LET'S TALK / PERFORMANCE

INFLUENCE OF POST-CURE ON MECHANICAL AND CHEMICAL RESISTANCE OF POLYESTERS AND VINYL ESTERS

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FRP Unlimited
February 6-7, 2018
END-USE PERFORMANCE REQUIREMENTS

- Resistance to chemicals
- Heat resistance
- Low maintenance
- Strength, stiffness, toughness
- Food contact (when required)
- Light weight, easy installation
- Design flexibility

**Exposure determines resin choice**
Different solutions available for heat and chemicals involved. Good chemical resistance means low maintenance and peace-of-mind on performance

**High mechanical strength**
Selection of right resin, reinforcement, and their interaction is key

**Food contact**
Resins made in line with GMP for good food quality and consumer safety

**Key benefit vs. steel**
Enabling technology for light weight constructions in corrosive environment

**Optimized design**
Shaping flexibility and part integration possibility is a key composites benefit.
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INDUSTRY STANDARDS HELP IN ACHIEVING GREAT PART PERFORMANCE

• Well-established international standards
  – Focus today: EN 13121 “GRP tanks and vessels for use above ground”
• Providing guidelines on part design, manufacturing and installation
  – Part 1: Raw materials, specifications, acceptance conditions
    • Resin chemistry linked to 8 classes with increasing corrosion resistance
  – Part 2: Composite materials – Chemical resistance
    • Media types according 3 groups of increasing chemical attack
    • Build-up of laminate for optimal performance
  – Part 3: Design and workmanship
    • Calculation of loads, design of supports, fittings
    • Quality control, including pressure testing
  – Part 4: Delivery, installation and maintenance
    • Handling and transport, installation guidelines
    • Ensuring installation quality and avoiding damage
IMPORTANT FOR QUALITY OF COMPOSITE PART

- Resin selection
- Reinforcement selection
- Curing agent formulation
- Optimal curing

- Are determined by design standard, customer specifications, corrosion resistant lists, and/or following Aliancys Chemical Resistance advice

- Proper part cure is very important for final part performance
SELECTING THE RIGHT RESIN FOR ELEVATED TEMPERATURES

- Chemicals are mostly more corrosive at elevated temperatures
- EN 13121 standard prescribes that HDT of the resin should be at least 20°C higher than the exposure temperature of the part
- Component may lose mechanical integrity if use temperature gets too close or above HDT
BASICS OF CURE THROUGH FREE RADICAL POLYMERIZATION

Monomer like Styrene

Polymer like VE or UP
CURE MECHANISM
GLASSY STATE WITH UNREACTED RADICALS AND DOUBLE BONDS
POST CURE: REINITIATING FREE RADICAL POLYMERIZATION
COMPLETE CURE ACHIEVED
SOME CONSIDERATIONS ON POST-CURE

TIME AND TEMPERATURE

• Norm suggests post-cure of 1 hour per mm of laminate, at a temperature close to HDT
• According EN13121-2 at least 4 hours at 80°C or HDT (for certain media)
• According DIN18820: 1 hour per mm laminate thickness, at maximum 100°C for 15 hours, but at least 5 hours at minimum 80°C, and slow cooling down

IMPORTANT

• Post-cure is strongly recommended in BPO/amine cure system and should be done within 2 weeks after construction
• Obviously, post-curing temperature should also reach the inner part of the tank
HEAT TRANSFER OVEN TEST

- Atlac 430 10 layer CSM laminate made with 5 thermocouples inside
- Hand lay-up
- Oven test at 60°C and 80°C
HEAT TRANSFER TAKES 2-2.5 HOURS FOR 4-5 MM THICKNESS
HDT LOWER WHEN CURED AT AMBIENT TEMPERATURES
POST-CURE HELPS TO BUILD HDT

HDT VS. POST-CURE TIME AT 60 °C

Note that at 60 °C the HDT does not reach the maximum level possible.

HDT, °C

Time at 60 °C (days)

- Atlac 430
- Atlac 580
- Atlac 382A
- Atlac 590

Aliancys
QUALITY RESINS
POST-CURE HAS MAJOR EFFECT ON HDT AND RESIDUAL STYRENE CONTENT

VE resin: Atlac 430

![Bar chart showing HDT (°C) and Residual styrene content (wt%) for various postcure cycles.](chart.png)
POST-CURE HAS MAJOR EFFECT ON HDT AND RESIDUAL STYRENE CONTENT

High heat VE resin: Atlac 590

HDT [°C]

<table>
<thead>
<tr>
<th>Postcure cycle</th>
<th>HDT [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPC</td>
<td>90</td>
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<tr>
<td>24 hrs 60°C</td>
<td>60</td>
</tr>
<tr>
<td>24 hrs 80°C</td>
<td>100</td>
</tr>
<tr>
<td>6 hrs 100°C</td>
<td>150</td>
</tr>
<tr>
<td>6 hrs 150</td>
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</tbody>
</table>

Residual styrene content, [wt%]

<table>
<thead>
<tr>
<th>Postcure cycle</th>
<th>Residual styrene content, [wt%]</th>
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<tr>
<td>NPC</td>
<td>3.0</td>
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<tr>
<td>24 hrs 60°C</td>
<td>2.0</td>
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<tr>
<td>24 hrs 80°C</td>
<td>1.5</td>
</tr>
<tr>
<td>6 hrs 100°C</td>
<td>1.0</td>
</tr>
<tr>
<td>6 hrs 150</td>
<td>1.0</td>
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</tbody>
</table>
SAME FOR ISOPHTHALIC RESIN

Palatal A 410-01

- HDT (°C)
  - NPC
  - 24 hrs 60°C
  - 24 hrs 80°C
  - 6 hrs 100°C

- Residual styrene content, (wt%)
  - 6
  - 5
  - 4
  - 3
  - 2
  - 1
  - 0

Postcure cycle
IN-HOUSE CHEMICAL RESISTANCE TESTING CAPABILITY

According to:
ASTM C 581 and DIN 53393
(EN 977 - EN 13121-2)
ASSESSMENT OF CHEMICAL RESISTANCE

**Test Criteria**
Aliancys interpretation method (based on ASTM C581 and EN13121):

\[
\text{Retained Flexural Strength} \ [\%] = \frac{\text{Flexural Strength of specimen after test period}}{\text{Flexural Strength of specimen after cure}} \times 100\%
\]

\[
\text{Retained Flexural Modulus} \ [\%] = \frac{\text{Flexural Modulus of specimen after test period}}{\text{Flexural Modulus of specimen after cure}} \times 100\%
\]

\[
\text{retention of Chemical Strength} \ [\%] = \frac{\text{retention of Flexural Strength} + \text{retention of Flexural Modulus}}{2}
\]
EXTRAPOLATION TO ASSESS LONG TERM PERFORMANCE

![Graph showing logarithmic extrapolation to 10 years with retention (%) on the y-axis and time (years) on the x-axis. The graph includes lines for Log. (Chemical strength), Log. (Modulus), and Log. (Strength). There are shaded areas for Critical and Not Resistant.]
AT LOWER EXPOSURE TEMPERATURE EFFECT OF POST-CURE ALREADY VISIBLE

Influence of post-cure on chemical resistance at 20 °C in toluene

- **Atiac 590**
- **Atiac E-Nova FW 1045**

Chemical Strength, extrapolated to 10 years [%]

<table>
<thead>
<tr>
<th>Post-cure conditions</th>
<th>None</th>
<th>16hrs, 50°C</th>
<th>6hrs, 90°C</th>
<th>3hrs, 100°C, 3hrs 150°C</th>
</tr>
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<tbody>
<tr>
<td><strong>Atiac 590</strong></td>
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POST-CURE NECESSARY FOR BETTER RESISTANCE TO SOLVENTS

Influence of post-cure on chemical resistance at 40 °C in toluene

- Atlac 590
- Atlac E-Nova FW 1045

Chemical Strength, extrapolated to 10 years [%]

0 20 40 60 80 100 120

None 16hrs, 50°C 6hrs, 90°C 3hrs, 100°C, 3hrs 150°C

Post-cure conditions

Aliancys Quality Resins
EFFECT POST-CURE MORE PRONOUNCED AT HIGHER EXPOSURE TEMPERATURES

Influence of post-cure on chemical resistance at 50 °C in toluene

- Atlac 590
- Atlac E-Nova FW 1045

Post-cure conditions
- None
- 16hrs, 50°C
- 6hrs, 90°C
- 3hrs, 100°C, 3hrs 150°C

Chemical strength, extrapolated to 10 years [%]
CONCLUSIONS ON POSTCURE

- HDT of ambient cured composites will stay around 50-60°C and it will not reach maximum HDT value
- No post-cure and mild post-cure results in same degree of chemical resistance
- In order to obtain highest possible heat resistance and chemical resistance, composite equipment has to be post-cured at a temperature around maximum HDT/Tg value
  - Will result in highest heat resistance
  - Will result in highest chemical resistance
- For less demanding circumstances follow the standards
GENERAL RECOMMENDATIONS

• Postcure is strongly recommended in BPO/amine cure system, and should be done within 2 weeks after construction
• Postcuring temperature should also reach the inner part of the tank
• Ambient temperature cured composite components will resist aqueous acid and salt solutions at ambient conditions
• Ambient temperature cured composite components will resist aqueous solutions also at elevated temperature.
  – Post curing process progresses faster then diffusion process
GENERAL RECOMMENDATIONS

• Barcol of finished part should be at least 80% of the value quoted by the resin manufacturer
  – To be measured on sections cut out after post cure
  – If not possible to take out sections, it is required to connect a test laminate to the tank representative for the entire process
  – It is not allowed to measure Barcol hardness on the tank wall (part interior), as this may damage the surface and reduce tank lifetime.

• The maximum service temperature given in the chemical resistance guide is based on fully postcured material in combination with the correct reinforcement material and curing system
PROVIDING EXPERTISE FOR OUR CUSTOMERS

- Excellent track record of use Atlac resins in Industrial markets
- Extensive experience in chemical resistance testing, laminate build-up for maximizing chemical resistance
- “Chemical Resistance Advice” as official document for your reference
- Experienced Technical Service team to support you in troubleshooting and continuous process improvement
ALIANCYS CAN HELP IN MAKING THE BEST RESIN SELECTION FOR YOUR APPLICATION

- To make accurate recommendations we need to know:
  - Chemical environment, composition, concentrations, pH values, storage conditions
  - Service temperature, temperature profiles, maximum temperatures
  - Mechanical exposure, pressure, static and cyclic loading
  - Type of composite material/ build-up used (fiber volume, chemical resistance layer)
  - Equipment and process
- Available in 5 languages
- chemical.resistance@aliancys.com
# Chemical Resistance Guide

**Let's Talk: Durability**

## Chemical Resistance Guide

### Table of Chemical Resistance

<table>
<thead>
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<th>Chemical Resistant</th>
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### Image Description

- **Title:** Let's Talk: Durability
- **Subtitle:** Chemical Resistance Guide
- **Company:** Aliancys
- **Quality Resins**

### Additional Notes

- The guide provides detailed chemical resistance information for various materials.
- It includes a table with concentration codes indicating resistance levels.
- The guide emphasizes the durability and chemical resistance of Aliancys' quality resins.

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*Note: The table and image content is representative and not actual*
MORE INFORMATION

- Product and case study information on www.aliancys.com
- Please contact your Aliancys Technical Service representative for more detailed information and for our Chemical Resistance information service