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NCAMP Process Specification

Fabrication of NMS 380 Qualification, Equivalency, and Acceptance Test Panels

Toray TC380 prepregs

This specification is generated and maintained in accordance with
NCAMP Standard Operating Procedures, NSP 100

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REVISIONS

Rev	By	Date	Description
-	Vinsensius Tanoto	2/21/2024	Initial Release
A	Vinsensius Tanoto	5/20/2024	Section 4.2.5: - Tedlar was revised to optional. Figure 2 was also updated. - Typos were corrected, "Using and alignment bar" to "Using an alignment bar". Section 4.2.6: - Tedlar was revised to optional. Figure 3 was also updated. Section 4.2.7: - Tedlar was revised to optional. Figure 4 was also updated. Section 4.3: - Added autoclave pressure rate tolerance.
B	Vinsensius Tanoto	10/22/2024	Section 4.2.4: - Added "(Optional) Increasing Prepreg Tackiness" information. Section 4.3: - Added "Note for inspection requirements".

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1 SCOPE

This process specification describes the methods of fabricating test panels using NMS 380 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 380	Toughened Epoxy Prepregs, Toray TC380
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2.2 ISO Publication

ISO 9000	Quality Management System
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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

Material	Material Description	Material Source
Vacuum bag	Nylon film, 10-30 mils P/D: IPPLON WN1500-002-36 inch, P/N: WN2363M Or equivalent	• Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647 • Or equivalent
Breather Cloth	Polyester P/D: Airweave-N7-30 inch, P/N: AWN760 Or equivalent	• Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647 • Or equivalent
Pressure (Caul) Plate	≥0.125 inch thick, 0.250 inch is preferred, aluminum or stainless steel, smooth and scratch free (~<32rms), flat (0.002" per foot). MIC 6 or 5080P standards are preferred. Or equivalent	• Open source
Release Film	FEP/Mylar (P/D): A400R-001-30 inch (P/N): A4000R130600 Or equivalent	• Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647 • Or equivalent
Release Film	PVF (Tedlar) film (P/N): TWH10SS3 Or equivalent	• DuPont • Or equivalent
Release Agents	Frekote 44-NC, Frekote 55- NC, Frekote 700-NC Or equivalent	• Henkel, One Henkel Way, Rocky Hill, CT 06067 • Or equivalent
Tape (Optional)	Orange flash breaker, 1.0 inch wide P/N: FB01172	• Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647

	Or equivalent	• Or equivalent
Vacuum Sealant	Chromate, 0.5 inch wide P/N: AT200 Y 1/2 Or equivalent	• Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647 • Or equivalent
Mold (Bottom Tool)	Aluminum, 0.500 inch thick, flat and smooth (MIC6 or 5080P surface	• Or equivalent
Edge Dam	Silicon Rubber Edge Dams Sildam 1/41/230 Orange Sildam 1/4"x1/2"x30FT P/D: Sildam 1/41/230 Or equivalent	• www.jj-paper-packaging.com • Or equivalent
Release Ease (Peel Ply)	Porous TFE Coated Glass 200TFP, TFP234 or TX-1040 Or equivalent	• Solvay, 4500 McGinnis Ferry Rd. Alpharetta, GA 30005 • 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 tabletop with utility knife) or automated method. The method of cutting must not contaminate the prepreg. **The prepreg shall be cut a minimum of 1/2" 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 Layup and Bagging

4.2.1 General Information

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 380.

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.

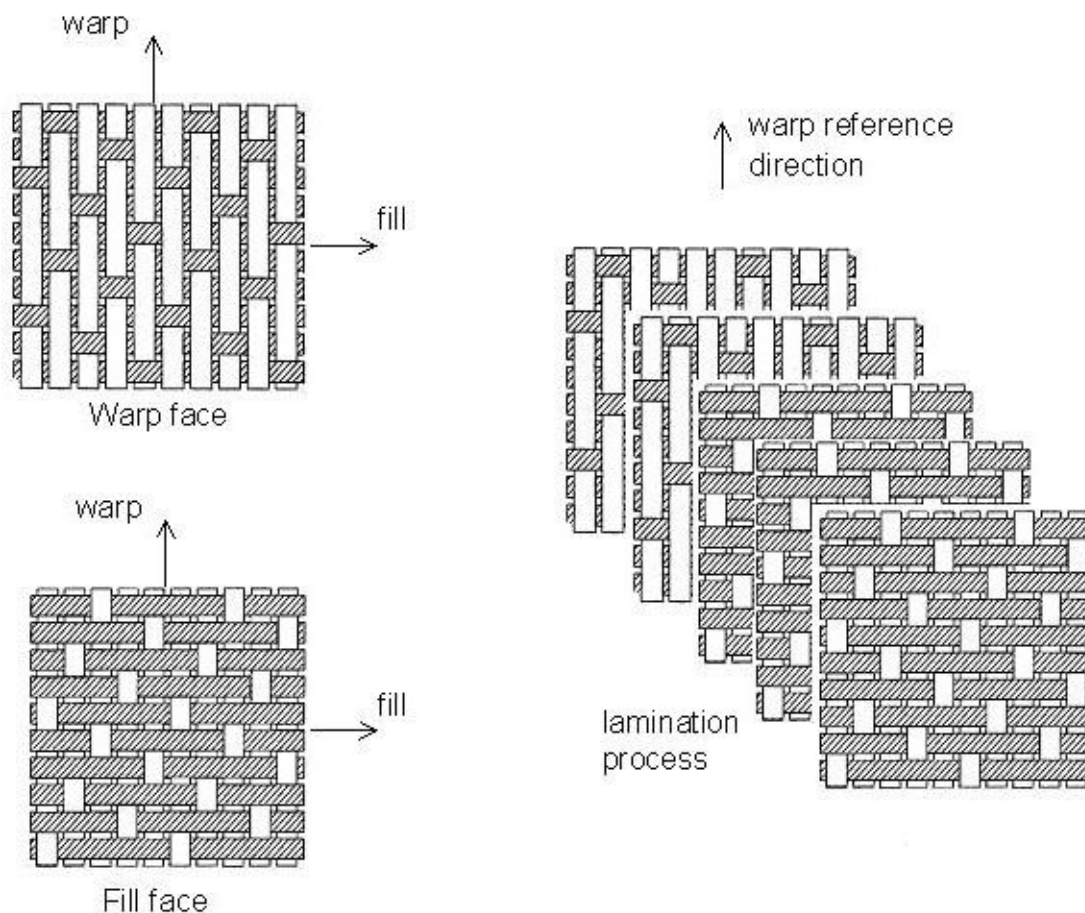


Figure 1 – Example Satin Weave Showing Warp and Fill Faces Used for Ply Collation

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.

4.2.2 Panel Identification

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 →”, “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 →” marking is near to the reference edge and points in the 0° direction or warp direction. Appendix 2 of the test plan contains the panel

identification information.

For batch release testing and receiving inspections, marker such as Sharpie may be used for panel identification.

4.2.3 Reference Edge

One edge of each panel, perpendicular to the 0° direction, will be molded against aluminum or steel edge reference bar to facilitate sub panel and specimen cutting and machining.

4.2.4 (Optional) Increasing Prepreg Tackiness

Highly impregnated (HIP) TC380 materials (NMS 380/1) have a low level of tack at room temperature. Warming up the prepreg slightly can increase the level of prepreg tackiness to aid in consolidating plies during layup. Heat guns or other mild sources of heat may be used to aid in the layup process when laying prepreg plies. Heat guns must be kept approximately 8 to 12 inches away from the prepreg and surface temperature of the prepreg on the tools should not be higher than 90°F. Heat guns must be moving continuously over the area to prevent excessive heat at the same location. Heat guns must not be used to heat up the same area of prepreg for more than 1 second continuously. It is recommended to apply heat on the prepreg paper whenever possible.

Excessive heat application from heat guns may cause advancement of the resin in the prepreg and potentially part rejection.

Heat guns should only be used whenever it is necessary to aid layup process.

4.2.5 Thermocouple

Thermocouple wires should be used to monitor and record the temperature of representative test panels.

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 alternate method is to place the thermocouple junctions on the laminate. Placing the thermocouples between edge dam and laminate is also acceptable. The latter method allows the thermocouple wires to be reused if the thermocouple junctions are wrapped with Teflon or flash-breaker tape so that they can be removed from the part after cure.

4.2.6 Debulk

Using a debulking table, debulk every 4 plies for 15 minutes per Figure 2 at room temperature.

- a. (Optional) Cut and place a single layer of Tedlar (Part Number (P/N): TWH10SS3), larger in size than the laminate plies, onto the debulking table.
- b. Cut and place a single layer of FEP (P/N): A4000R130, Part Description (P/N): A4000R-011-30", (same size/or equivalent in size to the Tedlar if Tedlar is utilized), onto the top layer of the Tedlar if Tedlar is utilized.
- c. Create stacks of 4 plies off of debulk table on solid surface covered with FEP.
- d. Using an alignment bar or square, place each ply on top of one another to create the stack. Use a hand roller to tack each ply and remove trapped air as it is applied to the stack before removing backing paper or film. Do not roll all the way to the edge of the laminate as this will tend to pinch the ends and seal off air escape path. Leave cover film or paper on last applied ply.
- e. Using an alignment bar or square, place first stack on top of the two single layers of Tedlar if Tedlar is utilized and FEP on the debulk table. (Place subsequent stacks on top of existing stacks on debulk table). Roll stack similarly to the individual plies placed in previous step to adhere the 4 plies to the rest of the stack and push out air. Remove cover film or paper.
- f. Cut and place a single layer of porous Teflon coated glass (Release Ease, Part Number: TFP234, TX-1040, or equivalent) that extends beyond the laminate plies, on top of the laminate plies. The Teflon coated glass layer may be reused a maximum of 8 times.
- g. Cut and place a single layer of FEP, smaller than the Teflon coated glass (to allow for breathability), on top of the Teflon.
- h. Place, and square up, a caul plate wrapped with Tedlar (PVF) if Tedlar is utilized (caul plate should be the same size as the laminate layers) on top of the FEP layer, the Teflon coated glass layer, and the plies that are going to be debulked.
- i. Place breather cloth (P/D): Airweave-N7, (P/N): AWN73050, (larger in size than the Teflon coated glass layer), over the caul plate, FEP, Teflon coated glass, and prepreg plies.
- j. Connect vacuum hoses to the vacuum ports, located on the debulking table, and pull vacuum for a minimum of 15 minutes.
- k. Vacuum level shall be better than 25 inch Hg at all times.

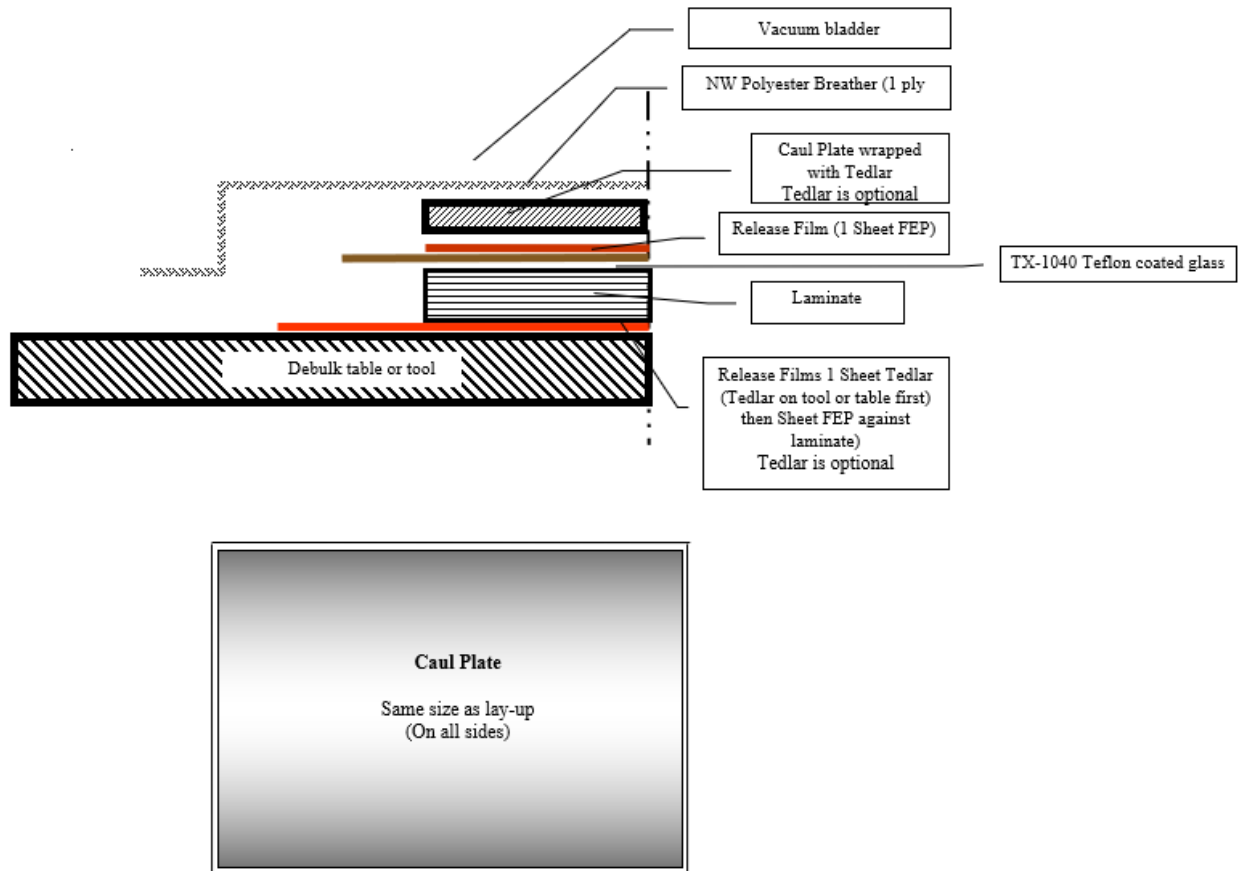


Figure 2 – Debulk Layup Stack

4.2.7 Bagging Procedure

The following bagging arrangement will be used for the manufacture of mechanical test panels.

- (Optional) Place one ply of Tedlar, larger in size than the laminate plies, onto the tool surface.
- Place one ply of FEP, same size/or equivalent in size to the Tedlar, onto the top layer of the Tedlar if Tedlar is utilized.
- Place the laminate on top of the two single layers of Tedlar if Tedlar is utilized and FEP.
- Dam the edges of the laminate for cure, by placing 0.50 inch wide silicone edge dams around the perimeter of the laminate (must be taller than the laminate – multiple layers of edge dams may be needed).
- Place one ply of FEP onto the surface of the laminate with it overlaying the outer perimeter of the silicone edge dams.
- Place, and square up, a Tedlar wrapped caul plate (the same size as the laminate) if Tedlar is utilized, on top of the FEP layer, and the laminate that is going to be cured.
- Place two thermocouple wires in the lay-up bag, one on the caul plate and the

other near the laminate.

- h. Place breather layers, over the caul plate, FEP, and the laminate, to assure a clear path for vacuum.
- i. Place vacuum ports onto breather cloth.
- j. Install vacuum bag on the tool, using 0.5 inch wide chromate as a sealant between the tool plate and the vacuum bag for cure.
- k. Connect vacuum hoses to the vacuum ports.

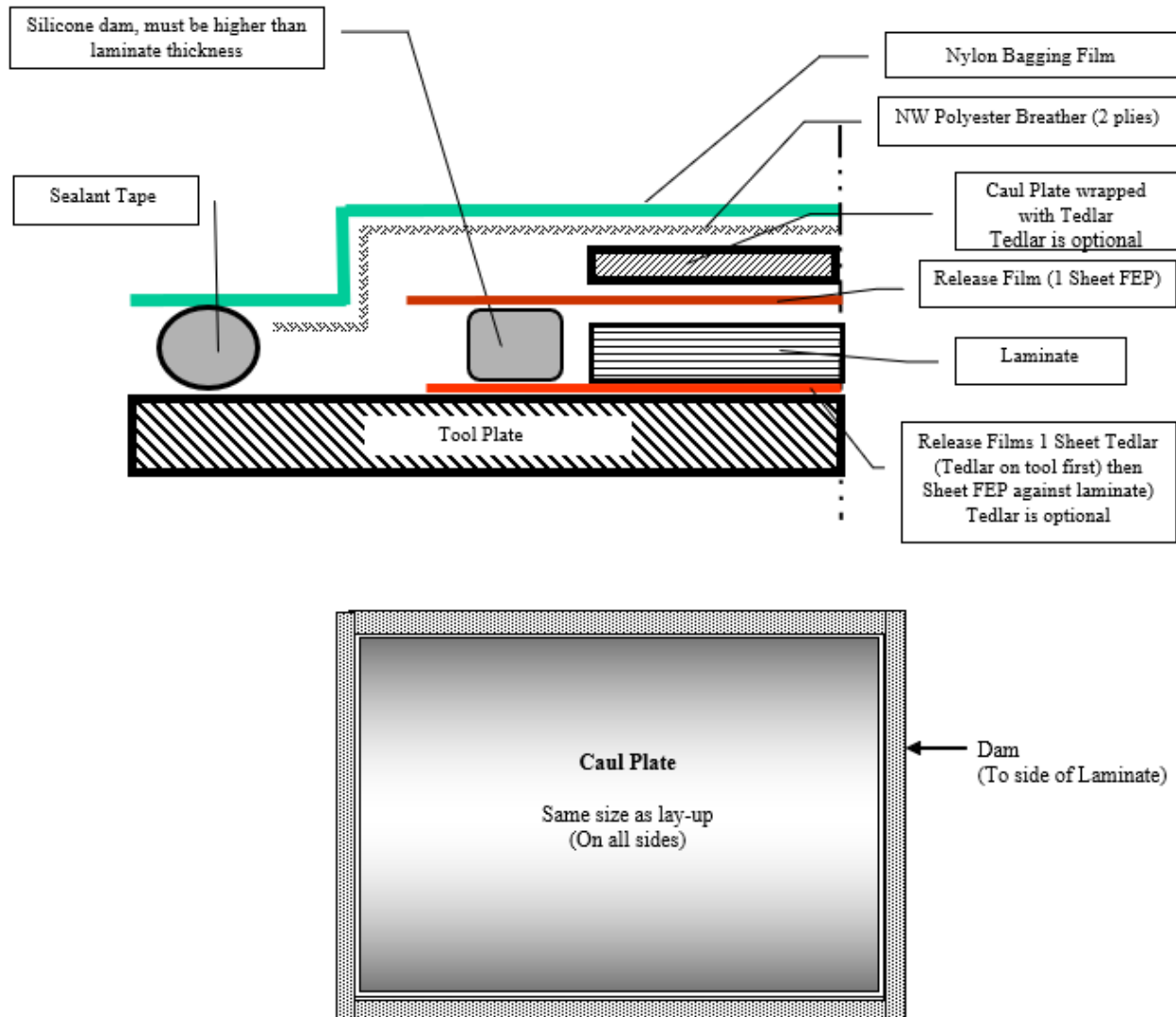


Figure 3 – Bagging/Layup Stack

Notes:

- The edge of the dams must be higher than the laminate thickness.
- Optionally, include fiberglass breather strings around the edge of the laminate between the laminate and the dams for the cure bagging. The

fiberglass strings should extend beyond the dams to the breather cloth (either in between the dams or over them)

- Thermocouple wires shall be used to monitor and record the temperature of representative test panels either placed in between laminate and dams or in the laminate stack. Thermocouples can be mounted to the caul plate directly if not able to be placed near or in the laminate.

4.2.8 Alternate Bagging Procedure

The following bagging arrangement will be used for the manufacture of mechanical test panels. Alternate bagging procedure utilizing Teflon Coated Glass peel ply which will be beneficial for some applications.

- (Optional) Place one ply of Tedlar, larger in size than the laminate plies, onto the tool surface.
- Place one ply of FEP, same size/or equivalent in size to the Tedlar, onto the top layer of the Tedlar if Tedlar is utilized.
- Place one ply of Teflon Coated Glass peel ply (TX-1040) onto the FEP same size as laminate.
- Place the laminate on top of the three single layers of Tedlar if Tedlar is utilized, FEP and TX-1040.
- Dam the edges of the laminate for cure, by placing 0.50 inch wide silicone edge dams around the perimeter of the laminate (must be taller than the laminate – multiple layers of edge dams may be needed).
- Place one ply of Teflon Coated Glass peel ply (TX-1040) onto the laminate, same size as laminate.
- Place one ply of FEP on top of the TX-1040 peel ply with the FEP overlaying the outer perimeter of the silicone dams.
- Place, and square up, a Tedlar wrapped caul plate (the same size as the laminate) if Tedlar is utilized, on top of the FEP layer, and the laminate that is going to be cured.
- Place two thermocouple wires in the lay-up bag, one on the caul plate and the other near the laminate.
- Place breather layers, over the caul plate, FEP, and the laminate, to assure a clear path for vacuum.
- Place vacuum ports onto breather cloth.
- Install vacuum bag on the tool, using 0.5 inch wide chromate as a sealant between the tool plate and the vacuum bag for cure.
- Connect vacuum hoses to the vacuum ports.

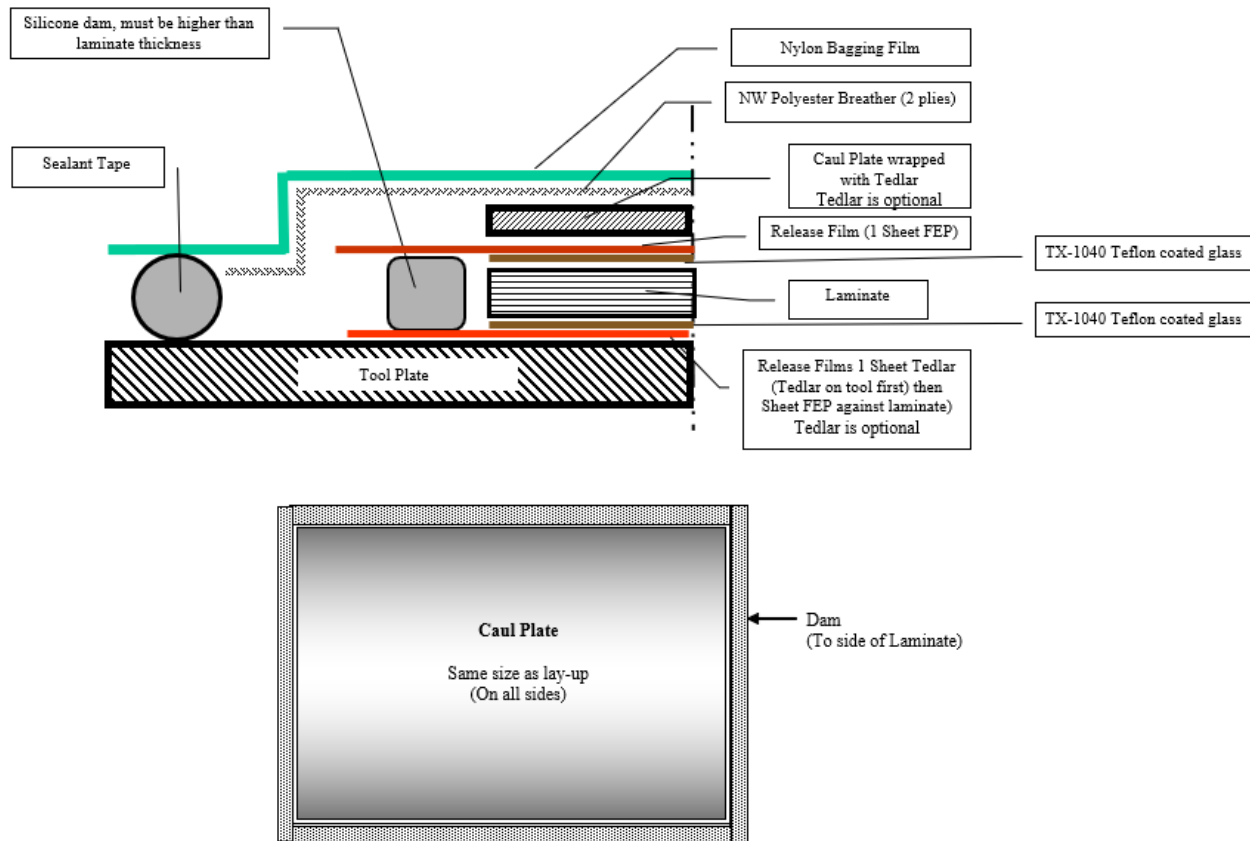


Figure 4 – Alternate Bagging/Layup Stack

4.3 Baseline Cure Cycle (C)

The baseline cure cycle shall be in accordance with the following process in Figure 5. For the purpose of specimen naming, this cure cycle is designated as “C.” The material qualification panels are processed in accordance with this baseline cure cycle. All temperatures are part temperatures. Steps 5 through 9 are based on the lagging thermocouple unless otherwise stated.

1. Prior to curing the laminate, leak check the bag to ensure a good seal. No more than 1 in. Hg of vacuum over a 2-minute period allowed. Leak check by taking an initial reading after 2-minute isolation and then take a final reading after an additional 2 minutes. The difference between the 2 readings is the leak rate.
2. Apply full vacuum, minimum required vacuum at initiation is 25 in. Hg.
3. Maintain active vacuum at room temperature (R/T) for a minimum of 4 hours total prior to cure. Vacuum hold can occur inside or outside of autoclave chamber and does not have to be continuous. If vacuum hold is performed outside of the autoclave chamber, leak check bag in autoclave prior to cure.
4. Apply pressure of 45 ± 5 psig at 10 ± 5 psig/minute rate. Maintain minimum vacuum of 25 in Hg.
5. Heat from R/T to $225 \pm 10^\circ\text{F}$ at $3 \pm 2^\circ\text{F/minute}$ based on the part temperature. Maintain full vacuum (per step 2. requirement) through ramp.

6. Hold at $225 \pm 10^\circ\text{F}$ for 60 (+60, -0) minutes. Start the hold when the lagging thermocouple reaches 215°F . Maintain full vacuum (per step 2. requirement) through hold.
7. Heat from 225°F to $356 \pm 10^\circ\text{F}$ at $3 \pm 2^\circ\text{F/minute}$. A minimum vacuum of 18 in. Hg under the vacuum bag shall be maintained during the remainder of the cure.
8. Hold at temperature for 120 (+60, -0) minutes. Start the hold when the lagging thermocouple reaches 346°F .
9. Cool to $< 140^\circ\text{F}$ at 5°F/minute maximum rate. Gradual vacuum delay is permitted during cool cycle.

Note for inspection requirements:

1. Ramp rate in Step (5) shall apply from 100°F to 200°F .
2. Ramp rate in Step (7) shall apply from 248°F to 330°F .
3. Ramp rate in Step (9) shall apply from 340°F to 140°F .

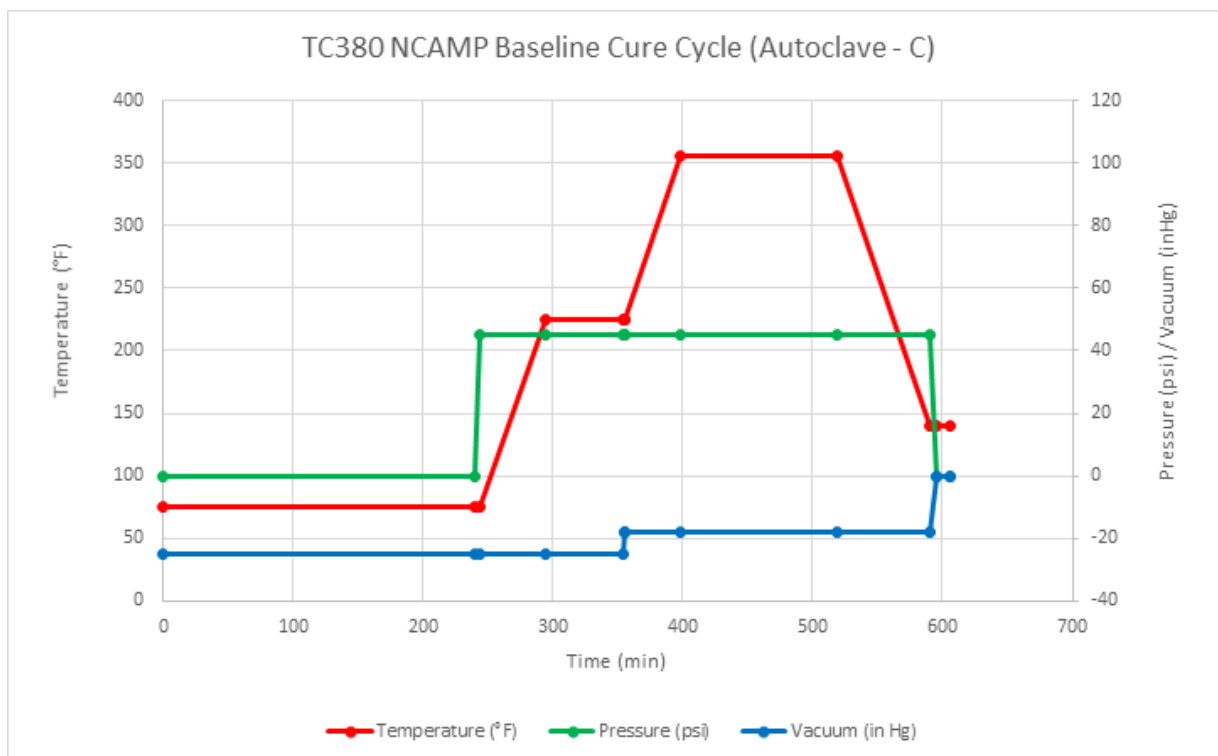


Figure 5 – Baseline Cure Cycle (C)

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 Panel Identification & Handling

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, autoclave pressure, 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.