CHAPTER 5

Placing Sprues

Overview

Sprues are passageways through which metal enters a mold. A *founder*, one who usually pours cast iron, brass, or bronze, may use the term gates to refer to the same openings. The precise term may not be important, but the precise location of each sprue is important for quality casting.

Jewelry investment becomes porous during burnout and thus does not need vents.

Whenever molten metal enters a mold, it must displace air or gases trapped in the mold cavity. If the mold is made of an impermeable material such as metal or clay, passageways must be created for the gases to escape. These openings are called vents. The term riser is sometimes used to denote another type of cavity purposely placed within a mold. Most jewelers and dental technicians use investment for making the mold, which becomes porous during burnout and thus does not need vents. However, to produce quality castings using investment molds, the caster must understand the reasoning behind the correct placement of gates, vents, sprues, and risers.

Figure 5.1 represents a mold cavity surrounded by

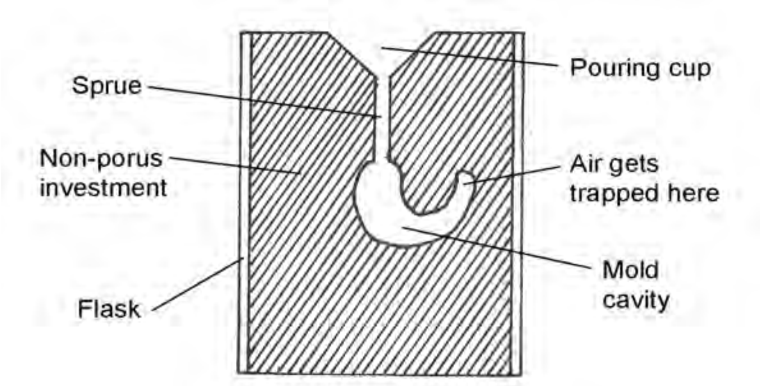


Figure 5.1
Cross-section of a mold surrounded by an impermeable block of investment

an impermeable block of investment. If one simply pours metal into the pouring cup, the metal will soon plug up the gate or sprue and trapped gases will prevent the metal from completely filling the mold. On the other hand, if a vent is added as shown in Figure 5.2, the gases within the mold are no longer trapped, and the mold can fill completely.

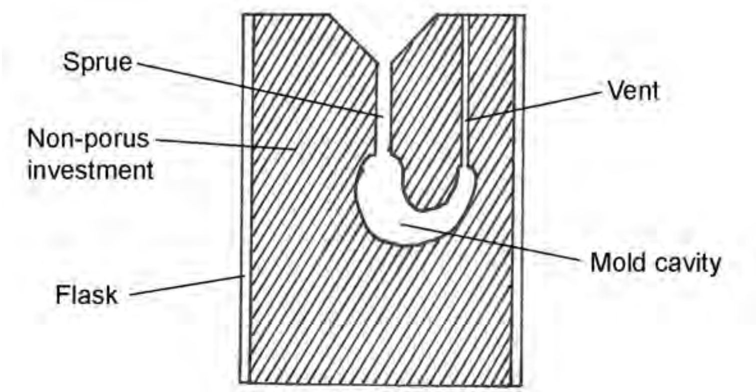


Figure 5.2
Cross-section of a flask with a vent added to permit gases to escape from mold cavity

Sculptors often use the "bottom feed" that includes a long sprue to the bottom of the mold, while several vents permit air and gases to escape from the top of the mold. The long descending sprue allows the weight of the column of metal to apply pressure that helps fill the mold completely.

Jewelers and dental technicians generally use different approaches from sculptors, because investments used for jewelry or dental work are designed to become porous during burnout. The pores are small and do not affect the surface finish of the casting; however, they are large enough to permit gases to be displaced from the cavity, especially if extra force is used to drive the metal into the mold cavity.

Metal must be forced into a mold to expel gases

Centrifugal casting or compressed air casting causes metal to be injected into the mold cavity with sufficient force to expel the trapped gases from the mold through the porous investment. Steam casting uses the pressure caused by the expansion of water into steam to force the metal into the mold, and thus force the gases out of the mold. Vacuum-assisted casting involves using a vacuum pump to remove the gas from the mold cavity so that ordinary atmospheric pressure can force metal into the mold. It is the same physical principle that allows us to suck on a straw and have atmospheric pressure force fluid up the straw. We often think that the vacuum pump is sucking the metal into the mold. However, it is more technically correct to realize that an atmospheric pressure of about 15 pounds per square inch is pressing on the metal in the pour cup, and this forces the liquid metal into the cavity after the vacuum pump removes the trapped gas and creates a vacuum.

Controlled shrinkage

There are other factors to consider in the placement of sprues besides the escape of gases from the mold. Most metals shrink as they cool. However, it is not desirable for the casting to end up smaller than the mold. If the cast object starts to shrink and no molten metal is available to continue filling the mold, shrinkage imperfections, called porosities, will form. The sprue must be designed and attached in such a way as to permit additional metal from the pouring cup or other reservoirs to enter the mold during the cooling process. This is why jewelers and dental technicians always must calculate the amount of metal to be sufficient to form a button in the bottom of the pour cup.

Controlling shrinkage is probably the single most important concept … to produce quality castings.

Other methods are used to produce the same result. Founders may add risers that store additional molten metal to supply the shrinking metal in the mold cavity. Risers may be particularly important if an unusually shaped object does not permit sprues to be attached to all of the heavier masses of the object.

Controlling shrinkage is probably the single most important concept that must be understood in order to produce quality castings. Metal alloys for casting do not solidify at a specific temperature as do pure metals such as copper or 24-karat gold. Instead, metal alloys "freeze," or solidify, over a range of temperatures, and this progressive solidification affects the size a sprue should be and where sprues should be placed on a wax model. Because the concept of progressive freezing and the effect on sprue placement is sometimes difficult to understand, some further illustrations may help.

Assume that a ring to be cast consists of a massive head attached to a thin shank. Before investing, a wax sprue must be connected to the wax model to form a passageway for metal to enter the mold. If the sprue were attached to the shank of the ring, as shown in Figure 5.3, the metal would freeze in the

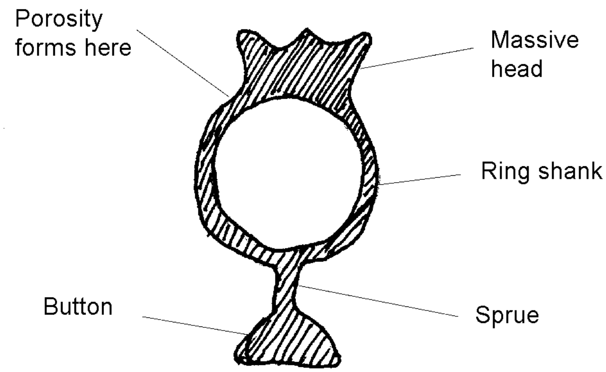


Figure 5.3
Ring with massive head showing porosity that develops from improper sprueing

sprue and narrow section of the mold before the larger mass solidifies. Frozen metal in the sprue and narrow part of the object would prevent metal from entering the more massive part of the mold cavity and shrinkage porosity probably would result near the location where the head is attached to the shank. This is because the shrinking mass tries to draw metal into the large mass from the area near the already solidified sprue. Because there is insufficient metal to fill the large mass, the resulting shrinkage leaves a lot of little pits in the shank and perhaps a larger cavity in the center of the large mass.

Sprues should always be attached to the more massive parts of the model. Sprues should always be large enough to freeze after the segment of the object to which the sprue is attached. More than one sprue may be necessary if there are multiple masses separated by thinner regions. This permits molten metal to be drawn from the button as the casting hardens progressively. Because the button is the last mass to freeze, shrinkage porosity is limited to the button or along the sprue attached to the button.

Rules for attaching sprues

As a general rule: *Sprues should be attached to the most massive elements of a model and each sprue should be of sufficient diameter to not freeze before the object freezes.*

As a second general rule: *Where there are multiple massive elements in the model, a sprue should be attached to each major mass.*

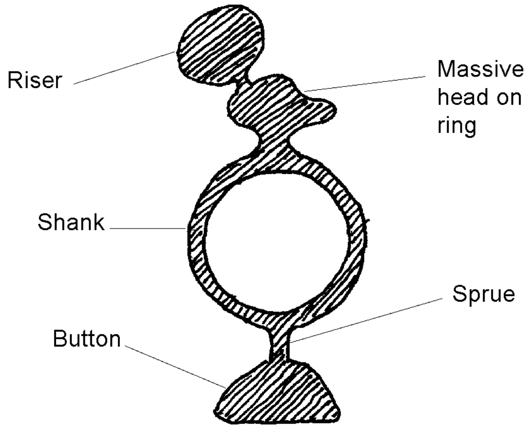
The third general rule is a result of the first rule: *The cross-sectional area of a sprue should be greater than the cross-sectional area of the mass to which it is attached.* Of course, this is to allow the metal in the sprue to remain molten to supply additional metal to shrinking metal in the cooling cast object.

Where the surface contours of the model are complex, be sure to attach the sprue to a convex surface because it is generally easier to cut off the sprue and finish up a surface that is convex than one that is concave.

Risers are sometimes attached to models when the shape of the object makes it inconvenient to have a sprue attached to each major mass. The riser is a reservoir to supply molten metal to the cooling object such as shown in Figure 5.4. While risers are more commonly seen in bronze statuary casting, the same approach could be used to prevent shrinkage porosity on some complex jewelry castings.

Figure 5.5 shows special sprues designed for steam casting which will be described in more detail later.

Figure 5.4
Illustration showing how a riser can be used to supply metal to a massive ring head to prevent shrinkage porosity



The small sprues enter a ball of wax and a larger sprue that is attached to the model. The total cross-sectional area of the three small sprues should equal the cross-sectional area of the large sprue, so that a sufficient metal flow can be achieved. Because the small sprues will freeze before the large sprue, a ball of wax is included as shown to form a metal mass that will supply molten metal to the cooling object when the casting is made. It functions as a riser. The sprue between the wax ball (riser) and the model should be large enough and only about 1/8 inch long.

Figure 5.5
Special sprues for steam casting with balls on the sprue that function as risers

Finally, as a precaution, sprues are often made with a wax with a lower melting point than the rest of the wax model. This allows the sprue to melt first during wax elimination or burnout and prevents any possible pressure buildup that could result if the model were to melt before the sprue. For convenience, many casters do not take this precaution and obtain perfectly satisfactory results.

Welding sprues to models

Sprues can be attached to a model simply by heating the sprue and pressing it against the model. Such a joint will not be very strong but additional heating could strengthen it. A better approach would be to add wax to the joint with a heated tool as described earlier.

Little wax fillets as shown in Figure 5.6 should be

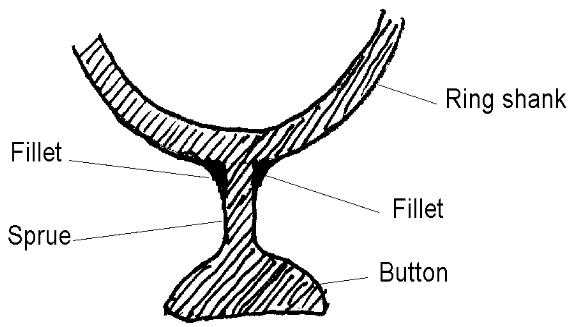


Figure 5.6
Wax fillets are added to the junctions between sprue and model to prevent turbulence in flowing metal during casting.

added to cause a smooth transition between the sprue and the object. A *fillet* is a rounding of an internal angle to avoid sharp corners that cause turbulence in the metal flowing into a model during casting. The turbulence may result in improper solidification and casting imperfections. Fillets should always be added to the junction between sprues and models and between sprue segments so that no sharp or abrupt junctions are present.

Sticky wax is a special wax with a low melting point that readily sticks to other waxes. It is available in rods or chunks, and in small tins. Sticky wax may be used to attach sprues to models. Because it is often convenient to use regular modeling wax for attaching sprues, a common use for sticky wax is to attach many models to the main trunk sprue when casting many models using a tree.

Take a heated tool, or heat a re-shaped dental probe in an alcohol flame. Hold the model and sprue near each other so that both pieces may be heated simultaneously with the tool. When both surfaces have melted, press together and hold in place until the wax solidifies. While the sprue may be firmly attached to the ring shank at this point, the spruing operation is not complete. More wax must be flowed

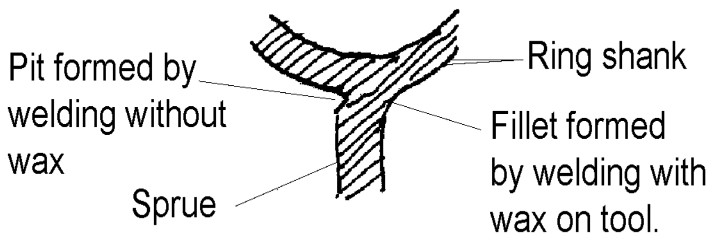


Figure 5.7
Results of welding sprue with and without wax on the welding tool

into the joint to form the fillet shown on the right side of Figure 5.7. If one simply tries to heat the junction between the sprue and model, the wax will stick to the tool and cause a cavity to form as shown on the left side. Instead, the heated probe should be pressed into sticky wax and removed to lift a drop of wax on the probe tip. Then while the drop is still fluid, touch the junction between the sprue and model, and the drop will form a neat fillet. Repeat all around the sprue so that there are no sharp corners.

Once all sprues have been attached to the model, the model and all attached sprues should be weighed carefully, and the weight should be recorded to permit later calculation of the amount of metal to be used for the casting. Of course, the sprues should be cut to approximately the final length or the wrong weight will be calculated.

Finally, using extra wax when necessary, attach the model and sprue to a sprue base as shown in Figure 5.8, and everything is ready for investing. Rubber sprue bases are available in a number of sizes to seal the end of a flask and provide a location to attach the sprue.

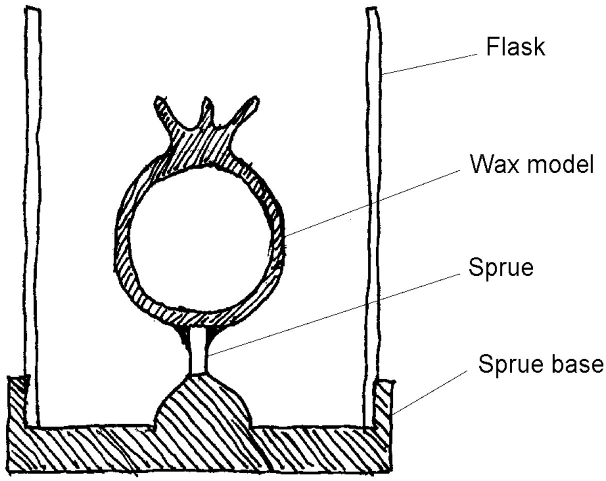


Figure 5.8
Model and sprue attached to sprue base ready for investing

Venting to increase investment porosity

While this discussion will be emphasized in the chapter on vacuum-assisted casting, the subject is brought up here because vents are part of the spruing process. Incomplete castings sometimes result when using non-perforated flasks because the investment around a model is not sufficiently porous for the trapped gases to be expelled during casting. This can result when a large model or tree containing many models is enclosed in a large flask. Examine Figure 8.2 to see how molds near the upper end of a flask will not be sufficiently evacuated by the vacuum pump during vacuum-assisted casting.

To reduce the resistance to airflow, a wax grid can

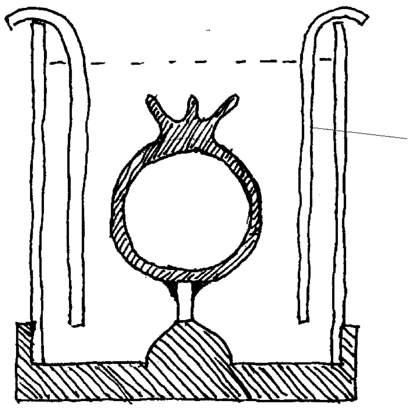


Figure 5.9
A commercial wax grid or simple rods or straws are used to produce additional air passages to reduce resistance to air flow during casting

be inserted around the perimeter of the flask. This will be eliminated during burnout, producing additional passageways for gas to be evacuated from the upper molds. The wax grid has an effect similar to adding vents to a mold; however, the grid is not directly attached to the model. The same effect can be produced, as shown in Figure 5.9, by sticking pieces of sprue wax into the investment around the model while making sure that the extra pieces of sprue wax do not project completely through the investment. Perforated flasks, which will be described later in the vacuum-casting chapter, are also used to minimize the resistance to air or gas flow when using large flasks.

Other considerations

There is some debate regarding the shape of the sprue junction with the model. I have taught that the junction should be flared. That is, a fillet of wax should be added completely around the sprue-model junction as described earlier to permit a smooth flow of metal from the sprue into the model cavity. The fillet will eliminate any sharp corner or point of investment that could break off and damage the casting. The metal will also slow as it enters the model cavity and will be less likely to erode the walls of the mold.

On the other hand, others argue that instead of flaring, the sprue should be necked down at the point where it is attached to the model. This will act as a jet and increase the velocity of the metal entering the mold cavity and possibly will reduce the likelihood of metal freezing in the sprue. In my opinion, the benefits of flaring the junction outweigh the possible benefits of increasing the velocity of the flowing metal.