Comparison of Plastic vs Metal Processes
Alan Federl: SABIC Innovative Plastics Growth Leader - West
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**Structural Foam:**

*Overview*

- Definition
- Comparison of Processes
- Plastics vs Metals

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**Structural Foam:**

*SABIC Grades*

- SABIC Innovative Plastics Structural Foam Grades
- Potential Benefits of SABIC Innovative Plastics Structural Foam Grades

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**Structural Foam:**

*Design*

- Design Considerations
What is Engineering Structural Foam?

A form of molding in which a plastic melt/gas mixture is injected into a mold in order to create a foam core with two external skins.

Structural foam creates parts without sink in thick sections or ribs, and with a 5-20% density reduction.

Similar concept to injection molding

Low pressure process due to foam in plastic melt.

Creates lightweight but rigid parts suitable for structural applications, diecast replacement.
What about Injection Molding for Medical Enclosures??

Are parts larger than a toaster?  YES

NO

Part Volume less than 20000??  YES

Structural Foam Candidates

NO

Part requires greater than normal loads?? (i.e., Wall >4mm, Ribs = Wall, High Filler content??)

NO

YES

Injection Molding is a very suitable process...
Key Advantages of Injection Molding

- No Paint Solution
- Lowest Piece part solution (typically)
- Best part complexity solution
- Large number of materials options
- Large number of converters, tool builders
- Very well understood process.
Structural Foam: Cross-section of Wall

- Gas expands inside plasticized material to create foam core
- Typical Wall Thickness is 0.250”
Inert Gas or Blowing Agent with Resin

Relative to Standard Injection Molding

**Advantages**
- Large Part Capability
- Low Pressure Process
- High Stiffness to Weight Ratio
- Lower Tooling Cost

**Disadvantages**
- Longer Cycle Time
- Aesthetic Applications Require Paint

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**Improved Rigidity and Economics for Large Parts**
Fig 1: Typical Clamp Tonnage Requirements for Structural Foam
Structural Foam is **not**: 

**NOT related to foam board or expandable type of foam systems (i.e., EPS), which have >80% density reductions.** These type of products typically are used for insulation and packaging applications, and have minimal structural integrity.

**NOT a thinwall process.** Structural foam requires thick walls, in order to obtain a cellular structure and are usually larger parts. .150” nominal wall is typical minimum, although thinner sections in select areas are possible.
Chemical blowing agent concentrates (CBAs) are used in the structural foam process. They are blended with the base resin prior to being plasticized. After being exposed to a certain temperature, the blowing agent decomposes, releasing an inert gas that mixes with the molten resin. The gas/resin mixture remains under pressure in the injection machine. There are two basic types of CBA’s:

<table>
<thead>
<tr>
<th>Endothermic CBA’s</th>
<th>Exothermic CBA’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorb heat during processing</td>
<td>Produces heat during processing</td>
</tr>
<tr>
<td>Lower gas pressure generated</td>
<td>Higher gas pressure generated</td>
</tr>
<tr>
<td>Produces a finer cell structure</td>
<td>Better Sink Mark Control</td>
</tr>
<tr>
<td>Shorter cycle times</td>
<td>Larger Cells</td>
</tr>
<tr>
<td></td>
<td>Longer cooling time</td>
</tr>
</tbody>
</table>

Caution: some CBA’s produce water as a byproduct, which can aggressively attack Lexan* and Valox* Resins at the high processing temperatures involved.
Potential Applications

Dunnage for food, beverage, automotive applications
(Dividers/Trays, Compartments)
Telecommunication equipment
Traffic Safety/Transportation markets
Pallets for packaging
Medical and Diagnostic housings
Large Instrumentation housings
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Other types of Competing Processes

RIM Molding: A molding process that uses a two-component resin system. The two resins are combined and mixed together, then injected, under low pressure, into a mold cavity. In the mold cavity, the resin rapidly reacts and cures to form the composite part.

Pressure Forming: A plastics thermoforming process using pressure to push the plastic sheet to be formed against the mold surface, as opposed to using vacuum to suck the sheet flat against the mold.

Metal Diecasting: A metal forming process in which molten metal is forced into a cavity or mold under high pressure.

Fiberglass Reinforced plastics: A thermoplastic plastic resin matrix that is reinforced with glass fibers. These can be sheet form, or manually wound/oriented.
Comparison of Plastic Processes

Part Size and Complexity Affect Processing Selection
# Structural Foam vs RIM

<table>
<thead>
<tr>
<th>Structural Foam Advantages</th>
<th>RIM Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater degree of part design complexity</td>
<td>Lower Tooling (initial capital outlay)</td>
</tr>
<tr>
<td>Uniform cell structure</td>
<td>Very thick wall Capability (3-10+mm)</td>
</tr>
<tr>
<td>Lower post molding finishing costs</td>
<td>Lower Volume Capability (5-200)</td>
</tr>
<tr>
<td>Lower overall system cost</td>
<td></td>
</tr>
<tr>
<td>Higher Volumes (200-20M)</td>
<td></td>
</tr>
<tr>
<td>Recyclable Thermoplastic (vs RIM Thermoset)</td>
<td></td>
</tr>
<tr>
<td>Tight Dimensional specifications</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Production &gt;100/month</th>
<th>Production &lt;20/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Cost</td>
<td>Lower Cost</td>
</tr>
</tbody>
</table>
### Structural Foam vs Pressure forming

<table>
<thead>
<tr>
<th>Structural Foam Advantages</th>
<th>Pressure forming Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater degree of part design complexity</td>
<td>Lower Tooling (initial capital outlay)</td>
</tr>
<tr>
<td>Greater rigidity options through ribbing or glass fillers.</td>
<td>Very Large part capability</td>
</tr>
<tr>
<td>Variable and Controlled Wall Capability</td>
<td>Lower Volume Capability (5-200)</td>
</tr>
<tr>
<td>Lower post molding finishing costs</td>
<td></td>
</tr>
<tr>
<td>Higher Volumes (200-20M)</td>
<td></td>
</tr>
</tbody>
</table>

**Complex part design**

**Simple part design**

**Lower Cost**
# Str. Foam vs Diecast Metal

<table>
<thead>
<tr>
<th>Structural Foam Advantages</th>
<th>DieCast Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capable of snap fits, complicated attachment points.</td>
<td>Better Creep Resistance</td>
</tr>
<tr>
<td>Texture, lettering in finished tool</td>
<td>Lower Thermal expansion</td>
</tr>
<tr>
<td>Lower post molding finishing costs</td>
<td>Higher Heat resistance</td>
</tr>
<tr>
<td>Capable of as molded finished part</td>
<td>Higher strength/stiffness</td>
</tr>
<tr>
<td>Lower Weight</td>
<td>No EMI Shielding required</td>
</tr>
<tr>
<td>Base color matches paint</td>
<td></td>
</tr>
</tbody>
</table>

- **Complex part design**
  - Lower Cost

- **Simple part design**
  - Lower Cost
# Structural Foam vs Stamped Metal

<table>
<thead>
<tr>
<th>Structural Foam Advantages</th>
<th>Stamped Metal Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater degree of part design complexity</td>
<td>Lower Tooling (initial capital outlay)</td>
</tr>
<tr>
<td>Lower finishing costs for aesthetic parts. (Structure and Skin-in-one)</td>
<td>Lower Volume Capability (5-1000)</td>
</tr>
<tr>
<td>Lower weight</td>
<td>Strength/Stiffness</td>
</tr>
<tr>
<td>Base color to match paint</td>
<td>No EMI shielding required</td>
</tr>
<tr>
<td>Dent Resistance</td>
<td></td>
</tr>
<tr>
<td>Rust Resistance</td>
<td></td>
</tr>
</tbody>
</table>

Complex part design/aesthetics | Simple part design/non-aesthetic
Lower Cost                     | Lower Cost
Comparison of Structural Foam to other Processes

<table>
<thead>
<tr>
<th>Feature</th>
<th>Structural Foam</th>
<th>RIM Forming</th>
<th>Pressure Metal</th>
<th>Stamped Metal</th>
<th>Diecast Metal</th>
<th>Fiberglass layup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooling</td>
<td>![Strength]</td>
<td>![Strength]</td>
<td>![Strength]</td>
<td>![Strength]</td>
<td>![Neutral]</td>
<td>![Neutral]</td>
</tr>
<tr>
<td>Variable Walls</td>
<td>![Strength]</td>
<td>![Neutral]</td>
<td>![Weakness]</td>
<td>![Strength]</td>
<td>![Neutral]</td>
<td>![Neutral]</td>
</tr>
<tr>
<td>Volume (EAV)</td>
<td>200-20000</td>
<td>50-2000</td>
<td>50-1000</td>
<td>50-10000</td>
<td>50-5000</td>
<td>50-1000</td>
</tr>
</tbody>
</table>

- **Strength/Advantage**: Green
- **Neutral/Moderate**: Yellow
- **Weakness/Limited**: Red
Comparison of Processes: Notes

- **TOOLING** Refers to the initial outlay of tooling, and tool life. Production volume plays a major role in $/piece. Amortization of tooling will aide in comparing process options.

- **VARIABLE WALL RANGE** for various processes. Thinner and thicker walls are obtainable, but these are typical averages cited in manufacturing literature.

- **PART COMPLEXITY** refers to the ability to add: Ribs, Bosses, radii, contours, variable walls, lettering, snap fits, hinges, and other part features. Part Complexity is directly related to reduced assembly or secondary operations.

- **FINISHING COSTS** refer to cost of painting, but also include cost of sanding, deburring, and patching surfaces where needed, to obtain a smooth finish appropriate for painting.

- **VOLUMES** for production are from a survey of manufacturers. Setup times, volumes appropriate for manufacturing and tooling amortization are all considered in these volumes.

- **DIMENSIONAL TOLERANCES** vary greatly by application. Relative comparisons obtained by comparing design guides and part prints of the various processes.

- **MECHANICAL STRENGTH** refers to overall material performance in high load applications. Includes considerations such as temperature, creep, and load.
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## Potential Benefits of Plastics vs Metals

<table>
<thead>
<tr>
<th>Performance Advantages</th>
<th>Plastics</th>
<th>Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (stiffness to weight ratio)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Design freedom</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Functionality</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Styling freedom</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Dent resistance</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Corrosion resistance</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Sound absorption</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Structural strength</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Thin walls</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Chemical resistance (except oxidation)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Heat resistance</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Conductivity (thermal and electrical)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Shielding</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Challenges vs. Sheet Metal

- Expectation of One-For-One Replacement
- Time / Temperature Performance Dependency
- Higher Initial Tooling Costs
- EMI/RFI Shielding and Thermal Management

**Systems-Solution Approach Critical**
Potential Benefits of Plastics vs Metals

Cost Analysis – Part complexity

**Plastic**
Nominal Impact on Part Cost

**Sheet Metal**
Significant Impact on Part Cost
- Die Work
- Welding
- Grinding
- Rework

Cost Model Changes Dramatically As Part Complexity Increases
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- SABIC Innovative Plastics Structural Foam Grades
- Potential Benefits of SABIC Innovative Plastics Structural Foam Grades
Noryl Foam Grades have excellent flow, good strength and impact, and good processing stability.

Lexan Foam Grades have high RT and Low Temp impact, high heat resistance, good color stability, and available in Glass Filled grades for diecast replacement.

Valox Foam Grades have excellent chemical resistance.

Ultem Foam Grades have high heat resistance, chemical resistance, and good FST properties for Aerospace applications.
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Potential Benefits of SABIC IP Structural Foam Grades

Good Flame Retardancy
High Strength to Weight Ratio
Excellent Sound Dampening
Good Thermal Performance
Excellent Impact Resistance
Excellent Flow during Molding
SABIC Structural Foam FR Portfolio

Flame Retardant Grades

Lexan* PC Resins
- General Purpose
- 10% Glass
- 20% Glass
- 30% Glass
- Impact RT/-40

Noryl* PPO Resins
- General Purpose
- General Purpose
- Thin Wall

LNP* Thermocomp Resins
- FL3000 + 5% Glass Improved Surface

No. 30
## UL Flame Ratings for FR Structural Foam Grades

<table>
<thead>
<tr>
<th>Desc</th>
<th>FL403</th>
<th>FL410</th>
<th>FL900</th>
<th>FL910</th>
<th>FL930</th>
<th>FL3000</th>
<th>DX09042</th>
<th>FN150X</th>
<th>FN170X</th>
<th>FN215X</th>
<th>FV699</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>GP</td>
<td>GP</td>
<td>GP</td>
<td>Filled</td>
<td>Filled</td>
<td>Impact</td>
<td>Impact</td>
<td>GP</td>
<td>GP</td>
<td>GP</td>
<td>GP</td>
</tr>
<tr>
<td>Glass %</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>30</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>UL Ratings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UL94 V-0</td>
<td>3mm</td>
<td>3.8mm</td>
<td>6mm</td>
<td>3.85m</td>
<td>6mm</td>
<td>6mm</td>
<td>3mm(6)</td>
<td>4mm</td>
<td>-</td>
<td>6mm</td>
<td>4.9m</td>
</tr>
<tr>
<td>5VA</td>
<td>6mm</td>
<td>3.8m</td>
<td>6mm</td>
<td>3.85m</td>
<td>6mm</td>
<td>6mm</td>
<td>-</td>
<td>4mm</td>
<td>4.7mm</td>
<td>4.9m</td>
<td></td>
</tr>
<tr>
<td>UL746C</td>
<td>f2</td>
<td>none</td>
<td>f2(2)</td>
<td>f1(5)</td>
<td>-</td>
<td>f1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>f1</td>
<td>-</td>
</tr>
<tr>
<td>RTI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical</td>
<td>80C</td>
<td>80C</td>
<td>110C</td>
<td>80C</td>
<td>110C</td>
<td>80C</td>
<td>80C</td>
<td>50C</td>
<td>85C</td>
<td>85C</td>
<td>75C</td>
</tr>
<tr>
<td>Mech.</td>
<td>80C</td>
<td>80C</td>
<td>110C</td>
<td>80C</td>
<td>110C</td>
<td>80C</td>
<td>80C</td>
<td>50C</td>
<td>85C</td>
<td>85C</td>
<td>75C</td>
</tr>
<tr>
<td>Impact</td>
<td>80C</td>
<td>80C</td>
<td>110C</td>
<td>80C</td>
<td>110C</td>
<td>80C</td>
<td>80C</td>
<td>50C</td>
<td>85C</td>
<td>85C</td>
<td>75C</td>
</tr>
</tbody>
</table>
Fig 2: Strength to Weight

Ratio of Stiffness to Weight

FL930: 159
FL900: 116
Aluminum: 110
SMC: 100
SE100x: 73
Steel: 64
Zinc: 15

No. 32
Stiffness-to-Weight*

The high stiffness-to-weight ratio of Engineering Structural Foam is the primary advantage this material has over metal and standard (non-foamed) injection molded plastics. Stiffness is defined as the product of EI (modulus of elasticity times moment of inertia of the section). With NORYL FN215X resin at 100 for comparison, Figure 2 illustrates the advantage of Engineering Structural Foam over various alternate materials for equal weights of material.

An equivalent weight of 0.250 in (6.35 mm) thickness foam can have over seven times the rigidity of steel and thirteen times the rigidity of zinc. Compared to an equivalent weight of solid plastic, 0.250 in (6.35 mm) thickness foam can have twice the rigidity.

Thinner wall structural foam parts can also have the advantage of a high stiffness-to-weight ratio, but to a somewhat lesser extent than 0.250 in (6.35 mm) design. For comparison purposes a part made from LEXAN FL410 resin with a wall thickness of 0.157 in (4 mm) will have a stiffness-to-weight ratio of 95.

*From the GE Structural Foam Guide
Fig 3: Sound Dampening
Fig 4: Thermal performance

Effect of Temperature on Tensile Strength

Tensile Strength (psi)

Temperature (F)

FL900
FN215X
## Impact performance: Falling Ball Impact (ft-lbs/in)

<table>
<thead>
<tr>
<th>Density Reduction %</th>
<th>15% .157” (4mm)</th>
<th>25% .250” (6.35mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall Thickness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noryl FN150X Resin</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Noryl FN215X Resin</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>Lexan FL900 Resin</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td>Lexan FL910 Resin</td>
<td>14</td>
<td>30</td>
</tr>
<tr>
<td>Lexan FL930 Resin</td>
<td>12</td>
<td>30</td>
</tr>
</tbody>
</table>

10 lb Weight, .500” ball diameter
Fig 5: Comparison of Flow Lengths: Resin Families
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Wall Thickness Considerations

- Thickness can range from .157” up to .500” wall (This is due to structural requirements, part design, and other factors)
- To maximize foaming/weight reduction, uniform wall thickness and proper transitions are suggested: (Fig 1)

![Diagram of wall thickness considerations](image)

Fig 1

- Flow ribs, runners, and selective increases in wall thickness are all techniques to aide mold filling.
- Avoid selecting resin grades that do not have sufficient flow length to fill the mold, which will adversely affect density reduction.
Generous **radii** in the part will maximize impact

**Textured** surfaces generally require an additional 1° draft per 0.001 in (0.0254 mm) depth of texture. For

A **draft angle** of 0.5-3.0 degrees is advisable
Ribs

Wall Thickness (WT) | Rib Thickness as Percent of Surrounding Wall Thickness (RT)

<table>
<thead>
<tr>
<th>WT Range</th>
<th>Rib Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.157&quot; - 0.175&quot;</td>
<td>60%</td>
</tr>
<tr>
<td>0.176&quot; - 0.215&quot;</td>
<td>70%</td>
</tr>
<tr>
<td>0.216&quot; - 0.250&quot;</td>
<td>80%</td>
</tr>
<tr>
<td>0.251&quot; - 0.300&quot;</td>
<td>100%</td>
</tr>
<tr>
<td>&gt; 0.300&quot; (&gt; 7.6mm)</td>
<td>120%</td>
</tr>
</tbody>
</table>

The proper design for ribs with wall thickness approaching the maximum recommended is shown above.
Bosses and Snap fits

Snap fits can eliminate the need for added screws, brackets, and fasteners, significantly reducing labor and assembly costs.

The optimum boss diameter is 1.6 to 2.0 times the diameter of the cored hole, with a minimum boss wall thickness of 0.080 in.
Zero degree draft on guides is possible over limited areas when the wall section of the part is over 0.200 in (5 mm).
Hinges

Properly designed, integral structural foam hinges can offer fatigue strength comparable to metal, while eliminating costly bracketry and assembly time.

Contact SABIC Innovative Plastics Technical Support for other Hinge design options.
Tooling

Low-cost prototype tooling can be employed for producing a small number of actual parts molded in structural foam:
Plaster – Low-cost molds used to produce one part.
Silicone – Produces one to five parts; limited to somewhat simple shapes.
Epoxy – Low-cost method of producing one to twenty-five parts, depending on size and complexity.
Cast Aluminum – Used for prototype tools and in some cases, for limited production.

Converted Tools
In metal replacement products, die-cast tools may be successfully used for shooting sample parts. Some modifications are usually required including:
Increasing wall thickness to a value acceptable for structural foam.
Adding a sprue bushing and closing the shooting pot in aluminum die-cast tools. Frequently, zinc die-cast molds can be used with no modifications except for necessary wall section revisions.
Tolerance Guidelines

Tolerances for Fine Conditions, Plus or Minus

The key to tolerance and warpage control in a structural foam part is to achieve a good and consistent density reduction throughout the part.
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**Structural Foam: Design**
- Design Considerations
SABIC Innovative Plastics Global Application Technology

Global Centers of Excellence
Where our Customers are
In the world of engineering plastics application development...

It is the leading customer facility.

Innovation and Application Development
- 20+ years of product and processing innovation
- Industry leading design, processing and performance engineering
- Over 100 companies visit the PPDC annually

Performance Fibers & Foam  Advanced Injection Molding
Laser Marking  Coatings
Thermoplastic Composites  Induction Heating
Ultra-Thin Films  Thermoforming
Part Performance  Extrusion Blow Molding
Application Performance

- Assembly Processes
- Painting & Decoration
- Part Testing & End Use Simulation
- Regulatory Standards

Process Development

- All Conversion Processes
- NPI Support
- New Tech Scoping & Validation
- Training and Consultation

Predictive Engineering

- Computer Aided Engineering
- Computer Aided Design
- Process Simulation

Aesthetics & Industrial Design

- Complete Application Teardowns
- Concept Designs
- Prototype Development

Enabling Growth Through Application Innovation
Device Considerations

**General Factors**
- Regulatory – What will influence my choice of materials?
- Biocompatibility – Does my device require biocompatibility?
- Globalization – Do different countries have different standards?
- Trends – Is my market growing? Where?
- Unit Build – What is the most cost effective manufacturing method?
- Supply Chain – Can my supplier support my development efforts?

**“Inside the Box”**
- EMI / RFI Shielding
- Wear Resistance
- Tight Tolerance
- Strength / Stiffness
- Flame Retardancy

**“Outside the Box”**
- Aesthetics / Image
- Flame Retardancy
- Heat Requirements
- Impact Performance
- EMI / RFI Shielding
- Chemical Compatibility
- Dimensional Stability

Numerous Influences Will Affect Material Choices
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