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NCAMP Process Specification
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Fabrication of NMS 532 Qualification, Equivalency, and Acceptance Test Panels (Solvay (formerly Cytec) Cycom 5320-1)

Prepared by: Amy Buxman (Solvay), Debra Lush (Solvay), Thien Nong (Solvay), Yeow Ng (NCAMP), John Tomblin (NCAMP/NIAR), Evelyn Lian (NCAMP)

Reviewed by: Susan Daggett (Gulfstream), Francis Russo (Gulfstream), Brian Wiley (Solvay), Chris Ridgard (Solvay), Royal Lovingfoss (NCAMP), Vinsensius Tanoto (NCAMP), Garrison McGee (Syensqo)

National Center for Advanced Materials Performance
Wichita State University – NIAR
1845 Fairmount Ave., Wichita, KS 67260-0093, USA

REVISIONS

Rev	By	Date	Description
-	Yeow Ng	7/9/2010	Initial Release
A	Yeow Ng	9/23/2010	Updated Section 4.2 – changed layup tolerance from ±1º to ±5° for fabric and ±3° for tape
B	Yeow Ng	11/10/2014	Editorial changes, updated Section 1, removed Section 3.12 and 3.13.
C	Evelyn Lian	5/31/2018	Editorial changes, updated Section 4.3, added Section 4.4.1 and 4.4.2
D	Vinsensius Tanoto	8/12/2025	Cover Page • Added “Garrison McGee (Syensqo)”. Revisions • Moved to the beginning of the documents. Updated Section 4.3.2 • Integrated dwell time at 250F was updated from 180 mins to 120 mins. This was a typo, please refer to NPS 85321 Rev B integrated post cure. • Step 4 was added for Alternative Post Cure at 350°F to add clarity. • Additional “Note” was added for integrated post cure. • Additional “Note” were added for alternative post cure. Updated Section 4.4.1 • Changed ramp rate of “1-3ºF/min” to “1-5°F/min” and ramp rate of “2-4ºF/min” to “1-5°F/min” to match the figure 4. Updated Section 4.4.2 • Ramp up rates were revised. Step (3) from “1 to 3°F” to “1 to 5°F”. Step (5) from “1 to 3°F” to “1 to 5°F”. Step (9) from “0.1 to 0.5°F” to “1 to 5°F”.

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1 SCOPE

This process specification describes the methods of fabricating test panels using Cycom 5320-1. Specifically, this specification covers prepreg cutting, layup, vacuum bagging, and curing process with a forced-air convection oven equipped with vacuum ports. In addition to the instructions contained in this specification, users are advised to obtain hands-on guidance directly from the prepreg manufacturer.

This specification does not contain all the necessary information typically required in a composite process specification for the fabrication of composite structures, such as personnel qualification and layup room requirements. Users should refer to their existing company process specification for such information. DOT/FAA/AR-02/110 provides guidance for the development of composite process specifications.

1.1 Purpose

The purpose of this process specification is to provide processing information for the fabrication of test panels for use in material qualification, equivalency, and acceptance testing. This process specification may also be used as a baseline by material users to develop a process specification for the fabrication of aerospace composite parts.

1.2 Health and Safety

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2 APPLICABLE DOCUMENTS

The following publications form a part of this specification to the extent specified herein. The latest issue of the NCAMP publications shall apply. 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 532	Low Initial Temperature Vacuum-Bag-Only Cure, Medium Toughness Epoxy Prepregs

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, qualified for use at 375ºF or above

- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

3.2 Breather

120 glass, 7781 glass, nonwoven polyester breather (i.e N-4, N-10, Super N-10)

- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Any glass fabric supplier

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 Breather Cord

1721-128PE Glass Cord, 1721-052PE Glass Cord Random

- Gudebrod, Inc., 274 Shoemake Rd, Pottstown, PA 19464
- Or equivalent

3.5 Solid and Perforated FEP

(no larger than 0.045” diameter holes with no less than 2” apart on centers)
Separator/ release film, 1 to 2 mils, qualified for use at 375°F or above

- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

3.6 Boat Cloth

3” – 4” wide fiberglass boar cloth, Style 1542

- Composites One, 11917 Altamar Place, Santa Fe Springs, CA 90670
- Or equivalent

3.7 Caul Plate

0.075” – 0.250” thick, aluminium, flat and smooth, or equivalent

- Open source

3.8 Tape

Pressure Sensitive Mylar Tape qualified for use at 375°F or above

- Keystone Tape, 3911 E. La Palma Ave., Suite V, Anaheim, CA 92807
- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

3.9 Sealant Tape

Compatible with nylon vacuum bag, qualified for use at 375°F or above

- Airtech International, Inc., 5700 Skylab Road, Huntington Beach, CA 92647
- Or equivalent

3.10 Mold

(Bottom Tool), minimum 0.250” thick, aluminum, flat and smooth, or equivalent

- Open source

3.11 Release Agents

Frekote 44-NC, Frekote 55-NC, Frekote 700-NC

- Henkel, One Henkel Way, Rocky Hill, CT 06067
- Or equivalent

3.12 Nonporous Teflon Coated Glass Fabric

3 mil

- Taconic, 3070 Skyway Drive, Bldg 203 Santa Maria, CA 93455
- 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 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. Each ply is marked to identify warp direction. The test panel dimensions shall be sufficient to allow a minimum trim allowance of 1” on all sides.

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 532.

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.

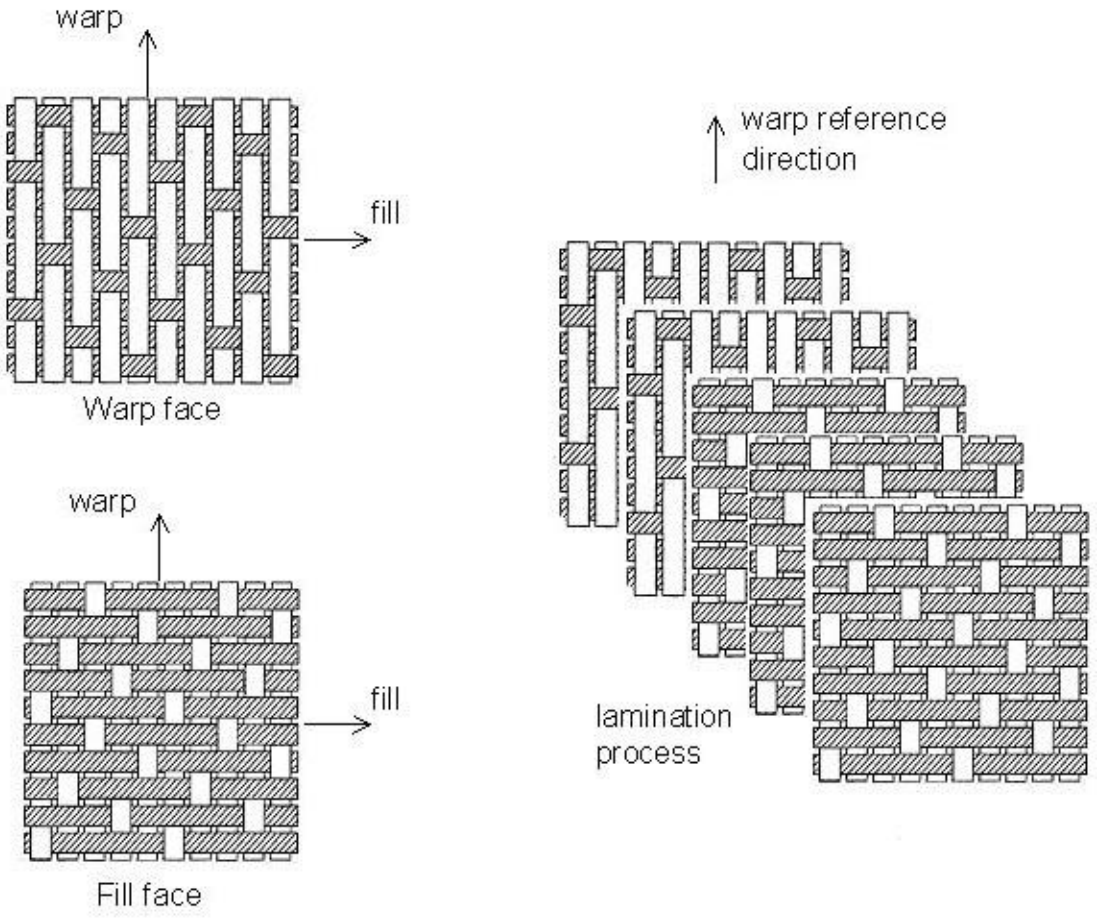

Figure 1 – Example Satin Weave Showing Warp and Fill Faces Used for Ply Collation

In order to maintain the fiber orientation, a reference edge should be created on each panel. The reference edge making needs to be at least 1” from the edge to allow for panel edge trim. During the layup process, each ply must be laid up within ±5° for fabric, and ±3° for tape 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 with 0.5” from the prepreg edge with the following information:

0° direction → – Test Plan Document Number – Prepregger ID – Material Code – Fabricator ID – Test Type – Batch ID – Cure Cycle ID – Test Panel ID

Make sure that the “0° direction →” actually points in the 0° direction or warp direction. Appendix 2 of the test plan contains the panel identification information.

Bagging Procedure:
Figure 2 shows the bagging arrangement which will be used for the manufacture of mechanical test panels.

a. 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.

b. Release agents may be used on the tool surface and the caul plate surface instead of non-porous FEP.

c. Place laminate on solid FEP or release coated tool plate. Ensure that all laminate edges are cut square.

d. Place 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. Cork, silicone or any other type of stiff dam may be used instead of sealant tape and boat cloth as long as there are 3 – 4 glass breather strings against all the edges of the laminate between the dam and the laminate. A fiberglass cord can be used in place 3 – 4 glass breather strings. Glass strings, cord, or boat cloth must be in contact with the laminate edges and be in contact with the 7781 glass plies.

e. Place a layer of perforated FEP on top of the laminate, extending it over the dam.

f. If caul plate is used then place one ply of 120 glass, extending it over the dam.

g. Use of the caul plate is optional. Place the FEP wrapped caul plate over the laminate. The caul plate shall be 0.075” to 0.250” thick. The caul shall be the same dimensions as the laminate, it shall not overlap the dams, and shall not leave a gap between the plate and the dam larger than 0.1”.

h. Place one to two plies of 7781 glass over the entire layup, extending beyond the dams. Nonwoven polyester breather may be used in place of 7781 glass.

i. Place a layer of Nylon bagging film over the entire layup, extending beyond the 7781 glass. Seal entire layup with sealant tape.

j. 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. 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 shall not fall more than 1” of Hg in 5 minutes. If this rate is exceeded, repair the leak and recheck the leak rate.

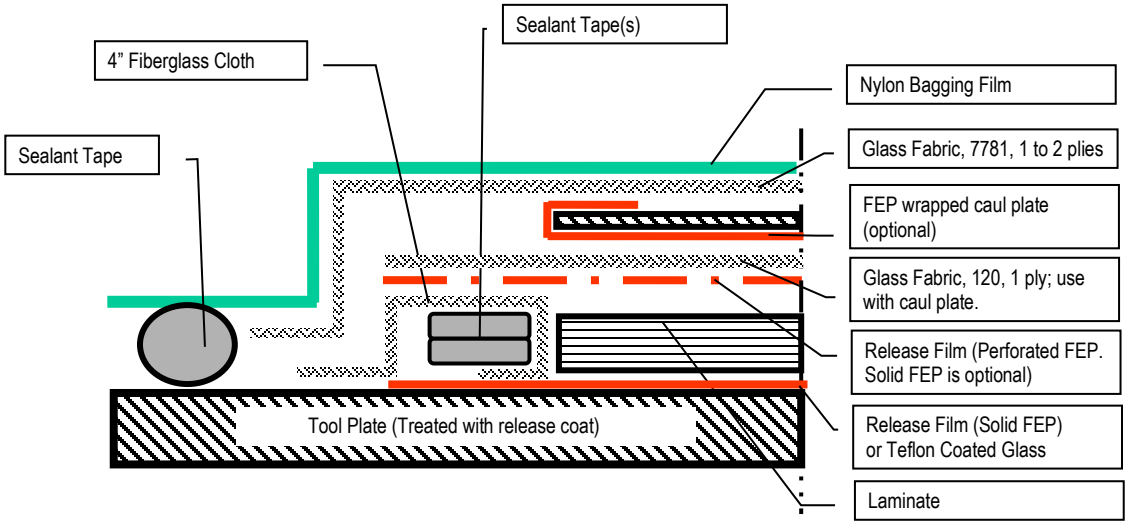

Figure 2 – Bagging Technique for 5320-1

4.3 Baseline Cure Cycle (C)

4.3.1 Pre-Cure Vacuum Hold

The test panels shall be held under a vacuum of 28” of Hg or greater (or within 2” of Hg of the local atmospheric pressure) prior to cure. For example, apply a minimum of 22.7” of Hg in most of Denver, Colorado where atmospheric pressure is 24.7” of Hg. For panels smaller than or equal to 4 ft^2, hold for 4 hours minimum. For panels greater than 4 ft^2, hold for 16 hours minimum. Vacuum shall not be released prior to cure, except if necessary to transport and reconnect to the oven vacuum source (limit this time to 20 minutes maximum).

4.3.2 Cure Cycle

The baseline cure cycle shall be in accordance with the following process. 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" of Hg in 5 minutes. All temperatures are panel temperatures based on the lagging thermocouple. The vacuum and temperatures shall be recorded at 5 minutes intervals maximum.

1. Prior to curing the laminate, leak check the bag to ensure a good seal per section 4.2 (j). No more than 1" of Hg of vacuum over a 5 minutes period is allowed.
2. Apply full vacuum within 2" of Hg of the local atmospheric pressure.
3. Heat from RT to 250 ± 10°F at 1 to 5°F/minute based on the panel temperature.
4. Hold at temperature for 120 ± 5 minutes. Start the hold when the lagging thermocouple reaches 240°F.
5. Heat from 250°F to 350 ± 10°F at 1 to 5°F/minute based on the panel temperature.
6. Hold at temperature for 120 ± 5 minutes. Start the hold when the lagging thermocouple reaches 340°F.
7. Cool to below150°F at 1 to 5 °F/minute maximum.

Note. NMS 532/5 and NMS 532/6 Qualifications were using the above integrated post cure, Syensqo's batch release testing is also using integrated post cure.

Alternative (separate) Post Cure at 350°F:
Figure 3 shows the baseline cure cycle with alternative post cure.
After step 3 above, continue with post cure as follows:

4. Hold at temperature for 180 ± 5 minutes. Start the hold when the lagging thermocouple reaches 240°F.
5. Cool under vacuum to below 150°F at 1 to 5°F/minute maximum.
6. Debag and place panels on support plate. Attach a minimum of two thermocouples per support plate. Place panels in oven.
7. Heat from RT to 350 ± 10 °F at 1 to 5°F/minute based on the panel temperature.
8. Hold at temperature for 120 ± 5 minutes. Start the hold when the lagging thermocouple reaches 340°F.
9. Cool to150°F at 1 to 5°F/minute maximum.

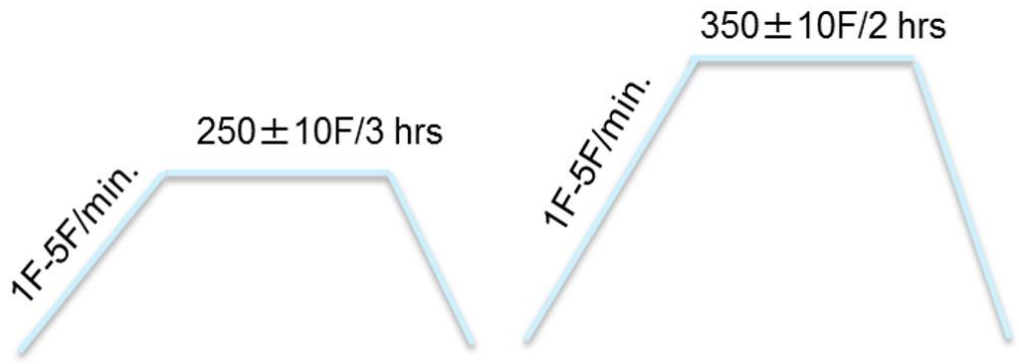

Figure 3 – Baseline Cure Cycle with alternative post cure for Test Panel Fabrication

Note. Alternative (separate) post cure at 350°F has showed to produce equivalent properties to Cure Cycle "C" with integrated post cure.

Note. Equivalency and production must use the same cure cycle and post cure parameters, cure cycle "C" with integrated post cure and (separate) alternative post cure are not substitutable.

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.

4.4.1 Alternate Cure Cycle 1 (AH) - unverified

This “AH” cure cycle is un-verified by NCAMP. This is added as requested by prepreg supplier. There is not enough evidence to show successful equivalency demonstration at this time.

The cure cycle should be in accordance with the following process and Figure 4. For the purpose of specimen naming, this alternate cure cycle with integrated 350°F post cure is designated as “AH”. Check vacuum bag integrity prior to starting cure cycle; leak rate shall not exceed 1” of Hg in 5 minutes. All temperatures are panel temperatures based on the lagging thermocouple. The vacuum and temperatures shall be recorded at 5 minutes intervals maximum.

1. Prior to curing the laminate, leak check the bag to ensure a good seal per section 4.2 (j). No more than 1” of Hg of vacuum over a 5 minutes period is allowed.
2. Apply full vacuum within 2” of Hg of the local atmospheric pressure.
3. Heat from RT to 140 ± 10°F at 1 to 5°F/minute.
4. Dwell at 140 ± 10°F for 120 ± 10 minutes.
5. Heat from 140°F to 250 ± 10°F at 1 to 5°F/minute.
6. Dwell at 250 ± 10°F for 120 ± 10 minutes.
7. Heat from 250°F to 350 ± 10°F at 1 to 5°F/minute.
8. Hold at 350 ± 10°F for 120^{+30}_{-10} minutes.
9. Cool to below 140°F at <10°F/minutes.

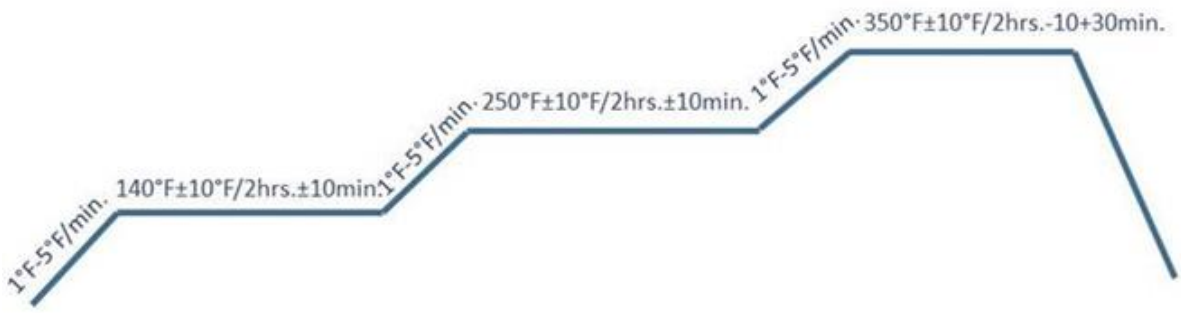

Figure 4 – Alternate Cure Cycle 1 for Test Panel Fabrication

4.4.2 Alternate Cure Cycle 2 (AL) - unverified

This “AL” cure cycle is un-verified by NCAMP. This is added as requested by prepreg supplier. There is not enough evidence to show successful equivalency demonstration at this time.

The cure cycle should be in accordance with the following process and Figure 5. For the purpose of specimen naming, this alternate cure cycle with separate 350°F post cure is designated as “AL”. Check vacuum bag integrity prior to starting cure cycle; leak rate shall not exceed 1” of Hg in 5 minutes. All temperatures are panel temperatures based on the lagging thermocouple. The vacuum and temperatures shall be recorded at 5 minutes intervals maximum.

1. Prior to curing the laminate, leak check the bag to ensure a good seal per section 4.2 (j). No more than 1” of Hg of vacuum over a 5 minutes period is allowed.
2. Apply full vacuum within 2” of Hg of the local atmospheric pressure.
3. Heat from RT to 140 ± 5°F at 1 to 5°F/minute.
4. Dwell at 140 ± 10°F for 120 ± 10 minutes.
5. Heat from 140°F to 250 ± 10°F at 1 to 5°F/minute.
6. Dwell at 250°F for 180 ± 10 minutes.
7. Cool to below 140°F at <10°F/minutes.
8. Demold part.
9. Heat from RT to 350 ± 10°F at 1 to 5°F/minute.
10. Hold at 350 ± 10°F for 120 ± 10 minutes.
11. Cool to below 140°F at <10°F/minutes.

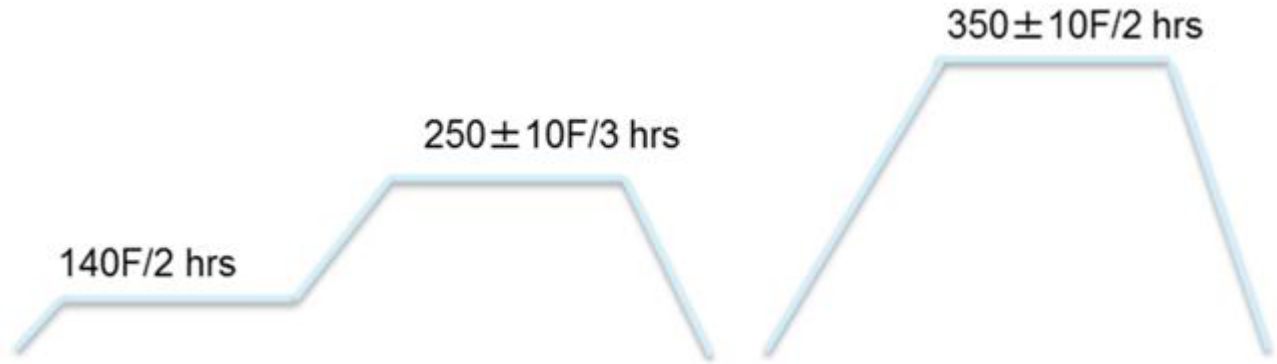

Figure 5 – Alternate Cure Cycle 2 for Test Panel Fabrication

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.

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 are no obvious defects such as warpage or dry spots. Panels for material qualification and equivalency purposes should be labeled in accordance with the applicable test plan for identification purposes.

6 SHIPPING

For material qualification and equivalency purposes, it may be necessary to send the

panels to a designated test lab. The panel shipping instruction is typically included in the applicable test plan.