BONDING LAYER TO THE BOTTOM SHEET AND CUT OUT THE BONDING LAYER AT THE DIBOND AREAS SHOWN BY FLAG NOTE 6
- APPLY THE SPECIFIED TOP SHEET AND BOND THE ALUMINUM SHEETS TOGETHER
- PUT A SAND BAG THAT WEIGHS APPROXIMATELY 25 LBS (12 KG) ON THE REFERENCE STANDARD TO MAKE SURE THE SHEETS ARE IN GOOD CONTACT DURING THE CURE
- CURE THE REFERENCE STANDARDS. THE CURE TIME IS DIFFERENT FOR DIFFERENT TYPES OF ADHESIVES
- DO A TEST OF THE REFERENCE STANDARD WITH THE INFRARED INSPECTION SYSTEM.

NOTE: TO PREVENT MOVEMENT BETWEEN THE ALUMINUM LAYERS DURING THE CURE PROCESS, IT IS HELPFUL TO ATTACH THE SHEETS WITH A SMALL RIVET OR BOLT.

t ₁ TOP	t ₂ BOTTOM	AIRPLANE SKIN THICKNESS RANGE (t ₁)	AIRPLANE DOUBLER MINIMUM THICKNESS (t ₂)
0.040 (1.02)	0.016 (0.4)	0.020 - 0.040 (0.51 - 1.02)	0.014 (0.36)
0.040 (1.02)	0.032 (0.8)	0.020 - 0.040 (0.51 - 1.02)	0.022 (0.56)
0.050 (1.27)	0.040 (1.02)	0.030 - 0.050 (0.76 - 1.27)	0.030 (0.76)
0.071 (1.80)	0.056 (1.42)	0.051 - 0.071 (1.30 - 1.80)	0.046 (1.17)

NOTES:

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

<u>INCHES</u>	<u>MILLIMETERS</u>
X.XXX = ±0.005	X.XX = ±0.10
X.XX = ±0.025	X.X = ±0.5
X.X = ±0.050	X = ±1
- MATERIAL: 2000 SERIES ALUMINUM, CLAD OR BARE

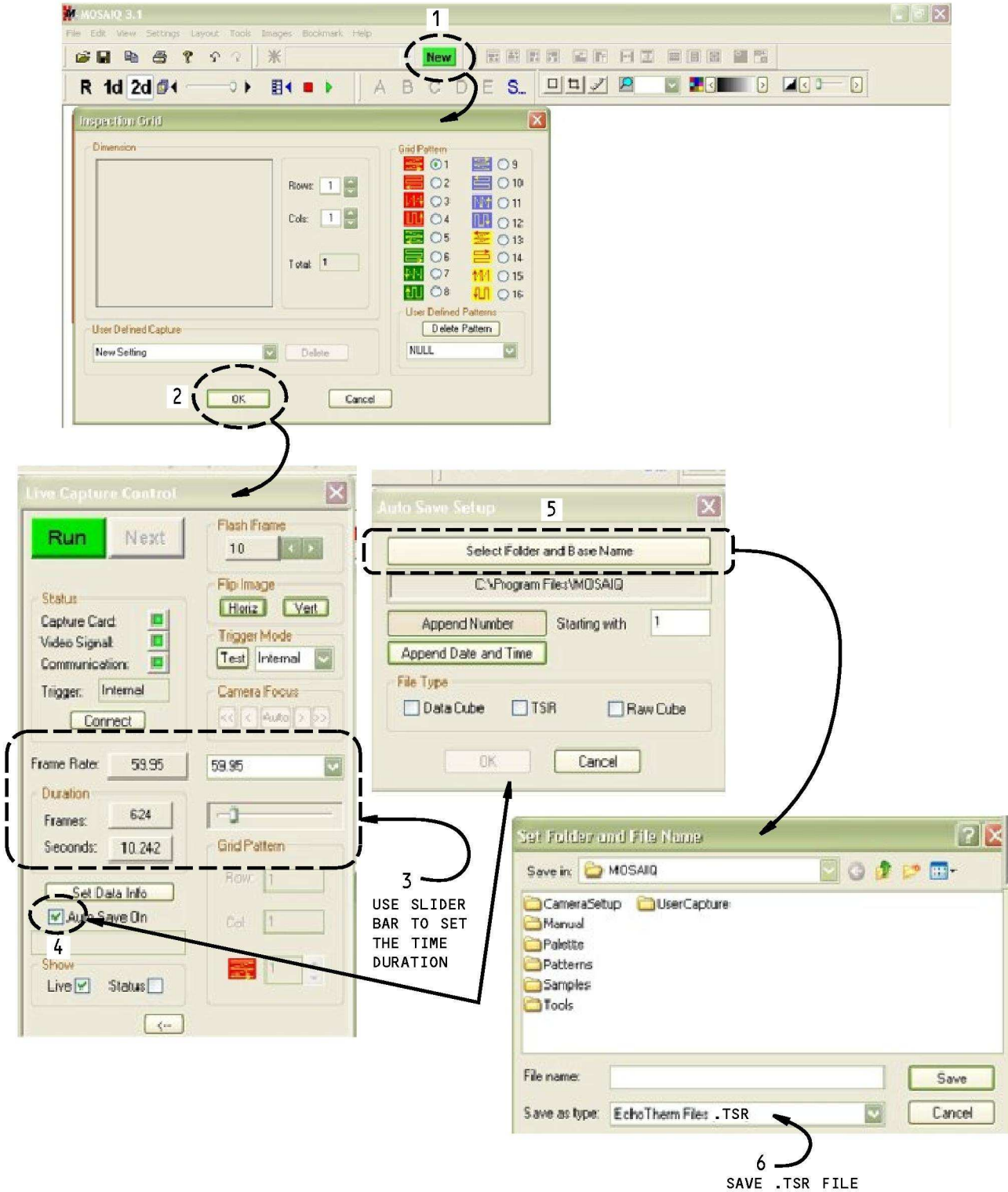
1 ETCH OR SCRIBE THE REFERENCE STANDARD NUMBER NDT1093-t₁/t₂. t₁ IS THE THICKNESS OF THE TOP SHEET AND t₂ IS THE THICKNESS OF THE BOTTOM SHEET.

- 2 TO MAKE THE DISBOND AREA, DO NOT APPLY ADHESIVE IN THIS AREA. YOU CAN USE A TEFLON INSERT THAT IS THE APPROXIMATE THICKNESS OF THE EPOXY ADHESIVE. THE INSERT WILL NOT LET THE ADHESIVE FLOW INTO THE DISBOND AREA.
- 3 USE AN EPOXY ADHESIVE THAT IS 0.004 - 0.005 (0.10 - 0.13) THICK FOR SUFFICIENT STRENGTH.
- 4 CHOOSE THE t₁ AND t₂ SHEET THICKNESSES FROM TABLE 1 ABOVE FOR THE STRUCTURE THICKNESSES TO BE EXAMINED.
- 5 THE TABLE IDENTIFIES SOME SKIN THICKNESS CONFIGURATIONS. OTHER t₁ AND t₂ CONFIGURATIONS CAN BE MADE AS NECESSARY. THE RANGE IDENTIFIES THE SKIN THICKNESSES ON THE AIRPLANE THAT CAN BE EXAMINED WITH THE SPECIFIED t₁ AND t₂ THICKNESS OF THE REFERENCE STANDARD.
- 6 CUT OUT THE BONDING LAYER IN THE DISBOND AREAS.

Reference Standard NDT1093-t₁/t₂
Figure 3

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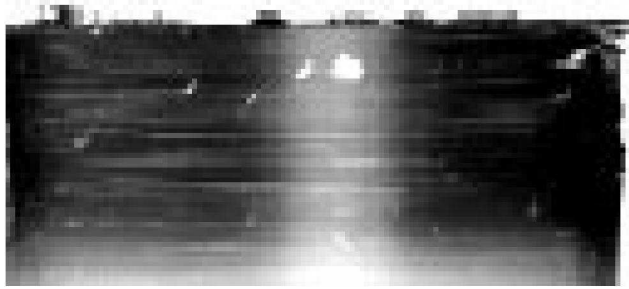
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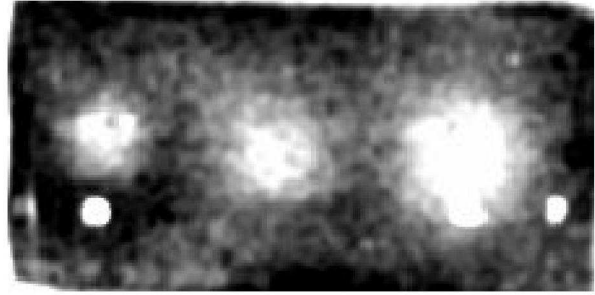
MOSAIQ Software Screen Displays
Figure 4

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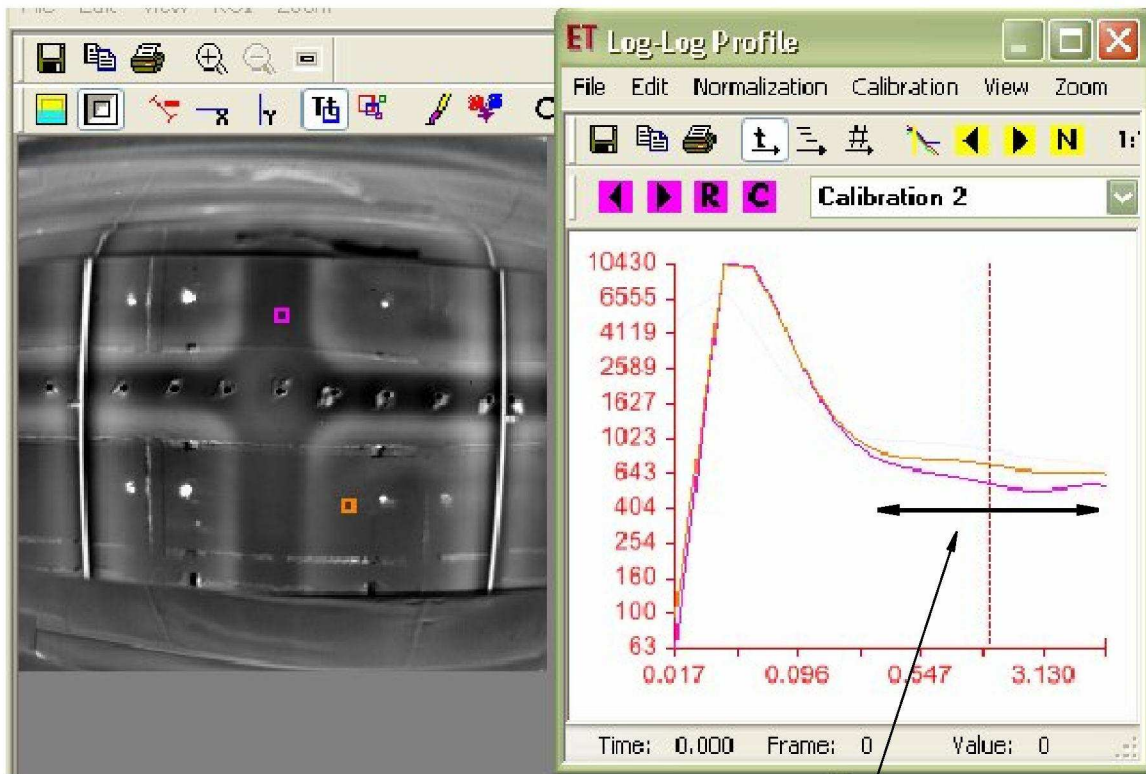


REFERENCE STANDARD NDT1092-040/040



REFERENCE STANDARD NDT1093-050/040

DETAIL I

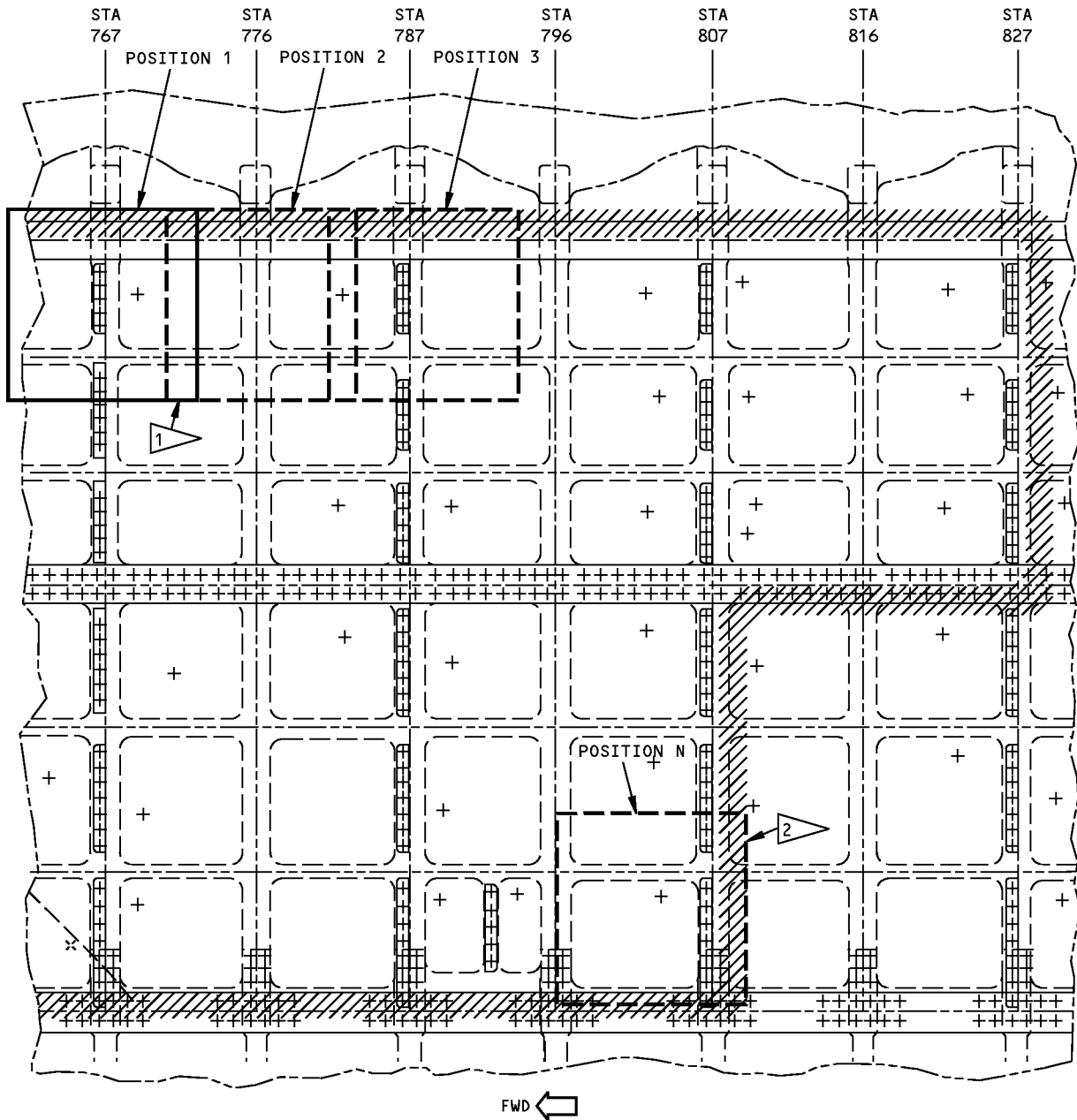


DETAIL II

**Disbond Images
Figure 5**

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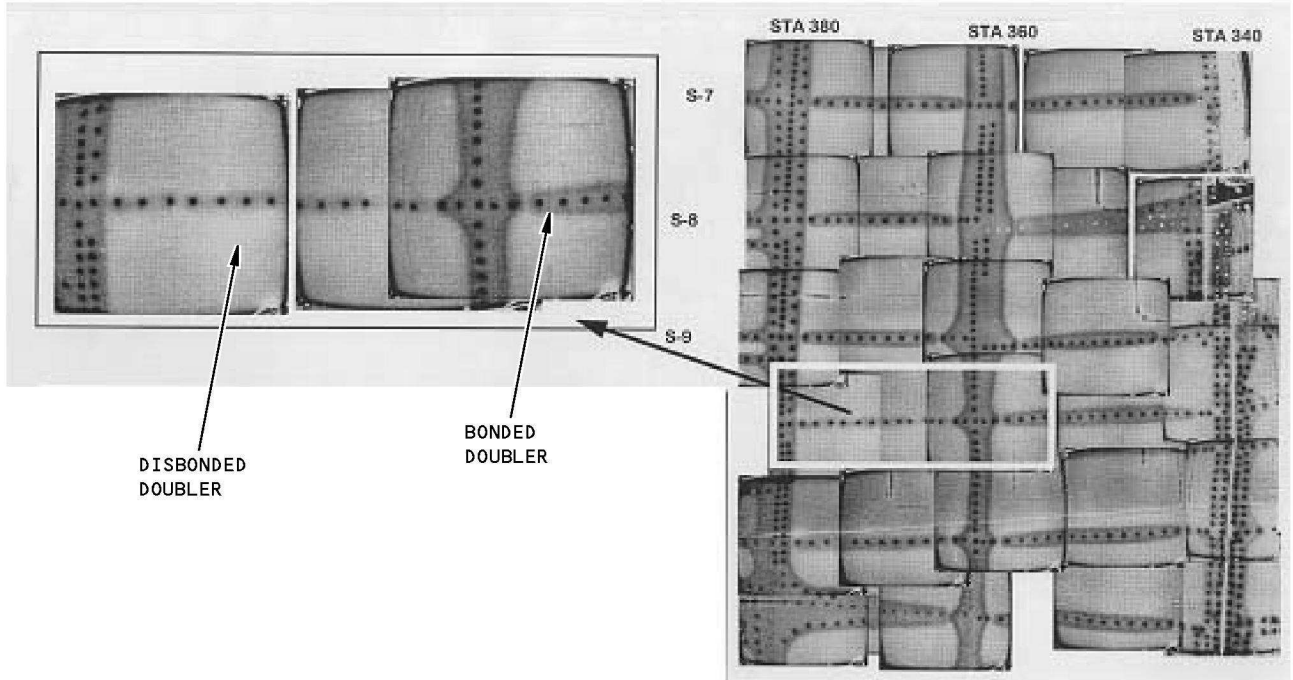
- 1 MAKE SURE THE INSPECTION AREA OVERLAPS THE LAST INSPECTION AREA BY 1 INCH (25.4 MM).
- 2 PUT THE SENSOR HEAD AT ADJACENT INSPECTION AREAS UNTIL THE FULL AREA HAS BEEN EXAMINED.

**Typical Sensor Head Placement
Figure 6**

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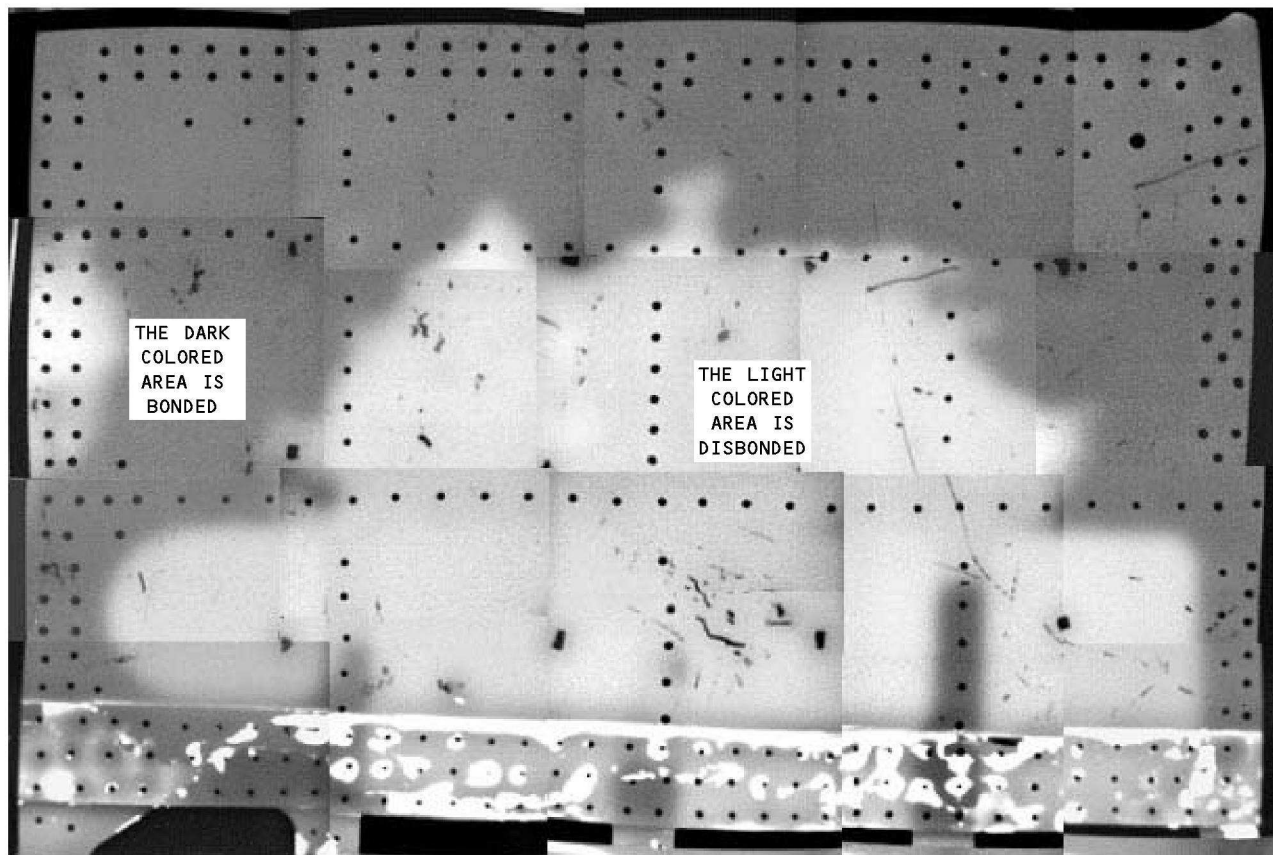
**Disbonded Doubler
Figure 7**

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NOTE:

- THE AREA SHOWN IS NOT CHEM MILLED.

**Complete Image of the Skin with Disbonded Doublers- Made from Individual Images
Figure 8**

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PART 9 - THERMOGRAPHY

LOCK-IN THERMOGRAPHY INSPECTION FOR DISBONDS IN BONDED ALUMINUM STRUCTURE

1. Purpose

A. Use this procedure to find disbonds in bonded aluminum structure.

NOTE: This procedure cannot be used to find skin-to-core disbonds.

B. An infrared camera and an IRLockin® (Version 4.0) Imaging System are necessary to do this procedure.

C. This procedure can be used to find 1 x 1 inch (25.4 x 25.4 mm) disbonds that are below first layer skins that are 0.08 inch (2.0 mm) thick or less.

D. This procedure can only be used to find disbonds that are between the 1st and 2nd layers of aluminum.

E. To do this procedure, calibration programs must be made and supplied by the IRLockin system manufacturer for the skin thickness ranges to be examined. It is necessary to identify all possible skin thickness configurations when you purchase the Lockin system to make sure that all necessary calibration programs are supplied. The calibration instructions in this procedure will let you calibrate the IRLockin system only after calibration programs have been supplied by the IRLockin system supplier, or made by an inspector who has been trained by the system manufacturer to make calibration programs.

2. Equipment

A. General

(1) Use an infrared camera and an imaging system that can be calibrated on the reference standards shown in Figure 1 or Figure 2.

B. Instruments

(1) Use an infrared camera that:

(a) Has a temperature sensitivity (Noise Equivalent Temperature Difference - NETD) that is 0.03 °C, or less. more.

(b) Has a dynamic range of 12 bits or more and a digital output of (RS-422) at 50 Hz or more. recommended).

(c) Gives a good thermal image with high spatial resolution (320 x 240 pixel arrays, or more, are recommended).

(d) Has a frame rate of 50 Hertz or more.

(2) The instrument that follows was used to help prepare this procedure.

(a) SC3000; FLIR

C. Heat Source

(1) A heat source with sufficient thermal power is necessary. The heat source must fully heat the area that the infrared camera monitors. Many images of the inspection area are usually necessary to fully examine the inspection area. The heat source that follows was used to help prepare this procedure.

(a) Halogen Lamp Panel with 16000 Watts of power

D. Image Acquisition and Processing System

(1) IRLockin System (Version 4.0) is necessary to do this procedure. It is used to:

(a) Trigger the heat source and control the excitation frequency.

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- (b) Make a record of the thermal images.
- (c) Examine the recorded images to identify disbonds.

E. Reference Standards

- (1) Use reference standard NDT1092-t1/t2 or NDT1093-t1/t2. See Figure 1 or Figure 2 for data about the reference standards.

NOTE: The surface of the reference standards must be equivalent to the surface of the airplane you will examine.

NOTE: Reference standards for ultrasonic calibration can be made with Teflon inserts to simulate a disbond. For the thermographic inspection, this type of reference standard can be difficult to calibrate the infrared equipment.

F. Surface Finishes**(1) Paint**

- (a) If your airplane surface is not painted, water washable paint is applied to the inspection area of your airplane to increase the emissivity of the inspection surface.

(2) Wax

- (a) External airplane wax can be used to decrease reflections from the surface of a painted airplane.

3. Preparation for Inspection

- A. Make a selection of the correct reference standard. Refer to Figure 1 or Figure 2.

- B. Make sure that you have the necessary calibration programs to let you calibrate the system for the skin thickness ranges that you will examine. These programs must be supplied by the manufacturer or by a qualified inspector who has been trained by the manufacturer.

- C. Prepare the reference standard for calibration as follows:

NOTE: You must prepare the surfaces of the reference standard and the inspection area so that they are equivalent to make sure that disbonds can be identified. This procedure cannot examine aluminum surfaces that are not painted.

(1) If your airplane is painted:

- (a) Use a reference standard that is painted with the same paint that is on the area to be examined.
- (b) You can apply a layer of external airplane wax or an equivalent material to the painted reference standard if reflections do not allow you to see the disbond image. Use a paint roller to apply a thick, even layer. This will keep the background reflections from the reference standard to a minimum and improve the inspection sensitivity.

(2) If the area to be examined is not painted:

- (a) Apply a smooth layer of water washable paint to the reference standard. Make sure the layer is smooth and that its thickness is sufficient so that when you do the inspection, you will not get reflections from the surface.
- (b) Tempera paint, made by the Crayola Company, or an equivalent paint, can be used as a temporary layer of paint because it is water washable.

(3) Make sure that the wax or the paint is dry before you do the inspection.

- D. Prepare the area to be examined for the inspection as follows:

- (1) Get access to the inspection area.
- (2) Remove loose paint, dirt or grease from the surface of the inspection area.

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- (3) If your airplane surface is not painted, apply water washable paint to the inspection area of your airplane to increase the emissivity of the inspection surface.
- (4) Apply external airplane wax, if necessary, to decrease reflections from the surface of a painted airplane.

NOTE: Wax can be used to decrease the reflections from the surface because it will not damage the surface and the surface will be clean when the wax is removed after the thermography inspection.

- (5) Let the wax or the paint dry before you do the inspection.

4. Instrument Calibration

- A. Use the manufacturer's instructions to do a non-uniformity calibration on the infrared camera.
- B. Make a selection of a reference standard that is identified in Figure 1 or Figure 2. Prepare the reference standard as specified in Paragraph 3.
- C. Energize the IRLockin inspection system. Use the manufacturer's instructions and let the camera cool down to its operation temperature.
- D. Adjust the focus of the infrared (IR) camera until you get a good image of the surface.
- E. Adjust the IRLockin system as follows:
 - (1) Select color greyscale.pal.
 - (2) Load the calibration program necessary for the skin thickness range you will examine.

NOTE: The equipment manufacturer must supply calibration programs for the skin thickness ranges you will examine. If a calibration program is not available for the skin thickness to be examined, you must ask the equipment manufacturer to do the tests necessary to make a calibration program for the skin thickness range you will examine. The calibration program can also be made by a qualified inspector who is trained by the manufacturer.

- (3) Put your reference standard in front of your IR camera. Use the maximum distance between the infrared camera and your reference standard that will be used when you examine the airplane. The field of view must be less than 78 X 59 inches (2 X 1.5 meters).
- (4) Put the heat source in front of the reference standard. Use the maximum distance between the heat source and reference standard that will be used when you examine the airplane.
- (5) Put the data about your reference standard in the Analysis Parameter window of the software.
- (6) Press the RUN Hotkey to start the measurement. The program will start to energize the heat source with data specified by the calibration program. The display window on the monitor will show the bonded areas.
- (7) Make the result image as good as you can with the brightness and span (contrast) controls as you monitor the phase image. The result image must clearly identify the disbonded and bonded areas.
- (8) Put the completed results in your data file storage.

5. Inspection Procedure

- A. Examine areas of bonded aluminum structure for disbonds as follows:
 - (1) Make sure that the Lock-in system is adjusted as specified in Paragraph 4. for the applicable skin thickness range.
 - (2) Put the reference standard in opposite corners of the area to be examined. If it is necessary to get more than 1 image to examine the complete inspection area, it is only necessary to put the reference standard on the first and last images if the skin thicknesses are constant in the inspection area.

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- (3) Adjust the inspection system to examine the first inspection area.
 - (a) If the inspection area is larger than the field of view of the infrared camera, make sure that the inspection area is fully examined. The maximum permitted field of view is 78 X 59 inches (2 X 1.5 meters).
 - (b) Begin the examination in one corner of the inspection area.
 - (c) Continue to move to adjacent inspection areas and record the necessary data until the inspection area is fully examined.
- (4) During the inspection of a skin panel, it is necessary to overlap the adjacent infrared images a minimum of 10 inches (254 mm) at the locations that follow:
 - (a) Forward and aft of a butt splice.
 - (b) Above and below a lap splice.
- (5) It is necessary to calibrate the equipment again if a condition that follows occurs:
 - (a) If the skin or doubler thickness changes such that they are not in the ranges identified in Figure 1 or Figure 2 for the reference standard that the equipment was initially calibrated on.
 - (b) The inspection area is larger than the area used for calibration, but less than the maximum permitted inspection area 78 X 59 inches (2 X 1.5 meters).
 - (c) A different camera lens is used that changes the field of view.
- (6) During the inspection, frequently use the reference standards to do a check of the calibration of the IR Lockin system. If the calibration is not satisfactory to identify the disbond, then examine all areas again that were examined after the last satisfactory calibration check.
- (7) Put the data about your inspection area in the Analysis Parameter window of the software.
- (8) Press Run Hotkey to begin the measurement.
- (9) Make sure that the IR camera and the heat source are pointed at the inspection area without movement, until all images are recorded. The distance between the camera or heat source and the inspection surface must not be larger than the distances that were used during calibration.
- (10) Make an analysis of the phase image. Make the image as good as you can with the brightness and span controls. Make sure that disbonds on the reference standards are clearly seen. The inspection area can have a disbond if:
 - (a) The dark or light (cool) outline of a doubler is gone.
 - (b) The brightness in the area above a doubler is the same as the single skin (see Figure 4).
- (11) Make a record of the disbond data.
 - (a) Keep the disbond image on a digital storage system to use as a permanent record during repair.
 - (b) Make a record of the disbond location on the airplane for use during repair. Use an approved pencil or marker.
- (12) Move the IRLockin system to the adjacent inspection area. Make sure that subsequent inspection areas overlap each other by at least 1 inch (25.4 mm).
- (13) Do Paragraph 5.A. as many times as necessary until the full inspection area is examined.

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6. Inspection Results

- A. Doubler inspection areas that cause images to occur that are different in color or gray scale level than other doubler images are disbond indications. Compare your images with the images shown in Figure 3 or Figure 4. Make sure that the disbond areas you identify do not occur in an area that does not contain a doubler.

NOTE: Changes in thermal image analysis can cause a 180-degree phase change in the phase-image. The data from the phase-image is the same, but the image can be an inverse image. That means:

- Bonded areas can be white and disbonded areas dark, or,
- Bonded areas can be dark and disbonded areas white.

- B. Compare the disbond indications with drawings of the inspection area.
- C. Compare the disbond image with the image you recorded during calibration.
- D. Use a different NDT procedure, if possible, to make sure of the results.
- (1) Use Part 4, 51-00-05 (Low Frequency Bondtester) or,
 - (2) Use Part 4, 51-00-01 (High Frequency Bondtester).

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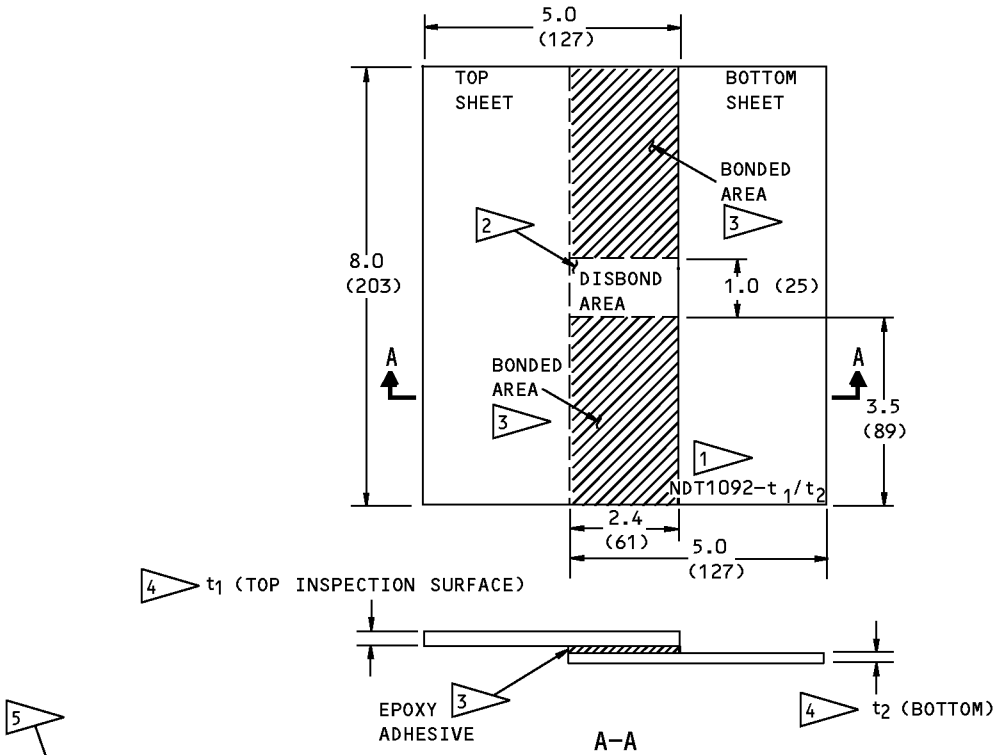
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t ₁ TOP	t ₂ BOTTOM	AIRPLANE SKIN THICKNESS RANGE (t ₁)	AIRPLANE DOUBLER MINIMUM THICKNESS (t ₂)
0.040 (1.02)	0.016 (0.4)	0.020 - 0.040 (0.51 - 1.02)	0.014 (0.36)
0.040 (1.02)	0.032 (0.8)	0.020 - 0.040 (0.51 - 1.02)	0.022 (0.56)
0.050 (1.27)	0.040 (1.02)	0.030 - 0.050 (0.76 - 1.27)	0.030 (0.76)
0.071 (1.80)	0.056 (1.42)	0.051 - 0.071 (1.30 - 1.80)	0.046 (1.17)

NOTES:

• ALL DIMENSIONS ARE IN INCHES (MILLIMETERS ARE IN PARENTHESES)

• DIMENSION TOLERANCES:

<u>INCHES</u>	<u>MILLIMETERS</u>
X.XXX = ±0.005	X.XX = ±0.10
X.XX = ±0.025	X.X = ±0.5
X.X = ±0.050	X = ±1

• MATERIAL: 2000 SERIES ALUMINUM, CLAD OR BARE

1 ETCH OR SCRIBE THE REFERENCE STANDARD NUMBER NDT1092-t₁/t₂. t₁ IS THE THICKNESS OF THE TOP SHEET AND t₂ IS THE THICKNESS OF THE BOTTOM SHEET.

2 TO MAKE THE DISBOND AREA, DO NOT APPLY ADHESIVE IN THIS AREA. YOU CAN USE A TEFLON INSERT THAT IS THE APPROXIMATE THICKNESS OF THE EPOXY ADHESIVE. THE INSERT WILL NOT LET THE ADHESIVE FLOW INTO THE DISBOND AREA.

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

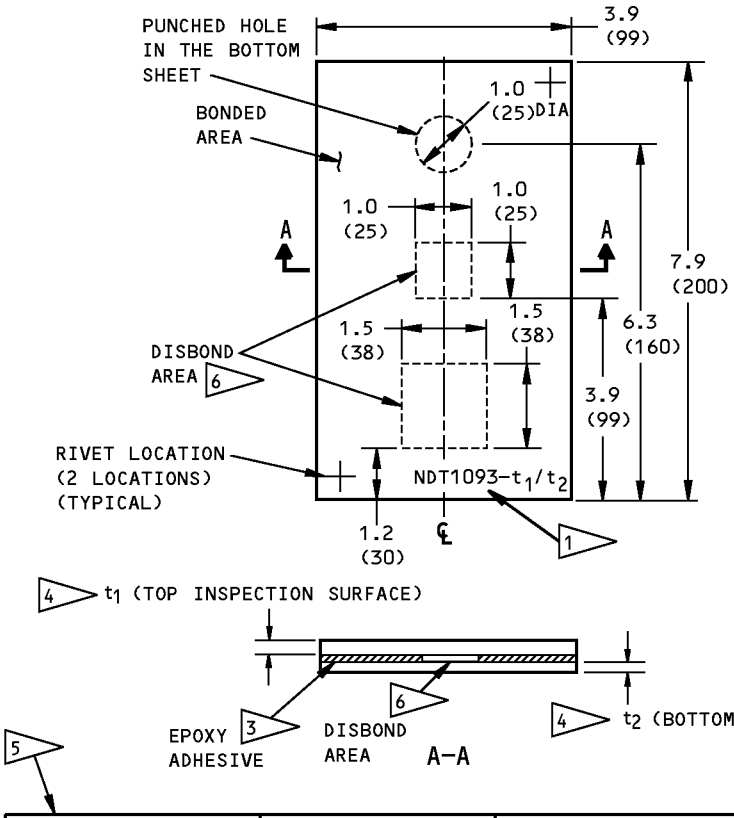
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Reference Standard NDT1092-t₁/t₂
Figure 1

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PROCEDURE TO MAKE THE REFERENCE STANDARD:

- PUNCH THE 1 INCH DIAMETER (25 mm) HOLE IN THE BOTTOM ALUMINUM SHEET
- APPLY A SHEET OF BONDING LAYER TO THE BOTTOM SHEET AND CUT OUT THE BONDING LAYER AT THE DISBOND AREAS SHOWN BY FLAG NOTE 6
- APPLY THE SPECIFIED TOP SHEET AND BOND THE ALUMINUM SHEETS TOGETHER
- PUT A SAND BAG THAT WEIGHS APPROXIMATELY 25 LBS (12 KG) ON THE REFERENCE STANDARD TO MAKE SURE THE SHEETS ARE IN GOOD CONTACT DURING THE CURE
- CURE THE REFERENCE STANDARDS. THE CURE TIME IS DIFFERENT FOR DIFFERENT TYPES OF ADHESIVES
- DO A TEST OF THE REFERENCE STANDARD WITH THE INFRARED INSPECTION SYSTEM.

NOTE: TO PREVENT MOVEMENT BETWEEN THE ALUMINUM LAYERS DURING THE CURE PROCESS, IT IS HELPFUL TO ATTACH THE SHEETS WITH A SMALL RIVET OR BOLT.

t ₁ TOP	t ₂ BOTTOM	AIRPLANE SKIN THICKNESS RANGE (t ₁)	AIRPLANE DOUBLER MINIMUM THICKNESS (t ₂)
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0.040 (1.02)	0.032 (0.8)	0.020 - 0.040 (0.51 - 1.02)	0.022 (0.56)
0.050 (1.27)	0.040 (1.02)	0.030 - 0.050 (0.76 - 1.27)	0.030 (0.76)
0.071 (1.80)	0.056 (1.42)	0.051 - 0.071 (1.30 - 1.80)	0.046 (1.17)

NOTES:

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- DIMENSION TOLERANCES:

<u>INCHES</u>	<u>MILLIMETERS</u>
X.XXX = ±0.005	X.XX = ±0.10
X.XX = ±0.025	X.X = ±0.5
X.X = ±0.050	X = ±1
- MATERIAL: 2000 SERIES ALUMINUM, CLAD OR BARE

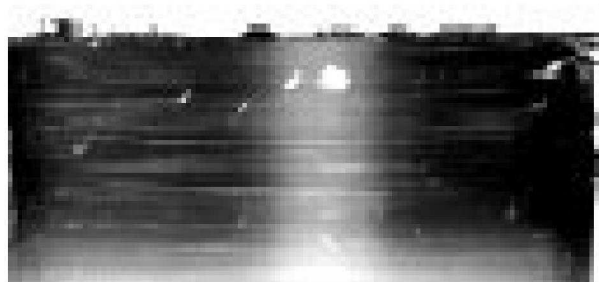
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- 6 CUT OUT THE BONDING LAYER IN THE DISBOND AREAS.

Reference Standard NDT1093-t₁/t₂
Figure 2

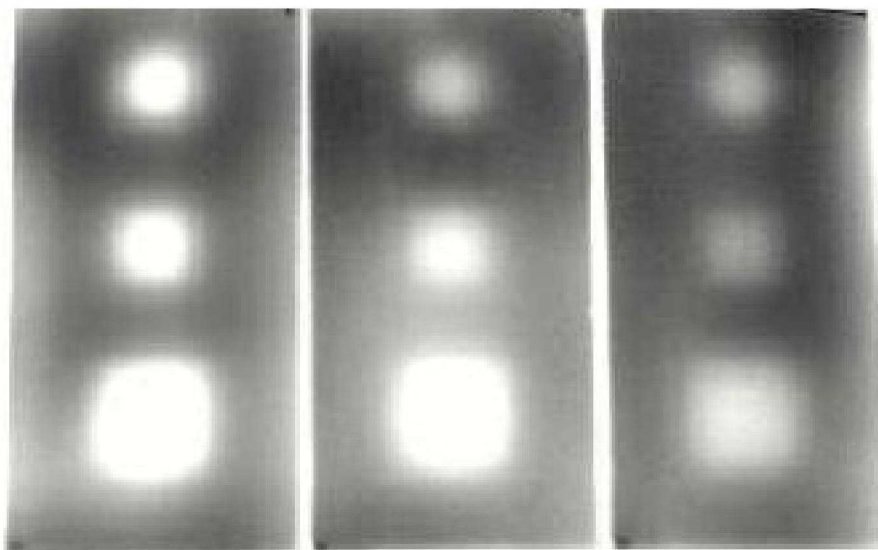
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REFERENCE STANDARD NDT1092-040/040
DETAIL I

IMAGE OF REFERENCE STANDARD NDT1092.
THE BONDED AREA IS DARK. THE DISBONDED AREA IS LIGHT.



t1/t2
0.050/0.040
(1.27/1.02)

t1/t2
0.080/0.040
(2.03/1.02)

t1/t2
0.10/0.040
(2.54/1.02)

DETAIL II

NOTE:

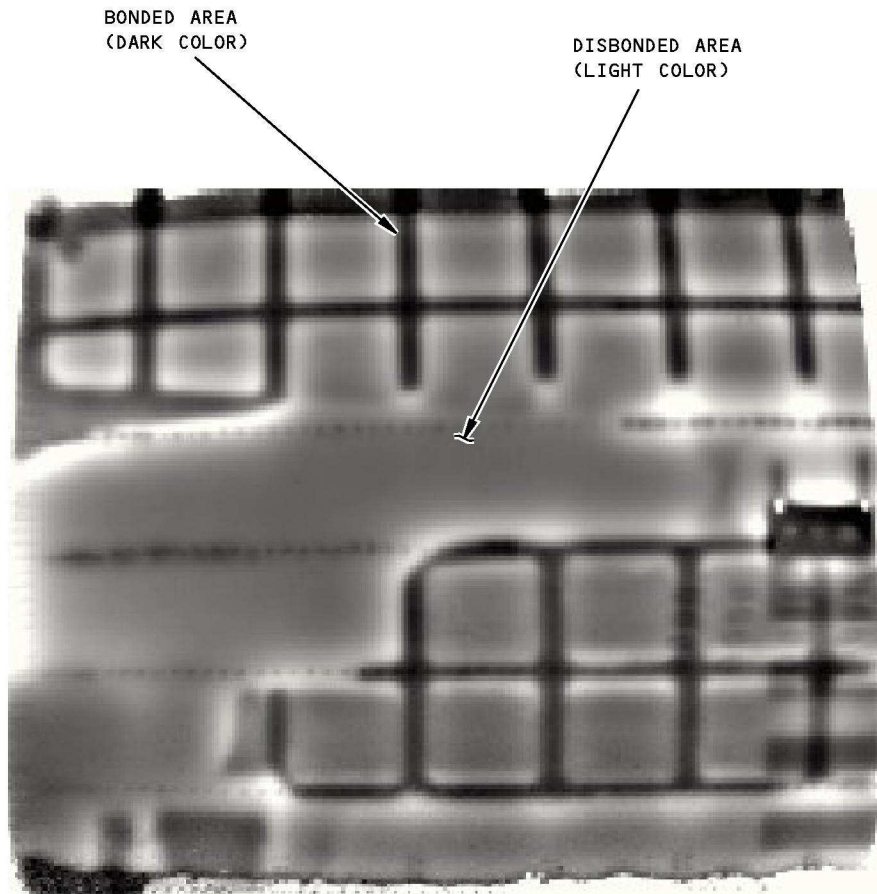
- DIMENSIONS ARE IN INCHES (MILLIMETERS ARE IN PARENTHESES)

Phase Image of Reference Standards
Figure 3



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Skin Panel with Disbonded and Bonded Doublers
Figure 4

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