Document No.: NPS 80530R Rev -, December 22, 2020

Process Specification for Composite Bonded Repair Material Test Panels using Solvay 5320-1 Prepreg

(Cured using a Composite Repair Console)

Prepared by: John Tomblin, Rachael Andrulonis, Jeff Gilchrist, Royal Lovingfoss

Reviewed by: Eric Chesmar, Phil Croft, Rusty Keller, Eric Stenne, Marie-Josee Landry, Glyn Richards, Steve Ward, Carl Rousseau, Curtis Davies, Cindy Ashforth, Rusty Jones

National Center for Advanced Materials Performance
Wichita State University – NIAR
1845 Fairmount Ave., Wichita, KS 67260-0093, USA

REVISIONS

Revision	Date	Description
-	12/22/2020	Initial Release

Table of Contents

1. SCOPE

This repair process specification describes the methods of fabricating repair material test panels using Solvay 5320-1. This specification does not provide process instructions for performing a repair on a composite part.

This specification covers prepreg cutting, layup, vacuum bagging, and curing process using a heat blanket and composite repair console (hot-bonder). In addition to the instructions contained in this specification, users are advised to obtain additional guidance directly from the prepreg manufacturer.

This specification does not contain all the necessary information typically required in a composite process specification for the fabrication and repair of composite structures, such as personnel qualification and layup room requirements. Users should refer to their existing company process specifications and structural repair manuals for such information. DOT/FAA/AR-02/110 provides guidance for the development of composite process specifications.

1.1. Purpose

The purpose of this repair process specification is to provide information for the fabrication of repair material test panels cured using a heat blanket (hot-bonder) for use in material qualification, equivalency, and acceptance testing. This repair process specification may also be used as a baseline by material users to develop a process specification for the repair of aerospace composite parts.

1.2. Health and Safety

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards that may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS

The following publications form a part of this specification to the extent specified herein. The latest issue of the NCAMP publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order unless otherwise specified. When a referenced document has been canceled and no superseding document has been specified, the last published issue of that document shall apply.

2.1. NCAMP Publications

NMS 532	Low Initial Temperature Vacuum-Bag-Only Cure, Medium Toughness Epoxy Prepregs
NMS 532/6	Low Initial Temperature Vacuum-Bag-Only Cure, Medium

	Toughness Epoxy Prepregs
NPS 85321	Fabrication of NMS 532 Qualification, Equivalency, and Acceptance Test panels

2.2. ISO Publications:

AS 9100	Quality Management Systems

2.3. US Government Publications:

DOT/FAA/AR-02/110	Guidelines for the Development of Process Specifications, Instructions, and Controls for the Fabrication of Fiber-Reinforced Polymer Composites

3. MATERIALS:

All materials that have the potential to become a foreign object within the laminate shall be verified to be detectable by nondestructive inspection (NDI) methods that will be used for the inspection of the test panels.

3.1. Contact Materials

Contact use materials are approved for use in direct contact with the part lay–up (deliverable materials) inside the trim line prior to completion of cure. Materials that can come in contact with the composite prepreg shall be evaluated to verify they do not contaminate the prepreg material. Any alternates to the specific listed vendor materials below shall be evaluated prior to use.

3.2. Non-Contact Materials

Non–contact use materials are approved for use as aids to processing but shall not contact the deliverable materials inside the trim line prior to cure. Non–contact use processing aid materials may not contact cured deliverable materials except as noted.

Vacuum bag, nylon film, 3 mils maximum, qualified for use at 375ºF or above

- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

Breather, 120 glass, 7781 glass, nonwoven polyester breather (i.e N-4, N-10, Super N-10)

- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

Peel Ply, Airtech Release Ply F, non-coated polyester peel ply (400°F)

- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

Non-Perforated and Perforated (no larger than 0.045 inch diameter holes with no less than 2 inch apart on centers) Fluorinated Ethylene Propylene (FEP), separator/release film, 1 to 2 mils, qualified for use at 375ºF or above

- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

Caul Plate, 0.075 – 0.250 inch thick, aluminum, flat and smooth

- Or equivalent

Tape, Pressure Sensitive Mylar Tape qualified for use at 375ºF or above, Flashbreaker® 1, 1 mil, qualified for use at 375 ºF or above

- Keystone Tape, 3911 E. La Palma Ave., Suite V Anaheim, CA 92807
- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

Sealant tape, compatible with nylon vacuum bag, qualified for use at 375ºF or above

- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

Mold (bottom tool), minimum 0.250 inch thick, aluminum, flat and smooth

- Or equivalent

Sealing Agents, Frekote B-15

- Henkel, One Henkel Way, Rocky Hill, CT 06067
- Or equivalent

Release Agents, Frekote 44-NC, Frekote 55-NC, Frekote 700-NC

- Henkel, One Henkel Way, Rocky Hill, CT 06067
- Or equivalent

4. PARENT LAMINATE FABRICATION

Manufacture parent laminate panels with Solvay 5320-1 T650 3K-PW using the following material and process specifications:

NPS 85321	Fabrication of NMS 532 Qualification, Equivalency and Acceptance Test Panels
NMS 532	Low Initial Temperature Vacuum-Bag-Only Cure, Medium Toughness Epoxy Prepregs
NMS 532/6	Low Initial Temperature Vacuum-Bag-Only Cure, Medium Toughness Epoxy Prepregs

5. PARENT LAMINATE SCARF PREPARATION AND MACHINING

Conduct panel thickness measurements utilizing ASTM D5687 as a guide to determine the

overall panel thickness and CPT. Continuous scarf the parent laminate panel with the applicable scarf ratio based on panel thickness. The repair ply overlaps are 0.5 inch. Machining can either occur on a CNC machine utilizing a ball nose end mill or surface grinder using a tilt table. Both scarf length and scarf angle are calculated based on the scarf ratio and average panel thickness. Once the appropriate calculations have occurred with 50:1 and 30:1 target scarf ratios, the parent panel is set flat on a CNC machine with a sacrificial fiberglass backing piece to allow for sculpting machining. Using a ball mill the panel is scarfed at the specified angle through the thickness to meet the desired scarf ratio. This setup is also transferred to the surface grinder when necessary. With the magnetic chuck engaged the machining tilt table is added to the surface grinder and the parent panel is machined to the desired scarf angle. Both machining methods use coolant for solid laminate scarf machining.

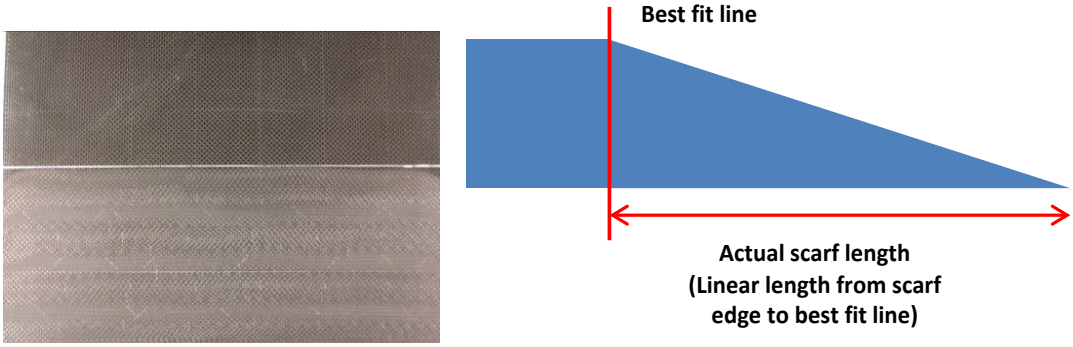

Figure 1. Sample of scarfed panel

6. REPAIR LAMINATE FABRICATION

6.1. Prepreg cutting

Non-contaminating gloves such as disposable powder-free nitrile gloves shall be worn when handling the prepreg. The prepreg may be cut using conventional method (i.e. on a clean polyurethane table top with utility knife) or automated method. The method of cutting shall not contaminate the prepreg. Fiber orientation (e.g. warp versus fill directions) shall be maintained during the cutting process. Each ply shall be marked to identify warp direction. The test panel dimensions shall be sufficient to allow a minimum trim allowance of one inch on all sides.

6.2. Prepreg layup and bagging

Non-contaminating gloves such as disposable powder-free nitrile gloves shall be worn when handling the prepreg. The panel layups (stacking sequences) for qualification and equivalency purposes shall be in accordance with appropriate test plans. For material acceptance purpose, the panel layups shall be in accordance with NMS 532.

In the case of materials that shall be not mid-plane symmetric, such as satin weave fabrics, plies shall be orientated such as to give a mid-plane symmetric laminate as best as possible, as shown in Figure 2.

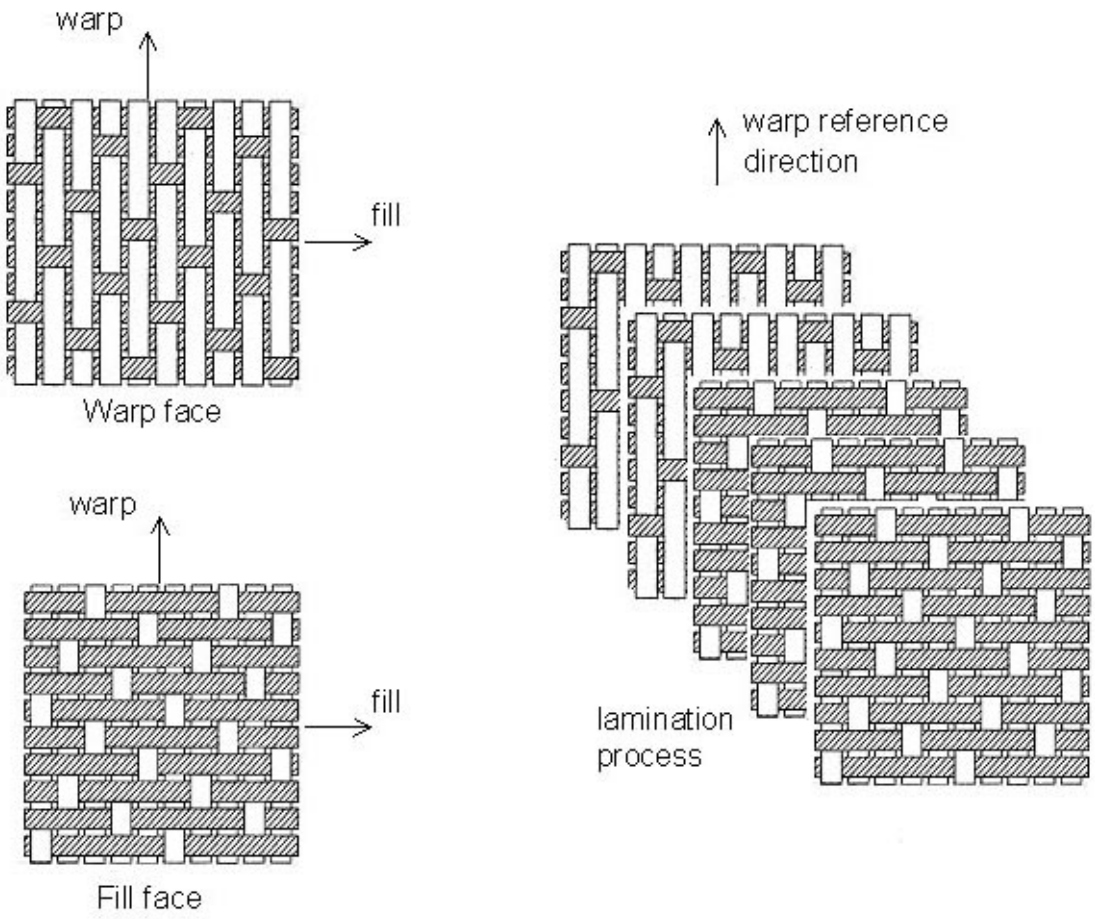

Figure 2. Example Satin Weave Showing Warp and Fill Faces Used for Ply Collation

In order to maintain the fiber orientation, a reference edge/marker shall be created on each panel. The reference edge marking shall be at least one inch from the edge to allow for panel edge trim. During the layup process, each ply shall be laid up within ±5° for fabric, and ±3° for tape of the reference edge. The edge dams around the layup/prepreg shall form a straight edge on the cured panel (see Figure 2).

In the layup of unidirectional prepreg, plies may be butt spliced in the 90º direction. Ply splicing is not allowed in the 0º direction. Ply splicing is not allowed in the layup of woven fabric prepreg in any direction. In material qualification and equivalency programs, for panel identification purpose, place a label within ½-inch from the prepreg edge with the following information: "0º direction →, Test Plan Document Number -Prepregger ID - Material Code - Fabricator ID - Test Type - Batch ID - Cure Cycle ID -Test Panel ID." Make sure that the "0º direction →" actually points in the 0º direction or warp direction.

6.3. Repair Panel Layup

1. Place the parent scarfed panel on to the layup tool and tape the parent panel in place as to where it is secured to the tool and will not shift during the repair and bagging process.

2. Using a right angle ruler, mark repair / scarf alignment line for each repair ply on both sides of the parent scarf as required by the amount of plies per panel that per were built per the panels in NPS 85321.

3. Clean the scarfed surface on the parent panel with isopropyl alcohol using a lint free cloth. Several iterations may be necessary to ensure adequate surface cleaning.

4. Apply a single layer of FM-300-2 adhesive to the scarfed region with 0.25” overhang from all sides of the scarf followed by the appropriated amount of plies using 5320-1 material.

5. Place the first repair ply against the first set marked lines and roll it along the fiber direction of the repair ply to remove wrinkles or air bubbles. Remove the backing paper and follow the same step until next all the plies have been laid up.

6. Ensure that the orientation of the layup of the repair region follows the parent laminate orientation. Count the backing films after repair completion and sign off on the various steps in the layup check sheet as specified (both operator and inspector must sign off on the steps as required).

7. Once the layup has finished use Flashbreaker® 1 tape to mask the parent panel surface leaving a minimum of 1/8” between the edge of adhesive and the Flashbreaker® 1 tape.

6.4. Repair Bagging Procedure

Figure 3 shows the bagging arrangement that shall be used for the manufacture of mechanical test panels. All panels, except those used as parent laminates, will be cured using a composite repair hot bonder.

a. Thermocouples shall be used to monitor and record the temperature of representative test panels. Thermocouple junctions shall be placed in between the part and the caul plate on the edge of the part with the thermocouple junctions wrapped with Teflon or flash-breaker tape so that they can be removed from the part after cure.

b. Approved release agents may be used on the tool surface and the caul plate surface instead of non-porous FEP. All release agents shall be applied in an area isolated from areas with uncured prepreg. All release agent shall be fully cured per manufacturer's instructions before the tool is moved to areas with uncured prepreg.

c. Place laminate on solid FEP or release coated tool plate. Ensure that all laminate edges are cut square.

d. Place strips of edge breather along the perimeter of the part. Ensure that edge breather is in contact with the laminate.

e. Place a layer of perforated release film followed by bleeder, solid release film, and caul plate.

f. Place the FEP-wrapped caul plate over the laminate. The caul plate shall be 0.075 to 0.250 inch thick. The caul shall be the same dimensions as the laminate; it shall not overlap the dams and shall not leave a gap between the plate and the dam larger than 0.1 inch.

g. Place the heat blanket followed by one to two plies of breather over the entire layup.

h. Place a layer of Nylon bagging film over the entire layup and seal the entire assembly with sealant tape. See Figure 3.

i. Apply a minimum vacuum of 28 inch of Hg (or within 2 inch of Hg of the local atmospheric pressure) and hold the layup under vacuum for a minimum of 5 minutes. Isolate the system by closing the vacuum source valve. Leak check by taking an initial reading after 5 minutes of isolation and then take a final reading after an additional 5 minutes. The difference between the two readings is the leak rate. The vacuum shall not fall more than 1 inch of Hg in 5 minutes. If this rate is exceeded, repair the leak, and recheck the leak rate.

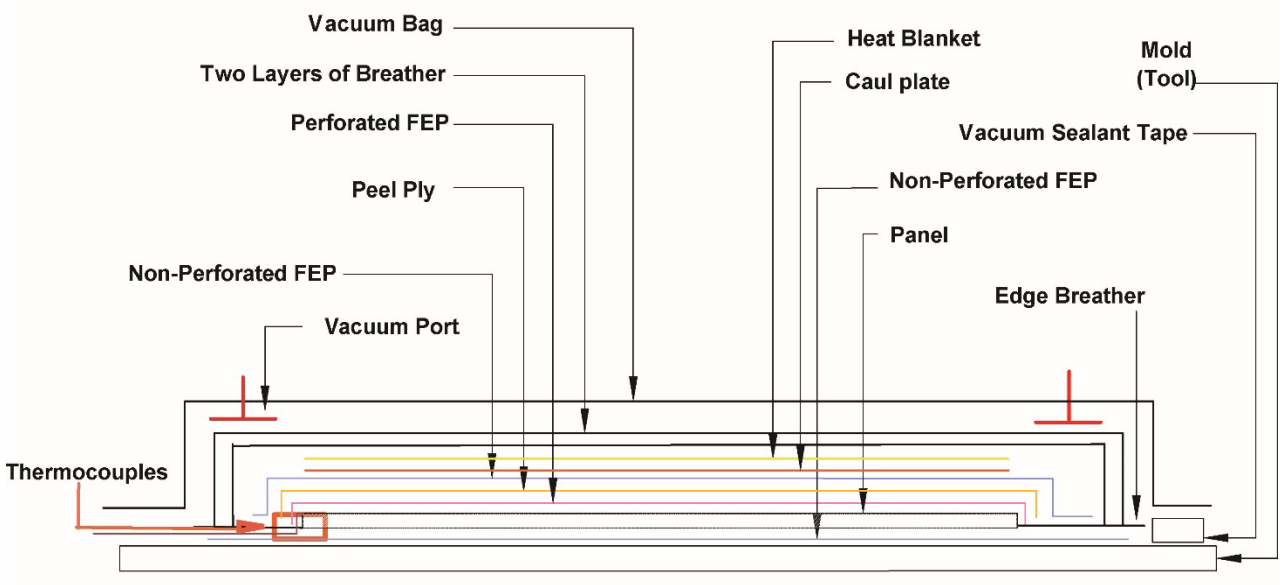

Figure 3. Bagging Technique for 5320-1 Repair Panels

6.5. Pre-Cure Vacuum Hold

The test panels shall be held under a vacuum of 28 inch of Hg or greater (or within 2 inch of Hg of the local atmospheric pressure) prior to cure. For example, apply a minimum of 22.7 inch of Hg in most of Denver, Colorado, where atmospheric pressure is 24.7 inch of Hg. For panels smaller than or equal to 4 ft^2, hold for 4 hours, minimum. For panels greater than 4 ft^2, hold for 16 hours, minimum. Vacuum shall not be released prior to cure, except if necessary to transport and reconnect to the hot bonder vacuum source

(this time shall be limited to 20 minutes, maximum).

6.6. Repair Baseline Cure Cycle (A)

The repair cure cycle shall be in accordance with the following process. For the purpose of maintaining traceability, this cure cycle is designated as "A." All panels using this cure cycle shall be bagged using the bagging scheme in Figure 3 and cured using a hot bonder. Check the vacuum bag integrity prior to starting cure cycle; leak rate shall not exceed 1 inch of Hg in 5 minutes. The driving temperature shall be based on the lagging thermocouple. The vacuum and temperatures shall be recorded at 5-minute intervals maximum.

1. Prior to curing the laminate, leak check the bag to ensure a good seal per Section 6.4 (i). No more than 1 inch of Hg of vacuum over a 5-minute period is allowed.
2. Apply full vacuum within 2 inch of Hg of the local atmospheric pressure.
3. Connect heat blanket and controller.
4. Heat from RT to 250 ± 10°F at 1 to 3°F/minute based on the panel temperature.
5. Hold at 250 ± 10°F temperature for 180-210 minutes. Start the hold when the lagging thermocouple reaches 240°F.
6. Heat from 250 ± 10°F to 350 ± 10°F at 1 to 3°F/minute based on the panel temperature.
7. Hold at temperature for 120-150 minutes. Start the hold when the lagging thermocouple reaches 340°F.
8. Cool to below 150°F at 1 to 5 °F/minute maximum.

6.7. Cured Panels

The reference edge created in Section 6.2 shall be clearly marked on each panel. This reference edge shall be used as datum for subsequent machining process. Sharp edges shall be removed from cured panels so that they can be handled and packaged safely.

7. QUALITY ASSURANCE

7.1. Process Control

In-process monitoring data such as part temperature, heat blanket temperature, vacuum, and part vacuum readings through the cycle shall be in accordance with user's applicable company process specification or an approved shop practice. For material qualification and equivalency purposes, the in-process monitoring data shall be provided to the appropriate organizations in accordance with the applicable test plan. Process control testing is not required for the fabrication of test panels.

7.2. Ultrasonic Nondestructive Inspection

For material qualification and equivalency purposes, the panels may be ultrasonically inspected by the testing lab in accordance with the applicable test plan.

7.3. Visual Inspection

Verify there are no obvious defects such as warpage or dry spots. Panels shall be labeled in accordance with the applicable test plan for identification purposes.

8. SHIPPING

For material qualification and equivalency purposes, it may be necessary to send the panels to a designated test lab. The panel shipping instruction is typically included in the applicable test plan.