

# Tenite™ cellulosic plastics— Injection molding

This publication deals with methods of injection molding Tenite™ cellulose acetate (CA), Tenite cellulose acetate butyrate (CAB), and Tenite cellulose acetate propionate (CAP) into finished articles and discusses design of injection molds for use with Tenite cellulosic plastic. Application information and physical property data for Tenite cellulosic plastic in the types, formulas, and flows regularly supplied for molding are contained in publication PPC-100, *Tenite cellulosic plastic*, and in data sheets.

## Tenite CA, CAB, and CAP

Tenite molding compositions are thermoplastic, which means they can be repeatedly softened and formed by the application of heat and pressure and hardened each time they cool.

Tenite for molding and extrusion is supplied in pellets of substantially uniform size with almost no fine or dust-like particles. Because of the uniform size of the pellets, the weight-to-volume ratio is subject to little variation. Tenite is supplied in a number of different formulas and flows to meet special molding conditions or to give special physical properties that may be desired in a molded article.

Tenite molds very easily, but butyrate and propionate are generally easier to mold than acetate. Because of lower viscosity at molding temperatures, butyrate and propionate also produce better welds. Various formulations of each cellulosic plastic also differ in moldability, with some formulas significantly easier to mold than others.

A better mold finish is generally easier to obtain with butyrate and propionate than with acetate. Proper drying before molding will often improve the finish of products made from any of these plastics.

If kept clean, sprue and runner scrap and rejected parts made of Tenite CA, CAB, and CAP can be granulated and reprocessed, affording practically 100% utility of the material and minimizing waste. It is suggested, however, that clean reground material be blended with virgin material to avoid remolding the same material excessively. The proportion of reground material used in the blend should be approximately the same in most cases as the ratio of the runner weight to the total shot weight.

Cellulose acetate is not compatible with CAB or CAP and must not be mixed with either of them. Butyrate can sometimes be mixed with propionate, but compatibility of these two materials must not be assumed in all cases. None of these plastics are compatible with noncellulosic plastics. Scrap from each material should be kept separate and clean if it is to be processed again or have any reclamation value.

## Choice of material

The properties required in the finished product and the characteristics of the manufacturing process should govern the selection of the plastic to be used. Tenite cellulosic plastic is supplied in various formulas and flows to provide a means of obtaining the most efficient production from a particular operation as well as the most desirable properties in the finished product. When a new application is being considered, Eastman's specialty plastics sales representatives or the technical staff of Eastman's plastics laboratory will be glad to suggest a formula and flow for initial molding trials. It is recommended that an Eastman representative be consulted if specific processing characteristics or physical properties are required.

### *Choice of plastic*

Tenite provides a versatile combination of properties, including easy processability, transparency, colorability, toughness, and rigidity. The availability of butyrate and propionate in special formulations for outdoor use gives additional versatility to this family of plastics.

It is impractical to discuss all the factors that affect the choice of one cellulosic plastic over another, but information in the remainder of this section can be used as a general guide. One factor that does not enter into the choice is color, because all three plastics have excellent colorability.

Plastics made from wood pulp—  
*a renewable resource*

Low moisture absorption and good plasticizer retention combine to give butyrate and propionate exceptional permanence and dimensional stability.

Butyrate and propionate are generally preferred to acetate when exceptional processing ease is a factor, when dimensional stability under severe conditions is important, or when some combination of these or other characteristics is desired.

Butyrate is chosen over propionate when its advantages in weatherability and dimensional stability are desired or when soft flows (not offered in propionate) are needed.

Propionate is selected over butyrate when properties of greater hardness, tensile strength, and stiffness are required.

Acetate has somewhat different chemical resistance properties than butyrate and propionate and is selected in applications where it may offer a chemical resistance advantage. Certain formulas and flows also offer greater surface hardness and higher tensile strength than either butyrate or propionate.

### ***Choice of formula***

Acetate, butyrate, and propionate differ chemically because they are based on different cellulose esters. The establishment of various basic formulas for each plastic is based on the use of different plasticizers. Derivative formulas have the same plasticizers and the same properties as basic formulas and, except for the effects of such additives as mold lubricants, the same processing characteristics.

### ***Choice of flow***

Flow designation is based on the temperature at which a plastic material will flow a specified distance through a specified orifice at a specific pressure. Within the same formula, the flow is governed by the plasticizer (PZ) content. The harder flows have a somewhat harder surface, higher heat resistance, and greater rigidity, tensile strength, and dimensional stability, whereas softer flows give greater impact strength.

When no particular processing difficulties are indicated by product design and when property requirements do not dictate the use of another flow, suggested flows for initial molding trials are as follows:

Plastic	Flow
Tenite acetate	MH
Tenite butyrate	MH
Tenite propionate	H2

These suggestions take into account the processing characteristics of each plastic and the types of applications for which each is ordinarily selected.

Eastman technical data sheets show both the old flow designation and the corresponding percentage of PZ for each flow and each formula. Orders produced by percentage of PZ result in less batch-to-batch variation, which gives a more consistent product. Therefore, we suggest that samples or trial orders be entered for percentages of PZ rather than for the old flow designations.

### ***Choice of color***

Tenite™ CA, CAB, and CAP are available in natural, clear, selected amber transparents, smoke transparents, and black translucents.

### ***Color concentrates and other additives***

Tenite CA, CAB, and CAP are also available in color concentrates with letdown ratios of 10:1, 20:1, or higher. These color concentrates are blended with natural clear acetate, butyrate, or propionate by the molder. This can be done by tumble blending or by automatic metering devices.

Several cellulosic formulations are available with internal lubricants added to aid processing or improve mold release. It is also possible for the molder to add lubricants. One of the best lubricants for cellulose is zinc stearate powder added at a level of 0.03% to 0.05%. Zinc stearate works well as a mold release without affecting the clarity of transparent formulations. Occasional problems with material feeding can often be solved by adding a small amount of zinc stearate powder to the material, which results in the shortening of screw return time.

# Drying cellulosic plastics for successful injection molding

Cellulose ester plastics absorb moisture and typically need to be dried before being processed. Acetate absorbs moisture faster than butyrate or propionate and reaches a higher moisture content. The affinity of all three plastics for water increases with temperature, and both the rate of absorption and the equilibrium content increase as atmospheric moisture concentration increases. Adequate drying can help reduce the evolution of fumes or gases during molding. Local exhaust ventilation can also be used as needed to help control the evolution of such fumes.

A brief summary on drying cellulose esters follows. For a more complete discussion on drying procedures and equipment, refer to publication PP-105, *Drying Tenite™ cellulosic plastic*.

## Effects of moisture on injection molded articles

Moisture causes two types of defects in molded products: surface roughness and bubbles in the interior. Surface roughness is the most frequent defect in thin parts, whereas internal bubbles tend to plague thick sections, which may also have rough surfaces. Internal bubbles can also persist even when the molding is cooled slowly, most likely due to moisture.

Surface roughness caused by moisture may appear as:

- Flow lines and streaks in the gate area—occur very frequently.
- A scaly surface—seen frequently
- A blister where a bubble expanded after ejection of the part from the mold—occurs frequently and often appears in clusters.
- A slight depression or rough, shallow crater where a bubble broke the surface or formed against the mold wall—occurs fairly infrequently and generally singly.

## Drying temperatures

For most operations, 65°C (150°F) should be considered the minimum operating temperature for drying cellulosic plastics, although the softer flows are sometimes dried at a temperature as low as 55°C (130°F). Temperatures may range up to 85°C (185°F) or even higher when hard flows are dried. In general, it is possible to use temperatures 55°–65°C (100°–120°F) below the flow temperature of the plastic to be dried; temperatures above 95°C (200°F) may be detrimental to the plastic.

## Drying times

It is impractical to list specific drying times for all possible combinations of plastics, dryers, and applications. In general, however, for an efficient dryer operated at 70°C (160°F) or higher and for a normal processing operation, the drying times listed in Table 1 will be satisfactory.

**Table 1.** Typical drying times for Tenite cellulosic plastic

Plastic	Stored less than 1 month	Stored more than 5 months
Tenite™ cellulose acetate	2½ hr	3½ hr
Tenite™ cellulose acetate butyrate	2 hr	3 hr
Tenite™ cellulose acetate propionate	2 hr	3 hr

# Injection molding conditions for cellulosic plastic

In addition to drying, other processing variables such as melt temperature, mold temperature, injection pressure, and injection speed affect the quality of articles molded from cellulose ester plastics.

In injection molding, the hot plastic material must be forced into the mold at sufficient speed to fill the mold cavities completely before the material begins to harden through contact with the cooler mold. Partial chilling of the plastic before the cavities are filled causes flow marks and strains that make the molded article more likely to warp under varying atmospheric conditions.

## Cylinder temperature

Melt temperature of the plastic material traveling through the cylinder is usually different from the cylinder temperature. On some injection molding machines, melt temperature may never reach cylinder temperature. On other machines, frictional heat may result in the melt temperature overriding the cylinder temperature.

The injection molding temperature for Tenite™ cellulosic plastic is usually between 175° and 260°C (350° and 500°F), depending on the formula, weight and thickness of the article, and cycle time.

Approximate cylinder temperatures for molding various flows of acetate, butyrate, and propionate are shown in Table 2.

As Table 2 shows, the cylinder temperatures for molding Tenite™ CAP would be approximately the same as those for CA or CAB that is two to three flows softer. For example, propionate in an H2 flow would mold at about the same cylinder temperature as acetate or butyrate in an MH flow.

It must be emphasized that Table 2 should serve as a starting guide only, because actual temperatures on any job depend on many factors—cycle, machine heating capacity, machine throughput, part design, and others.

If material insufficiently heated in the cylinder is injected using excessive pressure, the molded articles are likely to have surface flow marks and considerably lower impact resistance.

## Mold temperature

Accurate control of mold temperature is often as important as accurate control of cylinder temperature. Mold temperatures usually must be varied with the section thickness and size of the casting. It is necessary to provide adequate cooling channels and to control the temperature of the circulating water to the mold to maintain the proper differential between the temperature of the plastic material and that of the mold. Proper temperature conditions for each job must be determined by trial. For addition or removal of the required amount of heat, water circulation systems that are complete with automatic controls and ready to be connected to a mold are commercially available.

It is important that cellulosic plastics be cooled slowly to minimize strains in the molded article. Approximate mold temperatures for various flows of acetate, butyrate, and propionate are shown in Table 3.

With correct adjustment of temperature and pressure, hard-flow materials can be injected into hot molds on a cycle as fast as softer flows can be injected into relatively cool molds. If the mold is insufficiently heated, it will be difficult to fill or the articles will lack strength. If it is too hot, the molded articles may stick in the mold and show shrinkage or distortion.

**Table 2.** Cylinder temperatures<sup>a</sup> for various flows of Tenite™ CA, CAB, and CAP

Cylinder temperatures, °C (°F)		
Flow	Acetate and butyrate	Propionate
H4	250 (480)	245 (470)
H3	245 (470)	240 (460)
H2	245 (470)	230 (445)
H	240 (460)	220 (425)
MH	230 (445)	210 (405)
M	220 (430)	195 (385)
MS	215 (415)	—
S	200 (395)	—
S2	190 (375)	—
S3	175 (350)	—

<sup>a</sup>Temperatures rounded

**Table 3.** Mold temperatures<sup>a</sup> for various flows of Tenite™ CA, CAB, and CAP

Mold temperatures, °C (°F)		
Flow	Acetate and butyrate	Propionate
H4	85 (185)	75 (165)
H3	80 (175)	65 (150)
H2	70 (160)	55 (135)
H	65 (150)	50 (125)
MH	55 (135)	45 (110)
M	50 (125)	40 (100)
MS	45 (110)	—
S	40 (100)	—
S2	30 (90)	—
S3	25 (80)	—

<sup>a</sup>Temperatures rounded

## Injection pressure

The injection pressure required when molding cellulose ester plastics depends on the formula and flow of material; the number, size, and shape of mold cavities; the cross-sectional area of the nozzle orifice, sprue, and runners; and the temperature of the material and mold. Injection pressures can be varied on commercial injection molding machines by controlling pressure in the hydraulic line that actuates the injection system. A few trial shots are usually sufficient to establish the proper molding pressure.

Because excessive packing of the cavities can result in strains in the molded article, injection pressure is an important variable in producing tough parts. A good procedure is to use just enough injection pressure to fill the cavity and eliminate sink marks and voids.

## Injection speed

The injection speed should be fast enough to prevent excessive material cooling before the cavities are filled and slow enough to avoid excessive turbulence of flow. Some molding machines are equipped with profiled injection to control the rate of ram movement during injection. Pressure should be sustained to produce a part free of sink marks, but no longer than necessary.

Molding under these conditions produces articles with minimum strains and, consequently, maximum impact strength and dimensional stability.

# Design considerations for injection molds

When designing a mold, certain characteristics unique to the material selected should be considered. Mold shrinkage is directly related to tolerances of the molded article. Vent dimensions, gate design and location, and runner design are functions of various moldability characteristics of a specific plastic material.

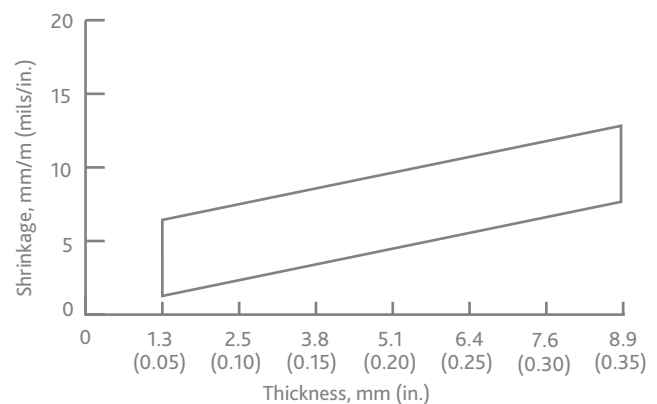
## Mold shrinkage

Mold shrinkages of Tenite are relatively low and uniform. Because the materials are amorphous, shrinkage is virtually the same in the direction of flow as it is across the flow.

Shrinkage subsequent to molding varies somewhat depending on the formula and flow of the material, shape and thickness of the molded article, and molding conditions used. For this reason, it is not practical to give a specific value for mold shrinkage. Figure 1 shows the range of mold shrinkage as a function of wall thickness for Tenite™ cellulosic plastic formulations.

The data shown in Figure 1 cover a wide variety of formulations molded on several different molds. The range of shrinkage values shown at any given thickness corresponds to changes in equipment, molding conditions, and processing techniques. It may be possible to obtain shrinkage values higher or lower than those shown in Figure 1, but most parts under typical operating conditions would be expected to have shrinkage values within the range shown.

**Figure 1.** Mold shrinkage as a function of wall thickness for Tenite™ cellulose plastic formulations



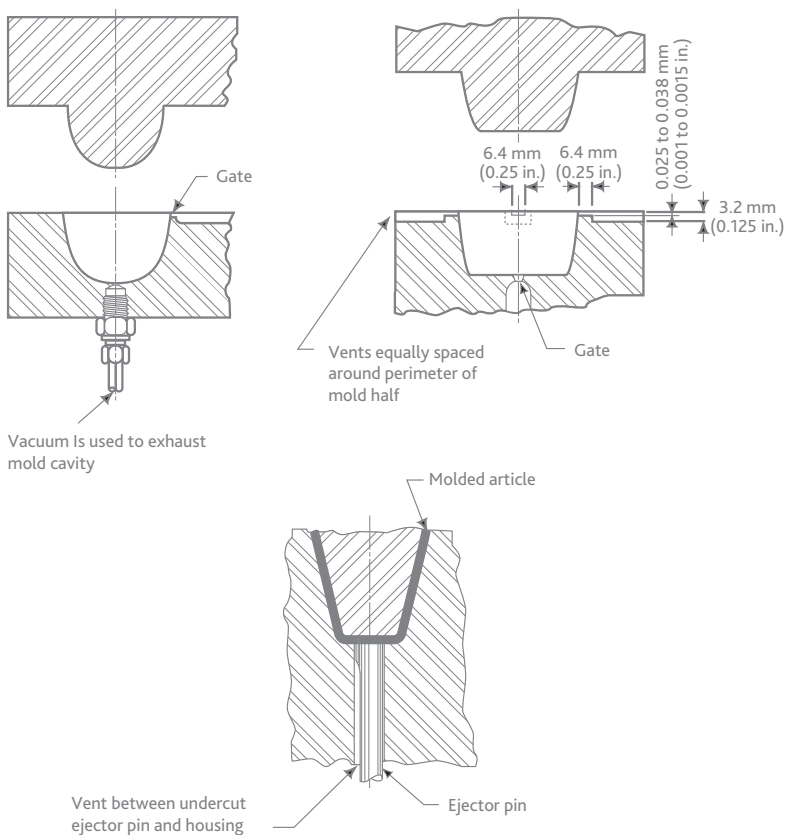
## Venting

Air entrapped in a mold cavity causes a void, or sink mark, to appear on the surface of the molded article, usually at the point farthest from the gate. Charring may also occur at the same point because of the heat generated by compression of the entrapped air. For this reason, vents should be provided in appropriate areas around the cavity.

Vents should be deep enough to allow for the rapid escape of air but not so deep that they allow molten material to flow into the vent. For cellulosic plastic materials, vent depths should be between 0.025 and 0.050 mm (0.001 and 0.002 in.) maximum.

A vent should be located as near as possible to the void, sink mark, or charred material that may appear in a molded article. If not properly located, the vent may become plugged with material before the air pocket it is designed to relieve is formed. Proper venting is essential to good mold design and should not be overlooked or added as an afterthought. Figure 2 shows three common methods of venting mold cavities.

**Figure 2.** Venting methods

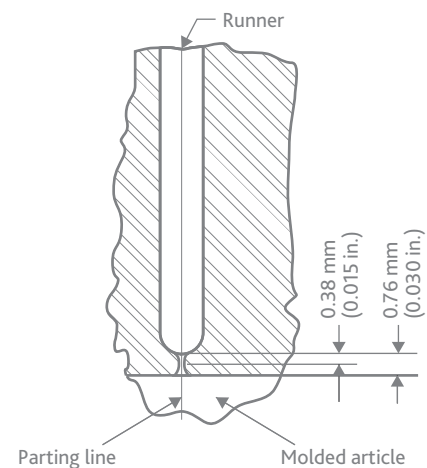


## General practices in gate design

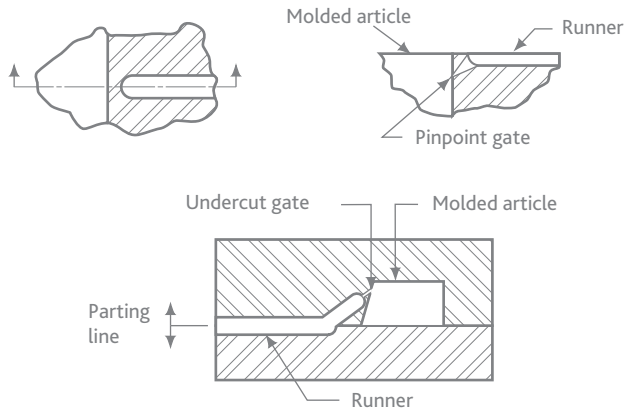
Successful injection molding of Tenite™ cellulosic plastic depends largely on proper mold gating. No definite rule can be stated for the depth or diameter of a gate because shape, size, wall thickness, and detail of the article to be molded influence the gate location and size. Generally, gates are either round or trapezoidal, with size depending on the size and design of the molded article and on the molding equipment. Provided the gate is properly located, a smaller gate reduces the possibility of strains forming in the molded article and, as a result, can reduce the need for costly finishing operations. For these reasons, use a gate size no larger than necessary to mold the article properly.

**Restricted gates.** For molding small articles from cellulose, it is a good practice to start with a restricted gate approximately 0.38 mm to 1.50 mm (0.015 in. to 0.060 in.) in diameter and, if needed, increase the diameter in small increments until a satisfactory article is obtained from the mold. Molding temperatures and pressures should be varied after each increase in gate size to determine whether the size is sufficient. A restricted gate is illustrated in Figure 3. Restricted gating can also be used successfully when molding cellulose in three-plate molds or in molds with tunnel gates.

**Figure 3.** Restricted gate



**Figure 4. Tunnel gating**



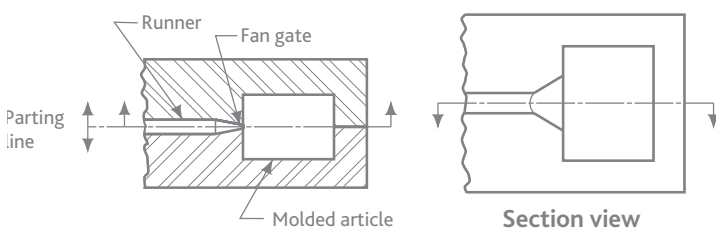
**Tunnel gates.** Tunnel gates, or submarine gates as they are sometimes called, can be used successfully when molding cellulose. Tunnel gates can be used only when the runner system is contained in both cavity plates. The runner system is machined along the parting line between both plates, and the tunnel gate is machined into one of the plates below the parting surface, as shown in Figure 4. With this type of gating, the molded part and the runner are not usually ejected simultaneously. The molded part is ejected first, shearing the gate. The runner system and gate are then ejected by a separate ejection system.

Tunnel gates may or may not be restricted gates, depending on the size of the molded part. Restricted gates usually work best, however, because they shear easily. Large gates are difficult to shear.

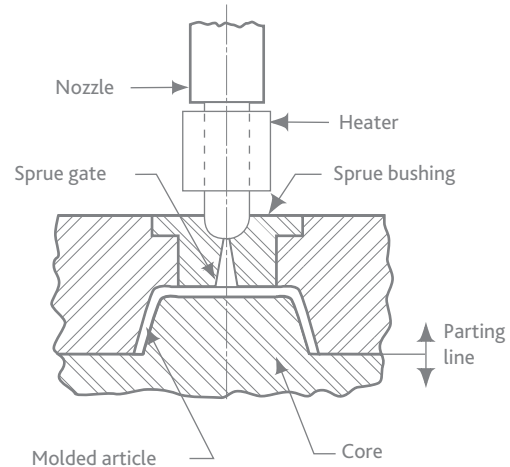
**Fan gates.** Fan gates have a fairly large cross-sectional area for feeding plastic into the mold. As illustrated in Figure 5, they resemble a film die in that the orifice is long and narrow and the flow channel from the runner to the gate is tapered. The degree of taper should be such that the cross-sectional area at any point between the runner and the gate will be the same as it is at the gate.

Fan gates can be used with good results when molding large, heavy parts from cellulose ester plastics. A gate 25 mm x 0.8 mm x 0.8 mm (1 in. x 0.030 in. x 0.030 in.) (L x W x land) fed by a heavy runner section minimizes the splay effect prevalent on some moldings. Large gates are sometimes difficult to shear from the molded part and often necessitate a finishing operation.

**Figure 5. Fan gating**



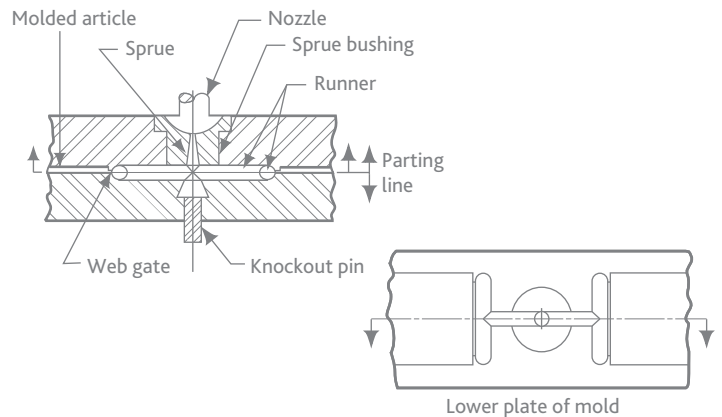
**Figure 6. Sprue gating**



**Sprue gates.** Sprue gating, shown in Figure 6, is normally used when molding large articles in a one-cavity mold. With this type of gating, there is a tendency for molded articles to be highly strained because there is no restriction to cause the material to freeze when the flow of plastic stops.

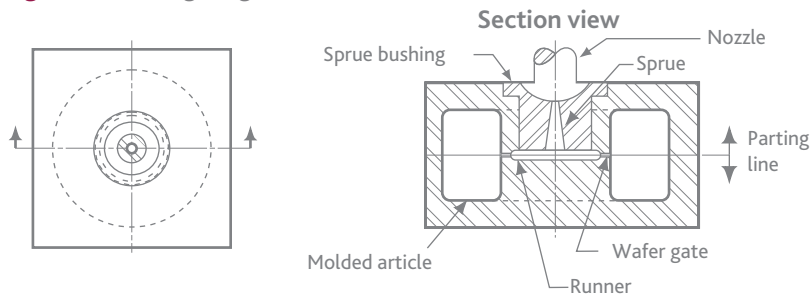
**Web gates.** When large, flat articles are being molded from cellulosic plastics, a web gate may be used successfully to reduce warpage, flow lines, jetting, and strains. This gate, illustrated in Figure 7, allows a long, continuous front of plastic to flow into the cavity, virtually eliminating weld lines in many instances. The gate opens from a runner cut along one edge of the mold cavity. The gate can be as long as the edge of the cavity and should be approximately 0.30 mm (0.012 in.) wide initially. It can be enlarged if necessary. The land between the runner and cavity should be approximately 0.50 mm (0.020 in.).

**Figure 7. Web gating**



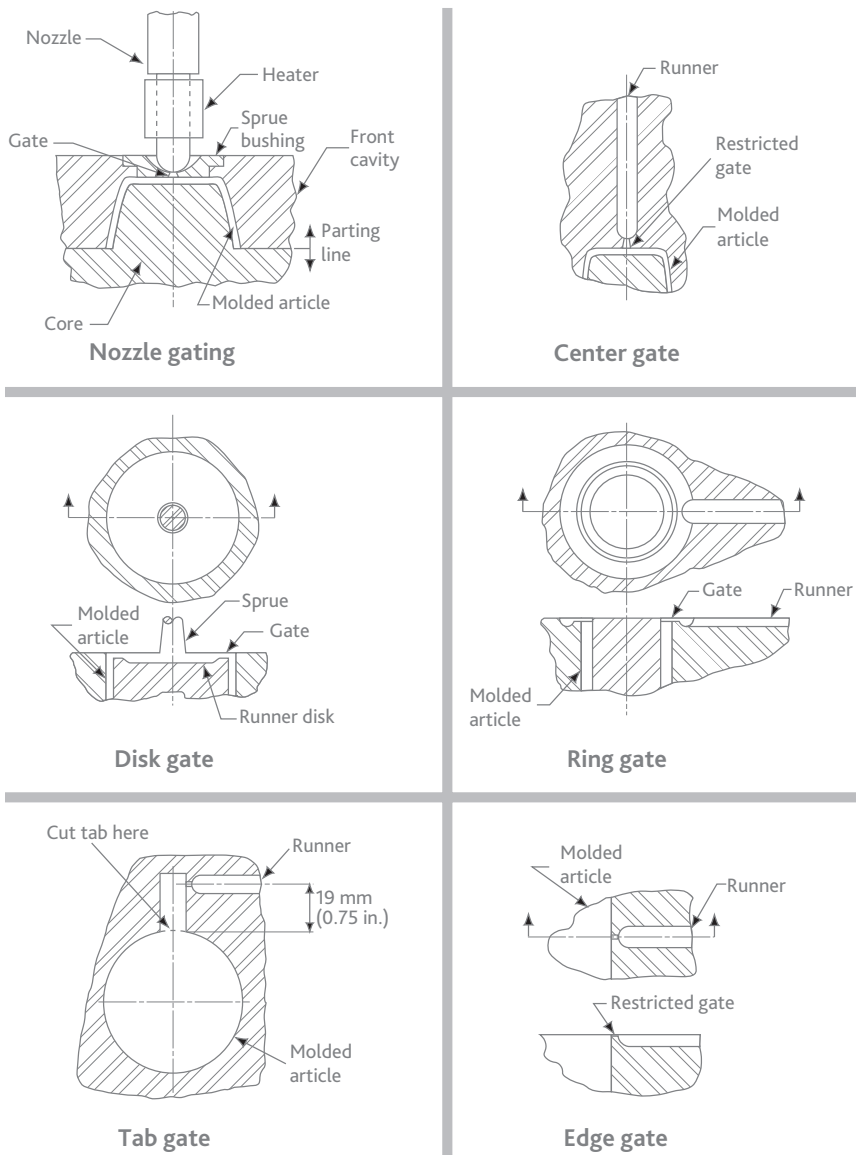
**Wafer gates.** The wafer gate, shown in Figure 8, is a circular web gate that is used when it is convenient to gate into a hole in the molded article. The gate width should be approximately 0.30 mm (0.012 in.) initially with a land length of 0.50 mm (0.020 in.).

**Figure 8.** Wafer gating



Other gates that may be used in molding Tenite™ cellulosic plastic are shown in Figure 9.

**Figure 9.** Other gates that may be used



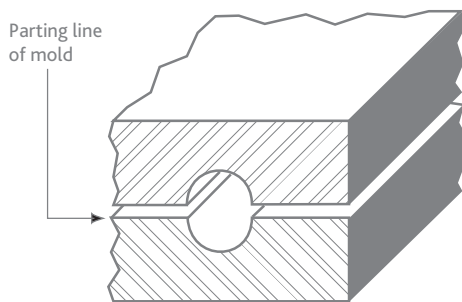


## Runners

Runners are channels leading from the sprue to the individual cavities. Runners should be as short and direct to the cavities as possible. Separate runners from the sprue to each cavity are preferable, but when this is inexpedient and branch runners are necessary, the cross-sectional area of the main runner should equal or exceed the sum of the cross-sectional area of the branches.

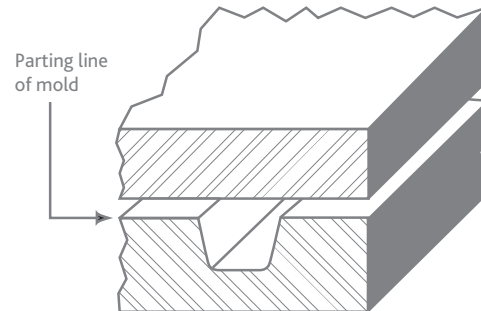
The adhesion between hot metal and molten cellulosic materials is high. In an injection cylinder without a core, the molten plastic flows through the center faster than at the sides, even though the material in direct contact with the hot walls has greater plasticity. This explains why it is so desirable to have as little surface friction as possible in the sprue and runner system of a mold. Low friction and low injection pressure combine to permit filling a large cavity mold area without forcing the two parts of the mold to open or "flash." Therefore, the best-shaped runners are those with surfaces of lowest friction—that is, of circular cross section as shown in Figure 10. However, round runners present machining difficulties because they must be formed with half in each mold plate, and each half must be accurately machined so that they match exactly when the mold is closed. A mold with multiple cavities and round runners requires considerable skill when laying out and machining, with consequent high mold cost. For these reasons, round runners are in limited use; but they are desirable with restricted gating.

**Figure 10.** Full round runner (best)



As a compromise, runners of trapezoidal and semicircular cross sections are frequently used because they can be located entirely in one mold half and are comparatively easy to machine. The sides of trapezoidal runners are inclined at an angle of  $10^\circ$  to  $15^\circ$  with the wide part of the runner at the parting surface of the mold. The bottom corners of the runner should be rounded. A trapezoidal runner is shown in Figure 11.

**Figure 11.** Trapezoidal runner (good)



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