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NCAMP Process Specification
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Fabrication of NMS 201 Qualification, Equivalency, and Acceptance Test Panels (RM-2014-LDk-Tk)

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REVISIONS

Revision	Date	Description
-	7/5/2023	Initial Release
A	7/12/2024	Section 3.2: Removed breather string, mylar tape and edge dam materials. ”preferred” was added for Ultraweave 1332 breather. Section 4.1: Additional clarification was added. Section 4.2.2: Additional clarification was added for debulk, TC placements. Caul plate requirement was revised to match Section 3.2. Breather step was revised. Edge dam was removed. Figure 2 was updated. Revision A was made to record NMS 201/1 Qualification panel fabrication.

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1. SCOPE

This process specification describes the methods of fabricating test panels using NMS 201 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 201	Autoclave Cure, Low Dielectric Epoxy Prepregs (RM-2014-LDk-Tk)

2.2 ISO Publication:

ISO 9000	Quality Management Systems

2.3 SAE Publication:

AS 9100	Quality Management Systems - Requirements for Aviation, Space and Defense Organizations
AS13100	AESQ Quality Management System Requirements for Aero Engine Design and Production 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
DOT/FAA/AR-03/19	Material Qualification and Equivalency for Polymer Matrix Composite Material Systems: Updated Procedure
DOT/FAA/AC-23-20	Acceptance Guidance on Material Procurement and Process Specifications for Polymer Matrix Composite Systems

3. MATERIALS:

3.1 **Vacuum bag**, nylon film, 3 mils maximum, qualified for use at 375ºF or above, or equivalent
- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

3.2 **Breather**, N-10 or Ultraweave 1332 (preferred), nonwoven polyester breather, or equivalent
- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

3.3 **Solid FEP film,** separator/release film, 1-2 mils thick, qualified for use at 375ºF or above
- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

3.4 **Solid (Nonporous) PTF- Coated Glass Fabric**, 3-5 mil
- Taconic, 3070 Skyway Drive, Bldg 203 Santa Maria, CA 93455
- Or equivalent

3.5 **Pressure (Caul) Plate**, 0.06 – 0.30 inch thick, aluminum is preferred, flat and smooth, or equivalent
- Open source

3.6 **Tacky (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

3.7 Mold (bottom tool), 0.200-0.750 inch thick, aluminum, flat and smooth, or equivalent
- Open source

3.8 Release Agents, Chem Trend Zyvax Composite Shield or Water Shield
- North American Region Headquarters 1445 W. McPherson Park Drive Howell, Michigan 48843
- 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 for qualification panels only (optional for release testing panels).** 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 whenever possible; this rectangular shape helps maintain direction traceability.

4.2 Prepreg lay-up and bagging

4.2.1 Ply Lay-Up

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 201.

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.

Note:
NMS 201/1 - warp face shall not be flipped for qualification, equivalency, or acceptance laminates.

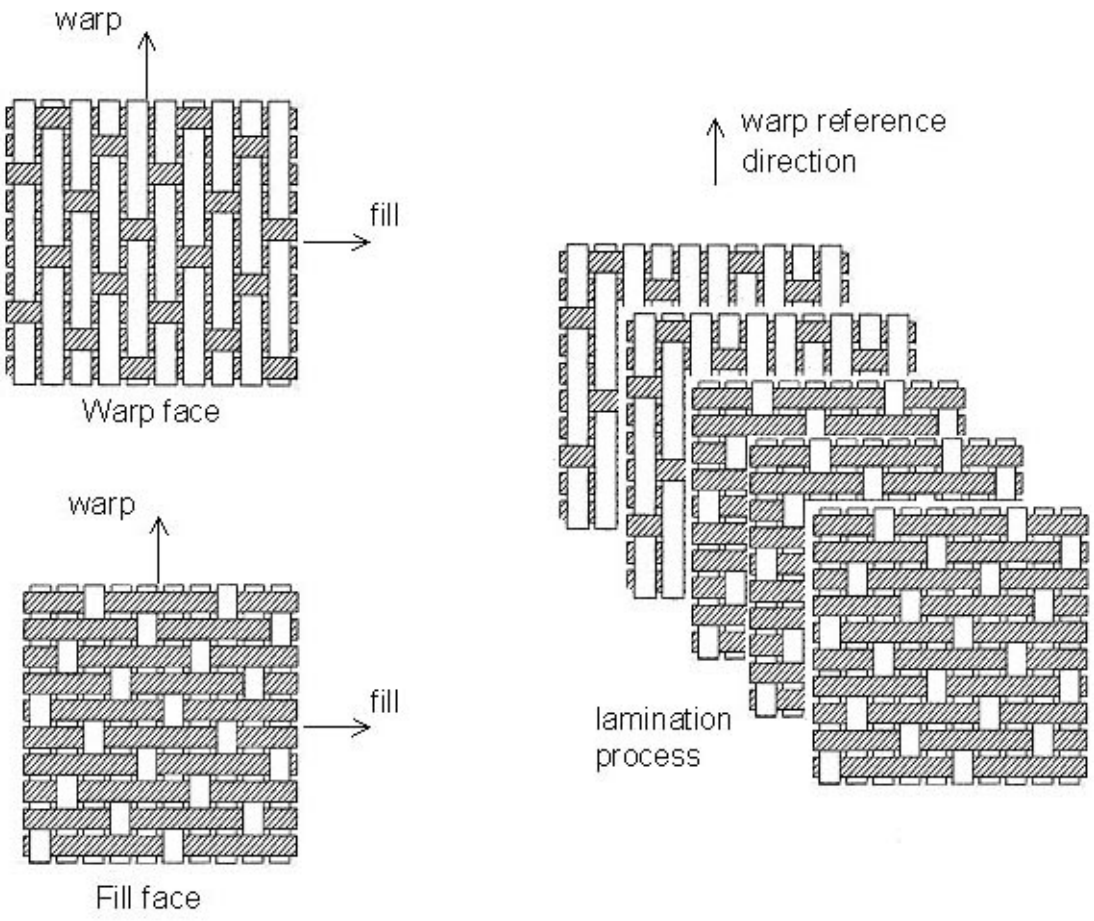

Figure 1 - Example Satin Weave Showing Warp and Fill Faces Used for Ply Collation

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 ±5°of the reference edge. In the layup process 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 →” marking is near to the reference edge and points in the 0º direction or warp direction. Appendix 2 of the test plan contains the panel identification information.

4.2.2 Bagging Procedure

Figure 2 shows the bagging arrangement which will be used for the manufacture of

mechanical test panels for qualification, equivalency, and acceptance.

Laminate shall be de-bulked at room temperature every 1-6 plies at 24 inHg vacuum minimum (or within 2 inHg of the local atmospheric pressure, whichever is less), for 5 minutes minimum. Heated de-bulks are optional at maximum 155°F for maximum 30 minutes, qualification panels shall not use heated de-bulks.

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. In both methods, the TC should be underneath the breather to better match the thermal insulation as well as prevent the TC from breaking the bag. 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 negligible temperature difference between the inside and outside of the bag can be demonstrated.

b. Release agents may be used on the tool surface instead of solid release film (e.g. non-porous FEP film). However, PTFE-coated fiberglass reduces propensity of air entrapment on the tool/bag surfaces and improves surface finish.

c. Place a solid PTFE-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. 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 a straight edge to ensure plies are aligned properly with respect to each other (±5°).

e. Place a solid FEP film over the prepreg layup, extending beyond the laminate. Place a caul plate on the FEP film. The caul plate may be 0.06 to 0.30 inches thick and be 0.5-inch smaller (nominal) than the prepreg on each edge.

f. Place a minimum of one layer of N10 or 1332 breather or an equivalent breather over the lay-up according to Figure 2.

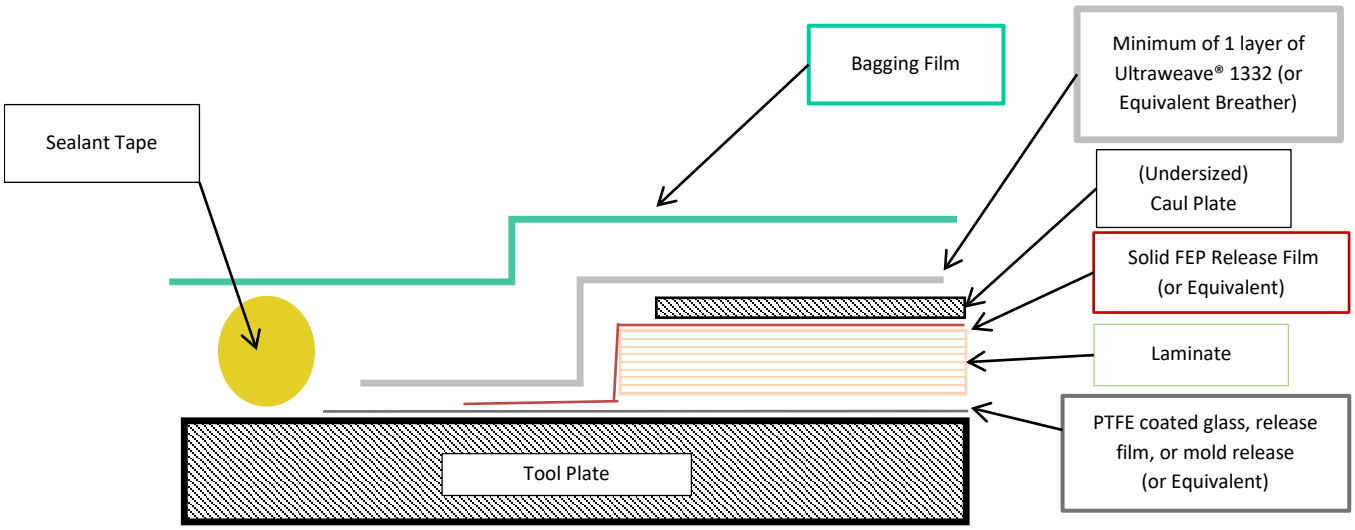

Figure 2 – Bagging Technique for NMS 201

g. Place a layer of nylon vacuum bagging film over the entire lay-up. Seal to the tool surface using an appropriate sealant tape.

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 24 inHg (or within 2 inHg of the local atmospheric pressure, whichever is less) 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, then take a final reading after 5 minutes of isolation from vacuum source. The difference between the two readings is the leak rate. The vacuum shall not fall more than 2 inHg in 5 minutes. If this rate is exceeded, repair the leak and recheck the leak rate.

4.3 Baseline Cure Cycle (A) – Low Pressure

The baseline cure cycle shall be in accordance with the following process. For the purpose of specimen naming, this cure cycle is designated as “A.” The material qualification panels are processed in accordance with the baseline cure cycle.

Cure Cycle

All temperatures are panel temperatures based on the lagging thermocouple unless specified. Minimum vacuum is as identified in cure, or within 2 inHg of local atmospheric pressure, whichever is less. The vacuum and temperatures shall be recorded at 5-minute maximum interval.

1. Laminate shall be de-bulked at room temperature, minimum vacuum of 24 inHg, for 30 minutes minimum prior to cure. A final heated debulk at maximum 150°F, minimum vacuum of 24 inHg, for maximum 30 minutes is optional (unverified) but shall not be used for qualification panels.
2. Insert bagged layup into the autoclave. Connect vacuum lines and thermocouple. Perform autoclave vacuum integrity check: vacuum loss shall not exceed 2 inHg in 5

minutes.
3. Maintain minimum vacuum of 24 inHg until lagging thermocouple reaches 300 +20/-10°F. It is permissible to release vacuum upon meeting this criteria.
4. Apply 15 ± 8 psi autoclave pressure prior to lead thermocouple reaching 250 ± 15°F. Pressure application is permitted at beginning of cycle.
5. Ramp from ambient to 250 ± 15°F at 1-12°F/minute average over ramp segment (4°F/minute nominal).
6. Dwell at 250±15°F; for 20-45 minutes (time starting when lagging thermocouple reaches 235°F).
7. Ramp to 300 +20/-10 °F at 1-12°F/minute (4°F/minute nominal).
8. Dwell at 300 +20/-10 °F; for 240-360 minutes (time starting when lagging thermocouple reaches 290°F).
9. Upon completion of the dwell, cool to 140°F at 1-12°F/minute average over ramp segment (4°F/minute nominal).
10. Release autoclave pressure. Remove part from autoclave.

4.4 Alternative Cure Cycle – Cure Cycle (B) – High Pressure

The high pressure cure cycle shall be in accordance with the following process. For the purpose of specimen naming, this cure cycle is designated as “B”.

Cure Cycle
All temperatures are panel temperatures based on the lagging thermocouple unless specified. Minimum vacuum is as identified in cure, or within 2 inHg of local atmospheric pressure, whichever is less. The vacuum and temperatures shall be recorded at 5-minute maximum interval.

1. Laminate shall be de-bulked at room temperature, minimum vacuum of 24 inHg, for 30 minutes minimum prior to cure. A final heated debulk at maximum 150°F, minimum vacuum of 24 inHg, for maximum 30 minutes is optional (unverified) but shall not be used for qualification panels.
2. Insert bagged layup into the autoclave. Connect vacuum lines and thermocouple. Perform autoclave vacuum integrity check: vacuum loss shall not exceed 2 inch Hg in 5 minutes.
3. Maintain a minimum vacuum of 24 inHg until lagging thermocouple reaches 300 +20/-10°F. Vacuum may be released once lagging thermocouple meets this criteria.
4. Apply 50 ± 10 psi autoclave pressure prior to lead thermocouple reaching 250 ± 15°F
5. Ramp from ambient to 250 ± 15°F at 1-12°F/minute average over ramp segment (4°F/minute nominal).
6. Dwell at 250±15°F; for 20-45 minutes (time starting when lagging thermocouple reaches 235°F).
7. Ramp to 300 +20/-10 °F at 1-12°F/minute (4°F/minute nominal).
8. Dwell at 300 +20/-10 °F; for 240-360 minutes (time starting when lagging thermocouple reaches 290°F).
9. Upon completion of the dwell, cool to 140°F at 1-12°F/minute average over ramp segment (4°F/minute nominal).
10. Release autoclave pressure. Remove part from autoclave.

4.5 Cure Cycle Abort Criteria

In the event of an equipment or vacuum bag failure, the following protocol for pausing and re-starting the cure process can be used. Any cure cycle can be aborted, cooled, re-bagged and re-initiated provided the following conditions have been met:

- Leading thermocouple has not reached 212°F
- Vacuum bag integrity has been maintained with the following exceptions:
  - Pinhole leaks
  - Small tears <2.0 inch
- The laminate remains protected from ambient air until panels have reached room temperature

In such of this failure scenarios, this has to be documented in panel fabrication paperwork which include the issue, solution, in-process monitoring data of first cure run attempt, affected panel IDs, etc. This section is not proven by any mechanical testing data, therefore engineering judgement through MRB process might need to take place.

4.6 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 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.