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NCAMP Process Specification

Definitions, Layup Requirements, and Processing Instructions of NMS 397 Test Panels with Automated Fiber Placement and Automated Tape Laying Equipment.

Prepared by: Shakya Liyanage (NIAR), Waruna Seneviratne (NIAR), and John Tomblin (NIAR)

Reviewed by: Upul Palliyaguru (NIAR), Vinsensius Tanoto (NCAMP), Royal Lovingfoss (NCAMP)

National Center for Advanced Materials Performance

Wichita State University – NIAR

1845 Fairmount Ave., Wichita, KS 67260-0093, USA

REVISIONS

Rev	By	Date	Description
-	Isaac Schmitz	03/18/2022	Initial release.
A	Shakya Liyanage	10/18/2023	Updated cover page.
B	Shakya Liyanage and Vinsensius Tanoto	02/22/2024	Updated cover page.
C	Shakya Liyanage and Vinsensius Tanoto	3/4/2024	Addition of ATLAS logo.
D	Vinsensius Tanoto	3/7/2025	Cover page: replaced “Distribution Statement: This document is intended for proprietary use and will be distributed at the discretion of NIAR until such a time that it is decided the data and reports can be released for public distribution.” To “Distribution Statement A. Approved for public release; distribution is unlimited.”

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1 SCOPE

This process specification describes the methods of fabricating NMS 397 test panels using automated fiber placement and tape laying. Specifically, this specification covers definitions and general processing and procedural layup requirements including bagging schemes, materials, and cure cycles.

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 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 automated 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 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.

1.3 Abbreviations and Acronym

ACN	Advanced Change Notice
AFM	Automated Fiber Placement Machine
AFP	Automated Fiber Placement
ATL	Automated Tape Laying
FOD	Foreign Object Debris
ipm	Inches per Minute
Lap	Overlap
MFP	Manual Fiber Placement
NCAMP	National Center for Advanced Materials Performance
NIST	National Institute of Standards and Technology
NMS	NCAMP Material Specification
NPS	NCAMP Process Specification
PM	Preventative Maintenance

1.4 Definitions

1.4.1 Automated Fiber Placement Machine: Any automated robotic machine or gantry system

capable of deposition of prepreg or dry fiber materials.

1.4.2 Automated Fiber Placement: Use of any AFM for deposition of material 2 inches wide or less.

1.4.3 Automated Tape Laying: Use of any AFM for deposition of material 2 inches wide or greater.

1.4.4 Course: Multiple tows laid up in a single, continuous AFM head movement.

1.4.5 Manual Fiber Placement: The placement of AFP tows or ATL tapes by hand.

1.4.6 Slit Tape: Unidirectional prepreg or dry fiber that has undergone the slitting process.

1.4.7 Tape: A single strip of prepeg or dry fiber with a width 2 inches wide or greater used in automated tape laying.

1.4.8 Tow: A single narrow strip of prepreg or dry fiber with a width less than 2 inches used in automated fiber placement.

1.4.9 Controlled Environment: Any environment in which processing of uncured material occurs.

2 APPLICABLE DOCUMENTS

The latest issue of 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 397 Rev-	High Toughness and High Tensile Performance Epoxy Prepregs Toray Composite Materials America, Inc. 3960
NMS 397/3 Rev-	High Toughness and High Tensile Performance Epoxy Prepregs, Type 33.5, Class 1, Form 3, Grade 192

2.2 ISO Publications

AS 9100	Quality Management Systems - Requirements for Aviation, Space and Defense Organizations
ISO 14644-1	Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness by particle concentration

3 MATERIALS

3.1 Expendable Materials

Materials noted in this section shall be used during the manufacturing of NMS 397 Test Panels.

3.1.1 Vacuum Bag (Film)

a. IPPLON KM1300 2mil
    i. Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
    ii. Qualified for use at 375ºF or above
b. Or Equivalent

3.1.2 Breather

a. Polyspun 2.1OZ
    i. Filtration Systems, 8506 Herrington CT, Pevely, MO 63070
b. N10 (10oz/yards) polyester – *if caul plate is utilized*
    i. Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
c. Or equivalent

3.1.3 Breather String

a. T30M
    i. Hexcel, 281 Tresser Blvd Stamford, CT 06901
b. Glass Roving
    i. Open source
c. Or equivalent

3.1.4 Solid FEP (Film)

a. A4000V220300
    i. Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
    ii. Qualified for use at 375ºF or above
b. Or equivalent

3.1.5 Pressure (Caul) Plate (0.1-0.25 inch thick)

a. Aluminum
    i. Open source
    ii. Flat and smooth
b. Composite
    i. Open source
    ii. Flat and smooth
c. Steel
    i. Open source
    ii. Flat and smooth
d. Or equivalent

3.1.6 Edge Dam

a. Tacky (Sealant) tape (refer to 3.1.8)

b. Silicone rubber
    i. Open source
    ii. Qualified for use at 400°F or above
    iii. Shore A hardness of 60
c. Solid piece of wood wrapped in Teflon tape
    i. Saint-Gobain CHR 2285 Hugh Modulus PTFE pressure sensitive tape or equivalent
d. Aluminum bar
    i. Open Source

3.1.7 Mylar Tape

a. Flashbreaker 2 Tape
    i. Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
    ii. Qualified for use at 375ºF or above
b. Or equivalent

3.1.8 Tacky (Sealant) Tape

a. 51271642, 1/8” x ½”
    i. ITW Polymer Sealants North America, 111 S. Nursery Road Irving, TX 75060
    ii. Qualified for use at 375ºF or above
b. Or equivalent

3.1.9 Mold (Bottom Tool)

a. Aluminum
    i. Open source
    ii. Flat and smooth
    iii. 0.125-0.35 inch thick
b. Composite
    i. Open source
    ii. Flat and smooth
    iii. 0.125-0.35 inch thick
c. Steel
    i. Open source
    ii. Flat and smooth
    iii. 0.125-0.35 inch thick
d. Or equivalent

3.1.10 Release Agents

a. Frekote 44-NC
    i. Henkel, One Henkel Way, Rocky Hill, CT 06067
b. Frekote 55-NC
    i. Henkel, One Henkel Way, Rocky Hill, CT 06067
c. Frekote 700-NC
    i. Henkel, One Henkel Way, Rocky Hill, CT 06067
d. Or equivalent

4 EQUIPMENT REQUIREMENTS

4.1 AFM

Automated fiber placement and automated tape laying machines may be used provided:

4.1.1 AFM environment meets the controlled environment requirements (5.1).

4.1.2 AFP and ATL uncured material maintain handling and process requirements (5.2 and 6.1.1) throughout layup and fabrication.

4.1.3 AFM is capable of maintaining ply orientation and layup requirements (5.4).

4.1.4 Machine Maintenance and Control

4.1.4.1 Preventative Maintenance

Preventative Maintenance (PM) including cleaning, inspection, or other procedures listed the most recent maintenance manual provided by the equipment manufacturer must occur according to the scheduled intervals. Scheduled PM intervals may be extended according to shift work times. For example, if the AFM cable carrier chain is to be inspected for damage and wear every 5 working days according to a 3-shift schedule, then this interval may be extended to 15 days only if the AFM was operated according to a 1-shift schedule during the entirety of this interval.

All maintenance procedures shall be performed according to the manuals instructions and by trained personnel.

4.1.4.2 Modifications or Repairs to Major Sub-Systems

Major sub-systems are defined as those only to be modified, repaired, or replaced by the equipment manufacturer. Such actions must be performed by the equipment manufacturer according to their internal specifications or requirements.

4.1.4.3 Maintenance Record

A maintenance record of all PM and changes to major sub-systems must be kept. The record shall include the completed line item, date of completion, and initials of any personnel that worked on the item.

4.1.5 Software Control

Specific software versions utilized for the qualification of the material will be controlled for that material. Any version changes to software used in this process shall include a change log by the software provider and shall be approved via ACN through NCAMP to ensure functionality of the process has not changed.

4.2 Curing Equipment

Autoclave or oven curing equipment capable of maintaining the cure cycle requirements (Section 6.11) shall be used.

4.3 Laser Projection Equipment

Laser projection equipment utilized for the purpose of prepreg placement and ply or panel cutting may be used provided ply orientation and layup requirements (5.4) are maintained.

4.4 Ultrasonic Cutting Equipment

Ultrasonic cutting equipment may be used provided defect requirements (5.3) and ply orientation and layup requirements (5.4) are maintained.

4.5 Cold Storage Equipment

Freezers monitoring equipment used for cold storage shall maintain the storage temperatures requirements (5.2) and thermal history record requirements (6.1.1).

4.6 Thermal Analysis Equipment

Temperature recording devices such as thermocouples and infrared cameras shall be calibrated according to NIST specifications where they exist, otherwise the equipment shall be calibrated to manufacturer specifications.

4.7 Miscellaneous Equipment

Any miscellaneous equipment utilized in the fabrication of NMS 397 panels that are not included in Section 4 shall not break the fulfillment of any requirement herein.

5 PROCESS AND PRODUCT REQUIREMENTS

5.1 Controlled Environment Requirements

Parts manufactured by NIAR ATLAS must be fabricated in a clean room environment per APCD 250900-01.

5.2 Material Handling Requirements

5.2.1 Material Storage

Prepreg material shall be stored according to NMS 397 by following procedures outlined in APCD 250900-02 and APCD 250900-03.

5.2.2 Material Thawing

Prepreg thawing shall be performed according to NMS 397 and tracked on the corresponding manufacturing work instructions.

5.2.3 Thermal History and Documentation

The prepreg thermal history including storage life, handling life, staging life, and out-time shall be documented in a material inventory and corresponding manufacturing work instructions.

5.3 Defect Requirements

The classification, determination and disposition requirements of defects that may occur throughout the automated manufacturing of laminates in the following sections shall be followed.

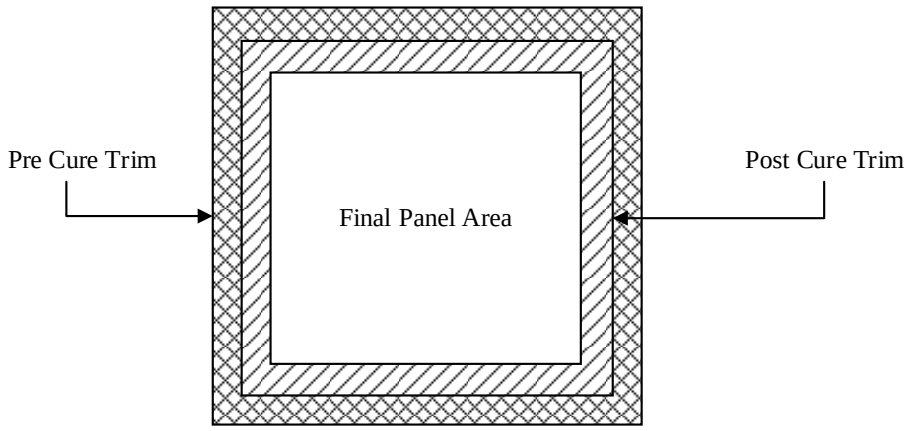

Figure 5.1 – Panel or Ply Area Definitions

5.3.1 Defects

The following defects shall be determined per 5.3.2 and rectified per 5.3.3. Records of all defects that occur, their location relative to the reference edge, and their disposition or

corrective action shall be maintained. Defects that occur within the pre cure trim area of a panel need not be corrected.

5.3.1.1 Gap: space between adjacent tows or courses. Gaps are allowable defects provided:

a. Gaps are smaller or equal to 0.04 inches.
b. Gaps of the same direction are not aligned through the laminates thickness in any of the previous or subsequent four plies of the same orientation.
c. The number of gaps in a ply must be no more than the number of courses.
d. Ply orientation requirements are within specification (5.4).

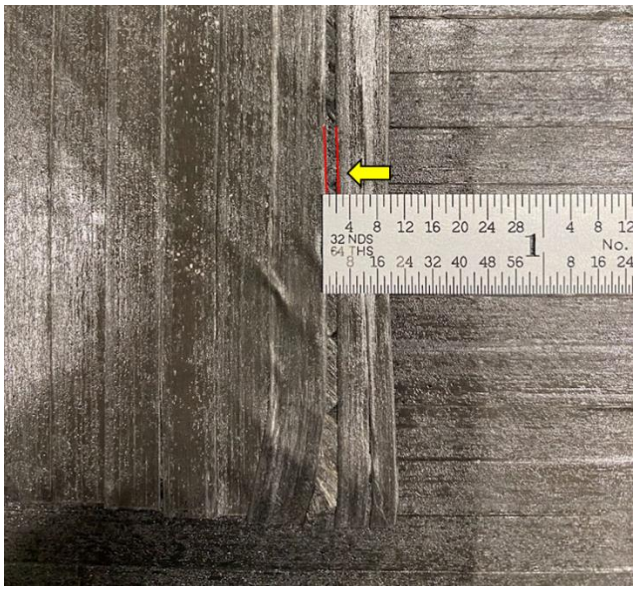

Figure 5.2 – Tow gaps (course to course)

5.3.1.2 Overlap (Lap): a tow that overlays an adjacent tow or course. Laps are allowable defects provided:

a. Laps are smaller or equal to 0.04 inches.
b. Laps of the same direction are not aligned through the laminates thickness in any of the previous or subsequent four plies of the same orientation.
c. The number of laps in a ply must be no more than the number of courses.
d. Ply orientation requirements are within specification (5.4).

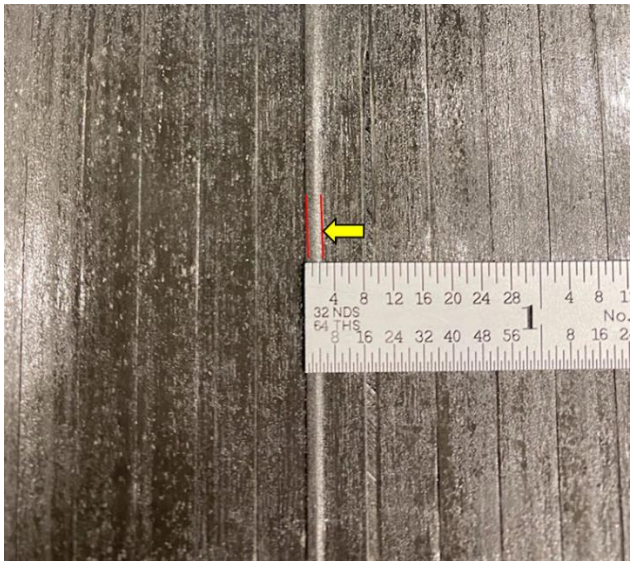

Figure 5.3 – Tow overlaps (course to course)

5.3.1.3 Twisted Tow: a tow that completes half or more turns along its length. Corrective action must occur.

Figure 5.4 – Twisted tow

5.3.1.4 Folded Tow: a tow that bends and doubles onto or under itself along its length. Corrective action must occur.

Figure 5.5 – Folded tow

5.3.1.5 Pucker/Blister: out-of-plane deformation transverse to the tow direction. Corrective action must occur.

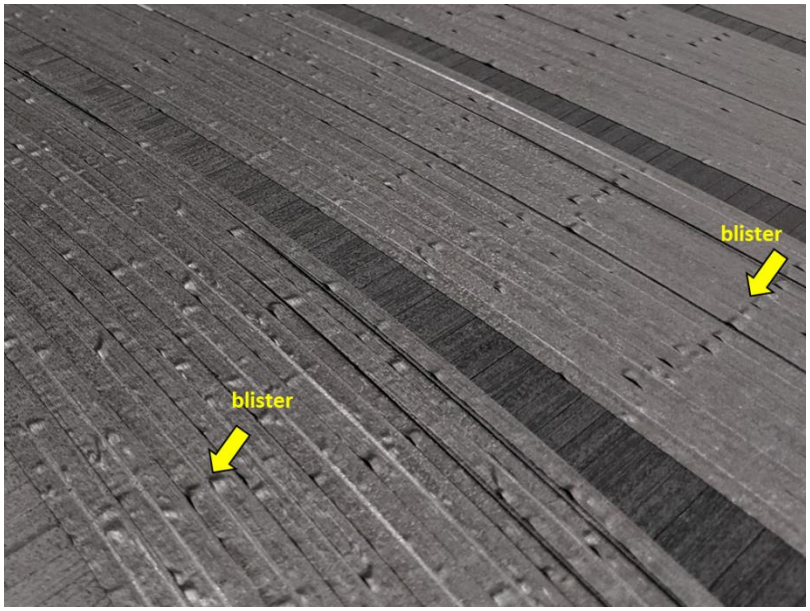

Figure 5.6 – Blister

5.3.1.6 Missing Tow: non-existent or omitted tow in programmed tow position. Corrective action must occur.

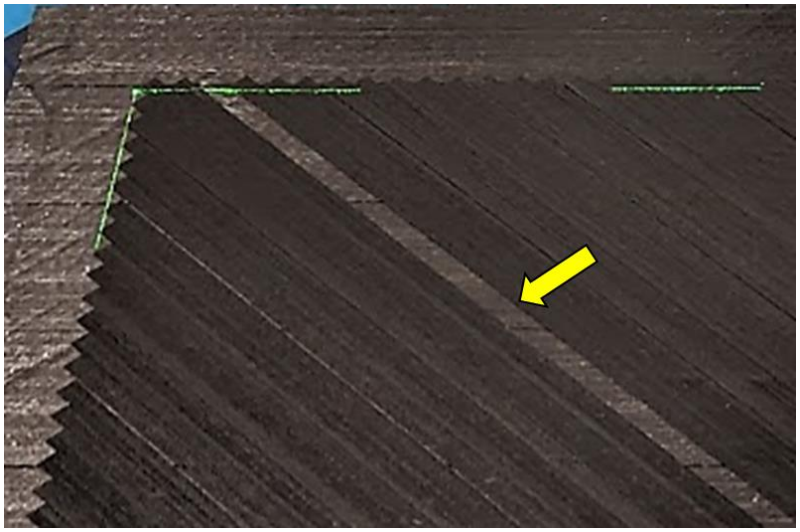

Figure 5.7 – Missing tow

5.3.1.7 Loose Tow: a tow that is not properly adhered to the previous ply. Corrective action must occur.

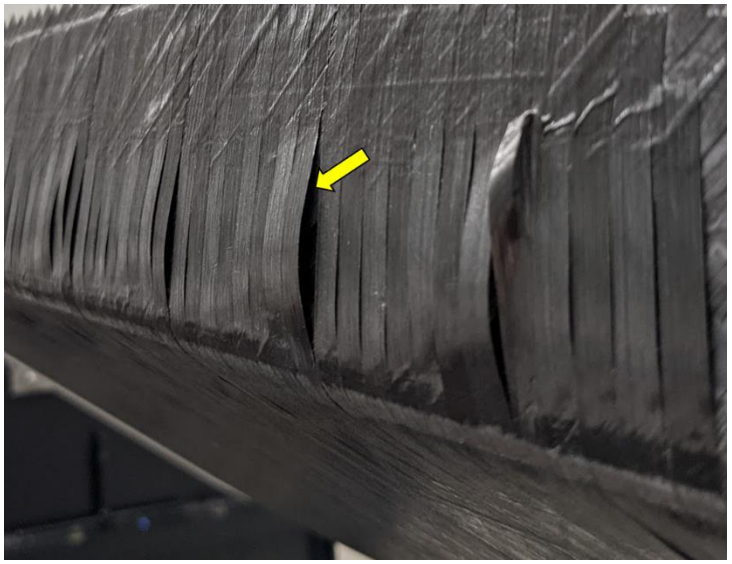

Figure 5.8 – Loose tow

5.3.1.8 Position Error: a tow that starts or ends within the final panel area. Corrective action must occur.

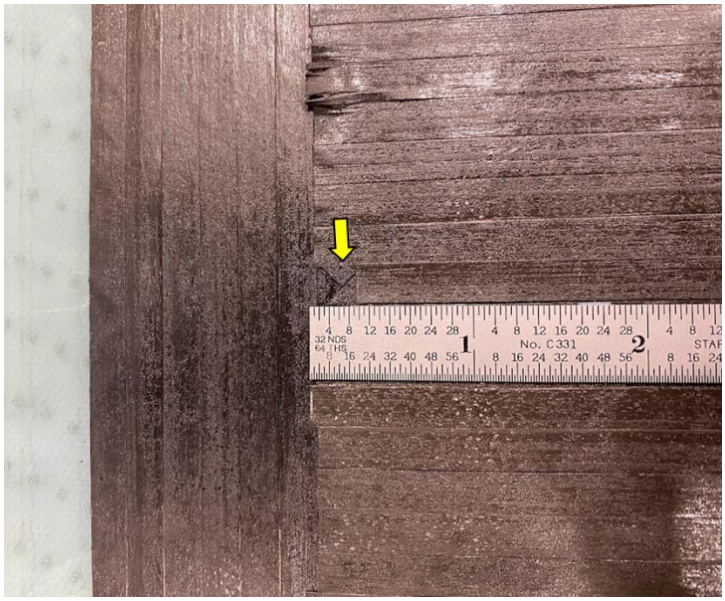

Figure 5.9 – Tow end placement error

5.3.1.9 Foreign Object Debris (FOD): any material on or between plies that is not in accordance with Sections 3 or 6.7 (i.e., fuzz ball or backing material). Corrective action must occur.

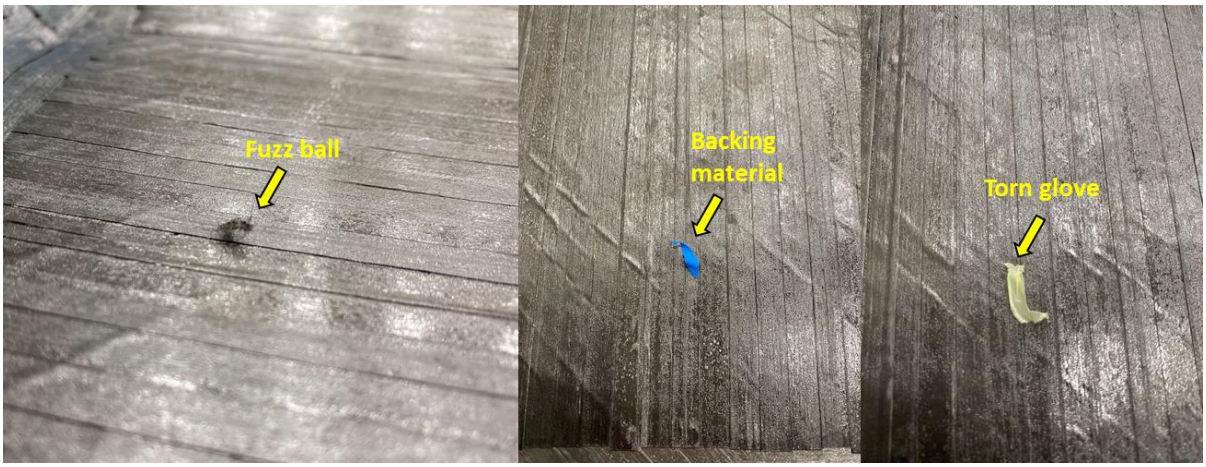

Figure 5.10 – FOD materials

5.3.1.10 Splice: two tows joined along their length via an overlap. Corrective action must occur.

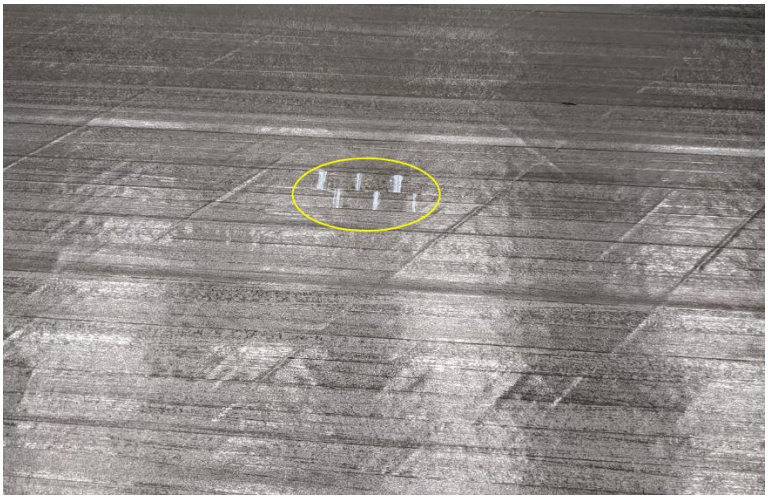

Figure 5.11 – Splices

5.3.2 Determination of Defect

In process inspection utilizing optical, laser profilometer, and/or thermography or personnel operated instruments (caliper, precision ruler, or equivalent) shall be used to identify:

a. Gaps
b. Overlaps
c. Position Errors

In process inspection utilizing optical, laser profilometer, and/or thermography or personnel visual inspection shall be used to identify:

a. Twisted Tow
b. Folded Tow
c. Pucker/Blister
d. Missing Tow
e. Loose Tow
f. Foreign Object Debris (FOD)
g. Splice

5.3.3 Rectification (Corrective Action) of Defects

Corrective action of defects must not cause visible damage to the tow or tape being corrected, previous plies, or surrounding tows/tapes.

5.3.3.1 Gap

Adjacent tows or tapes that produce gaps not within 5.3.1.1 shall be removed manually and replaced by AFP/ATL or by MFP per 5.3.3.11.

5.3.3.2 Overlap (Lap)

Adjacent tows or tapes that produce laps not within 5.3.1.2 shall be removed manually and replaced by AFP/ATL or by MFP per 5.3.3.11.

5.3.3.3 Twisted Tow

Twisted tows or tapes shall be removed manually and replaced by AFP/ATL or by MFP per 5.3.3.11.

5.3.3.4 Folded Tow

Folded tows or tapes shall be removed manually and replaced by AFP/ATL or by MFP per 5.3.3.11.

5.3.3.5 Pucker/Blister

Tows or tapes containing puckers or blisters shall be removed manually and replaced by AFP/ATL or by MFP per 5.3.3.11.

5.3.3.6 Missing Tow

Missing tows or tapes shall be placed by AFP/ATL or by MFP per 5.3.3.11.

5.3.3.7 Loose Tow

Loose tows or tapes shall be either removed manually and replaced by AFP/ATL or manually adhered to the previous ply.

5.3.3.8 Position Error

Tows or tapes with position errors shall be removed manually and replaced by AFP/ATL or by MFP per 5.3.3.11.

5.3.3.9 Foreign Object Debris (FOD)

FOD shall be removed by manually using either a gloved hand and/or a sharp pick.

5.3.3.10 Splice

Tows or tapes with a splice in the final panel area must be removed manually and replaced by AFP/ATL or by MFP per 5.3.3.11.

5.3.3.11 Manual Fiber Placement (MFP)

In manual replacement of tows, the operator will lift the defected tow with either a gloved hand and/or a sharp pick, making sure the ply beneath is not damaged, and to remove the remnants of the defected tow. To replace the tow the operator will feed a length of tow out of the AFP head that is longer than the one to be replaced. The operator will lay the tow into the trough created by the removed tow, making sure to keep the tow aligned and not overlap the adjacent tows. Using the heat and pressure of a gloved hand the operator will adhere the tow down to the AFP panel. After adhering the tow,

the operator will trim the length of the tow to align with the end placement of the AFP tows.

5.4 Ply Orientation Requirements

In order to maintain proper fiber orientation, each ply must be inspected to ensure it is laid up within ±3° of a stationary reference line or laser projection line. Each layup panel shall be cured with a straight edge ruler/dam along at least one edge to be used as reference edge for subsequent machining or NDI processes.

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.

6 PROCEDURE

6.1 Setup

6.1.1 Material Control and Traceability

Install NMS 397 material on the AFM per equipment manufacturers training and APCD 250901-00.

Qualified material (NMS 397) shall have passed the receiving inspection tests. Material must be within the storage/handling/outlife requirements. For traceability, roll or spool numbers and applicable prepreg batch/lot/expiration date shall be recorded on every panel's corresponding manufacturing instructions. Corresponding prepreg life records shall be maintained in accordance with 5.2.3.

6.1.2 Layup Tool Preparation

Tackifiers shall not be used. If the layup tool is not released for cure, non-contaminating FEP, nylon, or equivalent film may be placed wrinkle and crease free on the layup tool surface to be laid up upon; the uncured panel shall be transferred to a prepped curing tool per 6.4. Curing tool preparation must be completed per APCD 250900-05 and 6.7.

6.1.3 AFM Programming Procedures

Programming shall be completed by trained personnel only according to APCD 250901-01 utilizing applicable parameter values in APCD 250901-02. Program traceability must be recorded according to internal traceability traveler sheets. The following procedure includes steps that are important for traceability and may not include intermediate steps that are required to complete every program.

6.1.3.1 Setup

a. Import appropriate layup surface corresponding to the planned layup tool.
b. Create ply boundaries with dimensions according the test plan.
c. Ensure correct machine configuration and heater is selected.
d. Use an appropriate material thickness to ensure proper contact with the tool and subsequent plies (typical value is measured prepreg thickness $\pm$30%).

6.1.3.2 Laminate Program

a. A single sequence or program entity must be used for every required ply and must be created in order. For example, a laminate requires 24 plies so 24 unique program entities in the correct order must be created to avoid traceability issues with running a ply multiple times or non-sequentially.
b. Set ply directions according to the test plan.
c. Create plies offset from the tool according to the material thickness.
d. Blanket (oversized) plies may be programmed for tool adhesion purposes according to trained personnel judgment.
e. Layup compaction and speed shall be set within the operating ranges defined in 6.3.4 and 6.3.5.

6.1.3.3 Course and Tow Strategies

a. Stagger between the centerline of each course (often called ply stagger) must be 20% of the tow width to maintain 5.3.1.1 and 5.3.1.2.
b. Guide curves shall be linear (no steering) for flat laminates.

6.1.3.4 Export

a. Produce, post process, and export the program with an identifiable name or the file name required by the applicable test plan or traceability traveler sheet if a name exists.
b. The exported program must be transferred to the corresponding operator station and placed in a recorded file location.

6.1.3.5 Simulation

a. Each ply and course must be simulated and checked for errors, warnings, and machine collisions. Warnings must be recorded in the export log and errors must be resolved prior to final export.

6.2 Equipment Calibration

Perform calibration of the AFM according to the equipment manufacturers recommended procedures to ensure that the machine is capable of maintaining required ply orientation, tow placement, course gap, roller compaction tolerances.

6.3 Layup

Machine settings, variables, and procedures that are machine specific are listed in APCD 250901-02 and must be used for the layup of NMS 397.

6.3.1 Temperature

Nominal temperatures produced on NMS 397 prepreg during automated layup is 100-149°F. Heater power may be varied to produce varying temperature throughout the layup depending on part geometry, tack, and defect avoidance.

The heater shall not produce smoking, vaporization, bubbling, or any visible signs of deformation or degradation of an NMS 397 material.

6.3.2 Head Temperature

Head temperature shall be set safely above ambient dew temperature resulting in no visible moisture condensation on or in the head of an AFM.

6.3.3 Creel House Temperature

If a creel house is utilized, the temperature shall be 65$\pm$10°F while material is loaded in the AFM. Any feeding tubes or guides between the creel house and head shall be maintained to the same temperature requirement.

6.3.4 Roller Compaction

Nominal compaction pressure of NMS 397 prepreg is 25-50 psi average. Compaction pressure may be varied throughout the layup depending on part geometry, tack, and defect avoidance.

The maximum pressure exerted on the material shall not exceed 80psi and shall not cause visible resin to squeeze out from NMS 397 material.

6.3.5 Layup Speed

Layup speed must not exceed speed at which the heating system achieves max power output to avoid current overdraw or heat shutdown during a layup. Layup speed must be monitored congruently with layup temperature to ensure all applicable ranges are achieved.

6.3.5.1 First Ply

Nominal first ply speed of NMS 397 prepreg is 300-500 ipm. First ply speed may exceed this range provided prior trials on the same program (equivalent or larger panel dimensions and stacking sequence) display no adhesion issues, defects per 5.3, or panel lift off on the tool. Layup speed may be varied throughout the first ply depending on part geometry, tack, and defect avoidance.

6.3.5.2 Subsequent Plies

Subsequent (non-first ply) speed may be any value capable of the AFM and may be varied throughout the layup dependent on part geometry, tack, and defect avoidance.

6.3.6 Sacrificial Tows

To aid in the removal of splices or defects, sacrificial tows that are manually placed outside of the final panel trim area may be used provided they are perpendicular to the subsequent ply. Sacrificial tows must be removed prior to the layup of the following ply.

6.4 Uncured Panel Transfer

Uncured panels may be removed from the layup tool and transferred to a curing tool provided no defects per 5.3. The panel must be supported during transfer to ensure no bending, folding, or creasing occurs. Uncured parts may be transported to a curing facility per APCD 250900-06.

6.5 Uncured Panel Cutting Procedures

If required, uncured panels, subpanels, or individual plies may be cut using an ultrasonic cutter provided no defects per 5.3 occur. Ultrasonic cutting must maintain reference edge and ply orientation (5.4) requirements. Single or multiple cutting passes can be used based on operator judgement. Ultrasonic cutting shall be done according to equipment training and operation manual.

6.6 Thermocouples

A minimum of two thermocouple wires should be used to monitor and record the panel temperature of each 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.

6.7 Bagging

Figure 6.1 shows the bagging arrangement that will be used for the manufacture of NMS 397 mechanical test panels.

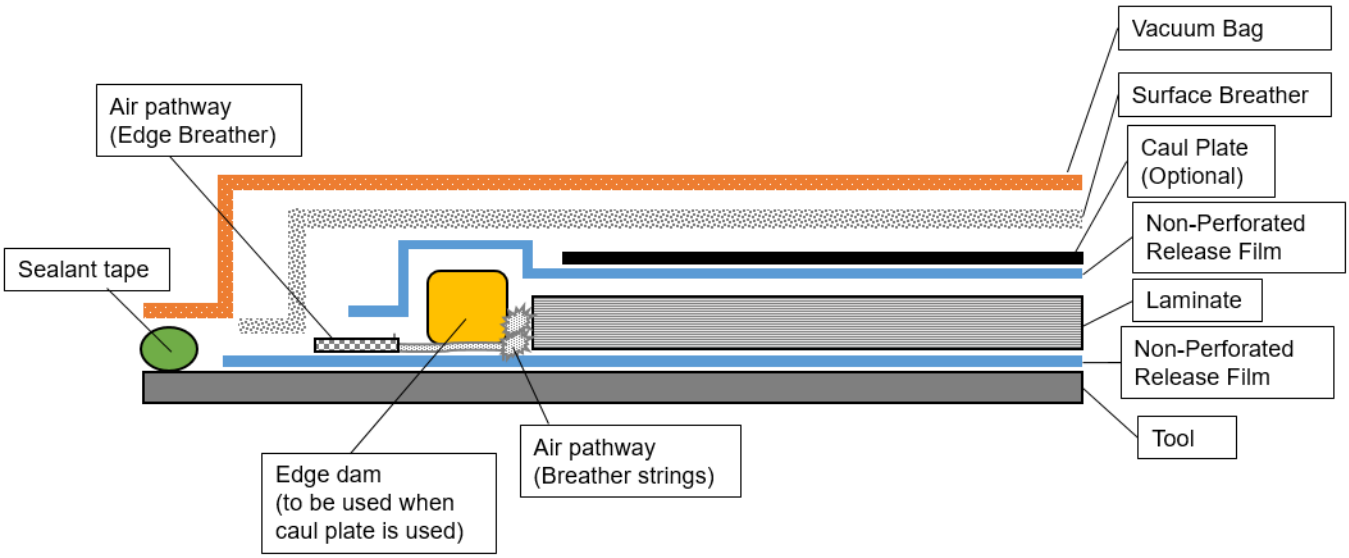

Figure 6.1 - Bagging Technique

a. Place a solid FEP film on the mold. Liquid release agent may be applied on the mold in lieu of the solid FEP film.
b. Place a straight edge ruler/dam on the mold/layup surface and secure it with tape. Begin laying up in accordance with the proper stacking sequences making sure that each ply is butt against the edge ruler/dam and thermocouples are placed in the panels as necessary.
c. Place edge breather, 2mm (breather string) wide glass yarn along the two edges of the prepreg laminate.
d. (Optional) Remove the straight edge ruler/dam from the mold.
e. Place a solid FEP film over the prepreg layup.
f. (Optional) Place a caul plate on the solid FEP film.
g. Place a layer of surface breather over the entire lay-up.
h. Place a layer of vacuum bag film over the entire surface breather.

i. While applying vacuum to the bag, make sure that there is sufficient solid FEP film, breather and vacuum bag to conform over the uneven surfaces to avoid bridging in the bag.

Note: it is recommended to use caul plate in Step f when edge ruler/dam in Step d is utilized. However, caul plate (Step f) may be utilized without edge ruler/dam (Step d) depending on the panel complexities such as ILT angle panels.

6.8 Vacuum Leak Check

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. Perform a leak check by taking an initial reading at the start of 5 minutes and then taking a final reading after the end of 5 minutes. The difference between the two readings is the leak rate. The vacuum must not drop more than 2” of Hg (6.77 kPa) in 5 minutes. If this rate is exceeded, repair the leak and recheck the leak rate.

6.9 Storage and Transportation of Bagged Assemblies Prior to Cure

Uncured parts may be transported to a curing facility per APCD 250900-06. Bagged assemblies must be leak checked per 6.8 prior to storage or transportation outside the controlled environment. Bagged assemblies stored or transported outside the controlled environment shall not reach temperatures exceeding the temperature requirements in 5.1.

6.10 Debulk

The bagged curing assembly must be debulked at room temperature ambient conditions for a minimum of 4 hours prior to cure. Debulk must occur with a minimum vacuum of 28 inches of Hg or within 2 in/Hg of the local atmospheric pressure.

6.11 Cure Cycle

6.11.1 Baseline Autoclave Cure Cycle (C)

The baseline cure cycle must be in accordance with the following process (Figure 6.2). 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 each vacuum bag assembly for leak before beginning the cure cycle per 6.8. All temperatures are panel temperatures based on the lagging thermocouple. The vacuum and temperatures must be recorded at 5-minute intervals maximum.

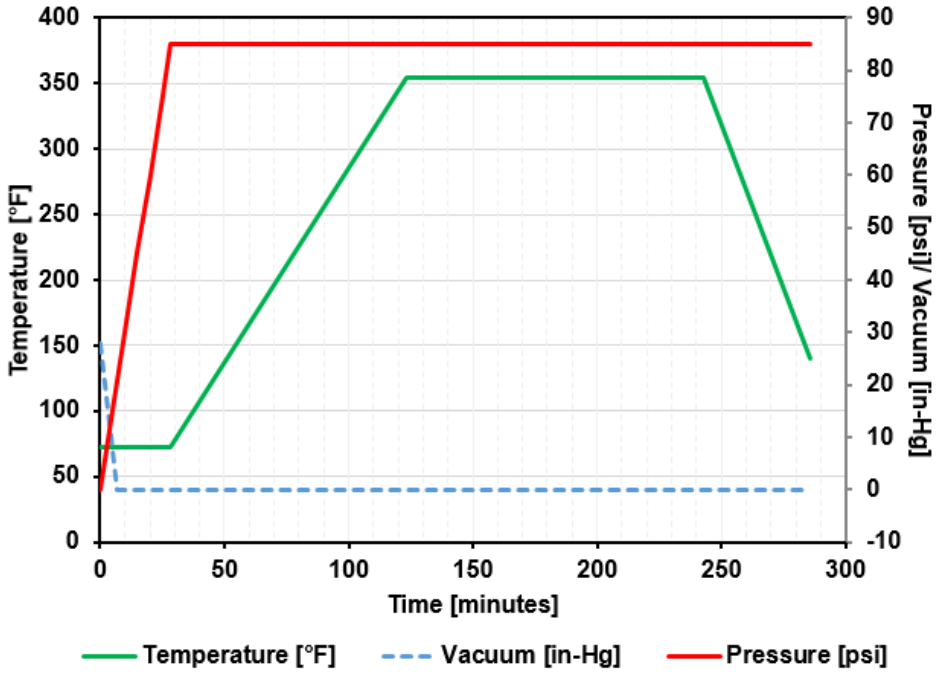

Figure 6.2 – Baseline Cure Cycle

a. Check each vacuum bag assembly for leak before beginning the cure cycle per 6.8.
b. Apply 85 +15/-0 psi (586 +103/-0 kPa) autoclave pressure to the laminate.
c. Vent the vacuum bag when the autoclave pressure reaches 20psi (138 kPa).
d. Apply the temperature ramp to 355 ± 10°F (179.4 ± 5.6°C) at rate of 3.0 ± 2.0 °F (1.67 ± 1.11°C) per minute.
e. Maintain the cure temperature at 355 ± 10°F (179.4 ± 5.6°C) for 120 – 180 minutes.
f. Cool vessel to 140°F (60°C) or lower at a maximum rate of 5°F (2.8°C) per minute before removing pressure.
g. Remove the bagged panels from the curing vessel and de-bag for inspection.

6.11.2 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.

6.11.3 Alternative Out of Autoclave Cure Cycle (O) (unverified)

This cure cycle may not show a successful equivalency demonstration to Qualification baseline autoclave cure cycle (C). Users may contact NCAMP if this cure cycle is being considered (Figure 6.3).

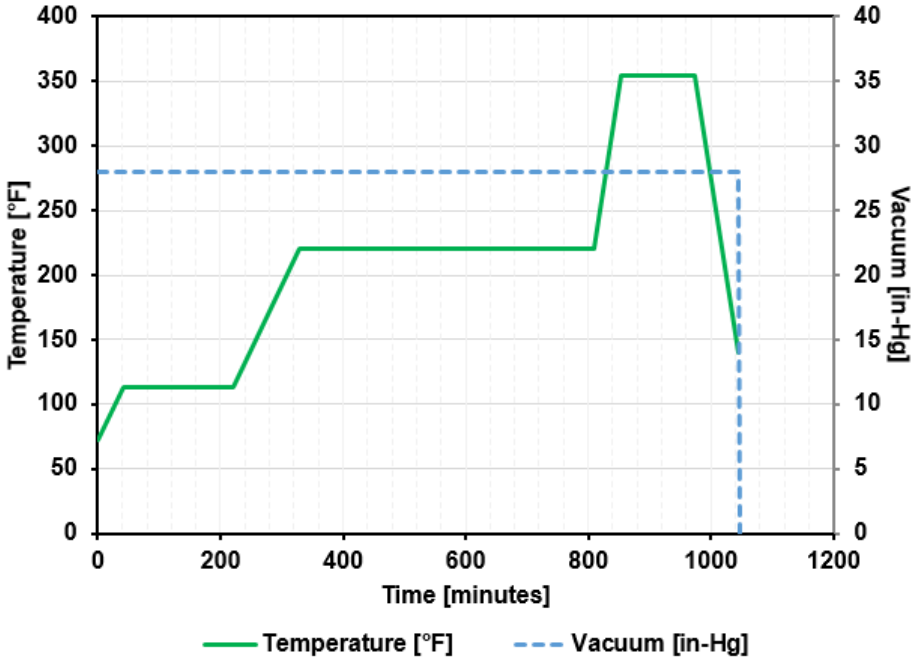

Figure 6.3 – Alternate Cure Cycle

a. Check each vacuum bag assembly for leak before beginning the cure cycle per 6.8.
b. Apply vacuum of 28 inHg (710 mmHg) minimum. Maintain vacuum for at least three hours prior to beginning cure cycle and throughout the cure cycle.
c. Heat the part temperature to 113 ± 10°F (45 ± 5°C) at a ramp rate of 1.0°F/min (0.5°C/min); with an allowable range of 0.2 to 2.0°F/min (0.1 to 1.0°C/min).
d. Hold for a minimum of 180 minutes at 113 -10°F/+18°F (45 -5°C/+10°C).
e. Heat the part temperature to 221 ± 6°F (105 ± 3°C) at a ramp rate of 1.0°F/min (0.5°C/min); with an allowable range of 1°F to 3.0°F/min (0.5 to 1.7°C/min).
f. Hold for 480 +240/0 minutes at 221 ± 6°F (105 ± 3°C).
g. Heat the part temperature to 355 ± 10°F (180 ± 5°C) at a ramp rate of 3°F/min (1.7°C/min); with an allowable range of 1.0 to 5.0°F/min (0.5 to 2.7°C/min).
h. Hold for 120 +30/0 minutes at 355 ± 10°F (180 ± 5°C).
i. Cool to 150°F (65°C) or lower at a maximum ramp rate of 5°F/min (2.7°C/min).

7 QUALITY ASSURANCE

7.1 Process Control

In-process monitoring data such as nip-point temperature (heating rate, dwell, cooling rate, etc.), pressure readings through the consolidation 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.

7.2 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 may be ultrasonically inspected by the testing lab in accordance with the applicable test plan.

7.3 Visual Inspection

Demold the part and perform inspections and procedures per APCD 250900-04. 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.

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.