

A WEBINAR ON:

RESIN BEHAVIOUR DURING PROCESSING:

*Key Resin Properties to Consider
When Developing a Manufacturing Process*

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YOUR HOSTS



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Assistant Professor of Teaching, University of British Columbia

Co-Director of Advanced Materials Manufacturing MEL Program, UBC

Director, Knowledge in Practice Centre, Composites Knowledge Network

- Ph.D. and M.A.Sc. in Composite Materials Engineering
- Over 15 years experience in industry and academia working on polymer matrix composites in aerospace, automotive, marine, energy, recreation and others
- Experience working with over 150 companies from SME to major international corporations
- Expertise in liquid composite moulding and thermal management

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YOUR HOSTS



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Research Associate/Sessional Lecturer, University of British Columbia

Team Lead, Composites Research Network

Director, Industry Projects, Composites Knowledge Network

- Ph.D. and M.A.Sc. in Chemical Engineering
- Awarded materials scientist – Rio Tinto Alcan award for academic research excellences
- Over 30 publications, conference presentations and patents in the field of polymer matrix composites
- Experience working with over 80 SMEs and international companies to develop new manufacturing processes and products

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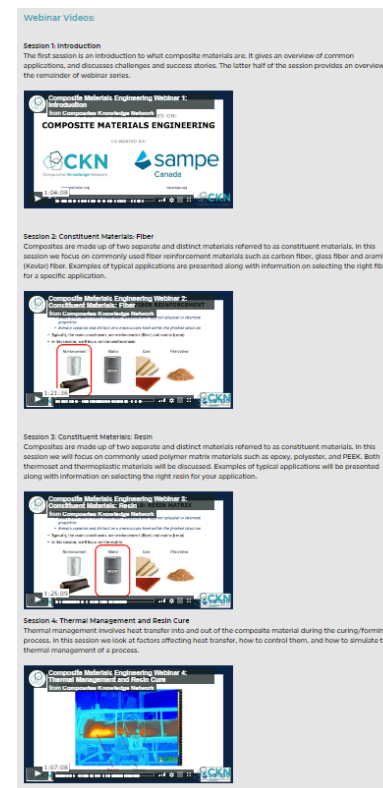


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WEBINARS

REIGNITING THE CANADIAN COMPOSITES MANUFACTURING INDUSTRY

12-PART WEBINAR SERIES



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KNOWLEDGE IN PRACTICE CENTRE (KPC)

- A freely available online resource for composites engineers:
<https://compositeskn.org/knowledge-in-practice-centre/>
- Focus on practice, guided by foundational knowledge and a systems-based approach to composites manufacturing

Practice

[Read more](#)



Systems Catalogue



Practice



Case Studies



Perspectives

Knowledge

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Introduction to
composites



Foundational Knowledge



Systems Knowledge

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Perspectives - A8


Welcome to the Perspectives volume. This volume is primarily based on multimedia content and serves as a bridge for linking what you have learned in the other volumes of the Knowledge in Practice Centre out to what other practitioners are doing in their projects and research. The three types of content linked below include presentations, interviews, and *Application and Impact Mobilization* (AIM) event recordings. Presentations and interviews are the primary sections linking out to external perspectives on composites, while the AIM event recording section contains CKN's perspective on how to apply composites knowledge.

Refer to the [Level I](#) view to navigate to the perspectives content quickly, or refer to the [Level II](#) view to navigate to the perspectives content with additional context. [Level II](#) provides more information on the relationship between know-how & know-why, and why it is important to protect the fundamentals of any processes or conventions already in place.

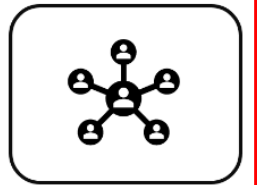
Level I **Level II**



Presentations



Interviews
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AIM Event Recordings

CKN Knowledge in Practice Centre

Welcome

Welcome to the CKN Knowledge in Practice Centre (KPC). The KPC is a resource for learning and applying scientific knowledge to the practice of composites manufacturing. As you navigate around the KPC, refer back to the information on this right-hand pane as a resource for understanding the intricacies of composites processing and why the KPC is laid out in the way that it is. The following video explains the KPC approach:



Understanding Composites Processing

The Knowledge in Practice Centre (KPC) is centered around a structured method of thinking about composite material manufacturing. From the top down, the hierarchy consists of:

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TODAY'S TOPIC:

RESIN BEHAVIOUR DURING PROCESSING:

*Key Resin Properties to Consider
When Developing a Manufacturing Process*

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INTRODUCTION

- Learning objectives:
 - Understand how the resin transforms during processing
 - Identify and understand the key properties to consider when developing, optimizing or troubleshooting a manufacturing process
 - Understand the information commonly available in technical data sheet
 - Understand instruments used to characterize manufacturing properties

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HOW DOES THE RESIN TRANSFORM DURING MANUFACTURING?

The resin liquid-to solid-transition

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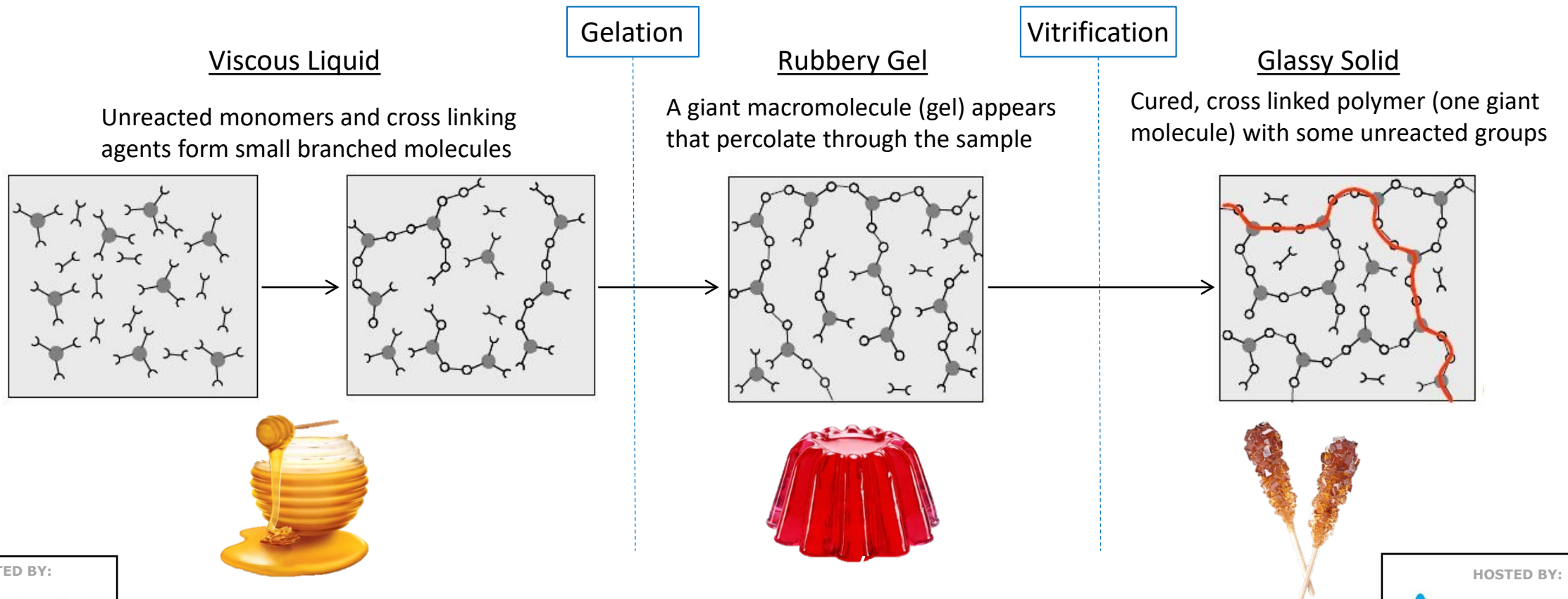


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KPC A162: CURE OF THERMOSETTING POLYMERS

- During polymerization the resin goes through different phases
- At gelation it changes from a viscous liquid to a rubbery gel
- As the curing advances, the rubbery gel transforms into a glassy solid at vitrification



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WHAT ARE THE KEY PROPERTIES TO CONSIDER?

Viscosity, gel time, heat of reaction, degree of cure, etc.

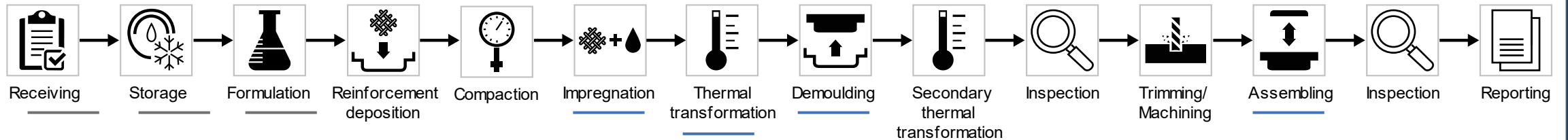
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KPC A215: MANUFACTURING WORKFLOW

- Let's look at a Resin Transfer Moulding (RTM) workflow
- Underlined in blue are the steps we will discuss

Key Manufacturing Steps:



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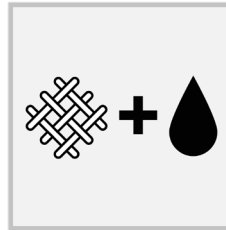
IMPREGNATION STEP

INPUT

Liquid resin

STEP

Impregnation



OUTCOMES

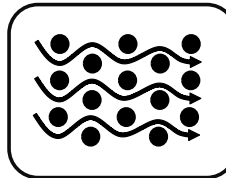
Impregnated reinforcement

Material properties:

- **Resin viscosity**
- **Resin gel time**
- *Reinforcement's permeability*
- *Resin/reinforcement surface tension and contact angle*
 - *etc.*

ANALYSIS

Flow and consolidation management



[KPC A158](#)

Filling time, dry spots, micro/macro-voids formation

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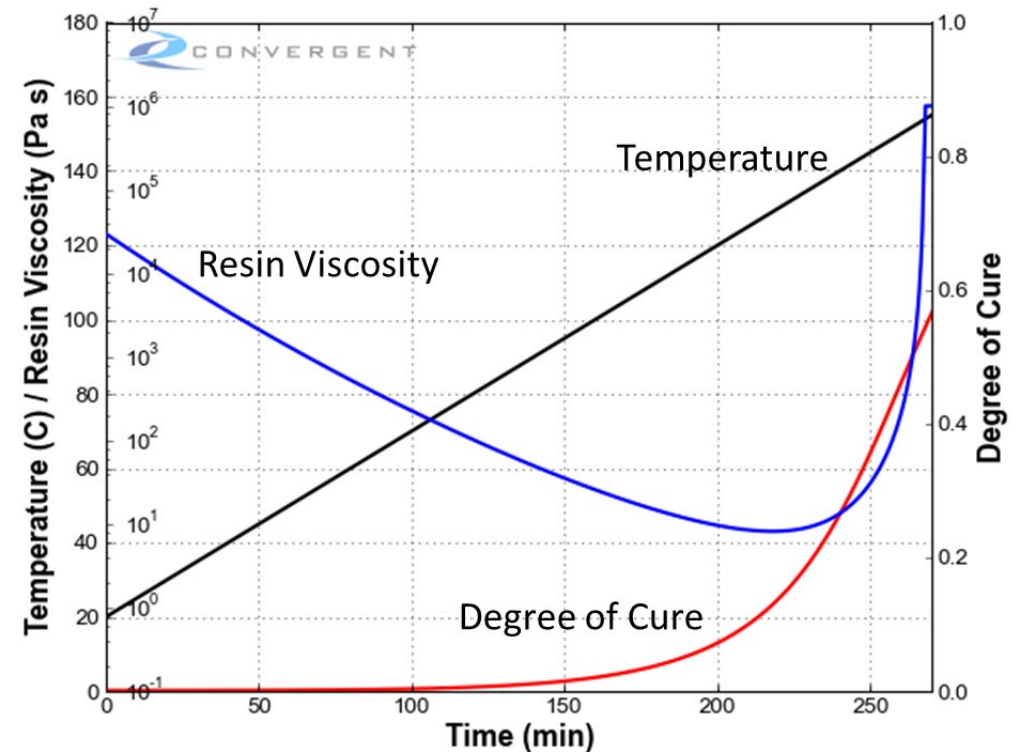
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KPC A203: VISCOSITY

- Viscosity is an indicator of how easily the resin will impregnate the reinforcement
- Viscosity is a function of both temperature and degree of cure and can be described using empirical models such as an Arrhenius-type equation:

$$\mu = Ae^{\frac{\Delta E}{RT}} f(\alpha)$$

Where A is a constant, ΔE is the activation energy, $f(\alpha)$ is the dependency on the degree of cure, α and RT describes the kinetic energy as a function of the temperature, T



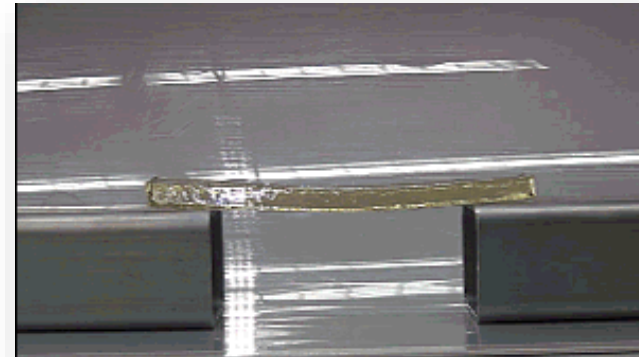
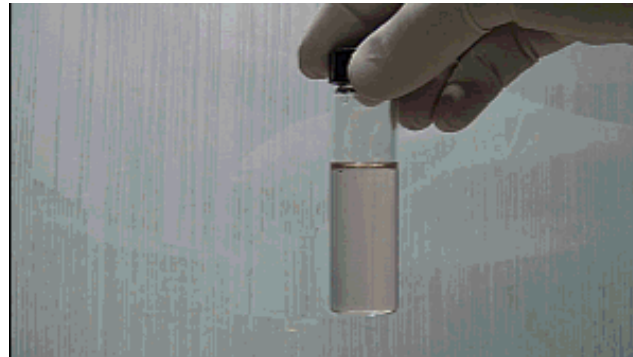
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KPC A162: GEL TIME

- Gel time indicates when gelation occurs, i.e. when the resin transforms from a liquid to a soft gel and stops flowing

GELATION
Liquid → Gel



- Gel time depends on degree of cure. Epoxy resins typically gel at a degree of cure of 0.5 while polyester resins gel before a degree of cure of 0.15

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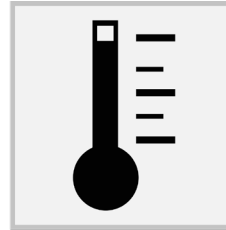
KPC A172: THERMAL TRANSFORMATION STEP

INPUT

Uncured resin

STEP

Thermal transformation



OUTCOMES

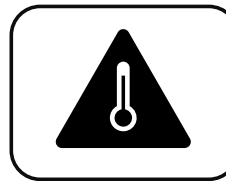
Cured resin

Material properties:

- **Resin's cure kinetics**
- **Resin's heat of reaction**
- *Resin's thermal conductivity*
 - *Resin's heat capacity*
 - *Resin's density*
- *Reinforcement's thermal conductivity*
 - *etc.*

ANALYSIS

Thermal management



KPC A107

Degree of cure, exotherm, etc.

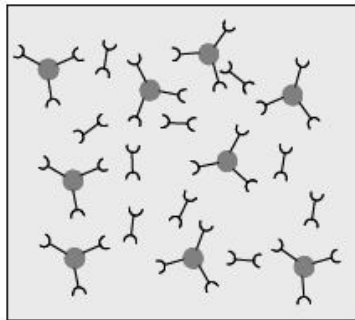
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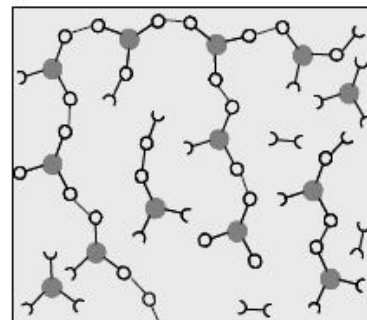
KPC A104: DEGREE OF CURE

- Degree of cure (DOC) is an indication of how far the crosslinking is advanced in a thermoset resin
- DOC is defined with a number between 0 and 1 (or 0% and 100%) where 100% is a fully cured resin

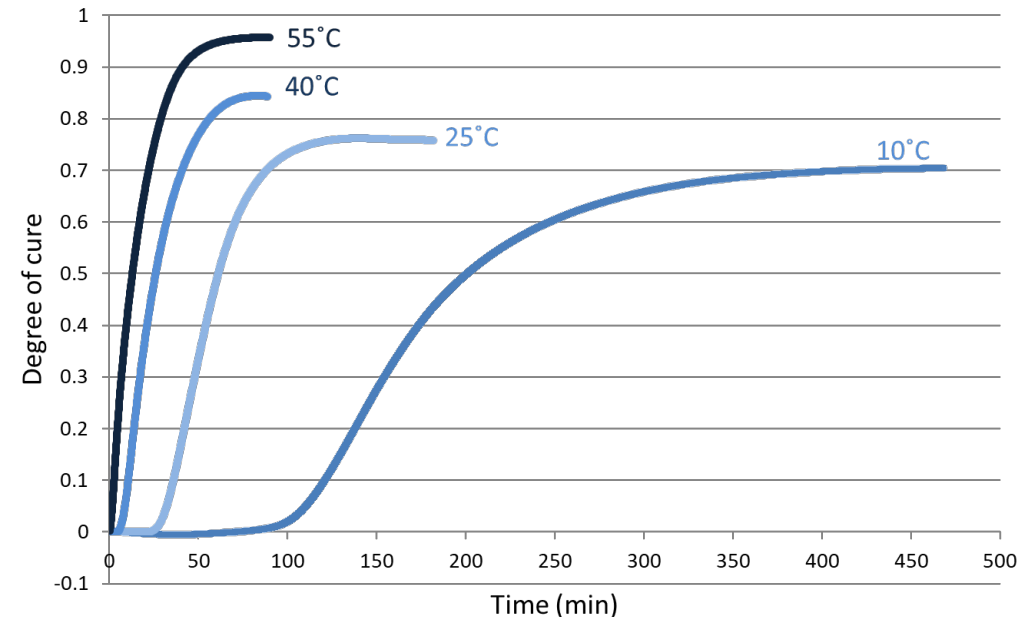
Low Degree of Cure



High Degree of Cure

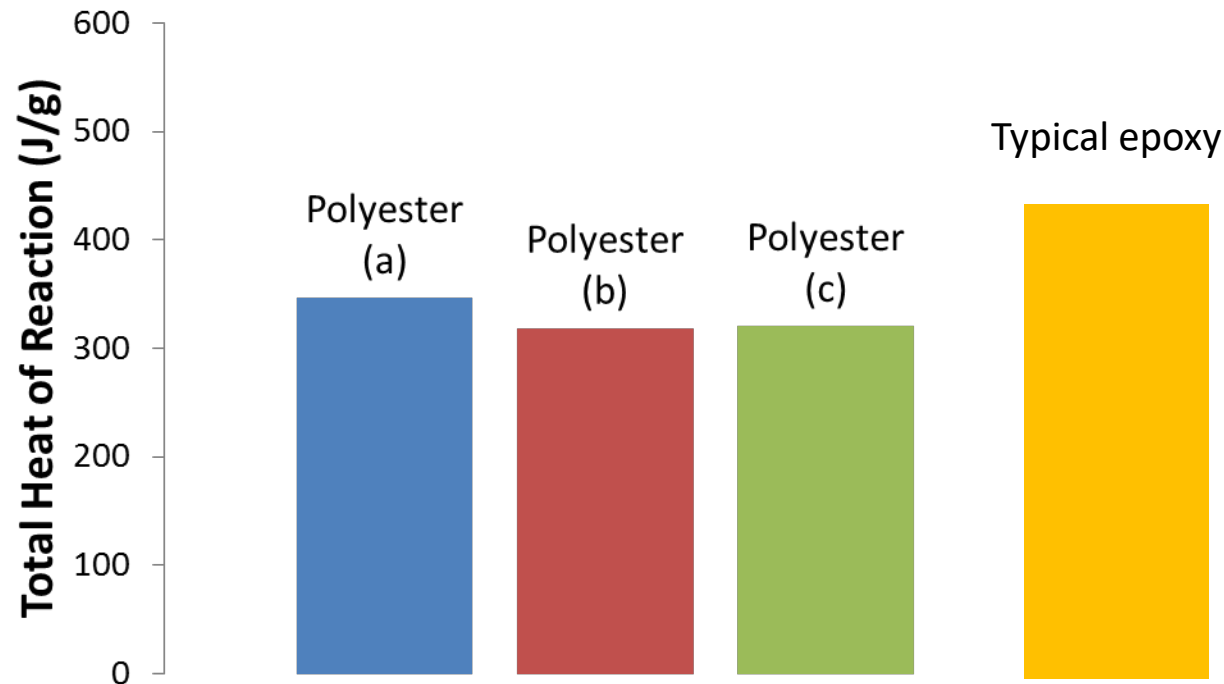


- Degree of cure is dependent on temperature and time (thermal history)



KPC A114: HEAT OF REACTION

- Cure of thermoset resins is an exothermic reaction and heat is generated during the curing process
- A thermoset resin has the potential to release a certain amount of energy while curing, referred to as the total heat of reaction, H_R (unit of J/g)



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DEMOLDING STEP

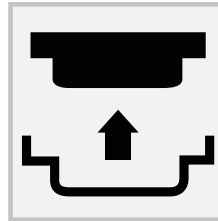
INPUT

Part on tool

- Material properties:
- Resin's cure kinetics
 - **Resin's glass transition temperature**
 - *Resin's thermal conductivity*
 - *Resin's heat capacity*
 - *Resin's density*
 - *Reinforcement's thermal conductivity*
 - *etc.*

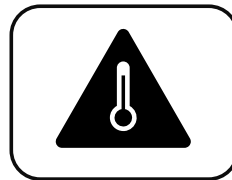
STEP

Demolding



ANALYSIS

Thermal management



[KPC A107](#)

OUTCOMES

Free-standing part

Resin's glass transition temperature and part's temperature

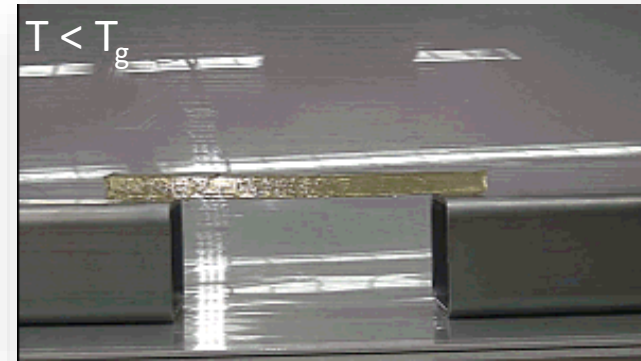
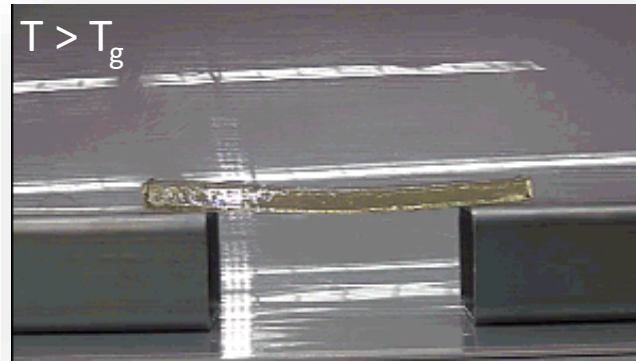
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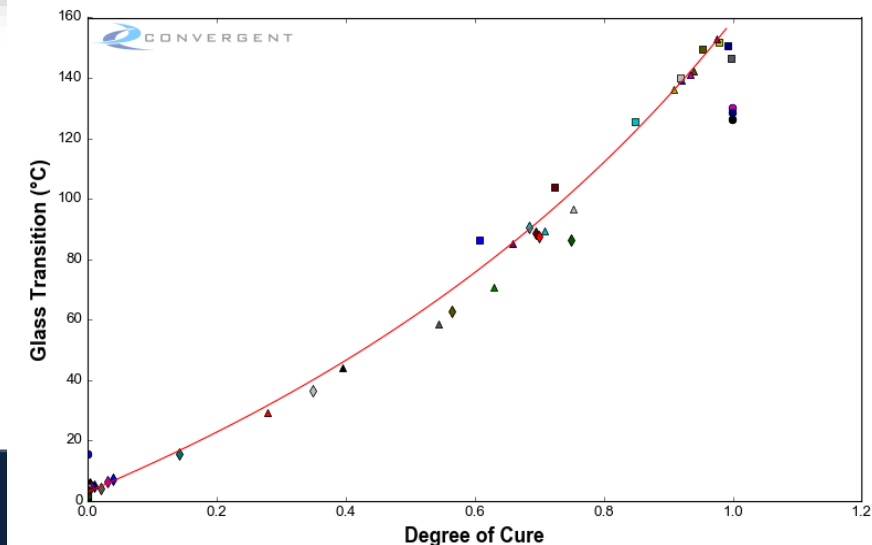
KPC A102: GLASS TRANSITION TEMPERATURE (T_g)

- When heated above their T_g , thermosets soften and transition from hard, glassy materials to soft, rubbery materials

GLASS TRANSITION
Gel \rightarrow Glass



- The glass transition temperature is a function of degree of cure
- Typically want to demould below T_g



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ASSEMBLY STEP

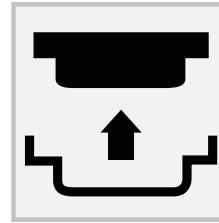
INPUT

Multiple components

- Material properties:
- **Resin's cure shrinkage**
 - **Resin's coefficient of thermal expansion**
 - *Reinforcement coefficient of thermal expansion*
 - *etc.*

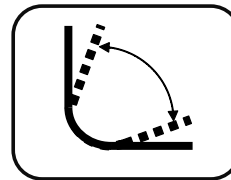
STEP

Assembly



ANALYSIS

Residual stress and dimensional control management



[KPC A165](#)

OUTCOMES

Assembly

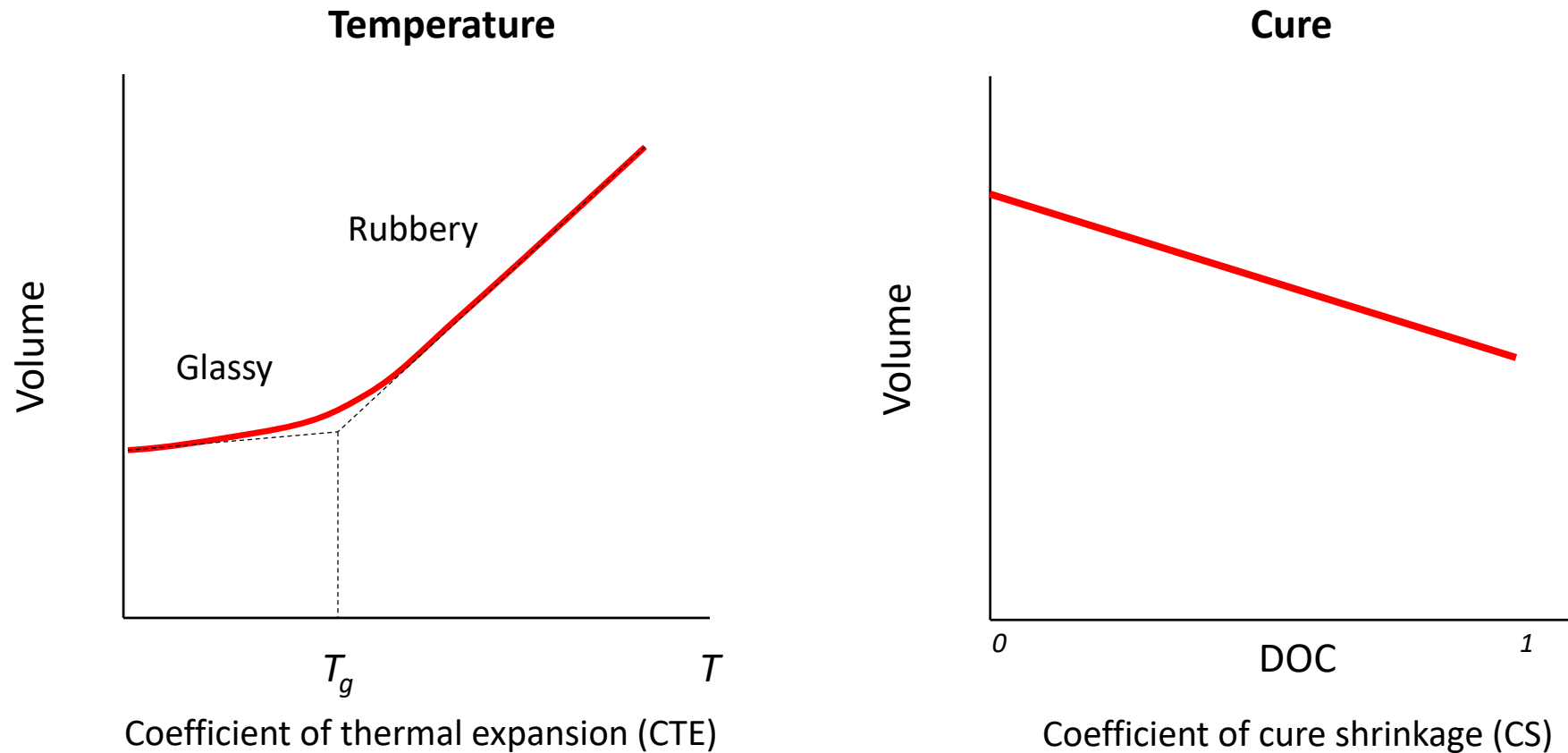
Spring in, warpage, residual stresses

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KPC A102: THERMO-VOLUMETRIC BEHAVIOUR

- Volume of thermoset resins changes with temperature and cure



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WHAT INFORMATION IS COMMONLY AVAILABLE IN TECHNICAL DATA SHEET?

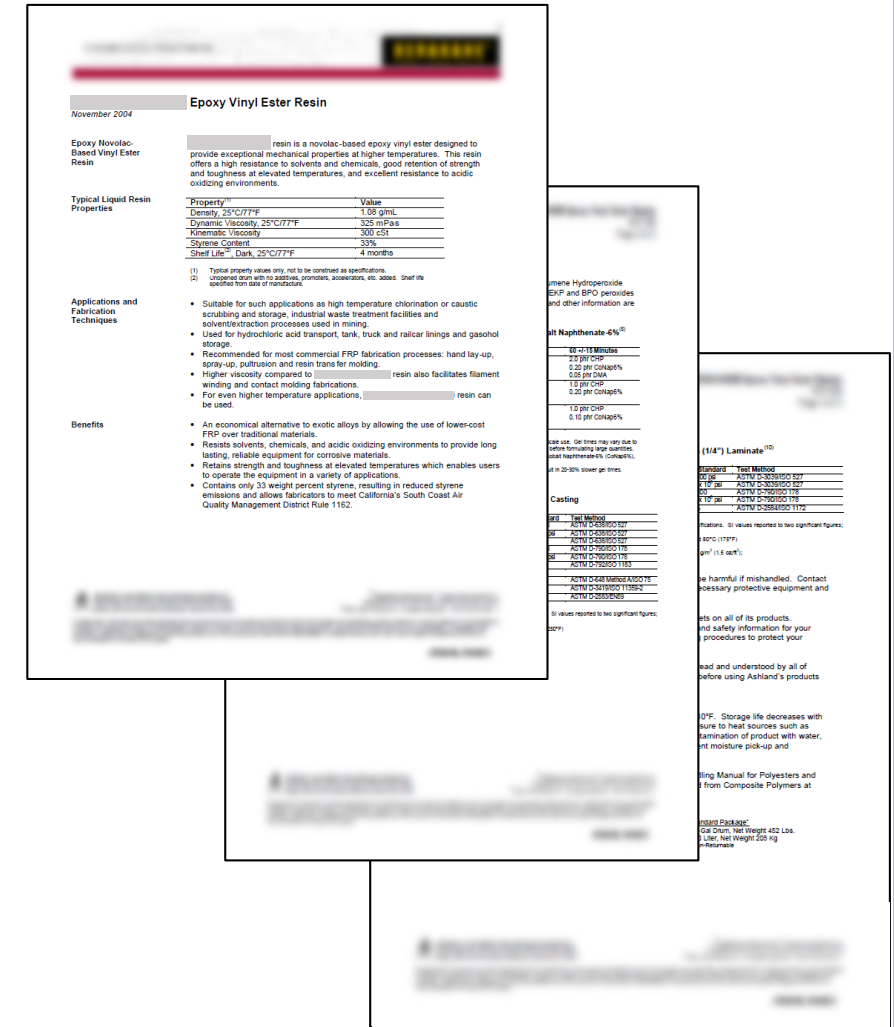
Let's look at neat resin and prepreg material systems

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Example Technical Data Sheets

- Technical Data Sheets (TDS) usually focus on design properties and include limited manufacturing properties*
- Viscosity, gel time and a baseline cure cycle are commonly given
- With polyester and vinyl ester, end users can define their own formulations, which further limits the information in a TDS
- The TDS is for the resin, what about the fibre, what about the composite?
- *Let's review a vinyl ester resin and epoxy prepreg TDS*



*Based on the review of over forty TDSs. Soon available on the KPC

Example TDS – Vinyl Ester Resin

- What can we expect from a resin TDS, specifically a vinyl ester or polyester resin?
- This is an 'industrial grade' resin vs an aerospace grade that we'll see next

November 2004

Epoxy Vinyl Ester Resin

Epoxy Novolac-Based Vinyl Ester Resin

Typical Liquid Resin Properties

[REDACTED] resin is a novolac-based epoxy vinyl ester designed to provide exceptional mechanical properties at higher temperatures. This resin offers a high resistance to solvents and chemicals, good retention of strength and toughness at elevated temperatures, and excellent resistance to acidic oxidizing environments.

Property ⁽¹⁾	Value
Density, 25°C/77°F	1.08 g/mL
Dynamic Viscosity, 25°C/77°F	335 mPa·s
Kinematic Viscosity	300 cSt
Styrene Content	35%
Shelf Life ⁽²⁾ , Dark, 25°C/77°F	4 months

(1) Typical property values only; not to be construed as specifications.
(2) Unopened drum with no additives, promoters, accelerators, etc. added. Drum life specified from date of manufacture.

Applications and Fabrication Techniques

- Suitable for such applications as high temperature chlorination or caustic scrubbing and storage, industrial waste treatment facilities and solvent-extraction processes used in mining.
- Used for hydrochloric acid transport, tank, truck and railcar linings and gasohol storage.
- Recommended for most commercial FRP fabrication processes: hand lay-up, spray-up, pultrusion and resin transfer molding.
- Higher viscosity compared to [REDACTED] resin also facilitates filament winding and contact molding fabrications.
- For even higher temperature applications, [REDACTED] resin can be used.

Benefits

- An economical alternative to exotic alloys by allowing the use of lower-cost FRP over traditional materials.
- Resists solvents, chemicals, and acidic oxidizing environments to provide long lasting, reliable equipment for corrosive materials.
- Retains strength and toughness at elevated temperatures which enables users to operate the equipment in a variety of applications.
- Contains only 33 weight percent styrene, resulting in reduced styrene emissions and allows fabricators to meet California's South Coast Air Quality Management District Rule 1162.

styrene Hydroperoxide
BKP and BPO peroxides
and other information are

3M Naphthenate 4%⁽¹⁾

Oil Type	Weight %
20 WEP OIL	0.01 wt %
0.01 wt % DPA	0.01 wt %
0.01 wt % DPA	0.01 wt %
0.01 wt % DPA	0.01 wt %
0.01 wt % DPA	0.01 wt %
0.01 wt % DPA	0.01 wt %

Note: Oil type. Oil type may vary due to lot-to-lot variations.

Notes: Naphthenate 4% (Naphthenate).

at 10-20% cover per lot.

Casting

ASTM Test Method	Test Method
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02

(1) Values reported to two significant figures.

(2) Values reported to two significant figures.

(1/4") Laminate⁽¹⁾

Material	Test Method
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02
ASTM D-3050-02	ASTM D-3050-02

Notes: (1) Values reported to two significant figures.

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(3) Values reported to two significant figures.

(4) Values reported to two significant figures.

(5) Values reported to two significant figures.

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(45) Values reported to two significant figures.

Example TDS – Vinyl Ester Resin

- Example of a common vinyl ester resin

Property ⁽¹⁾	Value
Density, 25°C/77°F	1.08 g/mL
Dynamic Viscosity, 25°C/77°F	325 mPas
Kinematic Viscosity	300 cSt
Styrene Content	33%
Shelf Life ⁽²⁾ , Dark, 25°C/77°F	4 months

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Applications and Fabrication Techniques

- Suitable for such applications as high temperature chipmolding or caustic scrubbing and storage, industrial waste treatment facilities and solvent/extraction processes used in mining.
- Used for hydrochloric acid transport, tank, truck and railcar linings and gasohol storage.
- Recommended for most commercial FRP fabrication processes: hand lay-up, spray-up, pultrusion and resin transfer molding. (resin) also facilitates filament winding and contact molding fabrications.
- For even higher temperature applications, (resin) can be used.

Benefits

- An economical alternative to exotic alloys by allowing the use of low-cost FRP over traditional materials.
- Resists solvents, chemicals, and acidic oxidizing environments to provide long lasting, reliable equipment for corrosive materials.
- Retains strength and toughness at elevated temperatures which enables users to operate the equipment in a variety of applications.
- Contains only 33 weight percent styrene, resulting in reduced styrene emissions and allows fabricators to meet California's South Coast Air Quality Management District Rule 1162.

mineral Hydroperoxide
BPO and BPO peroxides
and other information is

In Naphthalene 4%⁽¹⁾

Test Method	Value
ASTM D-3050D-02	2.0 phr CDP
ASTM D-3050D-02	0.05 phr CDA
ASTM D-3050D-02	0.05 phr CDA
ASTM D-3050D-02	1.0 phr CDP
ASTM D-3050D-02	0.10 phr CDA

See note. Gel times may vary due to ambient humidity and moisture.
Note: Naphthalene is combustible.

It is 20-30% slower gel times.

Casting

Test Method	Value
ASTM D-3050D-02	2.0 phr CDP
ASTM D-3050D-02	0.05 phr CDA
ASTM D-3050D-02	0.05 phr CDA
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ASTM D-3050D-02	0.10 phr CDA

Note: Values reported to two significant figures.
(phr) = parts per hundred.

1/4" Laminate⁽²⁾

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ASTM D-3050D-02	2.0 phr CDP
ASTM D-3050D-02	0.05 phr CDA
ASTM D-3050D-02	0.05 phr CDA
ASTM D-3050D-02	1.0 phr CDP
ASTM D-3050D-02	0.10 phr CDA

Note: Values reported to two significant figures.
(phr) = parts per hundred.
(1/4") = 1/4 inch.

If harmful if mishandled. Contact
necessary protective equipment and

its on all of its products.
to safety information for your
procedures to protect your

ad and understood by all of
before using Ashland's products

PF. Storage life decreases with
ure to heat sources such as
amination of product with water,
it moisture pick-up and

ing Manual for Polyesters and
from Composite Polymers at

Stand Package:
25 Gallon, Net Weight 432 Lbs.
Liner, Net Weight 25 kg
Net Weight

Example TDS – Vinyl Ester Resin

- Example of a common vinyl ester resin

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Kinematic viscosity, ν is the ratio of dynamic viscosity, μ to density, ρ :

$$v = \frac{\mu}{\rho}$$

November 2004

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- Resists solvents, chemicals, and acidic oxidizing environments to provide long lasting, reliable equipment for corrosive materials.
- Retains strength and toughness at elevated temperatures which enables users to operate the equipment in a variety of applications.
- Contains only 33 weight percent styrene, resulting in reduced styrene emissions and allows fabricators to meet California's South Coast Air Quality Management District Rule 1162.

Merine Hydroperoxide
BPO and BPO peroxides
and other information are

II Naphthalene-6%⁽⁴⁾

85-715MBUSA
2.0 phr CDP
0.25 phr ConAph4
0.05 phr DMA
1.0 phr CDP
0.25 phr ConAph4
1.0 phr CDP
0.10 phr ConAph4

See note. Gel times may vary due to
where humidity large quantities
are handled (e.g., ConAph4).

8 h 20-30% cover gel times.

Casting

Std.	Test Method
A	ASTM D-2000D2002
B	ASTM D-2000D2002
C	ASTM D-2000D2002
D	ASTM D-2000D2002
E	ASTM D-2000D2002
F	ASTM D-2000D2002
G	ASTM D-2000D2002
H	ASTM D-2000D2002
I	ASTM D-2000D2002
J	ASTM D-2000D2002
K	ASTM D-2000D2002
L	ASTM D-2000D2002
M	ASTM D-2000D2002
N	ASTM D-2000D2002
O	ASTM D-2000D2002
P	ASTM D-2000D2002
Q	ASTM D-2000D2002
R	ASTM D-2000D2002
S	ASTM D-2000D2002
T	ASTM D-2000D2002
U	ASTM D-2000D2002
V	ASTM D-2000D2002
W	ASTM D-2000D2002
X	ASTM D-2000D2002
Y	ASTM D-2000D2002
Z	ASTM D-2000D2002
AA	ASTM D-2000D2002
AB	ASTM D-2000D2002
AC	ASTM D-2000D2002
AD	ASTM D-2000D2002
AE	ASTM D-2000D2002
AF	ASTM D-2000D2002
AG	ASTM D-2000D2002
AH	ASTM D-2000D2002
AI	ASTM D-2000D2002
AJ	ASTM D-2000D2002
AK	ASTM D-2000D2002
AL	ASTM D-2000D2002
AM	ASTM D-2000D2002
AN	ASTM D-2000D2002
AO	ASTM D-2000D2002
AP	ASTM D-2000D2002
AQ	ASTM D-2000D2002
AR	ASTM D-2000D2002
AS	ASTM D-2000D2002
AT	ASTM D-2000D2002
AU	ASTM D-2000D2002
AV	ASTM D-2000D2002
AW	ASTM D-2000D2002
AX	ASTM D-2000D2002
AY	ASTM D-2000D2002
AZ	ASTM D-2000D2002
BA	ASTM D-2000D2002
BB	ASTM D-2000D2002
BC	ASTM D-2000D2002
BD	ASTM D-2000D2002
BE	ASTM D-2000D2002
BF	ASTM D-2000D2002
BG	ASTM D-2000D2002
BH	ASTM D-2000D2002
BI	ASTM D-2000D2002
BJ	ASTM D-2000D2002
BK	ASTM D-2000D2002
BL	ASTM D-2000D2002
BM	ASTM D-2000D2002
BN	ASTM D-2000D2002
BO	ASTM D-2000D2002
BP	ASTM D-2000D2002
BQ	ASTM D-2000D2002
BR	ASTM D-2000D2002
BS	ASTM D-2000D2002
BT	ASTM D-2000D2002
BU	ASTM D-2000D2002
BV	ASTM D-2000D2002
BW	ASTM D-2000D2002
BX	ASTM D-2000D2002
BY	ASTM D-2000D2002
BZ	ASTM D-2000D2002
CA	ASTM D-2000D2002
CB	ASTM D-2000D2002
CC	ASTM D-2000D2002
CD	ASTM D-2000D2002
CE	ASTM D-2000D2002
CF	ASTM D-2000D2002
CG	ASTM D-2000D2002
CH	ASTM D-2000D2002
CI	ASTM D-2000D2002
CJ	ASTM D-2000D2002
CK	ASTM D-2000D2002
CL	ASTM D-2000D2002
CM	ASTM D-2000D2002
CN	ASTM D-2000D2002
CO	ASTM D-2000D2002
CP	ASTM D-2000D2002
CQ	ASTM D-2000D2002
CR	ASTM D-2000D2002
CS	ASTM D-2000D2002
CT	ASTM D-2000D2

Example TDS – Vinyl Ester Resin

MEKP Gel Time Table

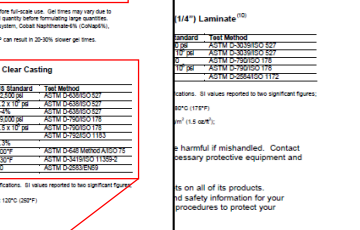
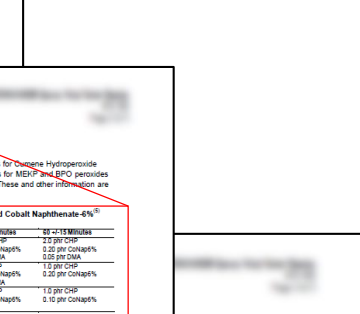
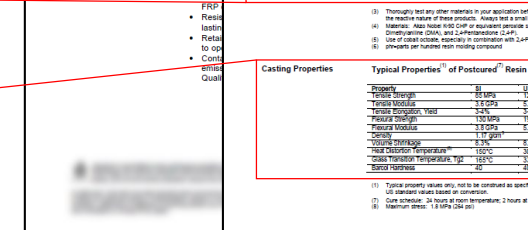
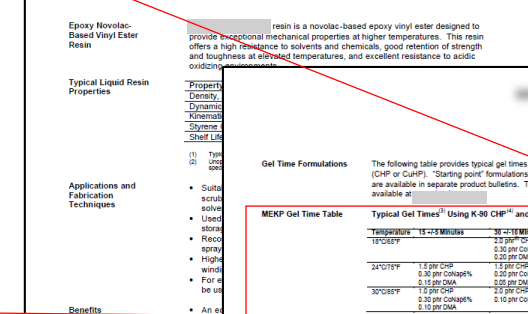
Typical Gel Times⁽³⁾ Using K-90 CHP⁽⁴⁾ and Cobalt Naphthenate -6%⁽⁵⁾

Temperature	15 +/-5 Minutes	30 +/-10 Minutes	60 +/-15 Minutes
18°C/65°F		2.0 phr ⁽¹⁾ CHP 0.30 phr CoNap8% 0.20 phr DMA	2.0 phr CHP 0.20 phr CoNap8% 0.05 phr DMA
24°C/75°F	1.5 phr CHP 0.30 phr CoNap8% 0.15 phr DMA	1.5 phr CHP 0.20 phr CoNap8% 0.05 phr DMA	1.0 phr CHP 0.20 phr CoNap8%
30°C/85°F	1.0 phr CHP 0.30 phr CoNap8% 0.10 phr DMA	2.0 phr CHP 0.10 phr CoNap8%	1.0 phr CHP

Casting Properties

Typical Properties⁽¹⁾ of Postcured⁽⁷⁾ Resin Clear Casting

Property	SI	US Standard	Test Method
Tensile Strength	85 MPa	12,500 psi	ASTM D-638/ISO 527
Tensile Modulus	3.6 GPa	5.2 x 10 ⁴ psi	ASTM D-638/ISO 527
Tensile Elongation, Yield	3-4%	3-4%	ASTM D-638/ISO 527
Flexural Strength	130 MPa	19,000 psi	ASTM D-790/ISO 178
Flexural Modulus	3.8 GPa	5.5 x 10 ⁴ psi	ASTM D-790/ISO 178
Density	1.17 g/cm ³		ASTM D-792/ISO 1183
Volume Shrinkage	8.3%	8.3%	
Heat Distortion Temperature ⁽⁶⁾	150°C	300°F	ASTM D-648 Method A/ISO 75
Glass Transition Temperature, Tg2	165°C	330°F	ASTM D-3419/ISO 11359-2
Barcol Hardness	40	40	ASTM D-2583/EN59



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Example TDS – Prepreg Material

- This is an aerospace grade material
- This TDS focuses on the resin but some information is specific to a certain prepreg model
- What can we expect from a prepreg TDS?

[illegible]

Example TDS – Prepreg Material

Features

- 10 days tack life and 21 days out life at 21°C (70°F)
- Available in fully, partially or selectively impregnated formats for vacuum or autoclave processing
- Excellent damage tolerance
- Low density offers 2-4% weight saving compared to standard aerospace matrices
- 80 to 180°C (176 to 356°F) initial cure
- 180°C (356°F) dry Tg following 180°C (356°F) post-cure
- 160°C (320°F) wet Tg following 180°C (356°F) post-cure

MAT8845-1 is a flexible curing temperature, high performance, toughened epoxy matrix system optimised for low pressure, vacuum bag processing. It can also be autoclave cured.

It may be cured at temperatures as low as 80°C (176°F), allowing the use of low cost tooling for prototypes and short production runs. After a free-standing 180°C (356°F) post-cure, the system is capable of 180°C (356°F) dry Tg and 160°C (320°F) wet Tg and will exhibit a high level of damage tolerance.

It offers a combination of properties that make it an ideal candidate for the Out-of-Autoclave (OoA) production of large aircraft primary structures. The process cost savings can equally be applied to other less critical structures such as fairings, which are typically produced using autoclave cure.

Features

- 10 days tack life and 21 days out life at 21°C (70°F)
- Available in fully, partially or selectively impregnated formats for vacuum or autoclave processing
- Excellent damage tolerance
- Low density offers 2-4% weight saving compared to standard aerospace matrices
- 80 to 180°C (176 to 356°F) initial cure
- 180°C (356°F) dry Tg following 180°C (356°F) post-cure
- 160°C (320°F) wet Tg following 180°C (356°F) post-cure

Related documents

Related products

Cure cycle

Open vacuum bag cure

Vacuum bag pressure Minimum of 980mbar (28"Hg)"

Ramp rate 1 to 2°C (1.8 to 3.6°F)/minute

Recommended cure cycle 180°C (356°F)

240°C (464°F)

16.5 hours

90 minutes

30 minutes

*No 1-4% wet vacuum time, however, it is recognised that it is not always possible to within. If in doubt, please contact our technical support team for

Results

1.18 g/cm³

180°C (356°F)

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Example TDS – Prepreg Material

Autoclave cure

Vacuum bag pressure	Minimum of 980mbar (29" Hg)*
Autoclave pressure	6.2 bar (90 psi)**
Ramp rate	1 to 2°C (1.8 to 3.6°F)/minute
Recommended cure cycle	4 hours at 120°C (248°F)
Cool down	Maximum of 3°C (5.4°F)/minute to 60°C (140°F)

Alternative cure cycle

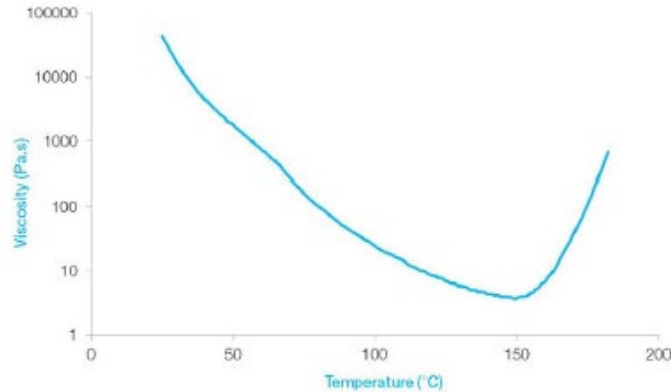
Temperature	Duration	Processing method
80°C (176°F)	20 hours	Oven vacuum bag cure/autoclave cure
130°C (266°F)*	2 hours	Oven vacuum bag cure/autoclave cure
180°C (356°F)	2 hours	Autoclave cure only

Physical properties

Test	Sample/test conditions	Results
Cured resin density	2 hours at 180°C (356°F)	1.18 g/cm ³
DMA E' onset T _g , SACMA	2 hours at 180°C (356°F), dry	180°C (356°F)
	2 hours at 180°C (356°F), wet*	160°C (311°F)
Resin gel time	At 80°C (176°F)	16.5 hours
	At 130°C (266°F)	90 minutes
	At 180°C (356°F)	10 minutes

Example TDS – Prepreg Material

Dynamic viscosity at 2°C/minute



MAT8845-1 is a flexible curing temperature, high performance, toughened epoxy matrix system optimised for low pressure, vacuum bag processing. It can also be autoclave cured.

It may be cured at temperatures as low as 80°C (176°F), allowing the use of low cost tooling for prototypes and short production runs. After a minimum standing 180°C (356°F) post-cure, the system is capable of 180°C (356°F) dry Tg and 160°C (320°F) wet Tg and will exhibit a high level of damage tolerance.

It offers a combination of properties for the Out-of-Autoclave (OoA) production of composites. The process cost savings can equally be applied to applications such as fairings, which are typically produced by autoclave.

- Features**
- 30 days shelf life and 24 days out life at 21°C (70°F)
 - Available in fully, partially or selectively impregnated formats for vacuum or autoclave processing
 - Excellent damage tolerance
 - Low density offers 2-4% weight saving compared to standard aerospace matrices

Related documents

Related products

Cure cycle

Open vacuum bag cure

Vacuum bag pressure

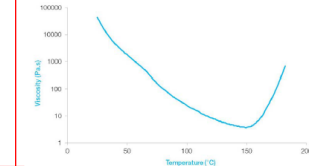
Ramp rate

Recommended cure cycle

Cool down

*This is the latest vacuum time, however, it is recognised that it is not always possible to

Dynamic viscosity at 2°C/minute



Mechanical properties

Several mechanical property databases including both lamina and laminate level A and B basis values have been generated or are in the process of being generated. The following are the product forms with associated databases either completed or planned:

Material Specification	Nomenclature	Fibre/Style	Fibre areal weight [FAW] [g/m²]	Resin weight [RW] (%)	Fibre volume fraction [Vf] (%)	Cured ply thickness [CPT] (mm)
1001-03	I	AQII/ 8HS fabric	288	35	50.01	0.262
1001-04	I	E-glass/ 7781 8HS fabric	300	35	46.42	0.254
1001-06	I	IM7/ Unidirectional	145	32	58.72	0.140
1001-07	I	AS4/ 3K PW fabric	193	36	54.34	0.201
1001-10	I	AS4/ 6k 5HS fabric	375	36	54.34	0.389
1001-11	I	AS4/ Unidirectional	145	32	58.72	0.140
1001-12	I	S2-glass/ 8HS fabric	300	35	47.02	0.257
1001-13	I	G30-500/ 3K PW fabric	193	36	54.48	0.201
1001-14	I	HTS5631/ Unidirectional	145	32	58.86	0.140

The databases, which have been generated with FEA, DDM, conformances and DDM wetting, are suitable for both commercial and military certified aircraft applications. Material specifications (CPT specifications) are available for each product form. Materials may be ordered to these specifications or to customer specific specifications. The specifications, these batch databases have been generated from parts that have been oven vacuum bag cured (or autoclave at 121°C (250°F) and post-cured for 2 hours at 177°C (350°F). In addition, single batch databases are available for some of the products with two cure cycle variants, namely:

- 20 hours at 82°C (180°F) cure followed by a 177°C (350°F) post-cure
- 121°C (250°F) cure with no post-cure

Other specific modification (SCM) (SCM-01) describe the process for SCM. These cure cycles.

Mechanical properties

Several mechanical property databases including both lamina and laminate level A and B basis values have been generated or are in the process of being generated. The following are the product forms with associated databases either completed or planned:

Material Specification	Nomenclature	Fibre/Style	Fibre areal weight [FAW] [g/m²]	Resin weight [RW] (%)	Fibre volume fraction [Vf] (%)	Cured ply thickness [CPT] (mm)
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1001-13		G30-500/ 3K PW fabric	193	36	54.48	0.201
1001-14		HTS5631/ Unidirectional	145	32	58.86	0.140

Material/Condition	82°C (180°F) dry	93°C (199°F) wet	121°C (250°F) wet
444	444	444	444
444	444	444	444
444	444	444	444
444	444	444	444

Material/Condition	82°C (180°F) dry	93°C (199°F) wet	121°C (250°F) wet
444	444	444	444
444	444	444	444
444	444	444	444
444	444	444	444

Material/Condition	82°C (180°F) dry	93°C (199°F) wet	121°C (250°F) wet
444	444	444	444
444	444	444	444
444	444	444	444
444	444	444	444

Material/Condition	82°C (180°F) dry	93°C (199°F) wet	121°C (250°F) wet
444	444	444	444
444	444	444	444
444	444	444	444
444	444	444	444

HOSTED BY:

Example TDS – Prepreg Material

Material:
Cure cycle: 4 hours at 121°C (250°F), oven vacuum bag cure
Post-cure: 2 hours at 177°C (350°F)

Test	Test method	Units	Test temperature/conditions				
			-54°C (-65°F) dry	20°C (68°F) dry	93°C (199°F) dry	93°C (199°F) wet	121°C (250°F) wet
0° Tensile strength	ASTM D3039	MPa (ksi)	533 (77.2)	469 (67.9)		294 (42.6)	282 (40.9)
0° Tensile modulus		GPa (msi)	25.2 (3.6)	25.0 (3.62)		22.5 (3.26)	
90° Tensile strength		MPa (ksi)	474 (68.7)	421 (61.0)	266 (38.5)		258 (37.3)
90° Tensile modulus		GPa (msi)	24.6 (3.5)	23.2 (3.3)	21.2 (3.07)		20.9 (3.03)
0° Compressive strength	ASTM D6641	MPa (ksi)	685 (99.3)	545 (79.0)		297 (43.1)	360 (52.1)
0° Compressive modulus		GPa (msi)	28.3 (4.1)	23.4 (3.3)		25.9 (3.7)	
90° Compressive strength		MPa (ksi)	699 (101.3)	547 (79.3)	298 (43.1)		249 (36.0)
90° Compressive modulus		GPa (msi)	26.7 (3.87)	23.5 (3.4)		25.7 (3.7)	
In-plane shear strength (IPSS)	ASTM D3518	MPa (ksi)	89.7 (13.0)	67.6 (9.8)	36.5 (5.2)	32.4 (4.6)	
In-plane shear modulus (IPSM)		GPa (msi)	4.40 (0.64)	3.70 (0.54)	2.40 (0.34)	2.30 (0.33)	
0° Interlaminar shear strength (ILSS)	ASTM D2344	MPa (ksi)	84.7 (12.2)	72.0 (10.4)	57.8 (8.38)	33.5 (4.86)	26.6 (3.86)
Open hole tension strength (Q/I laminate)	ASTM D5766	MPa (ksi)	232 (33.6)	183 (26.5)		127 (18.3)	120 (17.3)
Open hole compression strength (Q/I laminate)	ASTM D6484	MPa (ksi)		239 (34.7)		158 (22.9)	144 (20.8)
Filled hole tension strength (Q/I laminate)	ASTM D6742	MPa (ksi)		251 (36.3)		204 (29.6)	

MTM845-1 is a flexible curing temperature, high performance, toughened epoxy matrix system optimised for low pressure, vacuum bag processing. It can also be autoclave cured.

It may be cured at temperatures as low as 80°C (176°F), allowing the use of low cost tooling for prototypes and short production runs. After a free-standing 180°C (356°F) post-cure, the system is capable of 180°C (356°F) dry Tg and 160°C (320°F) wet Tg and will exhibit a high level of damage tolerance.

It offers a combination of properties that make it an ideal candidate for the Out-of-Autoclave (OOA) production of large aircraft primary structures. The process cost savings can equally be applied to other less critical structures such as fairings, which are typically produced using autoclave cure.

- Features**
- 30 days shelf life and 21 days out life at 21°C (70°F)
 - Available in fully, partially or selectively impregnated formats for vacuum or autoclave processing
 - Excellent damage tolerance
 - Low density offers 2-4% weight saving compared to standard aerospace matrices
 - 80 to 180°C (176 to 356°F) initial cure
 - 180°C (356°F) dry Tg following 180°C (356°F) post-cure
 - 160°C (320°F) wet Tg following 180°C (356°F) post-cure

Related documents

Related products

Cure cycle

Oven vacuum bag cure

Vacuum bag pressure	Minimum of 950mmbar (20"Hg)"
Ramp rate	1 to 2°C (1.8 to 3.6°F)/minute
Recommended cure cycle	4 hours at 120°C (249°F)*** 16.5 hours
Cool down	Maximum of 5°C (9°F)/minute to 80°C (180°F)
90 minutes	
30 minutes	

"No is the latest vacuum level, however, it is recognised that it is not always possible to obtain. If in doubt, please contact our technical support team for advice."

"Open hole post-cure cycle for a laminate or prepreg material: 180°C (356°F) for 16.5 hours, then 177°C (350°F) for 2 hours. For autoclave, single layer laminate products with two cure cycle variants, namely:

- 20 hours at 82°C (180°F) cure followed by a 177°C (350°F) post-cure.
- 121°C (250°F) cure with no post-cure.

Other process modifications (MDO, MDO-2) described in this document are for all these resin matrix systems.

Material:
Cure cycle: 4 hours at 121°C (250°F), oven vacuum bag cure
Post-cure: 2 hours at 177°C (350°F)

Test	Test method	Units	Test temperature/conditions				
			-54°C (-65°F) dry	20°C (68°F) dry	93°C (199°F) dry	93°C (199°F) wet	121°C (250°F) wet
0° Tensile strength	ASTM D3039	MPa (ksi)	533 (77.2)	469 (67.9)		294 (42.6)	282 (40.9)
0° Tensile modulus		GPa (msi)	25.2 (3.6)	25.0 (3.62)		22.5 (3.26)	
90° Tensile strength		MPa (ksi)	474 (68.7)	421 (61.0)	266 (38.5)		258 (37.3)
90° Tensile modulus		GPa (msi)	24.6 (3.5)	23.2 (3.3)	21.2 (3.07)		20.9 (3.03)
0° Compressive strength	ASTM D6641	MPa (ksi)	685 (99.3)	545 (79.0)		297 (43.1)	360 (52.1)
0° Compressive modulus		GPa (msi)	28.3 (4.1)	23.4 (3.3)		25.9 (3.7)	
90° Compressive strength		MPa (ksi)	699 (101.3)	547 (79.3)	298 (43.1)		249 (36.0)
90° Compressive modulus		GPa (msi)	26.7 (3.87)	23.5 (3.4)		25.7 (3.7)	
In-plane shear strength (IPSS)	ASTM D3518	MPa (ksi)	89.7 (13.0)	67.6 (9.8)	36.5 (5.2)	32.4 (4.6)	
In-plane shear modulus (IPSM)		GPa (msi)	4.40 (0.64)	3.70 (0.54)	2.40 (0.34)	2.30 (0.33)	
0° Interlaminar shear strength (ILSS)	ASTM D2344	MPa (ksi)	84.7 (12.2)	72.0 (10.4)	57.8 (8.38)	33.5 (4.86)	26.6 (3.86)
Open hole tension strength (Q/I laminate)	ASTM D5766	MPa (ksi)	232 (33.6)	183 (26.5)		127 (18.3)	120 (17.3)
Open hole compression strength (Q/I laminate)	ASTM D6484	MPa (ksi)		239 (34.7)		158 (22.9)	144 (20.8)
Filled hole tension strength (Q/I laminate)	ASTM D6742	MPa (ksi)		251 (36.3)		204 (29.6)	

Notes: 1. Data normalised to 0.25mm (0.010in) cured ply thickness except for ILSS and IPSS. 2. IPSS is a 200 g/m² (8 oz/yd²) resin ply thickness.

Availability

MTM845-1 is available as a fabric prepreg, unidirectional prepreg or slit tape.

Storage

Shelf life at 21°C (70°F) 30 days shelf life 21 days out life (minimum)

Storage at -18°C (0°F) 8 months from date of manufacture

*Due to the nature of the material, the date of the resin is not the date of the part is not.

Notes

The actual storage life, shelf life and out life are dependent on a number of factors, including: form type, format and application. For certain formats, it may be possible to extend the storage life, shelf life and out life to longer than stated. Please contact our technical support team for advice.

Example TDS – Prepreg Material

Exotherm

is a reactive formulation, but has a low exotherm risk and can be used for moulding thick sections. If in doubt, contact the Group's Technical support staff for advice when moulding sections greater than 50mm (2in) thick.

is a flexible curing temperature, high performance, toughened epoxy matrix system optimised for low pressure, vacuum bag processing. can also be autoclave cured.

may be cured at temperatures as low as 80°C (176°F), allowing the use of low cost tooling for prototypes and short production runs. After a free-standing 180°C (356°F) post-cure, the system is capable of 180°C (356°F) dry Tg and 160°C (320°F) wet Tg and will exhibit a high level of damage tolerance.

offers a combination of properties that make it an ideal candidate for the Out-of-Autoclave (OoA) production of large aircraft primary structures. The process cost savings can equally be applied to other less critical structures such as fairings, which are typically produced using autoclave cure.

Features

- 30 days shelf life and 24 days out of the pot at 21°C (70°F)
- Available in fully, partially or selectively impregnated formats for vacuum or autoclave processing
- Excellent damage tolerance
- Low density offers 2-4% weight saving compared to standard aerospace matrices
- 80 to 180°C (176 to 356°F) initial cure
- 180°C (356°F) dry Tg following 180°C (356°F) post-cure
- 160°C (320°F) wet Tg following 180°C (356°F) post-cure

Related documents

Related products

Cure cycle

Over vacuum bag cure	Minimum of 90min/24h (20°F/40°F)
Vacuum bag pressure	1.5 to 2.2 (1.4 to 2.0) bar
Ramp rate	1.5 to 2.2 (1.4 to 2.0) °C/minute
Recommended cure cycle	4 hours at 120°C (249°F)
Cool down	Maximum of 5°C (23°F) minutes to 80°C (176°F)

*This is the latest vacuum time, however, it is recognised that it is not always possible to within, if in doubt, please contact our technical support staff for

Technical support staff for

method

are/autoclave cure are/autoclave cure cure only

under that parts are tried out. However, necessary to post

values have been generated (database) either completed

Results	Fibre volume fraction (%)	Cured ply thickness (mm)
1.18 g/cm³	50.01	0.262
180°C (356°F)	46.42	0.254
200°C (392°F)	58.72	0.140
16.5 hours	54.34	0.201
90 minutes	54.34	0.389
30 minutes	58.72	0.140
	47.62	0.257
	54.45	0.201
	58.88	0.140

are suitable for both (mm) are available for each thickness. For all products, and for 4 hours at 121°C

are suitable for both (mm) are available for each thickness. For all products, and for 4 hours at 121°C

Exotherm

is a reactive formulation, but has a low exotherm risk and can be used for moulding thick sections. If in doubt, contact the Group's Technical support staff for advice when moulding sections greater than 50mm (2in) thick.

Health & Safety

is a reactive formulation which can cause allergic reactions by skin contact. Avoid contact with the skin. Gloves and eye protection must be worn.

Wash skin thoroughly with soap and water or resin removing cream after handling. Do not use solvents for cleaning the skin.

Use mechanical exhaust ventilation when heat curing the resin system. Exhaust from vacuum pumps should be vented to external atmosphere and not into the work place.

For further information, consult Cytec Safety Data Sheet number 105 644.

HOW ARE THE KEY MANUFACTURING PROPERTIES CHARACTERIZED?

Gel timer, rheometer, differential scanning calorimeter

HOSTED BY:



HOSTED BY:



KPC M101: GEL TIME



HOSTED BY:



<https://compositeskn.org/KPC/M101>

HOSTED BY:



KPC M100: DEGREE OF CURE



HOSTED BY:

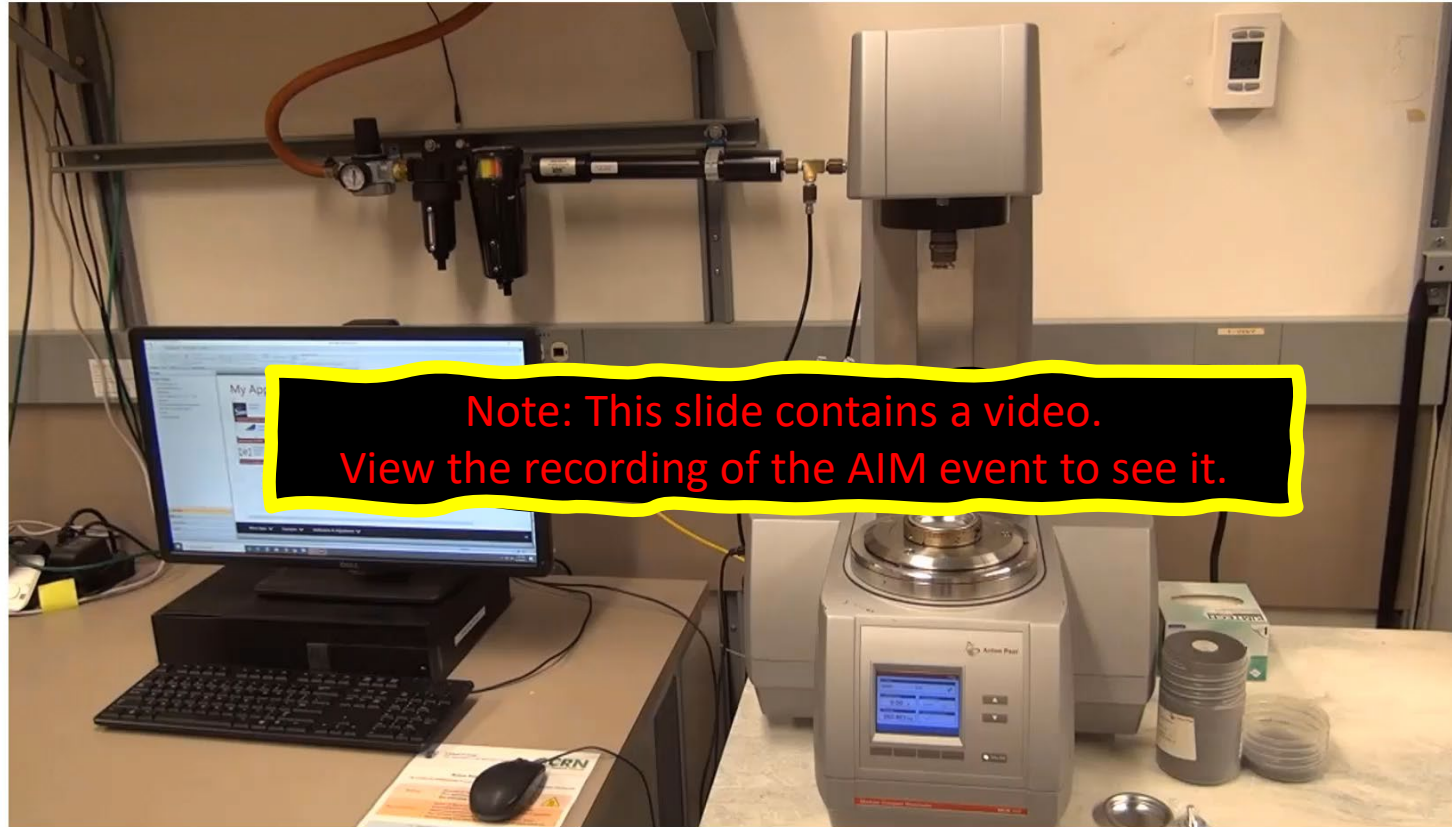


<https://compositeskn.org/KPC/M100>

HOSTED BY:



KPC A203: RHEOMETER



HOSTED BY:



<https://compositeskn.org/KPC/A203>

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Summary

- There are a number of important resin properties and concepts one needs to understand when developing, optimizing, or troubleshooting a manufacturing process

Manufacturing Step	Analysis Type	Resin Property
Storage, formulation, impregnation, thermal transformation, demolding, secondary thermal transformation	Thermo-Chemical Analysis	Degree-of-cure
		Glass Transition (vitrification)
		Heat of Reaction
		Density
		Specific Heat Capacity
		Thermal Conductivity
Assembly	Flow-Compaction Analysis	Viscosity
		Gelation
	Stress-Deformation Analysis	(Visco) Elastic Constants
		Thermal Expansion
		Cure Shrinkage

HOSTED BY:

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Thank you for joining us!

Keep an eye out for announcements on the next AIM events

And don't forget to visit the KPC for more information:

<https://compositeskn.org/knowledge-in-practice-centre/>

Questions?

For more information on future dates and times visit:

compositeskn.org