COOLING TOWER INSTITUTE

CTI CODE TOWER
Standard Specifications

Fiberglass Pultruded Structural Products for Use in Cooling Towers

Foreword

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This guideline document summarizes the best current state of knowledge regarding the specific subject. This document represents a consensus of those individual members who have reviewed this document, its scope and provisions. It is intended to aid all users or potential users of cooling towers.

Approved by the CTI Executive Board.

This document has been reviewed and approved as part of CTI's Five Year Review Cycle. This document is again subject to review in 2012.

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Fiberglass Pultruded Structural Products for Use in Cooling Towers

1.0 Scope

1.1 This Specification offers recommendations for classification, materials of construction, tolerances, defects, workmanship, inspection, physical, mechanical and design properties of glass fiber-reinforced pultruded structural shapes intended for use as construction items in cooling tower applications.

1.2 These specification recommendations are defined by existing American Society for Testing and Materials (ASTM) documents. Supplementary information on glass fiber-reinforced plastic pultruded structural products may be obtained from the pultrusion supplier. It is not intended to restrict or limit technological changes affecting performance when those changes are agreed upon by the pultrusion supplier and cooling tower manufacturer.

1.3 Laboratory tests under controlled conditions should be used to measure and describe the properties of materials, products or assemblies covered by this standard and not to assess risk conditions. It is the responsibility of the user of the document to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2.0 Applicable Documents

2.1 ASTM D-256 - Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials.

2.2 ASTM D-570 - Test Method for Water Absorption of Plastics.

2.3 ASTM D-618 - Methods of Conditioning Plastics and Electrical Insulating Material for Testing.

2.4 ASTM D-635 - Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position.

2.5 ASTM D-638 - Test Method for Tensile Properties of Plastics.

2.6 ASTM D-695 - Test Method for Compressive Properties of Rigid Plastics.

2.7 ASTM D-696 - Test Method for Coefficient of Linear Thermal Expansion of Plastics.

2.8 ASTM D-790 - Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.

2.9 ASTM D-792 - Test Methods for Specific Gravity and Density of Plastics by Displacement.

2.10 ASTM D-883 - Definitions of Terms Relating to Plastics.

2.11 ASTM D-2343 - Test Method for Tensile Properties of Glass Fiber Strands, Yarns and Rovings Used in Reinforced Plastics.

2.12 ASTM D-2344 - Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short-Beam Method.

2.13 ASTM D-2583 - Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor.

2.14 ASTM D-2584 - Test Method of Ignition Loss of Cured Reinforced Resins.

2.15 ASTM D-2734 - Test Methods for Void Content of Reinforced Plastics

2.16 ASTM D-3647 - Practice for Classifying Reinforced Plastic Pultruded Shapes According to Composition

2.17 ASTM D-3846 - Test Method for In-Plane Shear Strength of Reinforced Plastics.

2.18 ASTM D-3914 - Test Method of In-Plane Shear Strength of Pultruded Glass-Reinforced Plastic Rod.

2.19 ASTM D-3916 - Test Method for Tensile Properties of Pultruded Glass-Reinforced Plastic Rod.

2.20 ASTM D-3917 - Specification for Dimensional Tolerance of Thermosetting Glass-Reinforced Plastic Pultruded Shapes.

2.21 ASTM D-3918 - Definitions of Terms Relating to Reinforced Plastic Pultruded Products.

2.22 ASTM D-4065 - Practice for Determining and Reporting Dynamic Mechanical Properties of Plastics.

2.23 ASTM D-4357 - Specifications for Plastic Laminates Made from Woven-Roving and Woven-Yarn Glass Fabrics.

2.24 ASTM D-4385 - Practice for Classifying Visual Defects in Thermosetting Reinforced Plastic Pultruded Products.

2.25 ASTM D-4475 - Test Methods for Apparent Horizontal Shear Strength of Pultruded Reinforced Plastic Rods by the Short-Beam Method.

2.26 ASTM D-4476 - Test Method for Flexural Properties of Fiber Reinforced Pultruded Plastic Rods.

2.27 ASTM E-84 - Test Method for Surface Burning Characteristic of Burning Materials.

3.0 Terminology

3.1 Definition of terms relative to STD-137 (see Appendix –Glossary of Terms)

3.2 Pultrusion - The process of pulling continuous forms of reinforcing materials, such as glass-fiber rovings, glass-fiber mats and various surfacing veils through a bath of liquid resin. The mass of fully wetted-out material then continues to a performer and directly into a heated forming and curing die where a chemical reaction is initiated which causes the thermosetting resin to harden and the composite structural shape is formed. An optional method of cure is to pass the wetted-out composite through a radio frequency (RF) preheater. The RF preheat initiates the cure process prior to entering the heated forming die. This process is particularly useful for heavy section processing. The hardened (or cured) shape is cooled in line by water or air and then enters a pulling device where continuous pulling is maintained. Both caterpillar type and reciprocating pullers are used in pultrusion. Upon exiting the puller, the composite structural shape is cut to the desired length.

3.3 Definition of terms relative to pultrusion can be found in ASTM D-883 and ASTM D-3918.

3.4 Other forms or combinations of reinforcements such as carbon fiber, aramid fiber, etc. can also be utilized when different mechanical and physical properties are required. Specific mechanical and physical properties should be negotiated between the pultrusion supplier and cooling tower manufacturer for particular applications.

4.0 Classification

4.1 4.1.1 Type I - Fiberglass pultruded rod and bar without a synthetic surfacing veil meeting the minimum mechanical properties of Table I/1A.

4.1.2 Type II - Fiberglass pultruded flat plate with synthetic or polyester fiber surfacing veil meeting the minimum mechanical properties of Table I/1A.

4.1.3 Type III - Fiberglass pultruded standard shapes with synthetic polyester fiber surfacing veil meeting the minimum mechanical properties of Table I/1A.

4.1.4 Type IV - Custom pultruded structural products or modifications to Type I, II, or III as specified by purchaser and agreed to by the pultrusion manufacturer.

4.2 Fiberglass pultruded structural products utilize various resin systems to hold the composite together. The resin system selected, type and volume of reinforcement, loading, surfacing material, degree and method of fire retardancy and temperature requirements are several determining factors for corrosion resistance to the exposure encountered and the cost of the product. The flame retardancy of the composite can be achieved using a number of different techniques. Either a halogenated resin may be utilized in pultrusion, or the composite may be composed of a non-halogenated resin with the appropriate halogenated additives. However, the flame retardancy requirements must be associated with the composite and not with a particular resin. The cooling tower manufacturer should contact the pultrusion manufacturer for resin recommendations based on the anticipated application requirements; chemical exposure in the recirculating water or air, temperature extremes, flame spread/flammability ratings, etc. The resin grades are:

4.2.1 Grade 1 - Isophthalic polyester resin composite with a 25 or less flame spread rating per ASTM E-84 or vertical burn test per UL listing of 94 VO.

4.2.2 Grade 2 - Isophthalic polyester resin (no flame retardant additives).

4.2.3 Grade 3 - A vinyl ester flame retardant resin composite with a 25 or less flame spread rating per ASTM E-84 or UL listing of 94 VO.

4.2.4 Grade 4 - Vinyl ester resin (no flame retardant additives).

4.2.5 Grade 5 - Other resin (with a specified level of flame spread per ASTM E-84 or UL if flame retardance is to be claimed) to be selected by the cooling tower manufacturer in conjunction with the pultruded structural product supplier. Additives, not part of the resin matrix, may be used in the final composite to achieve other performance characteristics (i.e. mold release, fillers, UV inhibitor or antimony trioxide for flame retardancy).

5.0 Materials

5.1 Glass fiber-reinforcements may be either continuous rovings, continuous strand mats, woven or non-woven fabrics, uni-directional fabrics or combinations of these. Glass fibers shall be made for A, C, E or S-type glass. Other reinforcements may be specified for custom applications.

5.2 The resin used throughout the part shall be either an isophthalic polyester, vinyl ester or other resin agreed upon between cooling tower purchaser and cooling tower manufacturer. The resin may contain additives for various purposes such as flame retardancy, UV stabilization, pigmentation or smoke reduction. These additives should be selected so as to add to the overall performance of the product without affecting the structural properties, chemical resistance an/or longevity of the part.

5.3 Surfacing veils are thin (7 mils nominal) tissue-type products incorporated during the pultrusion manufacturing operation as the outermost surface layer of non-resinous material. The function of the veil is improved surface appearance, assistance in chemical resistance, improved weatherability and to prevent glass fibers from coming to the surface as a result of wear or UV attack. Heavier surfacing veils can be requested for custom applications. The final degree of UV protection is a function of the total manufactured thickness of the surfacing veils and/or surface coatings.

6.0 Physical Properties

6.1 Dimensional tolerances shall be in accordance with ASTM D-3917 "Specification for Dimensional Tolerance of Thermosetting Glass-Reinforced Plastic Pultruded Shapes". Physical properties are listed in Table I/1A.

7.0 Mechanical Properties From Coupons

7.1 Minimum mechanical properties (taken from coupons) for Types I, II and III composites, when tested at 77°F, are listed in Table I/1A. For Type IV products, the pultrusion supplier should supply the cooling tower manufacturer with minimum mechanical properties. These mechanical properties taken from the coupons are intended to be used as a proof test for the composite supplied and not to be used for design purposes. The purchaser should consult appropriate design manuals to obtain the necessary design data for agreed upon qualifying tests on full sections. Test coupons shall normally be taken from the largest flat surface of the composite.

8.0 Design Criteria and Allowable Design Values

8.1 Allowable design values for pultruded rod and bar, flat sheet and structural shapes used under flexural and/or compressive loads must be obtained from an appropriate engineering design guide, (i.e. The CTI FRP Design Guideline ESG-152(02)) or the pultrusion supplier.

8.2 For members in cooling towers which are subjected to extended periods of operation in temperatures greater than 77°F, the pultrusion suppliers published allowable design values for flexural and compressive loads shall be reduced to account for reduced properties at the higher temperatures. These correction factors are published in Table II. For Type IV products, pultrusion suppliers are to supply the cooling tower manufacturer with temperature-moisture correction factors. All structural components for the tower should be selected to account for maximum expected hot water temperature including any upset conditions as a minimum (i.e. maximum hot water temperature +212°F/100°C). This will account for the possible the effects of fan-off operation, tower idle in hot weather, and load excursions. A statement indicating the design temperature should be included as part of the cooling tower manufacturer's proposal.

8.3 Service Factors: The effective operating life of any pultruded FRP component is related to the service factor applied by the tower manufacturers design engineer and the severity of conditions to which the component is subjected. Sustained loads should carry a service factor sufficiently high to minimize long-term creep. On short-term loads such as wind, seismic, ice, etc., lower service factors may be acceptable. The tower manufacturer's design engineer should provide allowable design values, service factors and L/D ratios used to determine the tower design life.

8.4 Except where more restrictive design load specification requirements are indicated, the tower structure shall be designed, fabricated and built in accordance with the local building codes and cooling tower manufacturer's design data.

9.0 Workmanship

9.1 Fiberglass pultruded structural products shall be supplied to the requirements listed in ASTM D-4385 "Visual Defects in Thermosetting Reinforced Plastic Pultruded Products" at acceptance level 3. ***A two year research study revealed that sealing of cut and drilled edges does not positively affect the performance of pultruded structural shapes. The research suggests sealing of cut and drilled edges at the point of manufacture or at the field erected tower site is not required.***

10.0 Quality Assurance

10.1 The final inspection and acceptance criteria for the fiberglass reinforced pultruded structural products should be agreed upon between the pultrusion supplier and cooling tower manufacturer. The pultrusion supplier is responsible for developing a special quality assurance manual applicable to the particular CTI cooling tower manufacturer. The quality assurance system should contain the following as a minimum:

10.1.1 A quality assurance incoming inspection system that audits each shipment of resin and glass for previously agreed upon specifications between pultrusion supplier and cooling tower manufacturer using appropriate techniques to assure consistency of materials.

10.1.2 Pultrusion supplier and cooling tower manufacturer should review process controls to verify that production parts meet or exceed design values.

10.1.3 A glass content verification program for each particular structural pultrusion.

10.1.4 The capacity to perform in house mechanical property audits as required.

10.1.5 A modulus of elasticity verification on the pultruded structural shapes.

10.1.6 The ability to write a Certificate of Conformance to be supplied with the shipments.

10.1.7 Procedures to calibrate test equipment.

10.1.8 Procedure to handle non-conforming product.

Table I
Pultruded Fiberglass Mechanical and Physical Properties

						Polyester Plate			Vinyl Ester Plate		
Properties	Test Method	Units/ Value	Polyester Shapes	Vinyl Ester Shapes	Rod & Bar	1/8”	3/16"- 1/4"	3/8"- 1"	1/8"	3/16"- 1/4"	3/8"- 1"
Mechanical (Minimum Ultimate)											
Tensile Stress, LW	D638	psi	30,000	30,000	100,000	20,000	20,000	20,000	20,000	20,000	20,000
Tensile Stress, CW	D638	psi	7,000	7,000		7,500	10,000	10,000	7,500	10,000	10,000
Tensile Modulus, LW	D638	10(6)psi	2.5	2.6	6.0	1.8	1.8	1.8	1.8	1.8	1.8
Tensile Modulus, CW	D638	10(6)psi	0.8	0.8		0.7	0.9	1.4	1.0	1.0	1.4
Compressive Stress, LW	D695	psi	30,000	30,000	60,000	24,000	24,000	24,000	24,000	24,000	24,000
Compressive Stress, CW	D695	psi	15,000	16,000		15,500	16,500	20,000	16,500	17,500	20,000
Compressive Modulus, LW	D695	10(6)psi	2.5	2.6		1.8	1.8	1.8	1.8	1.8	1.8
Compressive Modulus, CW	D695	10(6)psi	1.0	1.0		1.0	1.0	1.0	1.0	1.0	1.0
Flexural Stress, LW	D790	psi	30,000	30,000	100,000	35,000	35,000	30,000	35,000	35,000	30,000
Flexural Stress, CW	D790	psi	10,000	10,000		13,000	15,000	18,000	13,000	15,000	18,000
Flexural Modulus, LW	D790	10(6)psi	1.8	2.2	6.0	1.8	2.0	2.0	1.8	2.0	2.0
Flexural Modulus, CW	D790	10(6)psi	0.8	0.8		0.9	1.1	1.4	1.0	1.1	1.4
Modulus of Elasticity, E	full section	10(6)psi	2.6	2.8							
Modulus of Elasticity, E											
W & I Shapes > 4"	full section	10(6)psi	2.5	2.5							
Compressive Shear											
Stress, LW (notches											
parallel to reinforcing)	D3846	psi	3,000	3,000							
Shear Modulus, LW	full section	10(6) psi	0.425	0.425							
Short Beam Shear, LW	D2344	psi	4,500	4,500	8,000						
Bearing Stress, LW	D953	psi	30,000	30,000		32,000	32,000	32,000	32,000	32,000	32,000
Bearing Stress, CW	D953	psi	30,000	30,000		32,000	32,000	32,000	32,000	32,000	32,000
Poisson's Ration, LW	D3039	in/in	0.33	0.33		0.31	0.31	0.31	0.31	0.31	0.31
Notched Izod Impact, LW	D256	ft-lbs/in	25	25	40	18.5	20	20	18.5	20	20
Notched Izod Impact, CW	D256	ft-lbs/in	4	4		5	5	5	5	5	5
Physical											
Barcol Hardness	D2583		45	45	50	40	40	40	40	40	40
24 HR Water Absorption	D570	% Max. by wt	0.60	0.60	0.25	0.60	0.60	0.60	0.60	0.60	0.60
Density	D792	lbs/in3	.062-.070	.062-.070	.072-.076	.060-.068	.060-.068	.060-.068	.060-.068	.060-.068	.060-.068
Coefficient of Thermal Expansion (Typical) LW	D696	10(-6)in/in/°F Max	4.4	4.4	3.0	4.4	4.4	4.4	4.4	4.4	
Thermal Conductivity	C177	BTU/SF/ Hr/OF/in	4	4							

Table IA
Pultruded Fiberglass Mechanical and Physical Properties – Metric Values

Properties	Test Method	Units/ Value	Polyester Shapes	Vinyl Ester Shapes	Rod & Bar	Polyester Plate			Vinyl Ester plate		
						3.175mm	4.76mm-6.35mm	9.5mm-25.4mm	3.175mm	4.76mm-6.35mm	9.5mm-25.4mm
Mechanical (Minimum Ultimate)											
Tensile Stress, LW	D638	A	206.8	206.8	689	137.9	137.9	137.9	137.9	137.9	137.9
Tensile Stress, CW	D638	A	48.2	48.2		51.7	68.9	68.9	51.7	68.9	68.9
Tensile Modulus, LW	D638	B	17.2	17.9	41.3	12.4	12.4	12.4	12.4	12.4	12.4
Tensile Modulus, CW	D638	B	5.5	5.5		4.8	6.2	9.6	6.9	6.9	9.6
Compressive Stress, LW	D695	A	206.8	206.8	413.6	165.4	165.4	165.4	165.4	165.4	165.4
Compressive Stress, CW	D695	A	103.4	110.3		106.8	113.7	137.9	113.79	120.6	137.9
Compressive Modulus, LW	D695	B	17.2	17.9		12.4	12.4	12.4	12.4	12.4	12.4
Compressive Modulus, CW	D695	B	6.9	6.9		6.9	6.9	6.9	6.9	6.9	6.9
Flexural Stress, LW	D790	A	206.8	206.8	689	241.3	241.3	206.8	241.3	24.3	206.8
Flexural Stress, CW	D790	A	68.9	68.9		89.6	103.4	124.1	89.6	103.4	124.1
Flexural Modulus, LW	D790	B	11.0	11.0	41.9	12.4	13.8	13.8	12.4	13.8	13.8
Flexural Modulus, CW	D790	B	5.5	5.5		6.2	7.6	9.6	6.2	7.6	9.6
Modulus of Elasticity, E	full section	B	17.9	19.3							
Modulus of Elasticity, E W & I Shapes > 4"	full section	B	17.2	17.2							
Compressive Shear Stress, LW (notches parallel to reinforcing)	D3846	A	20.7	20.7							
Shear Modulus, LW	full section	B	2.9	2.9							
Short Beam Shear, LW	D2344	A	31.0	31.0	55.2						
Bearing Stress, LW	D953	A	206.8	206.8		220.6	220.6	220.6	220.6	220.6	220.6
Bearing Stress, CW	D953	A	206.8	206.8		220.6	220.6	220.6	220.6	220.6	220.6
Poisson's Ration, LW	D3039	C	0.33	0.33		0.31	0.31	0.31	0.31	0.31	0.31
Notched Izod Impact, LW	D256	F	1.28	1.28	2.04	0.94	1.02	1.02	0.94	1.02	1.02
Notched Izod Impact, CW	D256	F	0.2	0.2		0.26	0.26	0.26	0.26	0.26	0.26
Physical											
Barcol Hardness	D2583		45	45	50	40	40	40	40	40	40
24 HR Water Absorption	D570	% Max. by wt	0.6	0.6	0.25	0.6	0.6	0.6	0.6	0.6	0.6
Density	D792	E	1.72-1.94	1.72-1.94	1.99-2.10	1.66-1.88	1.66-1.88	1.66-1.88	1.66-1.88	1.66-1.88	1.66-1.88
Coefficient of Thermal	D696										
Expansion		G	8.0	8.0	5.45	14.5	14.5	14.5	14.5	14.5	14.5
Thermal Conductivity	C177	D	0.58	0.58							

UNIT VALUES CODE;

A=N/mm(2) B=KN/mm(2); C=mm/mm; D=W-m/m(2)/C°; E=10(-3)g/mm(3); F=J/mm; G=10(-6)mm/mm/C°

Table 2
Correction Factors - Temperature Effect

Strength Reduction Factors for Temperature - Due to the behavior of composite material strengths in elevated temperature, it is necessary to account for the loss in strength and stability. The resulting loss is related to the resin system used in the construction of the member. The material property retention due to exposure at elevated temperatures varies with different resin systems. The reduction factor and the application methodology used in the structural design of the cooling tower members shall be made available to the cooling tower manufacturer.

If the characteristics of the resin system are unknown then the following correction factors shall be used by the tower manufacturer engineer and applied to both the ultimate stresses and modulus. Resin Systems with higher retention characteristics are available. The associated reduction factors reflect the percentage of strength and modulus of elasticity retained at that temperature. The following tables present these factors for poly and vinyl resin systems. This temperature reduction factor does not account for loss of strength of the composite material due to moisture exposure. (Comparisons were done dry at elevated temperatures)

Table 2.1

APPLICATION CONDITION VS. "AVERAGE" COMPRESSION STRENGTH REDUCTION, ASTM D695		
Temperature, °F/°C	**REDUCTION FACTOR**	
	POLY	**VINYL**
77/25	*1.0*	*1.0*
100/38	*0.85*	*0.90*
125/52	*0.70*	*0.80*
150/66	*0.50*	*0.80*
175/79	*NR*	*0.75*
200/93	*NR*	*0.50*

Table 2.2

APPLICATION CONDITION VS. "AVERAGE" MODULUS OF ELASTICITY REDUCTION, ASTM D638(* also reference modulus of elasticity procedure written for this application)		
Temperature, °F/°C	**REDUCTION FACTOR**	
	POLY	**VINYL**
77/25	*1.0*	*1.0*
100/38	*1.0*	*1.0*
125/52	*.90*	*.95*
150/66	*.85*	*.90*
175/79	*NR*	*.88*
200/93	*NR*	*.85*

The reduction factor is multiplied by the Ultimate Strengths or Modulus of Elasticity prior to applying service factors. Thus, the location of the member within the tower will dictate the exposure (i.e. fill support beams will be exposed to a lower temperature environment than the hot water distribution piping support beams). If the tower is to experience a short-term hot temperature excursion in excess of the design temperature this would be considered a live load condition.

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