

Injection Mold Design Guidelines

Maximizing Performance Using Copper Alloys

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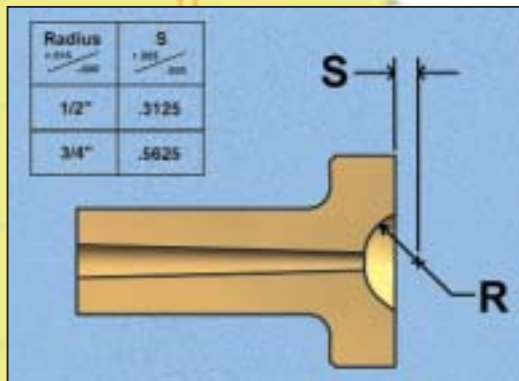


Illustration I, Sprue Radius

Copper Alloys for Conveying Plastic in Injection Molds

The high thermal conductivity of copper alloys makes them ideal materials for the injection mold sprue bushing and runner bars. Three alloys typically are utilized for the mold components, which will have contact with plastic. The copper alloys are:

- C17200, high hardness beryllium-copper alloy
- C17510, high conduct beryllium-copper alloy
- C18000, NiSiCr hardened high conductivity copper alloy

These Copper alloys have six to nine times greater heat transfer rates than conventional mold steels as indicated by the thermal conductivity.

Mold Material	Thermal Conductivity (Btu/Hr/Ft ² /°F)
C-17200	60
C-17510	135
C-18000	125
H-13	17
P-20	20
420 SS	14

The sprue or runner system must never control the cooling phase and/or overall molding cycle. Plastic in contact with copper alloys will set the sprue

and runner faster, allowing more efficient ejection or removal by sprue pickers or robots.

Sprue Bushing Radius

In North America two injection mold nozzle and sprue bushing radii are used, 1/2 and 3/4 inch. To insure proper fit up, the nozzle radius is nominal -.015 inch, while the sprue radius is nominal +.015 inch, required tolerances to use.

Swing points and tolerances used in establishing the radius on a sprue bushing are shown in illustration I.

Sprue Bushing Orifice

Machine nozzle orifices come in nominal 1/16" fractional inch sizes. To insure that the slug in the nozzle will pull through the sprue, the orifice must be .031 (1/32 inch) larger in diameter. This dimension is referred to as the "O" dimension. The relationship is shown in this chart.

Nozzle "O"	Sprue "O"
1/16"	3/32"
1/8"	5/32"
3/16"	7/32"
3/8"	9/32"
5/16"	11/32"
Nominal	+ 1/32"

Primary Runner Sizing Calculation

$$O_2 = O_1 + L (\tan 2.386^\circ)$$

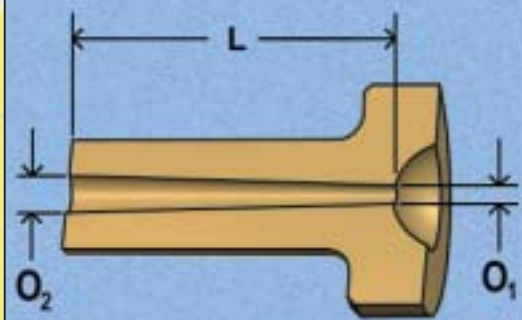


Illustration II, Sprue taper

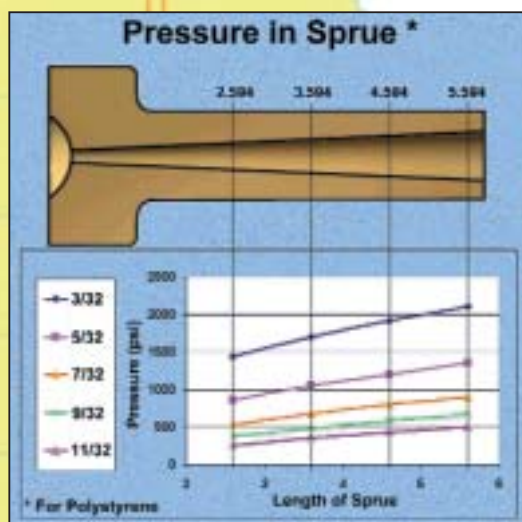


Illustration III, Pressure, Sprue Length

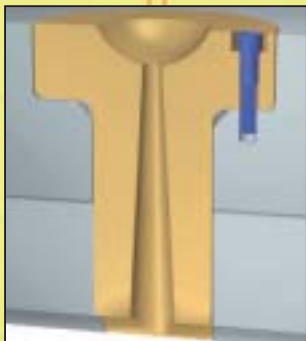


Illustration IV, Anti-rotation screw

$$E_R = \frac{A}{P}$$

E_R = Efficiency Ratio
 A = Area of runner cross section
 P = Periphery of runner cross section

Illustration V, Formula runner system

Sprue Bushing Taper

To aid in the removal of the sprue from the bushing, a taper of one-half inch per foot is normally used in injection molding. Calculate the sprue orifice at the parting line face, multiply the tangent of the taper angle times the length, plus the "O₂". Knowing this dimension, informed decisions can be made on primary runner sizing.

The sprue frequently controls the molding cycle when larger orifice conventional steel sprue bushings are used. The application of a copper alloy sprue bushing cools the sprue more quickly and efficiently, allowing the molding cycle to be controlled by the piece part.

Pressure loss is high in the sprue. This is the only place in the feed system where the channel progresses from a smaller area to larger. Frequently, smaller orifices are used on long sprue bushings in an effort to reduce the mass. This results in extremely high injection pressure losses, making the part hard to fill.

The chart in illustration III is a guide for determining the effect that the specific "O" dimension has on the pressure required to deliver plastic through the length of a sprue. Note that the difference between a 3/32 and 9/32-inch sprue is about 1,000 PSI over a short sprue and almost 1,500 pounds on a long sprue.

Using a copper alloy sprue bushing allows for an increased size orifice, thus reducing pressure loss while maintaining reasonable cooling times.

Sprue Retention and Anti-Rotation

Pressure acting on the parting line face of the sprue, due to projected area of the runner system or part detail, exerts pressure on the sprue bushing.

Also, a sprue bushing that is not keyed will rotate creating misalignment with the runner machined into the face of the sprue bushing and the runner system. To prevent these problems, retain and key the sprue into position with the use of a cap screw as illustrated in figure IV.

Sprue Fit

Heat must be transferred from the sprue through the copper alloy sprue bushing to the mold plates. Interference fit is recommended for optimum cooling. The bore through the "A" plate should be nominal size to plus .0005 inches with a surface finish of at least 16 RMS. The shank of the sprue bushing should be the nominal size, plus .0005 to plus .001 inches.

Standard Sprue Bushing Availability

Copper alloy sprue bushings with patented stainless steel nozzle seats are commercially available. An insulator between the nozzle and sprue is beneficial in controlling the flow of heat from the nozzle to the sprue. Special sprue bushings may be constructed to suit using standard 1/2 inch per foot sprue bushing tapered drills and reams. Sprue bushings with tapers of up to 3/4 inch per foot have been used for difficult to remove plastics. Care must be taken to insure that the taper is draw polished and free from undercuts or rough surfaces that could hinder sprue removal.

Conventional Injection Mold Runner Systems

The shape of the runner, full round or trapezoidal, or other configuration, is dictated by mold design. The most efficient runner cross section is full round. The efficiency of the runner cross section can be calculated with a formula, Figure V, the larger the ratio the better.

Injection Mold Runner Bars

Runner systems for high cavitation molds normally have larger diameters due to runner balancing. The runner system extends the molding cycles as heat is slowly transferred from the thick plastic to steel mold plates. Inserting copper alloy runner bars in the mold "A" and "B" plates, cooling the runner faster, is beneficial, in reducing the overall molding cycle.

Runner Sizing

Runner sizing is dependent on many things, including: plastic material; part size, weight and wall thickness; molding machine capabilities and processing parameters and, the number and placement of the cavities.

Each mold is unique and the designer must consider all parameters and options available on an individual case by case basis. Several mold design software packages are available, including Mold Flow and C-Mold, which address sizing of the runner system.

One method of runner sizing and balancing used by mold designers' starts at the sprue and then works toward the gate. Other designers start with the part wall thickness and work back to the sprue outlet orifice. The normally recommended procedure is that, in the direction of plastic flow, the runner area always goes from larger to smaller. Never from a smaller area to a larger area.

When the primary runner diameter is known, the sum of the areas of the multiple connecting runners must be equal or smaller in area than the preceding runner. When working back from the part, some designers size the final runner channel size (that runner which feeds the gate) to equal the thickest wall section in the part. Each runner intersection then is a function of the area of that runner times the number of connecting runners, usually two. Therefore, the area of the upstream runner is always at least equal to or larger in area than the sum of the branches. Note that a

runner with one-half the area is not the same as a runner of one-half the diameter.

Formulas for calculating the area of the runner:

Full Round Runner

$$A = 0.7854 d^2$$

Trapezoidal Runner

$$A = (w_1 + w_2) h / 2$$

A = area, d = diameter, l = length,
w = width, h = height

Runner Bar Mating

Best results are obtained by designing and building the runner bars to have zero to negative contact with each other when the mold is closed. This will prevent any deformation on the parting line surfaces that could result from high clamping pressures exceeding the compressive strength of the alloy. To accomplish this, the "A" and "B" runner bars should be flush to minus .001 inch on each side of the mold. This allows the mold base and/or cavity and core inserts to receive machine clamp force, not the runner bars.

Care must be taken to understand the characteristics of the plastic being molded and clearance should be short of allowing the runner system to flash. Additionally, it is important to insure that the mating halves of the runner system are in perfect alignment, with no mismatch at the parting line, to maximize plastic flow efficiency.

Runner Bar Cooling

The runner system must never control the molding cycle. To insure proper temperature control of the runner bars, cooling channels should be placed directly into the both the "A" and "B" side inserts. The cross-drilled holes should be blocked with a plug containing an "O" ring and a straight thread plug. Due to the high thermal conductivity of the copper alloys and the tendency to thermal cycle rapidly, tapered thread systems must be avoided in the copper alloys to prevent cracking.

With the increased cooling rate of the copper alloys and proper

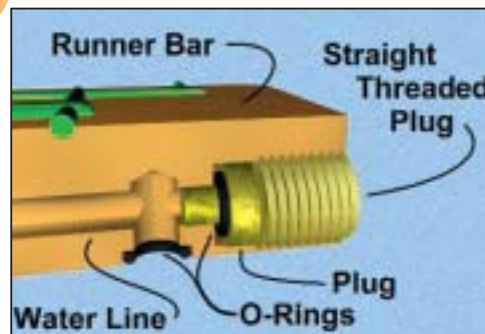


Illustration VI, Runner Bars

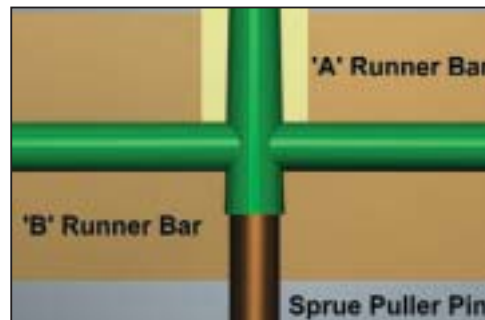


Illustration VII

cooling arrangements, larger diameter runners can be used in a mold equipped with copper alloy runner bars. Almost without exception, runner diameters one or two sizes larger can be set up quicker with the copper alloys, over traditional mold steels.

Sprue Puller

A reverse taper sprue puller, 3° for stiffer materials and 5° for flexible materials, is recommended to insure sprue removal. To rapidly cool the undercut machine, the puller directly into the runner bars or a copper alloy insert. Illustration VII gives more details.

Acknowledgements

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Disclaimer

These guidelines are a result of research at WMU and industry experience gained with the use of copper alloys in injection molding. While the information contained is deemed reliable, due to the wide variety of plastics materials, mold designs and possible molding applications available, no warranties are expressed or implied in the application of these guidelines.

Contact Information

Information regarding copper alloys for molds and molding is available from the Copper Development Association, 1-800-232-3282.