North American Pultrusion Conference

Inorganic Resin-based Composites that Meet Fire Performance Codes without Fire Retardant Additives

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ACMA American Composites Manufacturers Association | EPTA

PRESENTATION OUTLINE

- Introduction
- Materials: Organic vs. Inorganic Resins
- Applications
- Pultrusion Process-Development
- Summary and Conclusions

INTRODUCTION

- There is a technology gap between organic polymer composites and ceramic materials

- The need for non-metallic materials that exceed 370°C (700°F) service increases as performance requirements for state-of-the-art applications become more commonplace.

Materials: Reinforced Organic Resins

About Composites
More

From: McMaster Car Catalog

Structural FRP Fiberglass Square Tubes

- Color: Green
- Temperature Range: -60° F to 140° F
- Tensile Strength: 7,000-30,000 psi (Good)
- Impact Strength: 4-25 ft.-lbs./in. (Excellent)
- Hardness: Barcol 45 (Hard)
- For Use Outdoors: Yes

-60 F to 140 F

Use these FRP fiberglass square tubes as an alternative to wood in structural applications. Made of fiberglass-reinforced polyester, they are strong and lightweight.

CAD For technical drawings and 3-D models, click on a part number.

Outside				Inside			5 ft. Lg.		10 ft. Lg.	
Wd.	Wd. Tolerance	Ht.	Ht. Tolerance	Wd.	Ht.	Straightness Tolerance		Each		Each
1/8" Wall Thick. (-0.019" to 0.019")										
1"	-0.094" to 0.094"	1"	-0.094" to 0.094"	3/4"	3/4"	0.03" per ft.	8548K21	$29.88	8548K31	$54.05
1 1/4"	-0.094" to 0.094"	1 1/4"	-0.094" to 0.094"	1"	1"	0.03" per ft.	8548K42	36.57	8548K52	60.95
1 1/2"	-0.094" to 0.094"	1 1/2"	-0.094" to 0.094"	1 1/4"	1 1/4"	0.03" per ft.	8548K22	42.10	8548K32	76.19
1 3/4"	-0.094" to 0.094"	1 3/4"	-0.094" to 0.094"	1 1/2"	1 1/2"	0.03" per ft.	8548K43	52.99	8548K53	88.31
2"	-0.094" to 0.094"	2"	-0.094" to 0.094"	1 3/4"	1 3/4"	0.03" per ft.	8548K23	53.55	8548K33	96.90
1/4" Wall Thick. (-0.038" to 0.038")										
2"	-0.094" to 0.094"	2"	-0.094" to 0.094"	1 1/2"	1 1/2"	0.03" per ft.	8548K24	92.03	8548K34	172.73
2 1/2"	-0.094" to 0.094"	2 1/2"	-0.094" to 0.094"	2"	2"	0.03" per ft.	8548K71	106.95	8548K81	200.80
3"	-0.094" to 0.094"	3"	-0.094" to 0.094"	2 1/2"	2 1/2"	0.03" per ft.	8548K25	128.17	8548K35	240.65
4"	-0.094" to 0.094"	4"	-0.094" to 0.094"	3 1/2"	3 1/2"	0.03" per ft.	8548K26	176.12	8548K36	330.87
3/8" Wall Thick. (-0.056" to 0.056")										
6"	-0.094" to 0.094"	6"	-0.094" to 0.094"	5 1/4"	5 1/4"	0.03" per ft.	8548K29	318.72	8548K39	565.28

$565

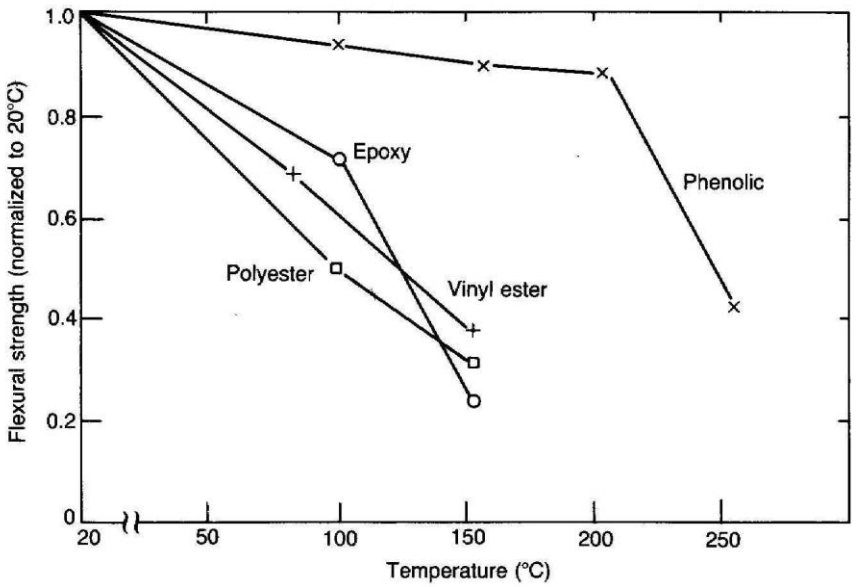
Materials: Organic Resins

healthier steps — Cooking Temperature Conversion Chart

Celsius	Fahrenheit
150° C	300° F
165° C	325° F
175° C	350° F
190° C	375° F
200° C	400° F
220° C	425° F
230° C	450° F
260° C	500° F

www.healthiersteps.com

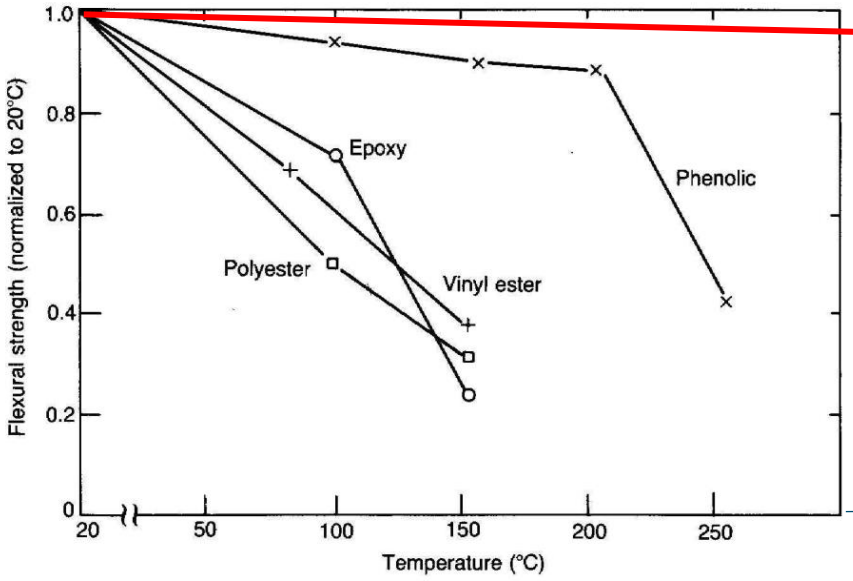
Temperature Limits



Materials: Organic Resins

Inorganic Resin (Chemically Bonded Ceramic)*

Meets E-119 with hydrocarbon fire Exposure curve



1000 C

(*) attributed to D.M. Roy

Application: Building & Entertainment

buildings

FIRES

Decorative Material Under Investigation

Las Vegas officials await results of facade-fire probe before taking any action relating to codes

02/20/2008

By Nadine M. Post and Tony Illia

The mystery surrounding the Jan. 25 rooftop fire at the 32-story MGM Monte Carlo Las Vegas hotel tower, which spread to a small section of the facade on the south and west faces, concerns the composition of the 30-ft-tall roof screen and ornaments that caught fire. Fire officials in Clark County are awaiting results of an investigation to determine whether there is any reason to make any changes to building codes or to survey other Las Vegas buildings that might sport the same decorative material.

Fire damage to hotel was restricted to the upper facade, which has already been repaired (Bottom).

"We don't see any need to amend our codes now, but if our analysis makes us think its necessary, it could be something that we would do," says Dan Kulin, a Clark County spokesman.

The material questions have not stopped the owner, MGM Mirage, from repairing the charred facade sections and reopening the 3,000-room hotel in stages. On Feb. 15, MGM Mirage reopened 1,200 rooms. By Feb. 22, 2,500 were to be back in operation. The remaining 500 rooms will be out of service until extensive remodeling is completed. MGM Mirage suffered $100 million in lost business and building damage during the 21-day closure, according to Alan Feldman, the company's chief spokesman.

For the facade repair, Bentar Development Inc., Las Vegas, is installing more than 400, 4-ft x 8-ft sheets of GlasRoc, a gypsum-based sheathing. It is offered in a 5⁄8-in.-thick Type X sheathing tested for use in fire-rated assemblies, says the maker, CertainTeed, Valley Forge, Pa.

Disney Suspends Fire Effects Globally After Fantasmic Incident

IN DISNEYLAND RESORT

Posted on April 23, 2023 by Adam James

Leave a comment

Last night's fire at Disneyland is bringing major changes to Disney Parks globally.

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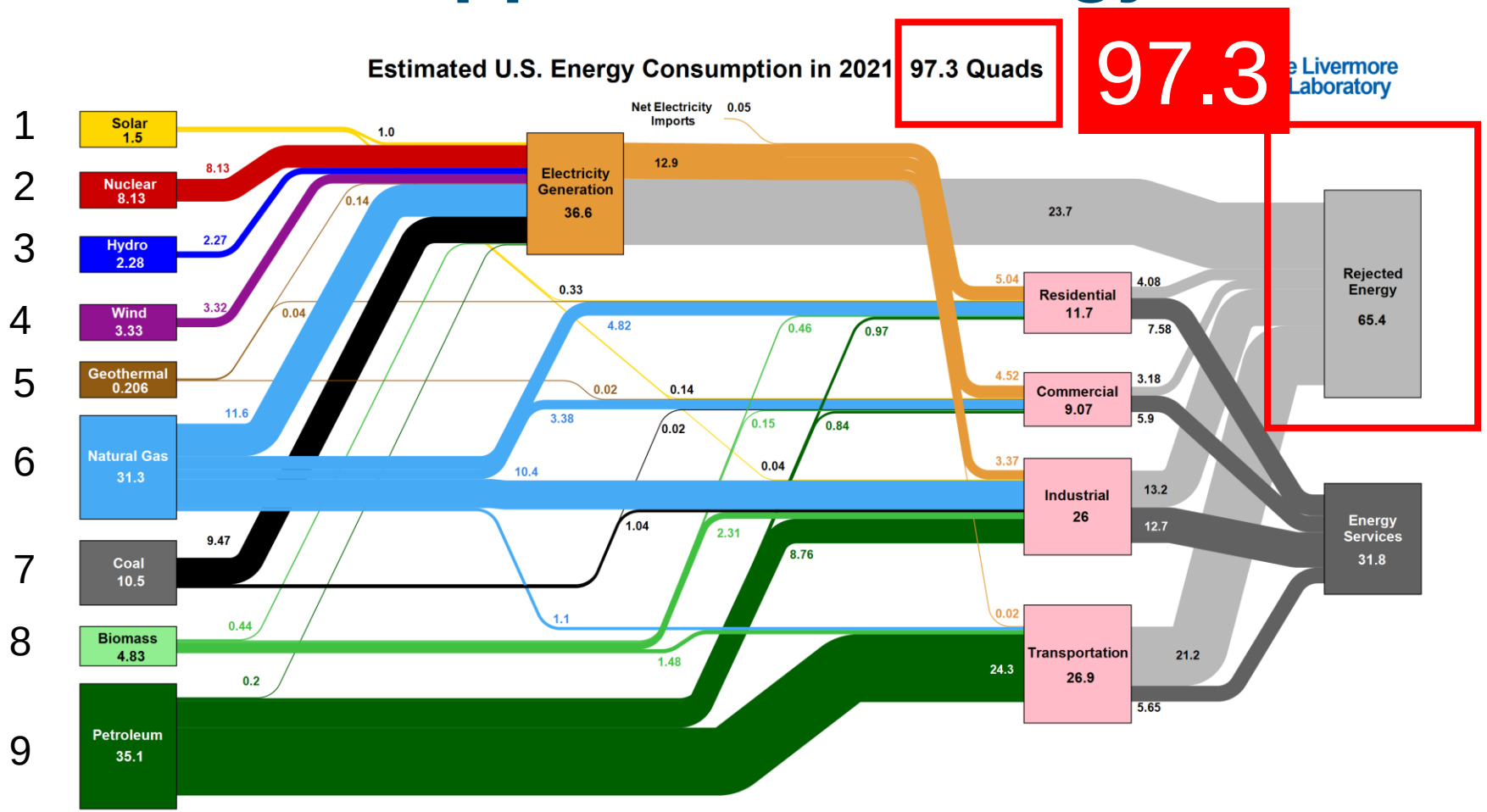
Application: Energy



97.3

65.4

31.8

Source: LLNL March, 2022. Data is based on DOE/EIA MER (2021). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

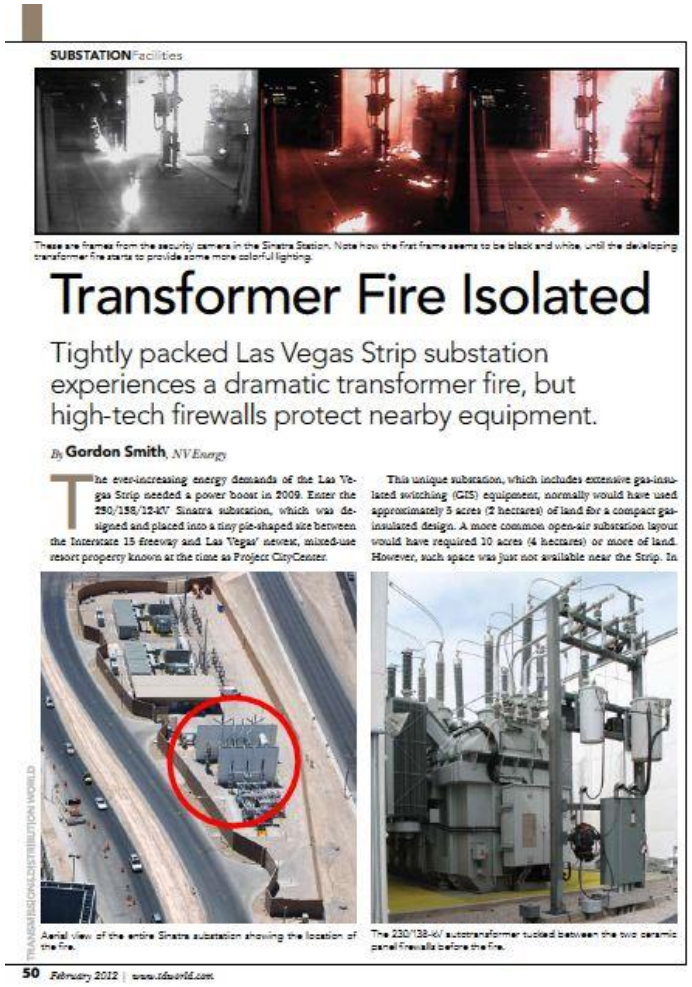
$$31.8 \cong \frac{97.3}{\pi}$$

Application: Asset Protection

Organic Resin
(the yellow grating)

Inorganic Resin
(the two white walls)

Application: Asset Protection



SUBSTATION Facilities

These are frames from the security camera in the Sinatra Station. Note how the first frame seems to be black and white, until the developing transformer fire starts to provide some more colorful lighting.

Transformer Fire Isolated

Tightly packed Las Vegas Strip substation experiences a dramatic transformer fire, but high-tech firewalls protect nearby equipment.

By **Gordon Smith**, *NV Energy*

The ever-increasing energy demands of the Las Vegas Strip needed a power boost in 2009. Enter the 230/138/12-kV Sinatra substation, which was designed and placed into a tiny pie-shaped site between the Interstate 15 freeway and Las Vegas' newest, mixed-use resort property known at the time as Project CityCenter.

This unique substation, which includes extensive gas-insulated switching (GIS) equipment, normally would have used approximately 5 acres (2 hectares) of land for a compact gas-insulated design. A more common open-air substation layout would have required 10 acres (4 hectares) or more of land. However, such space was just not available near the Strip. In

Aerial view of the entire Sinatra substation showing the location of the fire.

The 230/138-kV autotransformer tucked between the two ceramic panel firewalls before the fire.

TRANSMISSION&DISTRIBUTION WORLD

50 February 2012 | www.tdworld.com

Organic Resin (the yellow?? grating)

Application: (Bad) Asset Protection

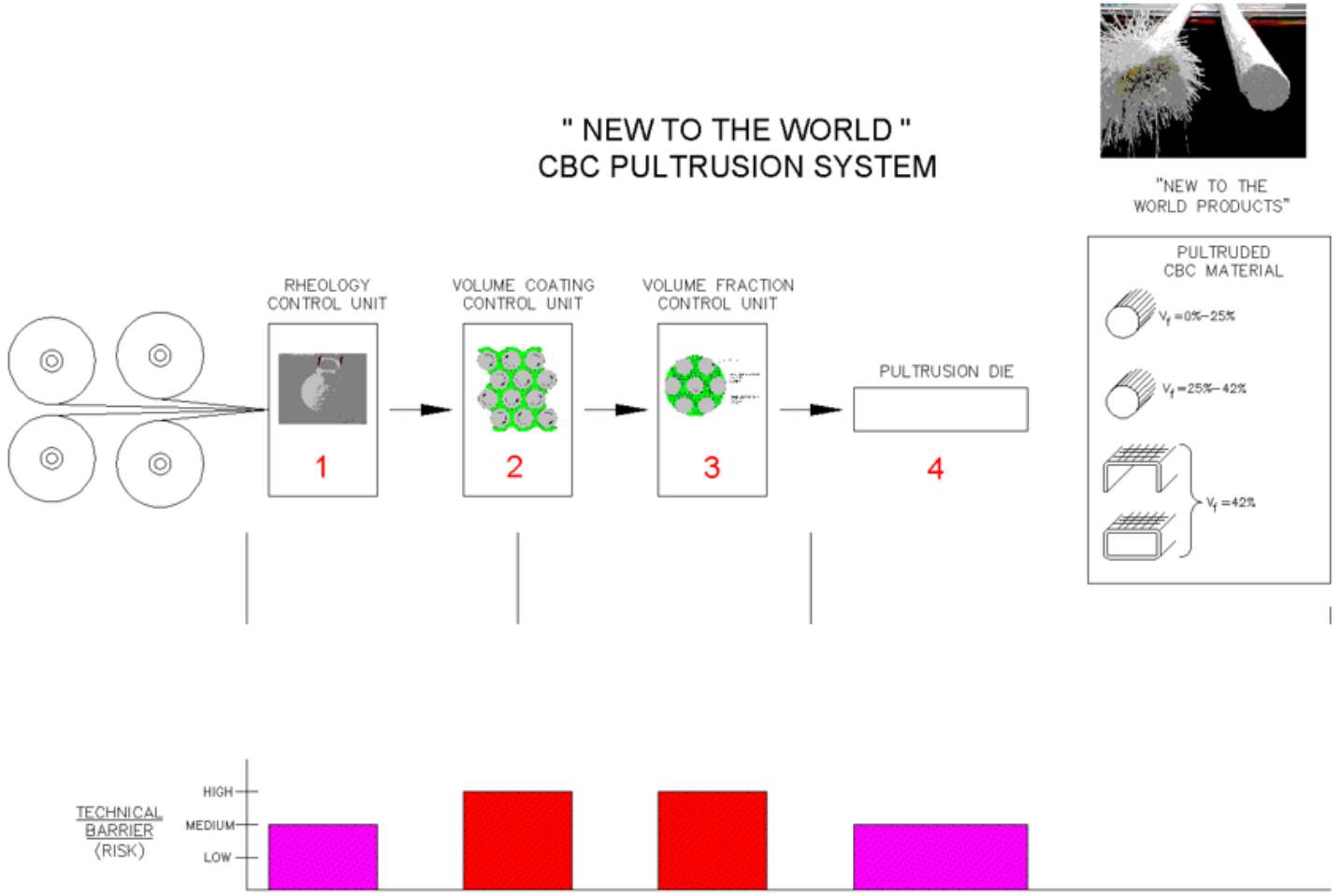
Newsweek + Follow

Russian MLRS Weapons Factory Bursts Into Flames: Reports

Story by Thomas Kika • Yesterday 12:17 PM

Above, a representational photo of an MLRS in use by Ukrainian forces. A Russian factory known to manufacture MLRSs was imperiled on Saturday when a transformer caught fire on its grounds.
© Genya Savilov/AFP via Getty Images

Pultrusion Process Development



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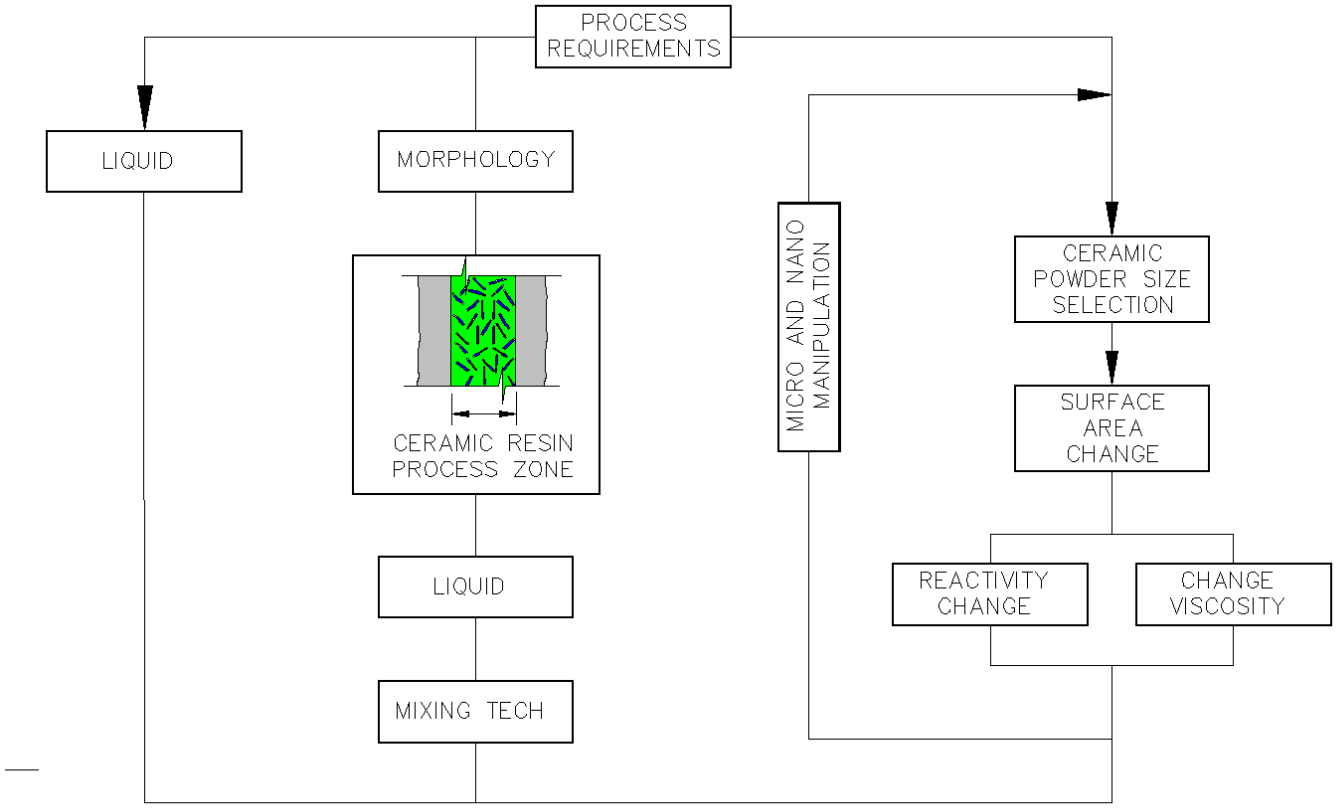
Pultrusion Process Development

Rheology Control (Cementitious)



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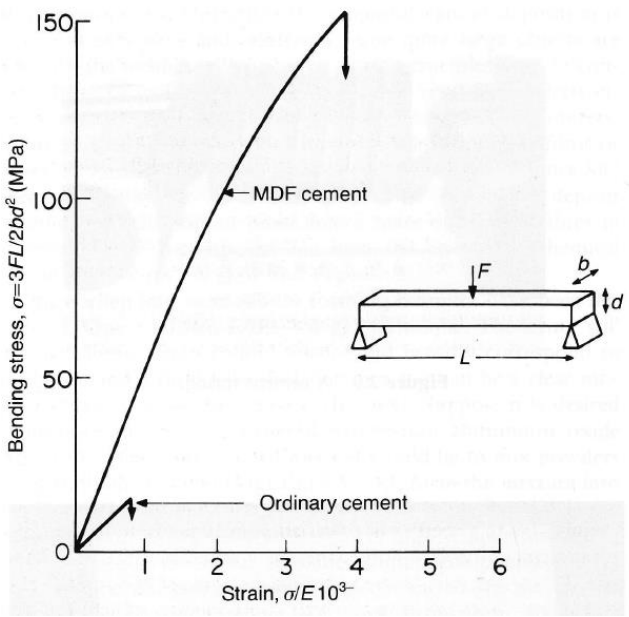
Pultrusion Process Development

How is Strength Dependency on Porosity and Pore Size? (Griffith 1921)

- $\sigma = \sqrt{(1-p)^3 exp(-kp)}\sqrt{\frac{E_0 R_0}{\pi c}}$

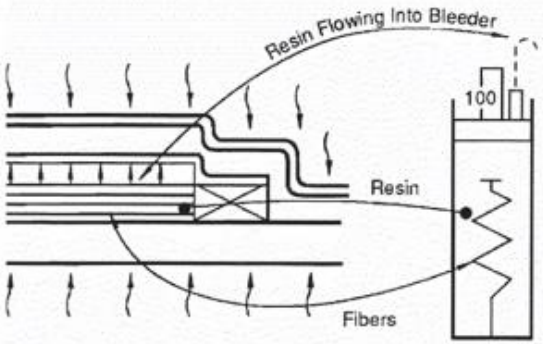


Key Observations

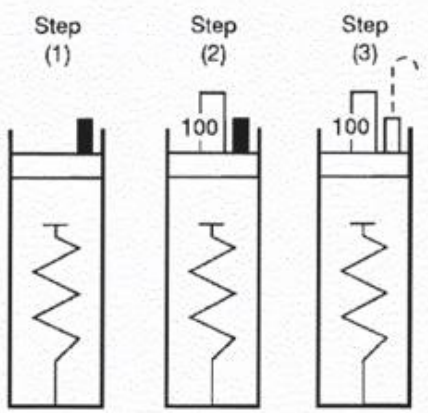
- Strength can be improved by reducing the porosity (p)
- The reduction of the porosity by 30% increases the strength by a factor of 2
- Strength can be improved by reducing the pore size c
- The reduction of the pore size from 1 mm to 0.01 mm increases the strength by a factor of 10

Pultrusion Process Development
Insights from Boeing Prepreg Porosity Study

Campbell, Flake C., Andrew R. Mallow, and Clarles E. Browning. "Porosity in carbon fiber composites an overview of causes." *Journal of Advanced Materials* 26.4 (1995): 18-33.



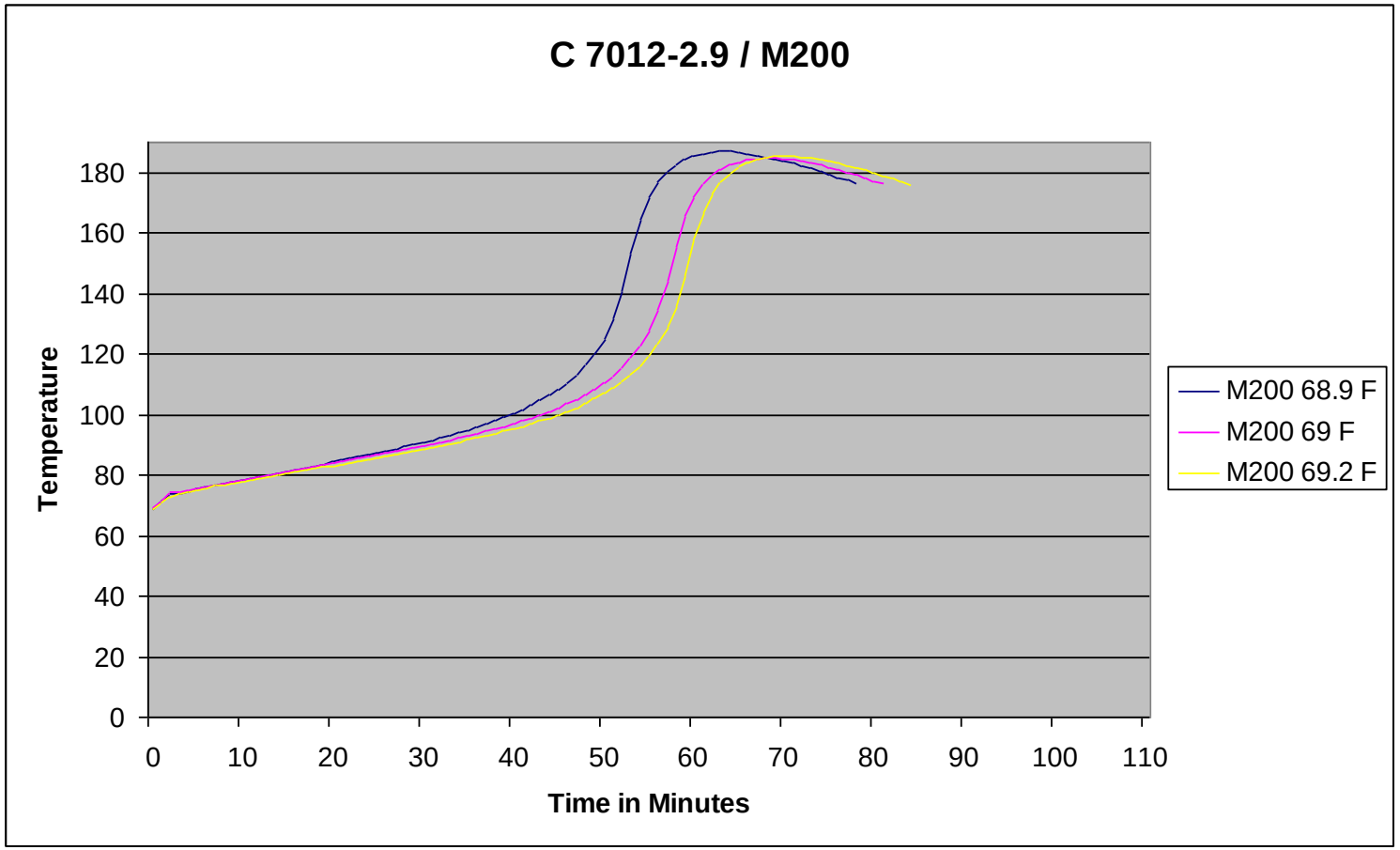
Prepreg can be modeled as a fluid-filled (resin) piston with spring (fiber bed) and valve (resin loss pathways)



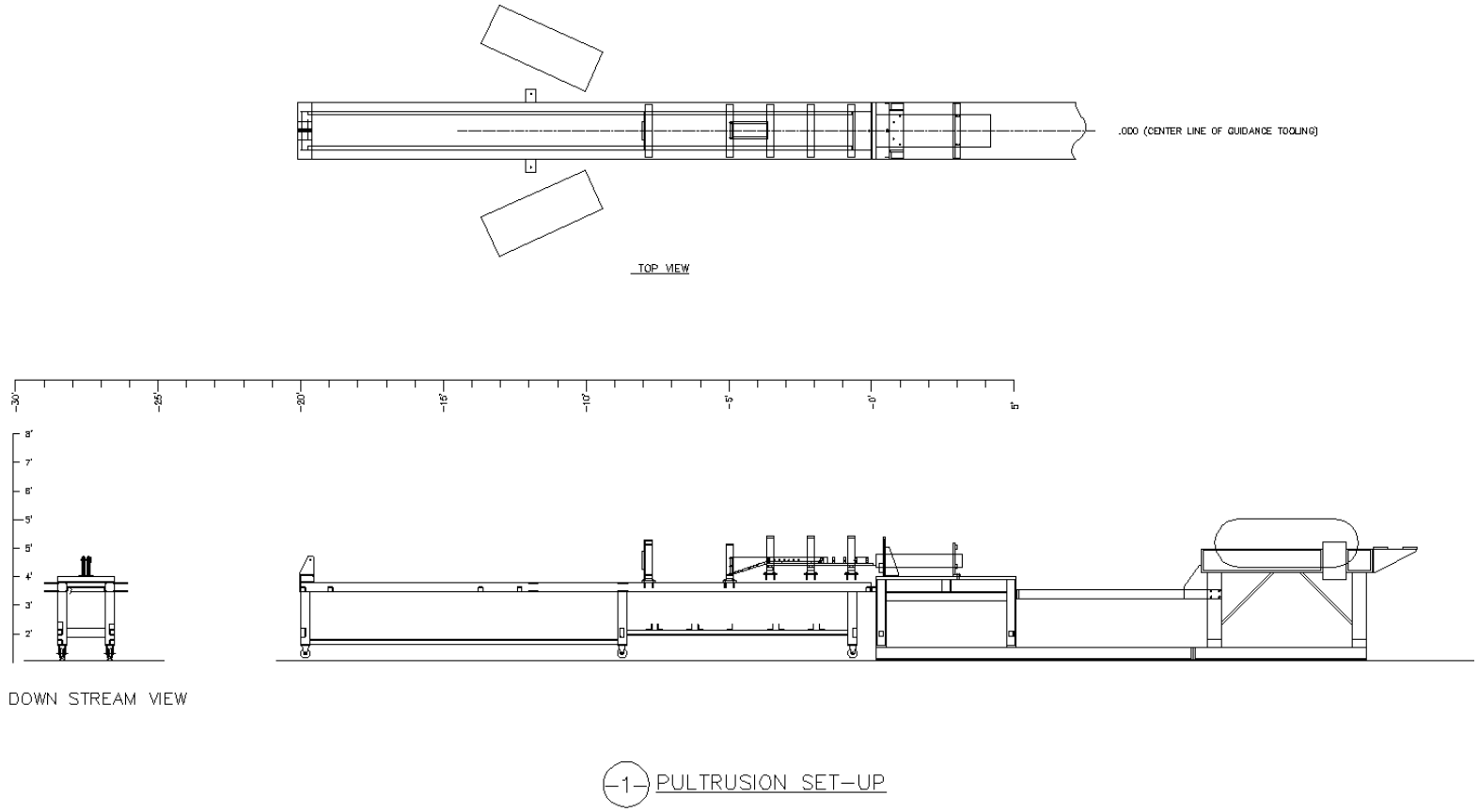
	Step (1)	Step (2)	Step (3)	Step (4)
$P_{applied}$	0	100	100	100
$P_{hydrostatic}$	0	100	100	75
P_{spring}	0	0	0	25
	Initial state, no applied pressure	Pressure applied, carried by resin	Valve opened, resin can escape	Load transfers to fiber bed with resin loss

Pultrusion Process Development

Cure Behavior/ Resin Cures to a PH of 7



Pultrusion Process Development



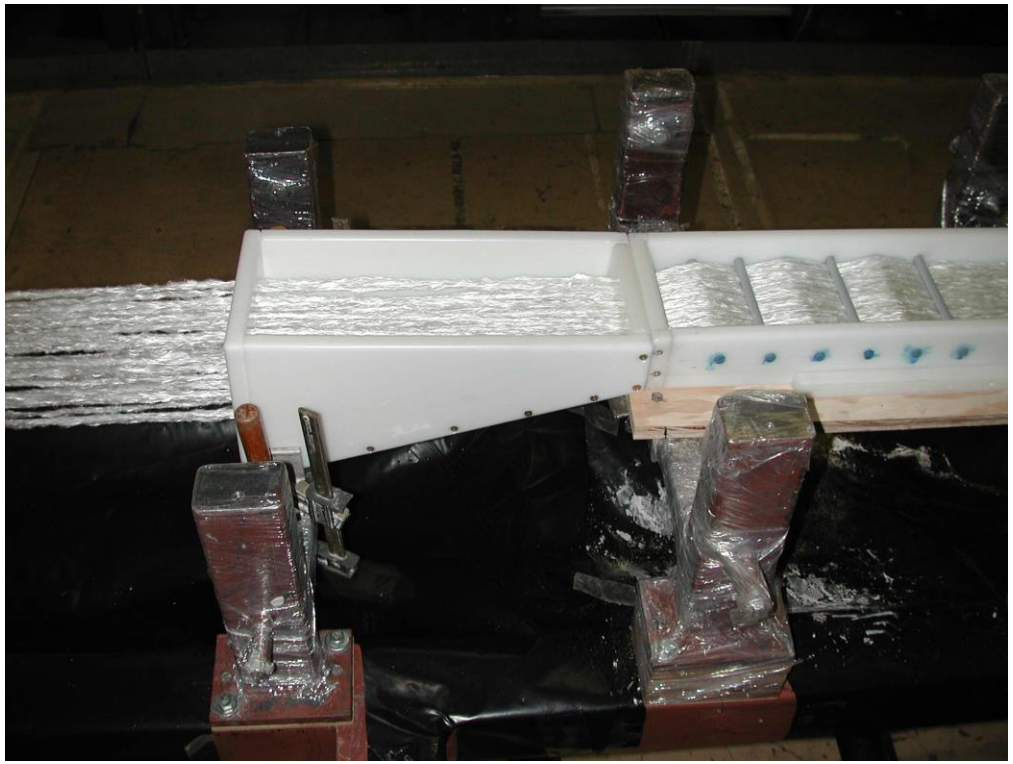
-1- PULTRUSION SET-UP

Pultrusion Process Development

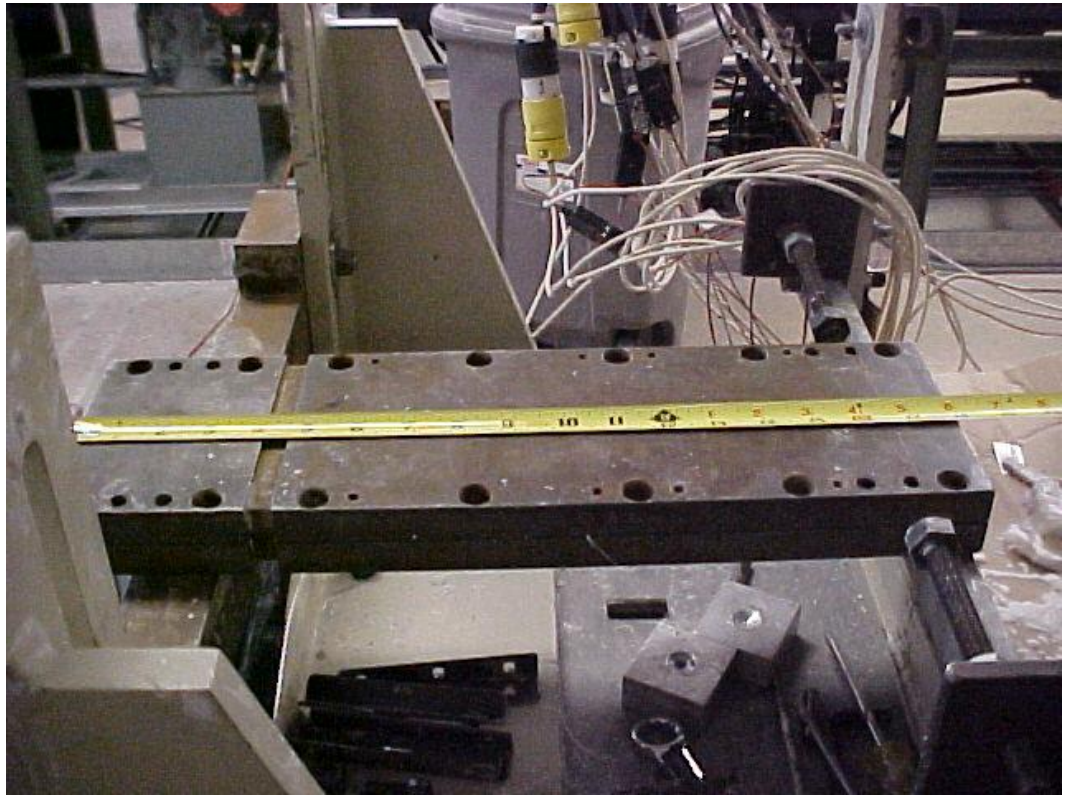
Open tank with CBC Resin meets OSHA requirements / Fiber is E-glass

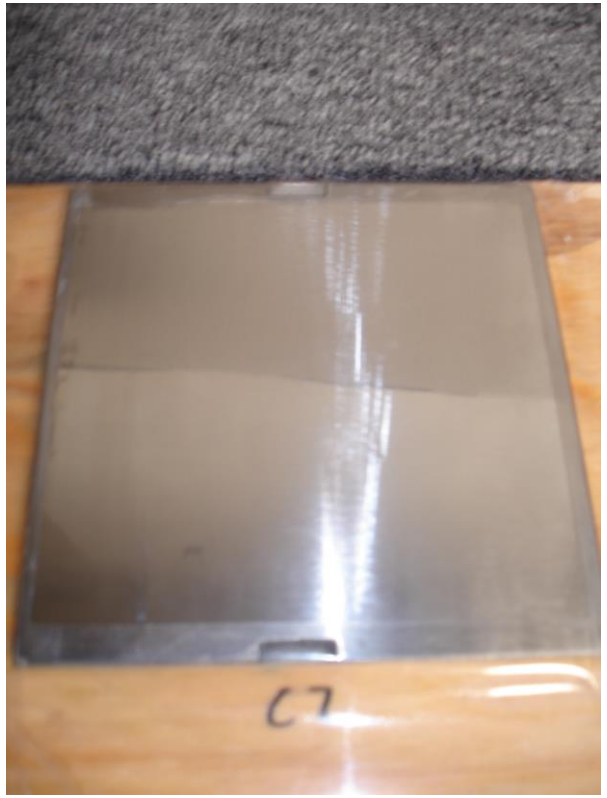
Pultrusion Setup

Impregnation



Pultrusion Process Development





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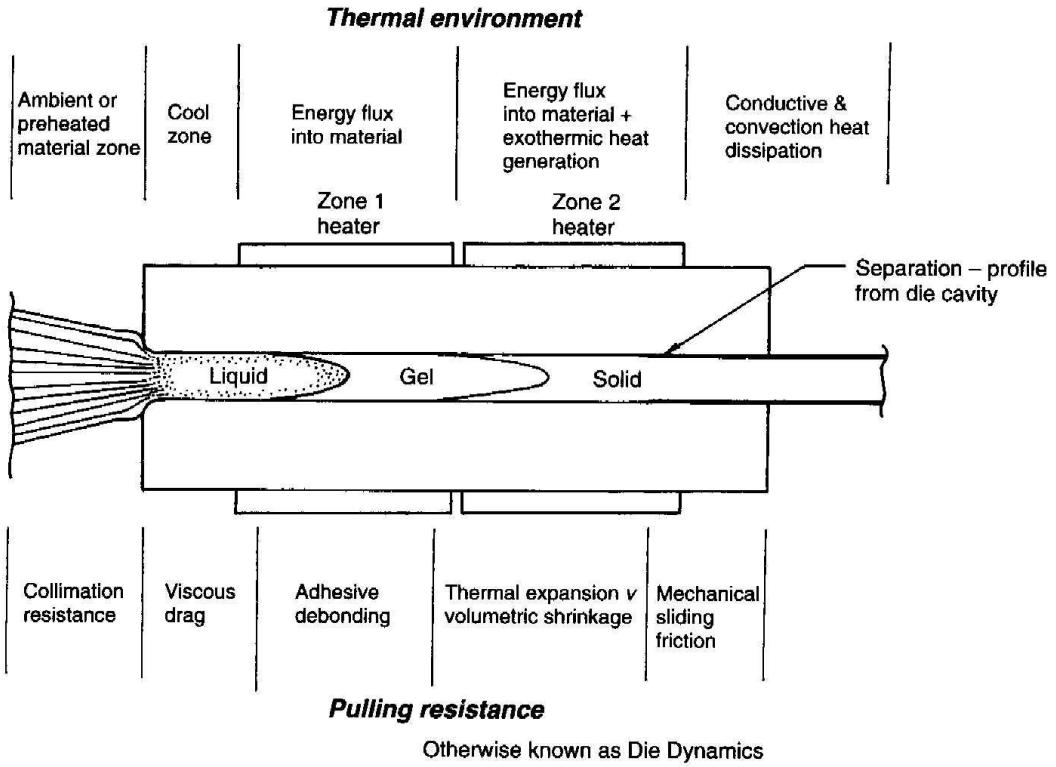
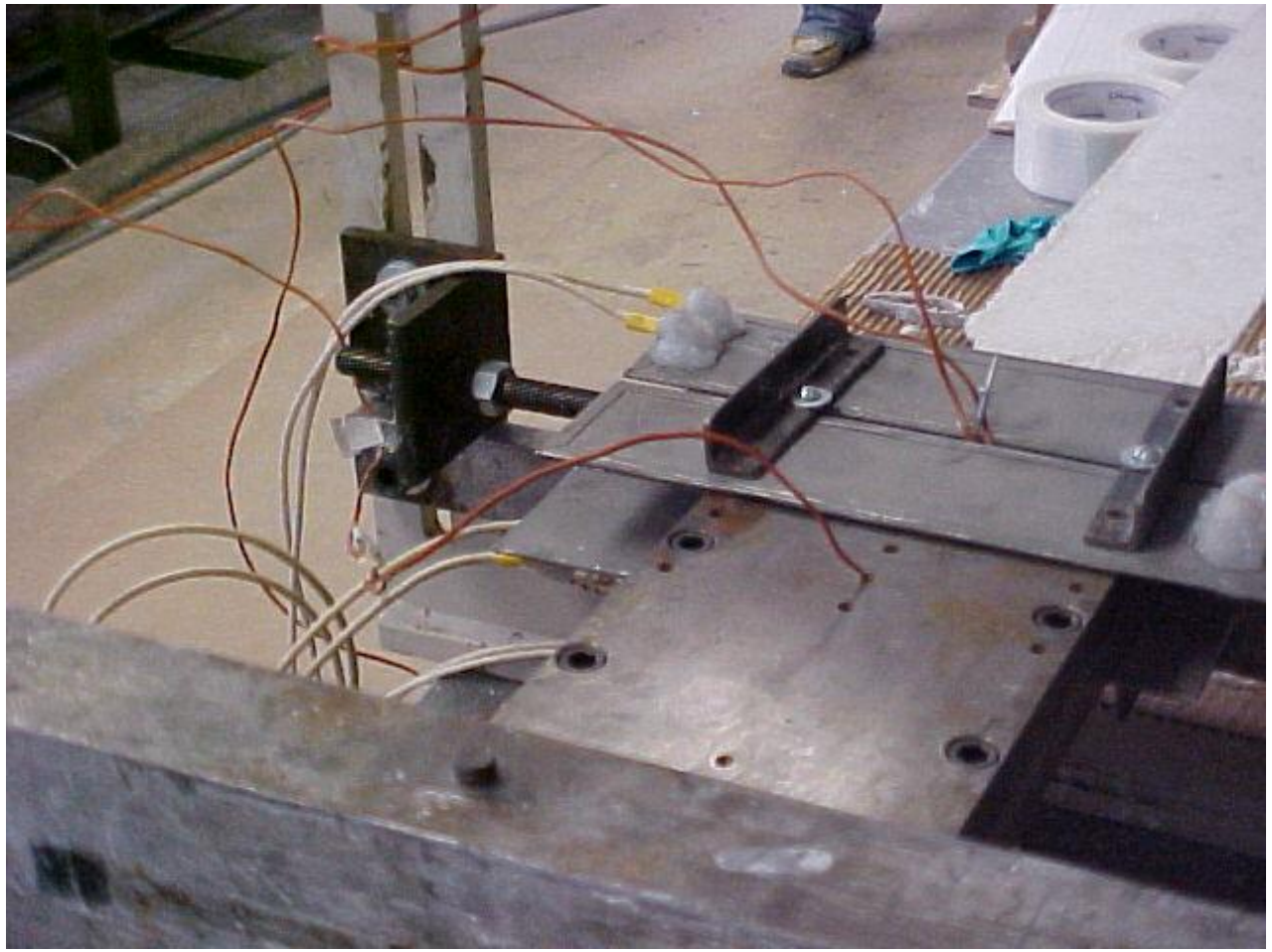
Pultrusion Process Development



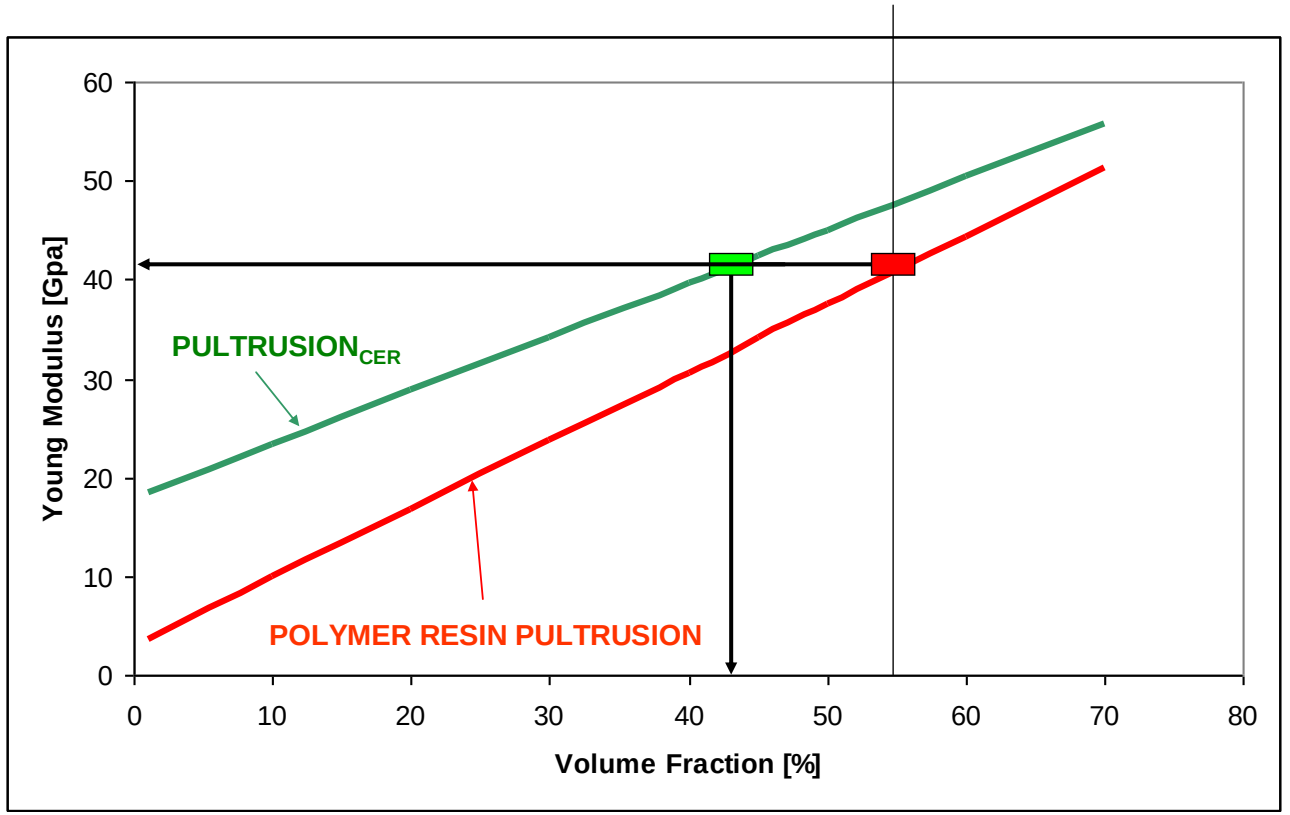


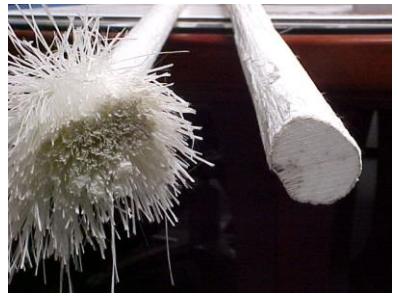
Pultrusion Process Development

Pultrusion Process Development

DETAIL JUSTIFICATION FOR VOLUME FRACTION TARGET OF 42%

Pultrusion Process Development





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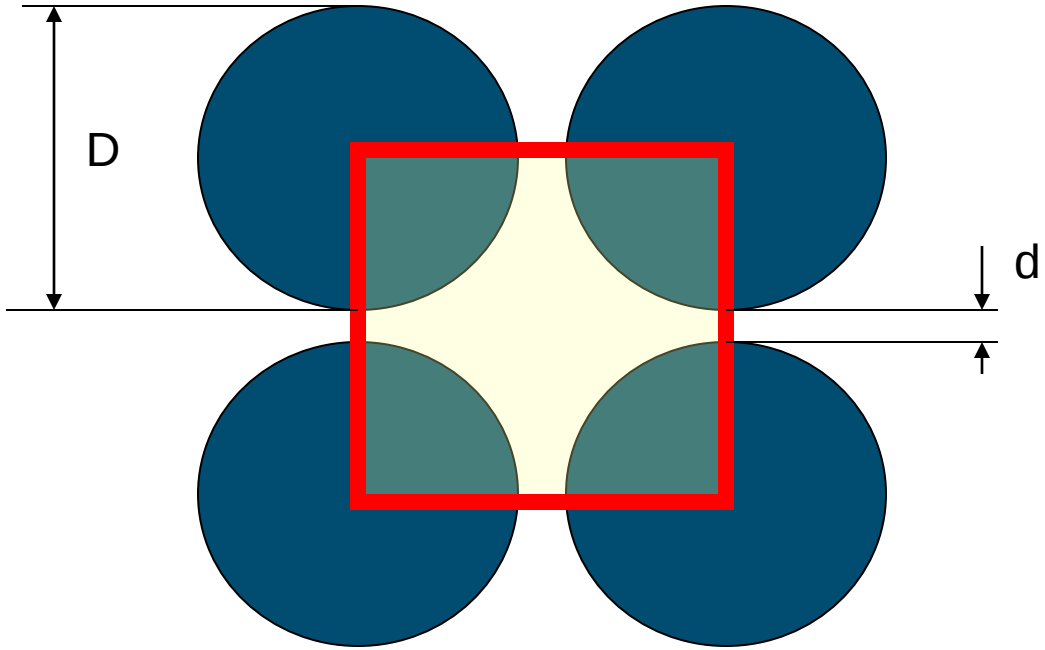
VOLUME FRACTION



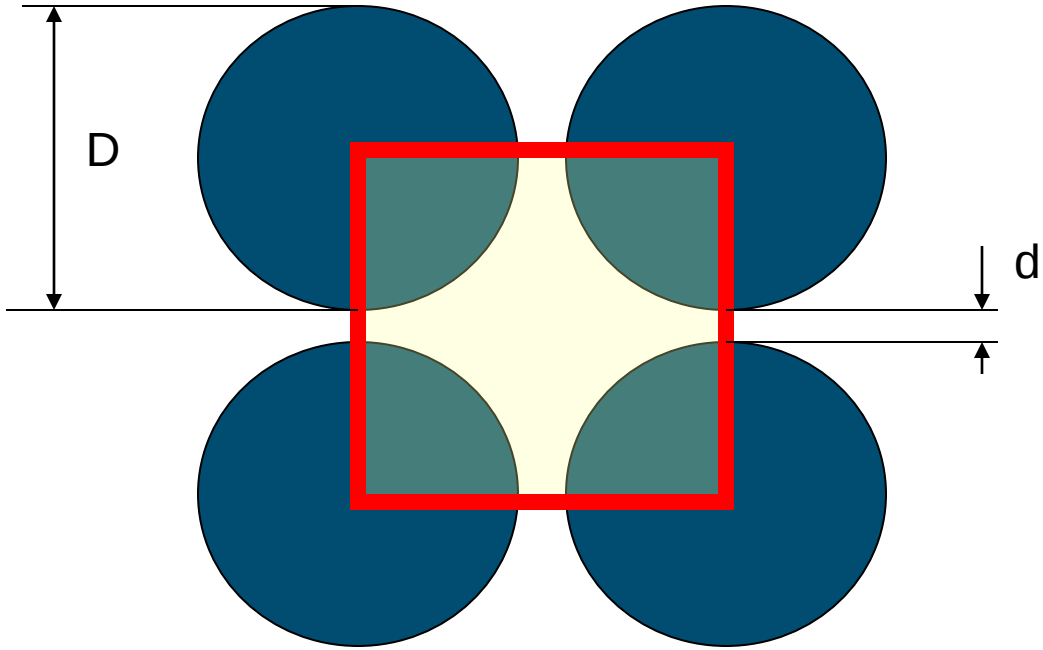
$$v_f = \frac{\frac{\pi D^2}{4}}{(D+d)^2}$$

$$D + d = D\sqrt{\frac{\pi}{4v_f}}$$

$$d = D\left(\sqrt{\frac{\pi}{4v_f}} - 1\right)$$

Pultrusion Process Development

VOLUME FRACTION

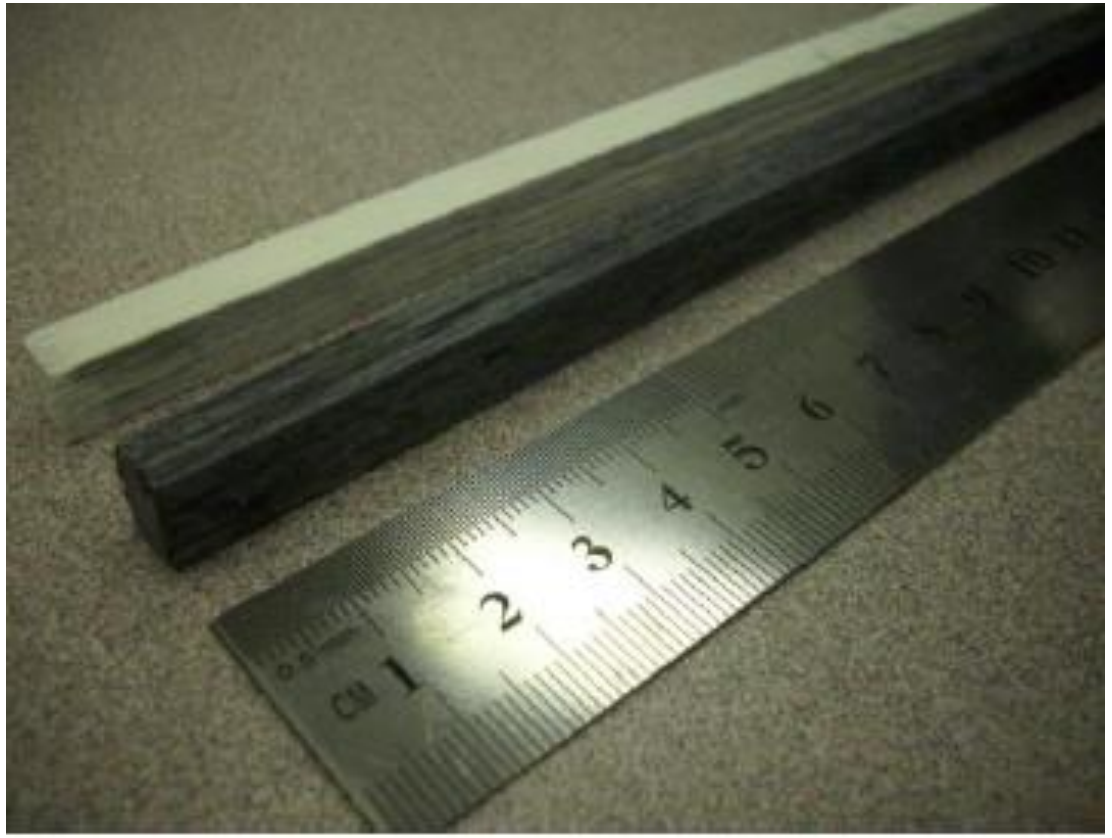


$$d = D\left(\sqrt{\frac{\pi}{4v_f}} - 1\right)$$

D	22	Micron					
Vf	d		d/D				
0.1	39.7		1.80				
0.2	21.6		0.98				
0.3	13.6		0.62				
0.4	8.83		0.40				
0.5	5.57		0.25				
0.6	3.17		0.14				
0.7	1.3		0.06				

$$\frac{d}{D} = 0.4$$

Pultrusion Process Development



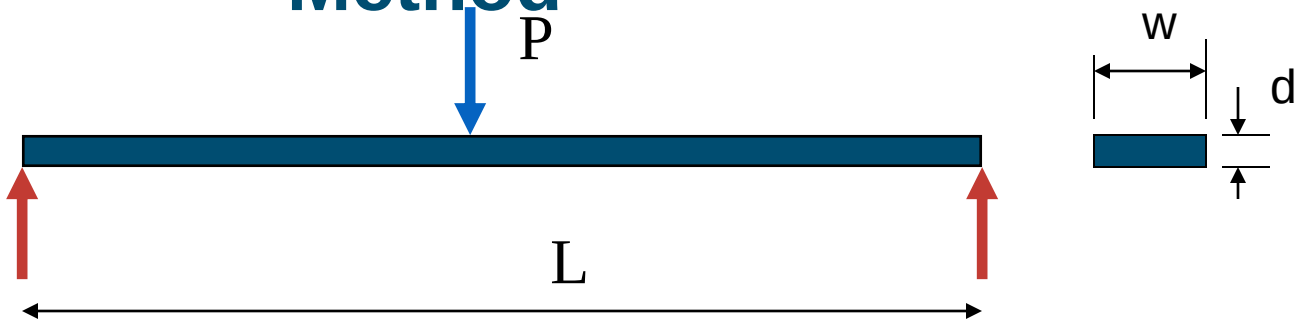
Pultrusion Process Development

COMPOSITE BEAM

$$m = Lwd(\rho_f V_f + \rho_m(1 - V_f)$$

$$S = \frac{F}{\delta} = \frac{48EI}{L^3} = \frac{48\left[E_f V_f + E_m(1 - V_f)\right]\frac{wd^3}{12}}{L^3}$$

Optimization with the Lagrange (Laurant) Multiplier Method



$$L = Lwd(\rho_f V_f + \rho_m(1 - V_f) + \mu\left\{S - \frac{48[E_f V_f + E_m(1 - V_f)]\frac{wd^3}{12}}{L^3}\right\}$$

$$\frac{\partial L}{\partial V_f} = 0$$

$$\frac{\partial L}{\partial d} = 0$$

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Pultrusion Process Development
COMPOSITE BEAM

$$V_f = \frac{\rho_m}{2(\rho_f - \rho_m)} - \frac{3E_m}{2(E_f - E_m)}$$

rho-m	1.6						
rho-f	2.5						
E-m	18						
E-f	72						
			Term 1	Term 2	Volume-fract		
			0.89	0.5	0.39		
E-comp	39.00						
Rho-comp	1.95						
merit-fig	6.67						

$$V_f = 39\%$$

Summary and Conclusions

- Inorganic resins fill the technology gap between organic polymer composites and ceramic composites.
- Inorganic resins could capture a significant share of the market for High Temperature/ Fire applications
- We presented results for a particular inorganic CBC resin that was developed at the university of Brussels around 2005 and significantly improved by CSSI.
- Several Applications have been reviewed
- The Inorganic CBC resin is pultrudable and compatible with E-glass (PH=7)