Benzoxazine Resin Technology

For Cost-Effective Composite Solutions
Always a Reliable Member of Your Development Crew

As the aerospace industry constantly changes and seeks effective solutions for tomorrow, Henkel is dedicated to providing a competitive advantage for its customers. Based on innovation and continuous dialog with design, production and maintenance specialists, Henkel’s experts are always tuned into the latest industry trends.

Henkel’s technical expertise is based on over 40 years of experience in aerospace applications, as a trusted supply chain partner to provide the optimum solution to meet the most rigorous industry requirements. Working with Henkel means more to customers than just high performance products. Based on sustainability and efficient assembly system solutions, Henkel is the development partner of choice for the latest generation of adhesive technology. In addition, Henkel now offers superior composite materials for aircraft structure, as well as advanced technical solutions for engines and systems. Your Henkel Experts will support the development of customized solutions to reach maximum product performance, while achieving production and supply chain efficiency throughout your process.

Henkel offers composites and adhesives for three core segments of airplane construction, maintenance and repair:

**Composites**
products for manufacturing fiber reinforced structural components

**Assembly**
materials for bonding, surface preparation and protection

**MRO**
repair solutions for composite and metal structures to support your commitment to the aircraft lifecycle
More than 40 years ago, the first composite was used to construct lighter, more durable and comfortable aircraft. The proportion of composite to metal has increased steadily ever since as the industry has gained confidence in the use of the technology.

Composites provide superior stiffness and strength to weight compared to metals, enable flexible design, and meet customers' expectation of comfort, operating cost and sustainability. Today's airplanes are designed with carbon fiber composite structures, in some cases accounting for more than half of the weight of the plane.

Meeting industry trends at cruising speed

Global population growth and mobility along with the increased cost of oil have led to demand for fuel-efficient airplanes. Composite materials provide a solution, which

- Enable lighter airplane design to reduce fuel consumption
- Enable design flexibility (for better aerodynamics, efficiency and comfort)
- Promote sustainability through reduced emissions and noise
- Enable large scale production and automation to satisfy growing demand

Now Henkel is introducing an alternative portfolio to existing composite chemistries. LOCTITE® Benzoxazine composite solutions provide cost-effective construction, improved technical performance, and sustainability throughout the entire value chain.
LOCTITE® Benzoxazine Resins –

Full T(h)rust for Composite Technology

Developed specifically for the aerospace industry, Benzoxazine resin technology offers a comprehensive solution over commonly used epoxies, phenolics, and BMIs. Benefits are seen in product performance, storage, processing, and health and safety.

Cross functional characteristics of Benzoxazine Resin-based products:

› Stability at ambient temperature eliminates the need for refrigerated shipping and storage
› Excellent flammability performance (flame, smoke and toxicity) leads to improved safety
› Minimal shrinkage means lower residual stress
› Low cure exotherm contributes to better thermal stability and improved safety
› Weight savings potential at least 30 % compared to conventional metal structures

Advantages to comparable technologies

<table>
<thead>
<tr>
<th>Epoxy</th>
<th>LOCTITE® Benzoxazine vs.</th>
<th>Phenolic</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Lower cure shrinkage and cure exotherm</td>
<td>• No microcracking</td>
<td>• Improved hot/wet performance</td>
<td>• Lower cure temperature and shorter cure cycle</td>
</tr>
<tr>
<td>• Improved hot/wet performance</td>
<td>• Improved durability</td>
<td>• Inherent Flame, Smoke and Toxicity characteristics</td>
<td>• Lower cost</td>
</tr>
<tr>
<td>• Inherent Flame, Smoke and Toxicity characteristics</td>
<td>• No water generated during cure</td>
<td></td>
<td>• Higher toughness</td>
</tr>
</tbody>
</table>
Following the route to sustainability

Like any new product from Henkel, Benzoxazine Resins contribute to a more sustainable future. By using this new generation of resins, you will see improvements throughout your production life-cycle.

Main improvements:

› Storage and shipping at room temperature
› Lower material consumption through improved performance
› Reduced waste due to less spoilage
› Reduced hazards from waste
› Improved health and safety
› Lighter weight allows lower fuel consumption of planes

Benzoxazine technology was developed with two processing aspects in mind:
The ability to be processed in existing and future product technologies, and enabling a new generation of process savings.

LOCTITE® Benzoxazines are suitable for most common production methods and processes:

<table>
<thead>
<tr>
<th>Prepregs:</th>
<th>Infusion resins:</th>
<th>Film adhesive for composite bonding:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Hand lay-up, AFP, ATL</td>
<td>• RTM</td>
<td>• Autoclave curing</td>
</tr>
<tr>
<td>• Autoclave curing</td>
<td>• VARTM</td>
<td>• Suitable for secondary bonding and co-curing</td>
</tr>
<tr>
<td></td>
<td>• RFI</td>
<td>• Can be used for honeycomb sandwich co-curing</td>
</tr>
</tbody>
</table>
Reducing Cost along the Entire Value Chain

Composites made with LOCTITE® Benzoxazine resins provide improvements in every stage of the value chain. Discover how much you can optimize your production with high-quality products and reduced process costs.

Improved performance
- Multifunctional resin
- Reduced complexity
- Design freedom
- Flammability resistance

Room Temperature Storage
- No refrigeration required
- No temperature records
- Less sampling
- No insulated boxes to dispose

Room Temperature Stability
- No thawing
- Less handling effort
- Lower risk of moisture contamination
- Less waste due to expired or mis-handled product

Model Calculation of cost savings*

| Handling: | $0.14/ft² ($1.46/m²) |
| Warehouse: | $0.23/ft² ($2.47/m²) |
| Processing: | $0.25/ft² ($2.69/m²) |

*Savings dependent on volume per year and application (Customer validated ± 15%).
**Lower Cure Shrinkage**
- Less fitting and shimming
- Reduced surface preparation
- Lower internal stress

**Lower Exotherm**
- Less labor
- Shorter processing time
- Easier autoclave scheduling
- Less \( N_2 / CO_2 \) required for autoclave
- Improved safety

**Lower Exotherm & Less Cure Shrinkage**
- Less microcracking
- Reduced repair rate
- Improved durability

**Lower Density**
- Better strength-weight ratio
- Reduced fuel consumption

**Operating / In-service Performance**
- Higher durability
- Fewer repairs

**Total savings:**
$ 1.09/ft^2 (\$ 11.62/m^2)$

**Autoclave:**
$ 0.19/ft^2 (\$ 2.09/m^2)$

**Finishing and Repair:**
$ 0.27/ft^2 (\$ 2.91/m^2)$
## Benzoxazine-Resin-Based Product Portfolio

### Product Treatment: Aerospace Structural Prepreg

<table>
<thead>
<tr>
<th>Product</th>
<th>LOCTITE® BZ 9703</th>
<th>LOCTITE® BZ 9704</th>
<th>LOCTITE® BZ 9705</th>
<th>LOCTITE® BZ 9110</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cure Conditions (1)</strong></td>
<td>177 °C (350 °F) / 2 hrs</td>
<td>185 °C (365 °F) / 3 hrs</td>
<td>210 °C (410 °F) / 2 hrs</td>
<td>180 °C (356 °F) / 2 hrs</td>
</tr>
<tr>
<td><strong>Maximum service temperature (2)</strong></td>
<td>120 °C (248 °F)</td>
<td>140 °C (284 °F)</td>
<td>180 °C (356 °F)</td>
<td>135 °C (275 °F)</td>
</tr>
<tr>
<td><strong>Toughness (3)</strong></td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Product Benefits</strong></td>
<td>Available in variety of product forms; High retention of hot/wet properties; Damage tolerance equivalent to toughened epoxy; Extended room temperature storage; Outstanding flammability resistance; Low shrinkage and residual stress; Other cure cycles available; Light weight</td>
<td></td>
<td></td>
<td>Balanced performance; Easy processing; Enhanced mechanical performance and durability with: High temperature performance (hot/wet); Lower cure shrinkage and heat release; VARTM processable</td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td>Hand lay-up; Automatic tape laying; Automated fiber placement; Autoclave cure</td>
<td></td>
<td></td>
<td>Resin transfer molding; Vacuum process</td>
</tr>
<tr>
<td><strong>Energy &amp; Climate</strong></td>
<td>RT storage &amp; shipping; Suitable for automated processing; Lower weight structure</td>
<td>RT storage &amp; shipping; Shorter processing cycle vs BMI; Suitable for automated processing</td>
<td>RT storage &amp; shipping; Can be shipped in bulk; Approved for air shipment</td>
<td></td>
</tr>
<tr>
<td><strong>Materials &amp; Waste</strong></td>
<td>Less materials use due to higher performance; Reduced waste due to lower spoilage; Reduced hazards of waste</td>
<td></td>
<td>Reduced</td>
<td>Reduced</td>
</tr>
<tr>
<td><strong>Safety &amp; Health</strong></td>
<td>Improved health &amp; hygiene vs epoxy; Lower weight of finished part</td>
<td>Improved health &amp; hygiene vs BMI</td>
<td></td>
<td>Very low risk of exotherm; Improved health &amp; hygiene vs epoxy</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td>Improved mechanical &amp; flammability performance and durability vs epoxy</td>
<td>Improved toughness and durability vs BMI</td>
<td></td>
<td>Reduced flammability vs epoxy</td>
</tr>
<tr>
<td><strong>Social Progress</strong></td>
<td>Improved aircraft fuel efficiency and lower emissions due to lower weight of finished part</td>
<td></td>
<td></td>
<td>Improved aircraft fuel efficiency</td>
</tr>
</tbody>
</table>

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1) Typical cure time and temperature  
2) Service temperature is defined as 28 °C below the wet Tg
### Resin

**LOCTITE® BZ 9120**
- 180 °C (356 °F) / 2 hrs
- 120 °C (248 °F)

**LOCTITE® BZ 9130**
- 180 °C (356 °F) / 2 hrs +
- 232 °C (450 °F) / 1 hr post-cure
- 168 °C (334 °F)

**LOCTITE® BZ 9691**
- 180 °C (365 °F) / 3 hrs
- 160 °C (320 °F)

### Film Adhesive for Composite Bonding

**LOCTITE® BZ 9703**
- High
- High temperature performance
- High toughness
- VARTM processable

**LOCTITE® BZ 9704**
- Medium
- Compatible with Henkel BZ composite matrix resins
- Capable of high temperature performance

**LOCTITE® BZ 9705**
- High

**LOCTITE® BZ 9110**
- 180 °C (356 °F) / 2 hrs +
- 232 °C (450 °F) / 1 hr post-cure
- 180 °C (356 °F) / 2 hrs

**LOCTITE® BZ 9120**
- 180 °C (356 °F) / 2 hrs
- 210 °C (410 °F) / 2 hrs

**LOCTITE® BZ 9130**
- 180 °C (356 °F) / 2 hrs

**LOCTITE® BZ 9691**
- 180 °C (365 °F) / 3 hrs
- 177 °C (350 °F) / 2 hrs

### Materials & Waste

- Less materials use due to higher performance
- Reduced waste due to lower spoilage
- Reduced hazards of waste (reactivity, HSE)
- Reduced machining of tools
- Less rejected tools and parts
- Reduced tooling rework
- Improved health & hygiene vs BMI

### Performance

- Improved mechanical & flammability performance and durability vs epoxy
- Higher toughness vs BMI

### Tooling Prepreg

**BETA PREPREG**

### Process

- Hand lay-up
- Automatic tape laying
- Automated fiber placement
- Autoclave cure
- Resin transfer molding (RTM)
- Vacuum only infusion and cure (VARTM)

### Energy & Climate

- RT storage & shipping
- Suitable for automated processing
- Lower weight structure
- Can be shipped in bulk
- Approved for air shipment

### Safety & Health

- Improved health & hygiene vs epoxy
- Very low risk of exotherm
- Improved health & hygiene vs BMI

### Social Progress

- Improved aircraft fuel efficiency and lower emissions due to lower weight of finished part
- Enables economic air travel
- No dry ice required

3) Compared to state of the art solutions
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Henkel Composite Assembly: www.henkelcompositeassembly.com

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