Process Specification for the Manufacture of Composite Laminate Prepreg Parts

Engineering Directorate

Structural Engineering Division

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REVISIONS		
VERSION	**CHANGES**	**DATE**
--	Original version	8/15/96
A	Change of document title. Rework of standard process note. Addition of more comprehensive quality assurance and traceability measures. Removal of process qualification requirements.	12/5/96
B	Change of document title; Deleted toolmaking MIP's; Changed "Class" to "Level" in Section 3.0. Changed work area humidity requirement. Deleted references to sealing and trimming in 3.3 and 6.15, which will be addressed in a separate PRC. Added MIP definition. Section 7.0 reflects the use of "second-party" inspection. Added particle size requirements for lamination facilities.	6/23/97
C	Reviewed due to ISO requirement. Added section on Process Qualification and renumbered accordingly.	11/1/99
D	Reviewed per QMS requirement. Removed references to old division name. Added TI-6001-03 to training requirements.	12/13/02
E	Reviewed per QMS requirement. No substantive changes.	3/9/2005
F	Updated document references to current designations.	5/23/07
G	Clarified ply joint requirements for unidirectional and tape prepreg (section 6.8). Updated 6.9 to clarify debulking requirements (every 7 plies, minimum).	2/24/10
H	Updated requirements for cold storage of materials in paragraph 5.3. Updated tool requirement to include a thermal survey of tools that weight more than 50 lbs in paragraph 6.4. Update section on laminated ply joints and splices to better clarify acceptable limits for unidirectional and fabric prepregs in paragraph 6.8. Added paragraph to include steps required to prevent contamination during processing in paragraph 6.15. Signature updates	5/15/20

1.0 SCOPE

This document provides the standard requirements for the manufacture of composite laminated parts by the lay-up of pre-impregnated (prepreg) materials.

2.0 APPLICABILITY

This specification shall be applicable whenever a laminated composite part d process is invoked per Section 3.0, “Usage”.

3.0 USAGE

This section gives the requirements for the proper use of this process specification.

In accordance with the drawing and part definition requirements of JPR 8500.4, “Engineering Drawing System Requirements”, the standard composite part manufacturing process shall be invoked by providing a process note in the applicable drawing or CAD model as exemplified in Figure 1.

MANUFACTURE LAMINATE PER JSC PRC-6001, LEVEL 1

3.1 LEVEL

The "Level" designator governs the extent to which quality assurance provisions are applied and shall be specified in the process note on the basis of the following definitions:

a. Level 1 — Level 1 processes shall include the practice of the quality assurance provisions as required by Section 8.1. Whenever invoking these Level 1 provisions, the designer should also consider calling out an NDE process specification on the drawing or CAD model.

b. Level 2 — Level 2 processes shall include the practice of the quality assurance provisions as required by Section 8.2.

3.2 CURE AND POST-CURE SCHEDULES

Unless otherwise stated on the drawing or CAD model, standard cure and post- cure schedules will be applied to the material in accordance with Sections 6.11 and 6.12. Add special cure or post-cure instructions, if necessary, to the process note on the applicable drawing or CAD model.

3.3 NON-DESTRUCTIVE EVALUATION (NDE)

This specification does not address the application of non-destructive evaluation (NDE) methods. However, when calling for Level 1 processing, the designer should also consider the use of NDE inspection by calling out a separate NDE process specification on the drawing or CAD model.

4.0 REFERENCES

The following documents were used in developing this specification:

JPR 8500.4	*Engineering Drawing System Requirements*
JPR 5322.1	*Contamination Control Requirements Manual*

The following document is invoked as part of this specification:

ANSI/NCSL Z540-1	*Calibration Laboratories and Measuring and Test Equipment General Requirements*
TI-6001-03	Training Instruction – Manufacture of Composite Laminate Prepreg Parts

5.0 MATERIAL REQUIREMENTS

5.1 PRECURSOR PART MATERIALS

Precursor part materials (i.e., pre-impregnated composite materials, neat resins, or reinforcement materials) shall satisfy the requirements of any applicable material specifications given on the applicable drawing or CAD model.

5.2 ANCILLARY MATERIALS

Ancillary materials including vacuum bagging, tapes, sealants, and mold release materials shall remain chemically inert with respect to the part material (or materials) throughout the extent of processing.

5.3 STORAGE REQUIREMENTS

Materials shall be stored in an environment as specified by an applicable Material Data Sheet (MDS). An MDS may be either a formal document produced by ES, or the manufacturer's material data sheet if a JSC document is not available. Out- time for a cold storage material is cumulative, and includes all the time a material is removed from refrigeration. Traceable storage temperature records shall be kept by the Manufacturer for materials whose MDS specifies storage temperature limits. Contractors shall obtain applicable MDS's from JSC Manufacturing before processing.

All cold temperature storage materials shall be sealed in a vapor barrier bag and stored at 0°F or below. Uncured part details or ply kits should be supported by a flat surface, lay-up template, or curing tool to prevent damage or distortion. Prepreg rolls should be supported by core inserts, saddles, or equivalent. Before opening a sealed vapor barrier bag, the refrigerated material shall be allowed to warm sufficiently at room temperature in an environmentally controlled area until there is no reformation of condensate on the bag surface when the exterior surface is wiped dry, or alternatively, when the outside surface temperature measures 60°F or above. During thaw, prepreg and adhesive rolls shall be properly supported such that the material is not deformed. When returning materials to refrigerated storage after use, the material and any desiccant provided in accordance with the applicable material specification, shall be resealed inside the vapor barrier bag.

6.0 PROCESS REQUIREMENTS

6.1 WRITTEN PROCEDURES AND STANDARDS

The Manufacturer shall use the most up-to-date procedures for the manufacturing of laminated composite parts.

For contracted work, refer to the contract for requirements concerning the use of written procedures. Contractors shall also obtain applicable Material Data Sheets (MDS) from JSC Manufacturing before processing.

For work performed at JSC facilities, written procedures shall be used and they shall consist of Detailed Process Instructions (DPI's) selected for use from the DPI- 6000- and DPI-6001- series of work instructions. MDS's shall also be used internally.

6.2 FACILITIES

Composite lamination facilities shall be continuously maintained between 67°F and 75°F with a relative humidity no greater than 55%. All work surfaces shall be free of all particulate matter visible to the unaided eye (corrective lenses are acceptable). Airborne particles shall be constantly limited in number according to the distribution given in Table I.

Table 1: Particle Size Requirement for Lamination Facility.

Particle Size:	Number of Particles per Cubic Foot:
$<$ 0.5 micron	Not measured or accounted
$\geq$ 0.5 micron	100,000
$\geq$ 5.0 microns	700

6.3 EQUIPMENT

For contracted work, refer to ANSI/NCSL Z540-1 or any applicable contractual requirements concerning the maintenance and calibration of equipment. For JSC in-house work, all applicable temperature and pressure measurement instrumentation shall be calibrated by the JSC Measurement Standards and Calibration Laboratory (MSCL).

6.4 TOOLS

Tools shall be designed and manufactured so that the final part shall possess the intended dimensional accuracy (see section 6.5) and specified surface finish. The tool design shall also be such that the chemical inhibition of the prepreg part material is minimized (i.e., the finished tool surface is compatible with the part material). A unique alphanumeric identification shall be placed directly on each tool. Tools used for autoclave processing shall be vacuum leak tested to an acceptable rate of no more than 5 in. Hg over a period of 5 minutes.

A thermal mapping heat survey shall be conducted on each new or extensively altered tool weighing more than 50 lbs. A minimum of one thermocouple per 20 square feet is required for this evaluation, resulting in a maximum temperature difference between the hottest and coldest regions of the tool of no more than 20°F. The heat survey must represent tool location and orientation within the curing equipment, and may be used to determine optimal placement of both leading and lagging temperature indicators for oven cure control during production. The addition of insulation and/or supplemental heating equipment on the tool may be required to meet cure profile requirements. Alternately, the target cure profile may be adjusted by M&P engineering to better accommodate the tool thermal characteristics.

6.5 DIMENSIONAL ACCURACY OF PARTS

Finished parts shall not violate the dimensional limits prescribed by an applicable drawing or CAD model, contract, or work order. If any dimensional errors are found, then a discrepancy report shall be generated and a corrective course of action shall be determined.

6.6 MOLD RELEASE MATERIALS

Mold release materials shall be chosen according to the MDS in order to ensure its compatibility with the part material and the proper demolding or separation of the part and tool after curing.

6.7 MATERIAL OUT-TIME AND SHELF-LIFE

The out-time and shelf-life of the material shall not exceed the shelf-life requirements specified by an applicable MDS. Traceable out-time and shelf-life records shall be kept for materials whose MDS specifies out-time and shelf-life limits. If the material out-time or shelf life exceeds the MDS specifications, then a requalification of the material shall be accomplished in a manner prescribed by the MDS.

6.8 LAMINATED PLY JOINTS AND SPLICES

The following requirements apply to all splices unless specified otherwise on the Engineering Drawing. Splicing of fabric plies shall be accomplished with an overlap from 0.5 to 1.0 inch. As shown in Figure 2, splices of uni-tape perpendicular to the fibers shall be accomplished with an end-to-end overlap from 1 to 2 inches. Splicing of uni-tape parallel to the fibers shall be accomplished with a butt splice. Film adhesives shall be spliced with a butt splice. Butt splices (if allowed) for uni- tape, fabric, and film adhesives shall have no gaps wider than 0.03 inch along its length. Splice locations in like-oriented plies shall not repeat more than every six plies through thickness. The minimum distance between splices within a ply is 24 inches. The minimum distance between splices from one ply to the next is 6 inches.

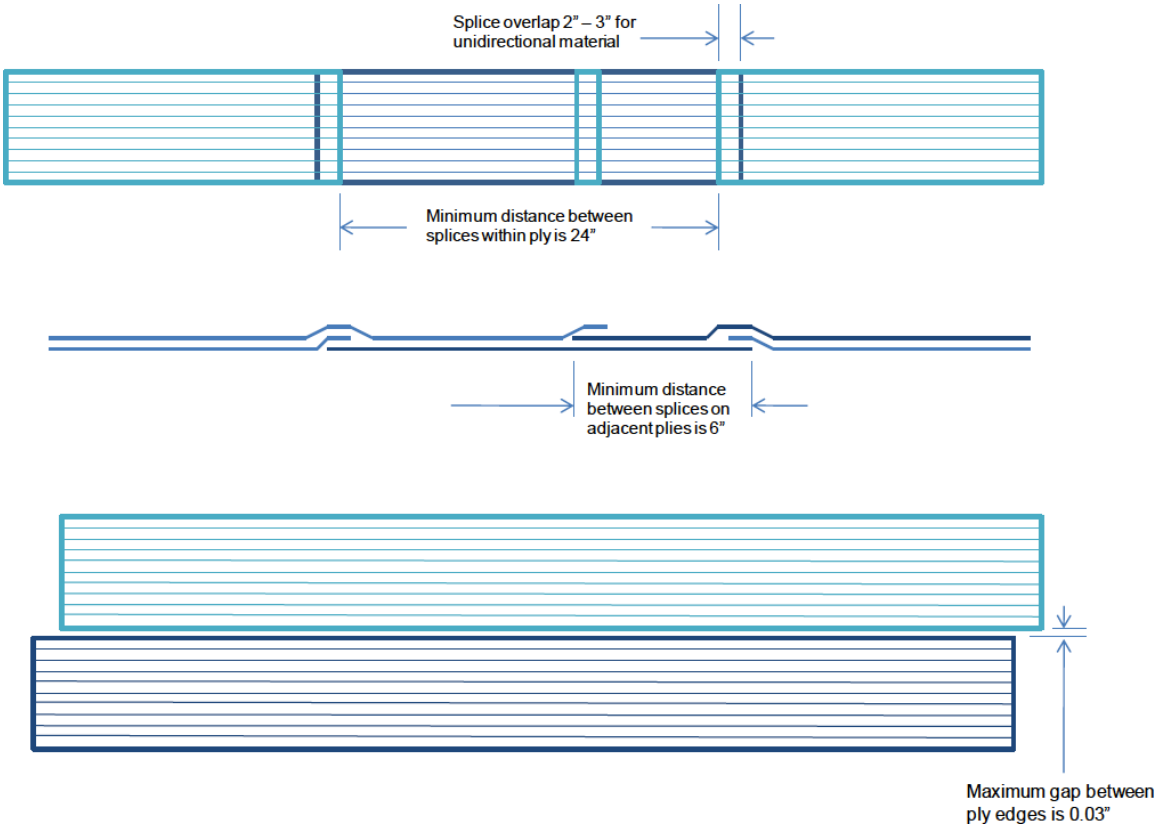

Figure 1: Splicing of Uni-Directional Tape

Any deviations from the above splicing requirements requires full development testing to establish the properties of the new splicing configurations.

6.9 DEBULKING/VACUUM COMPACTION

In most circumstances, bagging the part for consolidation at intervals during the lay-up process is required. MDS's will call out the specific requirements for this process. Perform debulking steps with a frequency given by the applicable MDS, or every 7 plies, whichever is smaller. More frequent debulking is allowed.

6.10 VACUUM BAG ASSEMBLIES

Vacuum bag assemblies are to be used to aid in the consolidation of the laminates. All vacuum bag assemblies shall be air tight to preclude underpressurization of the laminate. Sufficient amounts of bagging material should be used during lay-up in order to prevent material bridging which would result in serious vacuum leaks during cure. Leaks in vacuum bag assemblies shall not exceed 5 inches Hg/5 minutes. Any leaks larger than 5 inches Hg/5 minutes are acceptable only with engineering concurrence.

The materials used in vacuum bag assemblies shall be chosen to meet the requirements of the particular cure schedule, including temperature and pressure.

6.11 CURE SCHEDULES

Unless otherwise specified by the drawing or CAD model, standard cure parameters are prescribed by an applicable MDS that will call out the time, temperature, and pressure requirements of the cure schedule or program. Contractors shall obtain applicable MDS's from the originating activity before processing.

6.12 POST-CURE SCHEDULES

Unless otherwise specified by the drawing or CAD model, standard post-cure parameters are prescribed by an applicable MDS that will call out the time, temperature, and pressure requirements of the post-cure schedule or program. Contractors shall obtain applicable MDS's from the originating activity before processing. Special consideration shall be given to the use of tools or fixtures used to support the part during post-cure operations.

6.13 DEMOLDING (TOOL/PART SEPARATION)

Demolding (i.e., the removal or separation of the part from the tool) shall be accomplished in a manner that is safe and prevents damage from occurring to both part and tool.

6.14 HANDLING AND STORAGE

All raw materials (prepreg fabric, unidirectional tape, adhesives, mold releases, etc.) shall be handled in accordance with applicable Material Safety Data Sheets (MSDS's).

Finished composite panels require extreme care when handling due to sharp edges caused by excess resin (flash). Wearing of suitable hand protection is required. Composite parts shall be handled safely and stored in a manner that prevents damage and visible contamination from occurring to the part.

6.15 CONTAMINATION

Disposable gloves should be worn only once. Gloves which become soiled during normal manufacturing operations should be discarded immediately. Cleaning & mold release cloth should be discarded immediately following any sanding, cleaning and mold release application operations. Materials, tools, and parts shall be investigated to ensure visible cleanliness levels are maintained throughout production. If contamination is suspected and cannot be dispositioned, the discrepancy shall be documented per the appropriate non-conformance procedures. Where possible, cleaned detail parts and tools should be handled by the edges only. To avoid contamination of surfaces to be bonded, silicone type pressure-sensitive tape materials shall never contact any end item materials directly.

7.0 PROCESS QUALIFICATION

For work performed within the Structural Engineering Division, written procedures shall be used and they shall consist of Detailed Process Instructions (DPIs) selected for use from the DPI-6001 series of work instructions. The DPI-6001 series of work instructions shall be validated on non-flight hardware. No untested DPI shall be used to manufacture flight hardware.

8.0 PROCESS VERIFICATION

8.1 LEVEL 1 PROCESS VERIFICATION

Detailed procedures for Level 1 processing shall contain defined Mandatory Inspection Points (MIP's). These MIP's shall describe or refer to specific second- party inspection methods and criteria with which to verify the quality of the composite part. MIP's shall, at a minimum verify:

a. The out-time and shelf life of prepreg part material satisfies Section 6.7.

b. Material Certificates of Compliance (C of C's) are kept.

c. Lay-up sequence and orientation of ply details conform to the part design.

d. Proper execution of the cure and post-cure operations per Sections 6.11 and 6.12 as they pertain to the production of parts.

e. The dimensional accuracy of the part per Section 6.5.

f. The structural integrity of the part as determined by an NDE method, if one is employed (see Section 3.3).

8.2 LEVEL 2 PROCESS VERIFICATION

There are no special process verification requirements for Level 2 processing. Therefore, second party MIP's are not required.

8.3 VERIFICATION RECORDS

Traceable records for all MIP's shall be kept as quality assurance records.

9.0 TRAINING AND CERTIFICATION OF PERSONNEL

Training of all prepreg operators shall be performed according to written detailed procedures. Proper training shall, at a minimum, be structured in such a way as to ensure that each trainee is capable of fabricating flat and curved composite laminates that pass Level 1 process verification criteria as per TI-6001-03. Training and certification records shall be kept.

10.0 DEFINITIONS

Lay-up	An assembly consisting of the laminated composite part material laid on a tool in its final configuration together with any associated vacuum bag enclosures.
Mandatory Inspection Point (MIP)	A second-party inspection process designated during a manufacturing operation.
Material Data Sheet (MDS)	A document describing the material's characteristics, such as strength, modulus, or thermal properties, and standard processing conditions. A manufacturer's material data sheet may be used if an MDS is not available in the Quality Management System
Prepreg	A raw material form of polymer-matrix composite material in which the polymer matrix is provided in a partially cured state.