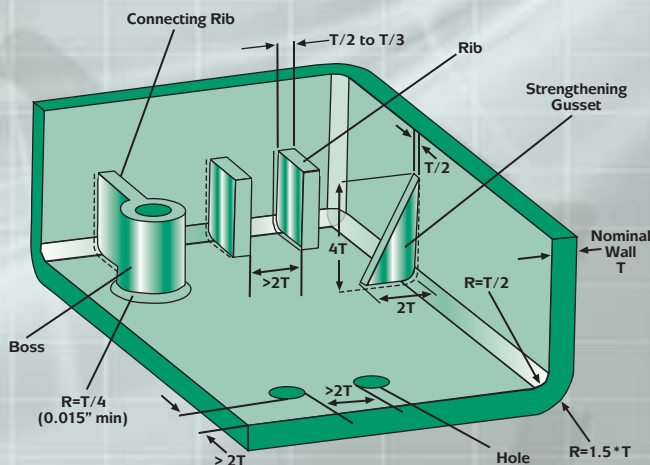


## DESIGNING YOUR PLASTIC PART

When designing parts for injection molding, the manufacturing process must be considered. Injection molding is a process in which solid thermoplastic resin pellets are melted, injected into a mold, and then cooled back to a solid state in a new form. During both the injection and cooling stages of the manufacturing process, there are several factors which will affect the quality of the final product as well as the repeatability of the manufacturing process. Following a few important guidelines during part design will help minimize problems during molding and in the field. Although it is not always possible to follow all of these guidelines, outlined on the following pages are some of the most fundamental recommendations when designing parts for injection molding.

RTP Company's experienced CAE Analysts can provide material data assistance, structural analysis, as well as filling and warpage analyses utilizing Moldflow®. Product design review and consultation is available as a service to our customers, please contact your local RTP Company Sales Engineer or Business Development Manager.

## IDEAL CONDITIONS IN PART DESIGN



## KEY DEFINITIONS

**Amorphous Polymer** – A polymer characterized by random entangled polymer chains. Generally amorphous materials have lower shrink and better dimensional stability than semi-crystalline materials.

**Anisotropic** – Not the same in all directions. This term might be applied to shrinkage for materials that shrink differently in the direction of flow than they do across the flow direction. Filled materials usually exhibit anisotropic shrinkage.

**Cavity/Core** – The cavity is the depression in the mold which forms the outer surface of the molded part. A core is a male part of a mold that shapes the inside of a molded part.

**Ejector Pin / Knockout Pin** – A pin that ejects a molded piece from the mold. Ejector pins typically leave a small indentation on the part surface. **Flash** – Excess plastic around the area of a mold parting line that appears as a standing edge on the molded part.

**Gate** – The channel through which molten polymer flows into the molded part. It is typically small and leaves a mark on the molded part.

**Isotropic** – The same in all directions. This term might be applied to shrinkage or other mechanical properties of a material. Unfilled materials are more likely to be isotropic.

**Parting Line** – The line formed by the mating surfaces of the mold halves.

**Runner** – The feed channel that plastic flows through to get from the injection unit sprue to the gate of the molded part.

**Semi-crystalline Polymer** – A polymer characterized by areas of order in which molecular chains line up. Semi-crystalline materials tend to have good chemical resistance but higher shrink than amorphous materials.

**Sink** – A depression in a molded plastic part caused by a thicker section of plastic shrinking and collapsing as it cools.

**Undercut** – A protrusion or indentation that impedes the withdrawal of a molded part from a two-piece, rigid mold.

**Viscosity** – The measure of the resistance of a fluid to movement. Lower viscosity means easier flowing, and higher viscosity materials are more difficult to push.

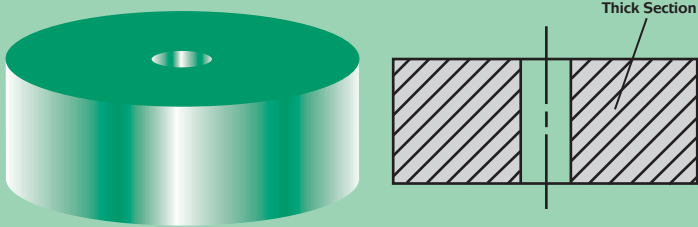
**Weld/Meld line** – A sometimes visible mark on the surface of a molded part where two separate flow fronts of plastic have come together. Weld lines often have reduced mechanical properties, and weld lines should be located away from structurally important areas of the molded part.

**Void** – A pocket of unfilled space or vacuum in a molded part usually caused by the shrinkage during cooling of thick sections.

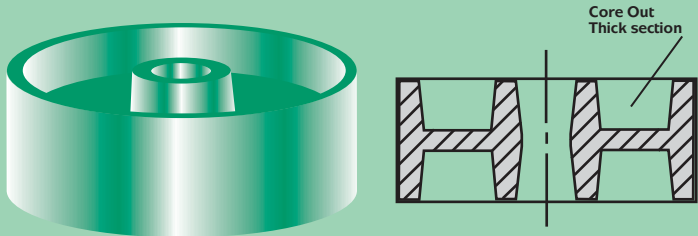
## WALL THICKNESS

- Maintain wall thicknesses less than 4mm.

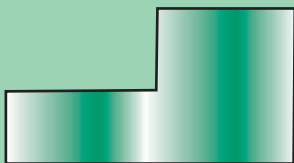
### Typical Metal Design:



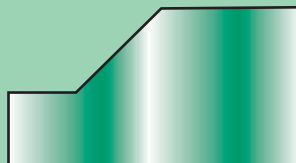
### Preferred Plastic Design:



- Avoid large variations in wall thickness
- Avoid abrupt changes in wall thickness.  
Abrupt changes in wall thickness can create stress concentration areas that can reduce a part's impact strength. Wall thickness changes should have transition zones which reduce the possibility of stress concentrations, sinks, voids, and warp.
- Avoid gating near an area with a large variation in wall thickness.



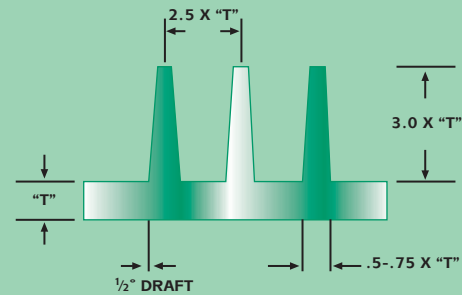
Not Recommended



Recommended

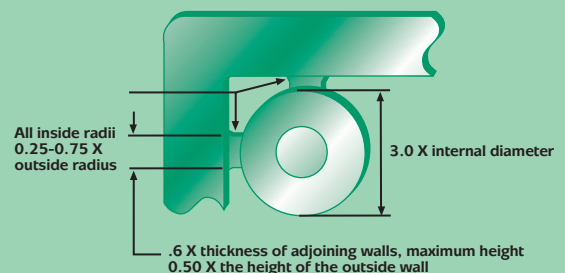
## RIBS

- Maximum rib thickness should be 0.5 to 0.75 of the nominal wall.
- Maximum rib height should be no greater than 3 times the nominal wall thickness.
- The distance between ribs should be at least 2.5 times the nominal wall thickness.
- Ribs should have a draft angle of at least  $1/2^\circ$  per side.
- Place ribs to encourage flow.



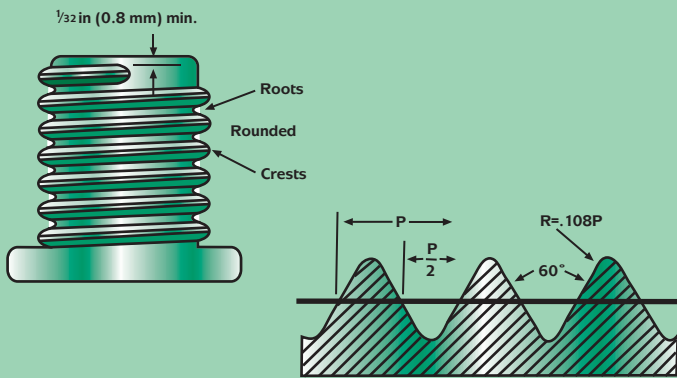
## BOSSES

- Stand-alone bosses should be designed following the design guidelines for ribs.
- Use connecting ribs if possible. Connecting ribs should be 0.6 times the nominal wall thickness at their base.
- Use supporting gussets if possible. Gussets should be 0.6 times the nominal wall thickness at their base.
- Bosses should be cored to the bottom of the boss to maintain uniform wall thickness.



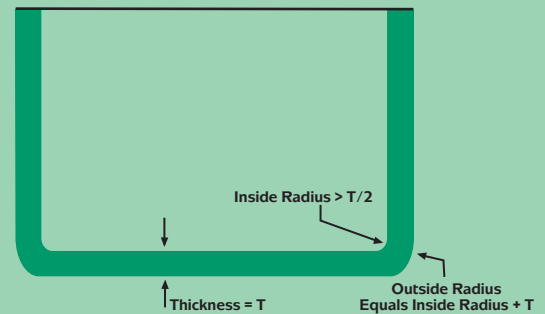
## THREADS

When designing molded-in threads, avoid feathered edges and include radiused roots. Sharp edges can be stress concentrators in plastic parts, and thread designs should consider this.



## RADII

- Avoid designing sharp corners. Radius corners to strengthen part features.
- An inside radius should be at least 50% of the nominal wall thickness.
- An outside radius should be the nominal wall thickness plus the inside radius (150% of nominal wall).



## PROPERTIES TABLE

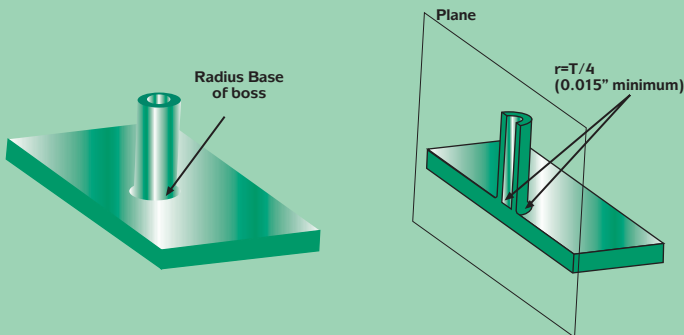
	100 Series with glass GF PP	200 Series with glass GF PA6/6	200 Series with carbon CF PA6/6	200A Series with glass GF PA6	200A Series with carbon CF PA6	200H Series with glass IM GF PA6	200H Series with carbon IM CF PA6	300 Series with glass GF PC	600 Series with glass GF ABS	800 Series with glass GF POM
Tensile Strength (psi) ASTM D 638	4,000 to 18,000	8,000 to 40,000	17,500 to 36,000	10,000 to 33,000	19,000 to 34,000	10,500 to 22,000	16,000 to 28,000	6,500 to 21,000	6,000 to 15,000	8,000 to 17,000
Tensile Elongation (%) ASTM D 638	1.0 to 10.0	1.0 to 8.0	1.0 to 5.0	1.5 to 10.0	1.0 to 4.0	2.0 to 9.0	1.0 to 5.0	1.0 to 10.0+	1.0 to 5.0	1.0 to 10.0+
Impact Strength, Izod (ft-lb/in) ASTM D 256 Notched 1/8 in (3.2mm) section	0.7 to NB	0.5 to 9.0	0.8 to 2.0	0.8 to 6.0	0.8 to 2.0	1.5 to 3.7	2.0 to 3.7	0.8 to 5.5	0.8 to 1.5	1.0 to 1.5
Specific Gravity ASTM D 792	0.97 to 1.50	1.21 to 1.75	1.14 to 1.57	1.16 to 1.69	1.17 to 1.38	1.16 to 1.59	1.14 to 1.33	1.24 to 1.61	1.11 to 1.40	1.42 to 1.82
Molding Shrinkage (in/in) ASTM D 955 1/8 in (3.2mm) section	0.001 to 0.008	0.001 to 0.012	0.0002 to 0.005	0.001 to 0.011	0.0002 to 0.003	0.002 to 0.010	0.0005 to 0.004	0.0005 to 0.007	0.001 to 0.005	0.001 to 0.017
Viscosity	Low-Medium	Low	Low	Low	Low	Low-Medium	Low-Medium	High	Medium	Low-Medium
HDT @ 264 psi	200°F to 310°F	300°F to 500°F	280°F to 500°F	175°F to 400°F	300°F to 400°F	430°F to 475°F	430°F to 475°F	270°F to 300°F	200°F to 220°F	290°F to 325°F
Continuous Use Temp	225°F	275°F	275°F	275°F	275°F	220°F	220°F	250°F	175°F	220°F
Water Absorption	<0.05%	<1.0%	<1.0%	<1.8%	<1.8%	<1.0%	<1.0%	<0.15%	<0.3%	<0.9%
Amorphous or Semi-crystalline	Semi-Crystalline	Semi-Crystalline	Semi-Crystalline	Semi-Crystalline	Semi-Crystalline	Semi-Crystalline	Semi-Crystalline	Amorphous	Amorphous	Semi-Crystalline
Chemical Resistance	Good	Good	Good	Good	Good	Fair	Fair	Fair	Fair	Fair
Weatherability	Fair	Poor	Poor	Fair	Fair	Fair	Fair	Fair	Poor	Poor

## PROPERTIES TABLE Cont.

	900 Series with glass GF PSU	1000 Series with glass GF PBT	1300 Series with glass GF PPS	2100 Series with carbon CF PEI	2200 Series with glass GF PEEK	2200 Series with carbon CF PEEK	2300A Series with glass GF RTPU	3400 Series with carbon CF LCP	4000 Series with glass GF PPA	4000 Series with carbon CF PPA	4700 Series with glass GF PTT
Tensile Strength (psi) ASTM D 638	11,000 to 19,000	9,000 to 24,500	10,000 to 26,000	20,000 to 35,000	15,000 to 32,000	21,000 to 40,000	11,000 to 30,000	15,500 to 29,000	10,000 to 37,500	22,000 to 43,000	11,000 to 22,000
Tensile Elongation (%) ASTM D 638	0.5 to 8.0	1.0 to 5.0	0.9 to 3.0	0.5 to 4.0	1.0 to 5.0	0.5 to 4.0	1.0 to 8.0	0.25 to 4.0	1.0 to 6.0	0.7 to 3.0	1.0 to 4.0
Impact Strength, Izod (ft-lb/in) ASTM D 256 Notched 1/8 in (3.2mm) section	0.8 to 1.6	0.6 to 5.0	0.7 to 1.7	0.8 to 1.3	1.0 to 4.5	0.9 to 2.0	1.3 to 7.0	0.8 to 6.0	0.5 to 5.4	0.6 to 1.5	0.6 to 3.5
Specific Gravity ASTM D 792	1.27 to 1.60	1.38 to 1.77	1.42 to 1.89	1.31 to 1.48	1.37 to 1.84	1.33 to 1.58	1.25 to 1.71	1.39 to 1.55	1.20 to 1.81	1.24 to 1.49	1.41 to 1.77
Molding Shrinkage (in/in) ASTM D 955 1/8 in (3.2mm) section	0.001 to 0.007	0.001 to 0.011	0.001 to 0.005	0.0005 to 0.002	0.001 to 0.006	0.0001 to 0.003	0.0005 to 0.006	0.0001 to 0.001	0.001 to 0.014	0.0005 to 0.004	0.001 to 0.008
Viscosity	Medium-High	Medium	Low	High	Medium	Medium-High	Low	Low	Low	Low	Low
HDT @ 264 psi	345°F to 365°F	175°F to 415°F	450°F to 510°F	375°F to 405°F	500°F to 600°F	500°F to 600°F	180°F to 235°F	420°F to 605°F	370°F to 550°F	475°F to 550°F	375°F to 410°F
Continuous Use Temp	320°F	250°F	425°F	375°F	475°F	475°F	170°F	450°F	375°F	375°F	250°F
Water Absorption	<0.3%	<0.08%	<0.02%	<0.2%	<0.15%	<0.15%	<0.15%	<0.1%	<0.3%	<0.3%	<0.08%
Amorphous or Semi-crystalline	Amorphous	Semi-Crystalline	Semi-Crystalline	Amorphous	Semi-Crystalline	Semi-Crystalline	Semi-Crystalline	Semi-Crystalline	Semi-Crystalline	Semi-Crystalline	Semi-Crystalline
Chemical Resistance	Good	Fair	Excellent	Good	Excellent	Excellent	Fair	Excellent	Excellent	Excellent	Fair
Weatherability	Good	Good	Good	Fair	Good	Good	Fair	Good	Good	Good	Good

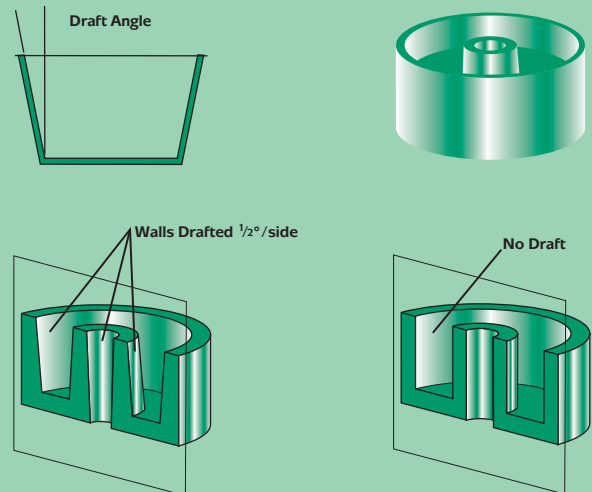
## RADI ON BOSSES AND RIBS

Sharp corners at the base of bosses and ribs can be stress concentrators. The edge where a boss meets the nominal wall should be radiused to reduce the sharp corner without increasing the wall thickness enough that it creates a sink problem. The radius at the base of a boss should be 1/2 of the nominal wall with a minimum radius of 0.015".

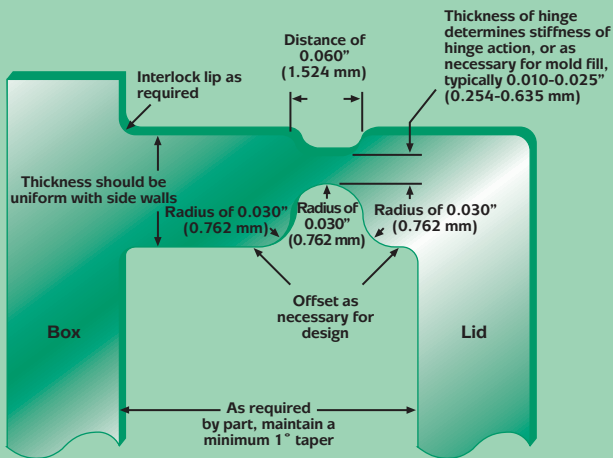


## DRAFT ANGLE

- Design parts with a minimum of 1/2°/side draft.



## LIVING HINGE



## AMORPHOUS VERSUS SEMI-CRYSTALLINE MATERIALS

Thermoplastic materials can be grouped into two categories: amorphous and semi-crystalline. It is important to understand the differences between these two material families when designing with plastics.

### Semi-crystalline materials

Semi-crystalline materials have an ordered structure in which adjacent polymer molecules are positioned in a definite geometry. These materials have a sharp melting point and are typically solvent resistant. These materials are also anisotropic which means they shrink differently in the flow and transverse directions.

## Typical Shrinkage Values for Semi-Crystalline Materials

	Mold Shrinkage (in./in.)
Unfilled Polypropylene	0.010-0.025
Talc filled PP	0.007-0.015
HDPE	0.015-0.040
Unfilled Nylon 6	0.005-0.015
Unfilled Nylon 6/6	0.008-0.015
Acetal	0.020-0.025

### Amorphous Materials

Amorphous materials are not crystalline, and adjacent molecules have a random structure. These materials have no identifiable "melting point" but progressively soften through a broad temperature range. Unfilled amorphous materials are typically isotropic, shrinking equally in the flow and transverse directions. Even fiber-filled amorphous materials typically have low shrink and good dimensional control.

## Typical Shrinkage Values for Amorphous Materials

	Mold Shrinkage (in./in.)
Unfilled ABS	0.004-0.008
Unfilled PC	0.003-0.007
Unfilled PSU	0.003-0.007
Unfilled PEI	0.004-0.009
Unfilled PMMA	0.003-0.007

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## COMPUTER-AIDED DESIGN

Computer-Aided Engineering, or CAE, is an important injection molding plastics tool that has the potential to save time and cost. RTP Company's CAE Support Services assists our customers with technical design issues from conception to final part manufacture for a multitude of competitive applications.

## CAE CAPABILITIES

Our CAE Support Services can effectively utilize state-of-the-art CAE tools for composite materials in both structural and moldability analysis. We offer product design review and consultation of the following:

- **Design Assistance for Metal to Plastic Conversions**
- **Plastic Part Design Assistance**
- **Mold Design Assistance**
- **Structural Failure Consultation**
- **Composite Materials Design Assistance and Education**
- **Quick Mechanical Structural Design Review**
- **Product Testing Recommendation**

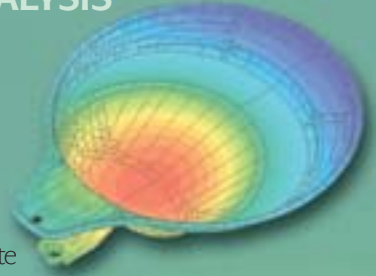
*For more information on our CAE Support Services, please contact your local RTP Company Sales Engineer or Business Development Manager.*

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## MOLDFLOW® FILLING ANALYSIS

### (Fusion™ and Midplane)

- Design plastic parts for ease of manufacturing and identify features that may limit the injection molding cycle
- Optimize gate size and location
- Determine and/or relocate weld line locations
- Estimate molding parameters and investigate alternatives to improve processing
- Identify undesirable fill patterns that could lead to warpage



## STRUCTURAL ANALYSIS

### (NEI/Nastran)

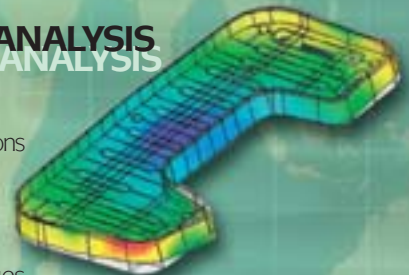
- Metal-to-plastic conversion
- Structural failure analysis
- Structural analysis which considers the non-uniform properties of plastic due to fiber orientation
- Locating gates for optimal structural product performance
- Part design assistance for optimal mechanical performance



## MOLDFLOW® WARPAGE ANALYSIS

### (Fusion™ and Midplane)

- Compare the effects of various gate locations on part warpage
- Compare part shape and warpage with various materials
- Design parts to minimize warpage issues during molding
- Diagnose and solve warpage problems with current molded parts



## MATERIAL DATA ASSISTANCE

RTP Company can provide guidance and material data for customers doing their own CAE Analysis. Customers will benefit from our in-house testing and curve-fitting for standard materials and custom materials. Your custom materials data will be processed with RTP Company's strict confidentiality procedures.

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