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NCAMP Process Specification

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Standard Operating Procedures, NSP 100*

Fabrication of NMS 220 Qualification, Equivalency, and Acceptance Test Panels
(Cytec Cycom EP 2202 prepregs)

Prepared by: Amy Buxman (Cytec), Yeow Ng (NCAMP), John Tomblin (NCAMP/NIAR).
Adrienne Strohmeyer (Cytec)

Reviewed by: Robert Bohaty (Spirit AeroSystems), Mark Chris (Bell Helicopter), Suvankar
Mishra (Bell Helicopter), Steve Stout (Spirit AeroSystems)

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1. SCOPE

This process specification describes the methods of fabricating test panels using NMS 220 prepregs. Specifically, this specification covers prepreg cutting, layup, vacuum bagging, and curing process with an autoclave equipped with vacuum ports. In addition to the instructions contained in this specification, users are advised to obtain hands-on 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 of composite structures, such as personnel qualification and layup room requirements. Users should refer to their existing company process specification for such information. DOT/FAA/AR-02/110 provides guidance for the development of composite process specifications.

1.1 Purpose

The purpose of this process specification is to provide processing information for the fabrication of test panels for use in material qualification, equivalency, and acceptance testing. This process specification may also be used as a baseline by material users to develop a process specification for the fabrication 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 which 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. 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 Publication

NMS 220	Autoclave Cure, High Toughness and High Open-Hole Compression Epoxy Prepregs
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2.2 ISO Publication:

ISO 9000	Quality Management Systems
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2.3 SAE Publication:

AS 9100 Quality Management Systems - Requirements for Aviation, Space and Defense Organizations

2.4 US Government Publication:

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:**3.1 Vacuum bag**, nylon film, 3 mils maximum, qualified for use at 375°F or above, or equivalent

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

3.2 Breather, Style 120 Fiberglass or N-10 or Ultraweave 1332 , nonwoven polyester breather, or equivalent

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

3.3 Breather string, glass roving strings/threads, ECDE 75 1/0, any finish (may be extracted from 7781 style glass fabric), or equivalent

- Open source

3.4 Solid FEP film, separator/release film, 1-2 mils thick, qualified for use at 375°F or above

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

3.5 Solid (Nonporous) Teflon Coated Glass Fabric, 3-5 mil

- Taconic, 3070 Skyway Drive, Bldg 203 Santa Maria, CA 93455
- Or equivalent

3.6 Pressure (Caul) Plate, 0.060 – 0.2500 inch thick, aluminum is preferred, flat and smooth, or equivalent

- Open source

3.7 Mylar Tape, Pressure Sensitive Mylar Tape qualified for use at 375°F 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

3.8 Tacky (Sealant) tape, compatible with nylon vacuum bag, qualified for use at 375°F or above

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

- Or equivalent

3.9 Mold (bottom tool), 0.250-0.500 inch thick, aluminum, flat and smooth, or equivalent

- Open source

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

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

4. TEST LAMINATE FABRICATION

4.1 Prepreg cutting

Wear non-contaminating gloves such as disposable powder-free nitrile gloves when handling the prepreg. The prepreg may be cut using conventional method (i.e. on a glass or non-contaminating polyurethane table top with utility knife) or automated method. The method of cutting must not contaminate the prepreg. **The prepreg shall be cut a minimum of ½” larger on each edge than the required panel dimensions. The required panel dimensions are specified in Appendix 2 of applicable test plan or work instruction.** Fiber orientation (e.g. warp versus fill directions) must be maintained during the cutting process. In Appendix 2 of applicable test plan, the warp/longitudinal directions are always larger than the fill/transverse directions; this rectangular shape helps maintain direction traceability.

4.2 Prepreg lay up and bagging

Wear non-contaminating gloves such as disposable powder-free nitrile gloves when handling the prepreg. The panel layups (stacking sequences) for qualification and equivalency purposes should be in accordance with Appendix 2 of appropriate test plans. For material acceptance purpose, the panel layups should be in accordance with NMS 220.

In the case of materials which are not mid-plane symmetric, such as satin weave fabrics, plies must be orientated such as to give a mid-plane symmetric laminate as best as possible, as shown in Figure 1.

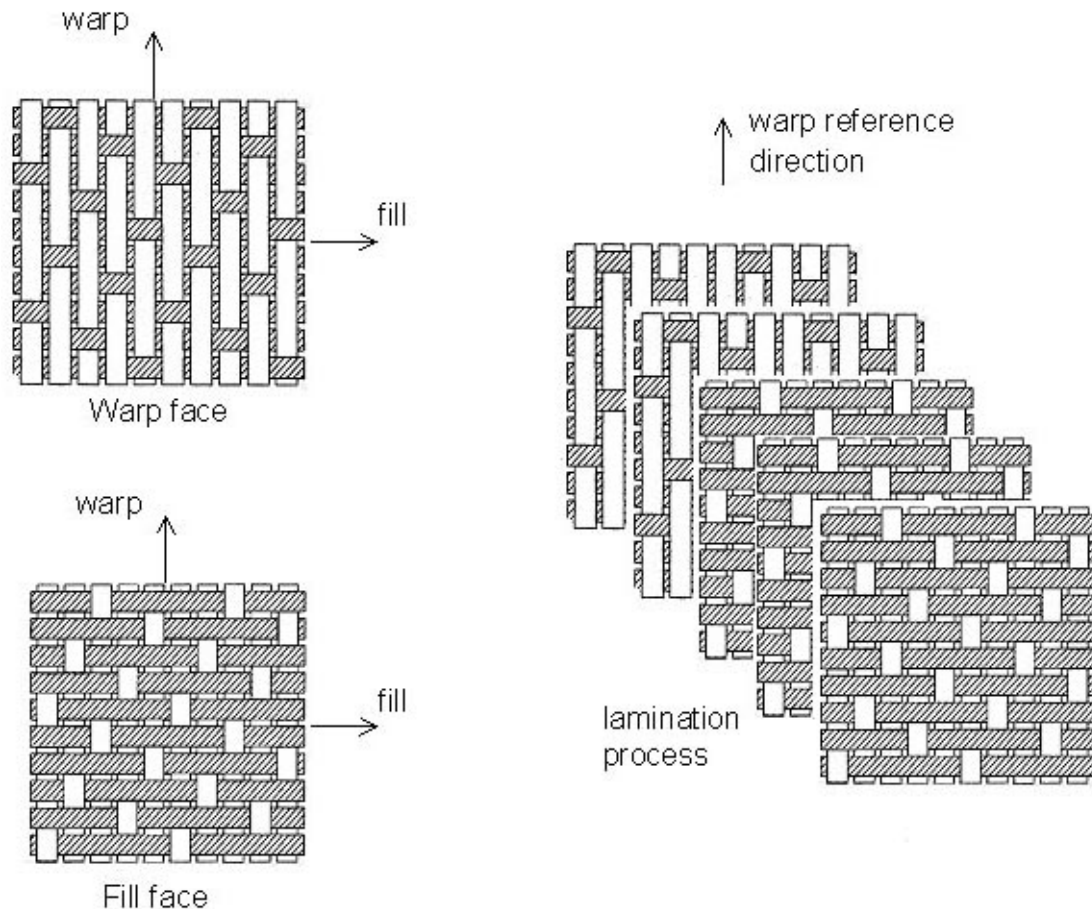


Figure 1 - Example Satin Weave Showing Warp and Fill Faces Used for Ply Collation

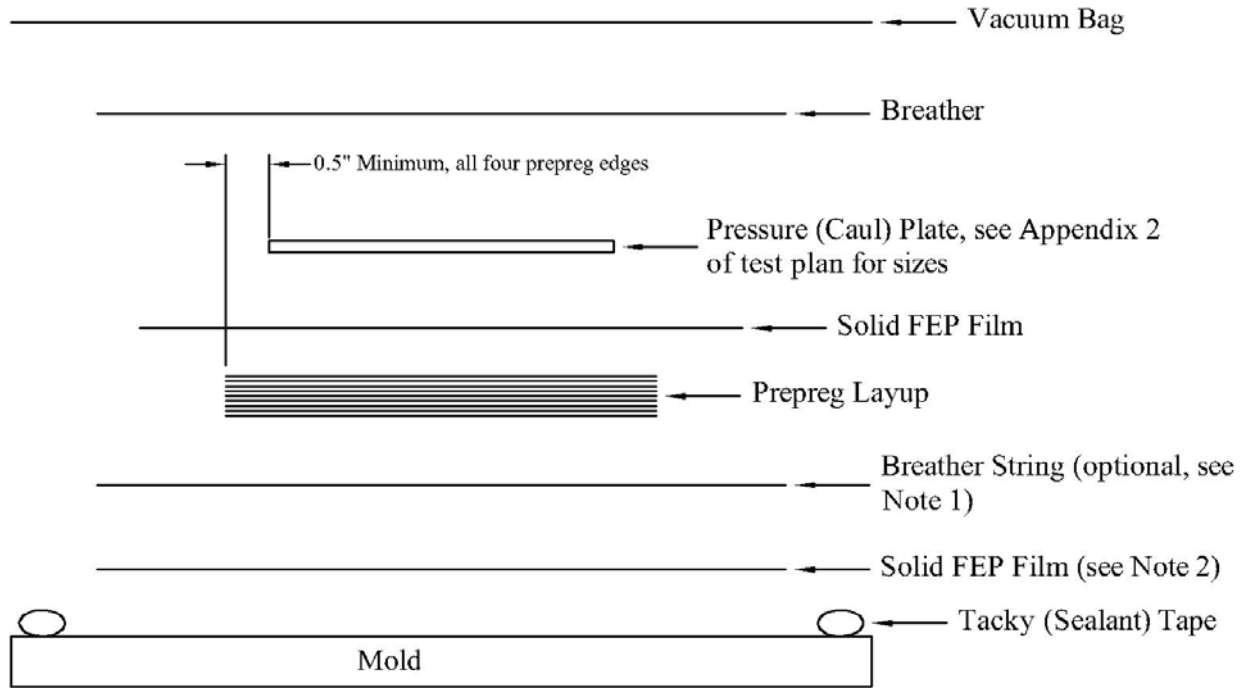
In order to maintain the fiber orientation, a reference edge should be indicated on each panel. Use a straight edge ruler/dam to ensure proper fiber orientation during layup. During the layup process, each ply must be laid up within $\pm 5^\circ$ for fabric, and $\pm 3^\circ$ for tape of the reference edge. In the layup process of unidirectional prepreg, plies may be butt spliced in the 90° direction; ply splicing is not allowed in the 0° 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 $\frac{1}{2}$ -inch from the prepreg edge with the following information: “ 0° direction \rightarrow , Test Plan Document Number -Prepregger ID - Material Code - Fabricator ID - Test Type - Batch ID - Cure Cycle ID -Test Panel ID.” Make sure that the “ 0° direction \rightarrow ” marking is near to the reference edge and actually points in the 0° direction or warp direction. Appendix 2 of the test plan contains the panel identification information.

Procedure:

Figure 2 shows the bagging arrangement which will be used for the manufacture of mechanical test panels.

- a. A minimum of two thermocouple wires should be used to monitor and record the panel temperature of each autoclave cure cycle run. One method is to place the thermocouple junctions at the laminate mid-plane and near the edge of the laminate where they will be trimmed off after the panels have been cured. An alternative method is to place the thermocouple junctions on the part about 0.25-0.50 inch away from the edge. The latter method allows the thermocouples wires to be reused if the thermocouple junctions are wrapped with Teflon or Mylar tape so that they can be removed from the part after cure. Thermocouples may be placed outside the bag only if it has been previously demonstrated that there is negligible temperature difference between the inside and outside of the bag.
- b. Release agents may be used on the tool surface instead of solid release film (i.e. non-porous FEP film). However, Teflon coated fiberglass reduces propensity of air entrapment on the tool/bag surfaces and improves surface finish.
- c. Place a solid Teflon coated fiberglass or solid FEP film on the mold. Liquid release agent may be applied on the mold in lieu of the solid Teflon coated fiberglass or solid FEP film.
- d. Place a straight edge ruler/dam on the mold and secure it with tape. Begin laying up in accordance with the proper stacking sequences (see Appendix 2 of test plan or appropriate specifications), making sure that each ply is butt against the dam. Optional to place single ECDE 75-1/0 yarn breather strings along each edge of the lay-up as shown in Figure 2b. Remove the straight edge ruler/dam from the mold.
- e. Place a solid FEP film over the prepreg layup. Place a caul plate on the FEP film. The caul plate shall be 0.060 to 0.250 inches thick and be at least 0.5-inch smaller than the prepreg on each edge.
- f. Place one layer of breather or 2 plies of style 120 fiberglass cloth breather or an equivalent breather over the lay-up according to Figure 2a.
- g. Place a layer of nylon vacuum bagging film over the entire lay-up.
- h. While applying vacuum to the bag, make sure that there is sufficient FEP film, breather, and vacuum bag to conform over the uneven surfaces to avoid bridging in the bag. Apply a minimum vacuum of 28" of Hg (or within 2" 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" of Hg in 5 minutes. If this rate is exceeded, repair the leak and recheck the leak rate.



Note 1: Breather strings are optional and not used in the fabrication of Qualification test panels. If used, breather strings must be placed along the prepeg edges only and not on the prepeg (see Figure 2b). Breather strings must contact breather in order to be effective.

Note 2: Optional to use Solid (Nonporous) Teflon Coated Fiberglass Fabric or liquid release agent.

Figure 2a - Bagging Technique for NMS 220

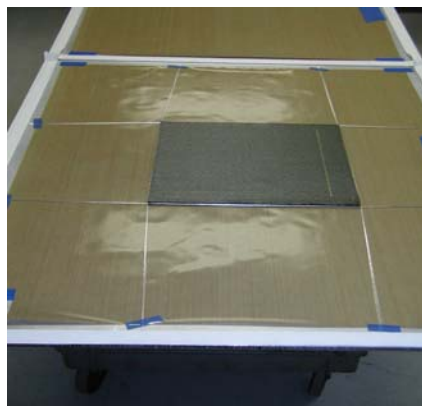


Figure 2b – Lay-up with Optional Breather Strings

4.3 Baseline Cure Cycle (C)

The baseline cure cycle shall be in accordance with the following process. For the purpose of specimen naming, this cure cycle is designated as "C." The material qualification panels are processed in accordance with the baseline cure cycle. Check vacuum bag integrity prior to starting cure cycle; leak rate shall not exceed 1" of Hg in 5 minutes. All temperatures are panel temperatures 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 4.2 (h). No more than 1" of Hg of vacuum over a 5 minute period is allowed.
2. Apply full vacuum within 2" of Hg of the local atmospheric pressure. Vent the vacuum to the atmosphere when the autoclave pressure reaches 14-20 psi. Apply and maintain autoclave pressure of 85 -100 psi. Pressure in the vacuum bag shall be less than 5psig throughout the cure cycle.
3. Heat up starts simultaneously with the start of autoclave pressurization. Heat from RT to 355 ± 10 °F at 1 to 5 °F/minute based on the panel temperature. If a vacuum bag leak is detected before the leading thermocouple temperature reaches 160°F, the process cycle may be aborted.
4. From 325°F to 355 ± 10 °F a minimum heat-up rate of 0.3 °F/min is acceptable. Hold at 355 ± 10 °F for 120 to 150 minutes. Start the hold when the lagging thermocouple reaches 345°F.
5. Cool under pressure until below 140°F at 5 °F/minute maximum. Release vacuum when the vacuum hoses are disconnected from the vacuum bag.

4.4 Alternative Cure Cycles

Based on limited historical data, a resin cure kinetics model, and a viscosity model, the lamina and laminate material properties are believed to be robust to some minor changes in the cure cycle, although deviations from the baseline qualification cure cycle may increase the risk of equivalency failure. The cure cycle tolerance (i.e. upper and lower cure cycle envelope) has also not been thoroughly investigated. Since not all properties are investigated in a typical equivalency program, users should not assume that successful equivalency demonstration also means that all other properties are equivalent; a more extensive test matrix that includes more test methods and test conditions may be necessary to thoroughly evaluate the true equivalency of the alternate cure cycle(s). Based on the popularity of the alternate cure cycle(s), NCAMP may perform more extensive testing to investigate the equivalency of the alternate cure cycle(s).

Users who wish to use the alternate or any other cure cycles may contact NCAMP to have the cure cycles evaluated against the cure kinetics model and the viscosity model. This evaluation will provide a reasonable level of confidence about the similarities of the two cure cycles and may improve the chance of successful equivalency demonstration.

4.5 Cured Panels

The reference edge in section 4.2 should be clearly marked on each panel. This reference edge will be used as datum for subsequent machining process. Sharp edges should be removed from cured panels so that they can be handled and packaged safely.

5. QUALITY ASSURANCE

5.1 Process Control

In-process monitoring data such as part temperature, autoclave temperature, vacuum, and part vacuum readings through the cycle should 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 should 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.

5.2 Ultrasonic Non-Destructive Inspection

Panel fabricator need not perform ultrasonic non-destructive inspection on the test panels. For material qualification and equivalency purposes, the panels shall be ultrasonically inspected by the testing lab in accordance with the applicable test plan.

5.3 Visual Inspection

Verify that there are no obvious defects such as warpage or dry spots. Panels for material qualification and equivalency purposes should be labeled in accordance with the applicable test plan for identification purposes.

6. SHIPPING

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

7. REVISIONS

Revision	Date	Description
-	1/26/2012	Initial Release