Glass Campus presents:

KILNFORMING KINDERGARTEN

A beginner's guide to fusing & slumping glass

by: **Dennis Brady**

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Introduction

Almost every question you ask can be accurately answered with the same simple reply. *"It depends".* It depends on the individual kiln, it depends on the kind and color of glass, it depends on the temperature it's fired at, and it depends on how long it's held at any specific temperature. It might even depend on the time of year, the lunar cycle, or maybe even what zodiac sign you were born under. It depends. Sometimes when you try something new it's a disaster, but sometimes (not often enough) it's a "happy accident". Something totally unplanned and completely unexpected happens – and it's wonderful. Whenever you've had something go wrong, just remind yourself, "There's a happy accident waiting to happen" – and remember..... there are no scraps …just unborn frit.

You WILL screw up.

Most beginners start off thinking all their projects will come out perfect. Then, when some (sometimes lots) fall far short of perfection, they begin to get discouraged. I think instructors should right at the beginning, make beginners understand that screw ups are all part of the process. I have a HUGE collection of past failures. I think I've not only made every mistake, I've invented new ways to make mistakes. When teaching, I make a point of pulling out my collection of failures to show the class, and tell them, *"You'll probably mess up a few projects, but if you want to see REAL screw ups, look at this stuff."* So don't worry about making some mistakes. Just get started. Make stuff. Most of it will be gorgeous and you'll be happy, but some (let's hope not a lot) will be a disaster. You'll screw up some stuff. That's okay. Save it for when you decide to teach.

Rule of project failure probability:

- *The probability of project failure is in direct proportion to the importance of the project.*
- *The probability of a material being available is in reverse proportion to how important that material is to completing a project.*
- *The probability of a particular color of glass being discontinued is in direct proportion to how much you like that color.*
- *The probability of your project coming out exactly the way you want it to is surprisingly good.*

Guidelines

Be patient. As much as you want to fill the kiln up each time you fire it, be careful you aren't trying to fire a mix of things together that really should be done in separate and different firings.

"Goldilocks" principle. Many of your kiln firings will be like the story of Goldilocks and the 3 bears. First the porridge was too hot, then it was too cold, and then finally it was just right. First you'll fire too much, then you'll fire too little, then finally you'll fire just right.

Allow for correction. You will make mistakes. But, if you're careful, you can keep it to mistakes that you can correct. If you fire too little, you can always fire it again to correct it. If you fire too much, your project is future frit – or a teaching tool.

The ¼ inch rule. Glass wants to be ¼" thick and if you give it enough heat and enough time, it will do it. If you fire a stack of glass ½" thick to a high enough temperature, it will spread out and become thinner. If you fire a single piece of ⅛" glass, it will pull in and become thicker. Firing a single layer of glass to full fuse temperatures will always cause it to distort. Remember - if you didn't fire enough, you can still redo it - but if you fired too much, there's no way to fix it.

Small pieces of glass will absorb heat quicker than large pieces, so will react quicker or at lower temperatures. A firing to 1400 might produce exactly the contour fuse you wanted on an 8 inch piece but cause a 4 inch piece to go to full fuse.

Bigger pieces slump quicker than small pieces and can be slumped at lower temperatures.

Spikes along the glass edges are caused by firing too high or too long. Experiment to see if you can achieve the desired results at a lower temperature or a quicker firing.

Universal rule. There isn't one. It depends on too many variables. Most of the time if something didn't come out right, you can correct if by firing slower but that's not always true. Sometimes if the glass has distorted or spikes have formed along the edges, the correction is to fire faster. The only universal rule is, "It depends".

Kilnforming Process

When heated, glass becomes soft. The more it's heated, the softer it gets. By controlling what temperature you heat glass to in a kiln, you can control what it does.

1200 to 1250° F – SLUMP or DRAPE
At this temperature, glass becomes soft enough that it will bend and can be slumped into, or draped over, a mold.

1300 to 1325° F - FIRE POLISH
A very thin layer of the glass surface becomes soft enough to melt just the surface. This will produce a smooth shiny surface and round off any edges. At this temperature, two pieces of glass in contact with each other will begin to fuse together but will not completely fuse.

1350 to 1375° F - TACK FUSE
Pieces of glass in contact with each other will fuse together as a single unit but both pieces of glass will still retain their original shape and thickness.

1400 to 1425° F – CONTOUR FUSE
Pieces of glass will fuse together and begin to soften towards melting into a single level.

1450 to 1475° F - FULL FUSE
Pieces of glass in contact with each other will fuse together and melt into a single level.

1475 to 1500° F - KILN CASTING
Glass stacked in a mold will melt together.

1600 to 1700° F - KILN POUR
Glass will become liquid enough to pour or drip into a mold.

Kilnforming Stages

Fusing & slumping glass requires taking the glass through specific stages at specific temperatures and times.

Heating Stage – the temperature of the glass is increased to the temperature at which fusing or slumping will happen. The speed at which the temperature is increased depends on the thickness of the glass. The thicker the glass, the slower the temperature is increased. If glass is heated so quickly that the outside is warmer then the inside, thermal shock can crack the glass.

Soaking Stage – the temperature is held at a specific level for a set period of time to produce the desired effect.

Cooling to Anneal Stage – the temperature is lowered to just above the annealing temperature range. This is done as quickly as possible to avoid devitrification.

Annealing Stage – the temperature is held or slowly lowered to relieve the stress in the glass. Different makes of glass have different anneal temperatures or temperatures ranges.

Final Cooling Stage – the glass is gradually cooled to where it can be safely removed from the kiln. This should be done at the same speed as the original heating stage to avoid thermal shock.

Kilnforming Hazards

There are many things that can go wrong with a kilnforming project, but the most common hazards are:

Incompatibility cracks happen when pieces of glass of different COE (coefficient of expansion) are fused together.

Thermal Shock happens when the glass is heated or cooled so quickly that the outside of the glass is a lot different temperature then the inside of the glass.

Bubbles result from air being trapped beneath the glass – either between the glass base and the kiln shelf or mold or between layers of glass.

Distortion results from the glass changing shape as it moves to become ¼ inch thick.

Devitrification is a white scum that forms when the glass crystallizes.

Insufficient Annealing will leave stress in the glass that leaves the glass fragile and very likely to crack.

Differences Count

Different kilns fire differently. A firing schedule that worked in one kiln might not produce identical results in a different kiln. Some kilns produce an evenly distributed heat while others have hot spots. Some fire hotter or colder than others. A kiln with side elements only won't distribute heat for fusing as evenly as one with top elements. A kiln with top elements only won't distribute heat as evenly for casting as one with both top and side elements. A round kiln usually distributes heat more evenly than a square or rectangular kiln.

Different makes of glass respond to heat at different temperatures. Spectrum COE 96 glass fired to 1400° won't produce the same effect as Bullseye or float glass fired to that temperature. Bullseye glass requires about 25° higher temperature and clear float about 50° higher temperature to produce the same effect as Spectrum.

Different colors of glass respond to heat at different temperatures. Black glass will absorb heat quicker than white glass.

Different thicknesses of glass absorb heat at different rates. The thicker the glass, the longer it takes to heat fully through. If glass is heated or cooled so quickly that the inside of the glass is lot different temperature than the outside of the glass, it will crack.

Different firing speeds produce different results. Ramping slower reduces the likelihood of thermal shock but increases the likelihood of the glass shifting or distorting.

Different temperatures produce different results. At different temperatures the same glass can respond anywhere from being just soft enough to bend or fully molten enough to be poured.

Different spans of glass slump at different speeds. A 12 inch wide piece of glass will slump quicker than a 6 inch wide piece.

Annealing

Annealing is essential

Properly annealing glass after it has been fired in a kiln is essential. Glass that has not been adequately annealed will be extremely fragile and very likely to break.

Annealing relieves stress

When the glass is heated, it expands. When it cools, it contracts. This expansion and contraction builds up stress within the glass. Holding the glass for a period of time during the anneal soak, releases these stresses. Think of it as relaxation for glass. It's a chance for the glass to relax, regroup, and regain strength. How long it needs to be annealed depends on the thickness of the glass, how long it has been in the kiln, and how high a temperature it has been fired to. The more stress it's been subjected to, the more soak time it needs to release that stress. If you've had an especially stress filled day, a good long soak in a hot bath is an effective way to relieve that stress. It's the same with glass.

Annealing requires even heat

Each different make of glass has a different temperature at which it can be annealed. Annealing requires heating the glass to above the annealing temperature and holding it at that temperature long enough for the glass to be heated evenly throughout. It is then cooled slowly through the annealing range

Slowly cooling the glass will eliminate thermal shock and relieve some of the stress, but will NOT anneal it. Unless it is properly annealed, glass is dangerously fragile.

A guideline to determine how long to anneal is 1 hour for every ¼ inch thickness of glass. A ⅛ inch thick piece of glass would only require ½ hour to anneal but a 1 inch thick piece would need 4 hours.

Kilns

SELECTING A KILN

IF you ask kiln owners, "What size kiln should I get?" most will answer, "The biggest one you can afford".
I disagree. Although it's common for people to economize and buy a kiln that ends up being too small for their needs, it's just as common for beginners to start off with a kiln that's too big for their needs. If you have a big kiln, you'll want to fill it whenever you fire it. That creates an incentive to put together mixed loads that often shouldn't have been mixed but instead fired separately. If you want to make big pieces, you'll need a kiln big enough to fire them, but if you plan to make small pieces, it's better to have a kiln just large enough to fire those small pieces. The idea that a large kiln will allow you to fire a lot of small pieces each time is more theory than reality. Large kilns take longer to fire and you'll not get more than one firing each day. Smaller kilns heat and cool quicker so can often fire twice each day. Firing twice as often means you can put twice as much stuff through the kiln. If you buy a small kiln and later decide it's inadequate, you can buy a larger one, but you'll likely keep using the small one just as often as you do the bigger one. There will always be times when you want to fire something that doesn't justify using the larger kiln. The other consideration is that larger kilns usually require 240 volt power supply. If you don't already have a 240 volt plug available, it can be expensive wiring one for you kiln. I suggest that the size of kiln you chose should be determined by the largest piece you expect to make. I believe the most versatile kiln to start off with is the largest one you can get that runs on 120 volts.

SOME FEATURES TO LOOK FOR

Both top & side elements -
Ceramic kilns usually have side elements only. These can be used for glass but don't work as well as kilns with top elements. Some glass kilns have top elements only. These work well for fusing, but don't distribute the heat as evenly as side elements will. The best kilns are those with both top and side elements.

Controller –
Although a kiln will work as well with only a pyrometer and switch as it will with a digital controller, working without a controller makes it likely you'll have a lot of failures. A controller is the best possible investment for a glass kiln. It allows you to program the firing schedule, then leave the kiln unattended knowing it will perform the firing schedule you programmed into it. A simple 3 key controller will perform just as well as an elaborate more expensive one. A more expensive controller is just easier to use and can store more schedules in memory.

Adjustable top elements -
If you want to "stack" loads on multiple levels in your kiln, a kiln with top elements will be hotter on the top level than the bottom level. Because they have only side elements, ceramic kilns are usually better for firing multiple levels. Some glass kilns have top elements that can be adjusted to reduce the amount of top heat provided so your kiln relies mostly on side element heat.

Add on ring -
Fusing and slumping shallow forms work best with a shallow kiln that will ensure even heat distribution, but there might be times when you want to fire something that requires a deeper kiln. You can start by buying a deeper kiln, but an alternative is to select a shallow kiln that has a blank ring that can be added to make your kiln deeper.

TESTING YOUR KILN

Every kiln fires a little differently. You'll find it a lot easier to understand what happens at different temperatures if you start by firing small tiles at different temperatures and making a record of exactly what happened at each temperature. I suggest you start at 1300 and do tests at 50 deg increments up to 1500.

CLEANING THE KILN

Kiln bricks are soft and crumble easily. Small bits of brick will frequently come loose. You should routinely vacuum out your kiln - especially in the groves where the lid elements are installed. You don't want to have even a small bit of brick drop down onto your glass. If it drops while you're at fusing temperature, it'll end up in the glass. When vacuuming you kiln, take care to not touch the kiln thermocouple with the vacuum cleaner - to avoid causing a power surge which can fry your digital controller.

LOCATING YOUR KILN

In selecting where to put your kiln, the most important thing is to place it far enough away from anything combustible so the heat from the kiln doesn't start a fire. Kilns are extremely efficient at holding heat (often more efficient than many users would like) but are still a potential fire hazard if not safely located. Pretty much all kilns now come with metal stands that hold them far enough up there's no concern about what you stand it on. Many users put their kiln up on wood tables. Although a kiln will dissipate heat through the sides, placing it at least 12" away from walls is sufficient. What's above the kiln is more important because to much heat rises from it. Nothing should be between the kiln and the ceiling. Do NOT place shelving or hang anything above the kiln.

Kilns can be placed in garages or even outdoors. Many users place them in outbuildings or covered porches. Just be sure it has some kind of covering to keep the rain off. The greatest possible worry is if you place your kiln in a room with an open flame natural gas or propane device. If you do, be CERTAIN you have a device to turn off the fuel if the flame goes out. You might not like what happens if you have a gas leak while your kiln has heated up to 1400 degrees.

KILN SHELVES

You can fire on the floor of your kiln, but it's better to use a kiln shelf. First, because the texture of the bricks will transfer to anything you place on the kiln floor, and second because if you have an accident and hot glass gets to the floor bricks, it can do serious damage. You might end up having to replace or repair your kiln floor. Kiln shelves are relatively inexpensive and make a good surface for fusing. You can either kiln wash the shelf or cover it with kiln paper. Shelves work best if stood up on 1" kiln posts instead of being set flat on the kiln floor. Many kiln users like to have 2 shelves so when one needs to be scrapped and re-kiln washed, they have another ready to use immediate.

LEVELING THE KILN SHELF

It's important to make sure your kiln shelf is level. If it's not level, many of your projects will come out distorted. You're not likely to notice it much on fused projects or shallow slumps, but on deep slumps, drop rings, and drapes, it'll be noticeable enough to ruin your work. If the shelf is lower at one point, the glass will drop first to that point and produce a noticeable distortion to the finished shape. Check to see the shelf is level in all directions. You can check with any level, but the best way to check is with a "Bullseye" level. This is like a little glass dome with a bubble in the middle. Place it in the middle of your kiln shelf (in the kiln). If the shelf is perfectly level, the bubble will be perfectly centered. Wherever the bubble is off center, you'll know where you have to shim your kiln to make it perfectly level.

You can use vermiculite fiberboard for a kiln shelf, but because fiberboard tends to break if too much weight is placed on it, it's a good idea to place it on a bed of sand.

KILN TEMPERATURE VARIANCE

Don't assume the temperature shown on your kiln gauge is the same as the temperature of the glass in the kiln. The kiln thermocouple reads the temperature of the air in the kiln, not the temperature of the glass. It's possible for the air temperature to be more than 100° above or below the glass temperature. It's always wise to allow for some difference to be safe.

KILN HOT SPOTS

Some kilns have spots that are hotter than other spots. Square kilns often are cooler in the corner than the middle. That's why round kilns are so popular. They're efficient. If your kiln has hot spots, it's important that you discover them so you can look for ways to compensate. A simple way to test is to take a number of small strips (about 1/2" wide x 3" long) of all the same glass propped up on each end with either kiln posts or other pieces of glass. Cover the entire kiln shelf with these and fire the kiln to slump temperature with only a 10 minute hold. If they all slumped uniformly, you have no hot spots. If some slumped more than others you can see where the kiln is hottest.

Operating Your Kiln

KILN WASH

Different users have different opinions as to how many coats should be applied. Kiln wash should be mixed 5 parts water to 1 part kiln wash. It's better to have it too thin then too thick. I use 6 coats applied with a brush. A "haik" brush works best, but any brush will do. My routine is to apply kiln wash is to match the compass directions. First I apply a coat up and down north to south. Than a coat side to side east to west. Then a coat diagonally southwest to northeast, then a final coat diagonally northwest to southeast. Some users prefer to spray the kiln wash on. You can use a compressor powered sprayer, a hand pump garden sprayer, or even a little plant sprayer. Whether you spray it on or brush it on, you'll have to keep agitating the mix because kiln wash won't stay dissolved very long but keeps settling to the bottom.

Kiln wash should be allowed to completely dry before using it. When applying multiple coats, it's best to allow each coat to dry before applying the next coat. If you apply multiple wet coats, the top surface can dry but trap moisture inside one of the lower layers of kiln wash. This moisture will then rise to the surface during firing and create a bubble in the glass. Having a 2nd kiln shelf makes it convenient to be coating one shelf while the other is being used. If you want to speed up drying, place your kiln shelf on the kiln while it's on. If you suspect your kiln shelf isn't thoroughly dry, place it in the kiln and heat it up to 500º F to dry it. You might be tempted to use gloves to immediately remove the shelf, but opening your kiln at this temperature can damage it. (see Crash Cooling). Pull the vent plug and slightly open the lid if you want to cool the kiln quicker.

How many times you can fire on a shelf before replacing the kiln was will depend on how high you're firing and what kind of glass you used. The higher the temperature, the more frequently you should reapply new kiln wash. Opaque glass tends to cause kiln wash to break down quicker then transparent. My practice is to fire the shelf 3 times than apply new kiln wash. Trying to get too many firings without replacing the kiln wash can cause it to stick to the bottom of your glass. Removing it is a lot of work, and sometimes it can't be removed at all. Better to be safe and not gamble. If the kiln wash has started to pit or flake, it should be completely scraped off down to a clean shelf. Sometimes it isn't necessary to completely scrape off the kiln wash and you can just clean it and apply another coat. A dry sponge works to wipe off and smooth off a kiln shelf to prepare for an extra coating. A putty knife works well to scrape kiln wash off a shelf. Any kiln wash that doesn't come off easily with scraping can be sanded

KILN PAPER

An alternative to using kiln wash is kiln paper that has been specially created for firing glass in a kiln. Bullseye Glass offers a product called "Thinfire" that is especially effective. It can be placed on the kiln shelf to prevent the glass sticking to the shelf, and after firing the reside from the paper just vacuumed out.

STACK FIRING

Every kiln has some spots that are a slightly different temperature than others. Glass kilns are designed with top elements because the direct heat works best for kilnforming glass. Ceramic kilns have side elements only and will have relatively even heat throughout the kiln. If you stack layers of shelves in a glass kiln, the temperature at the top shelf will be different than that at the bottom shelf. You might get away with fusing the top layer while slumping the bottom layer, but you will only be able to accurately control the temperature at the same level as the thermocouple. If you fire a single layer in your kiln, you can get a perfect firing. If you fire two layers, you'll probably just get two "not so good" firings. Be patient – take the time to fire twice and have two perfect firings.

CRASH COOLING

Opening the kilnto speed up cooling can be dangerous. Not only can it cause the glass to crack from thermal shock, the temperature shock can damage the kiln bricks. It's safe to remove the peep holes plugs and lift the lid an inch or so when the kiln temperature drops to 300° F, then safe to fully open the lid at 200°, and safe to remove the glass at 100°

FIRING LOG

It's important to keep a detailed record of your firings to have a record of the results you got from different firings. You will make mistakes, but a well kept Firing Log will help ensure you don't repeat them.

Molds

Most kilnformers start by purchasing molds made specifically for slumping glass. These are made from a high grade of clay that will tolerate the dramatic temperature changes of repeated kiln firings. You can make molds from raw clay or use "greenware" that has been fired to bisque. These are more fragile than commercially made molds and can't be used as many times, but are considerably cheaper and work fine. Be careful about shapes. Not all shapes used for creating ceramic pottery are suitable for slumping glass. Molds made for slumping glass must have holes in the bottoms to allow air to escape when the glass slumps. If you buy other molds (or make your own), make sure you drill holes. Also, make sure the vent holes aren't sitting on the kiln shelf. If your mold doesn't have side to keep the vent holes elevated, prop it up with kiln posts.

Stainless steel is the best material for molds. Regular steel will spall when heated in a kiln with bits of black metal flaking off like a kind of metallic dandruff. If you have a mold design you expect to use a great many times, it's worth investing the extra cost to buy stainless steel molds. Just about anything made from stainless steel can be used as a mold. Cheap sets of salad bowls are great for slumping, and a stainless steel cocktail shaker makes a great vase draping mold. Pieces of sheet material can be welded or riveted together to make interesting slumping or draping molds.

You can also make molds from a mixture of 50/50 silica flour and pottery plaster or any of a variety of compounds made specifically for making glass slumping molds.

PREPARING MOLDS

Molds must be thorough coated with kiln wash to prevent glass from sticking to them. Start by making sure they are thoroughly clean. When you buy a new mold, take care to avoid handling it. Skin oil can be absorbed by the clay and make it difficult to get the mold to hold kiln wash. This is especially so with bisque-fired greenware. Apply at least 6 coats of kiln wash the same as for kiln shelves. If you handle the kiln-washed molds carefully and don't scratch or otherwise damage the coating of kiln wash, you can reuse them dozens of times without recoating. Firing to fusing temperatures will cause kiln wash to deteriorate, so it's necessary to keep reapplying it after fusing, but firing only to slumping temperatures has considerably less effect on the kiln wash. Both the molds and the kiln shelf can be continuously reused – until you can visually see deterioration of the kiln wash.

It can be difficult to get kiln wash to stick to smooth steel molds. It's necessary to do something to rough up the surface. Sandblasting it with fine grit sand is a common way to do this. Also, if you've salvaged something to use as a mold (like a stainless steel salad bowl) it probably has a coating of oil from repetitious handling. Here's an easy and effective way to get kiln wash to stick to stainless steel.

- Scrub thoroughly with SOS pads. This will remove any oil and slightly scour the surface.

- Scrub thoroughly with 100 grit sandpaper to produce a "cross hatch" (scratched vertically and horizontally). You want to get a uniformly scratched surface. It doesn't have to be deep scratches, but it must be scratched.

- Heat up the mold, than apply kiln wash. You can heat it by placing it in your kitchen oven, or be heating in your kiln. My favorite method is to just place it on the lid of the kiln while the kiln is firing. It'll get hot enough that the kiln wash will dry on it almost as fast as you apply it. That's good. Be patient. At first, the kiln wash will appear to not adhere and just run off. Just keep putting more on until the mold is completely covered. The kiln wash will run down the mold, so to avoid getting it on you kiln lid, you might want to put down an old plate or a piece of tin foil.

USING MOLDS

Always check to see your mold is clean, adequately coated with kiln wash, and the vent holds haven't been plugged with kiln wash. If you've brushed on the kiln wash, there will be ridges left from the brush bristles. You can smooth these out by rubbing it with your finger tips, with a smooth dry sponge, or a piece of panty hose. Aren't you glad to have discovered a practical use for panty hose with runs in it?

CLAY or METAL

Clay molds should be used for slumping into, and stainless steel for draping over. If you slump into a metal mold, the heated metal will cool quicker than the heated glass and can either cause the glass to crack or press so firmly against the glass, you won't be able to get them apart. Metal other than stainless steel should not be used for molds.

Sample Firing Schedules

Every kiln fires a little differently, and every project requires a slightly different firing schedule. Only experimentation will teach you exactly what schedules will produce exactly the results you want. To get you started with your experiments, here are some sample schedules. These firing schedules are for COE 96 glass. For COE 90 glass, add 25 degrees fahrenheit to all temperatures (not the ramp rate). For clear float or architectural glass add 50 degrees.

FULL FUSE (up to 12 inch) *

Seg	Rate	Temp	Time
1	400	1000	20
2	400	1150	15
3	850	1450	15
4	FAP	950	60
5	400	100	0

- For tack fuse, fire only to 1350 in segment 3
- For contour fuse, fire to 1400 in segment 3

FULL FUSE (up to 21 inch)

1	300	1000	20
2	300	1150	20
3	850	1450	15
4	FAP	950	60
5	300	100	0

FULL FUSE (with bubble squeeze)

1	400	1000	20
2	400	1150	15
3	50	1250	20
4	850	1450	15
5	FAP	950	60
6	400	100	0

SLUMP (up to 12 inch, 1 or 2 layer)

1	400	1000	20
2	400	1250	20
3	AFAP	950	60
4	400	100	0

SLUMP (up to 21 inch with bubble squeeze)

1	300	1000	20
2	300	1150	20
3	300	1250	20
4	FAP	950	60
5	300	100	0

DRAPE

1	400	1000	20
2	850	1225	5
3	FAP	950	60
4	400	100	0

DROP RING

1	400	1000	20
2	850	1300	10
3	FAP	950	60
4	400	100	0

CASTING (small open mold)

1	500	1250	10
2	FAP	1475	20
3	FAP	950	45
4	500	100	0

CASTING FRIT

1	300	1000	60
2	300	1450	120
3	FAP	950	90
4	300	500	30
5	FAP	0	

POT MELT (small)

1	500	1600	60
2	FAP	950	120
3	300	750	0
4	300	100	0

POT MELT (large)

1	500	1600	90
2	FAP	1500	45
3	FAP	950	60
4	300	750	0
5	300	300	0
6	300	100	0

SHELF MELT

1	500	1500	60
2	FAP	950	240
3	200	750	0
4	300	100	0

- To calculate how much glass will be needed to produce a consistent ¼" thick melt, measure out 1 lb of glass for every 32 square feet to be covered.

FAP means Fast As Possible.

In most kilns, the program setting for this is 9999

Most Common Mistakes

Even the most experienced pros make mistakes. It's part of learning, but the most common mistakes made by beginners are caused by impatience - trying to get too much done too quickly.

- Firing too fast – causing thermal shock cracks.
- Overfiring – especially with single layers
- Insufficient change of kiln wash. Trying to get "just one more time".
- Mixed loads - so anxious to fill the kiln, projects were fired together that shouldn't be fired together.
- Air Bubbles. Trying to fire too fast.

If there is one "skill" that is probably the single most important one to acquire for kilnforming, it's patience.

Troubleshooting

Bubbles – air trapped either between the bottom glass and the kiln shelf or between layers of glass will expand as it's heated and can cause bubbles in the glass. Textured glass and glass of varying thickness, that has been capped, is especially likely to trap air. For textured or varying thickness glass, it's safer to put it on a base with the texture of thickness variation facing up. A not level kiln shelf is also likely to trap air. The best way to prevent bubbles is to fire slower and introduce a "Bubble Soak" by firing slowly from 1000° to 1200° and allow a long soak (30 minutes or more) at 1200 to allow air to escape before the glass fuses. It can also help if you insert "chads" (small pieces of glass along the perimeter between the layers of glass. These hold the glass apart and force the glass to drop in the center before the edges.

Spikes along the glass edges are caused either by firing too hot or too long.

Cracks can be either a compatibility stress fracture from having used glass that isn't compatible or from thermal shock resulting from increasing or decreasing temperature too fast. If the crack is sharp edged, it broke while the temperature was dropping. If the crack is smooth, or party fused, it broke as the temperature was rising.

Kiln wash stuck to glass
Residual moisture in kiln wash that hasn't been adequately dried, can create steam and cause the kiln wash to stick to the glass. Also, kiln wash that has deteriorated by having been used too many times will often stick to the glass. The higher the temperature you fire to, the more likely kiln wash will stick. If you're only firing to slumping temperatures, it will stand up to a dozen or more firings. If you fire to tack fuse temperatures, you can usually get 3 or 4 reuses. If you fire to full fuse temperature, it's best to reapply the kiln wash for every firing. It isn't necessary to completely remove the kiln wash unless it's pitted or chipped. Just slightly sand the old kiln wash (your finger tips work well for this) and apply a couple of fresh coats.

Removing stuck kiln wash
If it's just a small amount, it can usually be removed with a kitchen scrubber and a bit of elbow grease. If it's a lot and it's pitted into the glass, you can sometimes remove it by soaking in a strong vinegar and water solution. If that doesn't work, you'll have to sandblast it off. Removing stuck kiln wash is a lot of work. It's a good idea to take precautions to avoid having it happen.

Distortion
Glass will change shape when fired in a kiln. The hotter you fire it, the more the shape will change. If you fire a square to slump temperatures, the change will be almost unnoticeable. If you fire it to tack fuse temperatures, the corners and edge will round off just a little. If you fire to full fuse temperature, the corners and edges will become completely rounded. You must anticipate how different temperatures will change the shape of the glass to produce the end results you want. If you place a small square of glass on another piece and fire to tack fuse, it'll come out still square If you fire that same combination to full fuse, that square will end up close to round. In any kiln firing where you have a small area of shelf not being used, you should experiment with how different shapes and various layers respond to different firing temperatures.

Devitrification
As glass cools, it begins to crystallize and a white scum can form along the glass surface and edge. To reduce the chance of devitrification forming, kilnformers will drop the kiln temperature as fast as possible through the temperature range where devitrification occurs (between the top temperature and the annealing range. Glass made for kilnforming has been specially formulated to minimize the likelihood of devitrification.

Types of Glass

Architectural glass is clear glass made with a decorative texture.

Artíque is a scribed "antique" glass, alive with the surface striations characteristic of mouth blown sheet glass. A Spectrum exclusive.

Bariole Streakies contain one or more colors combined with opal, and flashed on either a clear or tinted base glass.

Baroque is a "reamy" glass, produced by combining glasses of mismatched compositions. The different glasses "oppose" each other when they are stirred together, creating textured swirls and vivid color contrast. Made exclusively by Spectrum Glass.

Cathedrals are single color glasses, with slight, irregular surface texture. Degree of light transmission is directly related to density of color; clear glass is highly transparent, dark colors are very opaque.

Catspaw is a reproduction of the original texture produced by Kokomo in 1888 and is highly desirable for restoration work and antique reproductions.

DIchroic glass is a decorative made with a metallic surface.

English Mottle is a cathedral glass characterized by a soft pebble-like texture.

Flash glass is composed of laminates of different colors.

Float glass clear window glass made by rolling molten glass onto a bed of molten tin.

Fractures are collage glasses that contain paper-thin chips of color glass.

Glue Chip is glass that has been textured by applying molten glue and then peeled away to produce a frost-like pattern.

Granite is a textured glass with up to eight colors and iridescent coatings to create activity and a subtle sophisticated surface.

Iridescent Glass contains a thin layer of metallic crystal that has been bonded to glass during sheet forming, creating a colorful, shimmering surface effect.

Opalescent glass contains one or more cathedral glasses combined with white opal glass to create a variegated, multi-colored sheet. Available with varying degrees of light transmission.

Opals are solid color, opaque glasses. These non-variegated products are highly reflective in nature and thus especially popular for mosaic and mural application.

Opalume is a very dense uniform mix of opal glass with no streakiness.

Ring Mottles are fashioned after those made by Tiffany. These organic dappled patterns of varied opalescence are used to simulate naturalistic qualities of light.

Rough Rolled cathedrals have a subtle, delicate texturing that gently mutes transmitted light and images.

SilverCoats contain a bright, reflective silver-coat on one side, turning specialty glasses into shimmering super-specialties perfect for projects that demand brilliance. Made exclusively by Spectrum Glass.

Streaky glass is a combination of two or more cathedral colors with no opal content.

Streamers are collage glasses that contain threads of color glass.

System 96 products are formulated and "Tested Compatible" especially for fusing, slumping and other hot glass work. This Spectrum line of sheet glass is complemented by many specialty glass products, including glass frits, noodle, stringer, dichroic glass, and casting billets, made and supplied by System 96 partner companies. All System 96 products are tested against an identical standard to insure compatibility of viscosity and expansion coefficient.

Vecchio glass contains a bark-like texture that resembles a cross between a soft granite and rough rolled, but more linear.

Victorian Mottle is opalescent glass manufactured with the traditional catspaw dappled pattern.

Waterglass is a cathedral glass with a natural surface texture created by stretching the hot glass sheet while it is still in a pliable state. The result is gentle, rolling waves that resemble the surface of a lake or stream. A Spectrum exclusive.

Wispy glasses are composed of about 75% cathedral glass and 25% opaque white glass.

Glossary

Air Side	The side of float glass that was facing the air (upwards) when they glass was made. The opposite of "tin side".
Annealing	The process where the stress is reduced by a controlled cooling that allows the glass molecules to align in a stable form.
Annealing point	The point at which annealing begins.
Annealing temperature	The temperature at which annealing occurs.
Annealing zone	The temperature zone where glass changes from liquid to solid.
Artique	A Spectrum glass with surface striations similar to those on mouth blown sheet glass.
Bail	A loop that is attached to jewelry to allow a pendant to be hung on a chain
Bariole Streakies	A glass with one or more colors combined with opal, and flashed onto either a clear or tinted base glass.
Baroque	A Spectrum glass made by combining glass of mismatched compositions creating textured swirls and vivid color contrast
Base	A piece of glass onto which another piece of glass is fused.
Billet	Bricks of glass to be melted down for casting
Bisque	Raw clay that has been fired but not glazed. Often used for glass slumping molds.
Blank	A piece of glass that has been partially finished to be further processed.
Bloom	White stretch marks on the tin side of glass.
Boron Nitride	A material use on stainless steel molds to prevent glass from sticking.
Borosilicate	A glass commonly used in lampworking.
Bubbles	Air trapped beneath or inside glass that has been kiln fired.
Burner	A flame producing torch used in lampworking
Cabochon	A fused piece of glass used to make jewelry.
Calcium Carbonate	Also know as chalk or whiting.
Came	U or H shaped lead unused in stained glass to hold pieces of glass tog
Cap	A single piece of glass fused over another piece or pieces of glass.
Casting	Melting glass into a mold.
Cathedral	Single colour translucent glass
Catspaw	A reproduction of the original Kokomo glass used for restoration work and antique reproductions.
Cerium oxide	Used as a polishing compound
Chad	A small piece of glass set on the outer rim to separate two pieces of glass to cause the center of the glass to drop before the perimeter to avoid trapping air.
Circle Cutter	A device for scoring circles in glass.
CMC	Methyl cellulose. Use to glue glass together.
COE	Coefficient of expansion. How much a material expands and contracts when it's heated and cooled.
Combing	A technique where a tool is drawn across hot glass inside a kiln to produce an special effect

Cold working	Cutting, grinding, polishing, etc. The work that is done when the glass is unheated.
Compatibility	How well different glasses will fuse. Incompatible glasses won't fuse.
Cones	Devices for controlling kilns. Commonly used for ceramics, but rarely for glass work.
Confetti	Very thin pieces of glass used for fusing.
Controller	A programmable device to control a kiln.
Crash cool	Anything done to speed up the rate a kiln cools. Usually by opening the lid, but also done by installing an exhaust vent.
Cullet	Pebbles of glass to be melted down for casting.
Devitrification	A white scum that appears on glass caused by the glass beginning to crystallize as it cools.
Dichroic	A decorative glass created by applying metal oxides to glass in a vacuum furnace.
Draping	Bending glass over a form (as opposed to slumping which is bending it into a form)
Drop Ring	A mold that has a hole in it into which glass is slumped.
English Muffle	A cathedral glass with pebble like texture.
Fiber Board	Stiff board used to insulate kilns and to make molds.
Fiber Paper	Special heat resistant paper used to prevent glass from sticking to shelves.
Fire Polishing	Heating the glass to where the edges will soften and leave a shiny rounded finish.
Flashed Glass	Glass made with laminates of different colors. Popular for sandblasting.
Float Glass	Clear window glass made by making glass on a bed of molten tin.
Floral Former	A draping mold like a cocktail shaker.
Flux	In soldering, a liquid or paste used to clean the metal and cause the solder to attach. In making glass, used to reduce the melting point.
Fractures	Collage glasses containing paper thin chips of colored glass.
Frit	Glass broken into small pieces. Available in a variety of sizes from fine powder to coarse pieces the size of pencil erasers.
Frit Casting	Melting frit into a mold.
Full Fuse	When the glass has been heated to where it all melts to a common level.
Glass Eye 2000	A computer program developed specifically for glass designs.
Glass Saw.	A saw made specially for glasswork that uses a diamond covered band, wire, or ring to cut glass.
Glue Chip	Glass textured by applying molten glue then peeling away to produce a frost-like pattern.
Greenware	Ceramic or porcelain clay that has been poured into a mold and dried but not kiln fired to bisque.
Grinder	A rotary machine that uses a small diamond covered head to grind glass.
Grog	Clay ground into a fine powder.
Grozing Pliers	Specialized tools to grinding or chewing the edge of glass to shape it.
Hand Rolled	Glass made by hand rolling molten glass onto a table.

Inclusion	Something included or imbedded inside glass.
Infinite Switch	A switch used to set kiln temperature.
Investment	Material used to make casting molds
Iridescent Glass	Glass with a metallic coating.
Kiln Casting	Casting glass by melting it in a mold in a kiln.
Kiln Log	A detailed record of all firings to be used to check previous results.
Kiln Sitter	A device to turn a kiln off at a preset temperature.
Kiln Wash	A powder mixed with water to paint onto molds and kiln shelves to prevent glass from sticking to them.
Laminated	Glass made a sheet of plastic sandwiched between two sheets of glass (like car windshields).
Lampworking	Shaping glass with an open flame
Lap Grinder	A machine using a round disc to grind glass.
Lost Wax	A may to make a mold by casting over a wax original then melting out the wax.
Machine Rolled	Glass made by drawing molten glass through steel rollers.
Mandrel	A steel rod on which glass beads are made
Opal Glass	Solid color opaque glass.
Opalescent Glass	Colored glass mixed with white opal glass.
Overspray	A material that is applied onto glass to prevent devitrification.
Pate de Verre	French for “glass paste”. Glass powder mixed with a liquid to form a paste that’s applied inside a mold then fired in a kiln.
Pattern Bar	Strips of glass fused together.
Polariscope	A device that uses two polarizing filters to identify stress in glass.
Pot Casting	Casting by melting glass dripping from the bottom of a flower pot
Pyrometer	A device for measure temperature.
Quartz Inversion	The clay equivalent of devitrification.
Quenching	Dropping hot glass into water to cause it to break into pieces.
Ramp	The rate at which temperature is raised or lowered.
Refractory	A material that will withstand kiln temperatures.
Rigidizer	A material used to harden soft materials.
Rod	A cylindrical length of glass. Used mostly for torchworking.
Roll Up	A way to make vessels by fusing a piece of glass then rolling it into the desired shape.
Streamers	Collage glass containing threads of colored glass.
Strip Cutter	A device for scoring consistent size strips in glass.
Tile Saw	A machine that uses a diamond rotary blade to cut glass.
Tin Side	The side of float glass that was in contact with the molten tin when it was made.
Venting	Opening the kiln to allow fumes escape or to cool quicker.
Viscosity	Stickiness. The willingness of a liquid to flow.
Wet Belt Sander	A machine that uses either diamond mesh or silicone carbide belts to grind or polish glass
Whiting	see Calcium Carbonate