

The Primary Stages in Firing Glass

When discussing the firing of glass projects, or planning a firing cycle, we think in terms of four processes: heating, forming, annealing and cooling.

Heating is the rise from room temperature to the glass's softening temperature (around 1000°F) for System 96 glass. Your kiln may be capable of covering that rise in a matter of minutes, but we almost always must go much slower to avoid thermal stress. The heating rate for projects about two glass layers (1/4-inch) thick is commonly 250-300 degrees F/hour. At that rate, the rise from 100°F to 1150°F will take over three hours.

Forming is the final stage in the heating cycle; it describes the change in shape and appearance of the glass during firing. The more total heat the glass receives during Forming, the greater its change in shape and appearance. Total heat is a function of both temperature and time.

Glass, as it gets hotter & hotter, becomes less like a solid and more like a liquid. It progresses from its cold, solid state to a soft and malleable one. Hotter still, it's surfaces become tacky, then gummy. Sharp corners and edges begin to blunt, then to soften and round. Distinct shapes become less definite, then distort and eventually deform as heat and gravity take its toll on the ever softening and increasingly viscous material. Allowed to continue, higher temperatures and more time in the superheated kiln will eventually render the glass molten, puddled and amorphous.

In the forming stage, we set the kiln time and temperature to create the amount of total heat we think will render the shape and appearance we desire for our project. "How hot for how long?" is the question we ask ourselves. The answer comes from recommended firing cycles, or from experience, or sometimes, from peeking through kiln-windows or peepholes. The chart describes four common forming choices, with descriptions of how they differ:

Forming Stage Diagrams (2 layers of glass in cross section)		
		
Tack Fuse	Contour Fuse	Full Fuse
1350° - 1370° F	1400-1450° F	1460° - 1480° F

FORMING CHART	Forming Stage	Definition	Forming Temp
	Slump	Glass softens and slumps to take the shape of a selected form or mold. Note: small molds may need higher temperatures and/or hold times.	1215° - 1250° F
	Tack Fuse	Separate glass layers are fused together with little deformation beyond softening of edges.	1350° - 1370° F
	Contour Fuse	Separate glass layers are fused together, edges are soft and rounded, project surface retains the degree of dimension desired by the artist (any degree beyond Tack but not yet Full fused).	1400° - 1450° F
	Full Fuse	Separate glass layers are completely fused into a single uniform layer, top surface is smooth and void of dimension or relief.	1460° - 1480° F



The Primary Stages in Firing Glass *continued*



Full Fuse



Contour Fuse



Tack Fuse



Similar Design/ Different Results

Left = Contour Right = Full

Annealing is the most critical stage in firing. After forming is complete, the firing cycle will reduce kiln heat quickly, and cool down to annealing temperatures. System 96® glasses anneal efficiently at about 950° F. Firing cycles will usually HOLD there for 60 minutes for projects 1/4-3/8-inch thick. And because annealing doesn't necessarily occur at a temperature point, but more accurately, within a temperature range, we usually recommend a very slow reduction of kiln temperature, from 950° to 800°F, after the long hold at 950° F.

Cooling is the final stage, during which we bring the glass back to room temperatures safely. Here, "safely" means uncracked and in one piece. We accomplish this by cooling very slowly to avoid thermal stress. Firing cycles will often end after annealing; the kiln shuts itself off and is then allowed to cool at its natural rate until the glass is safe to handle. Kilns are extremely well insulated, so this will take a few hours, which is exactly what we want. Larger, thicker or more aggressively designed projects need more tender care still, and the firing cycle's cooling rate will be set accordingly.

Remember, many a fine project has been ruined by a lack of patience – keep the kiln closed until it reaches room temperature (100°F). Even then, remember that the temperature is that of the kiln interior; the glass itself may still be much hotter.

