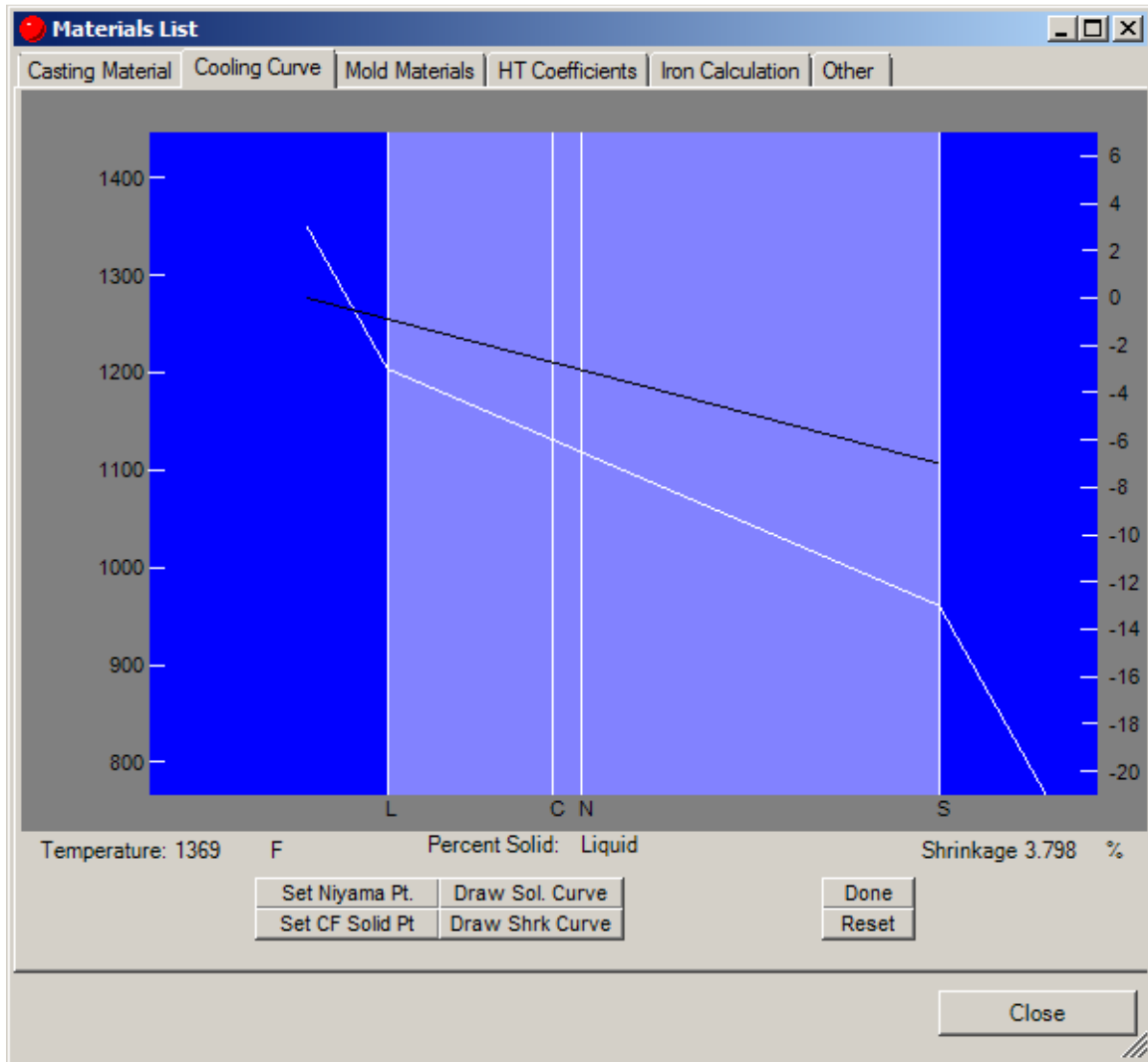# UNIT 5: Cooling Curves and Volumetric Change Curves

To see the cooling curve and the curve describing the volumetric change (shrinkage or expansion) of the selected alloy, click on Model… Materials List and then click on the Cooling Curve tab. You will see a window as follows:

The white line indicates the cooling curve (Percent Solid vs. Temperature), where temperatures are read from the scale on the left. The black line indicates the volume change (in %), read from the scale on the right. A positive value indicates expansion and a negative value indicates shrinkage.

The dark blue area on the left corresponds to the liquid state. The lighter blue area in the middle represents the transition from liquid to solid, and the dark area on the right is the solid state.

The vertical line with a C is the Critical Fraction Solid Point, and the vertical line with an N is the Niyama Point (where Temperature Gradient and Cooling Rate are calculated during a simulation). The L and S lines are the Liquidus(start of freeze) and Solidus(end of freeze) lines.

If you want to make sure that the curves are set according to the System Parameter settings, click on the Reset button.

COOLING CURVES and CRITICAL FRACTION SOLID

A **cooling curve** describes how a *single point* in a casting behaves as it cools, when its temperature is plotted against time.

We start at some initial time, with the liquid casting alloy at some initial temperature, typically the pouring temperature. This is the initial point on the curve. As the casting loses heat(superheat) to the mold, it cools down, remaining a liquid until it begins to solidify. The point that signifies the onset of solidification is called the **liquidus point**, and it shows up on our cooling curve as follows:
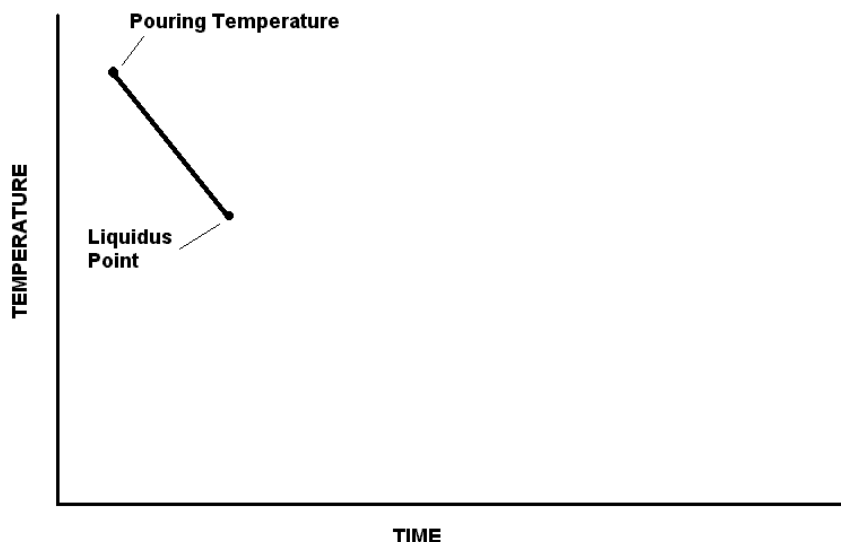

Once the alloy hits the liquidus point, it begins to solidify. At first, only a small fraction of the casting alloy is solid, but as the casting continues to lose heat, it becomes more and more solid.

During this transition from liquid to solid, the rate of cooling generally slows down. The reason for this is a quantity known as the **Latent Heat of Fusion**. As a metal solidifies, it releases heat due to the formation of the crystalline structure of the metal matrix. This release of heat prevents the metal from cooling as rapidly as it does in either the fully liquid or fully solid states.

The transition from liquid to solid appears as follows on our cooling curve:

Pouring Temperature

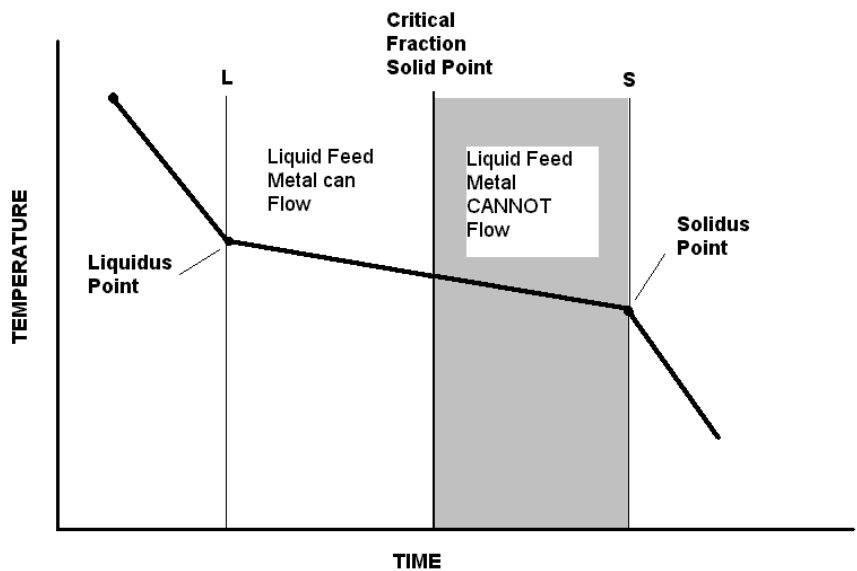**Liquidus Point**

Solidus Point

TEMPERATURE

TIME
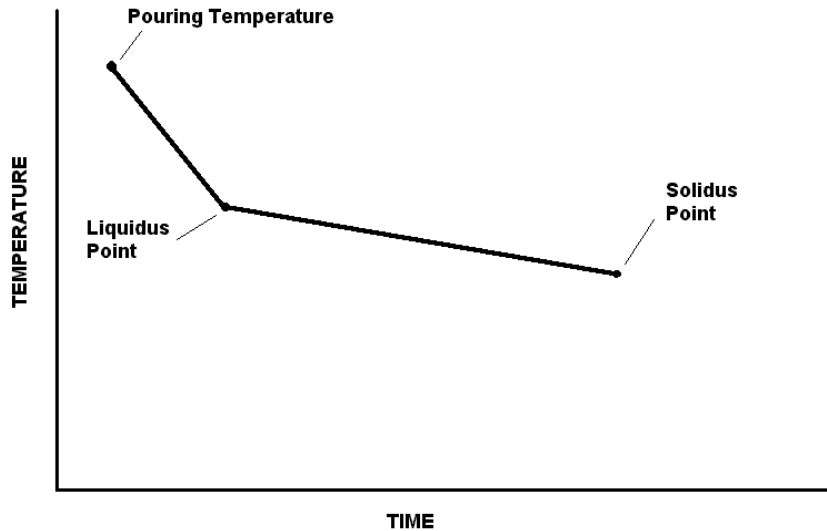
Once the alloy is completely solid, we say that it has reached the **Solidus Point**. After reaching this point, the metal begins to cool more rapidly as a solid again, because no more latent heat is being released. Thus, the cooling in the solid state shows a steeper slope on our cooling curve, as follows:

Pouring Temperature

Liquidus Point

Solidus Point

TEMPERATURE

TIME
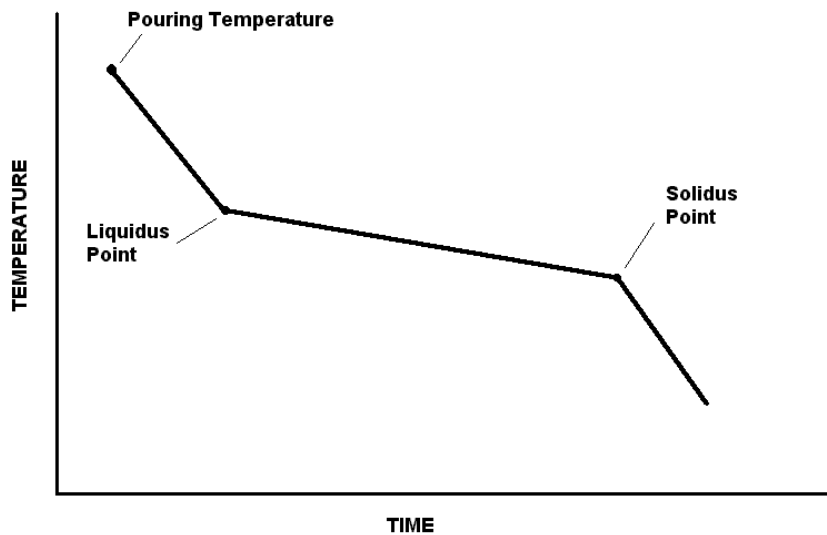
In SOLIDCast, the Liquidus Point and Solidus Point are designated by vertical lines, one with an L and one with an S at the top of the screen, as shown in the following picture:
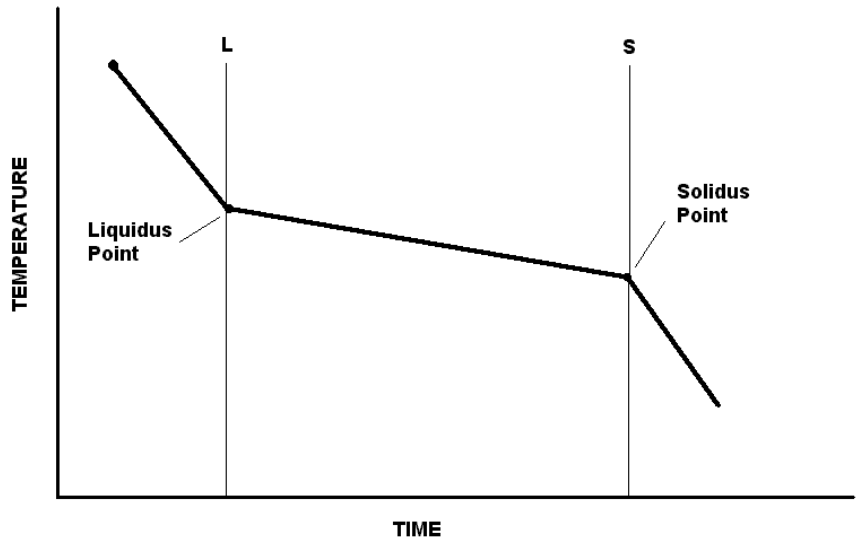
As the casting solidifies, it gradually changes from a fully liquid material to a fully solid material. We depend on the flow of liquid feed metal to feed any contraction that may be occurring, to avoid shrinkage porosity in the casting. As the metal alloy becomes more and more solid, there comes a point where the liquid feed metal can no longer flow. We call this point the **Critical Fraction Solid Point**. It is usually expressed as a percentage of full solidification, and appears on our cooling curve as shown here:

The significance of the Critical Fraction Solid Point can be appreciated by studying the following picture. Metal that is above the CFS Point is liquid enough to flow from one area of the casting to another, so if a section of the casting is solidifying and contracting, and the feeding path to that area from the riser is open (i.e., above CFS) then feed metal can be provided and no shrinkage should form.
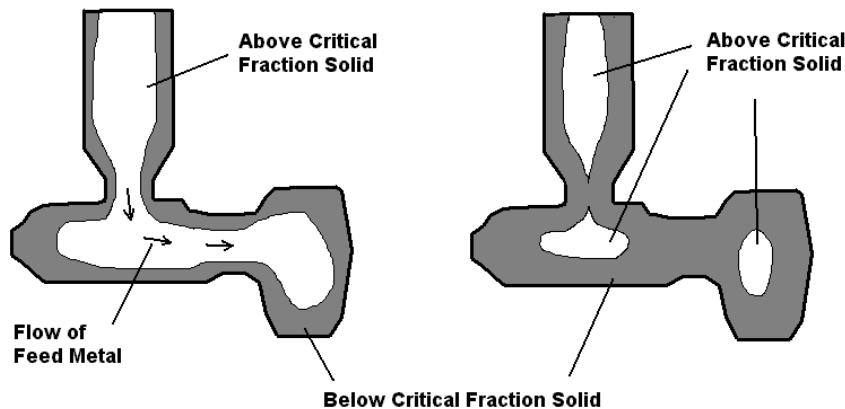
On the other hand, if the feeding path has cooled below the CFS point, no feed metal can flow and you have an isolated pocket of liquid metal in the casting. As this liquid metal cools and contracts, since there is no possibility of feeding from the riser, internal shrinkage porosity is likely to form.

In SOLIDCast, you can create a completely customized cooling or volume change curve by actually drawing with the mouse.

Suggested Starting Settings for CFS and Niyama Points

	CFS	Niyama	
Plain Carbon Steels	50%	55%	for large sand castings
Plain Carbon Steels	35%	40%	for small investment castings
Alloy Steels	45%	50%	for large sand castings
Alloy Steels	30%	35%	for small investment castings
Aluminums	20-30%	25-35%	
Copper Alloys	25-35%	30-40%	
Cast Irons	See Unit 6: Customizing Curves for Cast Irons		