**BOMBARDIER**

*Toronto Site*

**PROPRIETARY INFORMATION**

# PPS 10.15

**PRODUCTION PROCESS STANDARD**

# WET LAY-UP FABRICATION OF EPOXY RESIN/GLASS FABRIC REINFORCED LAMINATES

Issue 16
- This standard supersedes PPS 10.15, Issue15.
- Vertical lines in the left hand margin indicate changes over the previous issue.
- Direct PPS related questions to christie.chung@aero.bombardier.com or (416) 375-7641.
- This PPS is effective as of the distribution date.

Signed original on file. Validation of paper prints is the responsibility of the user.

| | | |
|---|---|---|
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## 1 SCOPE

1.1 This Production Process Standard (PPS) specifies the procedure and requirements for the fabrication of epoxy resin/glass fibre reinforced laminates, using the low pressure (vacuum bag) and low temperature (175°F maximum) curing method.

1.1.1 This PPS complements the engineering drawings that specify its use as an authorized instruction. The procedure specified in this PPS shall be followed to ensure compliance with all applicable specifications. In general, if this PPS conflicts with the engineering drawing, follow the engineering drawing. The requirements specified in this PPS are necessary to fulfil the engineering design and reliability objectives.

1.1.2 Refer to PPS 13.26 for the subcontractor provisions applicable to this PPS.

1.1.3 Procedure or requirements specified in a Bombardier BAPS, MPS, LES or P. Spec. do not supersede the procedure or requirements specified in this PPS. Similarly, the procedure and requirements specified in this PPS are not applicable when use of a BAPS, MPS, LES or P. Spec. is specified.

## 2 HAZARDOUS MATERIALS

2.1 Before receipt at Bombardier Toronto, all materials shall be approved and assigned Material Safety Data Sheet (MSDS) numbers by the Bombardier Toronto Environment, Health and Safety Department. Refer to the manufacturer's MSDS for specific safety data on any of the materials specified in this PPS. If the MSDS is not available, contact the Bombardier Toronto Environment, Health and Safety Department.

## 3 REFERENCES

3.1 ASTM D3039/D3039M - Materials, Polymer Matrix Composite, Tensile Properties of.

3.2 ASTM D2584 - Resins, Cured Reinforced, Ignition Loss of.

3.3 BAERD GEN-018 - Engineering Requirements for Laboratories.

3.4 EMCM-001 - Bombardier Aerospace Engineering Materials Control Manual.

3.5 PPS 10.22 - Preparation of Moulds.

3.6 PPS 10.28 - Assembly of Wire Thermocouples.

3.7 PPS 10.39 - Machining of Fibre Reinforced Composite Parts.

3.8 PPS 10.40 - Repairs to Laminates and Sandwich Panels.

3.9 PPS 10.51 - Certification of Ovens.

3.10 PPS 13.26 - General Subcontractor Provisions.

3.11 PPS 13.28 - Storage Life of Adhesives, Sealants, Paints and Composite Products.

3.12 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.13 PPS 31.17 - Solvent Usage.

3.14 PPS 34.34 - Surface Finishing Compounds (F33).

## 4 MATERIALS, EQUIPMENT AND FACILITIES

### 4.1 Materials

4.1.1 Epoxy resin, low pressure laminating, as specified by the engineering drawing. Upon receipt, test epoxy resin according to EMCM-001 before releasing the material to production.

4.1.2 Glass fabric, woven, as specified by the engineering drawing. If the engineering drawing specifies the use of MIL-C-9084, Class 2, Types III, VII, VIIIA, or VIIIB, substitute SAE-AMS-C-9084 Class 2 Type VIII (commercial designation 181) woven glass fabric in its place.

4.1.3 Epoxy resin filler, Cab-O-Sil.

4.1.4 Edge breather cloth (e.g., style 181 glass).

**TABLE I - LIST OF EXPENDABLE MATERIALS TO DSC 234**

| MATERIAL DSC 234 | MATERIAL TYPE |
|---|---|
| -1 | 2 Mil Nylon Vacuum Bagging Film, 250°F Cure Cycle |
| -5 | 1 Mil Perforated (pin prick) Release Film |
| -9 | Breather/Bleeder Cloth, Non-Woven Polyester, 4 oz. |
| -15 | High Temperature Pressure Sensitive Tape |
| -17 | Vacuum Bag Sealant |

### 4.2 Equipment

4.2.1 Shop vacuum tables of sufficient size, capable of maintaining and monitoring a vacuum of at least 24" Hg.

4.2.2 Curing oven, certified according to PPS 10.51 (only partial certification to 270°F maximum cure temperature capability is required).

4.2.3 Weighing scale (e.g., triple beam balance type) capable of weighing to ± 0.5 grams.

4.2.4 Disposable wax-free paperboard containers, (e.g., MELO take-out containers).

4.2.5 Thermocouples to PPS 10.28.

### 4.3 Facilities

4.3.1 This PPS has been identified as a “Critical or Special” process according to PPS 13.39 and as such only facilities specifically approved according to PPS 13.39 are authorized to perform the fabrication of epoxy resin/glass fibre reinforced laminates, using the low pressure (vacuum bag) and low temperature (175°F maximum) curing method according to this PPS.

4.3.2 Bombardier subcontractors shall direct requests for approval to Bombardier Aerospace Supplier Quality Management. Bombardier Aerospace facilities shall direct requests for approval to the appropriate internal Quality Manager.

4.3.3 Facility approval shall be based on a facility report, a facility survey and completion of a qualification test program, if required. The facility report shall detail the materials and equipment to be used, the process sequence to be followed and the laboratory facilities used to show compliance with the requirements of this PPS. Any deviation from the procedure or requirements of this PPS shall be detailed in the facility report. Based upon the facility report, Bombardier Toronto Materials Technology may identify additional qualification and/or process control test requirements. During the facility survey, the facility requesting qualification shall be prepared to demonstrate their capability. Once approved, no changes to subcontractor facilities may be made without prior written approval from Bombardier Aerospace Supplier Quality Management.

4.3.3.1 For approval of subcontractor facilities to perform the fabrication of epoxy resin/glass fibre reinforced laminates, using the low pressure (vacuum bag) and low temperature (175°F maximum) curing method according to this PPS, completion of a test program and submission of suitable test samples representative of production parts is required. Test samples shall meet the requirements specified in section 6.

4.3.3.2 All testing and evaluation specified herein shall only be performed by Bombardier Toronto Materials Laboratory or by laboratories accredited according to BAERD GEN-018.

## 5 PROCEDURE

### 5.1 General

5.1.1 For the purposes of this PPS, the term “MRB” (Material Review Board) shall be considered to include Bombardier Toronto MRB and Bombardier Toronto delegated MRB.

5.1.2 For the purposes of this PPS, laminates are considered to consist of single or multi-ply layers of glass fabric, laid-up in a mould, impregnated with epoxy resin and cured under vacuum and under low temperature (175°F maximum).

5.1.3 Unless otherwise specified on the engineering drawing, consider exterior epoxy resin/glass fabric laminates as Class A structural parts. Consider all other epoxy resin/glass fabric laminates as Class B non-structural parts.

5.1.4 Before preparation of production parts, for each glass fabric/resin system combination used in production the fabrication process shall be qualified as follows:

Step 1. Manufacture one 4 ply 24" x 24" flat test specimen according to the procedure specified in this PPS. Lay-up the test specimen with the warp direction of each ply at 90° to each preceding ply.

Step 2. Cut the test specimen into four 12" x 12" test panels.

Step 3. Identify each of the test panels with a suitable trace number.

Step 4. On one of the test panels, hardness test in at least 5 different areas of the test piece using a Barcol comparator. Barcol comparator readings shall be a minimum of 45. Disregard extremely low readings caused by piercing of blisters (test additional areas in this event).

Step 5. Cut the test panel which has been hardness tested into smaller test pieces for tensile testing according to ASTM D3039/D3039M. The average tensile strength of the test pieces shall be 1800 lbs per inch of test piece width.

Step 6. On the test panel which has been hardness and tensile tested, perform resin content testing according to ASTM D2584. The resin content shall be 40 ± 5%.

Step 7. Store and maintain the remaining test panels along with a copy of all test results, instructions, raw material traceability, cloth type, resin system, etc. If the hardness, tensile or resin content test requirements have not been met, determine the cause of failure and rectify it before attempting to re-qualify the process as specified herein.

## 5.2 Preparation of Materials and Equipment

5.2.1 Prepare epoxy resin gelcoat as follows:

Step 1. Thoroughly stir the resin and hardener in their separate containers.

Step 2. Weigh out the resin component into a disposable mixing container in even 100 gram increments or fraction thereof as required for the work on hand.

Step 3. Weigh the correct proportion of hardener according to Table II directly into the resin container on the scale. Do not weigh the hardener into a separate container.

Step 4. Thoroughly mix in 2 to 4 parts (by weight) of epoxy resin filler (see paragraph 4.1.3) to 100 parts of resin component to produce a thixotropic paste.

Step 5. Stir the resin and hardener to obtain a homogeneous air-free mixture.

**TABLE II - DHMS P1.49 EPOXY RESIN-GELCOAT MIXING RATIOS & CURE DATA**

| DHMS P1.49 EPOXY RESIN-GELCOAT | | MIXING RATIO RESIN/HARDENER (Parts by Weight) | GEL TIME/ POT LIFE (Note 1) | CURE TO HANDLE (@ 75 ± 5°F) | FULL CURE | |
|---|---|---|---|---|---|---|
| CLASS | COMPONENTS RESIN/HARDENER | | | | ROOM TEMP (@ 75 ± 5°F) | HEAT ACCELERATED (Note 2) |
| Class 1 | L-363-A FR Resin | 100 | 30 to 60 minutes | 4 hours minimum | 7 days | 3 hours at 120°F - 125°F |
| | L-363-B FR Hardener | 16 | | | | |
| Class 2 (Note 3) | EA 9396 Resin | 100 | 75 to 90 minutes | 48 hours minimum | 5 days | 180 minutes at 100°F - 120°F |
| | EA 9396 Hardener | 15 | | | | |
| Class 3 (Note 3) | EA 9390 Resin | 100 | 120 minutes | N/A (fully cure before handling) | N/A (heat accelerated cure only) | 220 minutes at 180°F - 200°F |
| | EA 9390 Hardener | 56 | | | | |
| | EA 9396 Resin | 100 | 75 to 90 minutes | 48 hours minimum | 5 days | 180 minutes at 100°F - 120°F |
| | EA 9396 Hardener | 15 | | | | |

Note 1. Pot life (or gel time) is the time during which a 100 gram mix of epoxy resin-gelcoat remains suitable for application at 75 ± 5°F. Discard excess material upon expiration of the pot life.
Note 2. Do not begin heat accelerated curing until gelation is complete.
Note 3. EA 9396 Resin/EA 9396 Hardener is qualified to both DHMS P1.49 Class 2 and Class 3 epoxy resin-gelcoat.

5.2.2 Prepare moulds according to PPS 10.22.

5.2.3 Prepare thermocouples according to PPS 10.28.

5.2.4 Prepare glass fabric as follows:

Step 1. Unroll and cut off a sufficient amount of fabric of the type specified on the engineering drawing. Ensure that the fabric is free of broken or damaged strands, streaks, stains or other contamination.

Step 2. If possible, pre-cut the fabric to size, allowing approximately 1/2" beyond the mould trim line.

Step 3. If the glass fabric has been stored in an uncontrolled area or the relative humidity in the storage area has exceeded 60%, dry the fabric in a warming oven at 175°F ± 25°F for approximately 90 minutes. After removal from the oven, place the fabric on the lay-up table and allow it to cool to room temperature.

5.2.5 Keep tools clean and free from oil, moisture, dirt or other foreign matter. Remove hardened resin on tools by solvent cleaning according to PPS 31.17.

### 5.3 Lay-up of Laminates

5.3.1 Lay-up laminates as follows:

Step 1. If specified on the engineering drawing, cover the mould surfaces with a thin (approximately 0.010") continuous coating of gelcoat prepared according to paragraph 5.2.1. Apply the gelcoat by brush and allow to cure until tacky before proceeding with the lay-up.

Step 2. Using a suitable paint roller, impregnate the cloth, prepared according to section 5.2.4, with the specified resin type. If it is not possible to impregnate the cloth before lay-up, coat the mould surface with the mixed resin gelcoat, lay-up the cloth on the mould and, using a suitable roller, apply pressure to the cloth so that the resin is impregnated into the cloth. Use a block to squeeze out excess resin between plies when the cloth is impregnated so as to avoid excessive resin build up.

Step 3. Thoroughly impregnate each subsequent fabric ply with resin and apply the cloth to the mould one ply at a time. Tailor and shape each ply as it is laid up taking care to avoid entrapment of air. Unless otherwise specified on the engineering drawing, lay-up the individual plies in a random pattern. If necessary, overlap fabric splices 0.50" to 1.00" and stagger them in order to produce as uniform a laminate surface as possible.

Step 4. If accelerated gelation and/or curing in an oven is going to be performed, for every 10 square feet of part surface incorporate a thermocouple end under the second last ply outside the trim line. Use DSC 234-15 tape to secure thermocouple wires to the tool. If the shape of the tooling makes it impossible to incorporate thermocouple ends under the second last ply, use DSC 234-15 tape to secure thermocouple ends (covered with two layers of breather cloth) to the tool after completion of the lay-up. Place thermocouples at opposite ends and sides of each other.

### 5.4 Preparation of Laid-Up Parts for Curing

5.4.1 Prepare parts for curing as follows:

Step 1. Cover the lay-up with one layer of DSC 234-5 perforated release film.

Step 2. Cover the lay-up with a layer of DSC 234-9 breather cloth. Place additional layers of breather cloth over protrusions, sharp edges, etc. to prevent puncturing of the bag.

Step 3. Position vacuum outlets around the part as evenly spaced as possible. Include at least one vacuum outlet for every 9 square feet of part area. Add an additional vacuum outlet for vacuum monitoring. Add 2 to 3 layers of breather cloth under each of the vacuum outlets. Do not place vacuum outlets directly over the laid up plies.

Step 4. Apply DSC 234-17 vacuum bag sealant to the mould surface to surround the perimeter of the part and vacuum ports. Leave a minimum of 1" from the ply ends to the vacuum bag sealant.

Step 5. Cover the lay-up with DSC 234-1 vacuum bagging film and work the edges firmly into the vacuum bag sealant. Apply additional vacuum bag sealant in areas where the vacuum bagging film has been doubled or pleated.

Step 6. Puncture the vacuum bagging film at the vacuum outlets.

Step 7. Connect the vacuum outlets to their applicable connectors.

Step 8. Slowly apply a minimum vacuum of 24" Hg to the bagged assembly. Adjust the bag while it is evacuating by pleating and folding to ensure complete contact and even pressure on the lay-up.

Step 9. When the vacuum is achieved, shut off the vacuum supply and check for leaks by observing the pressure gauge. The maximum acceptable leak rate is 1" Hg per minute over a 5 minute period. If the leak rate is greater than 1" Hg per minute over a 5 minute period, repair the leaks (or re-vacuum bag, if necessary) and re-test for leaks.

Step 10. Re-apply a minimum vacuum of 24" Hg to the bagged assembly.

Step 11. Maintain full vacuum until gelation is complete (4 hours minimum at room temperature). If possible, monitor the vacuum under the bag continuously and record the vacuum monitor readings every 5 minutes; if equipment is not capable of continuous monitoring, record the vacuum at the start of the gelation period, in the middle of the gelation period and at the end of the gelation period. Close the vacuum lines for 30 seconds before the vacuum check and re-open them after the check. Provided that thermocouples have been incorporated into the lay-up as specified in step 4 of paragraph 5.3.1, gelation time can be reduced to 2 hours by heating the part to 140°F - 160°F using a heat lamp.

## 5.5 Curing

5.5.1 Unless a heat accelerated cure is to be used, allow laminates to cure undisturbed, **after gelation,** at 75 ± 5°F for the cure to handle time specified in Table II.

5.5.2 For heat accelerated curing **after gelation**, cure according to the heat accelerated full cure specified in Table II. Prepare a cure chart and a cure plot, if available, for each oven load. Do not begin heat accelerated curing until after gelation is complete, otherwise part shrinkage will occur. Curing at an elevated temperature shall be accomplished in the mould or using suitable clamping fixtures to avoid warping. Each oven load shall include a cure chart showing the temperature reading of each thermocouple and the oven temperature recorded every 5 minutes or less.

### 5.6 Hardness Testing

5.6.1 After full cure, hardness test every part on not less than 5 different areas using a Barcol comparator. If possible, select areas that will be trimmed off or cut out. Barcol comparator readings shall be a minimum of 45. Disregard extremely low readings caused by piercing of blisters. If the part fails to meet the hardness requirement, refer the part to MRB for disposition.

### 5.7 Finishing

5.7.1 Finish parts as follows:

Step 1. Trim parts to the engineering drawing requirements according to PPS 10.39.

Step 2. Solvent clean the surfaces of the laminate according to PPS 31.17.

Step 3. If specified on the engineering drawing, surface finish laminates according to PPS 34.34.

Step 4. Check the part for defects as listed in Table III. If the part contains a defect within the limits specified in Table III which is not in an area designated as critical on the engineering drawing, repair the defect according to PPS 10.40. If the part contains a defect in an area designated as critical on the engineering drawing or the extent of the defect exceeds the limits specified in Table III, refer the part to MRB for disposition.

**TABLE III - APPLICABILITY OF REPAIRS**

| DEFECT TYPE | MAXIMUM EXTENT OF DEFECT (NOTE 1) | |
|---|---|---|
| | CLASS A PARTS | CLASS B PARTS |
| Parts Trimmed Too Small | • No fastener holes in area to be built up<br>• Maximum width of 1"<br>• Maximum length 25% of the part's periphery | • Maximum width of 1"<br>• Maximum length 25% of the part's periphery |
| Delamination and Internal Voids | • No more than 1 such defect per square foot<br>• Maximum size of 1 1/2 square inches<br>• Maximum length of 2" | • No more than 2 such defects per square foot<br>• Maximum size of 3 square inches<br>• Maximum length 2" |
| Resin Voids on Surface | • Maximum 10% of surface | • Maximum 20% of surface |
| Excess Resin on Surface | • Corners and fillets - resin cracked or chipped | |
| Surface Scratches, Abrasions and Partial Fractures | • Penetrating through first ply only<br>• Maximum depth of 0.020" | |
| Small Holes and Punctures | • No more than 1 such defect per square foot<br>• Maximum diameter of 1/4" | • No more than 2 such defects per square foot<br>• Maximum diameter of 1/4" |

Note 1. These are the limitations to which these defects may be repaired without MRB authorization. Defects exceeding the stated limits require MRB authorization for repair.

## 6 REQUIREMENTS

### 6.1 General

6.1.1 All testing and evaluation specified herein shall only be performed by Bombardier Toronto Materials Laboratory or by laboratories accredited according to BAERD GEN-018.

### 6.2 Production Parts

6.2.1 Finished parts shall meet the dimensional and material requirements of the engineering drawing. If the engineering drawing indicates critical areas, consult Engineering as to specific requirements.

6.2.2 There shall be no evidence of tackiness, crazing, internal voids (air pockets), delaminations or embedded foreign particles in the laminates.

6.2.3 Laminates shall be free from white or flushed areas caused by contamination of the resin or fabric or excessive curing temperatures.

6.2.4 Surfaces shall be free of resin voids (resin starved areas). However, isolated pin holes are acceptable.

6.2.5 Parts shall be smooth and wrinkle-free on the visible surface (as installed on the aircraft). Non-visible sides may show the fabric pattern.

6.2.6 Keep excess resin to a minimum. Remove resin ridges on visible surfaces or surfaces which are to be painted by sanding, taking care not to expose or damage the glass fibres. Excessive resin in corners and fillets is acceptable provided that there is no tendency for the resin to crack or chip.

6.2.7 There shall be no evidence of scratches, abrasions, fractures, holes or punctures in the laminate.

### 6.3 Lay-Up Area Conditions

6.3.1 The work areas shall be isolated from machining operations or conditions that will generate dust or other contaminating airborne particles.

6.3.2 The air entering the lay-up area shall be filtered and a positive air pressure differential maintained so that unfiltered air does not enter.

6.3.3 The machines and tools used for cutting raw materials shall not deposit internal lubricating fluids onto the work surfaces.

6.3.4 The floors and work surfaces shall be kept clean and free of dust and other contaminants and swept or cleaned at least once a day.

6.3.5 Parting or release agents and uncured silicone bearing material shall not be used in lay-up areas.

6.3.6 Keep the lay-up area temperature and relative humidity within the limits specified in Figure 1. If the temperature or relative humidity exceeds the limits specified in Figure 1, vacuum bag partially completed parts and store them under a minimum vacuum of 24" Hg.

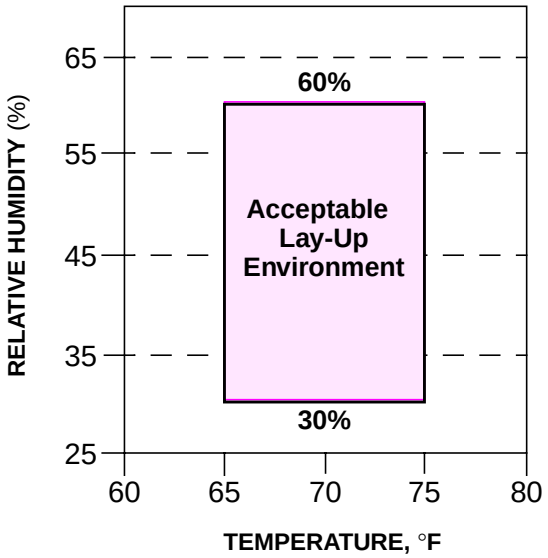


**FIGURE 1 - TEMPERATURE AND RELATIVE HUMIDITY LIMITS**

## *7 SAFETY PRECAUTIONS*

*7.1 Safety precautions applicable to the materials and procedures specified herein shall be defined by the subcontractor performing the work for Bombardier Toronto.*

## 8 PERSONNEL REQUIREMENTS

8.1 This PPS has been categorized as a “Critical or Special” process according to PPS 13.39. Refer to PPS 13.39 for additional personnel requirements. Certified and/or qualified personnel shall have a good working knowledge of the following, as applicable:

- the engineering drawing and work order notes regarding wet lay-up fabrication of epoxy resin/glass fabric reinforced laminates
- the significance of ply orientation
- the role and purpose of vacuum bagging materials (i.e., release film, vacuum bag, vacuum bag sealant, breather cloth, etc.)
- why vacuum outlet placement is important
- when to connect vacuum outlets to vacuum monitors
- the significance of leak testing
- the purpose of vacuum monitoring
- the purpose of pleating the vacuum bag
- the procedure for attaching thermocouple leads to connectors
- how to set up and operate the curing oven
- the significance of cure temperature and time limits

## 9 STORAGE

9.1 Carefully store and protect moulds against damage.

9.2 If possible, maintain the relative humidity where glass fabric is stored below 60%.

9.3 Store DHMS P1.49 resin and hardener at 67°F to 87°F according to precautions necessary for flammable materials.

9.4 Keep containers of resins and hardeners tightly closed in their original containers when not in use. Do not return unused hardener to its original container; store it in a suitable clean sealed container.

9.5 Store resins and hardeners in containers clearly marked with the storage life expiry date. Storage life shall be as specified in PPS 13.28. Issue resin and hardener on a first in/first out basis. Do not issue resin to production if the storage life expiry date has passed.