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NCAMP Process Specification

Fabrication of NMS 688 Qualification, Equivalency, and Acceptance Test Panels
(TenCate TC250)

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1. SCOPE

This process specification describes the methods of fabricating test panels using TenCate Advanced Composites USA Inc. (TCAC) TC 250 epoxy resin prepregs. Specifically, this specification covers prepreg cutting, layup, vacuum bagging, and curing process with a forced-air convection oven equipped with vacuum ports.

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. 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 688 | 265°F Vacuum Cure,Epoxy Prepregs (TC250), including all detail specifications |
|---------|---|

| | |
|-------------|---|
| NTP 6888Q1 | Material Property Data Acquisition and Qualification Test Plan For TenCate Advanced Composites USA, Inc (TCAC) HTS40 F13 150gsm/TC250 uni-directional prepreg |
| NTP 6888E1X | [Panel Fabricator Name] Process Equivalency Test Plan For TenCate Advanced Composites USA, Inc (TCAC) HTS40 F13 150gsm/TC250 uni-directional prepreg |
| NTP 6888Q2 | Material Property Data Acquisition and Qualification Test Plan For TenCate Advanced Composites USA, Inc (TCAC) 12 k HTS40 F13 SFP OSI (193 gsm)/TC250 prepreg |
| NTP 6888E2X | [Panel Fabricator Name] Process Equivalency Test Plan For TenCate Advanced Composites USA, Inc (TCAC) 12 k HTS40 F13 SFP OSI (193 gsm)/TC250 prepreg |
| NMS 818 | Carbon Fiber Tow |
| NMS 828 | Carbon Fiber Fabric |

2.2 ISO Publications:

| | |
|----------|----------------------------|
| ISO 9000 | Quality Management Systems |
|----------|----------------------------|

2.3 US Government Publications:

| | |
|-------------------|---|
| DOT/FAA/AR-02/110 | Guidelines for the Development of Process Specifications, Instructions, and Controls for the Fabrication of Fiber-Reinforced Polymer Composites |
|-------------------|---|

3. MATERIALS:

3.1 Vacuum bag, nylon film, 3 mils maximum, 375°F minimum use temperature

Sources:

- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Technology Marketing Inc. 6122 Stratler St, Salt Lake City, Utah 84107
- Richmond Aircraft Products, Inc., 13503 Pumice St., Norwalk, CA 90650
- Or equivalent

3.2 Breather, 120 glass and 7781 glass, polyester mat (non-woven) 2.2 oz/sqyd 375°F minimum use temperature

Sources:

- Any glass fabric supplier for glass breather
- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Technology Marketing Inc. 6122 Stratler St, Salt Lake City, Utah 84107

- Richmond Aircraft Products, Inc., 13503 Pumice St., Norwalk, CA 90650

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

Open source.

3.4 Solid FEP or Tedlar, separator/release film, 1 to 2 mils, 375°F minimum use temperature

Sources:

- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Technology Marketing Inc. 6122 Stratler St, Salt Lake City, Utah 84107
- Richmond Aircraft Products, Inc., 13503 Pumice St., Norwalk, CA 90650
- Or equivalent

3.5 Silicone Rubber dam, 375°F minimum use temperature

Sources:

- Saunders Corp, 975 N. Todd Ave, Azusa, CA 91702
- Technology Marketing Inc. 6122 Stratler St, Salt Lake City, Utah 84107
- Richmond Aircraft Products, Inc., 13503 Pumice St., Norwalk, CA 90650
- Or equivalent

3.6 Caul Plates, 0.125 – 0.275 inch thick, aluminum, flat and smooth, or equivalent

- *Optional:* Caul plates should be heat treated to assure that they remain flat through multiple uses. Heat treat and prepare as follows; heat at <5°F/minute to 300±5°F for >10 hours, cool to less than 150°F at less than 10°F/minute. Each plate that is not flat to less than 0.010" on the face, shall be flat or lap sanded using 220 grit or finer abrasive to better than 0.010" on the face. This face is to be used against the laminate lay-up to be cured and will be finished with 400 grit of finer abrasive.

3.7 Tape, Pressure Sensitive Mylar Tape 375°F minimum use temperature

Sources:

- Keystone Tape, 3911 E. La Palma Ave., Suite V Anaheim, CA 92807
- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Technology Marketing Inc. 6122 Stratler St, Salt Lake City, Utah 84107
- Richmond Aircraft Products, Inc., 13503 Pumice St., Norwalk, CA 90650
- Or equivalent

3.8 Sealant tape, compatible with nylon vacuum bag, 375°F minimum use temperature

Sources:

- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Technology Marketing Inc. 6122 Stratler St, Salt Lake City, Utah 84107
- Richmond Aircraft Products, Inc., 13503 Pumice St., Norwalk, CA 90650
- Or equivalent

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

3.10 Release Agents

- Frekote 44-NC, K.R. Anderson, Inc., 18330 Sutter Blvd. Morgan Hill, CA 95037
- ZYVAX Watershield, P.O. Box 825, Boca Raton, FL 33429
- Or equivalent

3.11 Porous Teflon Coated Glass Fabric, 3 mil TX-1040

- Technology Marketing Inc. 6122 Stratler St, Salt Lake City, Utah 84107
- Or equivalent

3.12 Peel-ply PE 60004

- Technology Marketing Inc. 6122 Stratler St, Salt Lake City, Utah 84107
- 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 polyurethane or float glass table top with utility knife) or automated method. The method of cutting must not contaminate the prepreg. Fiber orientation (e.g. warp versus fill directions) must be maintained during the cutting process. All the panels have rectangular shapes; intended to help maintain warp and fill direction traceability.

4.2 Prepreg layup and bagging

Wear non-contaminating gloves such as disposable powder-free nitrile gloves when handling the prepreg. The panel layups (stacking sequences) for qualification and equivalency purposes should be in accordance with appropriate test plans. For material acceptance purpose, the panel layups should be in accordance with NMS 688.

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.

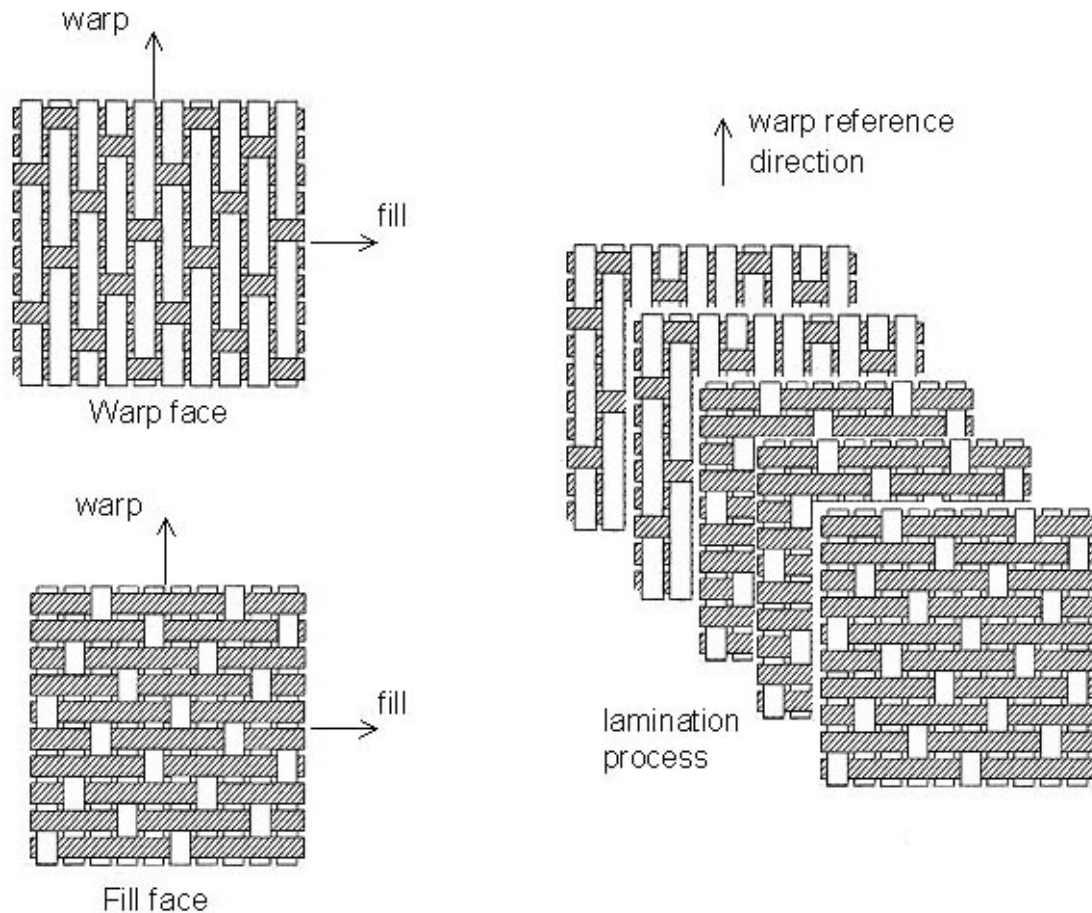


Figure 1 Example Satin Weave Showing Warp and Fill Faces Used for Ply Collation

In order to maintain the fiber orientation, a reference edge should be created on each panel. During the layup process, each ply must be laid up within ± 1 degree of the reference edge. The edge dams around the layup/prepreg will form a straight edge on the cured panel (see Figure 2). In the layup of unidirectional prepreg, plies may be butt spliced in the 90° direction; ply splicing is not allowed in the 0° direction. Ply splicing is not allowed in the layup of woven fabric prepreg in any direction.

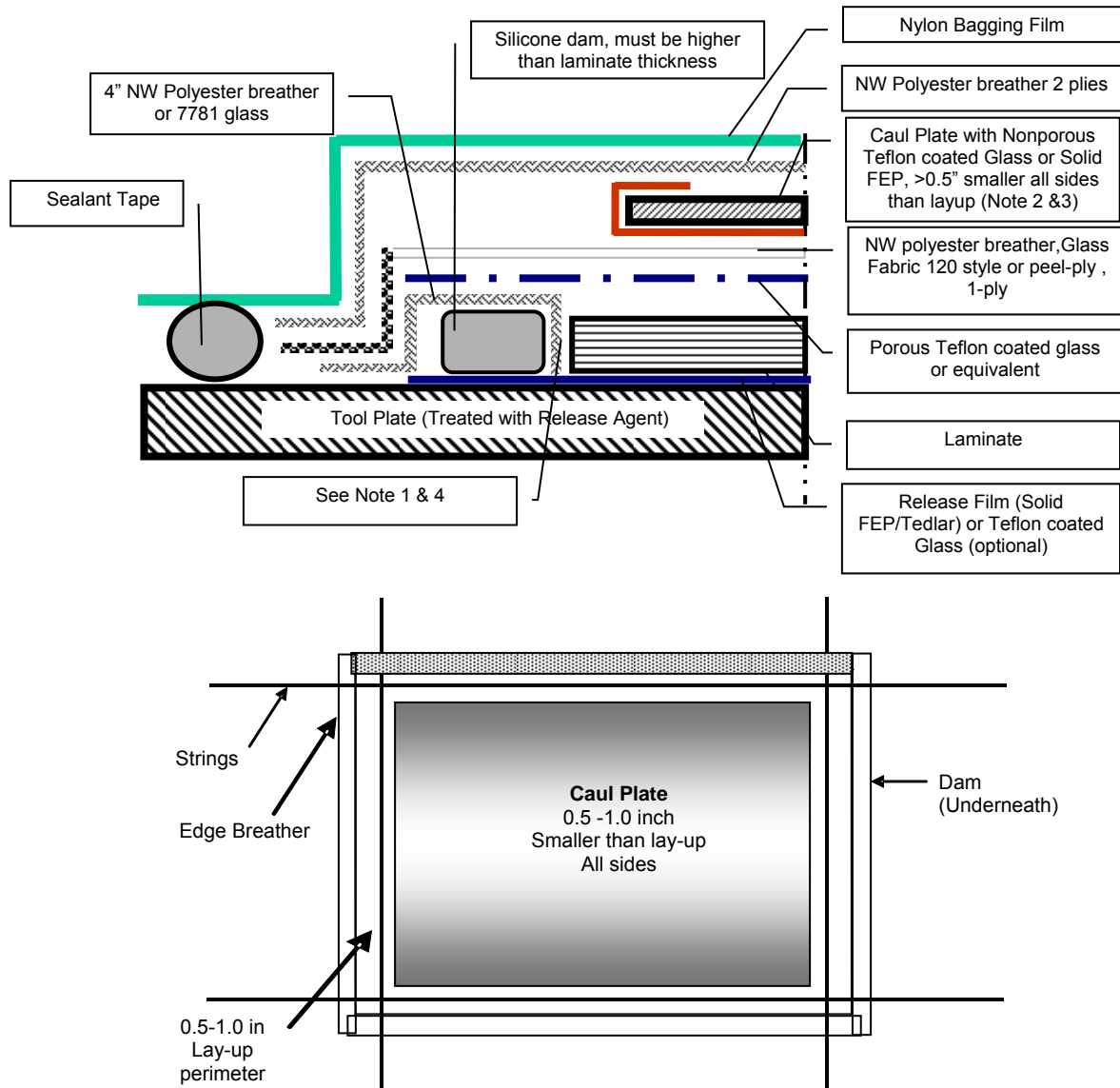
In material qualification and equivalency programs, for panel identification purpose, place a label within $\frac{1}{2}$ -inch from the prepreg edge with the following information: “ 0° direction \rightarrow , Test Plan Document Number -Prepregger ID - Material Code - Fabricator ID - Test Type - Batch ID - Cure Cycle ID -Test Panel ID.” Make sure that the “ 0° direction \rightarrow ” actually points in the 0° direction or warp direction. Appendix 2 of the test plan contains the panel identification information. Use a laser printer to print the labels on standard printer paper.

Figures 2 and 3 show the bagging arrangement which will be used for the manufacture of mechanical test panels from unitape and fabric prepreps, respectively. 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 alternative method is to place the thermocouple junctions in between the part and the caul plate (on the part but about 0.5 inch away from the edge). The latter method allows the thermocouples 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. 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.

Release agents may be used on tool surface instead of non-porous FEP/Tedlar.

Metal edge dams may be used instead of silicone dams. One edge defined as the reference edge must include a metal edge dam. The metal edge dam is used to produce a straight reference edge on the panel which will be used in machining and tabbing processes to maintain fiber orientation. Note that the caul sheet is smaller than the lay-up with approximately ½ to 1-inch of the lay-up exposed on four edges, designed to eliminate thickness taper at the panel edges. The required panel sizes refer to the size of the caul sheet. Cork, silicone or any other type of stiff dam may be used as long as there are 3 – 4 glass breather strings against all the edges of the laminate between the dam and the laminate. The edge of the dams must be higher than the laminate thickness.



Notes:

1. 7781 Fg or NW Polyester and the breather strings should be placed on all edges between the dam and laminate. The edge of the dams must be higher than the laminate thickness.
2. Porous release fabric is used on all laminates and must extend beyond the caul plate to contact the breather.
3. The tool and caul plate do not require a release film if it has been treated with a release.
4. The breather string & edge bleeder must be in the edge of the part, not laid on the top of the panel and must extend out past the dam to touch the breather

Figure 2 Bagging Technique

4.3 Baseline Cure Cycle (C)

The baseline cure cycle shall be in accordance with the following process and Figure 3. For the purpose of specimen naming, this cure cycle is designated as “C.” The material qualification panels are processed in accordance with the baseline cure cycle. Check vacuum bag integrity prior to starting cure cycle; leak rate shall not exceed 1 in.Hg in 2 minutes. All temperatures are part temperatures. Steps 1 through 7 are based on the lagging thermocouple.

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, within 3 in.Hg of the local atmospheric pressure (for example, apply a minimum of 21.7 in.Hg in most of Denver, Colorado where atmospheric pressure is 24.7 in.Hg). Hold at room temperature (R/T) under vacuum for a minimum of 4 hours.
3. Heat from R/T to 185 ±5 °F at 2 to 6 °F/minute based on the part temperature.
4. Hold at temperature for 45±15 minutes. Start the hold when the lagging thermocouple reaches 180 °F.
5. Heat from 185°F to 265 ±5 °F at 2 to 6 °F/minute.
6. Hold at temperature for 120-180 minutes. Start the hold when the lagging thermocouple reaches 260 °F.
7. Cool under vacuum to below 140 °F at 3 °F/minute maximum.

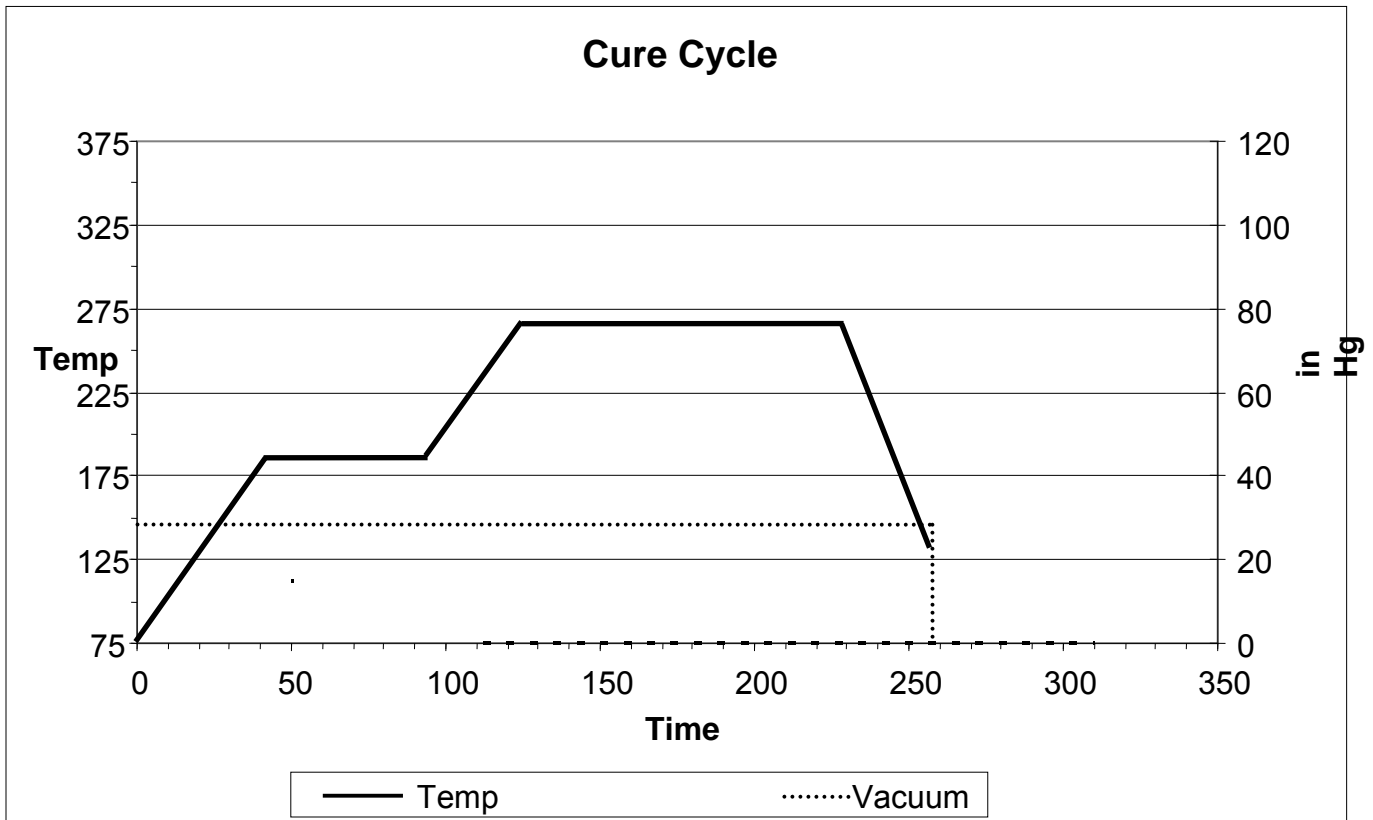


Figure 3 Baseline Cure Cycle for Test Panel Fabrication

4.4 Alternative Cure Cycles

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

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

4.5 Cured Panels

The reference edge created 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. No more than 0.5-inch shall be removed inside of the original edge of the prepreg.

5. QUALITY ASSURANCE

5.1 Process Control

In-process monitoring data such as part temperature, oven temperature, vacuum, and part vacuum readings through the cycle should be in accordance with user's applicable company process specification or an approved shop practice. For material qualification and equivalency purposes, the in-process monitoring data should be provided to the appropriate organizations in accordance with the applicable test plan. Process control testing is not required for the fabrication of test panels.

5.2 Ultrasonic Non-Destructive Inspection

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

5.3 Visual Inspection

Verify that there is no obvious defect such as warpage and dry spots. Panels for material

qualification and equivalency purposes should be labeled in accordance 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. The panel shipping instruction is typically included in the applicable test plan.

7. REVISIONS

| Revision | Date | Description |
|----------|-----------|---|
| - | 2/13/2007 | Initial release w cure notes BRM |
| - | 4/25/2007 | Include Yeow Ng Comments add separate autoclave cycle |
| A | 7/17/2007 | Include D.Ostrodka comments |
| B | 7/31/2007 | Include Ric Abbott comments |
| C | 7/29/2008 | Shifted cure temperature range + 1°F, corrected leading and lagging TC details, edited lay-up Figure, added caul plate type and preparation details. Removed alternative cure cycles and reformatted to new layout standard (Cyttec). B. Meyers |
| | | |