InsulWynd®

FILAMENT WOUND TUBES

Electrical • Oil & Gas • Defense • Waste Water

COMPOSITES
Cast. Wind. Press.

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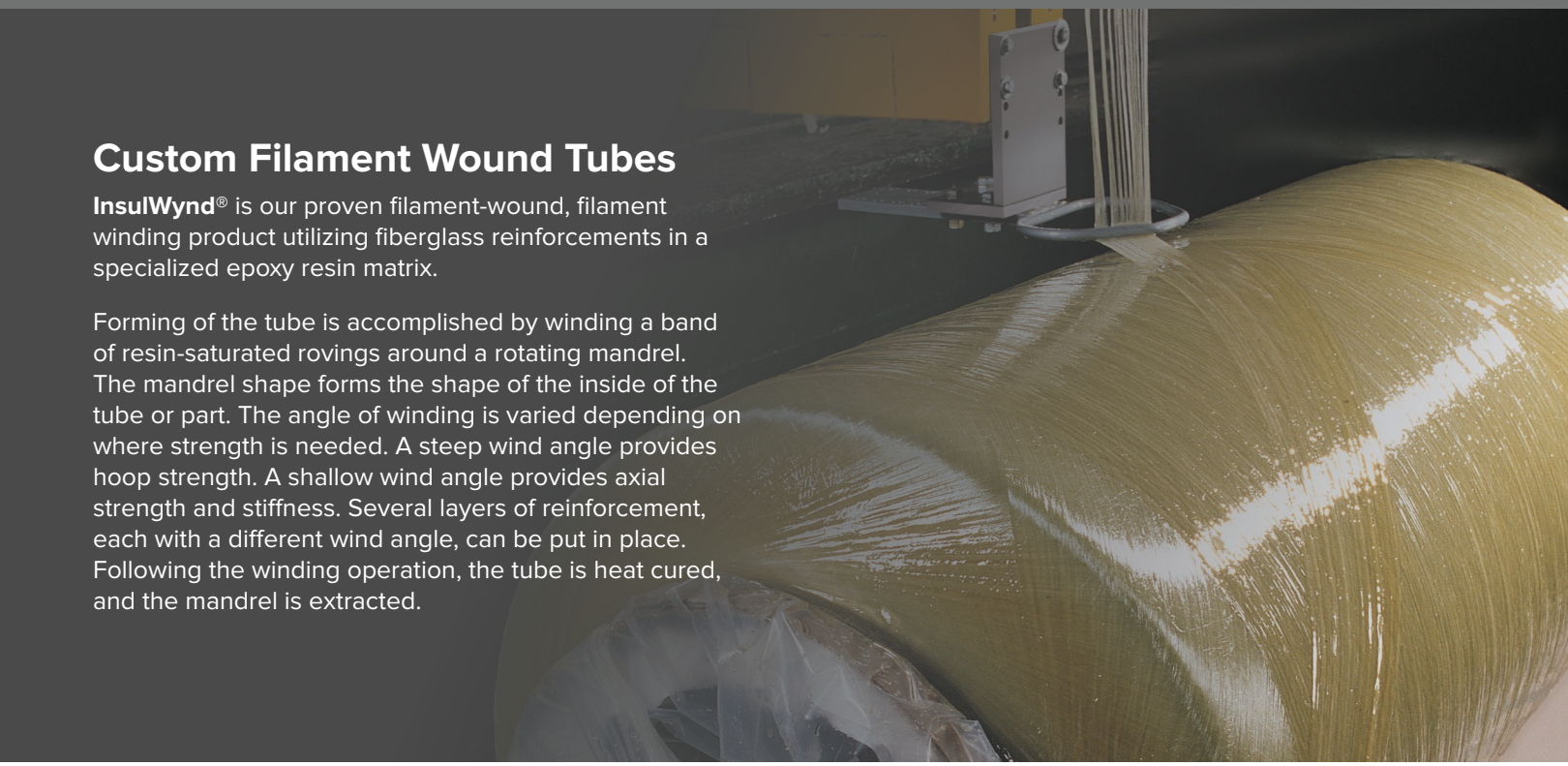
EFFECTIVE PERFORMANCE – EFFICIENTLY



Custom Filament Wound Tubes

InsulWynd® is our proven filament-wound, filament winding product utilizing fiberglass reinforcements in a specialized epoxy resin matrix.

Forming of the tube is accomplished by winding a band of resin-saturated rovings around a rotating mandrel. The mandrel shape forms the shape of the inside of the tube or part. The angle of winding is varied depending on where strength is needed. A steep wind angle provides hoop strength. A shallow wind angle provides axial strength and stiffness. Several layers of reinforcement, each with a different wind angle, can be put in place. Following the winding operation, the tube is heat cured, and the mandrel is extracted.

Product Advantages

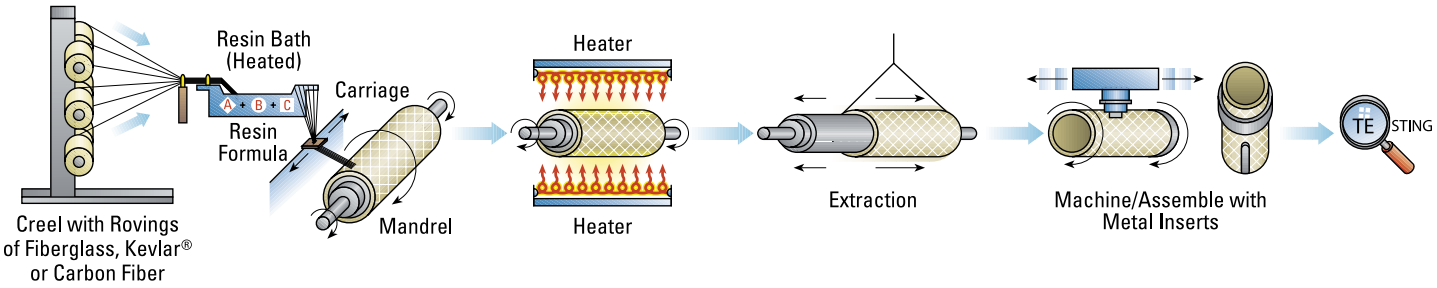
Filament-wound (filament winding) fiberglass tubes and fiberglass tubing provide a very high strength-to-weight ratio, excellent electrical insulation properties and high resistance to corrosion.

- No Yield Point / Elastic Behavior
- Chemical & Corrosion Resistant
- Excellent Insulator
- Machinable to Close Tolerances
- Non-Magnetic
- Cost Effective
- Ultraviolet Radiation Resistant
- Extreme Temperature Tolerances
- Flammability Ratins of 94-5VA and 94-VO
- Impact & Shatter Resistant
- Controlled Electrical Properties

Common Areas of Application

- MRI Tunnels
- Pressure Vessels
- Tubes & Drive Shafts
- Battery Shields
- Oil Circuit Breaker
- Interrupter tubes
- Insulator Tubes
- Reinforcement Boards
- Closed End Tubing
- Railgun Tubing
- Submarine Radome Housing
- Cryogenic Medical Composite Tubes
- Potable Water
- Medical Waste Treatment
- Highly Corrosive Environments
- Industrial, Aerospace and Military Products

Filament-Winding Process



Filament Reinforcements

Glass filaments are the most frequently used reinforcements, although aramid, graphite, boron and specially compounded materials are becoming more common to the production floor as proven reinforcements in specialized applications.

Unlike metals, glass reinforcements have no yield point. The exhibit perfectly elastic behavior from no-load to rupture and they do not creep under stress. See Table I for a comparison of properties of glass vs. steel.

Resin Systems

Both epoxy and polyester thermosetting resins have achieved commercial success in filament wound products. Often, the special needs of each product can be met with several resin systems and fillers. Engineers will balance these systems to achieve the most effective performance/ cost ratio. The most important functions of the resin systems are to:

- position the load bearing filaments
- distribute the load evenly among filaments
- protect filaments from abrasion
- control electrical and chemical resistance properties
- provide interlaminar shear strength

Mechanical Properties

Reinforcement/ resin ratios, winding tension and winding patterns affect mechanical properties of the finished product as summarized in Table II. Circumferential hoop windings and more longitudinal (helix) windings at predetermined wind angles give directions strength as required for each design. Figure 1. And Figure 2. show the relative effect of wind angle on modules of elasticity. High directional stiffness, (high modules of elasticity) is a achieved at wind angles approaching both zero and ninety degrees.

Process/products efficiency is reflected in thin wall sections. Compared to 7075 T6 Aluminum, a glass reinforced filament wound 6" I.D. tube with a 3000 psi maximum rating, weighs half as much and has a 38% thinner wall section. For internal pressure vessels this comparison yields a 214% improvement in efficiency based upon the ratio of pressure x volume per weight of material (i.e. PV/Wt).

Comparisons of structural efficiency may be shown by relative load carrying ability per unit weight of material. Table III illustrates the high strength, lightweight advantage of filament wound composites.

These mechanical characteristics are based upon values obtained in a 50-300° F operating range. For higher temperatures the strength is reduced, for low temperatures, the strength is increased. The resin system is the limiting factor at high temperatures since glass retains its strength up to 1000° F. Special resin systems are available to allow operation at temperature in excess of 500° F. In reported cases, strengths at –424°F were 150% of strengths at 70°F, without brittle failure.

Machinability: Filament wound components are machinable to close tolerances. Coolants and exhaust ventilation are required for dust control and to help minimize equipment wear.

Weather Resistance: High molecular weight thermostat resins in filament wound components offer excellent resistance to ultraviolet radiation, temperature extremes and moisture. Discoloration, erosion or fiber prominence are minimal on "as wound" surfaces. UV stabilizer additives and special coatings for machined surfaces help to extend product life in sever environments.

Electrical Properties

Both resin and glass are excellent insulators and are nonmagnetic. They will not interfere with radar or radio frequency signals. Under special circumstances these characteristics may be adjusted with conductive filaments, wound-in reflective shielding, or surface metalizing. Basic electrical properties are shown in Table IV.

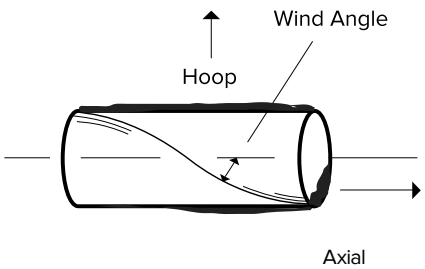


fig. 1

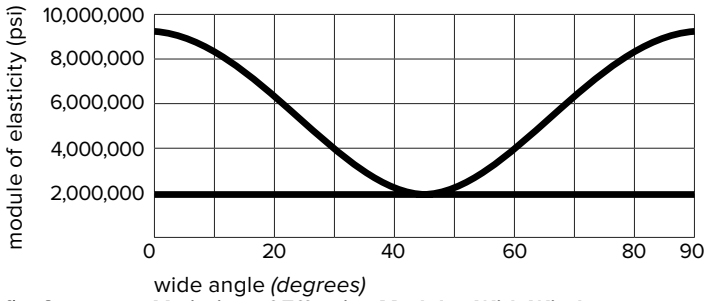


fig. 2 **Variation of Effective Modulus With Wind**

Chemical Resistance Properties

With few exceptions, filament wound materials are more resistant to chemical corrosion or wearing than stainless steel, monel or titanium. Sample or prototype testing is always recommended to verify compatibility in a given environment. Resistance to a wide variety of chemical environments can be achieves by proper choice of resin and reinforcements.

Physical Properties

(Glass Reinforced)

Glass (% by wt.)	Density (lb./in^3)
60	.062
70	.068
80	.074
90	.082
Typical 75-85	.072

- Density *(chart to right)*
- **Thermal Conductivity:** 1.92 to 2.20 BTU/hr./in/ft.2/ °F (6.6×10^{-4} to 7.6×10^{-4} cal/cm^2/cm/°C/sec).
- **Thermal Coefficient of Linear Expansion:** 5-6 x 10^{-6} in/in/°F (9 x 10^{-6} to 10.8 x 10^{-6} cm/cm/°C).
- Surface finish inside is governed by the finish quality of the mandrel care during extraction.
- Surface finish outside ranges from irregular as wound to very smooth ground surfaces.
- Special surfaces are available to meet needs for low friction or special protection.
- **Hardness:** Barcol 40-75.

Design Considerations

Deflection (stiffness) may be increased or decreased in filament winding by changing the winding pattern. Homogeneous Materials (non-fibrous) are only capable of changing this property by increasing or decreasing the cross section.

Frangible joints. CK can offer a system of controlled force breakaway joints in filament would light towers. This technology is applicable to other products which require controlled force breakage.

Inter-laminar shear stress. In good design practice, the reinforcements filaments carry all static and dynamic loading without transferring appreciable stress to the resin system. “Integral Winding” technique provides high shear strength.

Liners, coatings and inserts. Some applications require properties that cannot be achieved with filament winding alone. In these cases materials that will perform properly are added either inside or outside as liners or coatings. Inserts are frequently used to overcome fastening problems.

Common shapes. Sections of revolution such as round, square, rectangular, oval, teardrop or any convex shape can readily be wound. Concave or intersecting surface are difficult and should be avoided for filament winding.

Size. Finished products up to forty feet in length and forty-eight inches in diameter are within our present capability. Sometimes it is possible to manufacture larger sizes.

Cost/performance. Tooling complexity and tight tolerances add to the overall cost of any design. By combining mechanical functions or assemblies into a single filament wound component, cost/performance benefits can be achieved. Greater use of filament winding properties will yield better performance at lower cost over other materials and precesses. Tables V and VI summarize property utilizations and cost of typical filament wound products.

Product Consistency

Process integrity and part to part uniformity are assured by computer controlled winding equipment, a high capacity profile sander, a wide range of cutting and machining equipment, and most importantly by skilled craftsmen who are proud of their work.

Quality assurance and testing standards are an integral part of out manufacturing procedures. Complete documentation and government certification requirements are routine.

Table I Properties of High Strength Glass Filament Vs. High Strength Steel Filaments

Grade or Type	Composition	Youngs Modulus (psi)	Tensile Strength (psi)	Density (lbs./in^3)	Specific Tensile Strength (in.) (ten. str./density)
E	Calcium Alumina Borosilicate	10.7 x 10^6	450,000	.092	4,900,000
S	Magnesia Alumina Silicate	12.4 x 10^6	650,000	.090	7,220,000
Music Wire	Drawn Carbon Steel .004”	29.0 x 10^6	590,000 Ult. 500,00 Yield	.283	2,300,000

Table II Mechanical Properties of Filament Wound Products (Glass Reinforced)

Property	Typical Values	Predominant Process Variables*
Modulus of Elasticity (Tension)	3,000,000 - 6,000,000 psi	Glass Type, Wind Pattern
Tensile Strength: Helical Windings	50,000 - 150,000 psi	Glass Type, Glass/Resin Ratio, Wind Pattern
Compressive Strength: Helical Windings	40,000 - 80,000 psi	Glass/Resin Ration, Resin Type, Wind Pattern
Shear Strength: Inter-laminar Cross	 3,000 - 20,000 psi 8,000 - 30,000 psi	Resin Type, Wind Pattern, Glass/Resin Ratio, Resin Type
Modulus of Rigidity (Torsion)	1,600,000 - 2,000,000 psi	Wind Pattern
Flexural Strength	50,000 - 75,000 psi	Wind Pattern, Glass/Resin Ratio
Bearing Strength	2,000 - 35,000 psi	Glass/Resin Ratio
Density	.068 - .082 lb./in^3	Glass/Resin Ratio

Table III Comparative Strength to Weight Ratios (Specific Strength)

Material	Density (lb./in^3)	Tensile Strength (psi)	Tensile Modulus (10^6 psi)	Specific Tensile Strength (in.)
Filament Winding (Glass Reinforced)	0.072	150,000	4.5	2,080,000
Aluminum 7075-T6	0.10	82,000	10.3	820,000
Stainless Steel 301 Full Hard	0.29	185,000	29.0	637,000
Titanium Alloy Ti-13 V-12 Cr-3 Al	0.165	185,000	16.0	1,120,000

Table IV Electrical Properties

Typical Electrical Properties of FRWP Tubes	
Dielectric Constant (ASTM Test D 150-64T)	60 cps 4.7 1 Mc 4.5
Power Factor (ASTM Test D 150-64T)	60 cps .85% 1 Mc .0135-.0170
Insulation Resistance (ASTM Test D 257-61)	10^8 meg ohms
Arc Resistance (ASTM Test D 495-61)	150-180 sec.
Dielectric Strength (ASTM Test D 149-61) Step-by-step, perpendicular Short time perpendicular	 350-420 v/mil 400-550 v/mil
Loss Tan. (ASTM Test D 150-64T)	.018

Table V Product Value Improvement Analysis

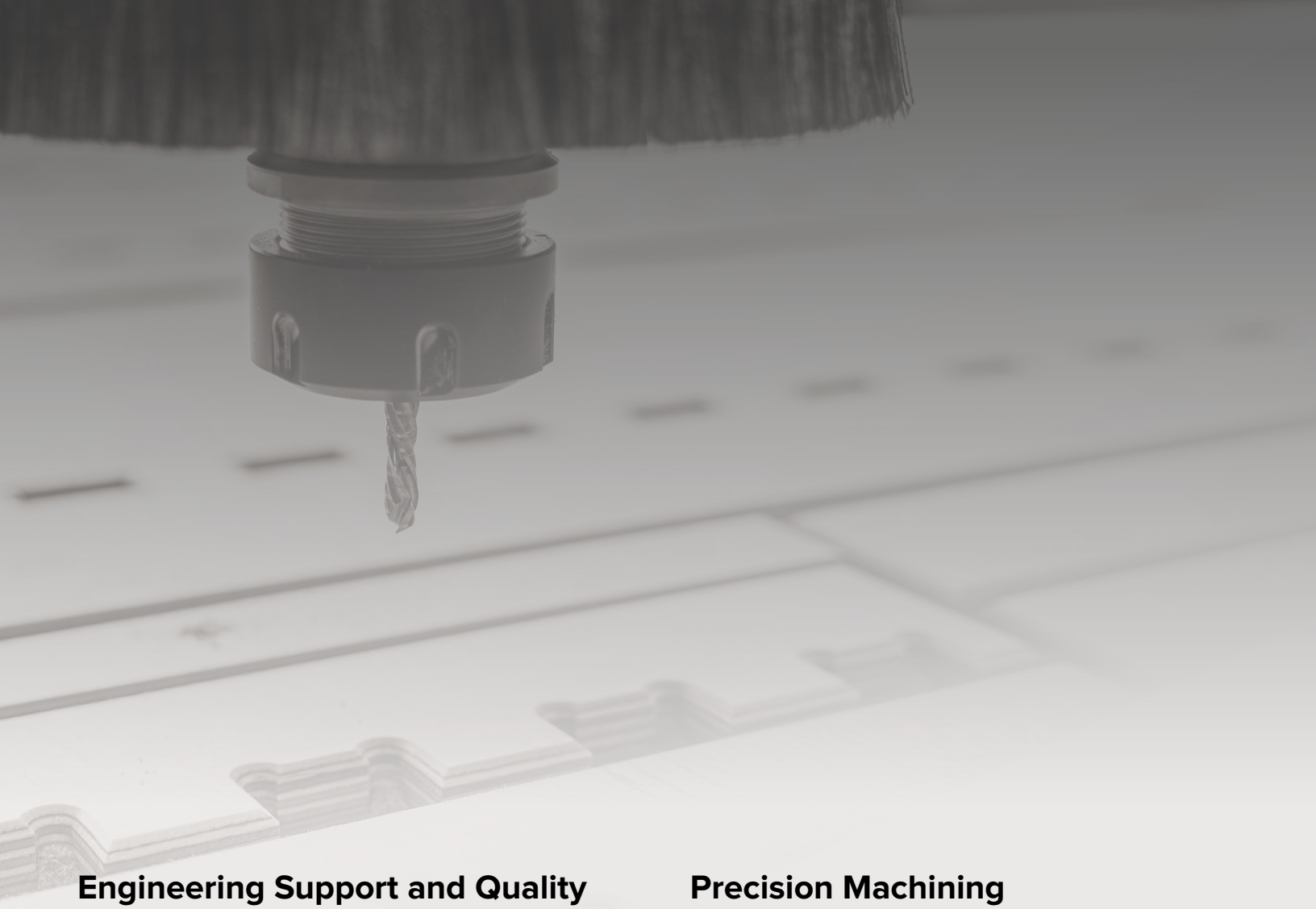
Application	Utilized Properties*	Previous Design
Rocket Motor Case	1, 2, 3, 7, 8	Welded Steel
Chemical Storage Tanks	3, 4, 7, 9	Coated Steel
Radomes	1, 3, 4, 5, 6, 8	Glass Cloth-Reinforced Plastics
Torpedo Battery Housing	1, 3, 4, 5, 7, 9	—
Rocket Launcher Tube	1, 3, 4, 7	Aluminum
Electrical Arc Interrupter Tube	1, 3, 5, 6, 9	Paper-Based Phenolic
Railway Tank Car	3, 4, 7, 8, 9	Steel
Chemical Pipe	3, 4, 7, 8, 9	Coated Steel or Stainless Steel
Truck Mounted Booms	1, 3, 4, 5, 7, 8	—

*Key to Properties

1. High strength to weight ratio
2. Directional strength
3. Low density
4. Corrosion resistance
5. Excellent electrical properties
6. Low dielectric loss
7. Impact and shatter resistance
8. Good reproducibility
9. Chemical resistance
10. Low thermal conductivity

Table VI Relative Costs

Part	Engineering & Development Costs	Quantity	Mandrel Cost
Pipes	Low	Large	Low
Tubes, Electrical Grade	Moderate	Large	Moderate
Pressure Vessels	Moderate-High	Small	Moderate
Rocket Motor Cases	High	Small	High



Engineering Support and Quality

Because components and products we manufacture usually perform a critical function, CK Composites has strong technical capabilities and quality assurance procedures. Our staff includes several individuals with a background and work experience in electrical, mechanical and chemical engineering as well as skilled production technicians, programmers and machinists. With these resources, we are able to offer assistance to customers in the areas of material development, product design and manufacturing, quality test development, and technical problem solving.

Customer satisfaction is CK Composites' number one priority and we have a stringent Quality Assurance program in place to ensure the performance requirements of our materials and services used in the industry are exceeded on a routine basis. Quality assurance procedures include testing and inspection of incoming raw materials, in-process inspection and both destructive and non-destructive material testing. Specific electrical, mechanical, and hydrostatic testing is performed on the completed products to customer specifications. We pride ourselves on the quality of our products.

Precision Machining

Not only can CK Composites develop and engineer materials with the desired properties in the customer's applications, we can provide finished parts or assemblies as well. We have a complete machine shop with precision milling, routing, turning and assembly capabilities. We employ both manual and CNC equipment to ensure we efficiently produce parts with the proper fit and finish required. To complete our offering to the industry, we can paint or varnish the parts if desired. We can help design the parts or manufacture them to specific designs our customers provide.

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