

SPECIALTY MATERIALS, INC.

Manufacturers of Boron and SCS Silicon Carbide Fibers and Boron Nanopowder

Hy-Bor[®] Materials for Structural Applications

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Presentation Outline

- Hy-Bor[®] Explained
- Designing with Hy-Bor[®]
- Three Potential Hy-Bor[®] Products
- Design Examples
- Summary

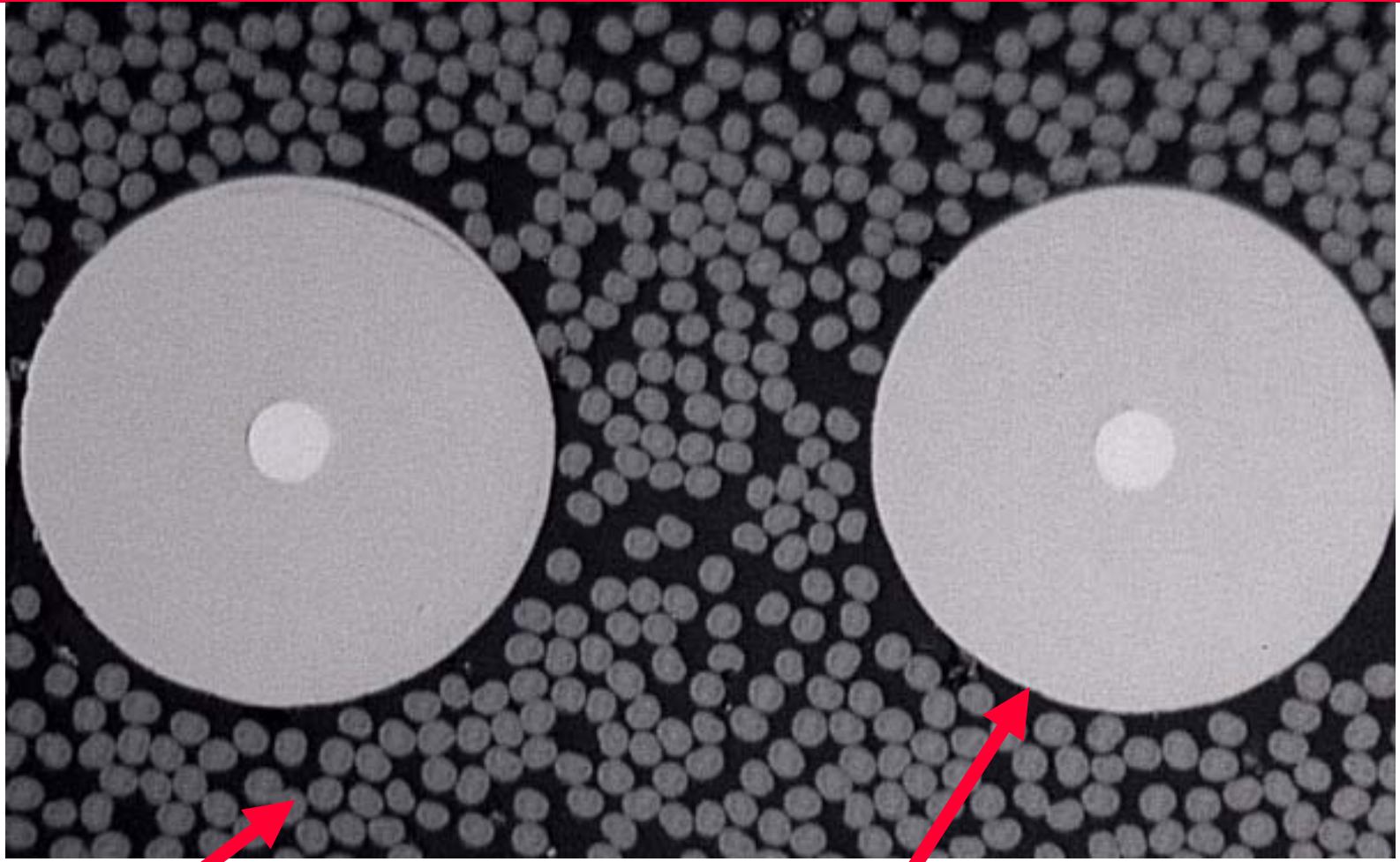
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Understanding Hy-Bor®

- Hy-Bor® is a mixture of Boron and Graphite Fibers commingled as a single ply
- Individually, each material is strain limited by the fiber properties
- Commingled, each fiber contributes and shares load according to micromechanic principles
- Graphite fiber improves Boron fiber microbuckling stability

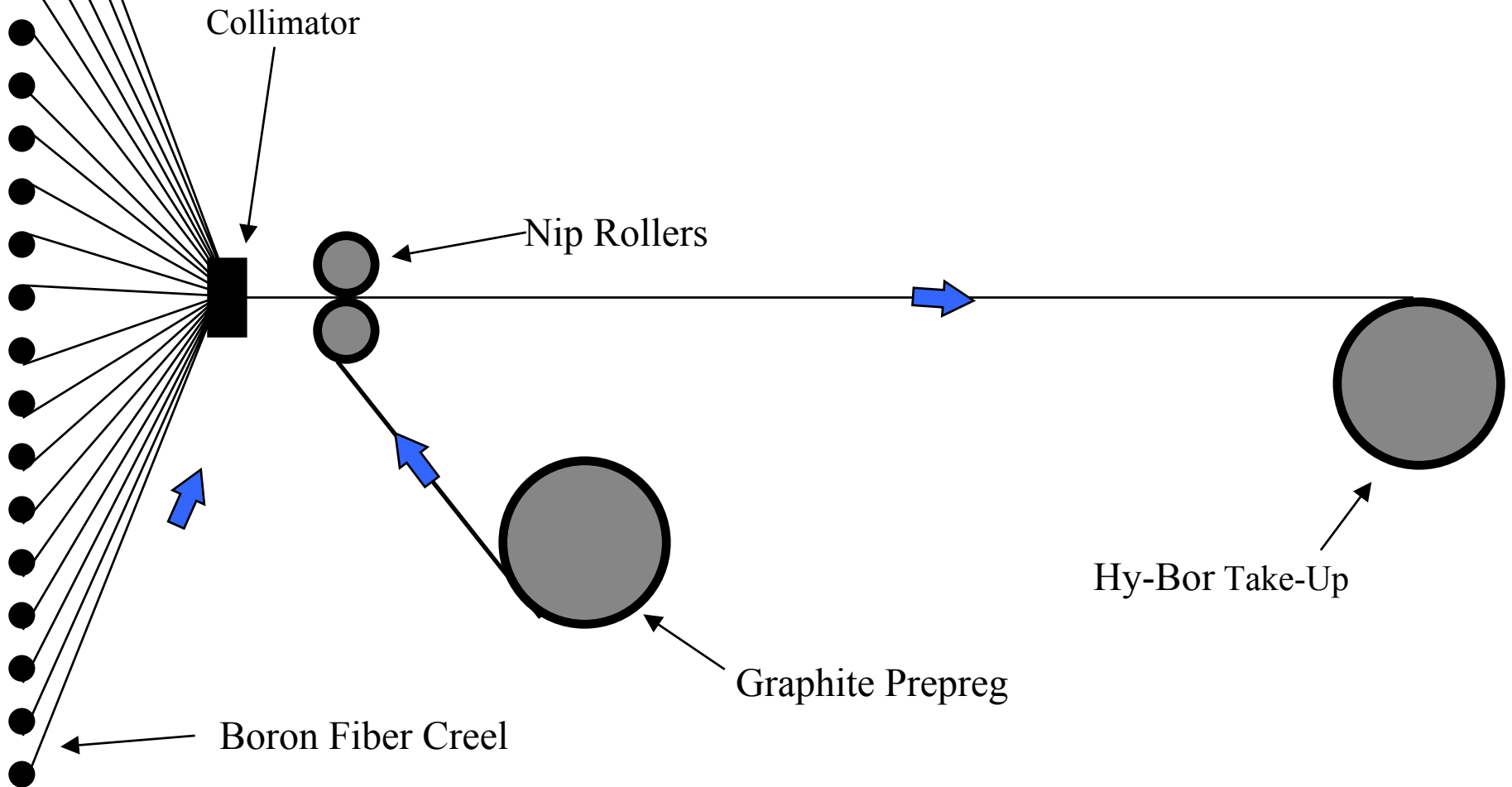
Hy-Bor[®] Cross-Section



Graphite Fiber - 0.0005" dia.

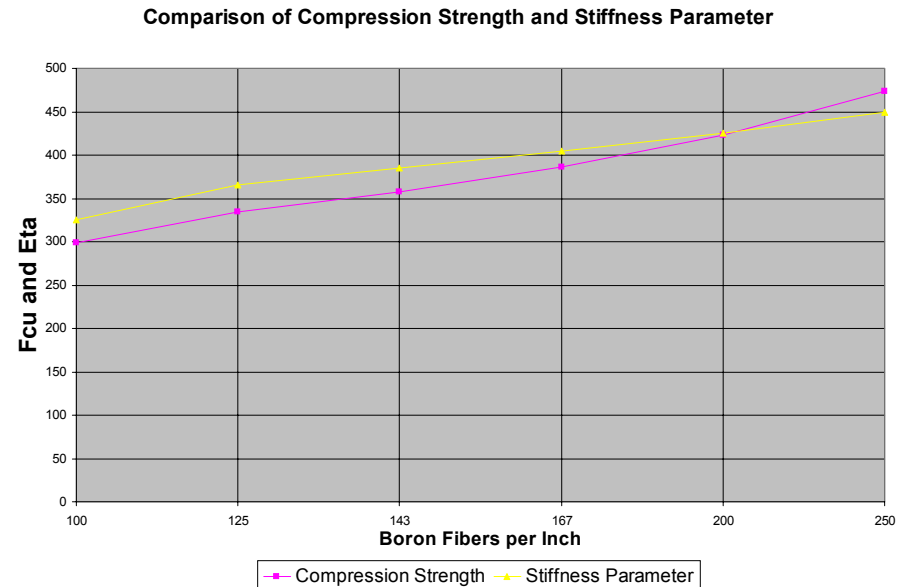
Boron Fiber - 0.004" dia.

Hy-Bor[®] Manufacturing Process



Compression Strength of Hy-Bor[®]

- Compression Strength of Hy-Bor[®] directly relates to Shear Modulus*
- Increasing Boron fiber count increases Fcu towards theoretical 600 ksi limit



* “The Influence of Local Failure Modes on the Compressive Strength of Boron/Epoxy Composites”, ASTM STP 497, J.A. Suarez, J.B. Whiteside & R.N. Hadcock, 1972

“Influence of Boron Fiber Count on Compressive and Shear Properties of HyBor”, Alliant Techsystems, J.W. Gillespie, 1986

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Benefits of Hy-Bor[®]

- Provides the Maximum Compression Strength of any continuous filament-based composite material
- Tailored to meet specific materials properties and design objectives (Graphite fiber type and Boron fiber ratio)
- Prepregged to customer resin preferences
- Analytically treated as another lamina within a laminate stack per Classical Lamination Theory
- Can be mixed with carbon plies or it can be the total laminate

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Balanced Strength Laminate Design

- Typically, all graphite unidirectional lamina are compression strength limited
- High tension strength is unavailable when cyclic loads and stress limit the strength to the compression strength allowable
- Graphite fiber + Boron fiber are matched to yield improved balance between tension and compression strength and modulus
- Increased strength efficiency translates to weight and cost savings

Potential Hy-Bor[®] Products

- Maximum Strength Hy-Bor[®]
 - T800H Graphite + 200 filaments per inch Boron
- High Stiffness Hy-Bor[®]
 - M55J Graphite + 175 filaments per inch Boron
- High Thermal Conductivity Hy-Bor[®]
 - K13D Graphite + 150 filaments per inch Boron

Maximum Strength Hy-Bor[®] Design Properties (T800H/Boron)

<u>Property</u>	<u>Expected Ave. Test Value</u>	<u>Pseudo-B Basis</u>
E-11	32.2 E6 psi	29.6 E6 psi
E-22	1.75 E6 psi	1.61 E6 psi
v-12	0.25	0.25
G-12	.95 E6 psi	.87 E6 psi
ϵ 11-tension	.00932 in/in	.00746 in/in
ϵ 22-tension	.00526 in/in	.00421 in/in
ϵ 11- compression	.02000 in/in	.00864 in/in
ϵ 22-compression	.01285 in/in	.01028 in/in
ϵ 12-shear	.01026 in/in	.00923 in/in
α 11	1.80 ppm/F	same
α 22	16.5 ppm/F	same

Properties determined by Micro-Mechanics analysis. To be verified by test

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Maximum Strength Hy-Bor[®] Applications

- Aircraft
 - Wing, Fuselage, Empennage
- Spacecraft
 - Launch Adapters, Struts, Deployment Booms
- Engines
 - Casings, Blades, Components
- Commercial
 - Golf Shafts, Repair Patches, Tennis Rackets, Bicycles

Design Example #1 - Struts and Tubes

- Hybrid of Maximum Strength
Hy-Bor® with M55J
- $[\pm\pm 21/0_2/\pm\pm 21/0_2/\pm 21/0/0_2/0]_S$
- Hy-Bor® = 0_2 6 plies
- M55J = ± 21 & 0 12 plies

- Axial Modulus 30.7 msi
- Tension Strength 100 ksi
- Compression Strength 95 ksi
- CTE .02 ppm/F



High Stiffness Hy-Bor[®] Design Properties (M55J/Boron)

<u>Property</u>	<u>Expected Ave. Test Value</u>	<u>Pseudo-B Basis</u>
E-11	39.6 E6 psi	36.5 E6 psi
E-22	2.00 E6 psi	1.90 E6 psi
ν -12	0.25	0.25
G-12	.95 E6 psi	.87 E6 psi
ϵ 11-tension	.00677 in/in	.00542 in/in
ϵ 22-tension	.00420 in/in	.00340 in/in
ϵ 11-compression	.01300 in/in	.00542 in/in
ϵ 22-compression	.01125 in/in	.00956 in/in
ϵ 12-shear	.01026 in/in	.00923 in/in
α 11	1.05 ppm/F	same
α 22	16.5 ppm/F	same

Properties determined by Micro-Mechanics analysis. To be verified by test.

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High Stiffness Hy-Bor[®] (B-M55J/RS-42)

PROPERTY	PREDICTED 175 fpi Boron	ACTUAL 167 fpi Boron
Elastic Modulus	39.6 MSI	41.6 MSI
Tensile Strength	268 KSI	256 KSI
Shear Strength	9.7 KSI	9.6 KSI

Historical Compression Strength Testing

Material	Testing Facility	Test Method	Compression Strength
B/5521	Delsen (8/02)	ASTM D695	380 KSI
Hy-Bor IM-7/3501	Delsen (12/95)	Bell Test Method	414 KSI
Hy-Bor MR40/NCT-301	U of DL (8/96)	IITRI	398 KSI
B/5521	Boeing (3/96)	ASTM D695	427-463 KSI (4 batches)

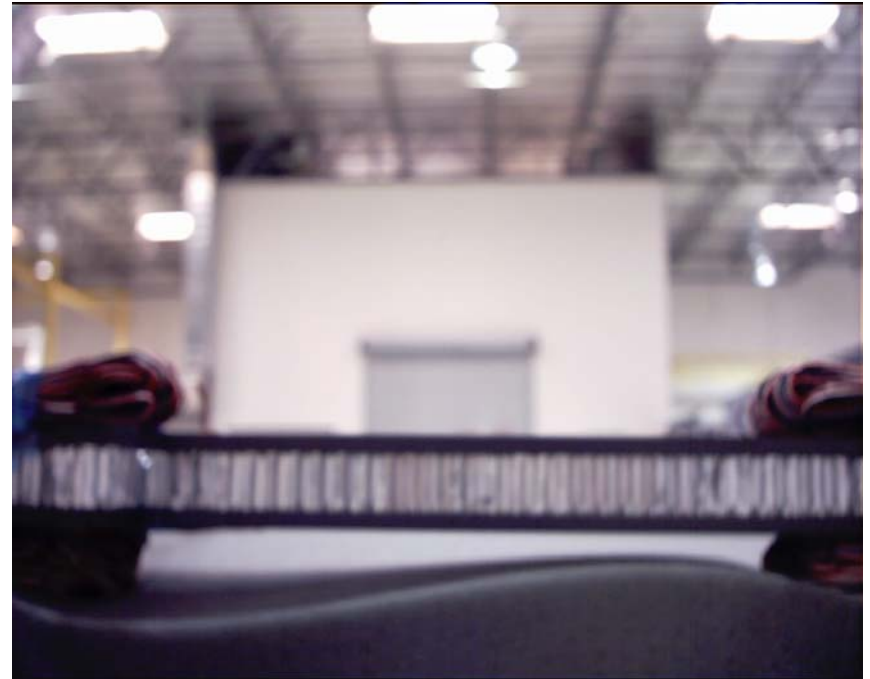
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High Stiffness Hy-Bor[®] Applications

- Aircraft
 - Flutter Critical Designs, Spar Caps, Stiffeners
- Spacecraft
 - Solar Arrays, Tank Struts, Low CTE Structure
- Engines
 - Fan Blades, Casings, Struts
- Commercial
 - Fishing Rods, Windmill Blades, Racing Yacht Mast

Design Example #2 - Aircraft Wing Skin Stiffener

- Hybrid of High Stiffness Hy-Bor® + M55J
- $[\pm 45/0_4/\pm 45/90/\pm 45/0_4/\pm 45]_N$
- HyBor = 0_4 8 plies
- M55J = $\pm 45, 90$ 9 plies
- Axial Modulus 21 msi
- Shear Modulus 6.3 msi
- Tension Strength 89 ksi
- Compression Strength 98 ksi
- CTE .28 ppm/F



High Thermal Conductivity Hy-Bor[®] Design Properties

<u>Property</u>	<u>Expected Ave. Test Value</u>	<u>Pseudo-B Basis</u>
E-11	55.4 E6 psi	51.0 E6 psi
E-22	2.20 E6 psi	2.00 E6 psi
v-12	0.25	0.25
G-12	1.5 E6 psi	1.3 E6 psi
ε 11-tension	.00487 in/in	.00389 in/in
ε 22-tension	.00359 in/in	.00305 in/in
ε 11-compression	.00960 in/in	.00389 in/in
ε 22-compression	.00955 in/in	.00811 in/in
ε 12-shear	.00520 in/in	.00425 in/in
α 11	.24 ppm/F	same
α 22	16.5 ppm/F	same
k 11	250 W/m-K	same
k 22	5 W/mK	same

Properties determined by Micro-Mechanics analysis. To be verified by test.

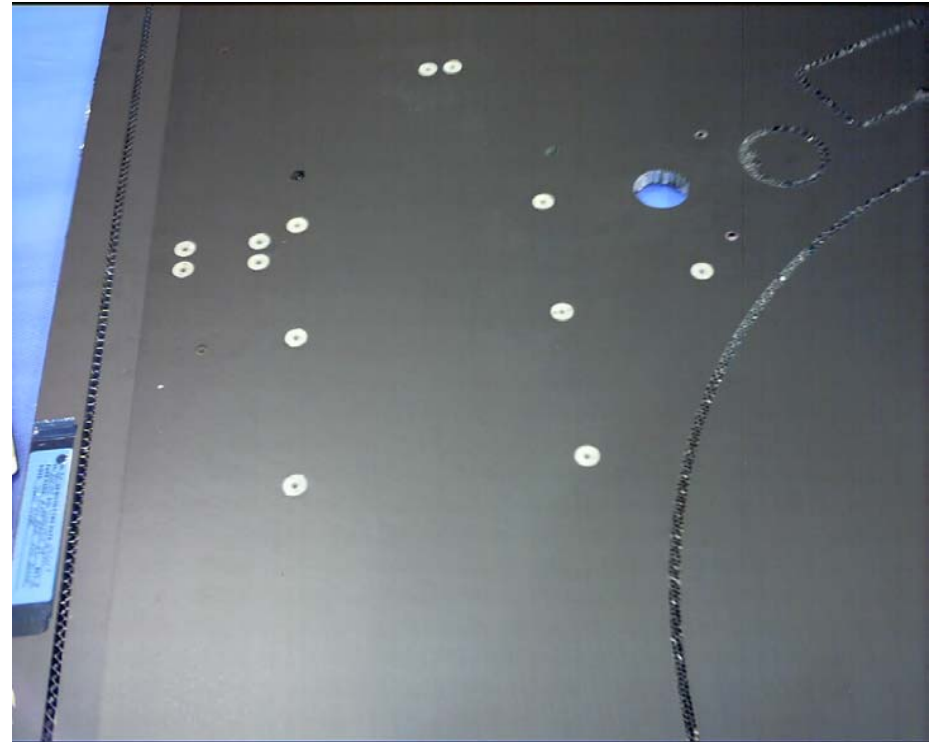
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High Thermal Conductivity Hy-Bor[®] Applications

- Any situation where high strength, high stiffness, low CTE and high thermal conductivity are design drivers
- Optical Benches, Optical Support Structure, Metering Truss
- Transponder Equipment Panels
- Scientific Apparatus, High Energy Test Structure
- Energy Production Equipment

Design Example #3 - Optical Bench

- All High Thermal Conductivity Hy-Bor®
- [0/45/90/-45]_s
- Aluminum Honeycomb for facesheet-to-facesheet thermal coupling
- Quasi-Isotropic Characteristics
 - Strength 71 ksi
 - Modulus 18.7 msi
 - CTE .50 ppm/F
 - Conductivity 125 W/m-K



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Summary

- Commingling Graphite and Boron fibers into a single lamina provides a synergistic blend of properties unavailable from any other source
- Hy-Bor[®] offers a broader range of properties than Graphite prepreg to meet challenging requirements
- Your qualified resin system can be employed on all Hy-Bor[®] products
- Specialty Materials can provide you with data and sample material for seamless integration into your product line