Power Demands for Curing Carbon Fiber Composites for Automotive Components

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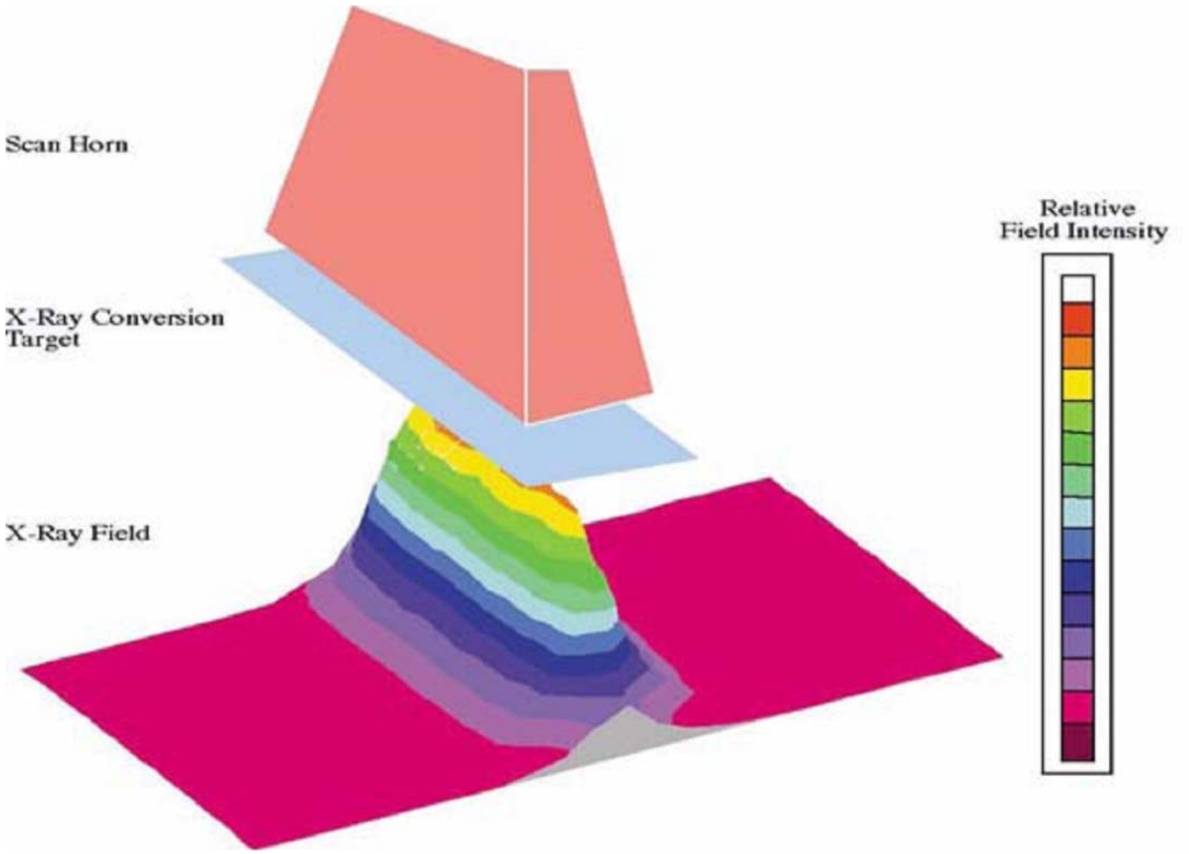
NEW YORK STATE OF OPPORTUNITY. | NYSERDA Supported

Vehicle Light-weighting
Nordan Composite Technologies – NYU Eco-marathon

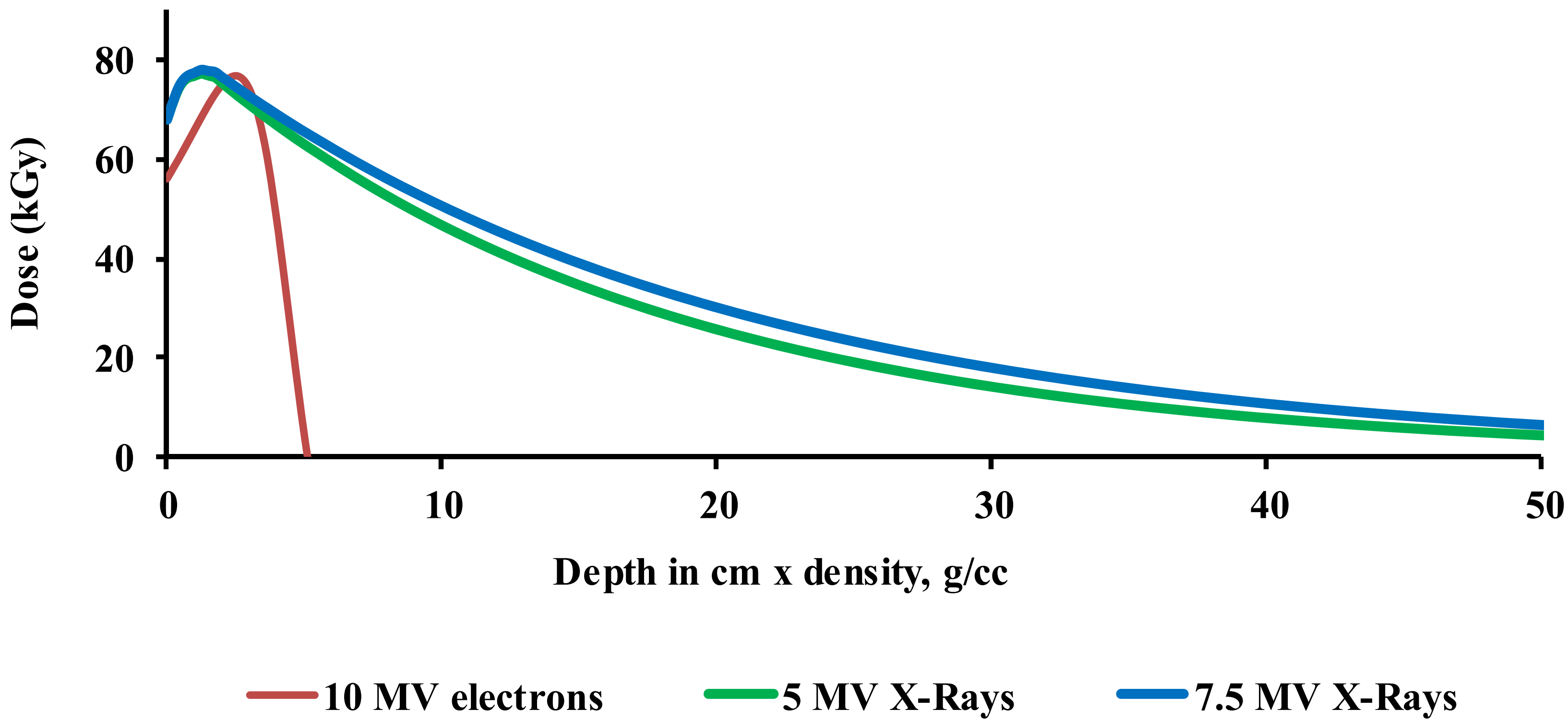
Concept Zero – 103 kg carbon fiber prototype vehicle
1.1 horsepower engine = 60 km/l

X-ray Generation



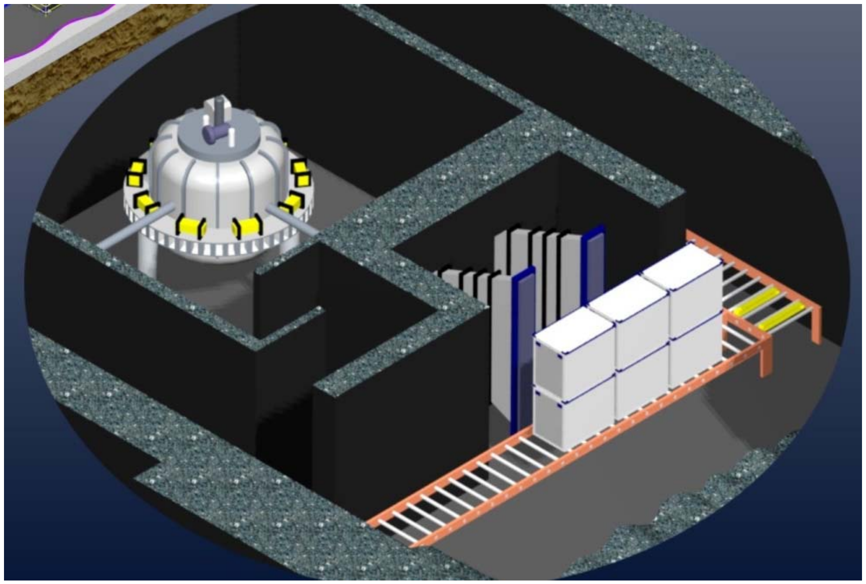
Water cooled Tantalum target interposed between EB source and material to be treated

X-ray Penetration



X-rays effectively penetrate ~25cm unit density material
Highest voltage industrial EB (10 MV) penetrates 3.8cm

X-ray Processing in use Since 2002



5 MV and 7 MV X-ray facility

Totes ready for X-ray processing

Decontaminating mail for the US Postal Service

Commercial EB Accelerator used for X-rays

7 MV 700 kW EB accelerator X-ray treatment in use since 2010

NYSERDA co-funded X-ray Feasibility Study

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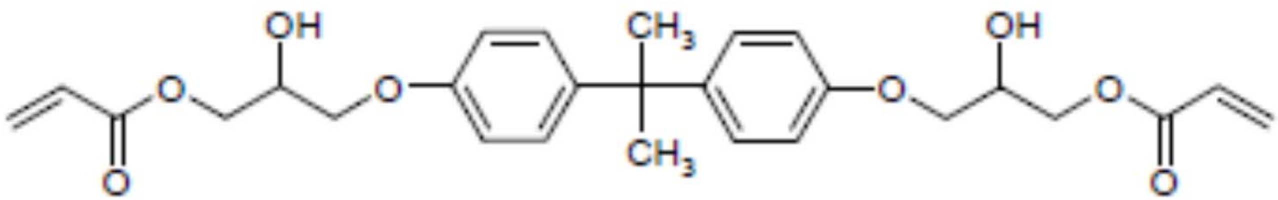

Bis-phenol A diacrylate

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Metal biscuit trays

2 cm aluminum block on top

Carbon fiber shape X-ray cured in the mold

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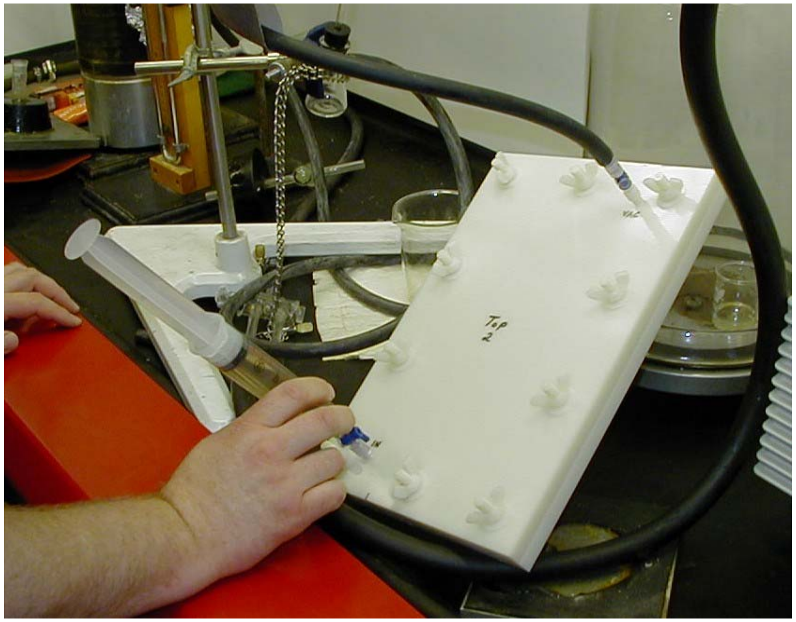
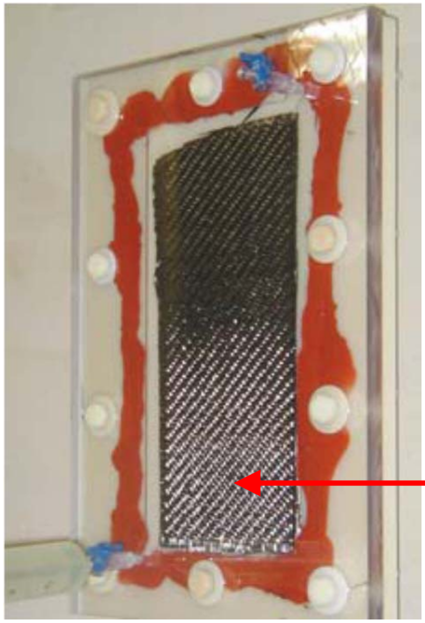


VARTM for test panels



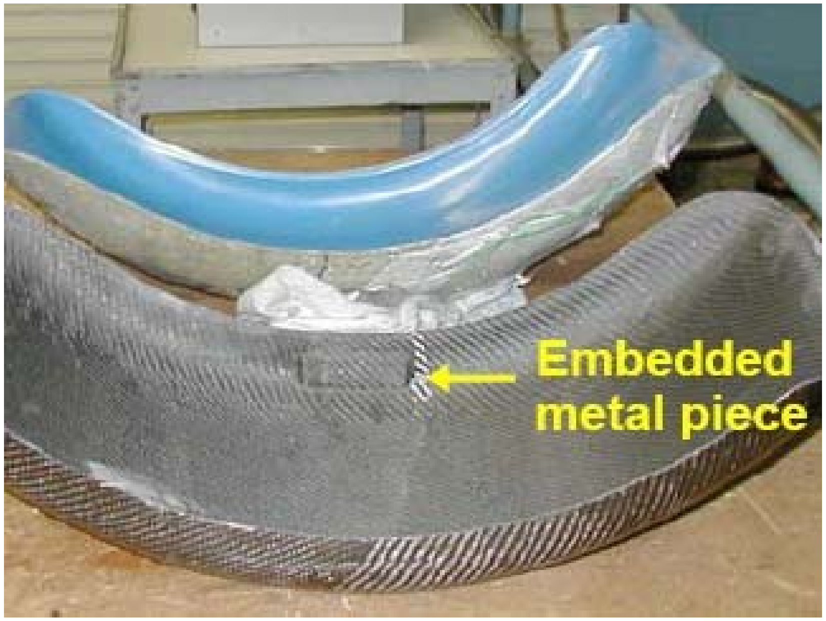
Low viscosity formulation wetting fibers

NYSERDA co-funded X-ray Feasibility Study

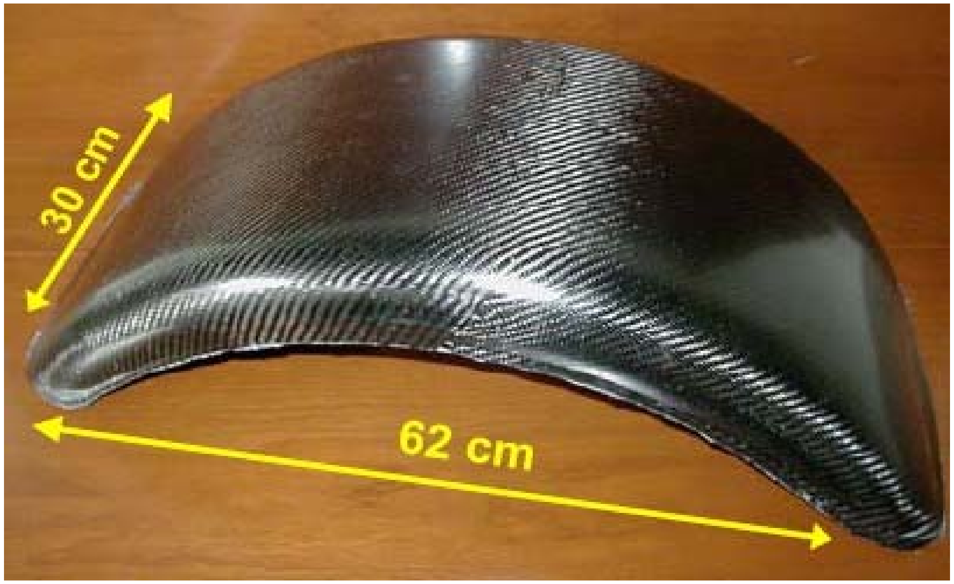
Hand trowelled low viscosity
epoxy-acrylate formulation

X-ray curing motorcycle
fenders in molds

NYSERDA co-funded X-ray Feasibility Study



Cured fender with metal piece embedded between plies



Class A finish motorcycle fender

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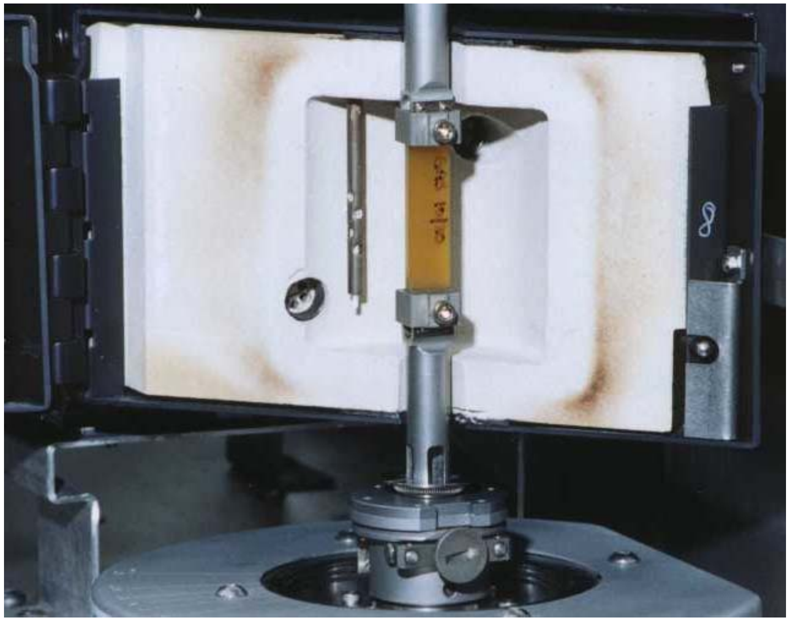
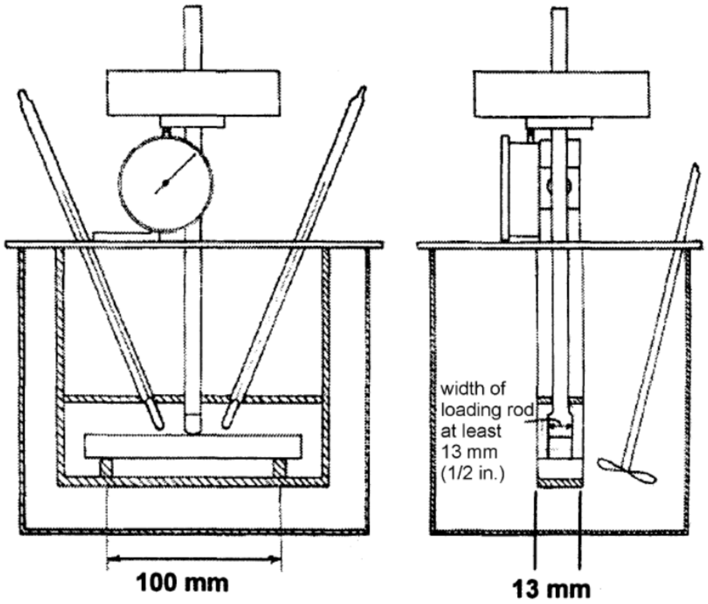


Dynamic mechanical analysis



Heat deflection test
No deflection up to 180° C

Automotive Acceptance of Radiation Processing

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Wiring – enhanced temperature durability (under the hood)
flame retardancy; lighter weight

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EB or UV curing in the future?

Vehicle Light-weighting
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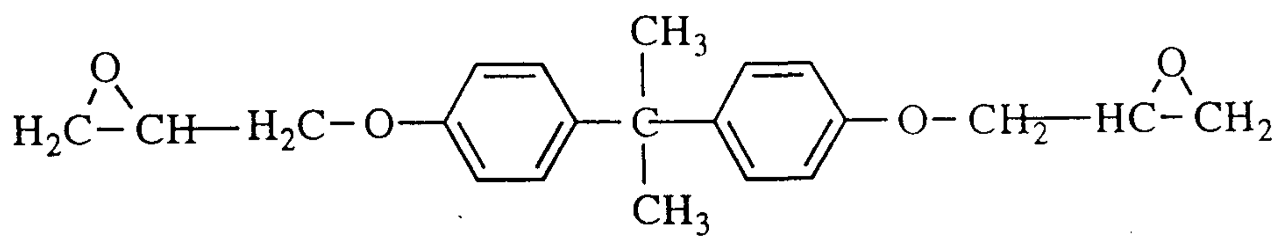
Automotive Component: Aston-Martin hood

Carbon fiber Aston-Martin hood now in use

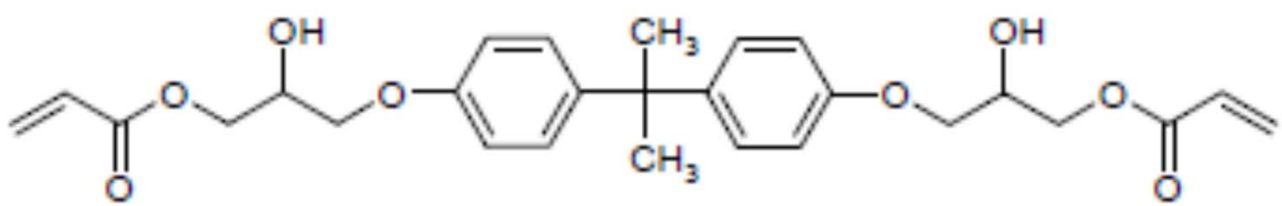
Automotive Component

Chassis

Matrix Materials: Bis-phenol A epoxies



Bis-phenol A epoxy



Bis-phenol A diacrylate

Matrix Materials: Bis-phenol A epoxies

Resin	Epoxy	Epoxy diacrylate
Density	1.16	1.17
Viscosity at 25° C, cps	~13,000	~190,000
Molecular weight, Daltons	377	393

Autoclave Curing

Commercial pre-preg was purchased from Cytec

Autoclave Curing

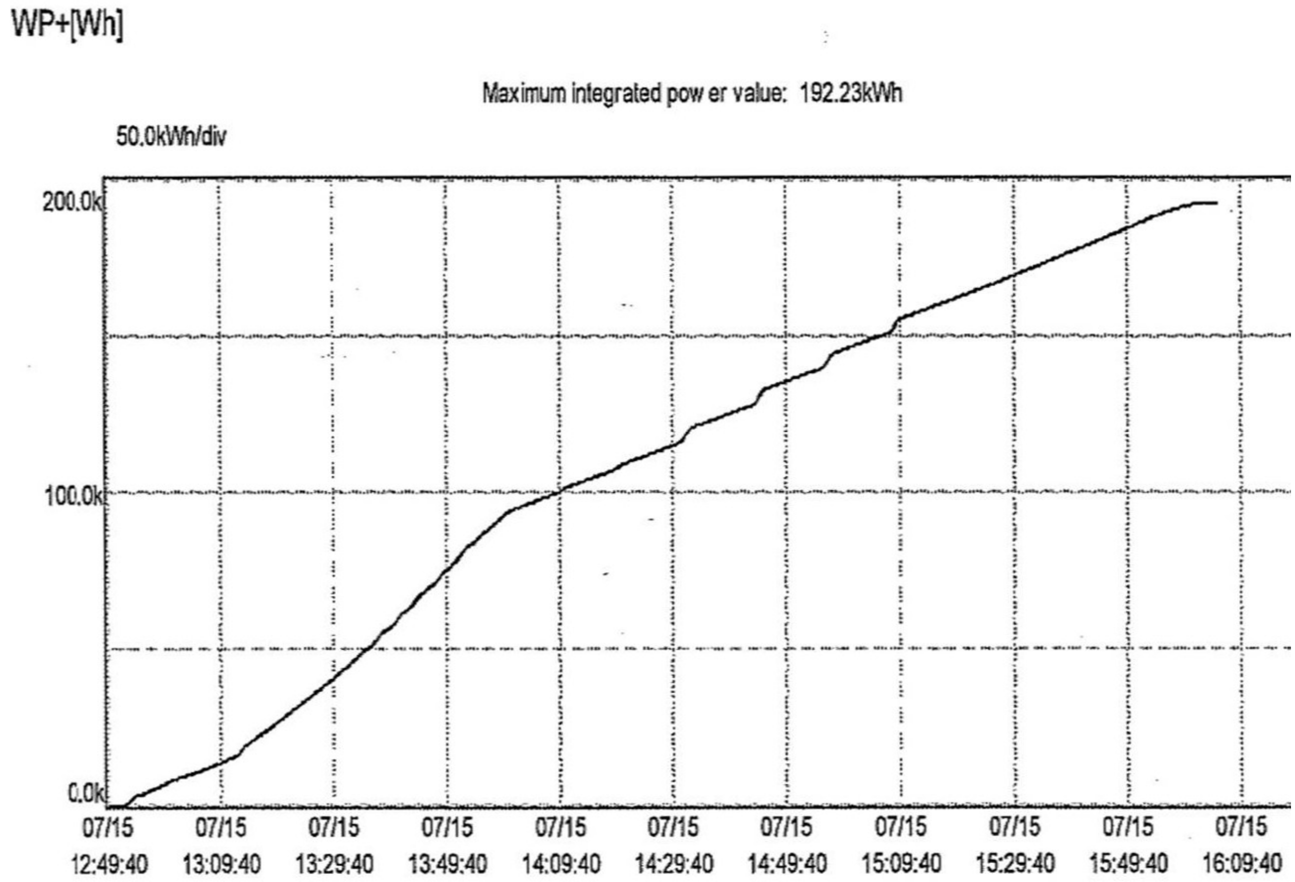
Composite Prototyping Center 2.4 m diameter, 6.1 m long autoclave
Supplier's recommended cure cycle:

one hour ramp up at 1.7° C/minute to 121° C
one hour cure at 121° C
one hour cool down to room temperature

Autoclave Curing

Aston-Martin hood cured at the CPC 15 July 2015

Autoclave Curing – Total Power Demand



Complete electrical demand: blowers, heaters, etc.
Integrated power consumption = 192 kWh

X-Ray Curing

Renegade produced the radiation curable pre-preg using a formulation provided by Rapid Cure Technologies

NYSERDA co-funded Power Demand Study

X-ray curing hood in mold

NYSERDA co-funded Power Demand Study

X-ray cured hood

X-ray Curing – Total Power Demand

Based on total power demand when operating the 7 MV, 700 kW accelerator in the X-ray mode, the electrical demand for curing a hood within its 1.49 m by 1.53 m mold passing in front of an X-ray target at 0.425 m/minute, using three passes (back-forth-back) to use full X-ray output, would be 25.26 kWh per hood

Using the 2.4 m diameter, 6.1 m long autoclave to its capacity to cure six hoods at a time, the power demand would be 32 kWh per hood (192 kWh/6)

X-ray curing would demand 21% less power per hood

X-ray Curing Advantages

+ Time to cure: 47 hoods per hour; 1.3 minutes per hood

+ Cure through embedded materials

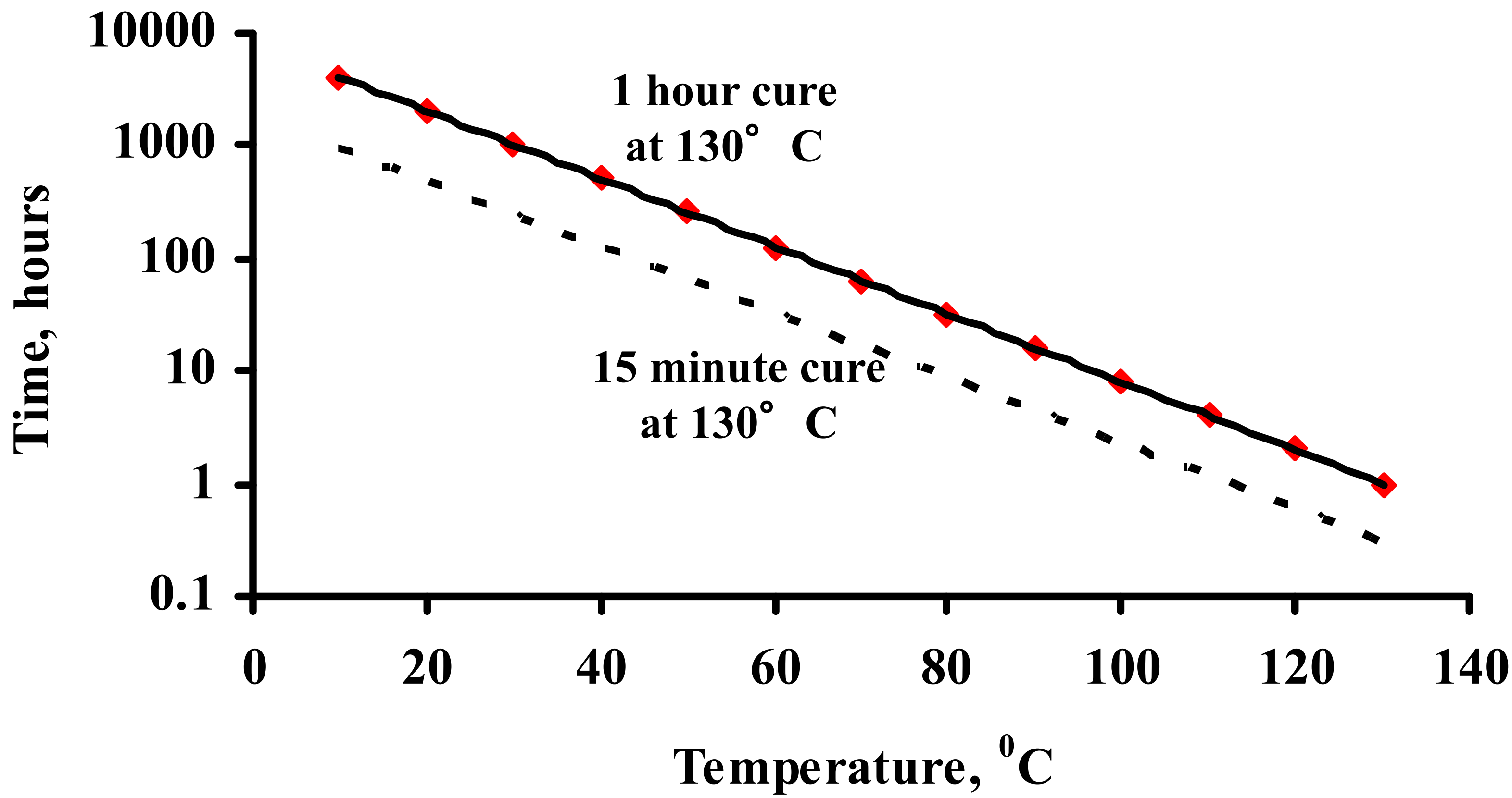
+ Cure through thick cross-sections

+ Extended shelf-life of matrix materials

  Material made for feasibility study on August 23, 2005 used as a control over the years; pre-preg stored at room temperature

+ Cure activated by ionizing radiation – no curatives

Time-Temperature Constraints of Epoxy Thermoset



Thermoset curing reaction kinetics – time at temperature

The Imperative of Vehicle Light-weighting

+ Carbon fiber composites have high specific strength

Weight-to-strength ratios for vehicle component materials

Material	Density g/cm3	Specific Strength kN·m/kg
Steel	7.86	254
Aluminum	2.80	214
Carbon fiber composite	1.58	785

The Imperative of Vehicle Light-weighting

+ Vehicle light-weighting using carbon fiber composites is the most straight-forward way to reduce green house gas emissions

2.3 liters of CO_2 are emitted per liter of hydrocarbon fuel used

Carbon Fiber Composites

+ Carbon fiber composites do not require corrosion protection

+ Coatings on carbon fiber composites can be cured with non-thermal ultraviolet (UV) radiation

Carbon Fiber Composites

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Thank You

Questions