Integrated Thermal Structures & Materials Overview

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- **Resins for transfer molding or infusion processing**
  - **POC:**
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- **Nonautoclave processable adhesives**
  - **POC:**
    - Dr. Brian J. Jensen
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- **Automated Tape Placement Device with e-beam cure**
  - **POC:**
    - Harry L. Belvin
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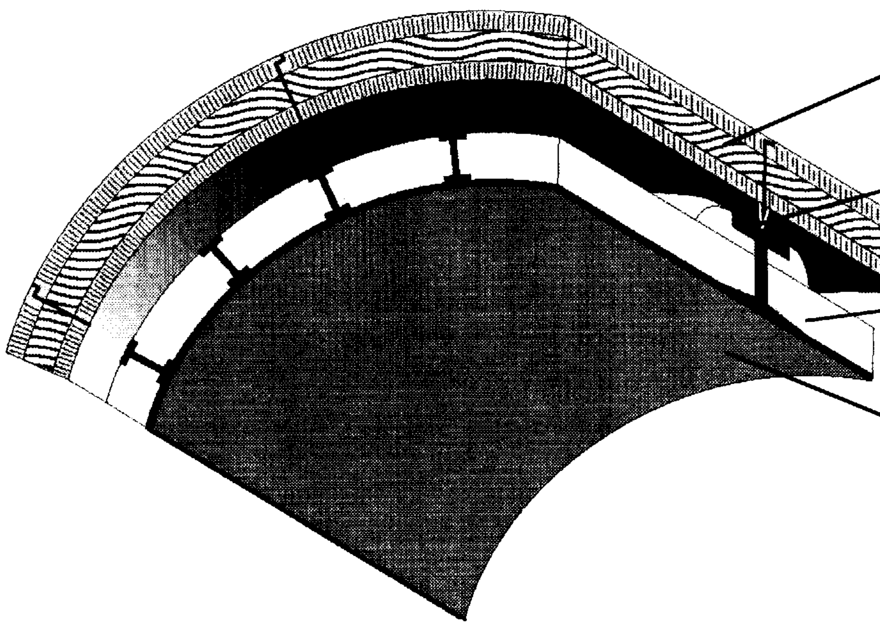
3rd Gen Airframe/TPS:

Int. Thermal Structures and Materials

High Temperature RLV Tank Concept



TPS:
SA/HC (LaRC Metallic tile)

Support Structure:
Gr-Poly lattice

Cryogenic insulation:
LaRC TEEK™ foam panels
E-Beam cured adhesive

Tank wall:
Externally stiffened Gr-Poly
Liquid Crystal Polymer (LCP) coating

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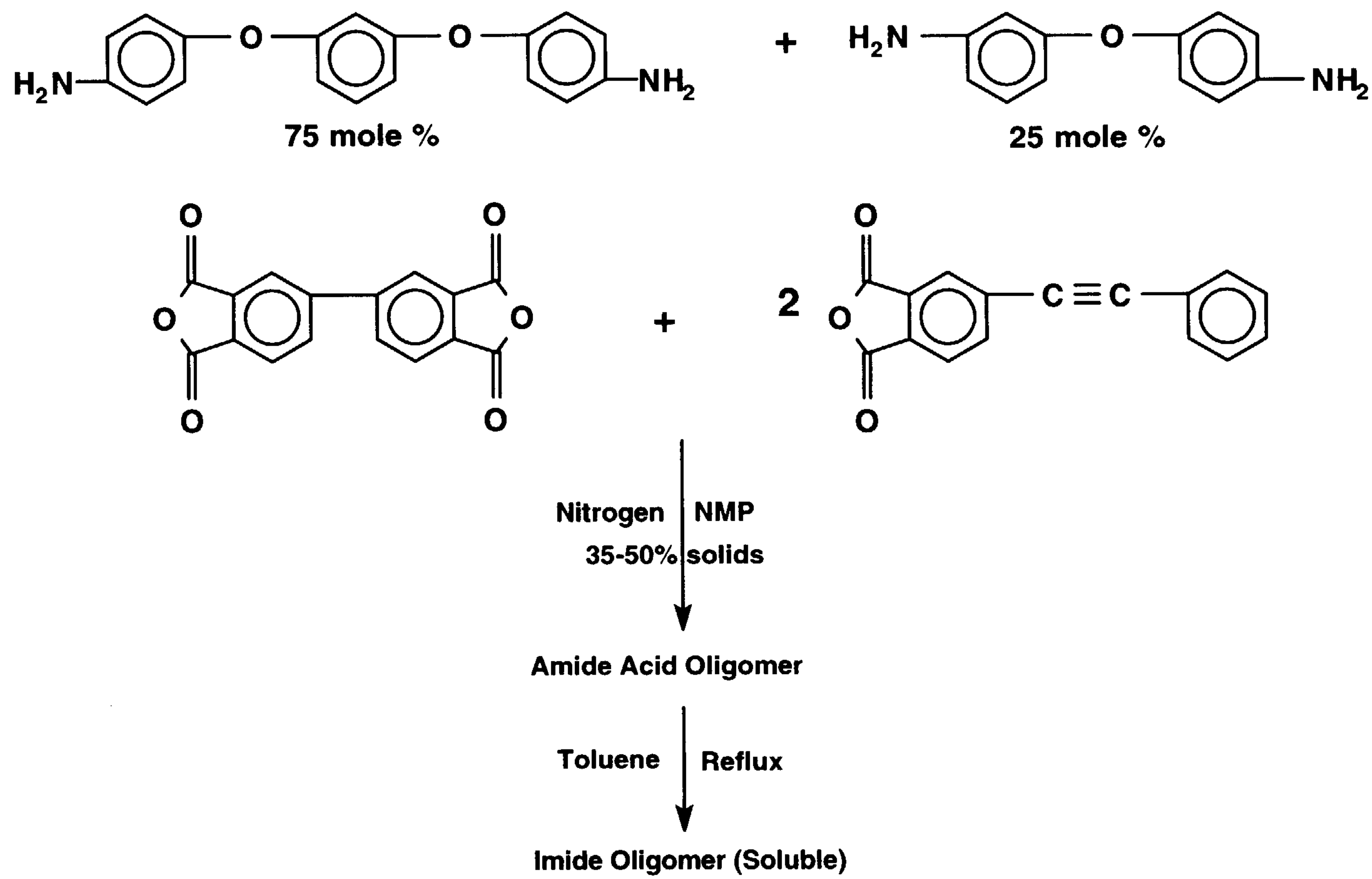
Accomplishments, RTM/RI Resins

- LaRC prepared 5 resins with Tgs as high as 625°F, <1% volatiles, moderate toughness and low melt viscosity and sent to Boeing or Lockheed Martin
- GRC prepared 4 resins with Tgs as high as 700°F, <10% volatiles and low melt viscosity and sent to Boeing
- Boeing successfully fabricated 2' x 2' x 36 ply composites by resin infusion (RI) of stitched preforms from all NASA supplied resins
- Lockheed Martin successfully fabricated 13" x 14" x 16 ply composites by resin transfer molding (RTM) from all NASA supplied resins

Chemistry of PETI-298



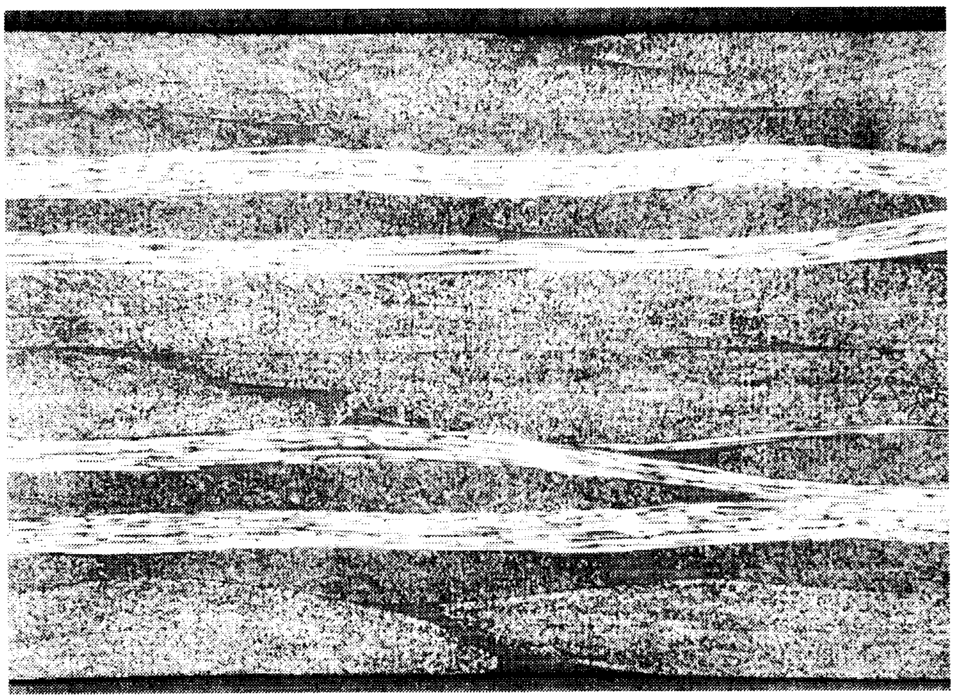
Calculated Mn 750 g/mole = PETI-298

Comparison of PETI Oligomers Prepared From 1,3,3 and 1,3,4 - APB

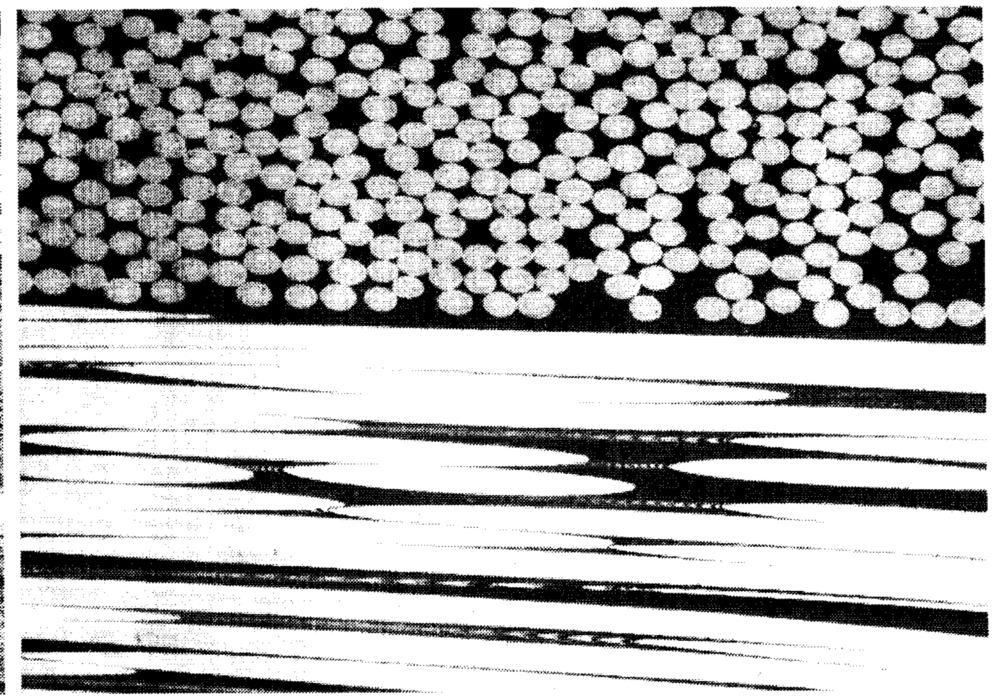
APB Diamine	Calculated Mn, g/mole	Glass Transition Temp., °C Initial	Cured*	Melt Viscosity @ 280°C, poise
1,3,3	750	132	258	1-6
1,3,3	1250	151	244	5-15
1,3,4	750	139	298	6-13
1,3,4	1250	165	285	10,000**

* Cured 1 hour at 371°C
**Viscosity dropped to ~30 poise at 325°C

Photomicrographs of PETI-298 Laminates Fabricated Via RTM

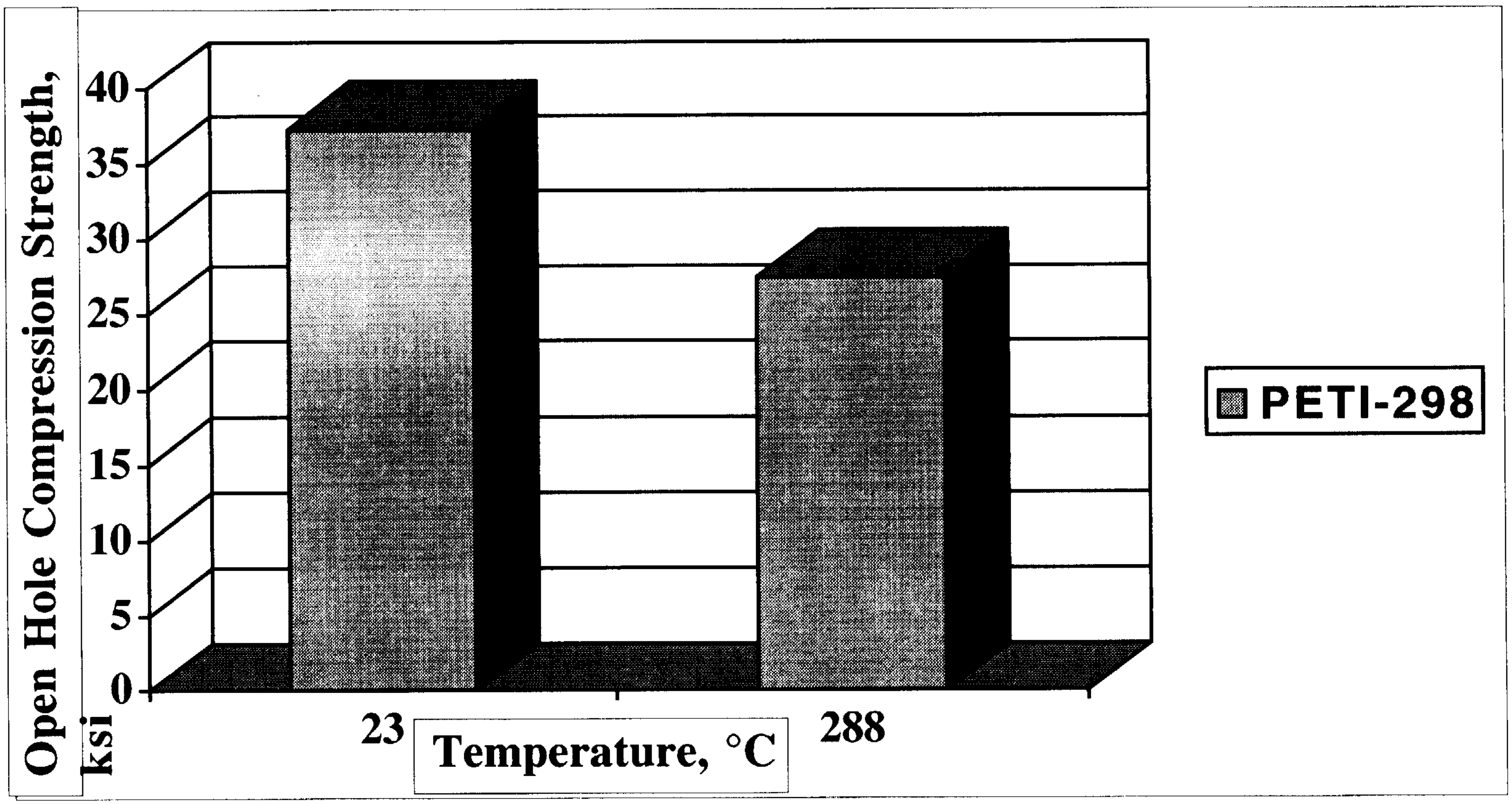


25 x Magnification



400 x Magnification

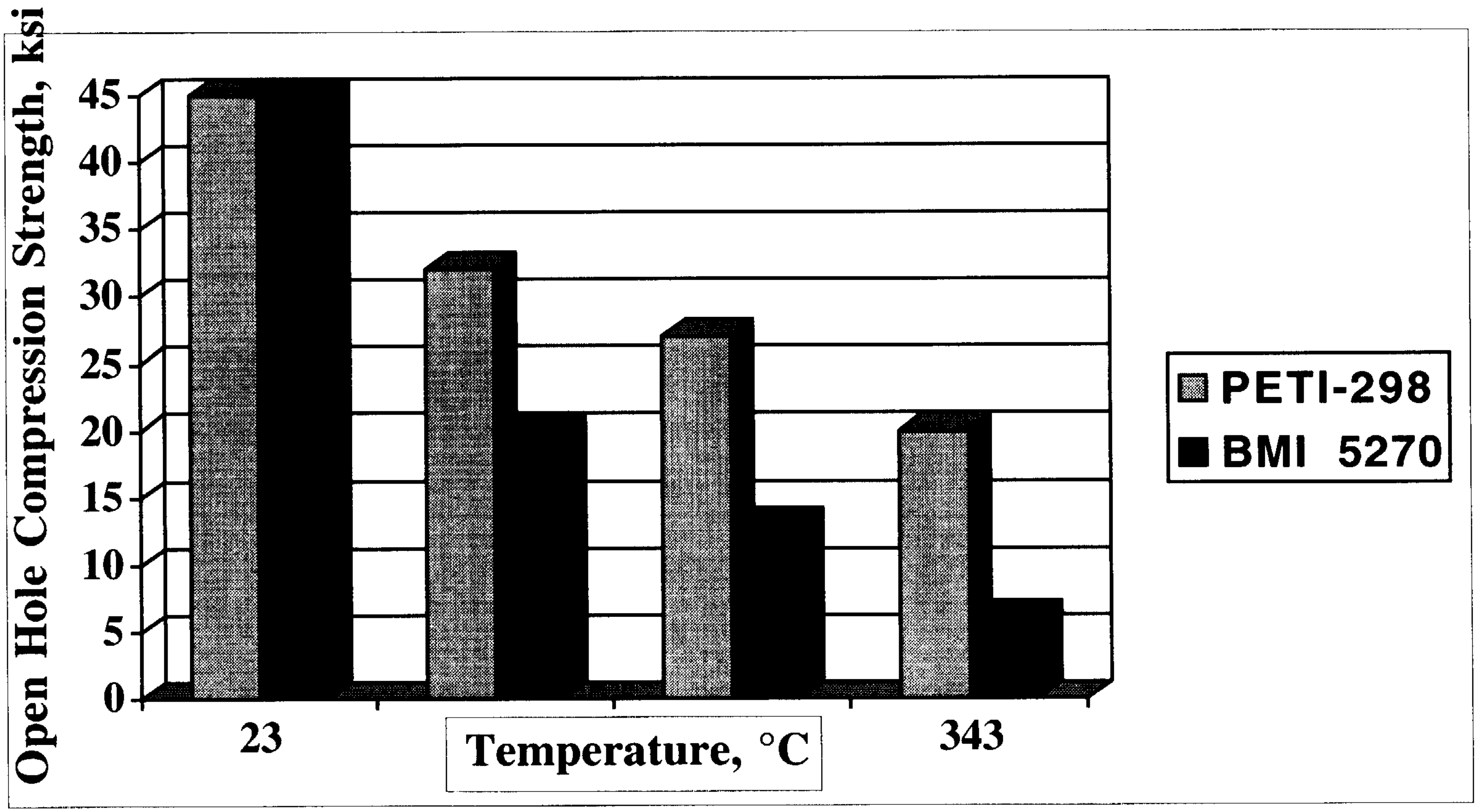
Mechanical Properties of AS-4/PETI-298 Fabric Composites Fabricated Via Resin Transfer Molding (8 ply)



PETI-298 cured 1 hr @ 370°C, Tg = 302°C (8 ply AS-4 fabric)

Un-notched Compression Strength at 23°C = 60 ksi

Mechanical Properties of IM-7 PETI-298 Stitched Composites Fabricated Via Resin Infusion (36 ply)



PETI-298 cured 1 hr @ 370°C, postcured at 370°C, Tg = 338°C (Panel 36 ply x 22"x 22", stitched)

BMI 5270 cured 4 hr @ 190°C, postcured at 232 and 260°C , Tg = 299°C

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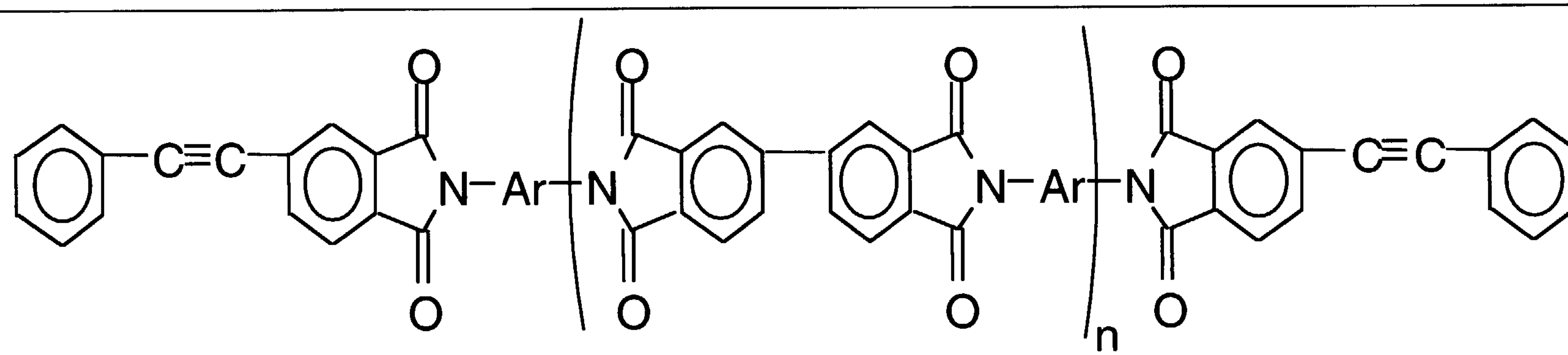
Accomplishments, LaRC PETI-8

- Developed and supplied to Cytec Fiberite several non-autoclave processable adhesives.

- LaRC PETI-8 is a phenylethynyl terminated polyimide adhesive which has low melt viscosity and excellent melt stability at temperatures below 300°C, allowing the production of excellent adhesive bonds under vacuum bag pressure, without the need for external pressure normally supplied by an autoclave. Heating at 316°C for 8 hours provides excellent titanium to titanium tensile shear strengths from 75°F to at least 350°F and excellent flatwise tensile strengths at 75°F.

- Plan to continue work on adhesives which do not require an autoclave for processing. Concentrate on vacuum bag / oven processing, hot melt adhesives and the use of e-beam radiation to cure advanced adhesives. Optimize the properties of LaRC PETI-8 by studying various formulations of the adhesive tape and various cure conditions.

LaRC PETI-8



Titanium to Titanium Tensile Shear Strengths

Required	Achieved
5000 psi at 75° F	**7400 psi**
3500 psi at 350° F	**6200 psi**

Flatwise Tensile Strength (Composite Skins over Titanium core)

Required	Achieved
1000 psi at 75° F	**1370 psi**

Bonding Conditions:

Vacuum Bag Only Pressure, 316°C, 8 hour hold, 5V CAA surface treatment

Cytec Fiberite Results for PETI-8 Bonding

Evaluated 550°F, 575°F and 600°F cycles from 4-12 hours under vacuum bag only pressure for several different formulations. Shown are results for 600°F, 4 hour cycle.

PETI-8 Tensile Shear Strength	75°F	350°F
Titanium substrate, CAA Anodized	7000 psi (min.)	5000 psi (min.)
PETI-5 composite substrate (interlaminar failure at both test temperatures)	5500 psi	4500 psi

PETI-8 Flatwise Tensile Strength	75°F
2024 Al face sheets, FPL etched, 3/16“ Ti core	1800 psi

Cytec currently preparing two 2’ x 2’ PETI-5 composite panels to be bonded together as a wide area specimen.

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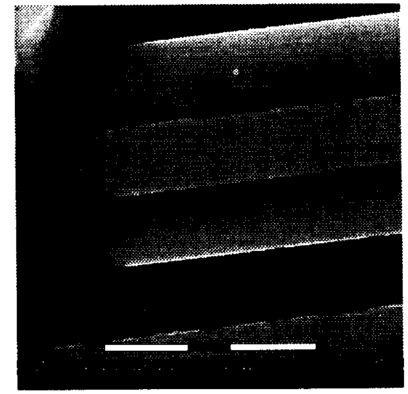
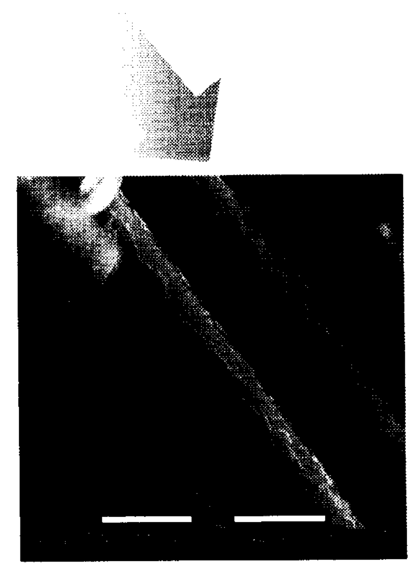
Accomplishments, ATP with E-Beam Cure

- GRC has Cooperative Agreement with Kent State University to study e-beam irradiation of polyimide thin films. (Shows little effect on mechanical properties or Tg)
- GRC has Cooperative Agreement with University of Delaware to study new e-beam curable resins. (Extent of cure dependent on molecular mobility)
- GRC in-house e-beam curable resin development. (Diels-Alder trapping of quinodimethane intermediates formed under radiation)
- LaRC and Boeing developing a tape laying machine with e-beam cure-on-the-fly processing. Undergoing acceptance testing at Boeing and will be shipped to LaRC when facilities are ready.

- **Products/ Benefits/Payoff:**
  - Validate the cause of low performance in E-beam cured graphite/epoxy composites and investigate methods for improving their performance through the use of novel sizings or resin additions.
  - The goals are to:
    - Positively identify the deficiencies causing reduced properties in E-beam cured composites
    - Identify and demonstrate the best method for performance improvement
  - Improved performance of E- beam composites will enable out-of-autoclave fabrication of large cryo tanks. Higher performance of these materials directly reduces RLV vehicle weight.



E-Beam Cured Cat-B



Thermally Cured 8552

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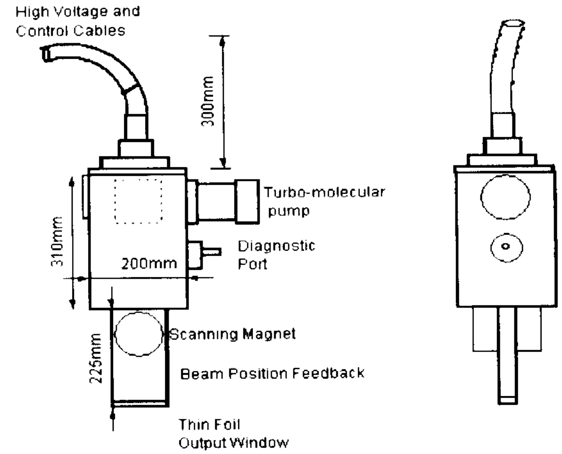
E-beam Gun Head from Electron Solutions, Inc.
E-beam Gun Head from Electron Solutions, Inc.
Boeing Tape Laying Gantry

• Description

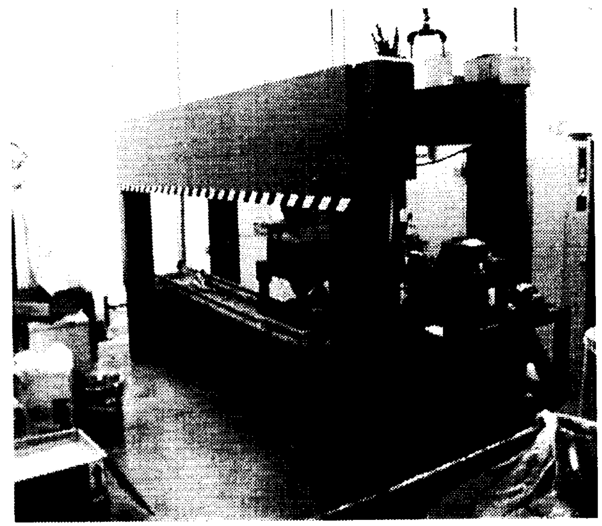
This task will design, fabricate and deliver a tape laying device capable of laying E-beam "cure-on-the-fly" (COTF) prepreg for material evaluations.

• **Products/ Benefits/Payoff:**

COTF E- beam curing will enable out-of-autoclave fabrication of RLV cryo tanks which will substantially reduce overall vehicle weight.



E-beam Gun Head from Electron Solutions, Inc.


Boeing Tape Laying Gantry

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