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INTERNATIONAL
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AEROSPACE RECOMMENDED PRACTICE

SAE ARP4991

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Submitted for recognition as an American National Standard

Core Restoration of Thermosetting Composite Components

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1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) describes standard methods for restoring damaged core on commercial aircraft sandwich structures. It currently applies to wet lay up repairs only. The methods shall only be used when specified in an approved repair procedure or with the agreement of the Original Equipment Manufacturer (OEM) or regulatory authority. The repair materials shall be defined in the approved repairs referencing these methods.

1.1 Purpose:

The purpose of this document is to provide a set of standard methods that may be referenced in repair documents produced by airlines or airframe and engine manufacturers. It is intended that this document be one of a number of ARPs that will cover other aspects of the techniques required to perform composite repairs. This will provide a suite of available repair techniques that are acceptable for use throughout the commercial aircraft industry.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ARP4844	Composite and Metal Bond Glossary
ARP4916	Masking and Cleaning of Epoxy and Polyester Matrix Thermosetting Composite Materials
ARP4977	Drying of Thermosetting Composite Materials
ARP5143	Vacuum Bagging of Thermosetting Composite Repairs
ARP5256	Mixing Resins, Adhesives and Potting Compounds
ARP5319	Ply Impregnation
ARP5144	Heat Application for Thermosetting Resins Curing
AIR5367	Machining of Epoxy and Polyester Matrix Thermosetting Composite Structures

2.2 Applicable References:

Original Equipment Manufacturers (OEM) Repair Manuals

3. GENERAL:

Sandwich structures can suffer various types of damage (Figure 1):

a. Disbonding of the skins with or without core damage.
b. Damage to one or both skins. The core is generally also damaged.
c. Contamination by water, skydrol, oil, etc.
d. Delamination of the plies within the skin. This is often associated with other damage at an impact site.

As one of the elements in restoring the structural integrity of the part, the load capability of the core will, in general, have to be restored either by stiffening the core or replacing it.

This document addresses the various techniques found in repair manuals. Only a selection of those commonly used are proposed as methods. These methods are given a name and number to allow further development of the document and to facilitate referencing.

In this document, it is assumed that the damaged area has been cleaned, dried and that the damage has been evaluated and the repair area prepared.

4. MATERIALS:

4.1 Repair Materials:

The techniques proposed in this document require the use of a limited number of material types (resins, adhesives, additives, potting compounds, fabrics, and honeycomb). In addition to the design considerations, material selection is often influenced by the repair conditions (aircraft or shop repair), and by the part orientation. Exothermic effects (heat generated by resin curing) should be also considered, especially when potting is used. The approved repair procedure shall specify which materials to use. The type of material that may be used will be discussed in the following paragraphs or sections with each technique.

4.2 Associated Materials:

In addition to the repair materials, various other materials are needed such as cleaning agents, bagging materials, etc. Information on these materials may, in general, be found in associated ARPs or manufacturer's documentation.

5. CORE RESTORATION:

5.1 Core Filling With Resin:

When using this method, consideration should be given to the skin strength reduction due to the holes.

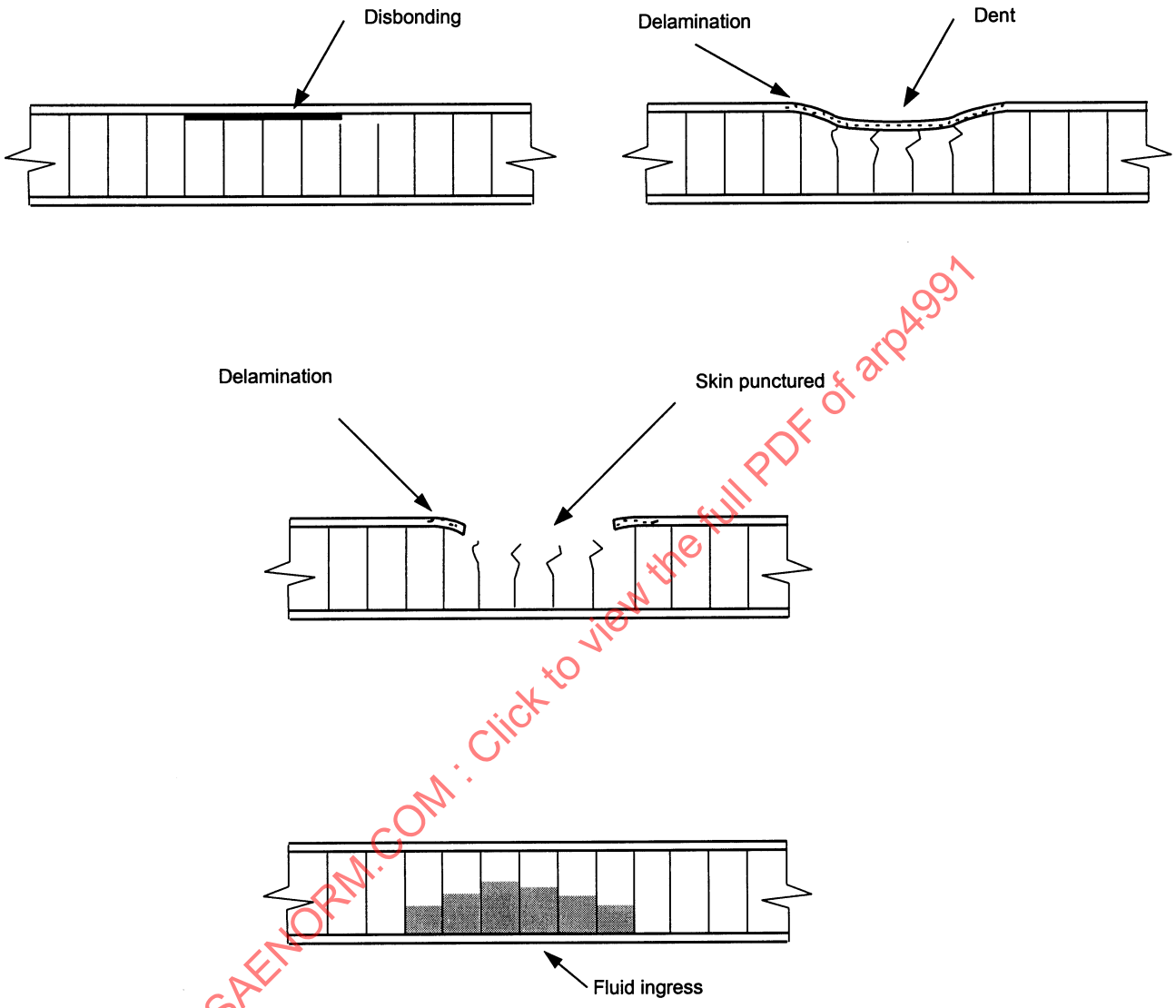

FIGURE 1 - Sandwich Structures Damage Types

5.1.1 Applicability: This method applies to small damage when skins are not punctured. The skins can be disbonded from the core or dented with possible degradation of the honeycomb underneath. To be effective this process should only be applied to a part with an uncontaminated core.

CAUTION: When the core is thicker than 0.5 in (12.5 mm), it is preferable not to fill the core completely as exothermic effects can damage the part or cause a fire. Complete filling of the cells also cause distortion of the opposite skin due to the shrinkage of the resin during cure.

5.1.2 Materials: Low viscosity resins or adhesives for injection with a syringe and preferably with a fast cure time and a low cure temperature should be used.

5.1.3 Core Filling With Resin Method (Figure 2):

Procedure:

a. Refer to the repair instructions for the following information:

1. The type of resin to use.
2. Cure time and temperature.

b. Drill (without lubrication) 0.1 in (2.5 mm) diameter holes 0.4 in (10 mm) apart in the damage area. Drill a minimum of two holes. Use a vacuum cleaner to remove dust while you drill the holes.

c. Remove any remaining dust.

d. Look for liquid contamination. (Refer to ARP4977) If contamination is found, the part is not repairable by this method.

e. Calculate the amount of resin that will be needed to fill the core to the depth specified. Prepare the resin in accordance with ARP5256 or OEM Repair Instruction.

CAUTION: When using air or mechanically operated syringes, avoid applying too much pressure as it can damage the honeycomb cells.

f. Fill a clean hypodermic syringe with the resin.

CAUTION: Depending on the design used, when the part cannot be turned over, the core should be filled and cured in steps if thicker than 0.5 in. This is recommended to avoid exothermic effects and possible damage to the part.

g. Through each hole insert the syringe at an angle to reach the surrounding cells and fill them to an approximate height of 0.3 to 0.5 in (7 to 12.5 mm). If the part cannot be turned so that the repair surface is down, fill the honeycomb cells fully.

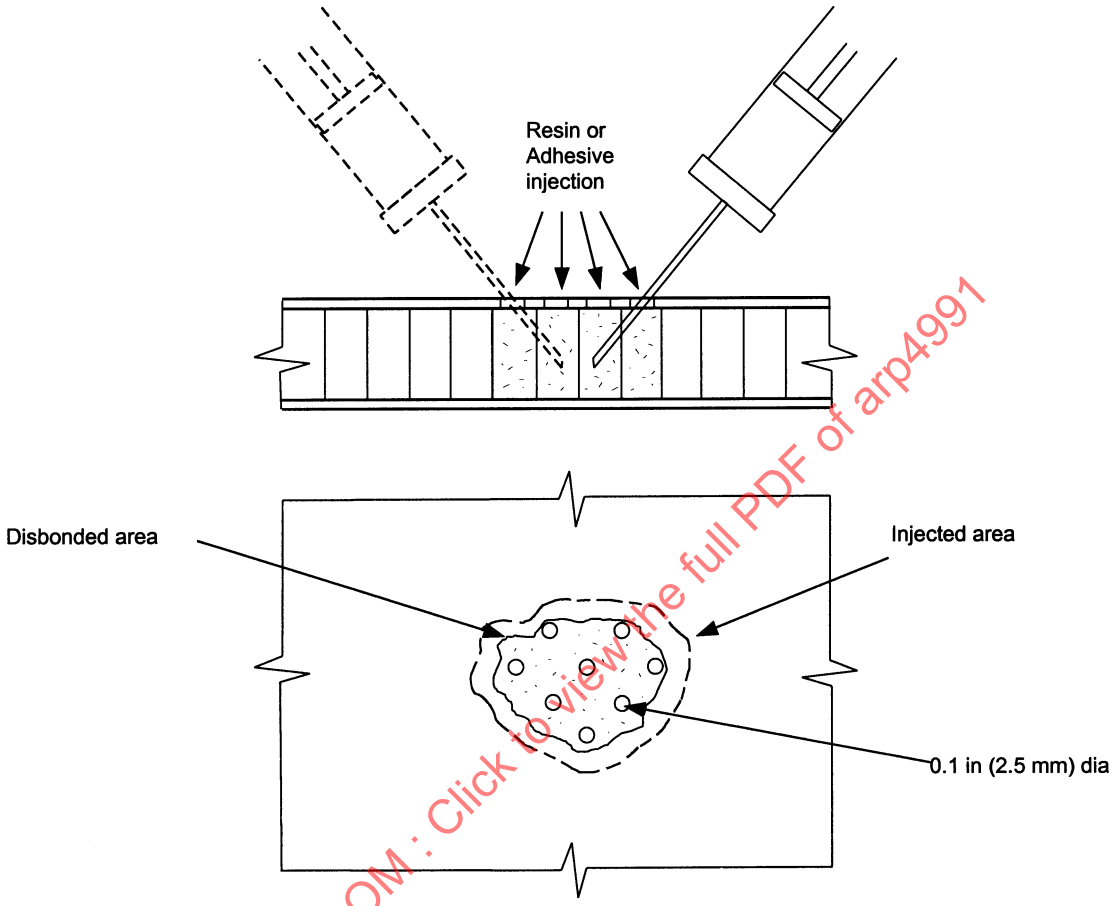

FIGURE 2 - Restoration With Resin Method

5.1.3 (Continued):

h. Put an adhesive tape that can be readily released over the holes and, if possible turn the component so that the repair surface faces down.

i. Let the resin cure.

j. Remove the tape. Make sure that the holes are sealed with resin. If any holes are not sealed, repeat the procedure for the unfilled holes.

5.2 Core Restoration With Potting Compound:

When core restoration with potting is requested in a repair directive it should be specified as a core restoration method (see 5.2.4) combined to a potting application method (see 5.2.3).

5.2.1 Applicability: Core restoration with potting generally applies to relatively small damage when one skin only is punctured. Potting quantity may be limited for weight reasons or to avoid damage due to exothermic effects and partial core filling might be required. As a general rule, potting thickness should not exceed 0.5 in (12.5 mm).

5.2.2 Materials: Different potting materials may be used for this application.

a. Resin or adhesive filled with an additive to obtain a thick paste (refer to ARP5256).

b. Ready to use potting compound.

5.2.3 Potting Application: The remaining honeycomb in the area to be potted may be filled partially or completely (Potting application Method 1 and Method 2 respectively). When no honeycomb remains, the cavity has to be completely filled (Potting application Method 3).

5.2.3.1 Potting Application - Method 1 - Complete Honeycomb Core Filling: A spatula or a pressure gun can be used.

a. Method with a spatula:

1. Apply part of the potting in the core cavity.

2. Force the potting inside each cell by moving the spatula over the honeycomb in different directions.

3. Add more potting and force it into the honeycomb until no more potting can be pushed into the cells.

4. Fill the remaining core cavity and make the surface smooth and flush with the skin.

CAUTION: Take care when applying pressure to the potting in the cells. Damage can occur.

5.2.3.1 (Continued):

b. Method with a pressure gun: Use a hand or air operated pressure gun with a nozzle that can go into the honeycomb cells without damaging them.

1. Fill each cell of the honeycomb from bottom to top by inserting the nozzle into the cell.

2. Fill the remaining core cavity.

3. With a spatula remove excess potting to make the surface smooth and flush with the skin.

5.2.3.2 Potting Application - Method 2 - Partial Honeycomb Core Filling:

a. With a spatula apply a layer of potting approximately 0.16 in (4 mm) to 0.25 in (6 mm) thick over the open cells of the honeycomb trying not to force too much potting into the cells.

b. When the thickness appears even, then force the potting into the cells with the spatula.

c. Without applying too much pressure, fill the remaining core cavity and make the surface flush and smooth with the skin.

5.2.3.3 Potting Application - Method 3 - Core Cavity Filling: It is assumed that the core has been removed completely in the damage area and the bottom skin abraded.

a. Using a spatula or a pressure gun, fill the cavity from bottom to top. Make sure that the potting makes intimate contact with the surrounding core, and bottom skin.

b. With a spatula remove excess potting to make the surface smooth and flush with the skin.

5.2.4 Core Restoration With Potting - Methods:

5.2.4.1 Core Restoration With Potting - Method 1 - Partial Damage Removal : Procedure (refer to Figure 3):

a. Refer to the repair instruction for the following information:

1. The potting application method to use (see 5.2.3).

- Method 1: Complete Honeycomb Core Filling
- Method 2: Partial Honeycomb Core Filling

2. The type of potting or resin mixture to use.

3. Cure time and temperature.

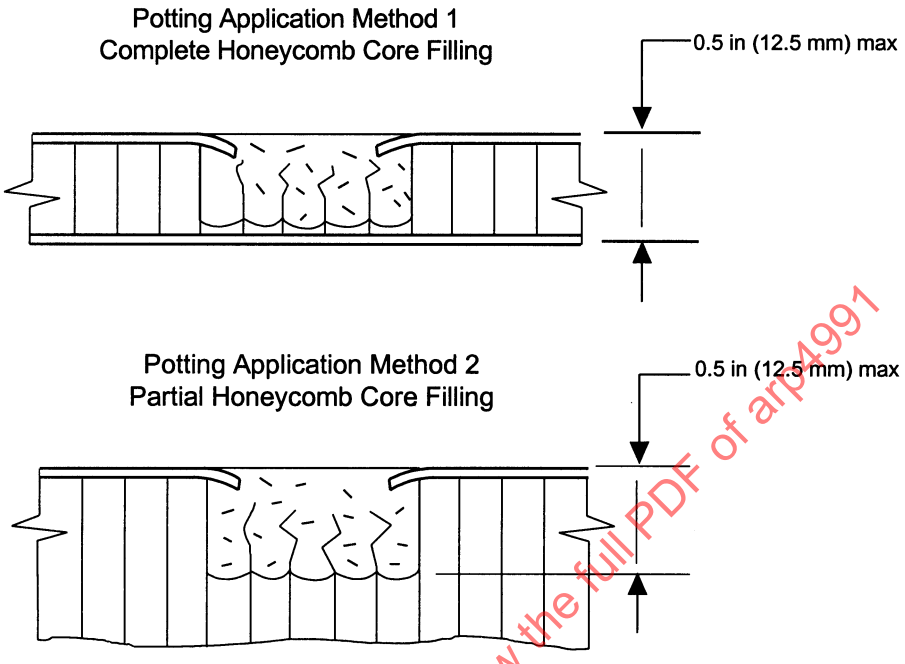

FIGURE 3 - Core Restoration With Potting - Method 1
Partial Damage Removal

5.2.4.1 (Continued):

b. Remove loose fibers and honeycomb as follows:

   1. Use a sharp knife and tweezers to remove loose skin and honeycomb material.

   2. Cut off pieces of honeycomb that are folded over the end of the cells. This is to allow potting to go into the cells.

c. Clean the repair area. Refer to ARP4916 Composite Cleaning Method 4 or 5 and Honeycomb Cleaning Method 3.

d. Dry the repair area. Refer to ARP4977 Absorbed Moisture Removal - Method 1, 2, 3, 4, or 5.

e. Prepare the potting material. Refer to ARP5256.

f. Apply the potting. Potting Application Method 1 or Method 2 of this document may be applied. Refer to the repair directive for the method to use.

5.2.4.1 (Continued):

g. Let the potting cure.

h. Remove the potting that is above the surface starting with abrasive cloth grade 80 or smoother and finishing with grade 280-320.

i. Make an inspection of the repair.

j. In areas that are not completely filled or below the surface repeat steps e. through i.

k. To complete the repair refer to the repair instructions.

5.2.4.2 Core Restoration With Potting - Method 2 - Full Damage Removal: Procedure (refer to Figure 4):

a. Refer to the repair instruction for the following information:

1. The potting application method to use (see 5.2.3).

- Method 1: Complete Honeycomb Core Filling
- Method 2: Partial Honeycomb Core Filling
- Method 3: Core Cavity Filling

2. The type of potting or resin mixture to use.

3. Cure time and temperature.

b. Cut out damaged skin and core as follows:

1. Refer to AIR5367.

2. Remove all damaged and disbonded skin.

3. Use a router to remove the damaged core.

c. Clean the repair area. Refer to ARP4916 Cleaning Method 4 or 5 and Honeycomb Cleaning Method 3.

d. Dry the repair area. Refer to ARP4977 Absorbed Moisture Removal - Method 1, 2, 3, 4, or 5.

e. Prepare the potting material. Refer to ARP5256.

f. Apply the potting. "Potting Application" Method 1, Method 2 or Method 3 of this document may be applied. Refer to the repair directive for the method to use.

g. Let the potting cure.

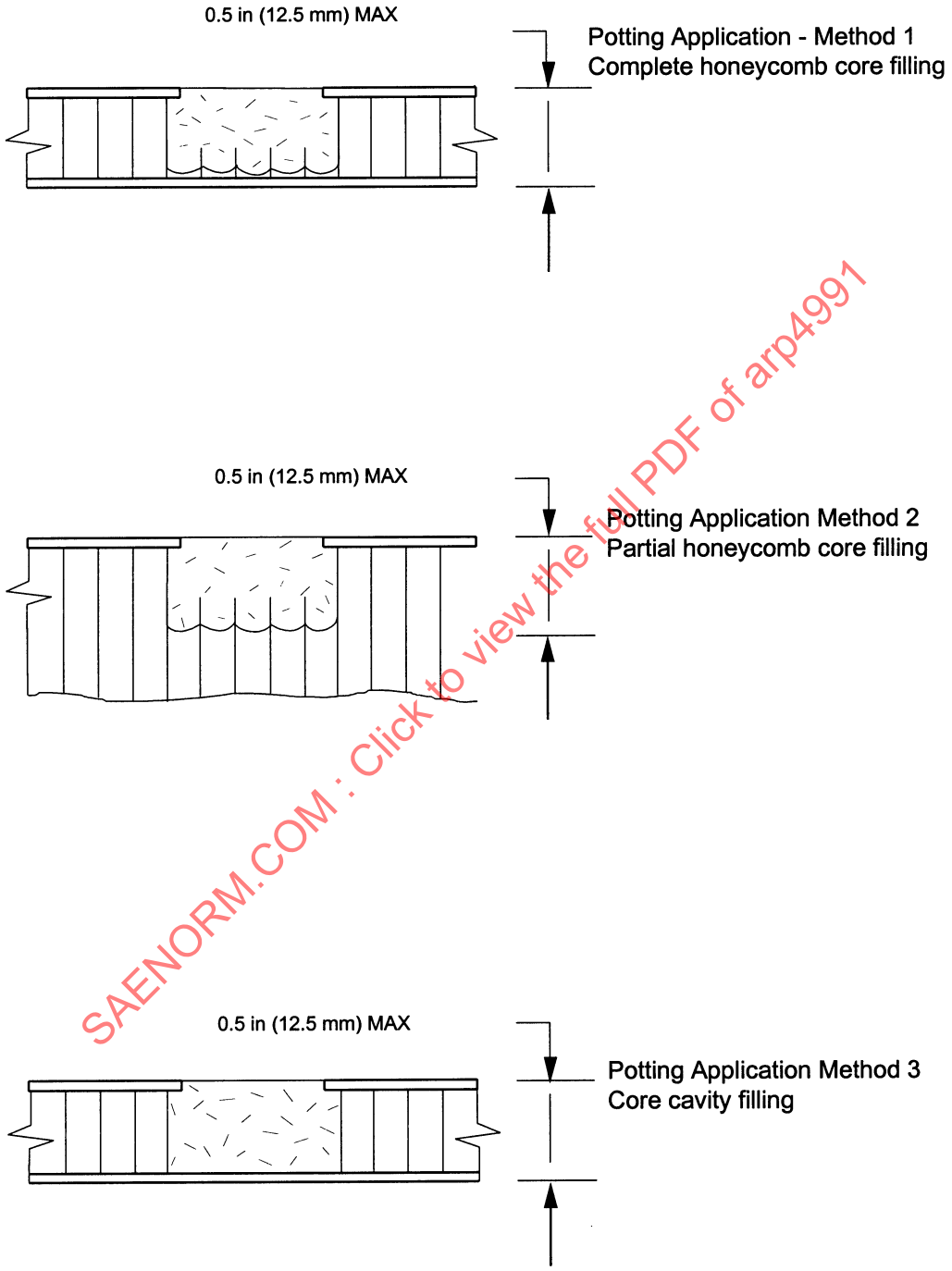

FIGURE 4 - Core Restoration With Potting - Method 2
Full Damage Removal

5.2.4.2 (Continued):

h. Remove the potting that is above the surface starting with abrasive cloth grade 80 or smoother and finishing with grade 280-320.

i. Make an inspection of the repair.

j. In areas that are not completely filled or below the surface repeat steps e. through i.

k. To complete the repair refer to the repair instructions.

5.3 Core Restoration With Honeycomb:

5.3.1 Applicability: Core Restoration with Honeycomb is required when extensive damage or contamination of the core has occured.

The core can be replaced completely or partially (on thick parts) and fitted flush with the skin or with the existing core depending on the damage and repair design (Figure 5).

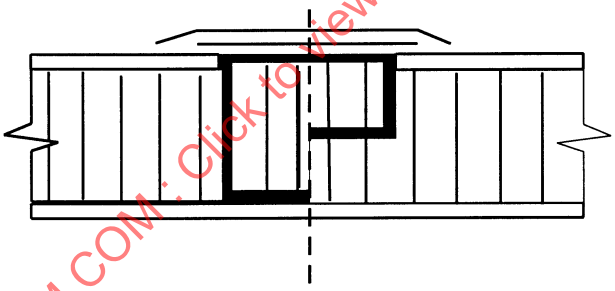

FIGURE 5A - Honeycomb Flush With Skin Upper Surface

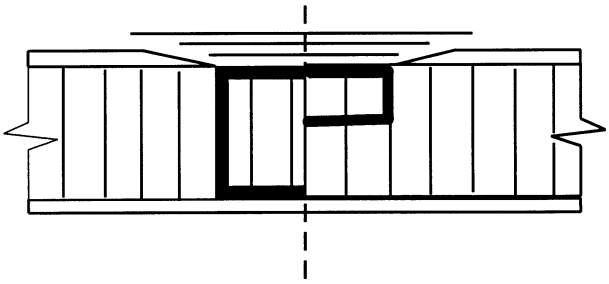

FIGURE 5B - Honeycomb Flush With Existing Honeycomb

FIGURE 5 - Core Restoration With Honeycomb

5.3.2 Materials:

5.3.2.1 General: A honeycomb core plug has to be spliced all around to the existing core and bonded either to the bottom skin or to the existing core (core partial replacement). Shear, tension, and compression loads will be transmitted through these bond lines (Figure 6).

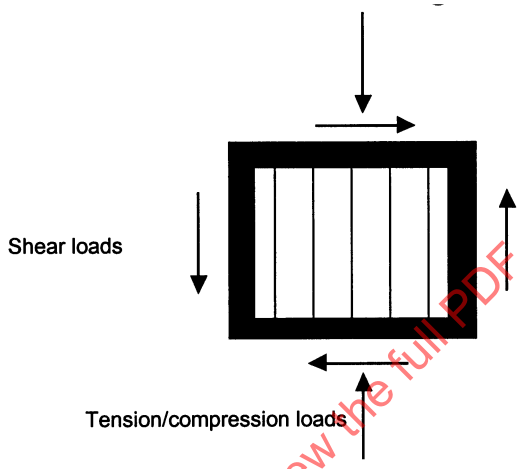

FIGURE 6 - Loads on a Core Plug

5.3.2.2 Honeycomb Plug Material Selection: The repair plug should be of the same type and strength as the original honeycomb. A higher strength and smaller cell size honeycomb type can sometimes be accepted (refer to the repair instruction).

5.3.2.3 Honeycomb Bonding Materials: Adhesive pastes, resin, and potting compounds may be used for this application, depending on the method selected. Material and process selection depend on the part design, repair conditions, and access. Typically, parts thicker than 0.5 in (12.5 mm) with access from one side only, will require particular attention when curing the core to the far side skin (Reference ARP5144).

5.3.3 Core Plug Preparation Method: Procedure:

a. Refer to the repair instructions for the following information:

1. The type of honeycomb to use.

2. The number and thickness of fabric plies used to bond the honeycomb plug to the bottom skin, if required.

3. The side of the skin that the honeycomb plug shall be level with. For example, for a non-flush patch the honeycomb will be level with the outer surface of the skin. Refer to Figure 5a. For a flush patch the honeycomb will be level with the existing honeycomb. Refer to Figure 5b.

b. Measure the dimensions of the honeycomb repair cut out area.

c. Determine the thickness of the honeycomb plug as follows:

1. Measure the thickness of the honeycomb plug needed to fill the cut out area.

NOTE: With aramid and glass honeycomb it is permissible to make the plug 0.04 to 0.08 in (1 to 2 mm) thicker and machine it level after bonding in the cut out area.

2. If fabric plies are used to bond the honeycomb plug, subtract the thickness of the compressed fabric plies from the thickness measurement of the honeycomb.

3. If the honeycomb plug is to be level with the outer surface of the skin, add the thickness of the skin to the core plug thickness measurement.

d. Cut out a honeycomb plug as follows:

1. Make the dimensions of the honeycomb plug one cell larger than the measurements of the cut out area.

2. The honeycomb ribbon direction shall match the original honeycomb.

3. Mark out the honeycomb to correspond to the plug dimension.

4. Cut out the honeycomb plug. Refer to AIR5367.

5. Clean the plug. Refer to ARP4916, Honeycomb Cleaning Method 1, 2, 3, or 4.

6. Make sure the honeycomb plug fits tightly in the honeycomb in the repair area.

5.3.3 (Continued):

e. Remove dust with a vacuum cleaner.

f. Dry the plug if necessary. Refer to ARP4977 - Absorbed Moisture Removal - Method 2, 3, 4, or 5.

5.3.4 Thick Core Plug Preparation Method (Figure 7): If the honeycomb available has insufficient thickness to make the honeycomb plug, the plug can be made from two or more pieces.

The method uses a ply of fabric impregnated with resin.

Procedure:

a. Refer to the repair instruction for the following information:

1. The type of resin and honeycomb to use.

2. Cure time and temperature of the resin.

b. Cut out two honeycomb plugs to the required dimensions. Refer to Core Plug Preparation Method of this document.

c. Cut one ply of style 1581 or 7781 glass fabric or the fabric to be used for the skin patch. Make the ply 0.5 in (12 mm) larger all around than the core.

d. Prepare the resin for ply impregnation. Refer to ARP5256.

e. Impregnate the fabric ply in between two pieces of release film. Refer to ARP5319.

f. Put the ply on a clean flat surface.

g. Remove one layer of release film.

h. Apply a thin layer of resin to the core cells edge.

i. Push the piece of honeycomb on the ply.

j. Turn the honeycomb and ply so that the ply faces up. Put the honeycomb and ply on a clean piece of parting film.

k. Remove the second release film from the ply.

l. Apply a thin layer of resin to the second honeycomb plug and position it on the ply. Align the ribbon direction of the plugs. Do not try to make the cells match.

m. Apply pressure to maintain contact between the two pieces of core plug and the septum ply, typically 1 to 2 psi (0.07 to 0.14 bar). Conformable weight could be applied.

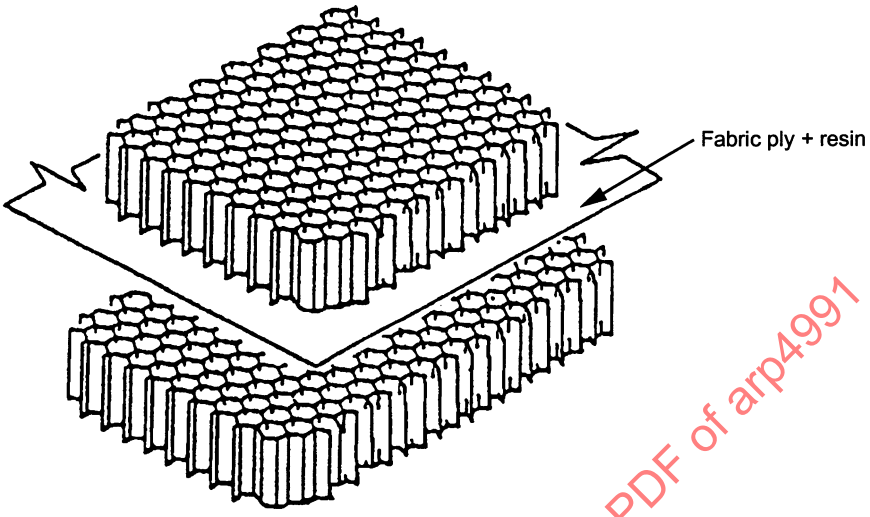

FIGURE 7 - Thick Core Plug Preparation Method

5.3.4 (Continued):

n. Cure the resin.

o. Remove the pressure.

p. Trim glass fabric ply and core as necessary.

5.3.5 Full Depth Core Restoration With Honeycomb - Method 1 (Figure 8): This method uses an adhesive paste as the common material for the honeycomb splicing and the bonding to the existing skin. Depending on the viscosity of the adhesive selected, an additive can be added.

Procedure:

a. Refer to the repair instructions for the following information:

1. The type of material to use.

2. Cure time and temperature.

3. How to apply the pressure:

- Option A: Use a vacuum bag.
- Option B: Use a dead weight.

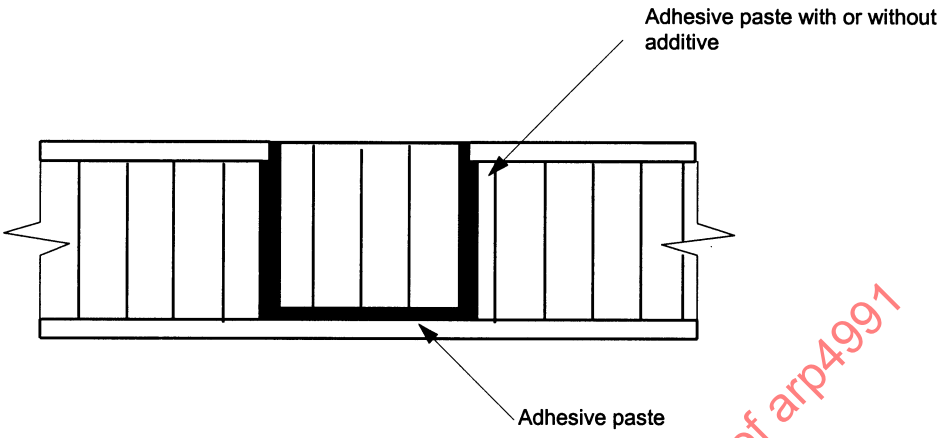

FIGURE 8 - Full Depth Core Restoration With Honeycomb - Method 1

5.3.5 (Continued):

b. Prepare the honeycomb core plug. Refer to Core Plug Preparation Method or Thick Core Plug Preparation Method of this document.

c. Prepare the adhesive paste and mix additive if necessary. Refer to ARP5256.

d. Use a spatula. Put a layer of adhesive paste on the sides of the honeycomb plug and hole sides of the honeycomb in the repair area.

e. Apply a 0.04 to 0.08 in (1 to 2 mm) thick layer of adhesive paste on the inner skin.

f. Align the honeycomb plug ribbon direction with the ribbon direction of the core in the part and push the honeycomb plug in position.

g. Ensure any adhesive starved areas have been filled.

h. Apply a constant pressure on the honeycomb plug:

- Option A: Install a vacuum bag. Refer to ARP5143 - Method 4 - Core restoration.
- Option B: Install a dead weight not exceeding 1 to 2 psi (0.07 to 0.14 bar) to avoid distortion of the far side skin (method suitable for small damage and room temperature cure).

i. Cure the resin. Keep the pressure constant during the cure cycle.

j. Remove the pressure.

k. Refer to the repair instructions to complete the repair.

5.3.6 Full Depth Core Restoration With Honeycomb - Method 2 (Figure 9): This method uses a laminating resin as the common material for the honeycomb splicing and the bonding to the existing skin. For splicing the core, the resin should be mixed with an additive. For the bonding to the existing skin, a ply of fabric impregnated with resin is used (style 1581 or 7781 glass fabric or the skin repair material).

Procedure:

a. Refer to the repair instructions for the following information:

1. The type of material to use.

2. Cure time and temperature.

3. How to apply the pressure:

- Option A: Use a vacuum bag.
- Option B: Use a dead weight.

b. Prepare the honeycomb core plug. Refer to Core Plug Preparation Method or Thick Core Plug Preparation Method of this document.

c. Cut a piece of style 1581 or 7781 glass fabric or a piece of skin repair fabric larger than the hole.

d. Prepare the resin. Refer to ARP5256.

e. Prepare the resin mix by separating the resin needed for core splicing and adding additive to it. Refer to ARP5256.

f. Impregnate the fabric ply in between two pieces of release film. Refer to ARP5319.

g. Cut to the size of the hole.

h. Apply a layer of resin on the skin at the bottom of the honeycomb hole.

i. Remove the release film from one side of the ply.

j. Position the ply on the skin at the bottom of the honeycomb hole and press lightly.

k. Remove the second release film.

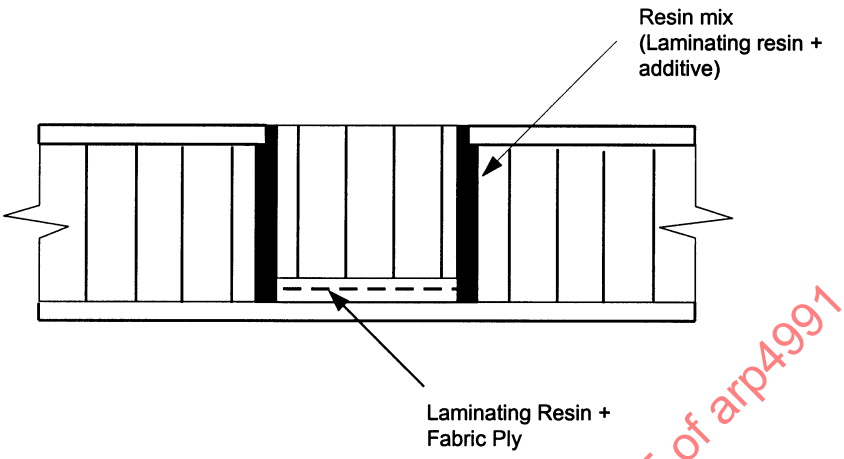

FIGURE 9 - Full Depth Core Restoration With Honeycomb - Method 2

5.3.6 (Continued):

l. Apply the resin mix on the sides of the honeycomb plug and hole sides of the honeycomb in the repair area.

m. Align the honeycomb plug ribbon direction with the ribbon direction of the core in the part and push the honeycomb plug in position.

n. Ensure any resin mix starved areas have been filled.

o. Apply a constant pressure on the honeycomb plug:

- Option A: Install a vacuum bag. Refer to ARP5143 - Method 4 - Core restoration.
- Option B: Install a dead weight not exceeding 1 to 2 psi (0.07 to 0.14 bar) to avoid distortion of the far side skin (method suitable for small damage and room temperature cure).

p. Cure the resin. Keep the pressure constant during the cure cycle.

q. Remove the pressure.

r. Refer to the repair instructions to complete the repair.