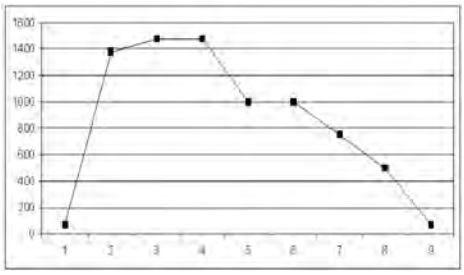
The following guidelines just scratch the surface of the knowledge base associated with firing glass. We highly suggest you take a firing class from your local distributor. If classes are not available in your area, there are numerous books available on the subject that can be found at bookstores and on the internet.

What is a Firing Program?

Glass is very sensitive to changes in temperature below 1000 °F. If it is heated or cooled too quickly through certain temperature ranges it creates stress within the glass which can cause breakage. Firing programs are used to control these temperature rates and limit the amount of stress created within the glass as well as create the desired effect on the glass.



A firing program is composed of one or more firing segments that dictate the heating or cooling rate throughout the program. Each one of the lines in the chart represents a segment or hold time within a segment and the slope of the line represents the rate of firing. A firing program is either entered into a kiln controller or on kilns without controllers it is replicated by turning up and down temperature switches.

Type of Glass

The art of firing glass has been around for centuries however, comparatively speaking, it has only been recently that companies have begun manufacturing glass specifically designed to fuse together. Glass, like most everything on earth, expands when exposed to heat and contracts when it is cooled. It expands at a measurable rate, known as the COE, or coefficient of expansion, and as it becomes liquid it flows at different rates which is referred to as it's viscosity level.

These variables and a host of others must be carefully managed to create glass that can be fused together without crazing, cracking, warping, or breaking. Always consult with your supplier of glass to determine if the glass you wish to fuse is compatible.

Heatwork

Heatwork is a term used to describe the relationship of time and temperature and their combined effects on glass. To a certain extent the two are inversely related. This means that the higher the temperature the less time is needed to create the same effect and likewise, the lower the temperature the more time is needed.

This concept becomes most useful at the "Working" temperature range of glass. This is the temperature range where the glass is fused, slumped or sagged. Most fusing glass will fuse between 1450 °F and 1480°F. It is possible to get the same results (or the same amount of heatwork), by bringing the kiln to 1450 °F and holding it at that temperature for 30 minutes as you would by bringing the kiln to 1480 °F and holding it for only 10 minutes. There may be other factors that make you choose one working temperature over the other such as the thickness of the project.

Size and Mass

The size of the piece is one of the most influential factors for creating a firing program. One of the keys to successful heatwork is having the entire piece go through critical temperature ranges at the same moment. When a piece is thick it takes longer for the center to heat up than it does the outside of the piece. When it is a large diameter, slight differences in temperature throughout the chamber of the kiln can cause the piece to expand at different rates.

The key to firing larger and thicker pieces is to slow the firing rates through critical temperature ranges. Determining how slow is often a trial and error proposition therefore it is best to start with a conservatively slow program. More projects are ruined by going too fast than too slow.

Critical Temperature Ranges

A **"Critical Temperature Range"** is any temperature or temperature range in the firing cycle that has a high level of potential for limiting the success of the project. Limited success can be expressed as over-fired, underfired, breakage, devitrification, or bubbles just to name a few. It can be argued that there are numerous critical temperature ranges. To keep things simple we are going to discuss the primary four: Heating Range, Process Range, Pre-Annealing Cooling Range, and Annealing Range.

Heating Range

The Heating Range goes from room temperature to the first set of data in the Process Range. The only concern during this range is heating the pieces too fast without adding steps to the program. Steps are hold periods at designated temperatures that allow the piece to balance out during the firing. Small pieces can normally be heated as fast as 800 F./Hr. as long as steps are added. With larger pieces you will want to slow the rate and possibly add additional steps depending on the size of the piece.

Process Range

The Process Range is the temperature range where the material begins to visibly change. It is this stage that determines the final shape of the piece. It is often a good idea to add a pre- Process Range segment to slow the kiln down before entering the Process Range. If the kiln is firing too fast into the process range it is possible to overshoot your goal temperature.

During the Process Range temperatures and hold times are key. If you are unsure of the desired peak temperature you may want to start on the low end of the range with a longer soak. This will help insure that thicker pieces receive the proper heatwork throughout the entire piece.

Pre-Annealing Cooling Range

After the process range is through, it is desirable to cool the piece quickly for several reasons. The first reason is to stop the heatwork. This is especially important on a project such as a less then 100% fuse or a drop mold.

The second reason is that an undesirable reaction known as devitrification can occur during this cooling period if the kiln is cooled to slow. Devitrification is a scummy white crystallization on the glass surface that is difficult if not impossible to remove. Be sure to slow down the cooling before you enter the Annealing Range.

Opening the kiln lid to increase the rate of cooling, while practiced, is not always recommended. On certain models the thermocouple is in the rear of the kiln and the temperature from front to back can vary greatly causing part of the piece to enter the annealing phase before the part in the rear.

Annealing Range

The final critical range is the Annealing Range. Every piece of glass has an annealing point, this is a point in the cooling cycle where the molecules in the glass realign themselves into a solid and stable form. It is very difficult to know exactly where that specific point will be, so during this period it is critical to fire the kiln at a slower rate throughout the range.

Our pre- programmed firing schedules in the Glass Fire Mode anneal from 1000 °F to 750 °F which should be adequate for most stained glass. By incorporating such a broad range the risk of breakage is limited. Be sure to keep the lid or door of the kiln closed until the kiln reaches room temperature. Opening the lid too soon can cause pieces to break.

Firing Processes

There are many different processes or techniques used for manipulating glass with heat inside a kiln. In this manual we will focus on two, Fusing and Slumping. Other techniques include but are not limited to Drop Molds, Pate de Verre, Casting, Painting, and Combing. For more information on using your kiln with these techniques please consult your glass supplier.

Fusing

Fusing is the process of joining 2 or more pieces of glass together by the application of heat. This glass can be in the form of sheets, stringers, frit or a host of other forms. There are different degrees of fusing. You may want to fuse glass so it sticks to another piece of glass without deforming. This is known as a "Fuse to Stick". If you were to apply more heatwork to the piece the edges would round slightly. This is known as a "Tack Fuse". A "Full Fuse" is created when the pieces have melted completely together and are 1/4" thick. A "Texture Fuse" is any point in-between a "Fuse to Stick" and a "Full Fuse".

There is a temperature range at which glass can be fused. The point at which it begins to fuse is influenced by the rate at which the temperature is climbing when it reaches the fusing range. Most fusing glass will begin to fuse between 1400 °F and 1480 °F. Remember that heatwork is a function of time and temperature.

Starting with glass that has been determined to be compatible is only the beginning to a successful fusing or slumping project. The temperature and various temperature rates in a firing program must be designed to the specific needs of the project you are creating. The size, thickness, shape, and type of glass all must be considered when designing a firing program.

The Glass Fire programs take advantage of a preprocess cycle that allow the pieces to slowly enter the working temperature of the process phase. This helps the glass achieve greater heat uniformity and allows air bubbles between layers a chance to escape before they are sealed between the layers. As a precaution you may want to provide a dam or barrier around the glass when fusing more than 2 layers. With more than 2 layers, the glass will spread until it finds a level of 1/4" and could possibly flow into another piece or off the shelf.

Slumping

Slumping can be defined as the controlled bending of glass under the influence of heat and gravity within a kiln. This is generally done over or into a mold. Molds can be made out of a variety of different materials and can be found at art glass supply businesses.

When slumping, it is necessary to take into account the shape of the mold, the thickness of the piece, and the degree of heatwork desired. The GlassFire mode may be used when the mold is simple and shallow, however, deeper more complex molds may require a custom designed firing program and close supervision.

Gravity plays a very important role in slumping, especially slumping over a mold as opposed to into a mold. If the shape of the mold dictates that the unbent glass is largely unsupported, the weight of the unsupported glass will pull the glass over the mold quicker than if only a small portion is unsupported.

A thin piece of glass will bend quicker than a thick piece of glass. A thick piece of glass requires more Hold time in the final segment of the process phase.

In some cases the artist may want to control the amount of bend by visually inspecting the kiln. Be sure to follow the safety guidelines listed in this manual when using this technique. When the proper amount of heatwork is reached the artist can press the **ANNEAL NOW** key to advance the kiln into the cooling cycle. Slumping projects that receive too much heatwork can take on unwanted texture from the mold or in extreme cases fuse to a puddle.

If you find yourself in this section of the manual please remember that Skutt and your Skutt Kiln distributor are here to help you as long as you own your kiln. If you are unable to determine the problem, or just need to order parts, please let us know.

Kiln Will Not Start

If there is no display, check to see if the kiln is plugged in and the breaker has not tripped. If there is a display, double check your programming instructions. The kiln must be in Idle Mode to start.

Kiln Will Not Reach Temperature

Make sure the kiln is connected to the proper voltage. After extended use the elements in the kiln wear out and eventually need to be replaced. Look for possible breaks in an element. Elements can break if they are contaminated by bits of glass. If an element is out, it will not glow. Program the kiln to at least 500 °F and look in the kiln to see if any individual elements are out.

Kilns cycle power on and off through relays. If a relay goes out, 1 or more elements in the kiln will not function. Look at the wiring diagram to determine if elements not glowing are connected to the same relay. If they are, chances are that relay needs to be replaced. Skutt recommends to replace all relays at the same time.

Kiln Overfires or Underfires

The thermocouple, which looks like a metal tube protruding into the kiln chamber, measures the temperature in the kiln chamber. As thermocouples begin to wear out, they slowly drift in the direction of an overfire. If you have noticed that your projects have become increasingly overfired, it may be time to change your thermocouple. If you are comparing your results to how they fire in other kilns, it is important to remember that every kiln fires slightly different and it may be necessary to adjust your firing programs.

Kiln Will Not Turn Off

Kilns cycle power on and off through relays. If a relay sticks on, 1 or more elements in the kiln will stay on. Skutt kilns are specifically designed to split the power between 2 or more relays, therefore, the likelihood of a severe over fire is extremely unlikely. Look at the wiring diagram to determine if elements glowing are connected to the same relay. If they are, chances are that relay needs to be replaced. Skutt recommends to replace all relays at the same time.