



WICHITA STATE
UNIVERSITY
NATIONAL INSTITUTE
FOR AVIATION RESEARCH

NPS 81225AFP Rev D

Date: February 24, 2026



Document No.: NPS 81225AFP, Revision C, August 4, 2025

NCAMP Process Specification

Definitions, Layup Requirements, and Processing Instructions of NMS 122 Test Panels with Automated Fiber Placement.

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REVISIONS

Rev	By	Date	Description
-	Ethan McDaniel	5/17/2024	Initial release.
A	Ethan McDaniel (Reviewed and Approved by NCAMP)	6/26/2024	Updated the consolidation cycle of section 6.11.1.
B	Ethan McDaniel (Reviewed and Approved by NCAMP)	7/17/2024	Corrected temperature errors in consolidation cycle update of Rev A, section 6.11.1 step (d) and (e).
C	Ethan McDaniel	8/4/2025	Added section 6.8, updated section 3 to include item 3.1.7
D	Vincent Tanoto	2/24/2026	Cover Page – Distribution statement changed to public release.

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1 SCOPE

This process specification describes the methods of fabricating NMS 122 test panels using automated fiber placement (AFP) and automated tape laying (ATL) equipment. Specifically, this specification covers definitions, general processing, and procedural layup requirements including bagging schemes, materials, and consolidation 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 less than 1 inch wide.
- 1.4.3 Automated Tape Laying: Use of any AFM for deposition of material 1 inch 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 prepreg or dry fiber with a width 1 inch 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 1 inch used in automated fiber placement.
- 1.4.9 Controlled Environment: Any environment in which processing of unconsolidated 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 122	Medium Toughness Polyaryletherketone (PAEK) Thermoplastics Toray (Formerly TenCate) Cetex® TC1225 Low Melt (LM) Polyaryletherketone (PAEK)
NMS 122/2	Medium Toughness Polyaryletherketone (PAEK) Thermoplastic Toray (Formerly TenCate) Cetex® TC1225 Low Melt (LM) Polyaryletherketone, Type 34, Class 1, Form 3 (0.25-inch Width), Grade 145

2.2 SAE and ISO Publications

AS9100	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 when manufacturing of NMS 122 test panels.

3.1.1 Polyimide Film

- a. Thermalimide, THERM532250
 - i. Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
 - ii. 5 mil
 - iii. Qualified for use up to 800°F or above.
- b. Or equivalent

3.1.2 Polyimide Film

- a. Thermalimide, THERM260340
 - i. Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
 - ii. 2 mil
 - iii. Release Coated on Both Sides (RCBS)
 - iv. Qualified for use up to 800°F or above.
- b. Or equivalent

3.1.3 Heavy Fiberglass Breather

- a. HexForce™ 7500
 - i. Hexcel, 1913 North King Street, Senguin, Texas 78155
 - ii. Plain weave
 - iii. Weight of 9.41 oz/yd²
- b. Or equivalent

3.1.4 High Temperature Fiberglass

- a. Airweave® UHT800
 - i. Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
 - ii. Non-woven
 - iii. Weight of 18 oz/yd²
- b. Or equivalent

3.1.5 Sealant Tape

- a. SM5160
 - i. Solvay Cytec AERIVAC North America, 955-10 National Parkway Schaumburg, IL 60173
- b. A-800-3G
 - i. Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- c. Or equivalent

3.1.6 Pressure (Caul) Plates

- a. 304 Stainless Steel
 - i. Thickness of 0.024 ± 0.01 inches
 - ii. Open source
 - iii. Flat and smooth
- b. Or equivalent

3.1.7 Flexible Caul Sheet

- a. Klingersil C-4433
 - i. Thickness of 0.0625 ± 0.01 inches
 - ii. Gallagher Fluid Seals, Inc., 500 Hertzog Boulevard, King of Prussia, PA 19406
- b. Or equivalent

3.1.8 Consolidation Tooling Material (Mold)

- a. Invar 36
 - i. Open source
 - ii. 0.1-0.75 inches thick
 - iii. Flat and smooth
- b. Or equivalent

3.1.9 Polyimide Tape

- a. Airkap 1
 - i. Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
 - ii. 1 inch width
 - iii. Qualified for use up to 750°F
- b. Airkap 1
 - i. Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
 - ii. 2 inch width
 - iii. Qualified for use up to 750°F
- c. Or equivalent

3.1.10 Edge Dam

- a. Aluminum, flat bar stock
 - i. Open Source
- b. 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 unconsolidated material maintains 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 by 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 manual’s instructions and by trained personnel. An example of some preventative tasks is shown below.

Table 1 – Preventive maintenance tasks

<u>Maintenance Interval</u>	<u>Maintenance Task</u>
<i>Weekly</i>	Check for oil, grease, or other contaminants on the head.
<i>Monthly</i>	Test operation of the compaction axis over-travel switch. Check robot arm for signs of leaking oil from the drivetrain on Joints 1 through 5. Wipe any oil with a rag.
<i>Bi-Monthly</i>	Check compaction roller for damage. Replace if needed.
<i>Quarterly</i>	Check that initial redirect rollers spin freely. Check for excessive wear of non-stick coating on tow guides. Check for binding in the compaction axis rails. Check that each spool spindle spins freely. Check that each backing film spindle spins freely. Check that each dancer spins freely. Check for bent or broken dancers. Check for bent brake rotors. Check Operator Station PC for dirt.

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 recorded and retained within the work orders for all test panels fabricated.

4.2 Curing Equipment

Autoclave or oven consolidation equipment capable of maintaining the consolidation 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 Thermal Analysis Equipment

Thermal cameras, thermocouples, and temperature recording devices shall be calibrated according to NIST specification if one exists, otherwise the equipment shall be calibrated to manufacturer specifications.

4.5 Miscellaneous Equipment

Any miscellaneous equipment utilized in the fabrication of NMS 122 panels that are not included in Section 4 shall not break the fulfillment of any requirements herein.

5 PROCESS AND PRODUCT REQUIREMENTS

5.1 Controlled Environment Requirements

A controlled environment is any room or environment in which dust particle count, temperature, humidity, and positive pressure are controlled. Material that is not contained in sealed bags or a leak checked bagged assembly must remain in a controlled environment. An environment becomes uncontrolled when non-standard activities take place or any of the clean room requirements are not met. Examples of non-standard activities are defined as (not limited to):

- a. Opening of bay/garage door(s)
- b. Use of Aerosols
- c. Use of grinding, sanding, or drilling equipment
- d. Use of release agents
- e. Operation of oil based vacuum or pressure pump

5.1.1 Dust Particle Count

The particle count in the atmosphere of the controlled environment shall be maintained to not exceed the following concentrations in a cubic meter or equivalent according to ISO 14644-1.

- At particle size 0.5 microns, concentration count must be less than 3,520,000
- At particle size 1 micron, concentration count must be less than 832,000
- At particle size 2.5 micron, concentration count must be less than 123,676
- At particle size 5 micron, concentration count must be less than 29,300

If particle count exceeds this requirement, the layup must be paused and any unconsolidated material open to the atmosphere must be sealed in an airtight bag or bagging assembly. If no partial layup or part exists, then no new layup shall begin. Layup shall only resume when 3 consecutive measurements 10 minutes apart are within the requirement.

Particle count shall be measured according to the following:

- 5.1.1.1 Particle count shall be measured at benchtop height approximately 3-5ft from ground.
- 5.1.1.2 Particle count shall be measured at one location for every 2000 square feet with a minimum two measurements in the controlled environment.
- 5.1.1.3 Particle count measurement shall occur every calendar day in which work is ongoing and during such times when standard work is occurring.
- 5.1.1.4 If the environment is uncontrolled for any period of time, then a particle count measurement must occur before work resumes.

5.1.2 Temperature

The temperature of the controlled environment or any room in which unconsolidated prepreg material is being processed during handling, staging, or transport shall be held within an ambient range for reliable function of process equipment.

Temperature shall be measured according to the following:

5.1.2.1 Environment temperature shall be measured at layup or unconsolidated material height level.

5.1.2.2 Temperature shall be measured every 15 minutes or less.

5.1.3 Humidity

The humidity level of the clean room shall be maintained between 35-63% at 65°F and 23-46% at 75°F. If humidity falls outside of this range, the layup must be paused and any unconsolidated material open to the atmosphere must be sealed in an airtight bag or bagging assembly. If no partial layup or part exists, then no new layup shall begin. Layup shall only resume when 3 consecutive measurements 10 minutes apart or greater are within the requirement

Humidity shall be measured according to the following:

5.1.3.1 Relative humidity shall be measured at layup or unconsolidated material height level.

5.1.3.2 Relative Humidity shall be measured every 15 minutes or less.

5.1.4 Compressed Air

Compressed air used in the controlled environment must use an onboard pressure regulator, particle filtration, water, and oil separation. Air-lines used in the controlled environment shall not have been used in an environment prior that does not adhere to the compressed air requirements.

5.1.5 Vacuum Air

Vacuum air used in the controlled environment must use a particle filtration, water, and oil separation. Vacuum air-lines used in the controlled environment shall not have been used in an environment prior that does not adhere to the vacuum air requirements.

5.2 Material Handling Requirements

5.2.1 Material Storage

Prepreg material shall be stored according to NMS 122.

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.

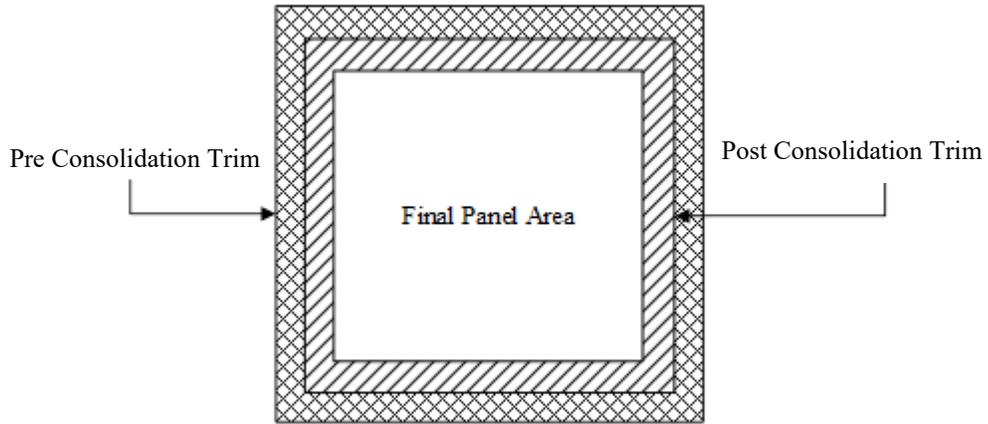


Figure 5.1 – Panel or Ply Area Definitions

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-consolidated trim area of a panel need not be corrected. Material defects must meet the requirements of the applicable material specification or purchasing agreement. Areas marked by the material manufacturer as defective must not be used.

- 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. No more than six gaps are within any six course-widths of a ply traverse to the ply orientation.
 - d. Ply orientation requirements are within specification (5.4)

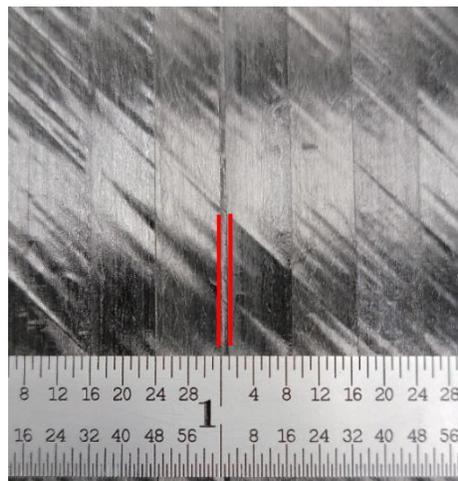


Figure 5.2 – Tow gaps (course to course)

5.3.1.2 Overlap (Lap): a tow that overlays an adjacent tow or course. No overlaps are allowed, corrective action must occur.

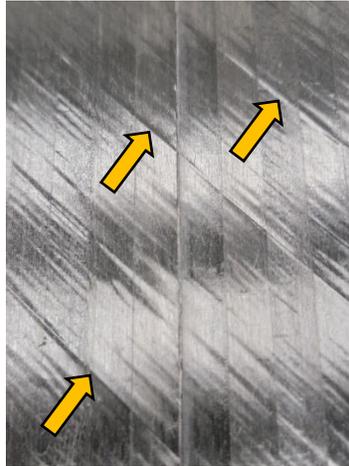


Figure 5.3 – Tow overlaps (course to course)

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

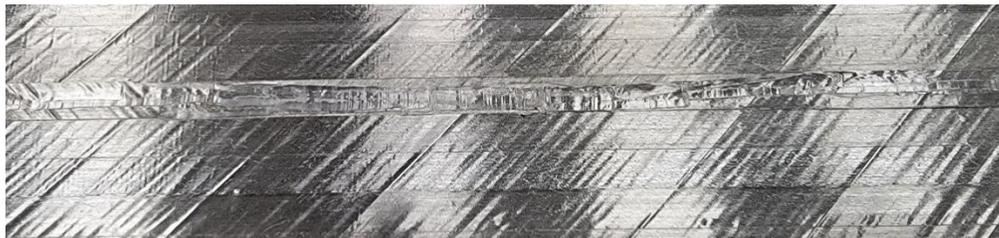


Figure 5.4 – Twisted Tow

5.3.1.4 Folded Slit Tape: 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 Split Slit Tape: a tow that has cracked along the tape length or has broken fibers along the width of the tow. Corrective action must occur.

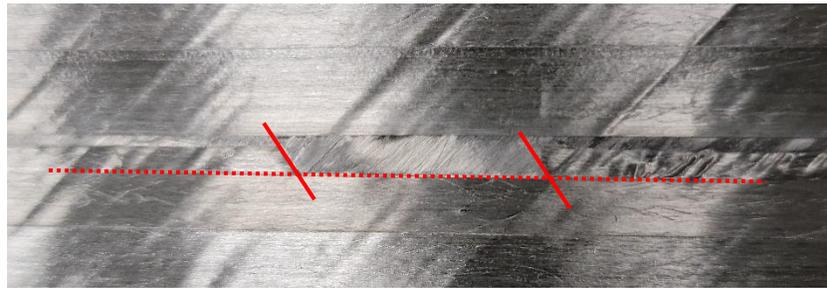


Figure 5.6 – Split Tow

5.3.1.6 Pucker/Blister: out of plane deformation traverse to the tow direction. Corrective action must occur.

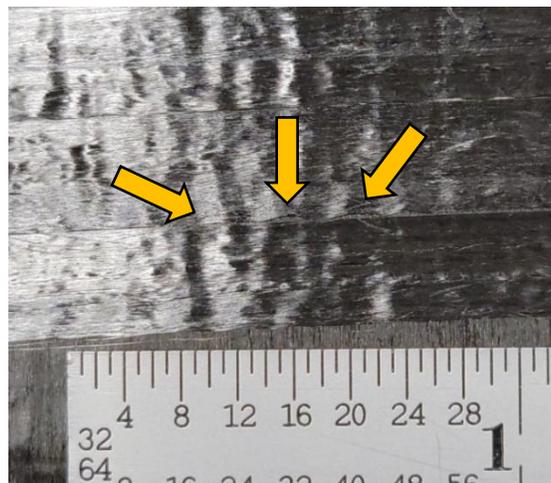


Figure 5.7 - Blister

5.3.1.7 Missing Slit Tape: nonexistent or omitted tow in programmed tow position. Corrective action must occur.

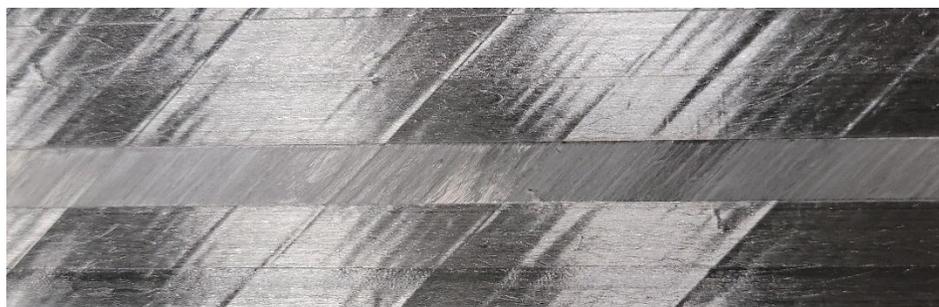


Figure 5.8 – Missing tow

5.3.1.8 Loose Slit Tape: a tow that is not properly adhered to the previous ply within the final panel area. Corrective action must occur.

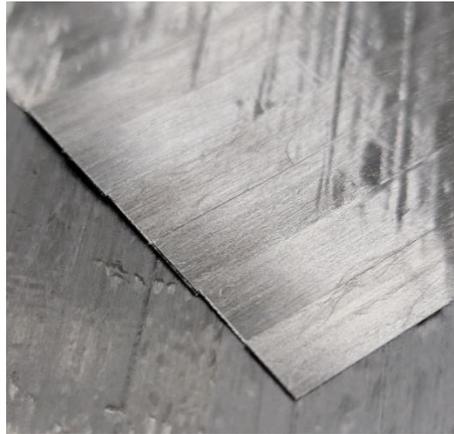


Figure 5.9 – Loose tow

5.3.1.9 Position Error: a tow that starts or ends within the final panel area. If the unsecured length is sufficient to allow gaps or overlaps, corrective action must occur.



Figure 5.10 – Tow end placement error

5.3.1.10 Foreign Object Debris (FOD): any material on or between plies that is not in accordance with Sections 3 or 0 (i.e. fuzz ball or backing material). Corrective action must occur.

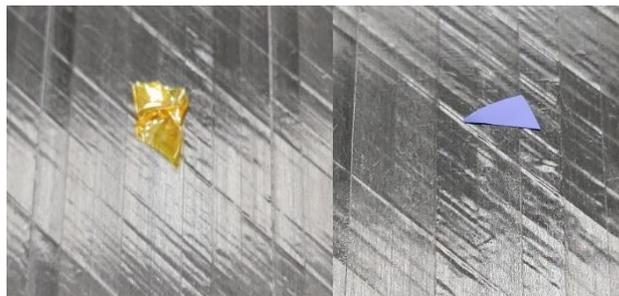


Figure 5.11 – FOD materials

- 5.3.1.11 Splice: two tows joined along their length via an overlap. Corrective action must occur if a splice falls within the final panel area. If a splice occurs within the trim region, no corrective action is required.

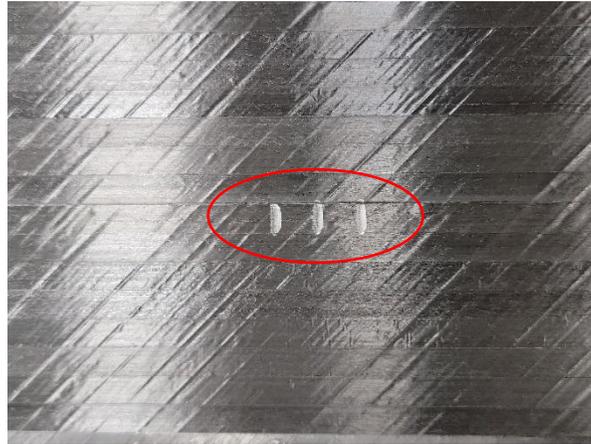


Figure 5.12 - Splice

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), or trained personnel 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. Split Tow
- d. Pucker/Blister
- e. Missing Tow
- f. Loose Tow
- g. Foreign Object Debris
- h. 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. Visible damage is defined in 5.3.4.

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 MFP or AFP/ATL per 5.3.3.12.

5.3.3.2 Overlap (Lap)

Adjacent tows or tapes that produce laps not within 5.3.1.2 shall be removed and replaced by MFP or AFP/ATL per 5.3.3.12.

5.3.3.3 Twisted Tow

Twisted tows or tapes shall be removed manually and replaced by MFP or AFP/ATL per 5.3.3.12.

5.3.3.4 Folded Tow

Folded tows or tapes shall be removed manually and replaced by MFP or AFP/ATL per 5.3.3.12.

5.3.3.5 Split Tow

Split tows or tapes shall be removed manually and replaced by MFP or AFP/ATL per 5.3.3.12.

5.3.3.6 Pucker/Blister

Tows or tapes containing puckers or blisters shall be removed manually and replaced by MFP or AFP/ATL per 5.3.3.12.

5.3.3.7 Missing Tow

Missing tows or tapes shall be placed by MFP or AFP/ATL per 5.3.3.12.

5.3.3.8 Loose Tow

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

5.3.3.9 Position Error

Tows or tapes with position errors shall be removed manually and replaced by MFP or AFP/ATL per 5.3.3.12.

5.3.3.10 Foreign Object Debris (FOD)

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

5.3.3.11 Splice

Tows or tapes with a splice must be removed manually and replaced by MFP or AFP/ATL per 5.3.3.12.

5.3.3.12 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 a soldering iron with a wide flat tip, 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.

5.3.4 Visible Damage

Visible damage as a result of corrective action of defects is characterized as the following:

5.3.4.1 Fiber Separation / Pull

Loose fibers lifted and pulled from the previous or surrounding prepreg.

5.4 Ply Orientation Requirements

In order to maintain proper fiber orientation, each ply must be inspected to ensure it is laid up within $\pm 3^\circ$ of a stationary reference line or laser projection line. Each layup panel shall be consolidated 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, write on the outermost layup ply using a marker with a metallic ink within $\frac{1}{2}$ -inch from the panel edge with the following information: "0° direction →, Test Plan Document Number - Prepregger ID - Material Code - Fabricator ID - Test Type - Batch ID - Consolidation Cycle ID - Test Panel ID." Make sure that the "0° direction →" marking is near to the reference edge and actually points in the 0° direction or warp direction. The appendix of the test plan contains the panel identification information.

6 PROCEDURE

6.1 Setup

6.1.1 Material Control and Traceability

Install NMS 122 material on the AFM per equipment manufacturers training and APCD 250901-00.

Qualified material (NMS 122) shall have passed the receiving inspection tests. Material must be within the storage/handling/shelf life requirements. For traceability, roll or spool numbers and applicable prepreg batch/lot/expiration date shall be recorded on every panel's corresponding manufacturing instructions/work order.

6.1.2 Layup Tool Preparation

Tackifiers shall not be used. If the layup tool is not released for consolidation, non-contaminating polyimide or equivalent film may be placed wrinkle and crease free on the layup tool surface to be laid up upon; the unconsolidated panel shall be transferred to a prepped tool per 6.4. Consolidation tool preparation must be completed per APCD 250900-05 and 0.

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 250901-07. 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 ply 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 speed and compaction 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, and roller compaction tolerances.

6.3 Layup

Machine settings, variables, and procedures that are machine specific are listed in APCD 250901-07 and must be used for the layup of NMS 122 materials (i.e. class 1, form 3).

6.3.1 Temperature

Nominal temperatures produced on NMS 122 prepreg during automated layup is 600-800°F. Heater power may be varied to produce varying temperature throughout the layup depending on part geometry, tack/melt, and defect avoidance.

The heater shall not produce smoking, vaporization, bubbling, or any visible signs of deformation or degradation of an NMS 122 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 used the temperature shall be room ambient 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 122 prepreg is 80-90 lbf per roller width. Compaction pressure may be varied throughout the layup depending on part geometry, tack/melt, and defect avoidance.

The maximum pressure exerted on the material shall not exceed 120 lbf per roller width and shall not cause visible resin squeeze out, fiber/tow distortion, spread, or waviness of the 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 while avoiding any induced defects.

6.3.5.1 First Ply

Nominal first ply speed of NMS 122 prepreg is 300-600 ipm. First ply speed may exceed this range provided prior trials on the same program (panel dimensions and stacking sequence) display no adhesion issues or panel lift off on the tool. Layup speed may be varied throughout the first ply depending on part geometry, tack/melt, and defect avoidance.

6.3.5.2 Subsequent Plies

Subsequent (non-first ply) speed may be any value and may be varied throughout the layup dependent on part geometry, tack/melt, 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 Unconsolidated Panel Transfer

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

6.5 Unconsolidated Panel Cutting Procedures

Unconsolidated panels, subpanels, or individual plies and tows may be cut using an ultrasonic cutter, blade/scissors, or other non-contaminating cutting device provided no defects defined per 5.3 occur. Cutting must maintain reference edge and ply orientation

(5.4) requirements. Single or multiple cutting passes can be used based on operator judgement.

6.6 Thermocouples

A minimum of two thermocouple wires should be used to monitor and record the panel temperature of each consolidation 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 consolidated. An alternative method is to place the thermocouple junctions on the part 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 polyimide tape so that they can be removed from the part after consolidation. 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 Flat Panel Bagging

Figure 6.1 shows the bagging arrangement that will be used for the manufacture of NMS 122 mechanical test panels.

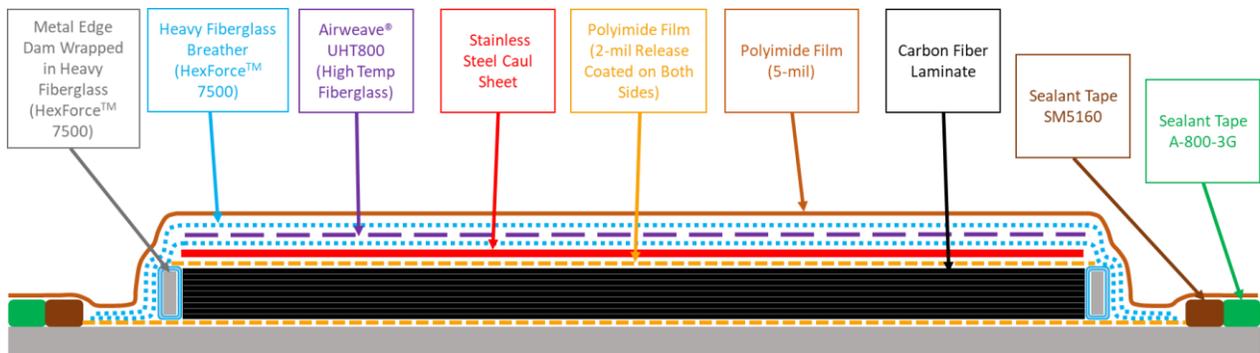


Figure 6.1 - Bagging Technique

- Place release coated polyimide film (2mil) on the mold.
- Place laminate on polyimide film. Ensure that all laminate edges are cut square.
- Place edge dams wrapped in heavy fiberglass around the entire periphery of the laminate. The edge of the dams must be higher than the laminate thickness, but no more than 0.15 inches higher.
- Place a layer of release coated polyimide film on top of the laminate, extending it over the dam.
- Place the caul plate over the laminate. The caul plate shall be 0.024 ± 0.01 inches thick. The caul shall be undersized of the laminate by 0.1 inches to 0.25 inches across all edges.
- Create a breather blanket of Airweave® UHT800 breather wrapped in heavy fiberglass breather sealed using polyimide tape and place over the entire layup, extending beyond the dams.
- Place a layer of polyimide bagging film (5mil) over the entire layup, extending beyond the heavy fiberglass breather. Seal entire layup with SM5160 and A-800-3G sealant tape.

6.8 ILT Panel Bagging

Figure 6.2 shows the bagging arrangement that will be used for the manufacture of NMS 122 ILT mechanical test panels.

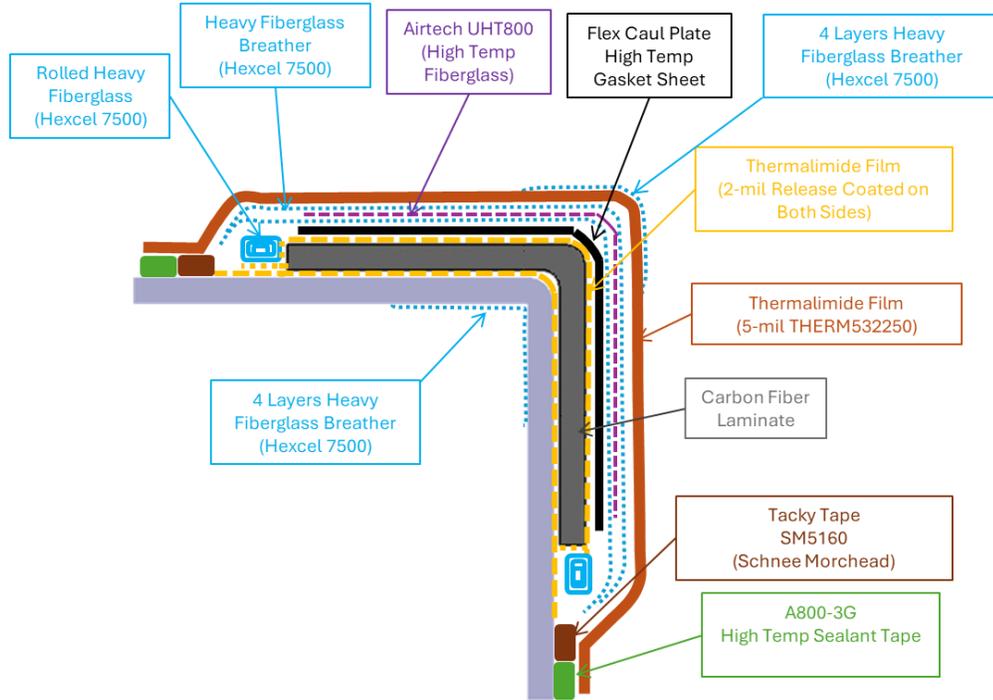


Figure 6.2 - ILT Bagging Technique

- a. Place release coated polyimide film (2mil) on the mold.
- b. Place laminate on polyimide film.
- c. Place a layer of release coated polyimide film on top of the laminate, extending it past the edge of the panel.
- d. Place rolled heavy fiberglass edge dams around the entire periphery of the laminate. The edge of the dams must be higher than the laminate thickness, but no more than 0.15 inches higher.
- e. Place the flex caul plate over the laminate. The caul plate shall be 0.0625 ± 0.01 inches thick. The caul shall be undersized of the laminate by 0.1 inches to 0.25 inches across all edges.
- f. Create a breather blanket of Airweave® UHT800 breather wrapped in heavy fiberglass breather sealed using polyimide tape and place over the entire layup, extending beyond the dams.
- g. Place a layer of polyimide bagging film (5mil) over the entire layup, extending beyond the heavy fiberglass breather. Seal entire layup with SM5160 and A-800-3G sealant tape.
- h. Wrap or secure four layers of heavy fiberglass breather covering the inside and outside radius of the assembled ILT bag to ensure the inside radius of the ILT does not become resin starved.

6.9 Vacuum Leak Check

Apply a minimum vacuum of 28 inHg (or within 2 inHg 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 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 must not fall more than 1 inHg in 5 minutes. If this rate is exceeded, repair the leak and recheck the leak rate.

6.10 Storage and Transportation of Bagged Assemblies Prior to Consolidation

Unconsolidated parts may be transported to a consolidation facility per APCD 250900-06. Bagged assemblies must be leak checked per 6.9 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 5.1.2.

6.11 Consolidation Cycle

6.11.1 Baseline Oven Consolidation Cycle (C)

The baseline consolidation cycle must be in accordance with the following process. For the purpose of specimen naming, this consolidation cycle is designated as "C." The material qualification panels are processed in accordance with the baseline consolidation cycle. Check each vacuum bag assembly for leak before beginning the consolidation cycle per 6.9. All temperatures are panel temperatures based on the lagging thermocouple. The vacuum and temperatures shall be recorded at 5-minute intervals maximum.

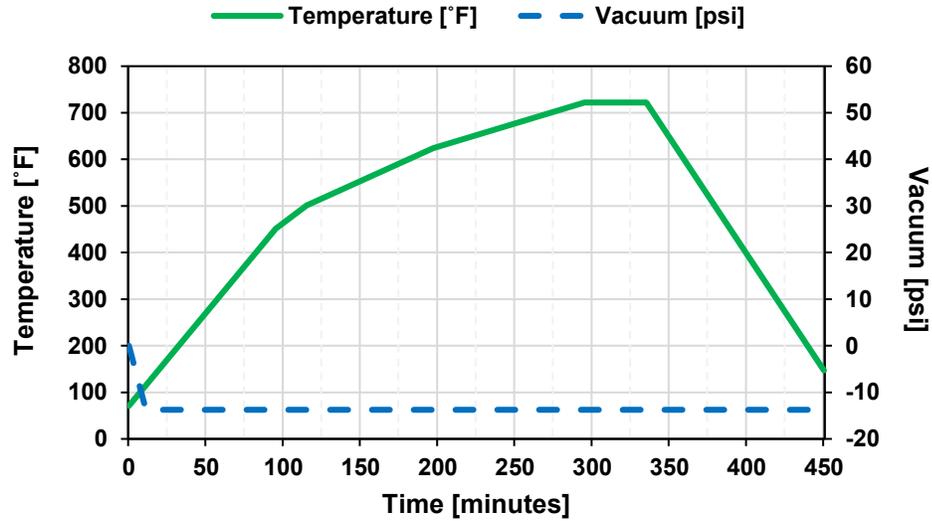


Figure 0.3 – Baseline Consolidation Cycle

- a. Check each vacuum bag assembly for leak before beginning the consolidation cycle per 6.9.
- b. Apply full vacuum within 2 inHg of the local atmospheric pressure.
- c. During the consolidation cycle, panel temperature ramp rate shall remain with 0.5 to 5 °F/minute.
- d. Heat from room temperature to 450 ± 10°F at nominal 4 °F/minute, from 450°F to 500°F ± 10°F at nominal 2.5 °F/minute, from 500°F to 625°F ± 10°F at nominal 1.5 °F/minute, and from 625 °F to 715 °F ± 10 °F at nominal 1 °F/minute based on the panel temperature.
- e. Hold at temperature for 40 ± 5 minutes. Start the hold when the lagging thermocouple reaches 705 °F.
- f. Cool to below 150 °F at 1 to 5 °F/minute maximum before venting the vacuum.

6.11.2 Alternative Autoclave Consolidation Cycle (O) (Unverified)

This consolidation cycle may not show a successful equivalency demonstration to the Qualification baseline oven consolidation cycle (C). Users may contact NCAMP if this consolidation cycle is being considered.

Check each vacuum bag assembly for leak before beginning the consolidation cycle per 6.9. All temperatures are panel temperatures based on the lagging thermocouple. The vacuum and temperatures must be recorded at 5-minute intervals maximum.

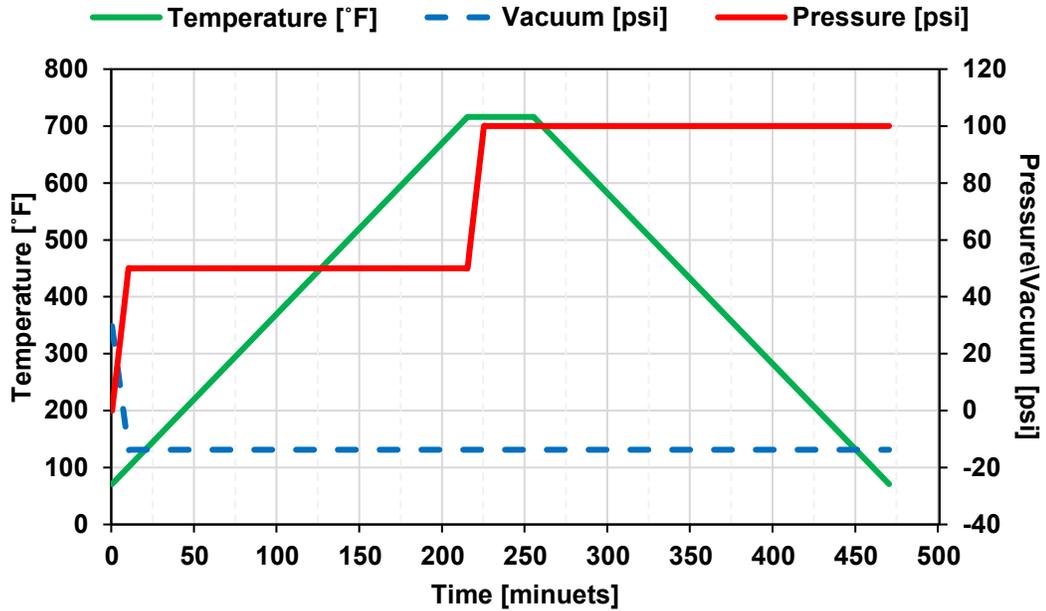


Figure 0.4 – Alternate Consolidation Cycle

- Check each vacuum bag assembly for leak before beginning the consolidation cycle per 6.9.
- Apply 50-psi autoclave pressure at a ramp rate of 5.0 psi per minute to the laminate.
- Heat from room temperature to $715 \pm 10^\circ\text{F}$ at 1 to 5 $^\circ\text{F}/\text{minute}$ based on the panel temperature.
- Apply 100-psi autoclave pressure at a ramp rate of 5.0 psi per minute to the laminate once the temperature ramp has achieved $715 \pm 10^\circ\text{F}$.
- Hold at temperature for 40 ± 5 minutes. Start the hold when the lagging thermocouple reaches 705°F .
- Cool to below 150°F at 1 to 5 $^\circ\text{F}/\text{minute}$ maximum before venting the vacuum and pressure.
- Remove the bagged panels from the autoclave vessel and de-bag for inspection.

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

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.