FOAM CORE MATERIAL

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1. SCOPE

1.1 This specification provides the functional requirements for foam core materials used in the construction of the wind turbine blades. Polymeric type for the foam is not limited, however, polyvinyl chloride (PVC) and polyacrylonitrile (SAN) foams have been successfully used.

2. APPLICABLE DOCUMENTS

2.1 The following documents shall form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue shall apply.

2.1.1 International Standard Organization

ISO 527-1	Plastics - Determination of tensile properties - Part 1: General principles
ISO 527-4	Plastics - Determination of tensile properties - Part 4: Test conditions for isotropic and orthotropic fiber-reinforced plastic composites
ISO 844	Rigid cellular plastics - Determination of compression properties
ISO 845	Cellular plastics and rubbers - Determination of apparent (bulk) density
ISO 1922	Rigid cellular plastics - Determination of shear strength

2.1.2 DIN (The German Institute for Standardization)

DIN 53421	Standard Test Method for Determination of Compression Properties

2.1.3 American Society for Testing and Materials

C271	Standard Test Method for Density of Sandwich Core Materials
ASTM C273	Standard Test Method for Shear Properties of Sandwich Core Materials

ASTM C393 Standard Test Method for Flexural Properties of Sandwich Constructions

ASTM D789 Standard Test Methods for Determination of Relative Viscosity and Moisture Content of Polyamide (PA)

ASTM D1622 Standard Test Method for Apparent Density of Rigid Cellular Plastics

ASTM E2004-04 Standard Test Method for Facing Cleavage of Sandwich Panels

2.1.4 GE Wind Energy Standards

A50WE001 Biax Layered Glass Fabric ± 45° 1000 G/M^2

A50WE002 RIM Resin System

A50WE013 Hand Lay-up Resin System

3. REQUIREMENTS

3.1 Definitions

3.1.1 Personnel

3.1.1.1 Purchaser - GE Wind Energy or its Business Associate.

3.1.1.2 External Supplier - The corporation, company, partnership, sole proprietorship or individual engaged to perform the process covered by this Specification.

3.1.1.3 Internal Supplier - Any GE Wind Energy Manufacturing Department.

3.1.1.4 Supplier - As used herein, unless specifically designated, refers to either an External or an Internal Supplier.

3.1.2 Specification Deviation Documents

3.1.2.1 Applicable to External Supplier

3.1.2.1.1 Supplier Deviation Request (SDR) - A method for the documentation, approval and control of a waiver for materials, processes, or dimensions that deviate from Purchase Order documents (drawings, specifications, engineering instructions, etc.).

3.1.2.2 Applicable to Internal Supplier

3.1.2.2.1 Non-Conformance Report (NCR) - GE Manufacturing Department non-conformance report initiated during processing through the factory. Used by Manufacturing to document non-conformance to governing documents and request corrective action.

3.1.3 Documentation

3.1.3.1 Manufacturing Process Plan (MPP) - A GE approved, detailed, step-by-step list of operations by which the parts are planned to be processed, tested and inspected.

3.1.3.2 Qualification Package - First Piece Qualification documentation containing the results of the test and inspections performed on the first Piece and required for qualification.

3.1.4 Terms

3.1.4.1 Lot/Batch - A Batch is all the material produced during one shift of production where the lot of each component is the same throughout. When a batch process is used, a Lot is all the material processed through a single cycle.

3.1.4.2 Room Temperature - Room temperature is defined as 23°C± 3 (73°F± 5).

3.1.4.3 Sample - Sample is defined as a quantity of material in cured or uncured condition depending on required testing.

3.1.4.4 Cure Cycle - Curing cycle is defined as 10 hours at 70 °C (minimum) with a heating and cooling ramping rate of 1.5 °C (±0.5 °C) per min. Prior to infusion 100% vacuum must be applied to the entire part and remain applied through the duration of the cure cycle. When the part has reached a temperature of 50 °C (maximum) during cool down, the vacuum may be released.

3.1.4.5 Sandwich - See Functional Requirements.

3.2 Functional Requirements

3.2.1 Foam Core Properties -This foam is to be used in production as core material in a planar sandwich structure laminated with layered biaxial glass fabrics saturated with hand lay-up resin or RIM resin system. The foam is characterized as rigid, closed cell foam with high stiffness and strength-to-weight ratio.

Para.	Property	Requirement	Test Method
3.2.1.1	Density, kg/m^3, max	70	4.6.1
3.2.1.2	Processing temperature, °C, (°F), max	95 (203)	-
3.2.1.3	Water absorption, after 1 week at 23°C, Kg/m² (lb/ft^2), max	0.05 (0.01)	4.6.2
3.2.1.4	Compression strength, MPa, min	0.8	ASTM D 1621
3.2.1.5	Compression modulus, MPa, min	58	ASTM D 1621
3.2.1.6	Shear Strength, MPa, min	0.7	ISO 1922
3.2.1.7	Shear modulus, MPa, min	22	ISO 1922

TABLE 1 - PROPERTIES OF FOAM CORE

3.2.2 Foam Dimensions and Slitting - Foams may feature varying thicknesses for specific dimensional requirements, refer to Engineering Drawings. To facilitate infusion, some core material may require slitting. For exact dimensions, refer to Engineering Drawings.

3.2.3 Sandwich - Sandwich is defined as a composite structure consisting of a foam core laminated with two plies of 1000g/m^2 layered biaxial glass fabrics qualified to A50WE001 on the top and the bottom sides. For the construction of the sandwich, vacuum assisted and/or hand lay-up process may be used. The chosen sandwich construction process should best represent the process used in the construction of GE wind turbine blades. This hand lay-up and/or infusion resin shall be qualified to A50WE002 and/or A50WE013 for epoxy based systems. Cross section view of a prospective sandwich construction is illustrated in Table 2. Follow curing cycle described in 3.1.4.4.

1st Ply	+ 45°
	- 45°
2nd Ply	- 45°
	+ 45°
Core	Foam
3rd Ply	+ 45°
	- 45°
4th Ply	- 45°
	+ 45°

TABLE 2 - CROSS SECTION VIEW OF FOAM SANDWICH LAMINATED WITH ±45° LAYERED FABRIC

3.2.4 Mechanical Properties of Sandwich Construction

Para.	Property	Requirement	Test Method
3.2.4.1	Compressive strength, (⊥ to plane), MPa, min	0.90	4.6.3.2
3.2.4.2	Compressive modulus, (⊥ to plane), MPa, min	50	4.6.3.2
3.2.4.3	Tensile strength, in plane, MPa, min	1.2	4.6.3.1
3.2.4.5	Shear strength MPa, min	0.75	4.6.3.3
3.2.4.6	Shear modulus MPa, min	39	4.6.3.3
3.2.4.7	Strain in shear at break, percent, nom	16	4.6.3.3
3.2.4.8	Peel Strength, J/m^2, min	170	4.6.3.4
3.2.4.9	Density of infused and cured foam core material, kg/m^3, max	290	4.6.3.5

TABLE 3 - MECHANICAL PROPERTIES OF SANDWICH CONSTRUCTION WITH FOAM CORE

3.2.5 Analysis - Report the mean and standard deviation for the sample set. For all material properties, with the exception of modulus, listed in 3.2.6 also report the Lower Specification Limit (LSL) value using the following equation:

$$LSL = x_{bar} - \sigma \cdot z \cdot (1+1/\sqrt{n})$$

Where:

LSL = Material Property
x_{bar} = mean
σ = Std. Deviation
z = 1.645
n = number of samples

3.2.6 It shall be the responsibility of the Supplier to understand thoroughly the work scope and all documentation needed to complete the work. This responsibility shall apply to the prime Supplier for any or all operations performed by sub-tier Suppliers (s).

3.2.7 Manufacture shall be conducted in accordance with a documented Frozen MPP. The Supplier shall monitor the actual process, compare the process to the MPP and report to the Purchaser any variances using the SDR/QCR.

3.2.8 Deviations - Any deviation from the requirements of this Specification shall be submitted by SDR/QCR for Engineering disposition before the item is shipped.

3.2.9 Shelf Life - the components shall retain all properties required by this specification for 1 year when stored in their original closed container at room temperature, 23°C ±3 (73°F ±3).

4. QUALITY ASSURANCE PROVISIONS

4.1 First Piece Qualification - A comprehensive evaluation for First Piece Qualification (FPQ) shall be required of a new Supplier, or when there is a significant change in the approved MPP or if a Supplier has not performed this process within the two years prior to Purchase Order placement. FPQ shall, as a minimum, include the following:

4.1.1 An MPP approved by the Purchaser prior to initiation of the FPQ.

4.1.2 Test data.

4.1.3 Certificate of Conformance

4.1.4 Qualification Samples - FPQ samples shall be provided as requested.

4.2 Qualification Package - The Supplier shall submit two (2) copies of the FPQ documentation for review/approval.

4.3 Frozen MPP - Upon receipt of written notification for FPQ, the Supplier is approved for production of the qualified part. The MPP shall be "FROZEN", not to be changed without approval of a new MPP.

4.4 Factory Trials - Final Supplier qualification and approval to supply components manufactured to this specification are subject to factory trials by the Purchaser.

4.5 Inspection and Test Requirements

4.5.1 Visual - The foam shall be dry and free of dust and dirt. Any debris located in the slits or grooves of the foam core material must be removed prior to the part lay-up process.

4.5.2 Density of the foam - Measure the density of the foam per section 4.6.1.

4.5.3 Dimensions of the foam - Dimensions of the foam shall meet the requirement specified in Section 3.2.2.

4.6 Test Methods

4.6.1 Density - Measure the density per either ISO 845 or ASTM D1622. The density is to be measured by determining the dimensions of a foam sample and then dividing its weight by its volume. It is desirable to have a sample in the shape allowing for easy calculation of its volume, one in the shape of cubic.

4.6.2 Moisture Content (water absorption) - Measure moisture content of foam using ASTM D789 or by a method approved by the purchaser.

4.6.3 Mechanical properties

4.6.3.1 Foam tensile properties (strength, modulus) - Perform tensile test either in accordance with ISO 527-1 or ISO 527-4. Calculate tensile properties including strength and modulus using proper test methods and equations. A minimum of 10 samples is to be tested for material qualification.

4.6.3.2 Foam compressive properties (strength, modulus) - Perform compressive test either in accordance with ISO 844 or DIN 53421. Calculate compressive properties including strength and modulus using proper test methods and equations. A minimum of 10 samples is to be tested for material qualification.

4.6.3.3 Foam shear properties (strength, modulus, strain) - Perform shear test either in accordance with ISO 1922. Calculate shear properties including strength, modulus, and strain using proper test methods and equations. A minimum of 10 samples is to be tested for material qualification.

4.6.3.4 Sandwich Peel - Perform peel test in accordance with ASTM E2004-04 Standard Test Method for Facing Cleavage of Sandwich Panels. Calculate peel strength properties using the proper procedures and equations. A minimum of 10 samples is to be tested for material qualification.

4.6.3.5 Density - Perform density test in accordance with ASTM D1622 or ISO 845. Calculate density using proper test procedures and equations. A minimum of 10 samples is to be tested for material qualification. (This test is to be performed on foam that has been infused and cured with approved RIM resin system. These coupons will not be a sandwich structure). To make infused foam panels, perform infuse without glass fabric on the top and bottom of core panels. A release ply should be used to prevent the infusion bag and media from sticking to the core.

4.7 Certificate of Test

4.7.1 Internal Supplier - The Internal Supplier shall submit the Certificate of Test to Manufacturing Quality Assurance.

4.7.2 External Supplier - The External Supplier shall submit the Certificate of Test to the Purchaser address shown on the Purchase Order.

4.7.3 A Certificate of Test shall be submitted for each Lot stating that the components were processed in accordance with the requirements of this Specification and other applicable documents. The Certificate shall be signed and dated by an authorized Supplier Representative and shall, as a minimum, include the following information:

- Supplier Name, Address and GE (External) Supplier Code
- GE Purchase/Shop Order Number and date
- MPP Identification Number, Revision Level and Revision date
- SDR(s)/QCR(s)
- GE Specification
- Date of Manufacture
- Test and Inspection Data (section 4.5 of this document)

4.8 Audit - The Purchaser reserves the right to periodically audit the Supplier's facilities and practices. Such audits shall not relieve the Supplier from the responsibility of producing the material in a suitable condition.

5. PREPARATION FOR DELIVERY

5.1 Packing and Marking

5.1.1 Material shall be shipped in standard commercial containers, which are suitable to meet Department of Transportation, and to protect against material contamination or damage during shipping and storage. Material to be marked as follows:

5.1.2 Each container shall be legibly labeled and include the following:

- Purchase Order Number
- GE Specification Number
- Manufacturer's Name
- Quantity
- Lot Number
- Manufacturing Date
- Appropriate safety and hazard information

6. NOTES

6.1 Qualification testing must take place at an A2LA accredited testing facility.

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