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Creating a Firing Schedule

Kiln cooking glass is no more complicated then stove cooking food. Once you learn how your materials respond to heat, you'll know how to cook anything you want. If you can learn to cook a pot roast, you can learn to fuse and slump glass.

Glass responds to heat in specific ways at specific temperature. Once you learn the basic science of what happens, you can create a firing schedule that applies for any glass to produce anything you want.

How it works
If you heat glass it gets soft. The more you heat it, the softer it gets. Anything that provides enough heat can be used to soften glass. Glass responds to heat in the flame of a torch exactly the same way it does in a kiln.

Different Glass = Different Temperature
How glass responds to heat depends on its composition but you can rely on a specific make of glass to always respond at the same temperatures. You can also rely on all makes of glass to respond to heat in the same way – but at different temperatures

Time + Temperature = Heatwork
It's not just the time and not just the temperature that determines what happens to the glass but a combination of both. However, it isn't always an even combination. For some things, glass responds quicker to time while for others it responds quicker to temperature.

Lower is slower
As a general guideline, you can assume that higher COE glass responds to heat at lower temperature. High COE cooks quicker, low COE cooks slower. A specific effect produced on Spectrum COE 96 would require an extra 20° F to produce the same effect on Bullseye COE 90 and and extra 50° F on clear float COE 82.

Thick ain't quick
To avoid thermal shock, the glass must be heated slowly enough the surface of the glass isn't a lot different temperature then the inside.

It takes time to heat the glass all the way through (just like it takes time to heat a pot roast all the way through). The thicker the glass (or the pot roast) the longer it takes to heat up.

Size does matter
How fast a piece of glass will slump depends directly on it's size. The wider the span, the faster it will respond to gravity and bend downward. Short spans take a lot longer to slump then long spans.

All kilns are born equal
Different makes of glass slump and fuse at different temperatures but the same makes of glass will respond to heat in the identical way at the identical temperature in all kilns. Any variance between kilns is caused by difference in temperature readings in those kilns. It's not the kiln that's different, and it's not the temperature that's different. It's what temperature is being displayed. Not all kilns read accurately. Adapting any kiln to any fixed firing schedule is as simple as learning how off true your kiln temperature readings are and compensating for the error margin.

Low and slow or fast and furious
Driving slow is safer then driving fast. The same applies to kiln firing glass. Ramping slower and holding longer at lower temperatures is safer. But there are times in both driving and kilnforming that you need to go faster. If you hit a slippery spot while driving and the cars starts to skid, hitting the brakes will cause you to lose control. The correct response is to hit the gas and drive out of the skid. There are times when the same applies for kilnforming. Speeding up sometimes prevents accidents.

Short span slumps – If you want to slump an unusually short span (as for creating weaving strips) it can take several hours (even days) for the glass to sag at the temperature you usually use to slump. To produce short slumps in a reasonable time, you'll have to go up to a much higher temperature then you usually would.

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Fire-polishing – If you want to fire-polish glass without it sagging, low and slow is the wrong way. You want to ramp as quickly as can be done with causing thermal shock up to fire-polish temperature, stay just long enough to produce the fire-polish, then ramp down as quickly as you can before the glass sags. This "fast and furious" fire polish method works on the identical principal as fire-walking. If you place a bare feet on glowing hot coals, you will burn that foot - but if you don't walk flat-footed and keep your feet constantly moving across those coals, you won't burn them. If you place your hand into boiling hot water, you WILL burn that hand - but if you have an egg bubbling away in boiling water, you can reach in, grab it, and pull it out without burning your hand - if you do it quick enough.

Devitrification - This happens between 1100°F and 1200°F (595C & 650C) The slower the glass cools through this temperature range, the greater the likelihood it will develop devitrification. That's why firing schedules invariably call for the glass to be cooled as fast as possible from the top performance temperance temperature down to the annealing temperature.

Annealing - Heating and cooling the glass during firing weakens it. Annealing rebuilds its strength. If you don't adequately anneal, the glass will be needlessly fragile and can even blow apart.

Keep it simple – If you create systems you can remember, you're a lot less likely to make mistakes. Establish fixed ramp speeds you can remember that depend only on the thickness of the glass. You can do your own experiments to see what ramp speeds, performance temperatures, and hold times work best for you. Here's some rounded off numbers I've consistently found work well for "System 96" COE 96 glass. For Bullseye COE 90 glass use the same speeds but add 2°F (7°C) to performance temperatures. For clear float or architectural glass, use the same ramp speeds but add 50°F (10°C) to all performance temperatures.

Ramp Speed up and down is determined by glass thickness.

Single layer	*500F dph (260C)*
Double layer	*400F dph (200C)*
Triple layer	*300F dph (150C)*

Thermal shock – it's difference not degree. If the heat is increased or decreased so rapidly it causes the surface of the glass to be a significantly temperature then the core of the glass, the resulting difference can cause the glass to crack. Any ramp speed that fails to cause thermal shock is safe.

Distortion
Glass softened by heat will respond to gravity and sag. A slow ramp speed is more likely to cause this than a quick ramp speed. Distortion is most frequently caused by glass exercising its wish to become ¼" (3mm) thick. If heated to full fuse temperature, the glass will get its wish.

Equalization Soak
The first segment in a firing schedule usually has a soak at near 1000°F (535C) to be sure the glass has become uniformly that temperature. Because thermal shock doesn't happen after that temperature, equalizing temperature at 1000°F (535C) allows you to ramp much faster up to performance temperature.

Performance Temperature is the temperature at which the glass performs the way you want. Different temperatures produce different performance.

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FIRING SCHEDULE ELEMENTS:

1. Ramp up (speed of temperature increase). This depends on the thickness of glass to prevent thermal shock cracks. When firing scraps, it's safe to ramp very fast. The glass is already broken so there's no reason to worry about it cracking. 600F (315C) dph (degrees per hour) would be conservative. You could ramp as fast as 800F dph (425C)

2. Equalization hold. Often done at 1000F (535C) to ensure glass is heated uniformly. Important with large pieces, but not needed with scraps. Equalization could be completely eliminated.

3. Ramp to performance. After equalization, it's possible to speed up ramp speed. Irrelevant if you skip equalization hold.

4. Performance hold. Glass responds to heat in different ways at different temperature. Each make of glass is different with higher COE glass usually melting at lower temperatures. COE 104 glass should full fuse at 1425F (775C)

5. Ramp to anneal. This is done as fast as possible to move the glass temperature quickly down through the zone likely to cause devitrification.

6. Anneal hold The glass is held at a set temperature to allow it to rebuild strength. How long depends on glass thickness.

7. Stain point hold. The glass is held at the strain point to release any residual stress in the glass.

8. Finished ramp down. Like the ramp up, the rate the glass cools will determine whether or not it cracks from thermal shock. For most projects, the down ramp will match the up ramp - but ramping up to melt scraps can be much faster then ramping down a finished project.