Bakelite® Molding Compounds Design Guide
General Design, Processing & Troubleshooting Guide

January 2018
1 Introduction

2 Material Selection
2.1 Material Type and Grade Selection
2.2 Why Consider Engineering Thermosets vs. Metals
2.3 Why Consider Engineering Thermosets vs. Engineering Thermoplastics
2.4 Hexion’s Product Portfolio for Automotive Solutions

3 Design Guide
3.1 Design Software
3.2 Best Practices
3.3 Part Design Recommendations
3.4 Mold Design Recommendations

4 Processing Guide
4.1 Process Selection
4.2 Process Parameters

5 Secondary Operations
5.1 Deflashing
5.2 Machining
5.3 Assembly
5.4 Decorating

6 Troubleshooting Guide
6.1 Injection Molding
6.2 Compression Molding
6.3 Examples of Common Defect Types

7 Disclaimer / Resources

8 Product Overview
Introduction
Bakelite® phenolic molding compounds, when they were invented over a century ago, revolutionized the manufacture of household goods such as radios and lamp cases. Today, molding compounds based on epoxy [EP], unsaturated polyester [UP], melamine phenolic [MP] and phenolic [PF] resins allow products to be mass produced in an infinite variety of contours and forms. Dimensional stability, surface hardness and heat resistance, coupled with inherently low flammability and superb electrical features, are hallmarks of these materials. Bakelite® molding compounds continue to be used in household appliances but are increasingly found in tight tolerance high performance parts in automotive under-the-hood applications such as pistons, pulleys, valve blocks and pump parts and in a variety of electrical components.

<table>
<thead>
<tr>
<th>Low Risk</th>
<th>Design Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenolic molding compounds have been used in demanding applications for decades.</td>
<td>Grades with inherently low shrinkage and low coefficient of thermal expansion make a range of tight tolerance parts possible.</td>
</tr>
<tr>
<td>- Inherent properties make them ideal for high-stress as well as high-heat environments</td>
<td>- Complex net shape parts</td>
</tr>
<tr>
<td>- Phenolic resins have been used for many years in electrical, automotive under-the-hood and transmission applications</td>
<td>- High precision parts</td>
</tr>
<tr>
<td>- Reliable supply chain trusted by multiple tier 1 manufacturers</td>
<td>- Tight tolerances over large spans</td>
</tr>
<tr>
<td>- Fast, low cost functional prototypes of large parts possible</td>
<td>- Special grades available with isotropic CTEs close to aluminium &amp; steel</td>
</tr>
<tr>
<td>- Inherently flame resistant</td>
<td>- Inherently flame resistant</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Easy to Process</th>
<th>Cost Effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can be injection molded</td>
<td>Cost effective parts vs. machined die-cast aluminum and high temperature engineering thermoplastics.</td>
</tr>
<tr>
<td>Possible to mold net shape parts without secondary machining</td>
<td>- Complex net shape parts save machining costs over metal equivalents</td>
</tr>
<tr>
<td>Possible to screw mechanical fasteners directly into molded material—no inserts</td>
<td>- Recyclable1</td>
</tr>
</tbody>
</table>

Ready to get started? Contact us today at molding-compounds@hexion.com

---

Table 1. Resin System Advantages & Strengths

<table>
<thead>
<tr>
<th>Molding Compounds</th>
<th>Advantages</th>
<th>Strengths</th>
</tr>
</thead>
</table>
| Phenolic          | • Good thermo-mechanical behavior & creep resistance  
                  • Inherently flame retardant | • Mechanical stability  
                  • Tolerant of temperature spikes in use |
| Melamine-phenolic | • Tougher than straight phenolic resin  
                  • Good electrical insulating properties | • Commutator applications  
                  • Electrical properties for small motors  
                  • Copper adhesive |
| Unsaturated polyester | • Free radical cure – no off-gas generated | • Exceptional high voltage tracking resistance |
| Epoxy             | • High strength & rigidity  
                  • Good thermal & electrical insulating properties  
                  • Low viscosity possible, fill tight dimensions | • Cure by polyaddition – no off-gas generated ideal for overmolding |

Figure 3. Automotive Underhood Parts

Modern processing techniques coupled with next-generation formulations are expanding the universe of applications where Bakelite® molding compounds are being used.

1.1.1 Engineering Thermosets

Bakelite® molding compounds are engineering thermosets (ETS) not engineering thermoplastics (ETP). Once processed and cured, they are infusible and cannot be re-melted or dissolved. This is the key to their strength, toughness and durability. Bakelite® molding compounds are formulated from one of four heat-cured, crosslinkable resin systems, which are combined with reinforcements, fillers and modifiers, to produce materials that meet or exceed a wide range of end use application requirements. The original and still predominant resin system used is phenolic; the other three are: melamine-phenolic, epoxy and unsaturated polyester. Advantages and strengths of each resin system are summarized in Table 1.

1.1.2 Types of Bakelite® Molding Compounds Available

**General purpose and specialty molding compounds**
- Organic or mineral fillers
- Graphite-extended for tribological performance
- Specialty grade capable of being galvanically chrome-plated
- Modified grades with enhanced dimensional stability and flame resistance

**Glass-fiber reinforced molding compounds**
- High modulus, low creep
- Mechanical strength at elevated temperatures
- Resistant to automotive fluids
- Dimensionally stable, capable of complex high precision tight tolerance parts
1.1.6 Engineering Thermosets can be Recycled

Material recyclability is increasingly important to automotive manufacturers. It is possible to recycle engineering thermosets in several ways: mechanical, chemical, or as a filler in making cement. Mechanical recycling involves grinding cured thermoset scrap and reintroducing it as a filler in fresh molding compounds. Chemical recycling involves pyrolysis or solvolysis whereby the matrix material is separated from the fiber reinforcement and is digested to basic components that can be reused. A third approach, promoted in Europe and Japan, involves the use of thermoset scrap in the cement making process. Inorganic components are reduced to ash and bond with the cement clinker, while the organic component serves as a thermal energy source in the calcination process. Finally, incineration is considered a suitable method for disposing of thermoset waste, extracting thermal energy from the organic component. Figure 4 diagrams a typical life-cycle for thermoset automotive under-the-hood parts. (See EPCD-HXN-682)

Thermoset parts may have lower environmental impact, eg. GWP (global warming potential), than aluminum over the lifecycle.  

2 Based on a case study, comparative peer-reviewed LCA (life cycle analysis) of a water pump housing made of injection molded phenolic engineering thermoset vs. die cast aluminum (Heide S. I., SPE AICE presentation 2015.)

Figure 4. Life-Cycle Supply Chain for Under-The-Hood Parts
Material Selection
2.1 Material Type and Grade Selection

Selecting the optimal material type and grade for a particular application can be a challenge given the wide range of commercially available materials. Ideally, it is done in a four step process that begins with careful consideration of end use performance requirements and leads to a material type and grade selection that best balances competing priorities.

Four steps for selecting material type and grade:
1. Define the end use performance requirements
2. Translate performance requirements into minimum material properties
3. Screen for candidate materials that meet minimum properties
4. Select the best grade from the candidate materials list

Figure 5. Grade Selection Process

Electronic databases also contain multipoint data typically not included in standard product data sheets. Stress-strain curves at elevated temperatures, modulus vs. temperature and creep elongation over time under different conditions are examples of the kind of multipoint data that are available for many materials, including certain Bakelite® Molding Compound grades. These data can often be imported directly into computer-aided design software.

2.2 Why Consider Engineering Thermosets vs. Metals

Engineering thermosets, like many engineering thermoplastics, have inherent features that make them attractive design options as replacements for metal.

Advantages of engineering thermosets over metals:
- Lightweight
- Inherently corrosion-resistant - no need for corrosion treatment
- Can be molded into finished, tight tolerance complex shapes in one step vs. needing to be cast and machined
- Low CTE (coefficient of thermal expansion), capable of matching steel or aluminium
- Reinforced materials more isotropic

Differences between engineering thermosets and metals:
- Thermosets are good thermal insulators, metals are not
- Thermosets are good electrical insulators, metals are not
- Thermosets are inherently corrosion resistant, metals are not
- Thermosets have extremely good fatigue properties, metals not

Through the selection of resin chemistry, fillers and reinforcements, engineering thermosets can display a wide range of customizable material properties. Overall, they are lightweight, stiff, hard surfaced materials that are good thermal and electrical insulators. Unlike metals, they are not ductile. The characteristics of engineering thermosets need to be considered during the design phase. A part design optimized for metal will not be an optimal design for engineering thermosets.

Material properties serve as a convenient screen to narrow options for the designer or engineer. Final grade selection is application specific and usually involves a compromise between part design, secondary performance features, handling and aesthetics. Commercial considerations such as cost and availability are also important factors in the decision, as are agency approvals, regulatory compliance and OEM (original equipment manufacturer) specifications, if applicable.

Manual screening using data sheets and information obtained directly from suppliers is practical when considering a limited number of materials. Data sheets for all commercial grades of Bakelite® Molding Compounds can be obtained directly from the Hexion website (www.hexion.com).

When evaluating a wide range of materials or comparing dissimilar types, such as engineering thermoplastics (ETP), engineering thermosets (ETS) and metals, manual screening is cumbersome but electronic material databases are an excellent resource. Search functions enable rapid screening by key properties and user created data tables allow side-by-side comparisons of multiple grades. CAMPUS (www.campusplastics.com), MatWeb (www.matweb.com), and UL Prospector (www.ulprospector.com) are three major global materials databases that contain data for engineering thermoplastics and engineering thermosets including all commercial grades of Bakelite® Molding Compounds. MatWeb & UL Prospector also contain metals data.

3 Collectively there is no net orientation in any particular direction.
2.3 Why Consider Engineering Thermosets vs. Engineering Thermoplastics

Engineering thermosets and engineering thermoplastics have many similarities, but one fundamental difference. Both are polymer systems that can be melt processed using injection molding equipment. ² Both are typically compounded with fillers and reinforcements to achieve high thermo-mechanical performance. And both can be used to replace metals in certain applications. The fundamental difference is in their chemistry.

Engineering thermosets crosslink when cured after melt processing, engineering thermoplastics do not. The covalently bonded, three dimensional crosslinked polymer networks formed by engineering thermosets are infusible and cannot be re-melted or dissolved.

The crosslinked polymer network is why engineering thermosets exhibit inherently good temperature and chemical resistance, and very low cold flow (creep) behavior. The polymer chains are connected, and cannot flow past each other under the influence of temperature, solvents or mechanical load.

Engineering thermoplastics do not crosslink during melt processing. They simply undergo a reversible phase transition, solidifying when cooled to form either a fully amorphous or semicrystalline polymer matrix. ³ When heated, they can be re-melted, which allows them to be reprocessed to a degree.⁴

There are no covalent crosslinks in engineering thermoplastics. Thermoplastic polymer chains are free to move past each other and separate when subjected to heat (melt), chemicals (dissolve) or load (cold flow or creep). Engineering thermoplastic performance is governed by the architecture of the polymer backbone, which determines the strength, rigidity, softening temperature, Tg, and melt temperature, Tm, (if crystalline) of the matrix.

Advantages of engineering thermosets over engineering thermoplastics:
- Higher thermal tolerance - won’t melt in use if temperature spikes
- Insoluble - won’t dissolve, better high temperature chemical resistance
- Significantly lower cold flow (creep) under load
- Long term mechanical stability
- Superior fatigue and wear properties
- Superior dimensional stability
- Inherently flame resistant
- High arc track resistance
- no pre-drying before processing

Differences between engineering thermosets and engineering thermoplastics:
- Thermosets are reactively cured to achieve final part properties
- Thermoset parts once cured can not be re-melted or dissolved
- Thermoplastics are solidified from the melt to achieve final part properties
- Thermoplastic parts can be re-melted and dissolved

Engineering thermoplastic structures are thermally reversible, engineering thermoset structures are not. Engineering thermosets crosslink in the mold cavity. They are melt processed once, at which time the polymer network is formed and cured into the final part shape.

Assembly methods that depend on softening or polymer flow, such as heat staking, solvent bonding or sonic welding, will not work with cured engineering thermosets. Other methods of assembly, such as, structural adhesives, self-tapping screws or molded-in threaded inserts need to be considered when designing assemblies with engineering thermosets.

---

² Engineering thermosets require special injection units with low compression screws and water jacketed barrels for temperature control. ³ Semicrystalline polymers, such as PPS and LCP, crystallize between their glass transition temperature, Tg, and melt temperature, Tm, dependent on conditions. ⁴ In practice, the thermoplastic polymers break down after repeated processing.
2.4 Hexion’s product portfolio for automotive solutions

**Exterior Applications**
- Phenolic resins
  - Tires
  - Brake linings & pads
- Precision molding compounds & Precision molded products
  - Brake pistons
- Epoxy fiber sizing
  - Tire cords
- CED coatings, topcoats & refinishing systems
- Epoxy structural panels & adhesives
- Epoxy primer coatings
- Composite structural panels
- Tackifying resins

**Interior Applications**
- Epoxy resin powder - electrical insulation
- Liquid epoxy resin - electronic components
- Phenolic resin copper - clad laminates
- Epoxy resin copper - clad laminates
- Epoxy resin multilayer - PWB materials
- Phenolic molding compounds - ash trays
- Phenolic resins - interior cushioning felt
- Dispersion for seating applications

**Underhood/Powertrain Applications**
- Phenolic molding compounds
  - Starter caps & oil caps
  - Switches
  - Brake booster valve bodies
  - Heat insulators
  - Fuel pump impellers
  - Various pulleys
  - Accumulator pistons-AT devices
  - Integrated exhaust tip
  - Heat shields & exhaust collectors
  - Water pumps
  - Crank scraper
- Cam carrier
- Plenums/housings
- Valve covers & component housings
- Precision molded products
  - Heat insulators
  - Various pulleys
  - Accumulator pistons-AT devices
- Phenolic resins
  - Engine shell molds
- Phenolic fuel additives
Performance in use is determined by more than just material selection. Part design, tool design and material processing are just as critical.

Part design impacts tool design, which, in turn, impacts material processing, which establishes the final polymer structure which, ultimately, determines part performance. Figure 6 shows this process schematically.

Figure 6. Part Performance Factors

Decisions made in each step of the process limit options available in the next. If each step is undertaken in isolation, the outcome will be a suboptimal part made in a suboptimal process. One way to avoid such a result is to allow for feedback from processing and tool design before the part design is frozen.

Part Design ↔ Tool Design ↔ Materials Processing

Part design can and should be influenced by tool design, which likewise, should be influenced by processing considerations. For complex new part designs in an unfamiliar material, this may require a prototype mold and test runs to optimize the part, tool and process before committing to full-scale commercial tooling.

Troubleshooting a problematic process after the fact on production tooling is frustrating, expensive, and can cause lasting issues. This is especially true if the solution is to adjust the process to accommodate a poorly designed tool or part.

Design issues should be preventable. Following sound part and tool design rules, and considering implications of part design decisions on tooling and process will not eliminate all issues, but, will minimize the number faced.

3.1 Design Software

CAD software commonly used by designers and engineers:
Part design: Unigraphics NX Series, Catia and Solidworks
Mold flow analysis: Autodesk Moldflow, Moldex3D and Sigmasoft

3.2 Best Practices

The perfect part design, tool design and molding process creates conditions that produce a void-free, fully crosslinked ETS polymer network, in which fillers and reinforcing fibers are isotropically oriented and uniformly distributed throughout the material matrix.

True perfection is not attainable. Molded ETS test specimens used to measure material properties come close. But they are small parts with simple geometry that are easy to mold. Real parts are complex.

To achieve optimal performance in a real ETS part, design, tooling and processing should create conditions as close to ideal as practically possible. Following a few basic best practice design principles will ensure the best outcome.

Best practice design principles for engineering thermosets:
1. Uniform wall thicknesses – avoid creating areas of material accumulation
2. Radius on all corners – inside corners especially critical
3. Draft on all features with depth (walls, ribs, gussets, bosses, stand-offs)
4. Adequate venting in tool (and process if practical)
5. Isolated tall features supported by gussets or ribs (bosses, stand-offs)
6. Material flow that allows even filling of features – fill from thick to thin
7. Minimal weld / knitlines located in non-critical areas
8. Gate type and size to minimize shear and avoid jetting
9. Balanced runners sized for minimal pressure drop
10. Uniform temperature control throughout tool

Mold flow analysis, in conjunction with CAD modeling, should be employed during the design of all parts. It is especially critical for complex tooling and large format parts. Together, the two techniques enable optimization of the material flow and management of heat transfer by allowing simulations of different part and tool configurations. Features, such as the number, type, size and location of gates as well as ribs, bosses, and flow leaders can be tested and refined before steel is cut. Likewise, modeling also makes it possible to predict heat flow in the cavity and tool during process cycles allowing for optimization of heat transfer systems.

Contact a Hexion Bakelite® product representative for technical assistance with your application.
3.3 Part Design Recommendations

Table 2 below contains general part design recommendations. These are intended as "best practice" guidelines applicable for all molding compounds. Successful commercial parts have been designed and produced that are exceptions to these guidelines. Contact your Hexion Bakelite® technical representative to determine what is possible for your specific application.

Table 2. Part Design Recommendations

<table>
<thead>
<tr>
<th>Design Element</th>
<th>Recommended</th>
<th>Rational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall section thickness [t]</td>
<td>t = 0.08” – 0.24” (2 – 6 mm)</td>
<td>• Ability to fill part features</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Minimize cure / cycle time</td>
</tr>
<tr>
<td>Variation in wall section thickness</td>
<td>±10 – 25% on primary structure</td>
<td>• Uniform part filling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Even cure throughout part</td>
</tr>
<tr>
<td>Radius corners</td>
<td>Filet: 0.2 t – 0.5 t Corner: 1.2 t – 1.5 t</td>
<td>• Eliminate stress concentrators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Improve material flow</td>
</tr>
<tr>
<td>Draft angle</td>
<td>1.5° – 2.5° standard 0.5° minimum</td>
<td>• Facilitate part removal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Prevent damage to part surface on removal</td>
</tr>
<tr>
<td>Ribs &amp; Gussets</td>
<td>Width: 0.4 t – 0.6 t (include draft) Height: &lt; 3 t Minimum spacing: 2 t</td>
<td>• Mechanical support</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ability to fill without thick sections</td>
</tr>
<tr>
<td>Bosses</td>
<td>2 – 3 x diameter of hole (include draft) Height: &lt; 3 t Support: 3 – 4 gussets / ribs</td>
<td>• Hoop strength to support fastener or pin insertion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Solid lateral mechanical support for feature</td>
</tr>
</tbody>
</table>

Thickness transitions should be kept to a minimum. Where necessary, they should be smooth. Suggested practice is to keep variations in the primary structure thickness to ±10 – 25% and to transition from thick to thin over a distance equal to three times the thickness change as illustrated in Figure 7.

Figure 7. Wall Section Thickness & Transition

Uniform thickness throughout the part minimizes thermal gradients, which promotes even curing. Smooth transitions avoid abrupt mass differences and disruptions in the flow of material around corners which can lead to "dead zones" in the melt (illustrated later in Figure 8). Dead zones can cause filling problems and trap gas.

Sharp differences in mass lead to differential curing and internal shrink stresses that may not be visible on the molded ETS part. In general, engineering thermoplastics exhibit visible sink marks where there are "accumulated mass" or mass difference issues, engineering thermosets do not.7

Faithfully applying the "uniform thickness – smooth transition" principle can prevent many design-related part problems.

3.3.1 Wall Section Thickness

Recommended primary structure thickness: 0.08” (2 mm) to 0.24” (6 mm) with variations within ±10 – 25%.

The recommended range in wall section thickness is suggested as a practical design range that balances the ability to fill parts on the low end with minimizing cure time on the upper end. What is achievable or practical in practice is highly dependent on the type of engineering thermoset used and the requirements of the part.

Thin wall sections can be difficult to properly fill, especially if the part has deep, intricate features and the material in use is glass fiber reinforced. Thick wall sections fill easily, but greatly extend cure times due to the increase in mass. Both extremes run the risk of voids due to trapped gases and internal shrink stresses, which can result in warpage.

3.3.2 Radii

Recommended radii: 0.2 – 0.5 x wall thickness for inside fillet; 1.2 – 1.5 x wall thickness for outside corner radius

Sharp corners should be avoided. External corners are prone to chipping due to the brittle nature of most engineering thermosets. Internal corners are stress concentrators and locations for mechanical failures, which makes fillet radii at wall junctions particularly critical. Sharp corners also disrupt polymer melt flow during processing.

Figure 8 illustrates schematically how the polymer melt transitioning around a sharp corner exhibits dead spots in its flow (left) but transitions smoothly with the proper radius on the (right). Dead spots, as mentioned previously, can result in poor packing, trapped gas and the defects associated with those issues.

7 This is due to the formation of crosslinks in thermosets; once the external skin is reacted, flow of material stops, preventing the polymer chains from sinking.
3.3.4 Ribs & Gussets

Recommended dimensions:
- **Width:** 0.4 – 0.6 x wall section thickness (include draft)
- **Height:** < 3 x wall section thickness
- **Minimum spacing:** 2 x wall section thickness

Figure 11 below shows a cross section of two ribs. The one on the left is too tall, too thick has no radii or draft. The rib on the right is shown with recommended dimensions, radii and draft.

3.3.3 Draft

**Recommended draft:**
1.5° – 2.5°

Engineering thermosets exhibit little mold shrinkage but still require some draft on features that have depth (walls, ribs, gussets, bosses & stand-offs) in order for the part to be removed from the tool post cure. The lower end of the recommended range, 1.5°, is appropriate for highly filled, low shrink grades, and the higher end 2.5° for higher shrink grades. The general rule of thumb for textured surfaces is to add 1 – 2°. It is possible to successfully mold parts with lower draft, but it is not good practice to go below 0.5°.
Ribs and gussets (or buttresses) can be used to support part features such as a wall, boss or stand-off. They can also be used to direct melt flow during processing or to allow removal or “core out” of material from thick sections to minimize cure time and prevent warpage.

Figure 12 shows a molded flange designed two ways. The one on the left has a thick base tab that uses more material than necessary. This lengthens cure time and can cause warpage due to shrink stresses. The flange on the right shows how ribs can be employed to remove or “core out” material without compromising part strength. This design will use less material, cure faster and more evenly and will be less likely to warp.

Figure 12. Cored Out Flange

**3.3.5 Bosses**

**Recommended dimensions:**
- 2-3 x diameter of hole (include draft)
- Height < 3 x wall section thickness

Figure 13 shows the cross section of a boss designed to recommended dimensions and supported by gussets. The diameter in the case of bosses is driven by the diameter of the hole. While no explicit limitations are cited, a practical limitation for the hole diameter is the thickness of the wall section the boss is attached to.

Figure 13. Cross Section of Boss

3.4 Mold Design Recommendations

Table 3 below contains general mold design recommendations. As in Table 2, these are intended as “best practice” guidelines applicable for all molding compounds. Successful commercial parts have been produced in molds that are exceptions to these guidelines. Contact your Hexion Bakelite® product technical representative to determine what is possible for your specific application.
Table 3. Mold Design Recommendations

<table>
<thead>
<tr>
<th>Design Element</th>
<th>Example</th>
<th>Rational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runners:</td>
<td>Full round (cavity &amp; force) or trapezoidal (cavity)</td>
<td>• Ability to machine into tool</td>
</tr>
<tr>
<td></td>
<td>Primary: 0.25” – 0.31” x 0.125” (6.4 – 7.9 mm x 3.2 mm)</td>
<td>• Minimize pressure drop during fill</td>
</tr>
<tr>
<td></td>
<td>Secondary: 0.125” x 0.094” (3.2 mm x 2.39 mm)</td>
<td></td>
</tr>
<tr>
<td>Gates:</td>
<td>All types possible sprue, fan, tab, pin, sub</td>
<td></td>
</tr>
<tr>
<td></td>
<td>General Purpose: 0.080” – 0.100” x 0.015” – 0.020” (2.00 – 2.54 mm x 0.38 – 0.51 mm)</td>
<td>• Allow even filling of cavity with minimal shear</td>
</tr>
<tr>
<td></td>
<td>Mineral Filled: 0.125” x 0.030” (3.18 mm x 0.76 mm)</td>
<td>• Avoid jetting</td>
</tr>
<tr>
<td></td>
<td>Glassfiber reinforced Phenolic MC: 0.500” x 0.125” (12.7 mm x 3.18 mm)</td>
<td></td>
</tr>
<tr>
<td>Vents:</td>
<td>Cavity</td>
<td>• Release air and gas formed during processing</td>
</tr>
<tr>
<td></td>
<td>Ejector pins</td>
<td>• Allow full filling of cavity</td>
</tr>
<tr>
<td></td>
<td>Depth: 0.0007” – 0.0050” (0.018 mm – 0.127 mm)</td>
<td>• Prevent burning and void formation</td>
</tr>
<tr>
<td></td>
<td>Min Width: 0.125” (3.2 mm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>flat ground on side of pin for 1st 0.75” (20 mm) then relieved 0.015” (0.38 mm)</td>
<td></td>
</tr>
<tr>
<td>Overflow:</td>
<td>Compression molds clearance between cavity perimeter and force with nominal land leading to overflow channel</td>
<td>• Allow complete filling and packing of part</td>
</tr>
<tr>
<td></td>
<td>0.001” – 0.005” (0.025 – 0.127 mm)</td>
<td></td>
</tr>
<tr>
<td>Thermal Control</td>
<td>Electric cartridge heaters for small simple parts</td>
<td>• Even consistent, well controlled heat</td>
</tr>
<tr>
<td></td>
<td>Circulating hot oil or steam for large complex parts</td>
<td>• Minimize thermal gradients, avoid hot spots</td>
</tr>
<tr>
<td>Tool Steel:</td>
<td>Cavities, gates, slides, lifters &amp; high wear areas</td>
<td>• Highest abrasion &amp; corrosion resistance</td>
</tr>
<tr>
<td></td>
<td>D2, M333, 1.2379, 1.2080, 1.2083 (or equivalent)</td>
<td>• Abrasion resistant</td>
</tr>
<tr>
<td></td>
<td>H13 HRC 44-48, 50 max for cavities</td>
<td>• Tough, thermal shock tolerant</td>
</tr>
<tr>
<td></td>
<td>S7 HRC 50-52 for cavities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S7 HRC 54-56 for slides &amp; lifters</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P20 HRC 28-32 38-40 max prototype or short run tools</td>
<td></td>
</tr>
<tr>
<td>Tool Steel:</td>
<td>Mold bases</td>
<td>• Tough, hard, best durability</td>
</tr>
<tr>
<td></td>
<td>P20 HRC 28-32</td>
<td>• Easy to machine tough</td>
</tr>
<tr>
<td></td>
<td>4130</td>
<td>• Free machining, soft</td>
</tr>
<tr>
<td></td>
<td>SAE 1030</td>
<td></td>
</tr>
</tbody>
</table>

3.4.1 Runners

Example:
Main cross section: 0.25” – 0.31” x 0.125” (6.4 – 7.9 mm x 3.2 mm)
Secondary cross section: 0.125” x 0.094” (3.2 mm x 2.39 mm)

Full round runners are the optimal geometry transporting the largest volume for the least surface area. Practically they are more work to machine. To form the full round runner, half round runners need to be machined on each surface of two mating plates (parting line in the middle). Trapezoidal cross sections are almost as efficient as a full round runner but need only to be machined in one plate.

3.4.2 Gating

The dimensions in each case depend on part design, expected mold filling, number of cavities and part volume.

Example dimensions:
- **General Purpose:** 0.080” - 0.100” x 0.015” – 0.020” (2.00 – 2.54 mm x 0.38 – 0.51 mm)
- **Mineral filled:** 0.125” x 0.030” (3.18 mm x 0.76 mm)
- **Glass filled phenolic:** 0.500” x 0.125” (12.7 mm x 3.18 mm)

All types of gating is possible with engineering thermosets:
- Sprue, tab, fan, pin and sub gates regardless of filler or reinforcement content.

The gate location, type and dimensions:
- Controls material flow into the cavity
- Determines level of shear the material experiences
- Determines where knitlines will form
- Determines flow path which impacts warpage

---

8 Knitlines form wherever two melt fronts moving in different directions contact each other. Knitlines are always weak points. When two impinge on each other the degree to which they are able to mix before reacting determines how strong the knitline will be (it is always less than 100%).
Material flowing into a thick section of a cavity through a gate that is too small can result in jetting or damage to reinforcing fibers. Location of the gate (or gates), type and size determines where melt fronts will impinge on each other forming knitlines.6

Moldflow analysis is an important tool in this aspect of design. Being able to simulate flow through different gate styles sizes and locations allows a designer to optimize how best to fill the part.

3.4.3 Venting

Example:
Cavity vents: 0.0007” – 0.0050” (0.018 mm – 0.127 mm) depth, minimum width 0.125” (3.2 mm)
Ejector pin vents: 0.0007” (0.018 mm)

Melts push process gasses ahead of the flow front. Parting line vents generally should be located opposite the gate in the cavity in such a manner to allow gasses to escape during filling and curing of the engineering thermoset. Additional venting in other locations is often necessary.

Venting can be accomplished by reliefs cut into the tooling that allows for gasses to escape when the tool is closed and by opening the mold to degas during the filling and curing cycle. Both are effective and can be used separately or together.

Ejector pin vents can be an elegant solution to a trapped gas problem. These should be approached with caution, however. Vents that are too deep result in flash.

3.4.4 Tool Steel

Example:
Cavities D2, M333 (or equivalent), H13 or S7, mold bases P20

Glass reinforced and mineral filled phenolic grades are highly abrasive. Production tooling for these materials should have cavities made of high chrome hardened tool steel; D2, M333 or equivalent hardened to HRC 48 – 52 are preferred. Other steels, such as hardened to HRC 44 – 48, or S7 hardened to HRC 50 – 52, can be used and either hard chrome plated or plasma nitrited for improved wear and corrosion resistance. Critical wear areas of production tools, such as gates, can be made with hardened inserts to allow easy replacement.

Standard mold bases commercially available from a number of suppliers6 in a range of standard sizes and configurations can be used, or custom bases can be designed and built. The recommended steel type is P20 (No 3) prehardened to HRC 28 – 30, 4130 (No 2) can also be used, but is softer and will not have the same durability.

Molds for prototyping or short production runs can be made from soft carbon steel and hardened, or, preferably, machined from P20 prehardened to HRC 28 – 30.

3.4.5 Heaters / Heat Control

Even heating in the mold is critical to achieving uniform curing of ETS resins. Electric cartridge heaters are efficient, cost effective and a good source for rapid concentrated heating. Their temperature control is adequate for small parts and multi cavity molds.

Thermal management in tooling for larger complex parts is more challenging with cartridge style heaters. For these applications, circulating fluid provides the most uniform heat and temperature control. The mass of fluid moving through the tool levels out temperature gradients and not only transports heat in, but transports excess heat out too.

Either hot oil or steam systems can be used. Oil is messy but can be operated at low pressures relative to steam which will require 225 – 350 psi (15 – 25 bar) to reach the required temperatures of 320 – 375 °F (160 – 190 °C).

3.4.6 Summary

Complex parts will likely require compromise on one or more design recommendation. Trade-offs are inevitable, but certain recommendations should be given greater consideration than others. Minimal draft angle, minimal fillet radii on inside corners, and adequate venting are three that should be incorporated in every part and tool design.

Finally, though it has not been mentioned explicitly, close to attention should be paid to the material shrinkage rate used in the design. This should correspond to the specific material grade being used. Incorrect shrinkage is a frequent cause of tooling problems.

Contact a Hexion Bakelite® product representative for technical assistance with your application.
Via E-Mail: moulding-compounds@hexion.com

6 DME division of Milacron (www.dme.com), Superior Die Set Corp (www.supdie.com), Mold Base Industries (www.moldbase.com) and others.
4

Processing Guide
Engineering thermosets, unlike engineering thermoplastics, are reacted and cured during molding. Hold time and temperature are critical control parameters to achieve a consistent degree of cure. Phenolics evolve a small amount of water as part of their curing process. Adequate venting is important for these materials.

### 4.1 Process Selection

The following methods are used to process engineering thermosets:
- Compression molding
- Transfer molding
- Injection molding
- Injection-compression molding.

#### 4.1.1 Compression molding

Compression molding is the simplest process. A set amount of molding compound, often preheated or preplasticized, is charged into the heated mold while it is open. The mold is then closed squeezing the softened material to fill out the cavity. After enough time is allowed for the molding compound to cure, the part can be removed from the mold.

Cure time is dependent on the reactivity of the molding compound, its prior treatment, the mold temperature and the wall thickness of the part being molded.

Figure 15 contains a schematic of the compression process showing two different style tools. Both are viable options for molding compounds; flash, or overflow, type molds are not recommended. Semipositive molds have been especially successful since they compress the molding compounds during cure and produce a consistent part despite variations in the material charged.

Compression molding may be a manual, semiautomatic or fully automatic process.

**Compression molding:** Lowest warpage, minimal shear stress on melt as it flows into cavities

**Advantages:**
- Low processing and post shrinkage
- Low warpage of molded part
- Minimal damage of reinforcing fibers

**Disadvantage:**
- Cycle times depend on cure time of the thickest wall section

#### 4.1.2 Transfer molding

Transfer molding, also known as “pot and piston” molding, is a process in between compression molding and injection molding. Pelletized and preheated or preplasticized molding compound is pushed from the heated pot by a plunger (piston) into the mold cavity via a runner and gate system where the material cures.

Three plate molds with the plunger working from the top can be built into conventional presses. Single split molds, easier from the point of view of process technology - the plunger works from below or horizontally from the side - require a press with two hydraulic plungers.

Transfer molding: More automated and consistent than compression molding.

**Advantages:**
- Shorter cycle times, compared to compression molding
- Minimal flash (cavity is filled with the mold closed)

**Disadvantage:**
- Higher degree of warpage than compression molding (due to anisotropy)

Transfer systems with screw preplastification and plunger feeding are an obvious choice for molding parts which are subjected to stress and have tight dimensional tolerances. This method can accommodate more reactive molding compounds which results in relatively short cycle times and accurate shot weights.

#### 4.1.3 Injection molding

Due to its high degree of automation and efficiency, injection molding is the most widely used process today. A no or low compression plasticating screw designed for free flowing (or pourable) thermosets, melts and homogenizes the molding compound then injects it into the mold.

Figure 15 contains a schematic of the compression process showing two different style tools. Both are viable options for molding compounds; flash, or overflow, type molds are not recommended. Semipositive molds have been especially successful since they compress the molding compounds during cure and produce a consistent part despite variations in the material charged.

Compression molding may be a manual, semiautomatic or fully automatic process.

**Compression molding:** Lowest warpage, minimal shear stress on melt as it flows into cavities

**Advantages:**
- Low processing and post shrinkage
- Low warpage of molded part
- Minimal damage of reinforcing fibers

**Disadvantage:**
- Cycle times depend on cure time of the thickest wall section

#### 4.1.2 Transfer molding

Transfer molding, also known as “pot and piston” molding, is a process in between compression molding and injection molding. Pelletized and preheated or preplasticized molding compound is pushed from the heated pot by a plunger (piston) into the mold cavity via a runner and gate system where the material cures.

Three plate molds with the plunger working from the top can be built into conventional presses. Single split molds, easier from the point of view of process technology - the plunger works from below or horizontally from the side - require a press with two hydraulic plungers.

Transfer molding: More automated and consistent than compression molding.

**Advantages:**
- Shorter cycle times, compared to compression molding
- Minimal flash (cavity is filled with the mold closed)

**Disadvantage:**
- Higher degree of warpage than compression molding (due to anisotropy)

Transfer systems with screw preplastification and plunger feeding are an obvious choice for molding parts which are subjected to stress and have tight dimensional tolerances. This method can accommodate more reactive molding compounds which results in relatively short cycle times and accurate shot weights.

#### 4.1.3 Injection molding

Due to its high degree of automation and efficiency, injection molding is the most widely used process today. A no or low compression plasticating screw designed for free flowing (or pourable) thermosets, melts and homogenizes the molding compound then injects it into the mold.

Figure 15 contains a schematic of the compression process showing two different style tools. Both are viable options for molding compounds; flash, or overflow, type molds are not recommended. Semipositive molds have been especially successful since they compress the molding compounds during cure and produce a consistent part despite variations in the material charged.

Compression molding may be a manual, semiautomatic or fully automatic process.

**Compression molding:** Lowest warpage, minimal shear stress on melt as it flows into cavities

**Advantages:**
- Low processing and post shrinkage
- Low warpage of molded part
- Minimal damage of reinforcing fibers

**Disadvantage:**
- Cycle times depend on cure time of the thickest wall section

#### 4.1.2 Transfer molding

Transfer molding, also known as “pot and piston” molding, is a process in between compression molding and injection molding. Pelletized and preheated or preplasticized molding compound is pushed from the heated pot by a plunger (piston) into the mold cavity via a runner and gate system where the material cures.

Three plate molds with the plunger working from the top can be built into conventional presses. Single split molds, easier from the point of view of process technology - the plunger works from below or horizontally from the side - require a press with two hydraulic plungers.

Transfer molding: More automated and consistent than compression molding.

**Advantages:**
- Shorter cycle times, compared to compression molding
- Minimal flash (cavity is filled with the mold closed)

**Disadvantage:**
- Higher degree of warpage than compression molding (due to anisotropy)

Transfer systems with screw preplastification and plunger feeding are an obvious choice for molding parts which are subjected to stress and have tight dimensional tolerances. This method can accommodate more reactive molding compounds which results in relatively short cycle times and accurate shot weights.

#### 4.1.3 Injection molding

Due to its high degree of automation and efficiency, injection molding is the most widely used process today. A no or low compression plasticating screw designed for free flowing (or pourable) thermosets, melts and homogenizes the molding compound then injects it into the mold.

Figure 15 contains a schematic of the compression process showing two different style tools. Both are viable options for molding compounds; flash, or overflow, type molds are not recommended. Semipositive molds have been especially successful since they compress the molding compounds during cure and produce a consistent part despite variations in the material charged.

Compression molding may be a manual, semiautomatic or fully automatic process.

**Compression molding:** Lowest warpage, minimal shear stress on melt as it flows into cavities

**Advantages:**
- Low processing and post shrinkage
- Low warpage of molded part
- Minimal damage of reinforcing fibers

**Disadvantage:**
- Cycle times depend on cure time of the thickest wall section

#### 4.1.2 Transfer molding

Transfer molding, also known as “pot and piston” molding, is a process in between compression molding and injection molding. Pelletized and preheated or preplasticized molding compound is pushed from the heated pot by a plunger (piston) into the mold cavity via a runner and gate system where the material cures.

Three plate molds with the plunger working from the top can be built into conventional presses. Single split molds, easier from the point of view of process technology - the plunger works from below or horizontally from the side - require a press with two hydraulic plungers.

Transfer molding: More automated and consistent than compression molding.

**Advantages:**
- Shorter cycle times, compared to compression molding
- Minimal flash (cavity is filled with the mold closed)

**Disadvantage:**
- Higher degree of warpage than compression molding (due to anisotropy)

Transfer systems with screw preplastification and plunger feeding are an obvious choice for molding parts which are subjected to stress and have tight dimensional tolerances. This method can accommodate more reactive molding compounds which results in relatively short cycle times and accurate shot weights.

#### 4.1.3 Injection molding

Due to its high degree of automation and efficiency, injection molding is the most widely used process today. A no or low compression plasticating screw designed for free flowing (or pourable) thermosets, melts and homogenizes the molding compound then injects it into the mold.
cavity tool via the sprue and runner system. The process is self-contained and machine-controlled, which leads to greater part-to-part consistency in the molding cycle.

**Injection molding:** Highest automation, highest consistency

**Advantages:**
- Shortest cycle times, compared to compression or transfer molding
- Highest degree of automation

**Disadvantage:**
- Tooling more complex
- High melt shear during injection

### 4.1.4 Injection-compression

This process is a hybrid that combines the quality benefits of compression molding with the efficiency and consistency of injection molding.

This is accomplished by injecting a fixed amount of plasticated molding compound into the mold while it is held partially open, followed by closing the mold to compress the material and fill out the part cavity. Figure 16 gives a schematic of the process.

**Injection-compression molding:** Low shear, low warp

---

### 4.2 Process Parameters

Bakelite® Molding Compounds are shipped ready for use. Any material with visible moisture or other contamination should not be used as is.

Entrained moisture from condensation can cause voids or cosmetic defects in the molded part. Care should be taken to equilibrate material to the molding facility environment before opening the packaging to avoid condensation.

Drying is not recommended for Bakelite® Molding Compounds. If packaging has been damaged or visible moisture is apparent in the material, contact a Hexion Bakelite® product representative for technical assistance.

### 4.2.1 Injection molding temperature profiles

Figure 17 shows the recommended temperatures for injection molding Bakelite® molding compounds.

**Figure 17. Temperature Profiles for Bakelite® Molding compounds (Diagram Modified From Arburg Brochure.)**

### 4.2.2 General process set up conditions

Table 4 gives the recommended process parameters for compression molding and injection molding Bakelite® molding compounds by resin type: epoxy (EP), melamine-phenolic (MP), phenolic (PF) and unsaturated polyester (UP).
### Table 4. Example Process Parameters

<table>
<thead>
<tr>
<th>Molding Conditions</th>
<th>Units</th>
<th>EP min</th>
<th>EP max</th>
<th>MP min</th>
<th>MP max</th>
<th>PF min</th>
<th>PF max</th>
<th>UP min</th>
<th>UP max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression Molding</td>
<td>°C</td>
<td>160</td>
<td>190</td>
<td>160</td>
<td>170</td>
<td>160</td>
<td>190</td>
<td>160</td>
<td>180</td>
</tr>
<tr>
<td>Cavity pressure</td>
<td>bar</td>
<td>&gt; 100</td>
<td>&gt; 150</td>
<td>&gt; 150</td>
<td>&gt; 100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cure time per 1 mm wall thickness</td>
<td>s</td>
<td>30</td>
<td>60</td>
<td>20</td>
<td>40</td>
<td>20</td>
<td>40</td>
<td>20</td>
<td>40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Injection Molding</th>
<th>Units</th>
<th>EP min</th>
<th>EP max</th>
<th>MP min</th>
<th>MP max</th>
<th>PF min</th>
<th>PF max</th>
<th>UP min</th>
<th>UP max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold Temp</td>
<td>°C</td>
<td>170</td>
<td>190</td>
<td>160</td>
<td>170</td>
<td>160</td>
<td>190</td>
<td>160</td>
<td>180</td>
</tr>
<tr>
<td>Barrel Temp</td>
<td>°C</td>
<td>60</td>
<td>75</td>
<td>60</td>
<td>75</td>
<td>60</td>
<td>75</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Nozzle</td>
<td>°C</td>
<td>70</td>
<td>100</td>
<td>80</td>
<td>100</td>
<td>80</td>
<td>100</td>
<td>70</td>
<td>100</td>
</tr>
<tr>
<td>Material Temp</td>
<td>°C</td>
<td>90</td>
<td>100</td>
<td>80</td>
<td>100</td>
<td>80</td>
<td>100</td>
<td>70</td>
<td>100</td>
</tr>
<tr>
<td>Cavity Pressure</td>
<td>bar</td>
<td>&gt; 100</td>
<td>&gt; 150</td>
<td>&gt; 150</td>
<td>&gt; 100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back Pressure</td>
<td>bar</td>
<td>5</td>
<td>20</td>
<td>5</td>
<td>20</td>
<td>5</td>
<td>20</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Cure Time per 1 mm wall thickness</td>
<td>sec</td>
<td>15</td>
<td>25</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Hold Pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compression Molding</th>
<th>Units</th>
<th>EP min</th>
<th>EP max</th>
<th>MP min</th>
<th>MP max</th>
<th>PF min</th>
<th>PF max</th>
<th>UP min</th>
<th>UP max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold Temp</td>
<td>°F</td>
<td>320</td>
<td>375</td>
<td>320</td>
<td>340</td>
<td>320</td>
<td>375</td>
<td>320</td>
<td>355</td>
</tr>
<tr>
<td>Cavity pressure</td>
<td>psi</td>
<td>&gt; 1,450</td>
<td>&gt; 2,175</td>
<td>&gt; 2,175</td>
<td>&gt; 1,450</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cure time per 0.04&quot; wall thickness</td>
<td>s</td>
<td>30</td>
<td>60</td>
<td>20</td>
<td>40</td>
<td>20</td>
<td>40</td>
<td>20</td>
<td>40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Injection Molding</th>
<th>Units</th>
<th>EP min</th>
<th>EP max</th>
<th>MP min</th>
<th>MP max</th>
<th>PF min</th>
<th>PF max</th>
<th>UP min</th>
<th>UP max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold Temp</td>
<td>°F</td>
<td>340</td>
<td>375</td>
<td>320</td>
<td>340</td>
<td>320</td>
<td>375</td>
<td>320</td>
<td>355</td>
</tr>
<tr>
<td>Barrel Temp</td>
<td>°F</td>
<td>140</td>
<td>165</td>
<td>140</td>
<td>165</td>
<td>140</td>
<td>165</td>
<td>140</td>
<td>160</td>
</tr>
<tr>
<td>Nozzle</td>
<td>°F</td>
<td>160</td>
<td>212</td>
<td>175</td>
<td>212</td>
<td>175</td>
<td>212</td>
<td>160</td>
<td>212</td>
</tr>
<tr>
<td>Material Temp</td>
<td>°F</td>
<td>195</td>
<td>212</td>
<td>175</td>
<td>212</td>
<td>175</td>
<td>212</td>
<td>160</td>
<td>212</td>
</tr>
<tr>
<td>Cavity Pressure</td>
<td>psi</td>
<td>&gt; 1,450</td>
<td>&gt; 2,175</td>
<td>&gt; 2,175</td>
<td>&gt; 1,450</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back Pressure</td>
<td>psi</td>
<td>75</td>
<td>290</td>
<td>75</td>
<td>290</td>
<td>75</td>
<td>290</td>
<td>75</td>
<td>145</td>
</tr>
<tr>
<td>Cure Time per 0.04&quot; wall thickness</td>
<td>s</td>
<td>15</td>
<td>25</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Hold Pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 4.2.3 Startup procedures

#### Compression molding:
Preheat the mold to the recommended temperature. Make sure the preheated material is at the correct temperature. Begin the molding process.

#### Injection molding:
Attach the nozzle to the barrel and, with the mold closed, move the injection unit forward until the nozzle is in contact with the sprue bushing. Turn on heaters. When the barrel, nozzle and mold have stabilized at the recommended temperatures, back the injection unit as far away from the sprue bushing as possible. With the screw in the forward position, open the feed hopper and allow material to flow into the unit. Dose up to 30% of the approximate final shot volume and inject the material into the open air. Repeat the dosing process two to three times increasing the amount until the approximate shot volume for the final part is reached and the material appears fully plasticized with no visible granules. At this point, clean the nozzle tip, sprue bushing and remove all extruded material. Move the injection unit into position with the nozzle against the sprue and begin the normal production process. Adjust the final shot volume during the first few molding cycles as necessary, until the process is stable at the target part weight and operating parameters.

### 4.2.4 Shut-down procedures

#### Compression molding:
Stop preheating material after the final dose has been loaded into the mold. Stop the press after ejection of the final part and turn off heaters. Remove all flash and clean the mold of any material residue. Close the mold once it is clean.

#### Injection molding:
Stop the press from cycling after ejecting the last part and shut off the material flow from the feed hopper. Back the injection unit away from the mold and purge out the remaining material in the screw. When the screw is empty, remove and clean the nozzle, making sure that no material is left in the threads. Turn off heaters. Remove all flash and clean the mold of any material residue. Close the mold once it is clean.

### 4.2.5 Process interruption procedures

#### Compression molding:
If the process will be interrupted for an extended period of time, stop preheating material. Begin preheating material when process is ready to be restarted.
Injection molding:

If the process will be interrupted for an extended period of time, shut off the material feed on the hopper, back the injection unit away from the mold and purge out the material in the screw. After the interruption is over, cycle a few doses of material through the barrel and make sure it is fully plasticized with no visible granules before restarting the molding process. Check the first few parts after the restart carefully to make sure they are properly molded. If it is not possible to purge material from the barrel during the interruption, go through the full shutdown procedure (4.2.4) and restart using the startup procedure (4.2.3).

4.2.6 Controllable parameters in injection molding

Pourable (granular or pelletized) thermosets can be fed into injection molding machines that have been fitted with special equipment.

- No or low compression screws (feed zone flight depth = nozzle zone flight depth)
- Precise temperature control injection barrel
- Screw-in nozzles with precise temperature control
- No non-return valves at nozzle (prevents material hang ups)

Figure 18 shows a stylized schematic for an injection molding machine identifying the key controllable parameters of the injection molding process.

Contact a Hexion Bakelite® product representative for technical assistance with your application.
Secondary Operations
5.1 Deflashing

Use of automatic deflashing machines is the state of the art. Small engineering thermoset parts can be deflashed in a tumble process using soft media, such as polyamide or polycarbonate pellets, filled polyamide, crushed nut shells, or thermoset materials. Larger parts can be deflashed using the same media in closed loop media blast machines. Parts can also be manually deflashed using hand tools and fixtures.

5.2 Machining

Engineering thermosets can be machined using standard machine tools but unlike metals, they are hard, brittle and often contain abrasive materials. This is especially true for grades that have high levels of glass fiber or sphere reinforcement.

Machining should be done with carbide tipped or diamond coated bits instead of high speed tool steel or nitrided bits. Production cutting tools should be fitted with replaceable carbide inserts to allow for frequent replacement of the cutting edges.

Material can be machined with high cutting speeds and feed rates but care must be taken not to chip or break off corners. Cutting fluid is not recommended because of the thick dust created during machining. The preferred method is to machine the material dry, using a dust collector for the cuttings and compressed air to cool the tool.

5.3 Assembly

5.3.1 Fasteners

Engineering thermoset parts can be assembled using threaded fasteners. There are a number of self-tapping screws with different configurations and thread profiles that are available for metals and plastics. They all fall into two general categories: thread forming and thread cutting.

Thread forming screws are designed to push material out of the way as they are driven in. The displaced material subsequently flows back into features on the threads locking them in place. Forming style screws can generate a large amount of hoop stress in the boss due to the material they displace. This type of fastener is not appropriate for stiff materials that do not cold flow and is therefore not recommended for use with engineering thermosets.

Thread cutting screws have a cutting edge, similar to a tap, that removes material as they are driven in. This type of screw does not generate the hoop stress that forming types do. It is recommended that only cutting style self-tapping screws be used with engineering thermosets. Fasteners, such as the Delta PT type DS from Ejot designed specifically for use with thermosets, or similar thread cutting screws from ITW Shakeproof, Screwerks, ATF or other manufacturers will provide the best results.

Care must be taken when inserting self-tapping screws. Automated screwdrivers set at speeds appropriate for metals are likely running too fast for engineering thermosets. This can result in cracking in the boss. Threaded inserts with knurled or diamond pattern exteriors can be used with engineering thermosets, but only if they are insert molded into the part. Heat staking, ultrasonic staking or cold staking of inserts is not recommended.

Boss design is also important when using mechanical fasteners. See earlier section on part design for recommended boss dimensions. Hole dimensions should comply with those specified by the manufacturer for the type of fastener selected.

5.3.2 Adhesive bonding

A variety of high strength structural adhesives systems are available for bonding engineering thermoset parts. Joint design, adhesive selection, substrate preparation and the bonding process are all critical to the success of a structural adhesive assembly.

It is recommended, therefore, that the user consult with a structural adhesive manufacturer early in the design process for technical assistance with joint design, and selection of an adhesive system appropriate for the application.

Loctite, ITW Plexus, Delo and 3M Structural Adhesives are a few of the well known manufacturers of high performance adhesives for structural assembly of engineering thermosets.

5.3.3 Other assembly methods

Common plastic assembly methods that require the material to soften or deflect, such as sonic or vibrational welding, solvent bonding or heat staking are not recommended for engineering thermoset resins. The inherent infusibility of the resins prevents these methods from working as designed.

Snap fits, in theory, can be designed for any material that has sufficient ductility. But these must be approached with caution on an individual basis. In general, engineering thermoset molding compounds, when cured, do not have sufficient ductility to allow design of a robust snap fit. This is especially true for grades that are filled with mineral or glass fibers.

5.4 Decorating

Engineering thermosets may be painted. They are compatible with a wide array of commercially available paint systems both liquid and powder. Surface preparation before painting is critical to achieve proper adhesion of the paint to the surface.

Contact a Hexion Bakelite® technical representative for specific recommendations on grades and for technical assistance with your application.

Bakelite® Molding Compounds are shipped ready for use. Any material with visible moisture or other contamination should not be used.
6 Troubleshooting Guide
6.1 Injection Molding

Bakelite® Molding Compounds are shipped ready for use. Any material with visible moisture or other contamination should not be used.

Excess trapped gas is frequently the root cause of voids or cosmetic defects in the molded part. Moisture in the molding compound can be a contributor, even for materials that are not known to absorb water such as most engineering thermosets. Proper venting of the tool and adjustment of the processing parameters will take care of most moisture-related problems. However, entrained moisture from condensation can overwhelm even a well vented tool. Care should be taken to equilibrate material to the molding facility environment before opening the packaging to avoid condensation. Drying is not recommended for Bakelite® Molding Compounds.

If packaging has been damaged or visible moisture is apparent in the material, contact a Hexion Bakelite® product representative for technical assistance.

Injection molding machine should be equipped with a non-compression screw (1:1 feed to nozzle) appropriate for thermosets with good temperature control over the feed and nozzle sections. The tool heating system should be in good working order with heat control uniform throughout the mold cavity: ± 5 °F (±2 °C).

Figure 21. Injection Molding Machine for free-flowing thermosets

Additional parameters to be considered
- Injection pressure
- consistency of melt cushion
- dosing time
<table>
<thead>
<tr>
<th>Injection Molding</th>
<th>Corrective Action</th>
<th>Nozz Temp</th>
<th>Feed Temp</th>
<th>Shot Size</th>
<th>Back Press</th>
<th>Screw Speed</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Defect</strong></td>
<td><strong>Root Cause</strong></td>
<td><strong>Mold Temp</strong></td>
<td><strong>Hold Press</strong></td>
<td><strong>Hold Time</strong></td>
<td><strong>Venting</strong></td>
<td><strong>Inject Speed</strong></td>
<td><strong>Actions</strong></td>
</tr>
<tr>
<td>Dim / Cloudy Areas</td>
<td>Trapped gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Clean vents, increase venting</td>
</tr>
<tr>
<td></td>
<td>Damaged mold surface</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Repair mold surface</td>
</tr>
<tr>
<td></td>
<td>Mold over waxed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Clean surface, use less wax</td>
</tr>
<tr>
<td></td>
<td>Lubricants blooming</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Adjust process 1st, contact supplier</td>
</tr>
<tr>
<td>Diesel Effect / Burns</td>
<td>Trapped gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Clean vents and/or increase venting</td>
</tr>
<tr>
<td></td>
<td>Material curing in nozzle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Adjust shot size, reduce nozzle temp if defect persists</td>
</tr>
<tr>
<td></td>
<td>Dead spots in cavity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Radius sharp corners in tool, eliminate right angle transitions in runners</td>
</tr>
<tr>
<td>White and Color Streaks</td>
<td>Pigment breakdown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reduce shear pigment, minimize cure in barrel and check mold for hot spots</td>
</tr>
<tr>
<td>Moisture Streaks</td>
<td>Unvented moisture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Clean vents and/or increase venting</td>
</tr>
<tr>
<td>Flow Marks</td>
<td>Weld lines, back areas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Consolidate melt fronts before cure, homogenize melt</td>
</tr>
<tr>
<td></td>
<td>End of flow path</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Consolidate melt fronts before cure, homogenize melt and fill faster</td>
</tr>
<tr>
<td>Grain Marks</td>
<td>Incomplete melting and fusing of granules</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Properly melt and homogenize molding compound</td>
</tr>
<tr>
<td>Porosity</td>
<td>Incomplete packing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Properly fill and pack, increase injection pressure if necessary</td>
</tr>
<tr>
<td>Blisters</td>
<td>Skin curing much faster than core</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reduce curing of outer skin</td>
</tr>
<tr>
<td></td>
<td>Hot spots in mold</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Look at performance and location of cartridge heaters</td>
</tr>
<tr>
<td></td>
<td>Molding compound too reactive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reduce reactivity of molding compound</td>
</tr>
<tr>
<td>Crack</td>
<td>Differential shrinkage stress</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reduce factors that contribute to differential shrinkage, check for uneven heat</td>
</tr>
<tr>
<td></td>
<td>Stress at gate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Relieve injection caused stresses</td>
</tr>
<tr>
<td></td>
<td>Part geometry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Smooth thickness transitions, address areas of material accumulations</td>
</tr>
<tr>
<td>Sink Marks</td>
<td>Differential shrinkage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fully fill and pack before cure</td>
</tr>
<tr>
<td></td>
<td>Part geometry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Smooth thickness transitions, address areas of material accumulations</td>
</tr>
<tr>
<td>Scratches on Ribs</td>
<td>Mechanical marks on tool</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Repair damage tool and/or add draft to scratched feature</td>
</tr>
</tbody>
</table>
## 6.2 Compression Molding

Table 6.

<table>
<thead>
<tr>
<th>Compression Molding</th>
<th>Corrective Action</th>
<th>Mold Temp</th>
<th>Mold Press</th>
<th>Cure Time</th>
<th>Clamp Speed</th>
<th>PreHeat Temp</th>
<th>PreHeat Time</th>
<th>Fill Volume</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dim / Cloudy Areas</td>
<td>Trapped gas</td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>Clean vents, increase venting</td>
</tr>
<tr>
<td></td>
<td>Damaged mold surface</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Repair mold surface</td>
</tr>
<tr>
<td></td>
<td>Mold over waxed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Clean surface, use less wax</td>
</tr>
<tr>
<td></td>
<td>Lubricants blooming</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Adjust process 1st, contact supplier</td>
</tr>
<tr>
<td>Diesel Effect / Burns</td>
<td>Trapped gas</td>
<td>↓</td>
<td></td>
<td></td>
<td></td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>Clean vents and/or increase venting</td>
</tr>
<tr>
<td>White and Color Streaks</td>
<td>Pigment breakdown</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td></td>
<td></td>
<td></td>
<td>Reduce thermal exposure of pigment, check mold for hot spots</td>
</tr>
<tr>
<td>Moisture Streaks</td>
<td>Unvented moisture</td>
<td>↑</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Clean vents and/or increase venting</td>
</tr>
<tr>
<td>Flow Marks</td>
<td>Weld lines, back areas</td>
<td>↑</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Properly melt and fill cavity before curing molding compound</td>
</tr>
<tr>
<td>Grain Marks</td>
<td>Incomplete melting and fusing of granules</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cure evenly under pressure, check mold for hot spots</td>
</tr>
<tr>
<td>Orange Skin</td>
<td>Differential shrinkage skin-core</td>
<td>↑</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Properly fill and pack</td>
</tr>
<tr>
<td>Porosity</td>
<td>Incomplete packing</td>
<td>↑</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blisters</td>
<td>Skin curing much faster than core</td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
<td></td>
<td></td>
<td></td>
<td>Reduce curing of outer skin</td>
</tr>
<tr>
<td></td>
<td>Hot spots in mold</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Look at performance and location of cartridge heaters</td>
</tr>
<tr>
<td></td>
<td>Molding compound not reactive enough</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Contact supplier</td>
</tr>
<tr>
<td>Cracks</td>
<td>Differential shrinkage stress</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td>Reduce factors that contribute to differential shrinkage, check for uneven heat</td>
</tr>
<tr>
<td></td>
<td>Part geometry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Smooth thickness transitions, address areas of material accumulations</td>
</tr>
<tr>
<td>Sink Marks</td>
<td>Differential shrinkage</td>
<td>↑</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fully fill and pack during cure</td>
</tr>
<tr>
<td></td>
<td>Part geometry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Smooth thickness transitions, address areas of material accumulations</td>
</tr>
<tr>
<td>Scratches on Ribs</td>
<td>Mechanical marks on tool</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Repair damage tool and/or add draft to scratched feature</td>
</tr>
</tbody>
</table>
6.3 Examples of Common Process Defects With Troubleshooting Tips

**Flow Mark**
- Homogenize melt and consolidate melt fronts before cure, optimize filling, holding pressure and/or change over point

**Blister Caused by Flash Contamination**
- Clean mold before cycling

**Flow Marks, Cloudy/Grey Surface**
- Clean vents or increase venting, optimize filling, holding pressure and/or change over point

**Orange Skin**
- Cure evenly under pressure, check mold for hot spots
Blister Because of Insufficient Curing in Core

- Improve curing time

Blister Because of Insufficient Curing in Core

- Improve curing time

Color Streaks

- Reduce shearing of pigment, check mold for hot spots

Diesel Effect

- Clean vents or improve venting, improve filling process
Flow Mark
- Optimize filling, holding pressure and/or change over point

Gas Streaks Due to Insufficient Venting
- Clean vents or increase venting

Entrapped Air Due to Insufficient Venting
- Clean vents or increase venting

Contamination
- Clean mold, check material
**Cured Slug**
- Adjust shot size, reduce nozzle temp if defect persists

**Contamination**
- Check material

**Color Streaks**
- Reduce shearing of pigment, check mold for hot spots

**Incomplete Melting of Granules**
- Properly melt and homogenize molding compound
Incomplete Melting of Granules
- Properly melt and homogenize molding compound

Blisters
- Reduce curing of outer skin, check mold for hot spots

Knitline Cracks
- Relieve stresses caused by injection

Sink Marks
- Fully fill and pack
Product Overview
Bakelite® Molding Compounds for Demanding Applications

Leading Technologies to Suit Your Requirements

Hexion scientists are constantly adding to the extensive family of Bakelite® resins and molding compounds by varying the reaction conditions and specific raw materials used. This formulation flexibility allows for an almost infinite number of modifications and products. We can optimize our products to fit customers’ needs.

Outstanding Performance Every Time

Challenging applications demand high-quality products with specific and reliable performance properties. The Bakelite® brand has always stood for the finest molding compounds available. Our products feature outstanding performance characteristics including high temperature resistance, high surface hardness, superior flame, smoke and toxicity performance, low creep, excellent dimensional stability, low flammability, and outstanding chemical resistance and electrical insulating properties.

Count on Hexion’s Bakelite® family of products, backed by the global resources and infrastructure of one of the world’s largest specialty chemical companies, to deliver consistent product performance time and time again—optimize our resin and molding compound to fulfill our customers’ unique process and technical needs.

Bakelite® Resins and Molding Compounds – The Preferred Choice

With their extraordinary heat and electrical resistance, the Bakelite® family of products sets the standard in a multitude of industrial and specialty applications, including under-the-hood components in the automotive industry, where phenolic engineering thermosets are fast replacing metal parts.

In 1907, in his Yonkers lab, Leo Baekeland synthesized the first man made thermosetting plastic and named it Bakelite® phenolic resin. Baekeland chose the infinity symbol to represent his brand, already recognizing the material’s tremendous versatility and near-infinite application potential. Today, after over 100 years of development through legacy companies linking back to Baekeland, Hexion drives the leading edge in application development expertise.

While the Bakelite® brand still implies a pioneering spirit, it also commands the resources of Hexion, a global corporation committed to provide consistently superlative quality and service wherever you do business.

Today, Bakelite® products are consistently produced around the world to the highest standards, to best serve our global customers.

Phenolics: the Original Multitasking Resins
The Bakelite® family of products serves a wide range of applications for customers around the globe.

### Typical Bakelite® Molding Compound Applications

<table>
<thead>
<tr>
<th>Category</th>
<th>Processes</th>
<th>Application Areas</th>
<th>Benefits</th>
<th>Brands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>Injection Molding</td>
<td>Automotive fuel and vacuum pump impellers and housings, brake pistons, pulleys,</td>
<td>High mechanical strength, dimensional accuracy, thermal stability, electrical insulation, flame</td>
<td>Bakelite®</td>
</tr>
<tr>
<td>Thermo-sets</td>
<td>Compression Molding</td>
<td>carbon brush holders, safety switch housings, and electro-technical parts,</td>
<td>retardance, automotive media resistance, abrasion resistance, economy, and reproducible processing; suitable for UL listed products</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transfer Molding</td>
<td>contactors, MCBs, MCCBs, switches, tribological parts, high temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>applications such as exhaust components, kitchenware</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Beyond the Basics: More Reasons to Choose Bakelite® Resins

#### Constant Evolution
The Bakelite® brand represents an ever-changing array of products researched and developed in response to customer demands. Hexion is the world's largest producer of thermoset resins and the leading global producer and supplier of high performance phenolic based resins. Our products are truly state-of-the-art.

#### Worldwide Distribution
With approximately 60 production and manufacturing facilities and 4,300 employees spread across the globe, Hexion offers customers easy access to our products and services. This extensive global production infrastructure and support network means you can count on Hexion for a ready supply of consistently high-quality Bakelite® products wherever you do business.

#### Superior Technical Assistance
When you choose Bakelite® resins and molding compounds, you choose to benefit from Hexion’s world-class technical service capabilities. Our specialists will help you customize and optimize technologies and solutions to meet your specific requirements for processing, costs and product performances.

#### Sustainable Solutions
Hexion is committed to excellence in environmental, health, and safety performance, the responsible stewardship of our products and considers the environmental, health, and safety impacts of our products throughout their lifecycles. Our plants are also ISO-9001 certified, highly integrated, and focused on stringent environmental health and safety and sustainability standards.
| Product | Chemical Resistance to Automotive Media | Creep resistance | Density (kg/dm³) | Coefficient of Thermal Expansion [ppm] | Heat Deflection Temperature (°C) | Tensile Strength (MPa) | Tensile Modulus (GPa) | Flexural Strength (MPa) | Flexural Modulus (GPa) | Creep Recovery [%] at 80.0 MPa load (1°C) | Tensile Modulus [%] longitudinal | Tensile Modulus [%] transversal | Post mold shrinkage [%] | Application areas | REACH EU | TSCA USA | PSL/NDSL Canada | MITI Japan | KECI South-Korea | IECSC China |
|---------|----------------------------------------|-----------------|-----------------|----------------------------------------|-------------------------------|------------------------|----------------------|------------------------|------------------------|------------------------------------------|---------------------------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Bakelite® PF 1110 | ----- ----- ----- | ----- ----- ----- | 2.05 | 10 | 195 | 120 | 26000 | 240 | 25000 | 13.0 | 0.15 | 0.03 | + + + + + + |
| Bakelite® PF 2874 | ----- ----- ----- | ----- ----- ----- | 1.57 | 32 | 155 | 65 | 10500 | 125 | 11000 | 9.5 | 0.50 | 0.25 | + + + + + + |
| Bakelite® PF 6501 | ----- ----- ----- | ----- ----- ----- | 1.60 | 35 | 170 | 90 | 14000 | 175 | 12500 | 12.5 | 0.25 | 0.10 | + + + + + + |
| Bakelite® PF 6510 | ----- ----- ----- | ----- ----- ----- | 1.70 | 25 | 175 | 100 | 16000 | 210 | 16000 | 15.5 | 0.20 | 0.05 | + + + + + + |
| Bakelite® PF 6680 | ----- ----- ----- | ----- ----- ----- | 1.71 | 26 | 170 | 115 | 20000 | 195 | 14500 | 14.5 | 0.25 | 0.05 | + + + + + + |
| Bakelite® PF 7596 | ----- ----- ----- | ----- ----- ----- | 1.63 | 23 | 175 | 60 | 16000 | 105 | 14500 | 5.0 | 0.30 | 0.10 | + + + + + + |
| Bakelite® EP 8412 | ----- ----- ----- | ----- ----- ----- | 1.89 | 23 | 120 | 55 | 13000 | 125 | 15500 | 8.5 | 0.30 | 0.02 | + + + + + + |

High precision, mechanically strong motor vehicle engine attachments, pump parts, pulleys and brake pistons.

General purpose parts with high demands on thermal stability, such as carbon brush holders, end plates for electrical motors etc.

Dynamically and thermally highly stressed automotive parts, vacuum pump parts and pulleys.

Parts subject to chemicals and heat, mechanically stressed automotive pump parts like water pump housings.

Parts requiring low abrasion in oil contact e.g. piston and guidance elements.

Fuel and diesel resistant automotive parts in which tribological properties are critical, such as fuel pump impellers and housings.

Encapsulation of electric parts, e.g. electromagnetic coil. Excellent moldability.
Disclaimer

Information presented in this brochure is meant to provide general guidelines to the use of Bakelite® Molding Compounds. Suitability of a material or design for a specific application is the sole responsibility of the end user.

Resources

- Jiang, Guozhan et al., Recycling Carbon Fibre/Epoxy Resin Composites Using Supercritical Propanol, 16th International Conference on Composite Materials, 2007
- Ejot Delta PTS Flyer (2017)

For more details about specific products and properties, please consult the following Hexion brochures:

HXN-662
Bakelite® Engineering Thermosets for Automotive Under-the-Hood Applications

HXN-654
EPIKOTE™ Resin Preform Binder Systems for Mass Production of Composite Parts

HXN-655
EPIKOTE™ Resins and EPIKURE™ Curing Agents and Catalysts

HXN-693
EPIKOTE™ Epoxy Resins for Resin Transfer Molding and Other Liquid Molding Technologies Used in Automotive Components

HXN-634
Accelerating Energy Efficiency, Safety and Comfort: Innovative Resin Solutions for Automotive Manufacturing

HXN-657
Bakelite® Engineering Thermosets for Water Pump Housings

HXN-659
Bakelite® Engineering Thermosets for Durable, Lightweight Pulleys

HXN-660
Bakelite® Engineering Thermosets for Pump Parts

HXN-662
Bakelite® Engineering Thermosets for Automotive Under-the-Hood Applications

HXN-677
Bakelite® Engineering Thermosets

HXN-682
Bakelite® Engineering Thermosets for Under-The-Hood Applications
Hexion: We are responsible Chemistry.

Our global team produces the best in specialty chemicals and performance materials and provides the technical expertise to customize them to your exact needs. The result? Specific solutions, not generic products, leading to thousands of breakthroughs that improve bottom lines and enhance lives.

Reach our Global Customer Service network at:

**U.S., Canada and Latin America**
+1 888 443 9466 / +1 614 986 2497
E-mail: 4information@hexion.com

**Europe, Middle East, Africa and India**
+800 836 43581 / +39 0331 355349
E-mail: 4information.eu@hexion.com

**China and Other Asia Pacific Countries**
+86 2 1386 04835
E-mail: 4information.ap@hexion.com

Please refer to the literature code HXN-755 when contacting us.