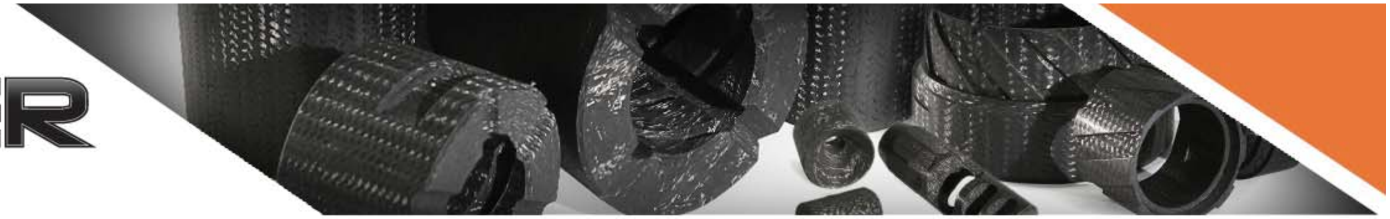
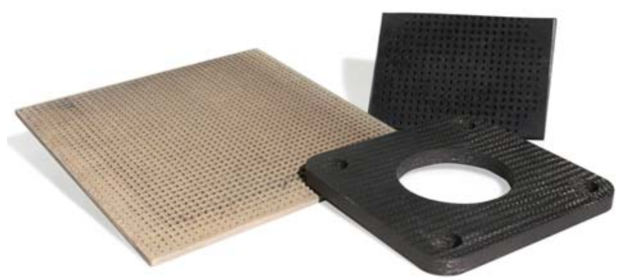


CeraComp®
Ceramic Matrix Composites

Why CMCs

- Suitable for use in extreme operating temperature environments (→ $600^{o}C$)
- Lightweight (density ≈ 2.0 g/cm3)
- Chemically resistant
- Thermally insulative
- Tailorable thermal/mechanical properties
- Improved structural integrity and fracture resistance compared to monolithic ceramics



Components of CMCs

- Pre-ceramic polymer
- Fillers
- Reinforcing fibers

} Slurry

Filler

Carbon fiber

Polymer

+

Slurry

Ceramic fiber

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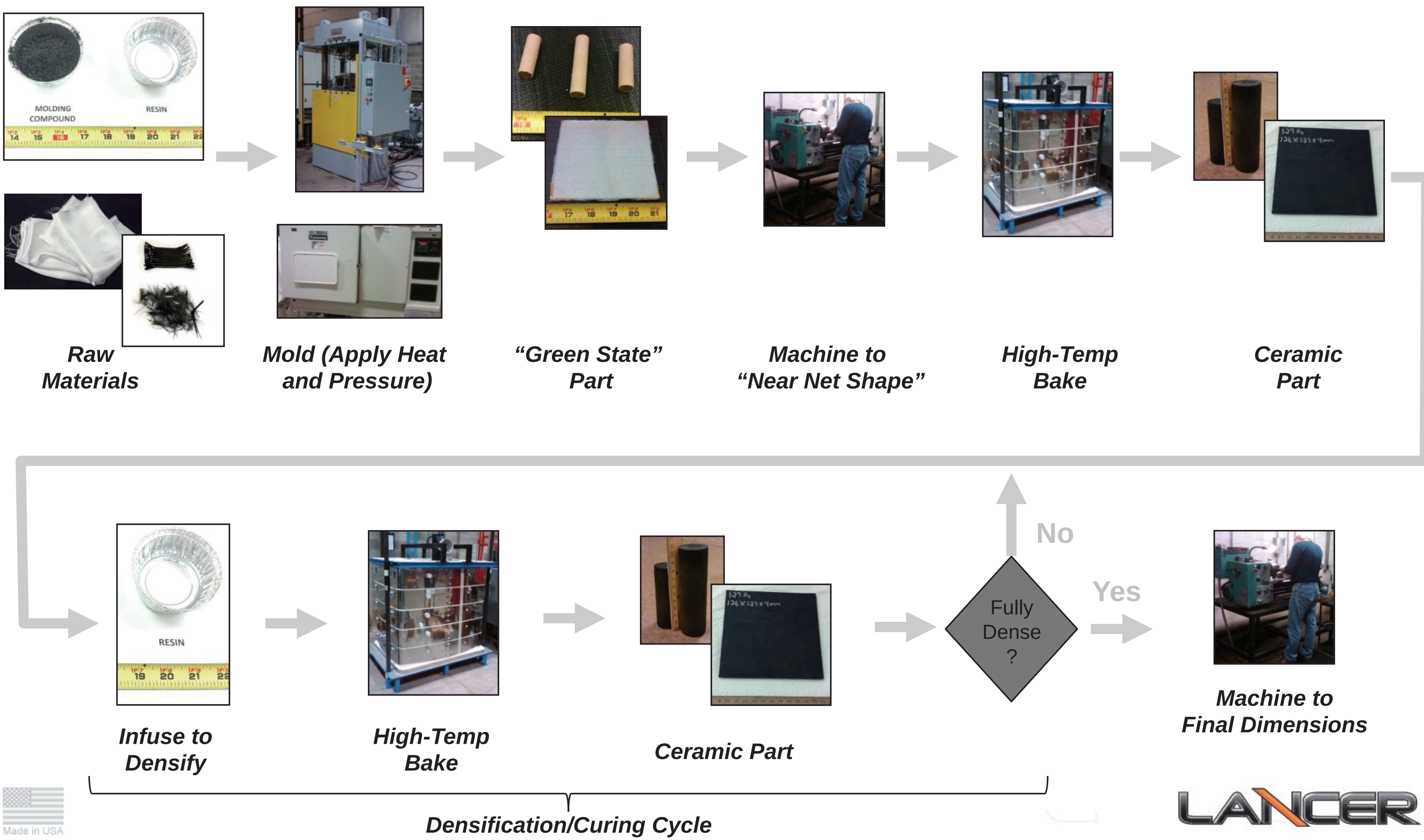
Ceramic Matrix Composites - PIP process



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Lancer CMC Materials

- CeraComp® 1100
  - SiOC matrix with continuous carbon fiber
  - Currently being characterized by Lancer

+

CeraComp® 1100

- CeraComp® 1102
  - SiOC matrix with chopped carbon fiber
  - Currently being characterized by Lancer

+

CeraComp® 1102

- CeraComp® 1201
  - SiOC matrix with continuous ceramic fiber
  - Similar to Blackglas™ (Honeywell)
  - Fully characterized by U.S. Government*

+

CeraComp® 1201

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*Source: Handbook of Ceramic Composites, Chapter 15, "Nextel 312/Silicon Oxycarbide Ceramic Composites", Stephen T. Gonczy & John G. Sikonia

CMC Typical Properties

PROPERTIES	UNITS	CeraComp® 1100
DENSITY	g/cm^3	2.00
MAX SERVICE TEMPERATURE	ºC	600
ULTIMATE TENSILE STRENGTH	MPa	245
STRAIN AT FAILURE	%	0.34
ELASTIC MODULUS	GPa	79.8
POISSON'S RATIO		0.51
FLEX STRENGTH (4 PT BEND)	MPa	267
FLEX STRENGTH (3 PT FLEXURE)	MPa	208.5
IZOD IMPACT STRENGTH	kJ/m^2	213,000
THERMAL CONDUCTIVITY - RADIAL	W/mK	2.7
THERMAL CONDUCTIVITY - AXIAL	W/mK	8.1

Note: Properties reflect typical properties. Actual properties will be dependent upon processing techniques, sample preparation, and test methods.

Coefficient of Thermal Expansion

CeraComp® 1100	CTE (RT to 100ºC)	CTE (RT to 200ºC)	CTE (RT to 300ºC)	CTE (RT to 400ºC)	Ave
OD	0.20	0.30	0.50	0.70	0.43
ID	-1.17	-0.97	-0.80	-0.57	-0.88
Length	0.63	0.47	0.60	0.77	0.62

CeraComp® 1102	CTE (RT to 100ºC)	CTE (RT to 200ºC)	CTE (RT to 300ºC)	CTE (RT to 400ºC)	Ave
OD	0.50	0.73	0.90	1.07	0.80
ID	-0.63	-0.43	-0.20	-0.07	-0.33
Length	2.93	2.90	3.07	3.47	3.09

CeraComp® 1201	CTE (RT to 100ºC)	CTE (RT to 200ºC)	CTE (RT to 300ºC)	CTE (RT to 400ºC)	Ave
OD					
ID					
Length					

All dimensions µm/m-ºC
Test Specimen: Ø4.13in [105mm] O.D. x Ø2.12in [54mm] I.D. x 2.00in [51mm] Length

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Impact Test (Gardner)

Test Details:

- Modified ASTM D5420 Method
- Gardner Impact Test

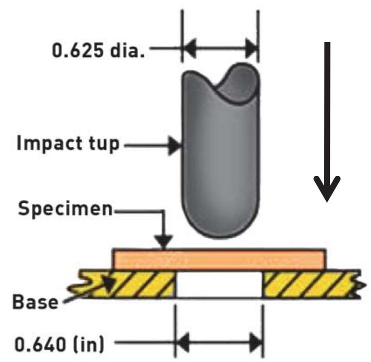
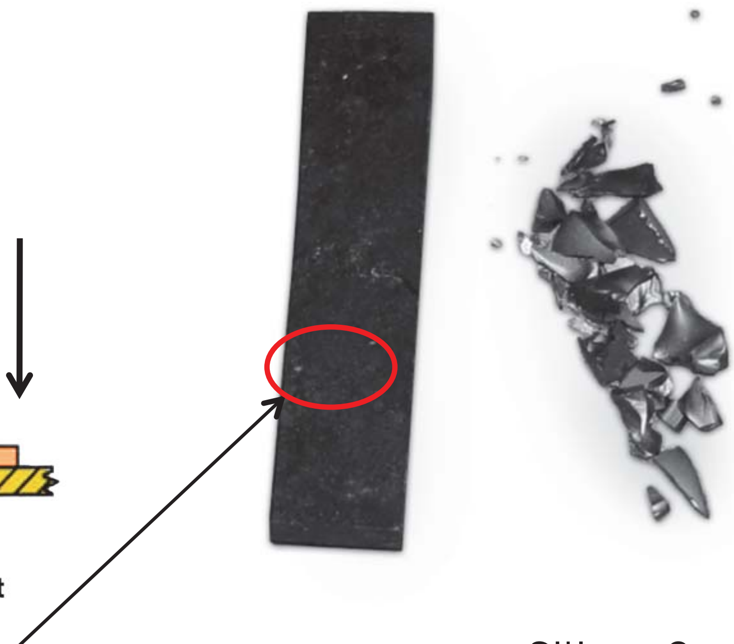


Fig. C Falling Dart

CeraComp®1102



Fine crack

Silicon Carbide

Material	Mean Failure Energy*	Observations
Silicon Carbide	18.75 kg·cm	Shattered
CeraComp® 1102	28.75 kg·cm	Very Fine Crack

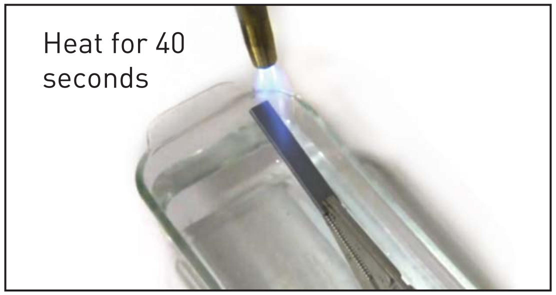
*Mean Failure Energy required to crack or break the sample. A higher mean failure energy is better.

Thermal Shock Test

Test Details:
- ASTM 1525
- Determination of thermal shock resistance by water quench
- Flexural strength measured post quench

CeraComp®1102

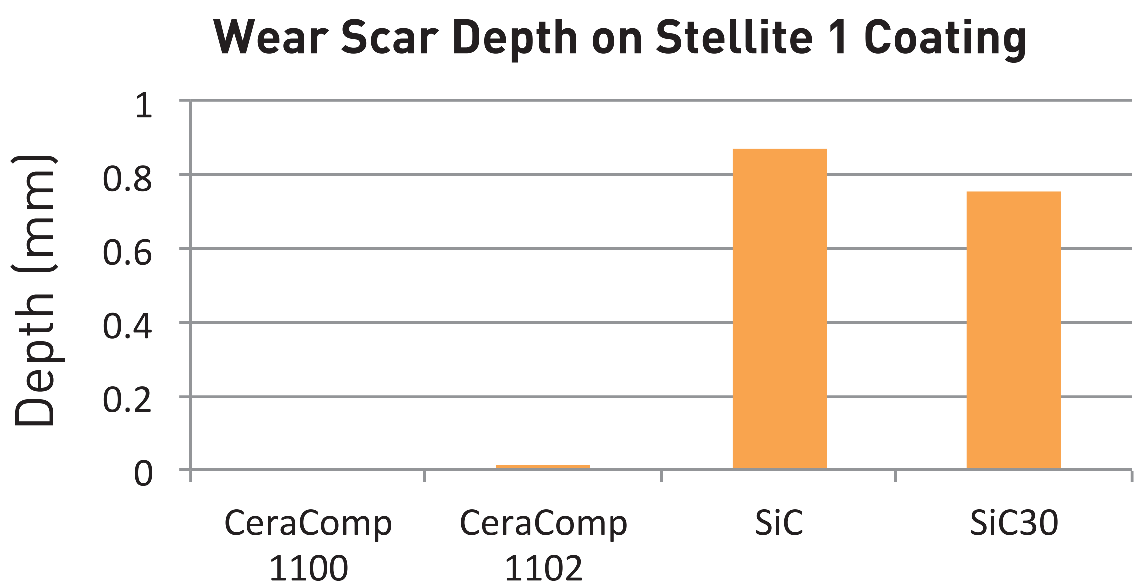
Silicon Carbide



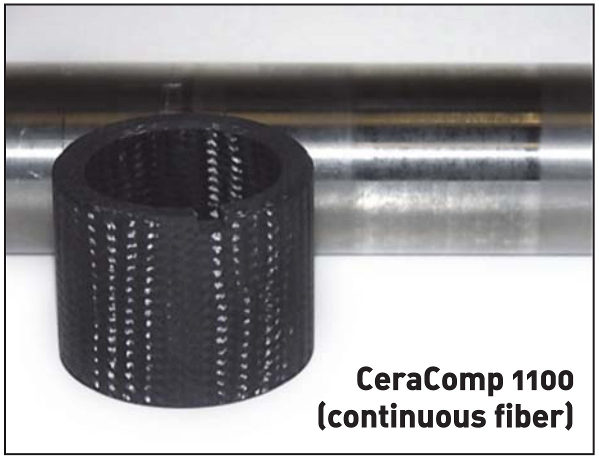
Results:

Exposure Temperature °F [°C]	CeraComp® 1102 Average Flexural Strength psi [MPa]	Silicon Carbide Average Flexural Strength psi [MPa]
Ambient	22,014 [151.8]	49,587 [341.9]
572°F [300°C]	46%	100%
752°F [400°C]	62%	100%
932°F [500°C]	46%	Samples shattered
1112°F [600°C]	36%	Samples shattered

Water Lubricated Bearing Tests



- Horizontal bearing tester
- Shaft speed = 1800 rpm
- Contact stress = 250 psi
- Stellite 1 coated stainless steel 304 shafts
- Water flow rate = 1.66 gpm
- Test interval = 1 hour



Imperceptible polishing/ run-in wear.

Excessive wear to a depth of 0.85 mm

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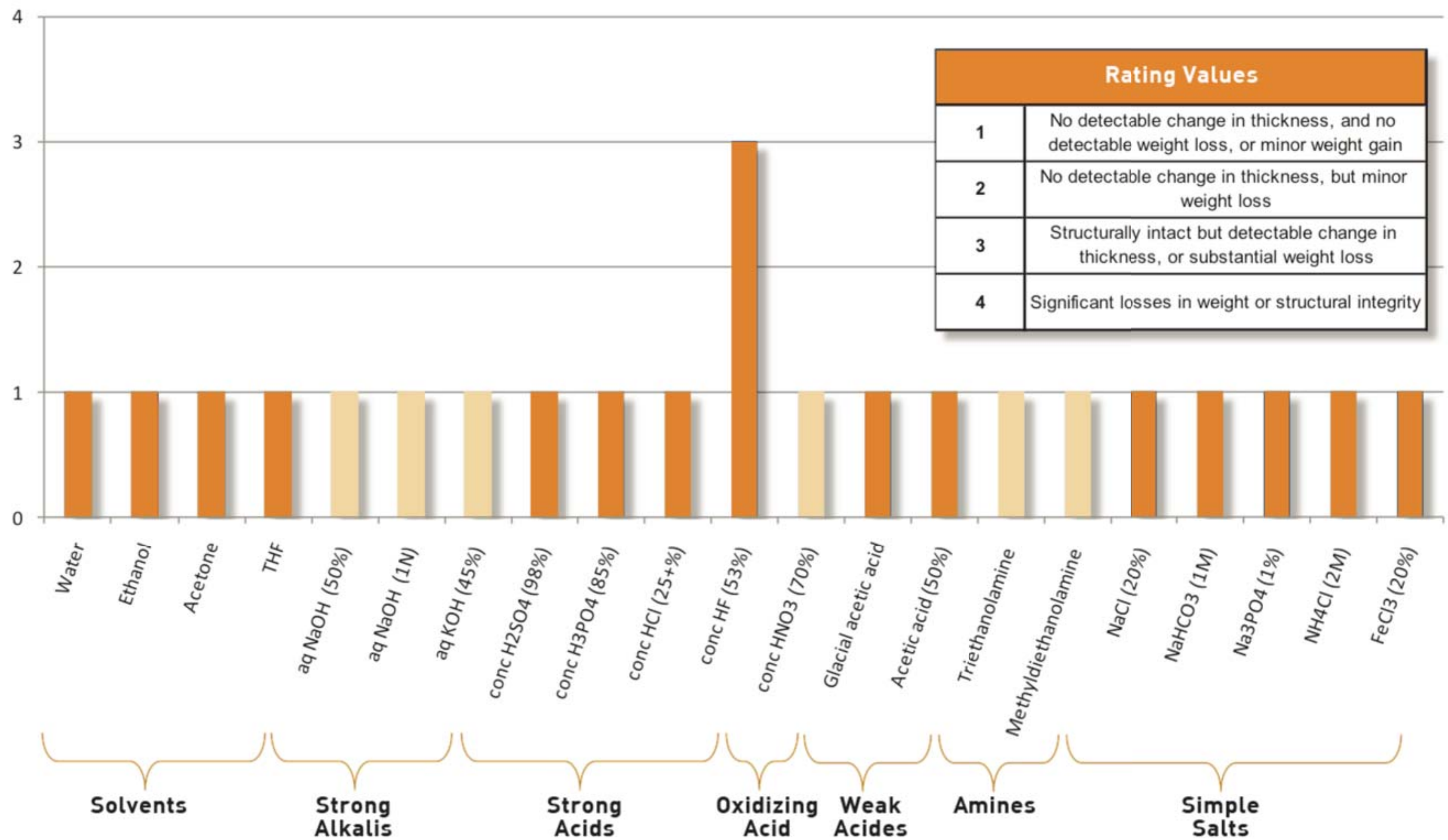
Chemical Compatibility Guide

CeraComp®1100a



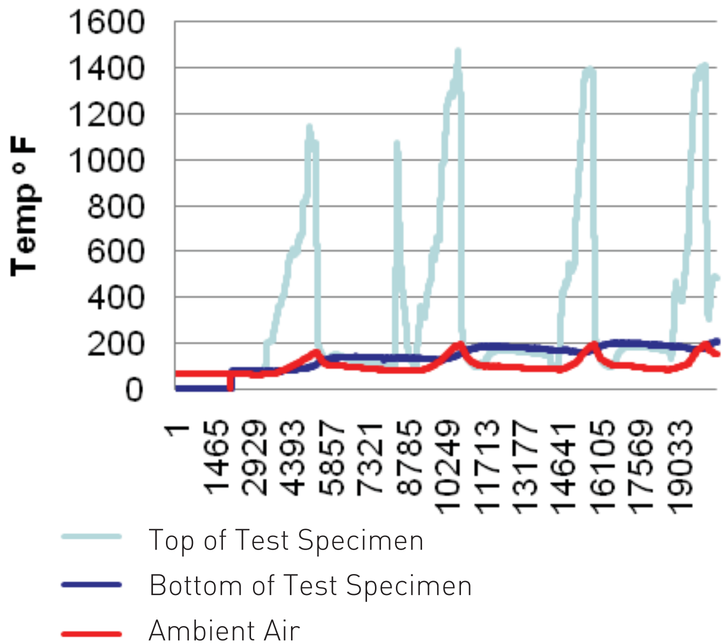
Rating Values	
1	No detectable change in thickness, and no detectable weight loss, or minor weight gain
2	No detectable change in thickness, but minor weight loss
3	Structurally intact but detectable change in thickness, or substantial weight loss
4	Significant losses in weight or structural integrity

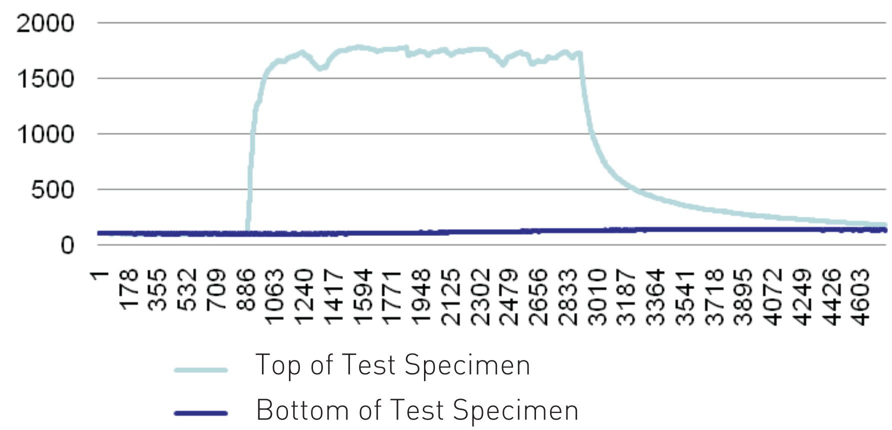
Thermal Insulation Test

- Multiple exposure & single-extended exposure to jet engine temperature (1600ºF/871ºC)

1/10 scale F414 engine, Univ. of Mississippi's National Center for Physical Acoustics

Test specimen: 12" x12", two-layer plate.
• Layer #1 – 0.25" thick CMC, carbon fiber.
• Layer #2 – 0.25" thick CMC, glass fiber.





- 1600°F (871ºC) at surface of test specimen, 7.5 minutes.
- 150°F (66ºC) max temp detected at underside of test specimen.

- Four exposures within 73 minutes.
- No thermal hysteresis experienced.

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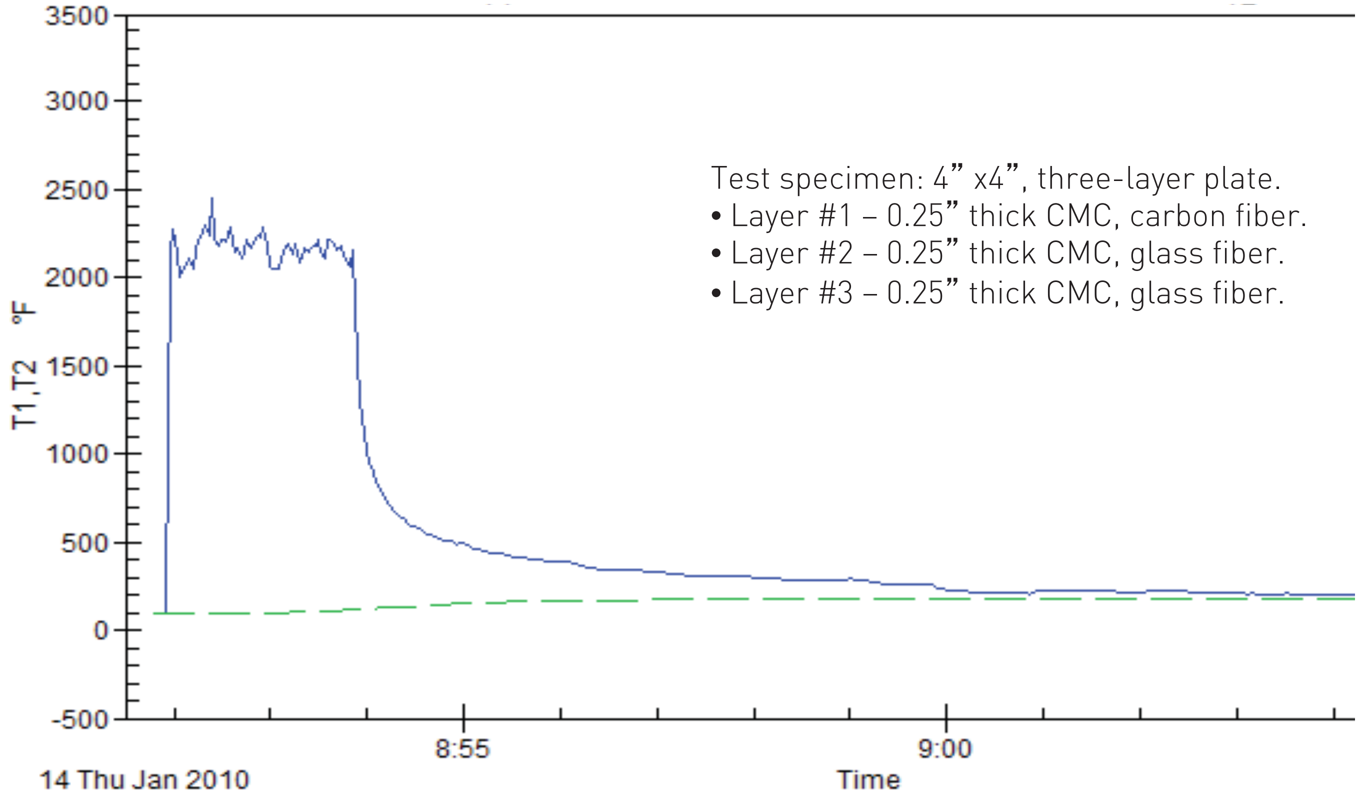
Thermal Insulation Test, con't

- Two-minute exposure to oxygen-acetylene torch



- 2200ºF (1204ºC) at surface of test specimen, two minutes.
- 157ºF (69ºC) max temp detected at underside of test specimen.

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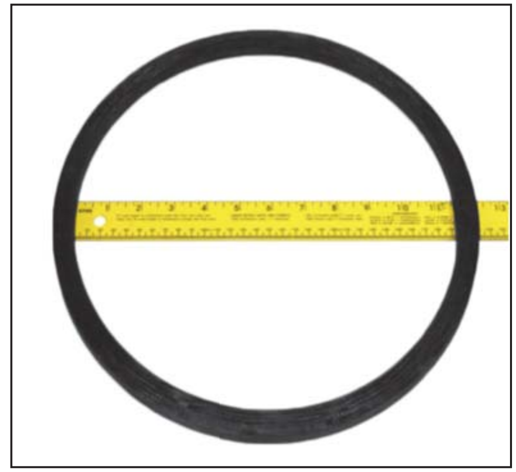
Manufacturing

- Max. Size of Shapes Produced to Date:
  - Plate:
    - 300 mm x 300 mm (12 in. x 12 in.)
    - 25 mm thick (1 in.)
  - Tube:
    - 300 mm (12 inch) O.D.
    - 19 mm (0.75 inch) wall thickness
    - 560 mm (22 inch) length
  - Rod:
    - 150 mm (6 inch) O.D.
    - 125 mm (5 inch) Length



- Tolerances
  - When required, manufacturing has been able to hold 0.015mm [0.0005 in] on critical dimensions
- Surface Finish
  - 0.8µm [32µin] Ra standard surface finish is typical
    - We have achieved surface finish of 0.2µm [8µin] Ra standard

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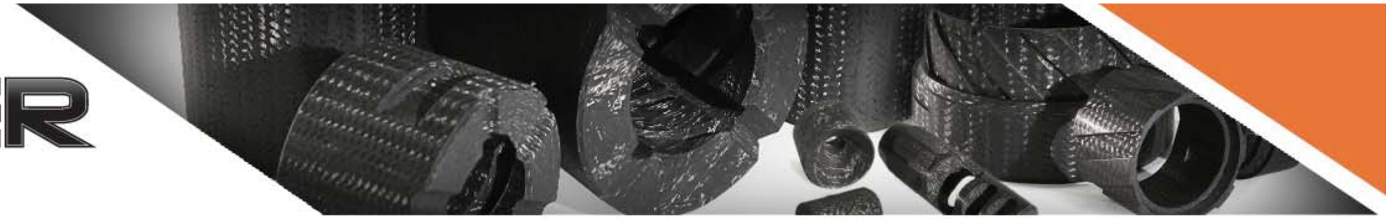

Why Choose Lancer Systems?

Lancer has invested significant resources over four years to develop world-class CMC materials and processes.

Our materials are mature and have been successfully demonstrated in a wide variety of applications.

At Lancer, our team is your team. Our people work directly with you as your collaborative partner to design, develop and manufacture lightweight, cost effective, and innovative material solutions.