# Understanding Stress in Glass Fusing

We deal with four kinds of stress in kiln-forming glass. Understanding them and keeping them in mind while we design and fire our glass projects will help us avoid the DIS-stress of broken projects.

## Physical Stress

This is the easiest one: the material we are working with is Glass, and if you drop it or whack it with a hammer, it will break.

## Compatibility Stress

Materials expand when they are heated and contract when they are cooled. Glass is no exception. When we melt two glasses together to form one, they must contract uniformly when cooling, otherwise, a tension (stress) develops between them, causing fracture. We say two glasses are "fusing compatible" when we know they will contract similarly once fused together.

Think ***you're*** stressed? With enough stress, glass will eventually break.

**Strict Rule:** any glass used in the same fusing project should come from the same family of fusing-compatible glasses.

System 96® is our family of glass products specifically formulated for fusing compatibility. Every glass and accessory carrying the brand can be trusted to fit together harmoniously, free from compatibility stress. Do not mix non-System 96 glass with System 96 glass in the same project. Breakage will result.

## Thermal Stress

Again with expansion and contraction. A piece of glass has a top surface and a bottom surface. It also has a middle, or interior. Subjected to heat or chill, we want the top and the bottom and the interior to expand and contract uniformly – at the same time – or else tension is created between them (one surface pulls away from another) and you-know-what happens. This is thermal stress. Different parts of the same object are expanding or contracting dissimilarly due to the uneven application of heat or chill. The only way to prevent it is to change temperature very slowly, so that no one surface heats or cools much faster than another.

In your kitchen, a hot glass dish breaks when placed under cold running water. Here's why: the dish is uniformly hot before the top surface alone is hit with severe chill. The top contracts instantly, before the middle and bottom surfaces are affected, creating more internal tension (stress) than the material can withstand. Prevention: allow the hot dish to cool slowly for a few minutes at room temperature. This prevents the radically uneven temperature change which creates thermal stress and its subsequent damage.

You can see why glass thickness would be directly related to thermal stress sensitivity. The thicker the glass, the longer it will take for it's interior to heat (or cool). The exterior surfaces must be prevented from heating (or cooling) too fast and "outrunning" the interior, creating thermal stress. This is accomplished by controlling the rate of temperature change in the kiln.

# Understanding Stress in Glass Fusing *continued*

So, in glass kiln-forming, we heat the kiln very slowly and cool the kiln very slowly. Just how slowly depends largely on the thickness of the project(s) being fired. We fire according to the thickest project in the kiln, or the thickest part of our project. And we don't open the kiln while the glass is still hot.

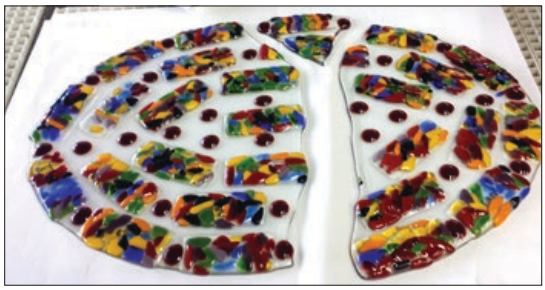
### Annealing Stress

Annealing is the process of cooling hot glass at a slow, controlled rate, to relieve internal stresses. Without it, glass would be weak and brittle and shatter very easily. Poor or inadequate annealing can render your project broken on the kilnshelf, or worse, leave invisible, dormant stress that can cause it to crack days, weeks or months later.

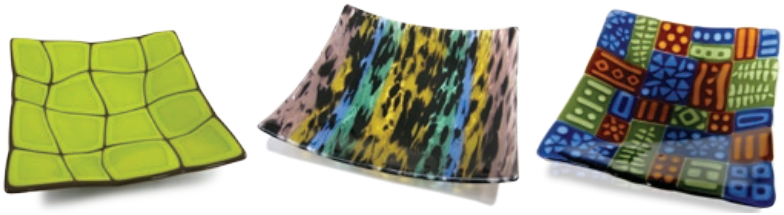
Proper annealing is simply a matter of following the firing cycle appropriate for the size and thickness of your project and adjusting as necessary based on your project. In the annealing segment of most firing cycles, the glass is held at a given temperature for a specified period of time (about 950ºF for System 96 glasses). Firing cycles for System 96 glasses are available on the System 96 website.

### Thick-Thin Design Stress

A design that varies significantly in thickness — such as the example shown at right —is a likely candidate for breakage. The piece was designed as a way to have young kids engage in creating a fused glass project. Each child made one of the rectangles consisting of colored glass on a Clear Base (2-layers thick). These were then arranged on a single-layer Clear Base. Stress resulted when the thin areas in the Base contracted while the thick areas of the children's designs were spreading. The net result is that the glass was moving in different directions simultaneously creating enough stress to cause it to break. The most stable designs are those that have approximately the same amount of glass evenly distributed on two or more layers.



*Example of Thick-Thin Design stress*



*Examples of very stable designs: Retro Warp, Sprited Colors Dish and Color Tint are all available as Project Guides.*

### Summary

Stress is something we want to avoid! Keys to success:

- Stay with one family of factory-tested fusing compatible glasses
- Follow general volume control guidelines in your design
- Don't rush the heating or cooling phases of firing
- Adjust your firing schedules to accommodate the largest, thickest, most complex project in the kiln
- Anneal fully
- Wait patiently for your kiln to reach room temperature before opening the lid