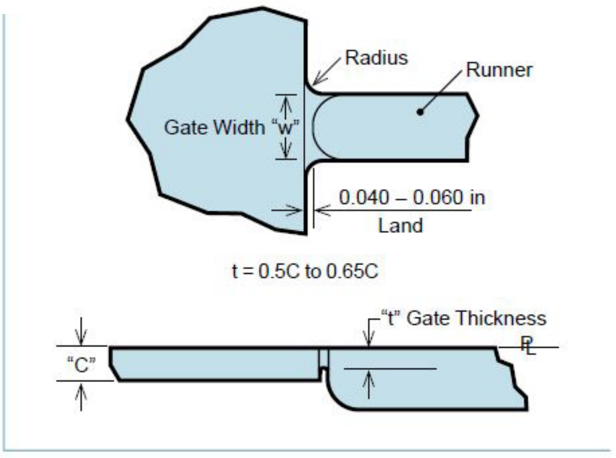
Automotive Headlamp Lens Technology from Covestro

Gate Design for Automotive Lighting

Gates are features in the part and mold designs to allow material to enter the injection mold. Gates can have a variety of configurations. They are classified in one of two categories—manually trimmed or automatically trimmed—based on the method of de-gating.

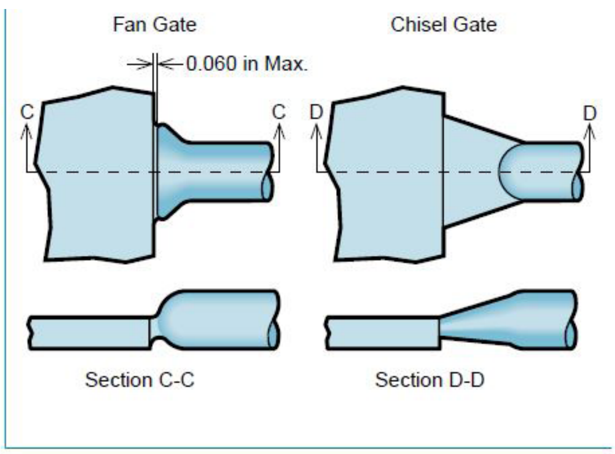
Manually trimmed gates are those that require an operator to separate parts from runners during a secondary operation. Edge gates, fan gates, chisel gates and tab gates are all versions of manually trimmed gates. The common edge gate typically projects from the end of the runner and feeds the part via a rectangular gate opening. Edge gates generate less flow shear and consume less pressure than most self-degating designs. Edge gates are therefore preferred for shear-sensitive materials, high-viscosity materials, highly cosmetic applications and large volume parts. When designing edge gates, limit the land length to no more than 0.060 inch for Covestro materials.

Common Edge Gate



Common edge-gate guidelines.

Variations of the Edge Gate

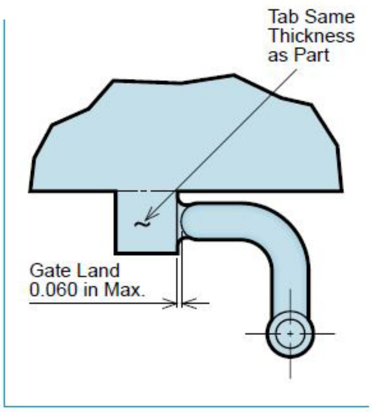


Fan gates and chisel gates can provide better cosmetics in some applications.

Fan gates and chisel gates are variations of the edge gate that flare wider from the runner to increase the gate width. Like the standard edge gate, limit the land length for fan and chisel gates to no more than 0.060 inch for Covestro materials. Chisel gates can provide better packing and cosmetics over standard edge gates for thick-walled parts.

Edge gates can also extend to tabs that are removed after molding or hidden by assembly. These tab gates allow quick removal of the gate without concern about gate appearance.

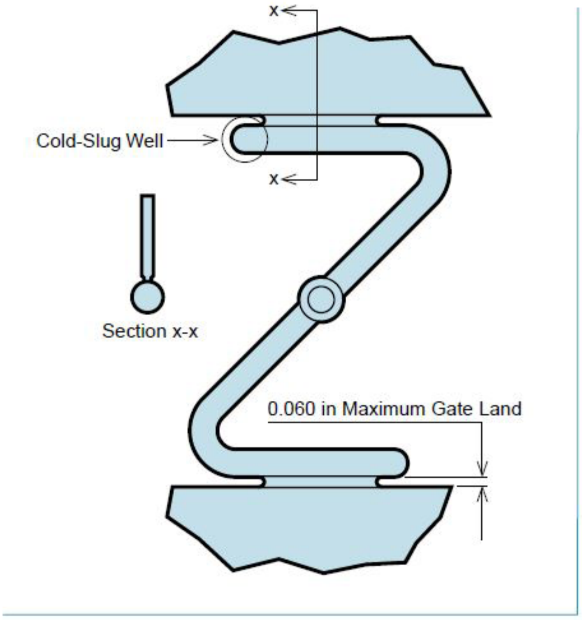
Tab Gate



The gate tab can be hidden in the assembly or trimmed off after molding.

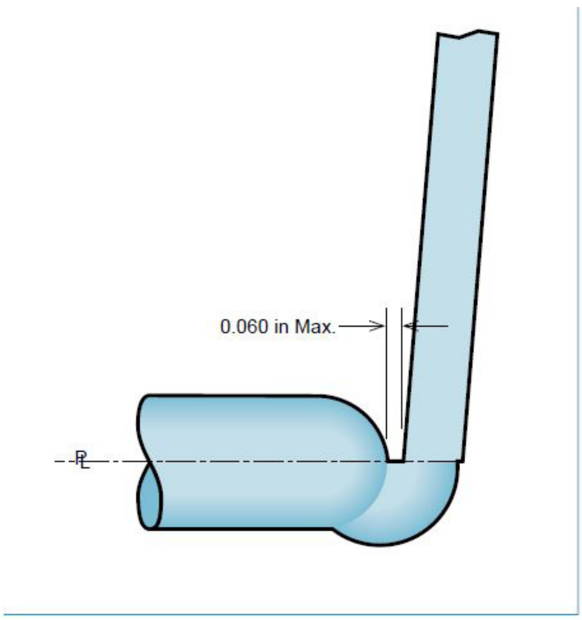
Edge gates may also extend from the side of the runner oriented parallel to the part edge. This design, coupled with a "Z" style runner, tends to reduce gate blush by providing uniform flow along the width of the gate and a cold slug well at the end of the runner. To hide the large gate vestige left by large edge gates, the gate can extend under the edge.

"Z" Runner



Edge gate from the side of a "Z" runner.

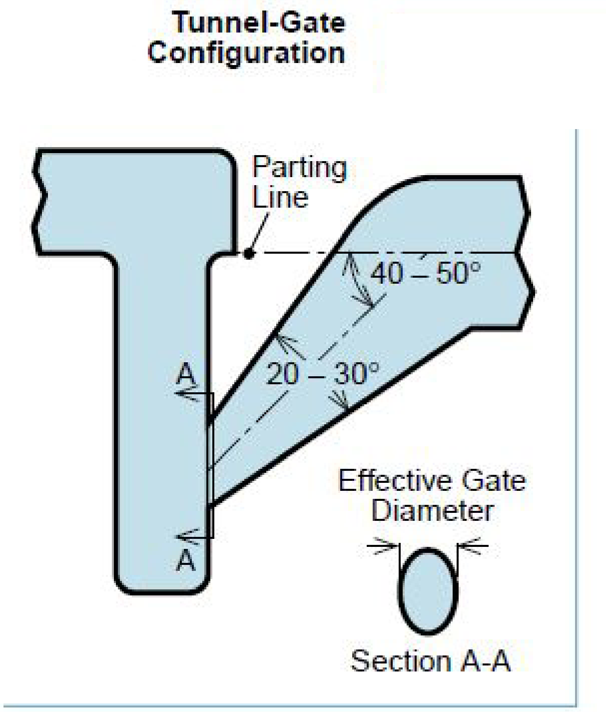
Gate Under the Edge



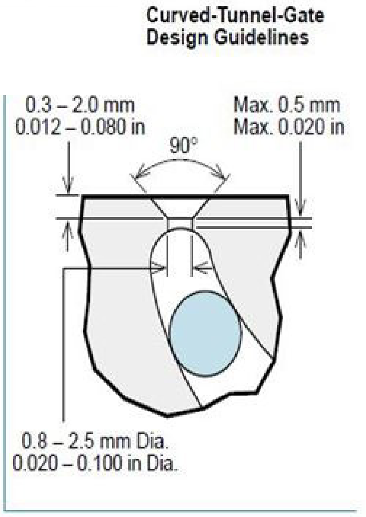
This gate can be trimmed without leaving a gate mark on the cosmetic part surface.

Automatically trimmed gates incorporate features in the tool to break or shear the gate as the molding tool is opened to eject the part. Tunnel gates and pinpoint gates are examples of automatically trimmed gates. Tunnel gates extend under the mold parting surface and can reach surfaces or features that are not located on the parting line. The gates typically feed material to surfaces that are oriented perpendicular to the mold face. Depending on their design, they degate during ejection or mold opening. Tunnel gates that degate during mold opening often require a sucker pin or a feature similar to a sprue puller to hold the runner on the ejector half of the mold. The runner must flex for the gate to clear the undercut in the mold steel. The gate may break or lock in the mold if the runner is too stiff or if the ejector pin is too close to the gate. Normally, the ejector pin should be at least two runner diameters away from the base of the gate. The orifice edge closest to the parting line must remain sharp to shear the gate cleanly.

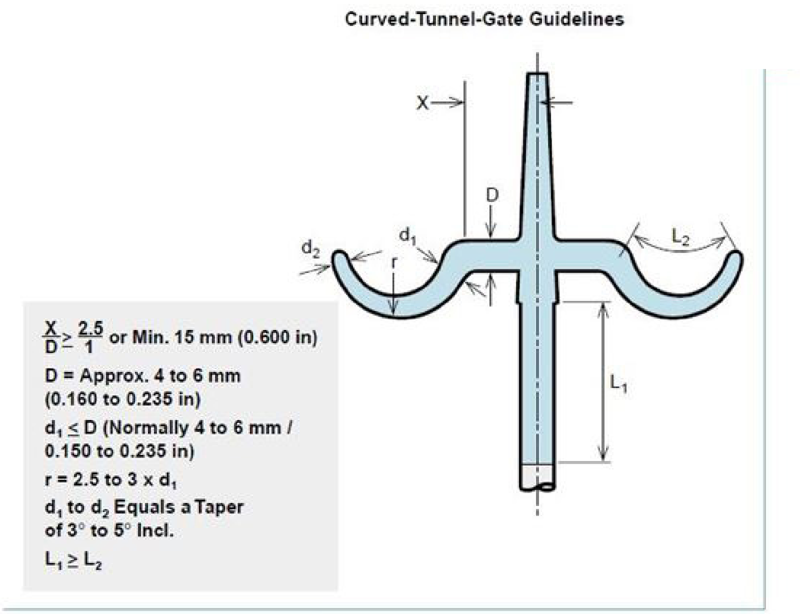
Curved tunnel gates permit gating into the underside of surfaces that are oriented parallel to the parting plane. Unlike mold fabrication for conventional tunnel gates, the curved, undercut shape of this design must be machined or EDM (electro discharge machining) burned on the surface of a split gate insert. The curved gate must uncurl as the runner advances on guided posts during ejection. This gate design works well for unfilled materials that remain somewhat flexible at ejection temperature.



Standard tunnel-gate guidelines.



The curved tunnel gate needs a well-defined break-off point for clean degating.



Gate Optimization:

Factors affecting optimum gate size include part thickness, part volume, filling speed, material properties and number of gates. Gate thickness controls packing ability. For proper packing, gates must remain open and free from freeze-off long enough to inject additional material during packing to compensate for shrinkage. In general, use gates that are two-thirds the part thickness for highly cosmetic parts or parts that could exhibit read-through from features such as ribs and bosses.

The volumetric flow rate through the gate may dictate gate sizes larger than needed for packing alone. High flow rates in gates can generate excessive shear rates and shear heating. This can damage the material and lead to a variety of molding problems.

Thin-walled parts, those with nominal wall thicknesses less than 1.5 mm, often require disproportionately large gates to accommodate the very high filling speeds needed for filling.

Gate diameters that are greater than 80% of the wall thickness are often required to prevent excessive gate shear. Ideally, these gates should feed into thickened wells that ease flow from the gate into the part wall sections. Hot runner valve gates are often required to achieve the required gate size without excessive gate vestige.

Volumetric flow rate and gate size control shear rate in the gate. Filling speed, or flow rate, affects the shear rate. The effect of gate size on bulk shear rate depends on the gate geometry. Computer flow analysis can take into account the best filling speed and injection velocity profile for a given system when calculating maximum shear rate encountered in the gate. A less accurate--but simpler--method is to calculate bulk shear rate using an estimated, uniform volumetric flow rate in the appropriate shear rate formula:

Shear rate = $4Q/\pi r^3$ for round gates
Shear rate = $6Q/wt^2$ for rectangular gates
Q = flow rate (in^3/sec)
R = gate radius (in)
W = gate width (in)
T = gate thickness (in)

To calculate flow rate, divide the volume passing through the gate by the estimated time to fill the cavity. For parts with multiple gates, this will mean assigning a portion of the part volume to each gate.

Materials differ in the maximum shear rate they can tolerate before problems occur. Makrolon® polycarbonate should have a maximum shear rate of no more than 40,000 1/s. For cosmetic applications like automotive lighting lenses, the shear rate should be half of that.

To minimize packing and shear problems:

- Set edge gate thickness according to the packing rules and adjust the width to achieve an acceptable gate shear rate.
- Adjust the diameter of round gates, such as tunnel gates and pinpoint gates, based upon the packing rules or on the size needed to stay within the shear rate limits of the material--whichever is larger.
- Increase the quantity of gates if the calculated gate size is too large to degate cleanly.

Gate Position:

Gate position can have a direct impact on part moldability, performance, appearance and cost. The location of the gate determines the filling pattern and the maximum flow length. Ideally, the gate would be positioned to balance filling and maximize flow length. This would typically be near the center of the part or at strategic intervals for multi-gated parts. However, restrictions like unsightly gate marks, weld lines or mechanisms in the mold, like lifters or slides, make this unacceptable. The best gate position is often a compromise between molding ease and efficiency, part performance and appearance, and mold design feasibility.

Gate position determines the filling pattern and the resulting flow orientation. Plastics usually exhibit greater strength in the flow direction. Keep this in mind when choosing gate locations for parts subjected to mechanical loads. When possible, position gates to direct filling in the direction of applied stress and strain.

Flow orientation also affects part shrinkage in the mold. Shrinkage in unfilled plastics, which tend to shrink just a little more in the flow direction than the cross-flow direction, is only slightly affected by flow orientation. As a general rule, in parts that have varying thickness, always try to gate into the thickest sections to avoid packing problems and sink.

Avoid thin to thick filling scenarios. When gating must feed a thinner wall, consider adding a thickened channel or flow leader from the gate to the thicker wall sections to facilitate packing and minimize shrinkage variations. The advancing flow front in parts with thick and thin wall sections will often hesitate in the thin walls until the thicker walls have filled. This flow hesitation can lead to freeze-off and incomplete filling of the thin-wall section. Often, positioning the gate so that the thinnest walls are near the end of fill reduces the hesitation time, enabling the thin sections to fill. This is particularly helpful in thin-walled parts, which are prone to flow-hesitation problems.

Gates typically generate elevated levels of molded-in stress in the part area near the gate. Also, gate removal often leaves scratches or notches that can act as stress concentrators that weaken the area. For these reasons, avoid gating into or near areas that will be subject to high levels of applied stress such as screw bosses, snap arms or attachment points.

The flow length resulting from the chosen gate locations must not exceed the flow capabilities of the material. Check the calculated flow length, usually the shortest distance from the gate to the last area to fill, against the published spiral flow data for the material. Consider computerized mold-filling analysis if the flow length is marginal or if the wall thickness varies or is outside the range of published spiral flow data. Flow leaders— thickened areas extending from the gate toward the areas to fill—can aid filling without thickening the entire part.

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