Understanding Float Glass Firing Schedules

There is a lot of misunderstanding about firing schedules for float glass. Most of that confusion comes from the assumption firing schedules will be very similar to those used for art glass. That confusion is compounded by a lot of misinformation being distributed that perpetuates myths about float glass.

We should first talk about how float glass is different than art glass. Let's start with the most common myth – the assumption you can use the same firing schedules for float you use for art glass by just changing the top performance temperature by a fixed amount. You can use the same firing schedules used for COE 96 glass for COE 90° by just firing to 20°F higher but claiming you can do the same with float glass is wrong. There is no fixed temperature difference that will work. Let's compare the differences between COE 96 fusing glass and float.

	COE 96	Float	Difference
DRAPE	1200°F	1200°F.	**Same**
SLUMP	1250°F	1250°F.	**Same**
FIRE POLISH	1300°F	1350°F	+ **50°F**
TACK FUSE	1350°F	1425°F	+ **75°F**
CONTOUR FUSE	1400°F	1500°F	+ **100°F**
FULL FUSE	1450°F	1575°F	+ **175°F**
FULL FLOW	1600°F	1800°F	+ **200°F**

Float Glass Variables

If you work with float glass there are some distinct differences from art glass you must allow for.

Different Chemistry

Each glass maker has their own chemical formula for the glass they make so there can be some variance in COE and viscosity from different sources. That makes it especially difficult to create firing schedules that can be fully trusted for all float glass projects. What worked for glass from one glass maker might not produce identical results for glass from a different glass maker.

Different Thickness

With art glass if you want a 6m thick project you must fuse 2 layers of glass together. With float glass you can instead just use 6mm thick glass.

Different Viscosity

Float is much stiffer than art glass so is slower to soften and requires higher temperatures to produce the same effects as art glass.

Tin Side

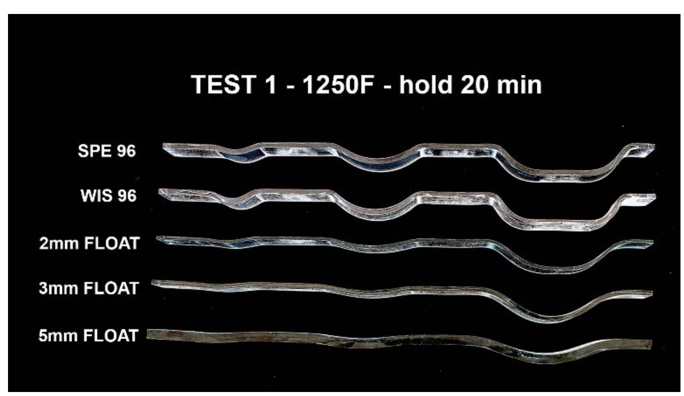
With art glass it makes no difference which side of the glass faces up unless you're using textured glass and want to retain the texture. Float is smooth on both sides but it can make a huge difference whether you fire it in your kiln air side up or tin side up.

Allowances

These variables make it more difficult to get reliably predicable results with float glass. You will have to adapt to these variables as best you can. The best way to minimize variables is to buy large sheets (or better still, full crates) so you know all the glass you're working with was part of the same production lot.

Slump Resistance

Float glass is stiffer than art glass so it resists sagging more than art glass. Sometimes it will require longer holds or higher temperature to slump. That is especially a concern with thicker glass.



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This photo shows the results of firing different glass in the same firing with the same slump spans. You can see how the float glass slumped much less than the Spectrum or Wissmach art glass.

Ramp Speed

You can use faster ramp speeds for float glass than would be safe for art glass. Like art glass, float glass will crack if heated or cooled too fast but it will tolerate faster temperature change without cracking. Float is especially susceptible to devitrification. Ramping faster is preferred because faster ramp speeds reduce the likelihood of devitrification.

With art glass many artisans ramp intentionally slow thinking, “Better safe than sorry”. There’s no harm in ramping slow. It’s different with float glass. There is harm in ramping slow. It’s important to know with some degree of accuracy how fast is safe to ramp up and down and program firings to go as close to that safe margin as you can.

Hold Times

Holding at a set temperature at high temperatures encourages devitrification so to produce the desired results it’s better to fire float glass to a higher temperature with a short hold than to fire lower with a short hold.

Also, because float glass is much stiffer than art glass it takes longer to absorb heat. It responds better to a constant steady temperature change than to the start/stop with holds used for art glass. It’s like the difference between pushing a small car and pushing a bus. With a small car if you push for a while and let it stop for a rest, it’s not a big problem to get it moving again. It’s different with a bus. It’s much harder to get it moving once it has stopped so it’s better to be sure you keep it moving once it is in motion. Float glass fuses better when heat is applied in a steady consistency without any start and stop other than anneal.

Ramp & Hold Issues

Molten glass doesn’t flow like water but oozes more like pancake batter. Float glass is a lot stiffer than art glass so oozes a lot slower. It takes longer to move and takes longer to get it to start moving.

Think of it like pushing a car. Getting a small car to start moving is a lot easier than getting a big car to start moving. Art glass is like the small car. Easy to get moving. Float glass is like the big car. Harder to get moving.

When you program a hold in a ramp when firing art glass, it’s not too hard to get the glass to start moving again but it’s a lot harder with the much harder float glass. Once it has lost momentum, it takes a lot more heat and time to start oozing again.

For that reason, float glass responds best to firing schedules that have either very short holds or no holds at all other than to anneal. Just like pushing a car, once you get it to start moving, it’s best to keep it moving and not stopping sometimes and losing momentum.

6 mm Rule

When art glass is fired to full fuse or higher, it moves to become a uniform 6 mm thick. If you start with thicker glass, it will press down and spread out the same way pancake batter spreads out when you pour it onto a griddle. If you start with thinner glass, it will draw in to contract as it moves to become thicker. The ***6 mm Rule*** is as persistent as gravity. If you toss something into the air, gravity will make it fall back down. If you fire glass to above tack fuse temperature, it will move to become 6 mm thick. If you don’t want something to fall down, don’t throw it into the air. If you don’t want your glass to thin or thicken, don’t fire it above tack fuse temperature. Float glass responds the same way. You must allow for this in your firing schedule. Tack fuse temperature for float glass is 1425°F (775°C).

Almost all art glass is 3 mm thick. To ensure the glass becomes the required 6 mm thick, glass artisans fuse two layers of glass together. One of the advantages to working with float glass is it's available 6 mm thick. Instead of fusing two layers together, you can just start with 6 mm thick glass.

Devitrification

Float glass is especially susceptible to devitrification. This appears as a milky foggy haze on the top surface of the glass. Glass molecules heated in the kiln crystallize causing the glass to become opaque and brittle. Some artisans like the appearance of devitrification but most consider it undesirable and unattractive.

What encourages devitrification

- Firing tin side down. Firing tin side up discourages devitrification but be careful because firing tin side up can encourage tin bloom.
- Slow ramp speeds. High speed ramps allow the glass to travel quickly through the temperature range devitrification is likely to appear. The most dangerous is between 1100 & 1400°F.
- Long holds. Holding at a high temperature allows the glass time to crystallize and form devitrification.
- Coating on the glass. Anything coated on the glass will encourage devitrification.
- Dirty glass. Any dirt or contaminants on the glass will encourage devitrification.

What discourages devitrification?

- **Single firings.** Devitrification happens rarely on the first firing but almost always on the second firing. The best way to discourage it is to engineer some way to complete your project in a single kiln firing.
- **Thorough cleaning.** The cleaner the glass the less likely devitrification will happen.
- **Devitrification compounds**. If your project design requires firing tin side down, using a devitrification spray *(like Spray A or Super Spray)* will help. WARNING – some devitrification sprays contain lead or chemicals that will make your project unsafe for contact with food. Check what you're using before assuming it will be food safe.

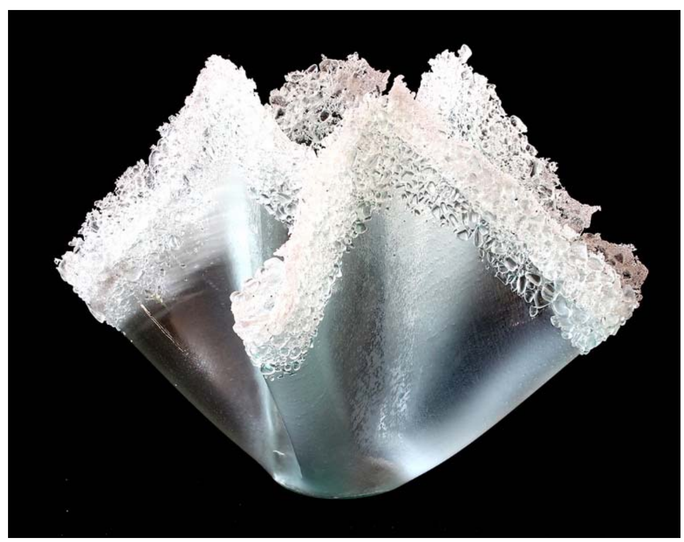
How to remove devitrification?

- **Mechanical.** You can sandblast or hand sand to remove the devitrified surface and refire to polish.
- **Overlay**. You can apply frit or glass powder to fuse over the devitrified areas.

Tin Bloom

Tin bloom appears as a white opalescent discoloration on the tin side of the glass and is often mistaken for devitrification. It has a slight metallic appearance like stretch marks and is created by the glass bending inward along the tin side. If you slump with tin side up you risk causing tin bloom. If you drape with tine side down you risk causing it.

Tin up to dodge devit.
Tin down to bypass bloom.



This glass vase exhibits tin bloom.

While many artisans dislike tin bloom, others think it's pearlescent sheen is attractive and will even intentionally induce it.

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Annealing Float Glass

Anneal temperature for float glass is 1050°F (565°C). Annealing for too long can do no harm but insufficient anneal time can result in needlessly fragile glass. Required anneal times for float glass are less than for art glass and can often be much less but most glass artisans use the same times for float as are used for art glass of same thickness.

Float Glass Compatibility

The COE of float glass can vary from 82 to 86 depending on the glass maker and even depending on different production runs from the same glass maker. Sometimes you can fuse pieces from different sheets but you can only fully trust it to be fuse compatible if you use only glass from the same original sheet. Artisans that use a lot of float glass will often buy full cases so they can expect all the glass to be from the same production run and therefore fully compatible. Those that work a lot of float glass for fusing report that more recently made glass is more likely to be compatible than older glass. That's probably because most glass makers today are using a relatively similar formula for their glass.

Fusing glass from different sheets is more likely to work than to fail but if you choose to do that you must accept the possibility the glass you use is incompatible. It's a risk. It's your choice whether or not to take the risk.

Float Glass Frit

You cannot assume frit that is sold as "float compatible" frit is assured to be fully compatible with any float glass you use but float is a lot more forgiving of a little variance so if the particles are small, close is good enough. The only time you can be assured any frit you use is fully compatible is if it's frit you made from the same sheet of glass you're planning to fuse it onto.

Fire Polish Float Glass

A fire polish schedule is to polish the surface of the glass without distorting the project being fired. The objective is to fire high enough to melt just enough of the surface to produce a shine like wet paint but not high enough, or held long enough, to do anything else. An example would be a sandblasted project that was fired to polish the frosted matt surface created by the sandblasting or a project that had been coldworked to a less than full polish.

This can be done with any glass but works especially well with float glass. Softer art glass softens quicker than float glass so is more likely to lose some shape in a fire polish. A sharp edge on art glass will soften and round a lot more than it does on float glass.

Fire polish temperature for float glass is 1400°F (760°C)

This sandblasted project was fire polished to polish the matt finish created by sandblasting.

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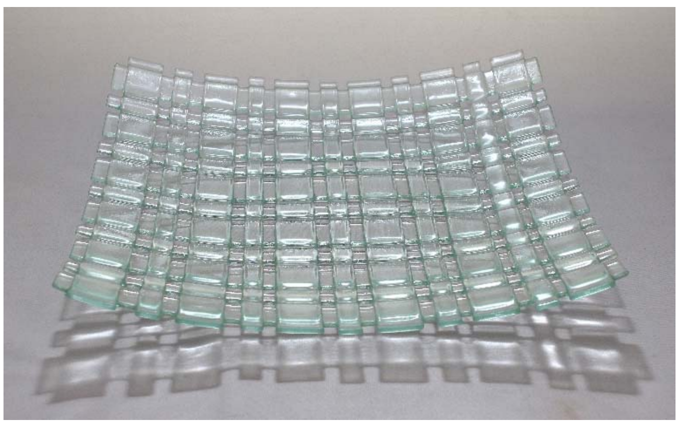
Adapting Firing Schedules

If you want to adapt a firing schedule to produce more of an effect, or less of an effect, you must change either the temperature or the time. Firing to a higher temperature will make the glass softer. Holding longer at the top temperature will allow the glass more time to respond to heat. Either adding more temperature or more time will increase the effect but will not necessarily produce the effect you want.



A lattice tray created by tack fusing strips of 3mm thick float glass at 1425°F (775°C)

A coral bowl created by full fusing 3mm thick float glass at 1550°F (843°C)

Higher temperature to make the glass softer will also make it move faster. Sometimes this is a good thing and sometimes a bad thing. Sometimes, like for a fire polish, you want the glass to move fast. For other projects higher temperature is essential

Longer hold allows the glass more time to respond to the heat so is usually a better solution for a drape or slump firing. Higher temperature makes the glass softer which will increase the amount of texture the glass adopts from anything it touches.

Firing hotter produces a much faster effect than firing longer. That is especially so with float glass that requires much higher temperature than art glass. It's not perfectly accurate but a guideline I use for more schedule changes is to assume an extra 5° temperature will increase the effect as much as 5 minute more time.

Relative Ramp Speed

If you heat glass so fast one part of the glass is a significantly different temperature than another part, the glass will suffer from thermal shock and crack. To avoid cracking the glass in your project you must increase and decrease temperature slow enough there is no great temperature difference between the surface of the glass and the core of the glass. Heat will travel through glass but will not do it quickly. How quickly you can safely increase or decrease temperature depends on how thick the glass is. Float glass can tolerate faster temperature change than art glass but it still has limit to how fast is safe.

Suggested ramp speed per hour

2mm (5/64”) 600°F (315°C)
3mm (1/8”) 550°F (288°C)
4mm (5/32”) 500°F (260°C
5mm (13/16”) 450°F (232°C)
6mm (1/4”) 400°F (205°C)
9mm (3/8”) 300°F (150°C)
12mm ((1/2”) 200°F (95°C)
18mm (3/4”) 100°F (40°C)
24mm (1”) 50°F (10°C)

Glass Campus

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This is needed ONLY at temperatures below 1000°F (540°C). Float glass, like art glass, is immune to thermal shock if temperature has been equalized through the glass to at least that. Equalizing temperature at that level will allow to increase temperature much faster if you wish. When you calculate your firing schedule you have two options:

- Apply a consistent temperature increase up to performance temperature.
- Hold at 1000F (540C) to equalize the temperature than ramp as fast as possible up to performance temperature.

Suggested hold time for float glass:

3mm 3 minutes
4mm 5
5mm 10
6mm 15
9mm 20
12mm 30
18mm 40
24mm 60

Rounding off Temperatures

To make it easier to remember temperatures, glass artisans that work in Fahrenheit have rounded off the numbers. Drape 1200, slump 1250, tack 1350, contour 1400, full 1450. When converted to Celsius, the numbers are not so rounded off so are not easy to read. I alternate between working in both F & C but because my memory sucks I don't try to remember the direct converted figures but have instead rounded them off to figures I can remember.

DRAPE 1200F = 649C use 650C
SLUMP 1250F = 675C use 675C
FIRE POLISH 1350F = 732C use 735C
TACK FUSE 1425F = 774C use 775C
CONTOUR FUSE 1500F = 816C use 815C
FULL FUSE 1575F = 857C use 860C
FULL FLOW 1600F = 871C use 870C
COMB 1700F = 927C use 925C

Using rounded off numbers will make it easier to remember the numbers which will make it less likely you make a mistake in programming a firing schedule.

Special Issues with Tempered Glass

Ramp up can be as fast as your kiln can generate heat. The little chips of glass are already broken so there's no reason to be concerned about thermal shock. The first segment of your firing schedule can be as fast as possible up to the top performance temperature.

Hold times would be the same as for float glass.

Anneal would be the same as for float glass.

Ramp down is where it is significantly different. How different depends on how high a temperature you fired it to. If you fired to full fuse, you can ramp down the same as you would for float glass. Not so if you fired to tack fuse. The chips of glass will have fused together where they touch but any air spaces between the chips will act an insulation to prevent even heat transfer through the glass pieces. That failure to transfer heat evenly will cause thermal shock cracks. To avoid cracking your project you must slow the ramp down speed to about half the speed you would use if the project was a full fuse. For example, if a safe speed for a full fused project of that thickness was 400°F (205°C) per hour, you should reduce it to 200°F (95C) per hour. Going even slower is a good practice. You were able to ramp up super fast so there's no reason you can't take your time cooling your project.

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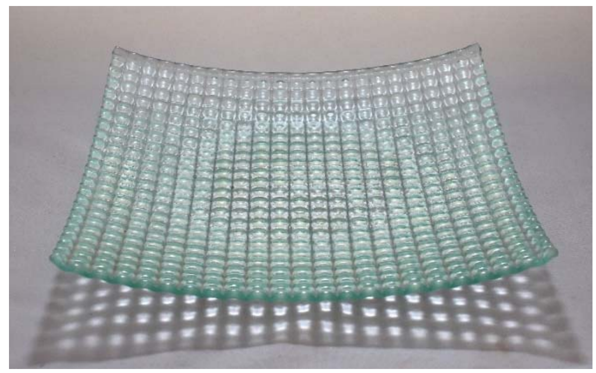
A 12 inch (30cm) diameter bowl created by tack fusing tempered glass chips onto 5mm thick float glass then slumping it into a ceramic mold. The finished projects was carefully tested to confirm there is no residual compatibility stress. It demonstrates how, although glass from different sheets is not guaranteed to be compatible, it often is.

A 12 inch (30cm) diameter bowl made by tack fusing tempered glass chips on the kiln shelf then slumping into a ceramic bowl then blue fabric dyes applied.

A glass starfish made by casting tempered glass chips in a ceramic mold.

Creating Texture in Float Glass

You can create texture in float glass the same way you do in art glass. It just takes higher temperature.



A project made by firing 6mm float glass over a mesh screen at 1425°F (775°C) to create bumps where the glass sag into the mesh openings.

A bas relief kiln sculpture project done in 12 mm thick float glass.